SECURITY

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■ BUILDING 2ND LINE OF DEFENCE FOR SAFER RAIL

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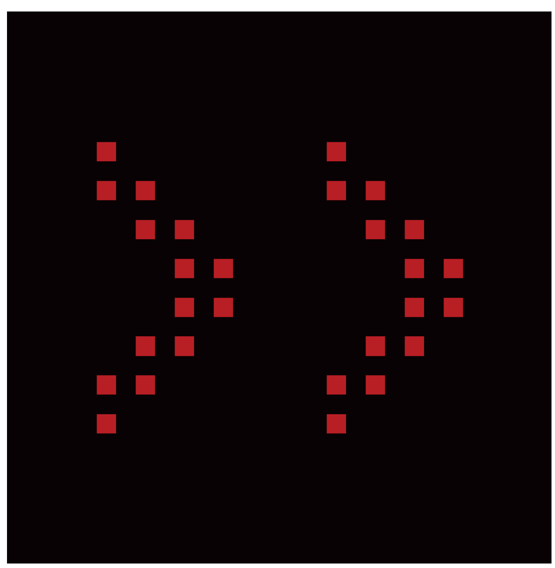
IMMUNOLOGISTS KNOW IT VERY WELL, HISTORIANS CAN GIVE MULTIPLE SUCCESSFUL EXAMPLES AND IT WASN'T IMPLEMENTED PROPERLY IN THE FINANCIAL MARKETS – THE CONCEPT OF A SECOND LINE OF DEFENCE. THIS ARTICLE INTRODUCES THE APPLICATION OF THIS CONCEPT AS A NEW APPROACH TO BOOSTING SAFETY MARGINS IN TODAY'S RAILWAY SYSTEMS.

Lines of defence

It is common knowledge that despite significant investments in railway safety technology, the amount of collisions of trains with trains, cars or other obstacles still remains high today, both in Europe and worldwide. The cause of train collisions is frequently attributed to a "chain of unfortunate circumstances" or "human error", in some cases also to exceptional operational conditions – all factors which prevented a first line of defence to avoid the risky situation. And this is exactly the crux of the matter: serious accidents often have a highly complex pattern of faults. Simple cause-effect scenarios are covered by infrastructural or operative measures. They guarantee to a large extent that dangerous situations are identified and avoided. However it is impossible to entirely avoid situations that nobody has ever thought of, but which could turn into catastrophes. And humans continue to be the greatest element of uncertainty.



How can accidents be avoided?

This is one of the questions addressed by transport research at the German Aerospace Center (DLR). In the case of trains, an entirely new approach is being explored. At the core, the basic assumption is that there will always be situations where even the most sophisticated safety functions will remain ineffective. Consequently in addition to research and development performed to support the roll-out of ERTMS, scientists are not concentrating on further improving the infrastructure or operative processes in this case. Instead they are investigating how the probability of collisions can be significantly decreased through additional "awareness", or, more specifically, "awareness-creating measures".

At the end of the day, once again humans are at the end of the chain of events, in the form of the driver. It actually appears quite simple: as soon as the driver knows what awaits him on his route, he can react properly. For a train driver this generally means braking. There are no other options in situations such as a construction vehicle in the middle of the track section which has, in fact, been exclusively cleared for the train.

