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A Radio-Broadcast System for Inter-Train Communication

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ABSTRACT

Despite massive expenditures in infrastructure-based safety mechanisms, the current state of railway transportation data shows that the frequency of accidents is still too high. Using direct communication in mobile ad hoc networks (MANETs), exchanging location and other relevant context information provided by multiple sensors in the trains, and other hallmarks of pervasive computing, we demonstrate that an infrastructure-free cross-layer train-to-train communication system can reveal dangerous situations. While infrastructure-free communications have proven useful for maritime and aviation transportation, and comparable apps built on top of car-to-car communications may soon be accessible for road users, no such thing currently exists for rail transport systems. A six-stage process of work is carried out in order to create such a system: Each layer of the system—from the initial study and frequency band selection to the detailed characterization of the propagation channel to the development of the media access control (MAC) layer, the implementation of the physical layer, and finally the verification of the system—must be carefully considered. During this procedure, navigation systems and other sensors are used to offer context information, such as location, time, and speed, that is used to enhance the conversation.

INTRODUCTION

Current statistics of the International Union of Railways (UIC) show, that there are three significant train accidents in Europe every day [2], despite millions of Euros which have been invested in trackside and in-train safety equipment. In order to increase safety in railway traffic, some countries are partially installing control systems, mainly centrally managed ones, especially the Automatic Train Control (ATC), where the trains are monitored by devices located along the rail. These devices send the collected information to an operaaction center that can pass specific instructions to the train. A European ATC standard, European Train Control System teem (ETCS), is intended to replace the various European ATC systems, in order to protect international train trapfic. However, according to estimations of the German railway company ”Deutsche Bahn” (DB), it could take up to 20 years and cost up to 8 billion Euro to introduce ETCS right across Europe [1]. Furthermore, only the operation center has an overall overview of the traffic situation, and a train driver could only be warned against hypothetical collisions if the operation center decides so. While maritime, air, and road transport have a vehicle intograted collision avoidance system available or in the development phase, we find no satisfactory solution of this type of technology in railway transportation.

Therefore, it is necessary to develop a system that will allow the train conductors to have an up-to-date accurate knowedge of the traffic situation in the vicinity and act in consequence. The system is intended to not rely on componets in the infrastructure, this way substantially reducing its rollout- and maintenance costs, as well as inherently provoiding a migration strategy. The basic idea is to communictate relevant own context information to all other nearby trains. In this particular case, each train has to calculate its own position and movement vector and broadcast this information as well as additional data like vehicle dimesons to all other trains in the area.

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Thus, the driver's cabin could be equipped with a display showing the position of the other vehicles in the region. Computer analysis of all receiled context information, the own position and movement vector and an electronic track map detects possible colisons, displaying an alert signal, and advising the driver of the most convenient strategy to follow in order to avoid the danger. The system can take into account different danger sources, like advancing trains or road vehicles or obstacles, and classify them according to a specific scale.

PROBLEM DOMAIN AND EXPECTED CONTRIBUTIONS

The aim of our work is the design, development, similarton, optimization and verification of a communication system that will allow the transmission of messages of a railway collision avoidance system. We need to consider the physical constraints of the application in order to infer the commanication parameters as shown in Figure 1. In particular the distance the trains need to brake, their speed, the number of trains in a network and the characteristics of the propagation channel will delimit the communication system features.

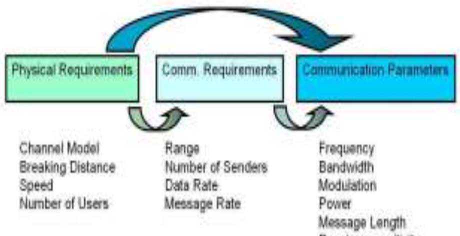

Figure 1: Relationship between physical requirements, and communication parameters.

There are a number of obstacles to overcome while developing the system.

Wireless communication adds significant complexity to any communication system, yet it is not possible to leverage any pre-existing infrastructure. In order to overcome range limitations, many of these systems rely on external components like repeaters. However, this approach has a detrimental effect on finances. So, because our system doesn't rely on any pre-existing infrastructure, we need to worry about the careful design of the communication parameters, especially with the physical layer, to provide sufficient range.

