Poster: RSSI-based antenna evaluation for robust BLE communication in in-car environments

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Abstract

Achieving reliable wireless communications using COTS devices in vehicles has been an unattainable target so far. One reason is that the high safety requirements of automotive applications cannot be met by the relative unreliability of wireless communication in such complex environments. This poster presents an approach for utilizing RSSI as a first benchmark to evaluate antennas for a Bluetooth Low Energy (BLE) based wireless communication system design to determine underlying link robustness.

1 Introduction

Wireless communication for vehicles is an ongoing research topic [3, 4]. Compared to wired communication, wireless communication allows for a straightforward installation of components at various sensing locations and decreases vehicle weight, and installation and maintenance complexity [2]. Especially during product development, wireless communication can decrease the complexity and costs in a test bed. Unfortunately, a motor constitutes a harsh wireless communication environment. The prevailing heat, dirt, vibrations, materials, and the small gaps between components lead to a significant degradation of wireless links and devices, and thus, prevents the application of COTS devices. Current research topics are focused on improving protocols and communication topologies [1]. Antennas, however, are often overlooked and not necessarily taken into account [2].

This poster presents RSSI measurements as an approach to evaluate and pre-select antennas suitable for the application in specific in-car sensor locations to design an overall dependable communication system.

2 Basic Concept

The concept of the approach is as follows: We try to improve reliability of the wireless communication system by selecting optimal antennas for each required sensing location. A first antenna benchmark is required to narrow down suitable candidates. This initial benchmark uses the received signal strength indicator (RSSI). Even though RSSI is an inaccurate measurement and only an indication of the received radio signal power, it provides valuable information to evaluate the behavior and performance of antennas. Consequently, a test setup in the context of in-car communication is required (see section 2.1). It serves as a starting point to identify antennas which might be suitable for deployment in in-car environments. Suitable candidates undergo a more detailed simulation-driven follow-up evaluation.

2.1 Evaluation Setup

The test setup consists of an aluminium box with dimensions 1500x500x500 mm (L x W x H) and imitates an in-car environment. A total number of 20 antennas were selected for evaluation based on their properties and size (dimensions are a critical factor to allow application in confined spaces). 80% of the chosen antennas exhibit an omnidirectional radiation pattern and were rotated to different angles (90°, 180° both horizontal and vertical) to investigate the impact on the RSSI. The other 20% were directional. For the antenna evaluation, nRF52840 DK boards were used, with a BLE 5.0 transmission protocol and a data rate of 1 Mbit/s. The transmission power was set to 0 dBm in advertising mode (broadcasting on channel 37, 38, and 39) and the distance between sender and receiver was approx. 1.4 meters. The boards were used in standard advertising mode to cover the whole frequency range of Bluetooth (2.4 - 2.48 GHz). The exact frequencies of the channels are 2.402 GHz (Channel 37), 2.426 GHz (Channel 38), and 2.48 GHz (Channel 39). The tested antennas were plugged in the u.FL interface at the nRF52840 DK boards. While there is slight attenuation at the board connector (test probe MXHS83QE3000 required to activate the switch in the connector) the setup suffices for RSSI estimations. One important aspect is the positioning of the devices, as metal (in the near field) will significantly impact the RSSI value (similar to a motor room). Hence, the position of the transmitter antenna was chosen close to one side panel of the box. In all experiments the receiver position was the same since this is also the most likely scenario in a vehicle (if a star topology is applied). One evaluation run lasts for 150 packet receptions (equals 30-40 seconds)

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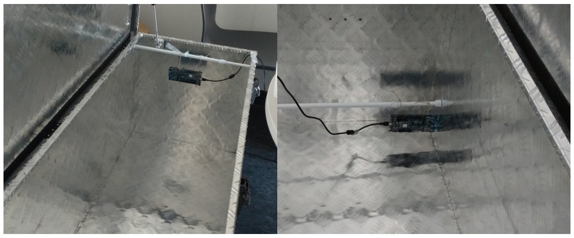

Figure 1. Setup with nRF52 boards in aluminium box to recreate an engine compartment environment

on each channel, and the RSSI for each packet is measured. The setup is depicted in Figure 1.