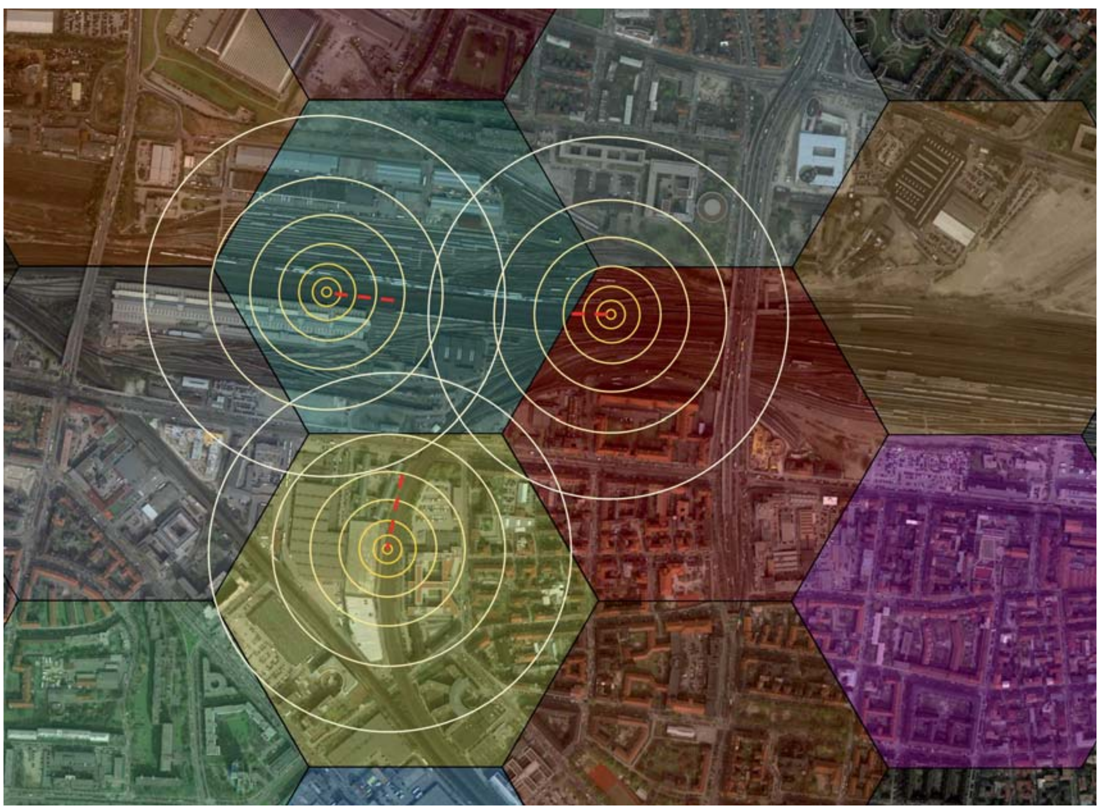
Technically this "second line of defence" situation awareness can be enabled by transmitting traffic situation information via radio communications to any train. Each vehicle equipped with a suitable receiver unit can perform a data fusion of all the available information about 'itself", e.g. position, speed, planned routing etc, in relation to all other vehicles in the vicinity; and by doing so, it performs a distributed situation analysis to identify potentially upcoming critical situations.

Ad-hoc, direct communication

A particular innovative approach for implementing this radio communication is ad-hoc, direct communication between the trains, i.e. without any base station network or any other railway infrastructure-based component. While for other means of transport similar ad-hoc radio communication based systems for avoiding collisions are already in daily use (ADS-B in aviation, AIS in the maritime domain), this is a radically new approach in the rail sector. The desired ad-hoc properties, i.e. self-organisation (no special configuration required before a connection is established) and decentralism (no central control nodes), perfectly match the requirements of a second line of defence distributed situation awareness. Analysis suggests that the whole collision avoidance application does not require any connection-oriented communication, which would be too time consuming because of the extra delay introduced by the connection set-up and disconnection phases. Instead, the whole functionality can be established through multi-broadcast, i.e. none of the conflict detection algorithms require a consecutive sequence of communication packets between each two communication peers.