• It will operate on regional train lines: Due to the fact that most people's attention is currently focused on high-speed rail, regional networks have been neglected. An intriguing viewpoint is added by such lines of fer, but the communication system faces significant challenges as a result. Regional rail networks, in contrast to high-speed lines, are characterised by a greater emphasis on bends of varying radii. Consequently, a propagation channel with significant fading and multipath is to be anticipated, which has a profound effect on the quality of communication. High-speed lines are the primary emphasis of the channel models now available for railway networks. A proper channel model must thus be created.

Any information transmitted by a train should reach all nearby residents quickly since transmissions are aired. As a result, broadcast is the optimal tactic. The resultant communication network is a fast and very dense MANET (mobile ad hoc network) capable of broadcasting messages. Despite the fact that a trustworthy MAC layer for such networks is a pressing modern problem and research topic, no workable solution has been identified as of yet.

• A GNSS receiver and other sensors on board the trains provide location and context data: The system's in-built GNSS receiver makes it possible to leverage data like time, location, velocity, and heading to improve communication on several levels, including the Physical and MAC RELATED WORK.

Traditional optical or mechanical methods, such as semaphores, are still used for railway safety systems. However, GSM R, a new railway safety system based on GSM, has just been created. Due to its heavy reliance on pre-existing infrastructure, its rollout price tag is over the roof. As a result, GSM-R is optimised for high-speed lines but leaves rural networks vulnerable since implementation is time-consuming and expensive. Since GSM-R is a centralised system, with all communications going via one location, it will be more prone to disruptions. Instead, we'll recommend a collision-avoidance system that's designed to work flawlessly in spite of these obstacles. It relies not on a central hub or any supporting infrastructure but rather on decentralised, locally-based networks. Automatic Identification System (AIS) [3] for maritime, Au somaticDependence Surveillance (ADS-B) [4] for air, and Car2Car [5] for road transportation are only a few examples of infrastructure-less collision avoidance technologies.

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All of these systems employ the data supplied by a GNSS to conduct surveillance, and they have a few commonalities in how they do so: they are broadcast, distributed, and rely on this data at the application level. However, they are often inapplicable to railway transportation because to the disparities un environmental features and needs across the various modes of transportation. Railroad transportation has little room for manoeuvre, therefore stopping the train is sometimes the only choice for a quick reply. Due to the possible speed of the trains, the limited capacity for response, and the close geographical proximity between adjacent tracks, a high precision need on position determination is introduced. While multichip network expansion is possible due to the large vehicle density on highways, such an assumption cannot be made for rail transport. Therefore, we will not be considering any higher-level modes of communication beyond Medium Access. Trains create a dynamic network since they only spend a brief time within communication range of one another. This causes significant issues at the MAC layer. Distinct variations in the physical layer are especially noticeable. Long distances are necessary for air and sea travel. However, there are fewer constraints because to the channel's relaxed nature compared to a train station. However, the road transport channel is analogous to the rail transport channel. However, the minimum required distance is substantially smaller. It's clear from considering all these variables that train transportation presents the most difficulties [8].

DESIGN OF AN ORIENTATION AWARE RAILROAD COLLISION AVOIDANCE SYSTEM

Preliminary analysis and selection of an adequate transmission band

The aim of the preliminary analysis is to point out the pariometers that should be designed. It has to be explained how to infer these values from the physical characteristics of a railway transportation system. Furthermore, an approximate value of these communication parameters must be given, as well as the key aspects and influence that the parameters will produce in the overall system will be noted. Since the frequency is a key aspect that will condition the

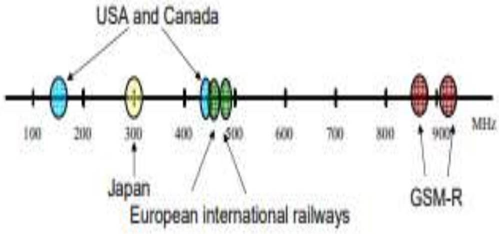

Figure 2: Worldwide distribution of frequency bands for railway applications

It is the primary parameter in the system's overall design and should be selected first. We selected the 400MHz band for our system and many other characteristic parameters that can be found in [8] together with the reasons for their deduction. This was done after taking into account all of the system's circumstances and the current availabilities (see the current frequency ofcurations in Figure 2).

