Chapter 41
Communication Networks to Connect Moving Vehicles to Transportation Systems to Infrastructure

Kira Kastell
Frankfurt University of Applied Sciences, Germany

ABSTRACT

Communication in transportation systems not only involves the communication inside a vehicle, train, or airplane but it also includes the transfer of data to and from the transportation system or between devices belonging to that system. This will be done using different types of wireless communication. Therefore in this chapter, first, the fundamentals of mobile communication networks are shortly described. Thereafter, possible candidate networks are discussed. Their suitability for a certain transportation system can be evaluated taking into consideration the system's requirements. Among the most prominent are the influence of speed and mobility, data rate and bit error rate constraints, reliability of the system and on-going connections. As in most of the cases, there will be no single best wireless communication network to fulfil all requirements, and in this chapter also hybrid networks are discussed. These are networks consisting of different (wireless) access networks. The devices may use the best suited network for a given situation but also change to another network while continuing the on-going connection or data transfer. Here the design of the handover or relocation plays a critical role as well as localization.

FUNDAMENTALS OF WIRELESS COMMUNICATION

In principle, wireless communication can reach every position intended. But in contrast to fixed line communication more sources of noise and distortion come into play. Fixed line communication mostly suffers from the attenuation of the communication line and also from its low or band pass characteristic, but the signal only is transmitted along one dedicated path. In wireless communication multipath propagation comes into play.

The source signal is processed to fit the channel and finally transmitted over an antenna into the

DOI: 10.4018/978-1-4666-8473-7.ch041

wireless channel. It is also received by an antenna and then converted to be delivered to the sink in an according format. As the channel is the air, there is no guiding of the electromagnetic wave (including optical waves). The preferred transmission path is the direct path between transmitter and receiver. This only exists if there is a line-of-sight connection between both. If there is an obstacle between transmitter and receiver the wave may penetrate the obstacle suffering from additional attenuation and phase shift. Besides these two paths also reflection, scattering and diffraction play a role. Here the signal does not follow a straight line between transmitter and receiver, but because of the directional characteristic of the antenna, which never focuses on only one single direction but always covers at least an angle of some degrees, is not only transmitted in the direction of the receiver. Nevertheless, these parts of the signal may also reach the receiver taking longer paths. Reflection and diffraction both are based on the same principle, reflection is widely known and occurs if obstacles have the dimension of one wavelength or more. Scattering takes place at smaller obstacles and does not only lead to one reflected signal but the incoming signal is split up and scattered with different attenuation, phase shift and in different directions. Finally diffraction takes place when the signal hits an edge, then it changes its direction, often turning around that edge. Multipath propagation therefore leads to a multitude of received signals where only one signal has been transmitted. They arrive with different time delays, amplitudes and phase shifts. These effects make it more difficult to detect and process the signal at the receiver but they are necessary to be able to transmit the signals everywhere. Otherwise only line of sight communication would be possible, which would require too many transmitters to cover an area completely.

This aspect is even more important for mobile communication (wireless communication with moving devices) needed for transportation systems. But the mobility also contributes to another effect: Doppler shift. This takes into consideration the relative change of position between transmitter and receiver changing the distance and characteristics of the wireless channel. It results in a shift of the received frequency compared to the transmitted one and has to be taken into consideration in receiver design. In addition the wireless channel also suffers from different sources of distortion, mostly noticeable as attenuation. The conditions of the wireless channel change randomly as moving obstacles are not predictable and rain, smog and other changes of the composition of the air may cause severe signal degradation. Objects covering the antenna have an impact on signal quality as well, e.g. insects, pollen.

A wireless mobile communication network needs to take this into consideration. As for transportation systems we may not be willing to design and setup a dedicated wireless access network here the main principles of system design for existing wireless networks will be explained. The parameter on which the transportation system planer has the most influence is the antenna of the transportation device. Taking into consideration multipath propagation it is preferable to make use of an omnidirectional antenna to be able to receive signals from every direction with (nearly) the same quality. But the antenna may also have a more directional characteristic, if some directions are preferred or should be excluded because of distortions, e.g. signal reception along a track, distortions from a known adjacent transmitter or bright star. Communication to and from a mobile device not only involves the wireless device and its direct counterpart on the other end of the air interface, the network access point (NAP), but also the complete network that is behind the network access point. So the air interface is only a small part of the network. And this, besides the roll out costs, is why communication in transportation systems most likely will make use of existing networks to communicate with other systems.

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