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RESEARCH ARTICLE

Radio Frequency Identification in Supporting Traffic Safety

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Abstract

Due to the increased demands of traffic safety applications many parameters of the traffic flow have to be measured by different kind of techniques. The sensors of vehicle sensing and detection are to be inexpensive, currently available and easy to deploy. Therefore, the state-of-the-art safety applications are usually based on mature technologies, such as video cameras, smart dust sensors, and wireless communication technologies.

This paper discusses the application of RFID technology for transportation applications. RFID is widely used for different purposes (e.g. cargo logistics, storage management), but is still considered as new technology in the field of safety-related applications.

The paper gives an overview about the technology and describes scenarios of using RFID as infrastructure as well as vehicle sensor. The capabilities and limitations of RFID technology is demonstrated through the ghost driver (wrong way driving) detection, which is discussed in detail. In this particular application RFID is used as an infrastructure sensor, multiple readers are connected in a network, thus able to monitor the traffic flow directions in a particular road segment (e.g. in a motorway junction). Additional applications, such as flow classification, road toll control and emergency monitoring are also discussed in the paper.

Keywords

cooperative systems, intelligent infrastructure, radio frequency identification, road safety

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1 Introduction

Radio frequency identification (RFID) is a radio based communication technique originally developed for identifying own airplanes in the World War II ("friend-or-foe" system). The technique is already used also in transportation (e.g. cargo logistics), but is still considered as new technology in the field of safety-related applications.

The integrated project SAFESPOT cofounded by the Information Society Technologies aims to understand how intelligent vehicles and intelligent roads can cooperate to produce a breakthrough for road safety [1,2,3]. To reach this goal the key project activities are: the use of the vehicle and road information sources, modern communication platforms, and the development of enabling technologies in networking, sensing and applications. Authors of the current paper are involved in the roadside subproject, called INFRASENS.

The focus of INFRASENS is to support the future co-operative driving concept by offering a roadside sensing platform [4]. The platform is connected via a bidirectional vehicle-to-infrastructure (V2I) communication link to the local vehicles in the "SAFESPOT" area which is determined to be approx. 1-3 km. Moreover, the co-operative driving means vehicle ad-hoc networks where the mutual vehicles are connected and can share safety relevant information (e.g. possible accident of vehicles when approaching an intersection). Fusing the vehicle acquired data with the information captured by the infrastructure sensors, coverage and robustness of object/incident detection can be highly improved which is one of the major objectives of the SAFESPOT initiative.

The RFID technology [5,6,7], which also mimics the future electronic license plates, is one key element of the infrastructure sensors [8]. In addition, the infrastructure platform of SAFESPOT includes (Fig. 1):

- CCTV for road condition monitoring,
- thermal camera for pedestrian/animal detection,
- laser scanner for object detection,
- wireless sensor networks (WSN) for counting vehicles.

The selected sensors enable comprehensive vehicle and traffic monitoring through to fusion of sensor data. The data is fed into automatic incident detection which raises warning message and allows a driver to react possible increased accident risk by adapting speed and driving behavior accordingly.

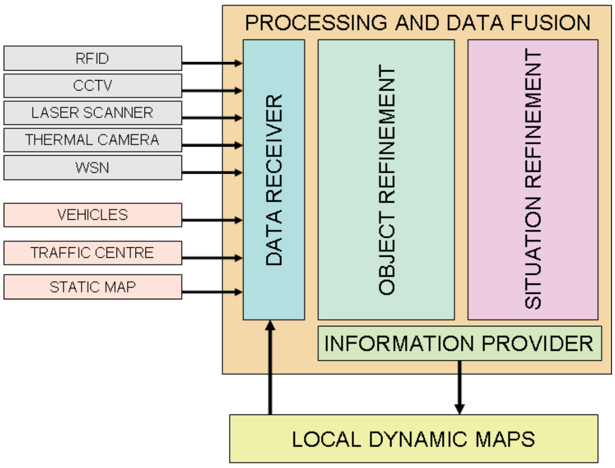

Fig. 1 Infrastructure sub-system architecture in the SAFESPOT project

2 The long range RFID system

The RFID system consists of reader and tags. Both reader and tags are equipped with antenna. In communication between reader and tags the most applied frequencies and their ranges are the following:

- LF (low frequency): 125-134 kHz (range: < 0.5 m)
- HF (high frequency): 13.56 MHz (range: ~ 1 m)
- UHF (ultrahigh frequency): 868-956 MHz (range: ~ 4-5 m)
- Microwaves: 2.45 GHz (range: >>1 m).