The Propagation Channel's Characterization

The design process must take into account the unique features of the communication channel if it is to provide optimal results. Since the communication range is one of the most important criteria [8], the channel type should be selected with attention. The instantaneous amplitude of a railway channel might fluctuate wildly, making it impossible to use a deterministic method to calculate its parameters. There hasn't been a lot of effort put on defining the railway propagation environment. GSM-R [9], which operates on a dedicated frequency band, is the primary focus of current research (876-880 MHz uplink, 921-925 MHz downlink). Our technology, in contrast to GSM-R, will function on regional networks as well as high-speed ones, thus we cannot make assumptions like LOS. Studies of deterministic channel models in the 25 GHz range [10] and the 5 GHz band [11] have also been conducted. Research like this is often conducted for high-speed railways. Alternatively, when designing a terrestrial system, broad propagation prediction models like Hate-Okumura, Ibrahim, and Parson are often utilised [12]. Similar to Figure 3 from [7]), our characterisation of the propagation channel is frequency-specific and takes into consideration the following: Negative path loss:

Prediction techniques that are both accurate and trustworthy are necessary for setting the parameters of a system that must deliver efficient and dependable coverage. Constructions and other man-made obstacles cause signal attenuation due to a phenomenon known as multipath. However, vegetation such as trees and shrubs cause shadowing, dispersion, and absorption. Doppler:

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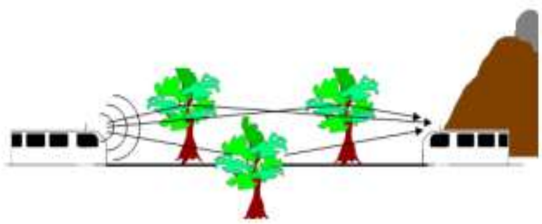
It is well-known that a perceived shift in frequency results from the movement of a transmitter and receiver relative to one another. Doppler effect This is the effect of the Doppler shift. When the communication trains are travelling in opposing directions along a straight line, the Doppler frequency shift is at its greatest. As there are several scatters originating from various directions, the apparent frequency shift will vary for each scatter. As a result, a Doppler spectrum forms. Fading:

Changes in the surroundings may cause noise levels to fluctuate by a few tens of decibels around this average. The median signal shifts as the train travels from one location to another owing to large-scale changes in the terrain profile along the route brought on by shifts in the character of the local topography. Having a log-normal distribution, this is the gradual fading we're talking about. Variations in signal strength due to several paths in close proximity, known as fast fading, might occur unexpectedly. Channels are considered Rician when line-of-sight (LOS) is feasible; otherwise, they are considered Rayleigh. Relative Time Delay:

Within the signal's bandwidth, this parameter characterises the multipath impact. For a given channel to exhibit flat fading, the bandwidth of the broadcast signal must be limited enough such that all frequencies react identically. Path delay is included into the transmitted symbol. In the presence of a delay spread larger than the symbol period, the channel will display frequency-selective fading, resulting in intermoult interference (ISI), which severely distorts the transmitted information. To put it another way, the coherence bandwidth is the range of frequencies where the transmitted signal is not excessively distorted, and it is defined by the delay spread. Problems with background noise and sonic interference:

This parameter is often left out of Channel models;however, it indicates how reliable the receiver should be.



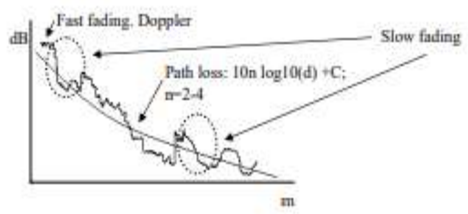


Figure 3: Complete characterization of a channel.

CONCLUSION

In this study, we argue for the implementation of an infrastructure-free, broadcast, directional railroad collision avoidance system. We outlined the main points that will allow you to address the problems with current systems or modify them to work in a train setting. As may be seen in other publications of the German research project RCAS, many of the actions required to complete the system design have already been taken.

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