RSSIs were measured in four distinct scenarios (open box, closed box, open box with a metallic object, closed box with a metallic object) at varying transmitter locations. The open box scenario was included to see the influence of other wireless signals (e.g. WiFi) on the transmission quality. A closed box eliminates this interference. In Figure 2 the impact of the different transmitter positions for the same antenna in the closed box scenario is clearly visible. Since

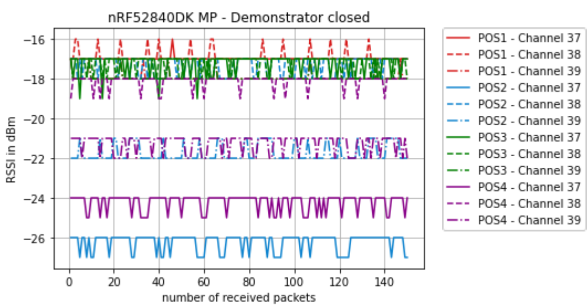

Figure 2. RSSI value evolution (150 packet receptions) of four transmitter locations in a closed box scenario

the box is closed, there is no external interference affecting the transmission. Still a clear difference in the RSSI is visible. The measurements were repeated three times at different dates and times to validate the results.

3 Results and discussion

For simplicity, only the results of one transmitter location are discussed. These results suggest that there are differences in the antenna performance for various positions in the setup. We compared 20 antennas for the same positions to identify major performance differences. While rotation significantly impacts directional antennas, no such impact was identified for omnidirectional antennas. Figure 3 shows the results of the comparison of the Molex 146220-0100 and Yageo ANTX100P001B24003 for a scenario, where a metal object was placed in the box. The x-axis denotes the number of received packets over time and the moment when the object is placed in the box is clearly visible. As soon as the box is stationary, the RSSI values will stabilize at lower values than before, since the transmission paths are slightly affected by the additional object. The biggest difference in signal power is noticeable for channel 39 of the Yageo ANTX100P001B24003 antenna. The performance degrades significantly for the upper parts of the BLE band, rendering the antenna useless in more complex scenarios. To gain

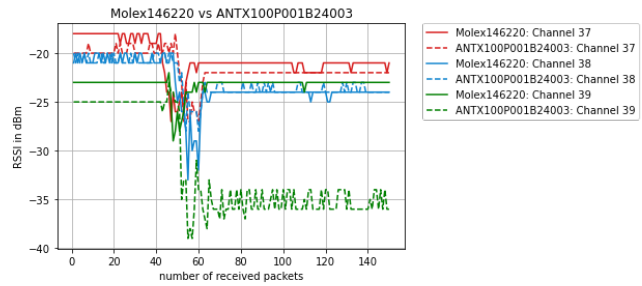

Figure 3. Comparison of RSSI evolution (150 packet receptions) for two antennas, where an object is actively placed in the environment

such important information from such a simple setup is astonishing: the antenna behavior is very different from the expected results (data sheets). Even though the selected antennas should work rather well in such a scenario, the results show otherwise for many antennas. E.g., according to data sheets, the Antenova SR4W030 antenna should be the best option for metal surface scenarios; however, results suggest that other antennas (e.g., Molex 47950-0011) perform much better. Given the rather high discrepancy to the expected results implies that this method can be used for a first fast antenna selection for more complex scenarios.

4 Outlook

An RSSI evaluation is just the first step towards identifying the best antennas for such in-car communication scenarios. For further analyses, suitable antennas and setup will be modeled in a simulation environment. To tune the simulations, supplementary measurement methods (i.e., Vector Network Analyzer) will be used for an in-depth experiment, to assess the S-parameters of selected antennas. First simulation results suggest a coherence between the real measurements and the simulation. Consequently, future work will investigate how simulations can be used to determine the best fitting antennas for specific application scenarios without the necessity to confirm results by measurements. The ultimate goal is to automatically derive the best antenna setup for individual sensor locations while achieving dependable wireless communication links.

Acknowledgements

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5 References

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