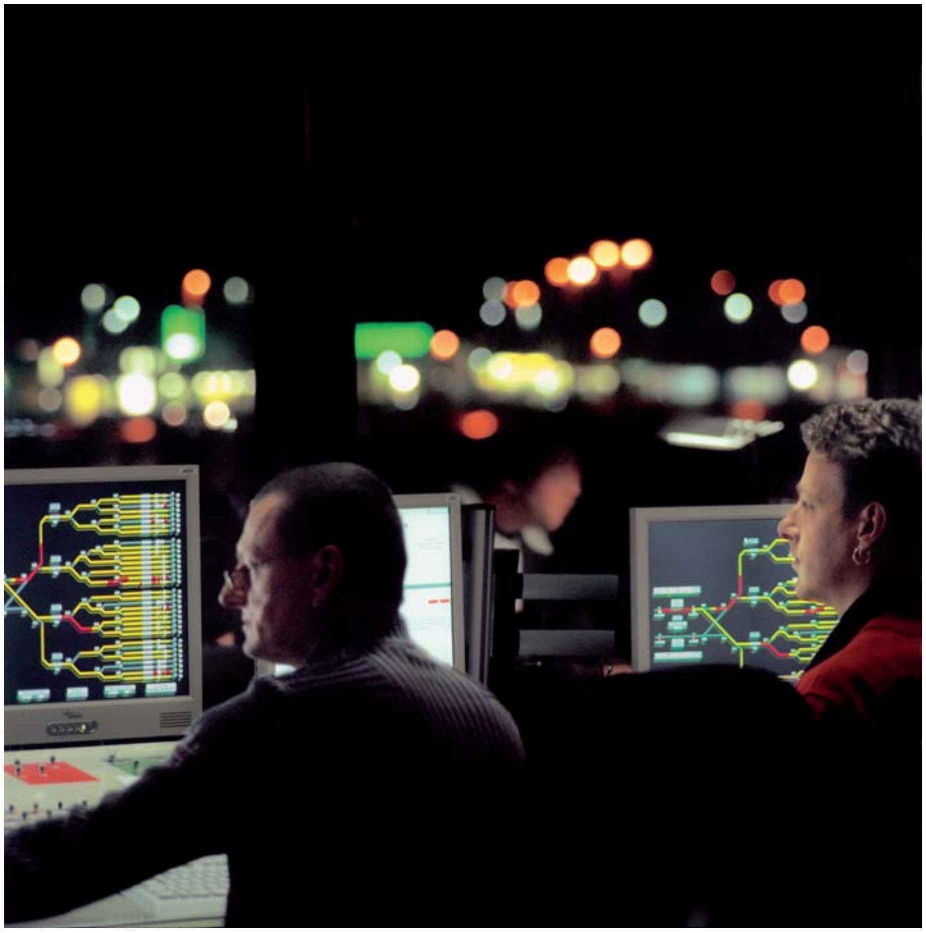
Following this design approach, each train or stationary object, such as the above mentioned construction vehicle, appropriately equipped with a transceiver unit, transmits its current position, speed, the planned routing (if known) and other data (e.g. obstacle clearance limits) to all receivers in the region (broadcast/-geocast). The regional relevance of the information exchanged (relatively low probability of collisions for trains far apart) directly maps to the non-centralised communication control, hence there is no need for a centralised,infrastructure-based backbone network.

The Cell-based, Orientation-aware MANET Broadcast (COMB) is a medium access scheme developed by the DLR[1]



Robust and reliable

Apart from safety-of-life level positioning issues, the most challenging aspect of this approach is designing a robust and reliable communication link. The connection-less communication, for instance, only allows forward error correction mechanisms on the communication link.



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> SCIENTISTS... ARE INVESTIGATING HOW THE PROBABILITY OF COLLISIONS CAN BE SIGNIFICANTLY DECREASED THROUGH ADDITIONAL "AWARENESS", OR, MORE SPECIFICALLY, "AWARENESS-CREATING MEASURES"

Mode of transport (Anti Collision System)	Minimum communication range (km)	Maximum velocity (km/hr)	Topological network dynamics (velocity divided by range)
Trains (RCAS)	5	200	40
Ships (AIS)	40	60	1.5
Aircraft (TCAS, ADS-B)	56	1000	18

Comparison of network dynamics

The table above reveals how the degree of topological network dynamics is more demanding for trains than for aircraft, which has a direct influence on the reliability of the communication between vehicles. To tackle the problem of radio medium access in an uncoordinated, ad-hoc network, DLR has developed an extremely robust, medium access scheme via a combined time-division/code-division technique, making particular use of location information[1]. This scheme is illustrated on page 93.