Tags can have own power supply (active tags) or they can use only the received energy to reply to the reader (passive tags). Depending on the tag types, the communication range strongly varies: from the very short range e-passports or building access control tags to the long range systems of military applications.

The system (Fig. 2) used in the project was an Identec Intelligent Long Range (ILR) system having 868 MHz (in Europe) or 915 MHz (in North-America) communication frequency and tags for 6 m range (passive, type i-D) and 100 m range (active, type i-Q). One type of i-Q-tag has a built-in thermometer (type i-QT). The low range tags were applied for indoor tests, while the long ones were mounted on vehicles and tested in real traffic conditions. Tags are relatively small in size: 131 × 28 × 21 mm, weight of 50 g.

Tags can also differ in the size of built-in memory. The simplest tag has only a unique identifier that can be read, but some of them have memory of several bytes. The applied i-D-tags have 64 byte memory, while i-Q-tags have 8 kB, and i-QT-tags have 32 kB. These rewriteable memories broaden the application field also in the transportation area.

Two types of antennas were used during the tests, omnidirectional and directed; the first can sense tags from all direction in space, whilst the second only in limited horizontal and vertical range.

One of the most important advantages of RFID technology is its operation without having direct line of sight between tag and reader. Under real conditions the ability of reading (downloading data from tags) has to be tested, because several circumstances (like weather, obstacles etc.) can significantly decrease the signal strength.

a) omnidirectional antenna

b) i-D (left) and i-Q (right) tags

Fig. 2 The Identec Intelligent Long Range RFID system

3 RFID in traffic flow monitoring

The simplest RFID system configuration in transportation applications is the following: at least one reader deployed on the roadside (e.g. onto the guardrail, traffic sign pose, motorway bridge). Tags are mounted on the vehicles in certain locations avoiding their electromagnetic shadowing and the Faraday-cage effect (e.g. tag under the engine hood). Tags are moving, whilst the reader is in fixed location (Fig. 3) [9].

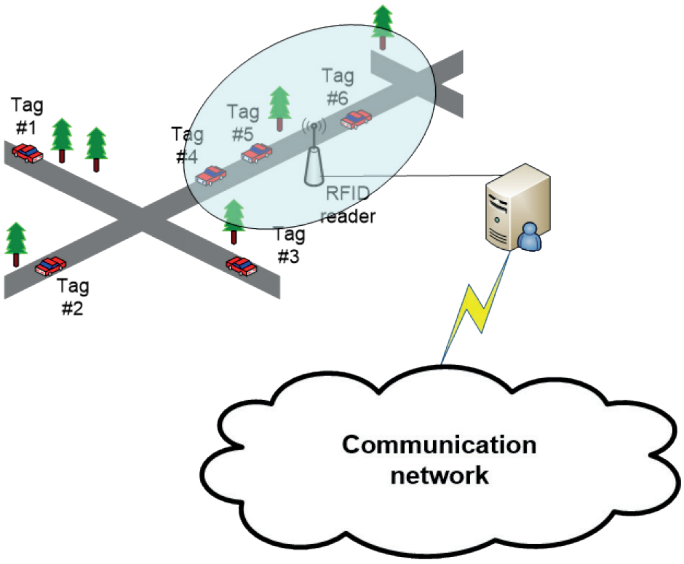

Fig. 3 Basic configuration of RFID system as roadside sensing component. The reader is installed close to the lanes, the tags are on the moving vehicles.

In this first configuration roadside RFID reader senses the approaching tags, and receives their identifiers. The zero-level hypothesis is that every vehicle is equipped with a tag, thus all moving vehicles in the range of the reader can be sensed by the system. Following this logic, the number of sensed tags in a period of time (vehicle/min or vehicle/hour) gives information about the traffic (vehicle count/volume) [10].

