FROM TRAIN TO TRAIN

Distributed Situation Awareness for Safe Rail Transport

By Prof. Dr. Thomas Strang

Evening news, 8.00 pm. Following the news on political developments in the world, a serious collision of a train with a construction vehicle is reported. A few days ago, there was an almost identical report: A regional train collided with a car at a railroad crossing. Why can collisions of this nature still happen today, especially given that the Europeans proudly refer to the high investments in the safety of their technology? Scientists at three different DLR institutes are investigating this question.

The cause of train collisions is frequently attributed to a "chain of unfortunate circumstances" or "human error." 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 degree that dangerous situations are identified and avoided.

It is impossible to entirely avoid situations that nobody has ever thought of, but which could develop into catastrophes. Humans continue to be the greatest element of uncertainty.

How can accidents be avoided? This is one of the questions to which transport research is dedicated at DLR. In the area of trains, an entirely new approach is being investigated. At the core the basic assumption is made that there will always be situations where even the most sophisticated safety functions will not be effective.

The scientists are thus not concentrating on further improving the infrastructure or operative processes. Instead they are investigating how collisions can be avoided through additional “awareness,” or, more specifically, awareness-creating measures. At the end of the day, it is once again humans who are last in the chain of events in the form of the driver.

It actually sounds quite simple: As soon as the driver knows what awaits him on his route, he can react. For the driver of a train this generally means braking. There are no other options in situations such as a construction vehicle in the middle of the track section which had in fact been exclusively cleared for the train.

Broadcasting and analyzing traffic situation information in a distributed manner in trains is therefore the way to a solution. For this, a robust and reliable radio communication proce-

Ad-Hoc Properties, Vehicular Ad-Hoc Network
A Vehicular Ad-Hoc Network (VANet) is a mobile ad-hoc network whose nodes are vehicles. Important properties are the self-organization (no special configuration required before a connection is established) and decentrality (there are no central control nodes). A VANet must fulfill special requirements that are derived from its field of use. The nodes of a VANet move at different but potentially extremely high speeds.

Connection-Oriented Communication
Before data can be exchanged with aid of a communication connection, the connection first needs to be established and then disconnected after successful transmission. The advantage of connection-oriented communication is the direct addressability of the recipient and the possibility of deploying error-correcting measures. The main disadvantage is the additional time for establishing a connection and disconnecting.

High-Speed Train Network
Almost continuous double-track railroad network with typical speeds of over 160 kilometers per hour

Regional Train Lines
Mostly single tracks with typical speeds within a range of 80 to 160 kilometers per hour

Shunting Yards
10 to 40 parallel tracks, typical speed of around 30 kilometers per hour

dure is necessary with what are referred to as "ad-hoc properties." They are particularly important because neither can a central control component take over the coordination of all communication connections nor is there enough time in practice for connection-oriented processes. For other means of transport (aviation, shipping), similar concepts for avoiding collisions are already daily practice.

This communication principle also has the big advantage that no investments need to be made in the infrastructure, as for example for the introduction of the rail-specific variant of the mobile network GSM-R. A migration scenario, in other words, a scaled, step-by-step introduction of the system, also already exists. All trains that are equipped with the necessary technology can analyze the received traffic situation information and cross-reference it with information about the train's own route in order to provide a warning of any potential danger situation. All trains that have not (yet) been 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 present safety systems is replaced. Instead a complementary system is being added. This can also become the primary safety technology due to economic considerations if other, infrastructure safety technologies are too expensive, for example, in less frequented parts of a regional rail network.

By looking at the deployment scenarios of such a radio-supported infrastructure-less collision avoidance system,

GREATEST BENEFIT ON REGIONAL ROUTES AND IN SHUNTING YARDS

it is clear that the benefits do not lie primarily with the high-speed rail networks. With these networks, 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 routes 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 communication system primarily needs to be designed according to the reaction times of this speed profile.

An analysis suggests that the whole application does not require any connection-oriented communication from train to train. Instead, each train, or even appropriately equipped stationary objects such as the above-mentioned construction vehicle, could transmit their current position, their planned routing, and other data to all receivers in the region (broadcast/geocast). Calculations have shown 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 around ten kilometers.

As with any radio transmission system, the dimensioning is closely linked with the issue of the usable frequency range. In addition to the general technical conditions (the propagation conditions of radio signals are, for example, are frequency-dependent), 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 dependent on their purpose of use.

INFORMATION EXCHANGE WITH ROAD VEHICLES

DLR researchers and engineers see potential for further solutions in the communication with road vehicles. If, for example, the collision avoidance system for trains could be linked with the standardization of Car2Car communication, which is also be driven forward by DLR, collisions between trains and road vehicles at railroad crossings could be significantly reduced. On average, such small collisions occur in Germany on two out of three days (according to statistics of Deutsche Bahn in 2004).

However, this plan is currently being thwarted by the frequencies that are already being used – Car2Car communication is just being standardized for the frequency range around 5.9 GHz. As part of the European Conference of Transport Research Institutes (ECTRI), DLR has committed itself to the holistic consideration of collision avoidance systems of both means of transport as part of an intelligent transport infrastructure.

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DLR DEVELOPMENT AS PART OF THE RAILWAY COLLISION AVOIDANCE SYSTEM PROJECT

The German Aerospace Center (DLR) is developing a Railway Collision Avoidance System (RCAS), a "safety overlay" system which can be deployed on top of any existing safety infrastructure in train networks. The core idea of RCAS 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 an up-to-date accurate knowledge of the traffic situation in the vicinity, and act in consequence. Computer analysis of the received information, the own position and movement vector and an electronic track map detects possible collisions, displaying an alert signal, and advising the driver of the most convenient strategy to follow in order to avoid the danger. The system is adaptive to a variety of situations like advancing trains or road vehicles or obstacles.

With the scientists at the Institute of Communications and Navigation who are developing the actual communication procedure under rail-specific conditions, scientists and engineers from two further DLR institutes are working on the RCAS project:
The Institute of Transporation Systems in Brunswick answers operational rail questions. It adjusts the jointly developed concept to the general conditions and the operational railway properties and further develops it to the stage of integrating the components in a test vehicle. The team at the Institute of Robotics and Mechatronics adds optical sub-systems to the RCAS system, for example, for monitoring that there are no obstacles on the track.