Designing to measure

By looking at the deployment scenarios for such a radio-supported, infrastructure-less, collision avoidance system, it is clear that the benefits do not lie primarily with high-speed rail networks. Here, thanks to largely crossroad-free routes, ultra modern, ETCS-equipped traction units and other measures, the probability of collisions is far lower than with regional networks or in shunting yards. While the collision impact energy may not be so great in shunting yards due to lower speeds, the overall probability of collisions is higher. As a result, the communi-

- The Railway Collision Avoidance System (RCAS) project, part of the DLR's transport research programme, began in 2007. It involves the Institute of Communications and Navigation, Institute of Robotics and Mechatronics and Institute of Transportation Systems
- The RCAS is a 'safety overlay' system that can be deployed on top of any existing safety infrastructure in train networks
- The core idea is to broadcast the position and intended track of trains, as well as additional data like vehicle dimensions, to all other trains in the area using ad-hoc train-to-train communications. This enables train drivers to have up-to-date and accurate knowledge of the traffic situation in the vicinity, and act in consequence
- Computer analysis of the received information in relation to the train's own position and movement vector, based on an electronic track map, detects possible collisions. This is followed by an alert signal and advice for the driver on the best response to avoid the danger
- The system can be adapted to a variety of situations, e.g. advancing trains, road vehicles or obstacles

cation system must be designed according to the reaction times of the speed profile. As typical speeds on regional networks are within a range of 80 to 160km/hr, the resulting relative speed of up to 320km/hr suggests a communication system designed to detect the potential danger of two trains approaching each other if they are at least five kilometres apart, i.e. a minimum transmission power must be chosen so that each train “violating” a five kilometre zone can receive the signal[2].

Calculations reveal that the system needs to be designed for at least 500 potentially simultaneously transmitting stations, i.e. trains and other objects, in an area with a diameter of about ten kilometres. As with any radio transmission system, the dimensioning is closely linked to the issue of the usable frequency range. In addition to the general technical conditions (the propagation conditions of radio signals are, for example, frequency-dependent[3]), regulatory aspects are equally important here. There are frequency ranges that are already intended for rail operations use (e.g., 460 MHz). Unfortunately they vary according to global regions and are also restricted to certain types of applications.

Gaining advantages

The ad-hoc, base station-less communication principle also has a big advantage because no infrastructure investments are needed, unlike, for example, when introducing the rail-specific variant of the GSM-R mobile network. A migration scenario, in other words, a scalable, step-by-step introduction of the system, also already exists. While not so much a critical issue for small island-networks such as a closed company, railway network, this is vital for all other, non-island-networks. All trains equipped with the necessary technology can analyse the received traffic situation information and cross-reference it with information about their own routes in order to issue warnings of any potential dangerous situation. All trains not (yet) equipped with this technology can proceed in accordance with the present (infrastructure-based) safety standards.

By following this so-called "Safety Overlay" concept, none of the current safety systems (LZB, ERTMS etc.) are replaced. However any equipment on board the train may help better represent the current situation – for instance, map data provided by an ETCS unit and an eddy current sensor can both significantly increase the precision and integrity of position information. So the approach is really a second line of defence with independent sources of information, which includes, in particular, an independency of errors. The latter is especially important because it guarantees the second line of defence remains unaffected from problems causing any first line to fail.

A prototype of the system, developed as part of the DLR’s Railway Collision Avoidance System (RCAS[4]) project, was presented to an international audience at InnoTrans 2008 (Berlin). The system approach was implemented on model trains (see photo left) that communicated wirelessly to each other based on the principles outlined above.

Linking modes

Researchers and engineers at the DLR see potential for further solutions involving communicating with road vehicles. If, for example, the collision avoidance system for trains could be linked to the standardisation of Car2Car communication (the DLR also contributed significantly to this project), this could reduce collisions between trains and road vehicles at level crossings. On average, such small collisions occur in Germany on two out of three days (according to Deutsche Bahn statistics, 2004). However this plan is already being thwarted by the frequencies currently in use – Car2Car communication is being standardised primarily for the frequency range around 5.9 GHz.

For its part, the DLR has adopted a holistic approach to its research on collision avoidance systems for both transport modes, as part of an intelligent transport system ■

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[4]www.collision-avoidance.org/rcas