Theoretically a tag can be read many times while being in the range of a reader, thus each identifier has to be recorded only once in a time-window. Of course it depends on the travelling speed; in urban areas there is more chance to sense a tag more than once.

The reader can collect information not only by counting the tags, but the unique identifier of each tag can be downloaded. With installing two equally equipped readers on a road segment connected by a communication network, speed estimation is feasible using the unique IDs. In this case the RFID system can work as a speed trap similarly to those systems operating with cameras detecting the license plate numbers.

Further applications become available if the reader not only scans the tags, but also reads (i.e. downloads) the data stored in them. Various kinds of vehicle-relevant information, such as vehicle type, engine size, fuel type, curb weight, total emission, special/dangerous cargo etc. can be written in the tags. Using these data more accurate traffic statistics can be derived, e.g. recording the vehicle categories the traffic flow classification can be solved. Based on similar method the emergency vehicles can be detected on the particular road segment and alert can be generated to the vehicles in the neighborhood. Note that the data content of the tags has to be stored in standardized form and maintained regularly; outdated data endangers the system reliability.

4 RFID in Ghost driver detection

The number of reports of drivers travelling against the right direction (i.e. wrong-way drivers, also known as ghost drivers) is increasing (more than 500 cases yearly in Austria, more than 780 in Spain and about 2000 in Germany reported). These events occur mostly on motorways, freeways (Fig. 4), vehicles are travelling at higher speed, followed by many other vehicles, and thus the chance of mass accidents is higher. The risk of these situations can be efficiently reduced by a rapid automatic warning system involving RFID technology.

Tracking vehicle trajectories is also part of SAFESPOT and other safety-related transportation projects. Detecting ghost drivers by optical systems has many difficulties: detection is unreliable in twilight, problematic in darkness, and fog makes it impossible. The application of weather independent system, such as RF identification, can help to overcome the detection difficulties.

The task is to detect the cars driving in a wrong-way direction. In these kind of applications all vehicles have to be equipped with tags. The trends of the spreading of the technology is promising, tags become more and more affordable and RFID system can serve several automotive applications from the factory documentation through trading through junkyard registration. Current research work assumes the accelerated expansion of using intelligent RFID networks in the everyday life [11].

The minimal RFID system configuration consists of two readers. If a vehicle passes the readers in #1 - #2 sequence (Fig. 4), it is in the right direction, but the reverse order indicates a ghost driver. The algorithm must therefore test all vehicles passing the second reader followed by the first reader pass. In many cases, if monitoring of a complete motorway junction is required, application of three or even more readers are needed. Therefore, the algorithm can be extended for three or more readers, too. Fig. 5 shows the sensed tags by three readers.

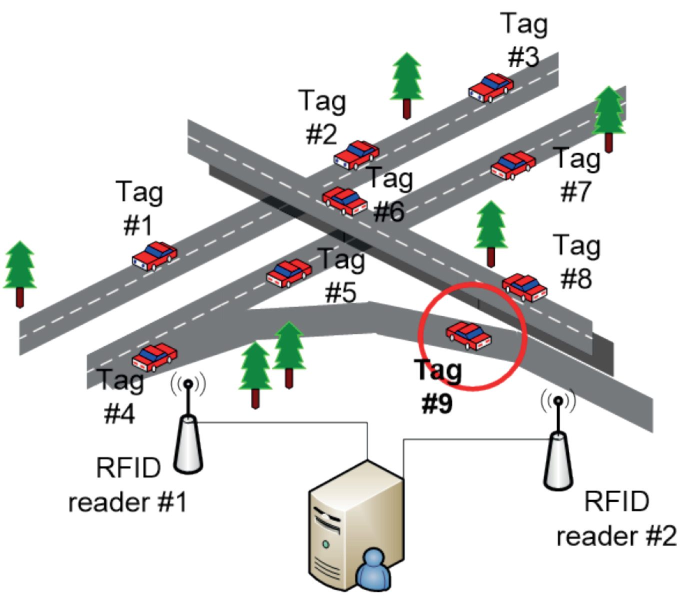

Fig. 4 Typical ghost driver situation on a motorway exit lane. Vehicle with Tag #9 is driving in wrong direction

The readers scan all passing vehicles' tags and collect the IDs into a list (vector). The width of the vector is defined by the number of simultaneously scanned tags, the length of the vector by the running (time) window. If the observation of a given ID (tag) at reader A is tA, while tB at reader B, and the given time window is dtB, then ghost drivers are within the time window.

$$|tA - tB| < dtB \,\&\, \mathrm{sgn}(tA - tB) = -1 \qquad (1)$$

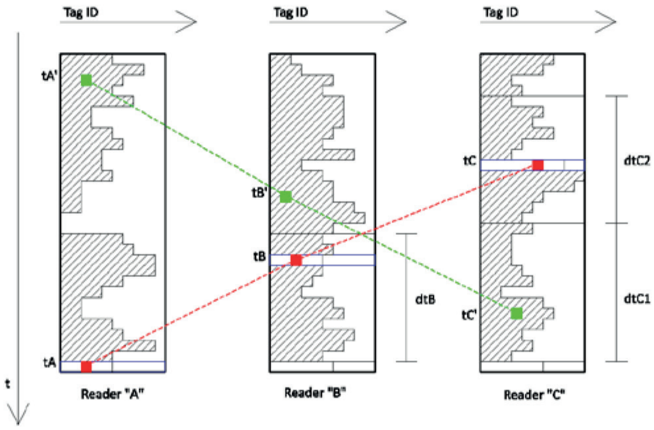

Fig. 5 Time-sensing diagram with three readers demonstrating a right driver (in green) and a ghost driver (in red). Shadowed areas show the number of sensed tags; width of the vectors is varying along time (depending on the traffic)

If these conditions aren't fulfilled, the observed vehicle is not a ghost driver. For the detection of ghost driver at least two such measurements are required. Regarding the practical implementation, (1) means that the second reader must collect and transmit all passing vehicles' ID to a computer running the detection test for all sensed IDs by reader A. The transmitted identifier vector must be continuously maintained: only observations in the last dtB must be kept, the previous ones can be dropped. If an ID occurs in this vector, an alert must be generated with ghost driver warning.

The described algorithm has been tested in the BME main building by the use of low range tags (feasibility test), and then outdoor tests were carried out: two laptops with RFID readers were installed on roadside connected by wireless LAN device (IEEE 802.11 router). The vehicles were equipped with long range tags. The detection software was running on the first laptop, which collected its reader's observations and received the sensing vector from the other laptop.

The laptop clocks were previously synchronized (by time server service). The second reader has transmitted the observation by UDP packets in order to get higher transmission (and therefore lower latency) rate.

If not only a lane, but a road junction is to be monitored, further readers should be applied. In real circumstances, e.g. for a motorway junction even a series of readers must be installed. As an example Fig. 6 shows a possible RFID reader configuration with the same types of omnidirectional antennas.

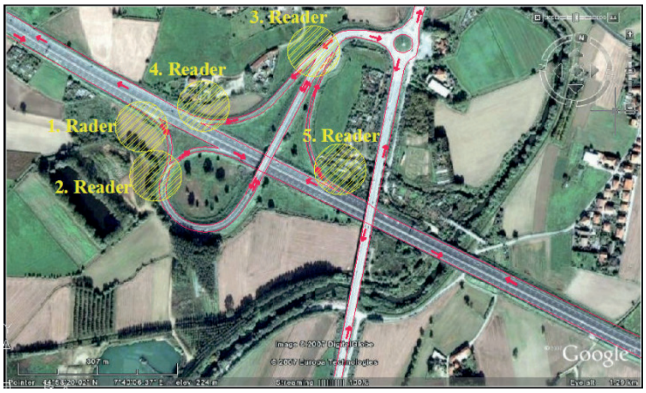

Fig. 6 RFID reader configuration for a road junction on a motorway Torino-Caselle

5 Warning black spots

RFID system can also be installed in an inverse way: reader can work in the vehicle onboard, whilst tags can mark special places (Fig. 7). A possible traffic safety application is where the tags mark dangerous road segments, the so-called black spots.

In this application the tags provide information about the status of the road segment. The moving reader is continuously scanning and getting an identifier from the fixed tag, the detection software can evaluate it in two ways:

- it compares the ID with a downloaded (continuously actualized) database content and by the incident identifier a message to the driver can be generated,
- it reads directly the stored information from the tag and generates the message to the driver.

The first solution requires connection to a database of traffic service center, but can provide more detailed information about danger, whilst the second way is database independent, but more compact description (message) can be achieved. Scanning mostly means faster operation with tags than reading, but the first feasibility tests are already promising also with the reading rate.

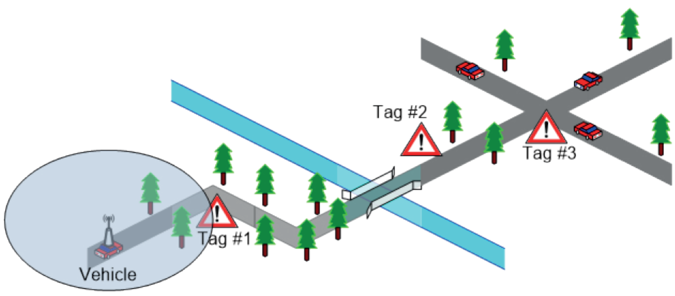

Fig. 7 Moving reader on a vehicle, fixed tags at dangerous places (mounted e.g. on traffic signs, tag #1 and tag #2), such as potentially icy roads near rivers or dangerous road crossings (tag #3)

At the application level drivers are able to receive important safety information in time, e.g. children supposedly in the neighborhood (e.g. close to playgrounds), slippery road, sharp curve, dangerous crossing. Radio frequency communication ensures that driver gets information even at limited or blocked visibility (e.g. weather/light conditions, obstacle roadside).

For better driver information, tags can be repeatedly installed: the same content can be offered several times along a road segment (not only directly at the interesting place) therefore can provide particularly emphasized warning e.g. before railroad crossing.

Further interesting points (POIs) can be similarly marked by tags, so even shops, petrol stations and others can be highlighted. The database is to be maintained similar to those of onboard navigation systems, the commercial service area (e.g. hotels, restaurants) is responsible for keeping the database up-to-date.

6 Conclusions

The paper illustrates how the radio frequency identification technology can be implemented in transportation and traffic safety projects. The advantage of the technique is the communication without direct line of sight. By the deployed readers and moving tags information about the traffic can be collected; distinguishing vehicle categories by weight, special permissions, emission parameters, emergency or dangerous cargo.

Repeated sensing of the same tags can give data about wrong way driving, enables speed estimation, but also traffic volume estimation along a segment of the road network. The weather independent and simple vehicle identification can provide efficient control data for road maintenance or police in detecting speeding cars: by the sensed data of two apart mounted RFID readers average speed can be calculated and in case of speed violence an alert can be generated.

The vehicle category information helps the maintenance work by monitoring the cargo traffic on a specific road segment, thus road construction works can be scheduled by the use of such measurements. As the only requirement, all vehicles must be equipped by a tag containing the necessary data on it.

In the case of moving reader and fix mounted tags, the reader receives the stored information (ID or even details) about natural (e.g. rivers) or man-made (e.g. children playground) objects in the roadside, which can be dangerous. The sensing can also be "affirmed" by repeatedly placed tags, similarly like traffic signs before rail road crossings.

When the tags are mounted in a regular pattern e.g. in a tunnel, and tags are storing their position, the sensing of these tags is a special case of positioning. In this case RFID system can provide location data in areas that cannot be served by GPS.

Not only dangerous but special places as points of interest (e.g. restaurants, gas stations) can be equipped with tags. The driver can be informed also by tags deployed on roadside about the forthcoming petrol stations or about the nearest restaurants. If the driver doesn't have to look for a restaurant, but her/his navigation system filters the signals of these smart tags, the safety of the traffic can be increased. These steps are very important in the way of making our transportation significantly better, safer.

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