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In-Vehicle Human Presence Detection and Breathing Rate Estimation using IEEE 802.11n Channel State Information.

ABSTRACT - Masterthesis

Recently, due to rapid developments of WLAN technology and growing capacities of physical layer, device-free motion detection and vital sign monitoring using WLAN signals. They have fostered a broad range of innovative applications such as healthcare, intrusion detection, localization, gesture recognition, so forth in hospitals, homes, and offices. However, research is lacking for human presence detection and health monitoring in vehicles, which has become hot topic for car manufacturing industries in the vision 2025 of European New Vehicle Assessment Program (Euro NCAP). Studies show that only in United States 849 children have died over past 22 years within cars because either they were forgotten and left alone in cars or children who gained access to unattended cars. Apart from child presence, detection these systems are also demanded for driver fatigue detection and health monitoring of other passengers. Currently, car manufacturing industries and other research centers are working to address this problem by embedding sensors. In contrast, the in-vehicle monitoring using WLAN signals is more suitable because it is device free, takes no space, and inexpensive to install.

In this work, we propose the human presence detection (HPD) and breathing rate estimation (BRE) system by exploiting channel state information (CSI) available in IEEE 802.11n. This system reuses existing Wi-Fi infrastructure available in cars. It exploits CSI extracted from commercial-off-the-shelf (COTS) network interface card (NIC) for human motion detection and periodic movements sensing generated by chest or abdomen. Verification of the measurement setup is done for 2.4 GHz and 5.2 GHz, before using it for sensitive measurements. Measurement setup is tested in the lab environment only for motion detection as an exemplary scenario after that it is used in the car for HPD and BRE.

We provide a simple two-path radio propagation model to explain the complementary relation between CSI phase and amplitude. The system takes an advantage of both amplitude and phase data of CSI streams for HPD and BRE. Measurements are conducted with individual Rx antennas and adjacent pair of Rx antennas. Different data preprocessing and signal processing techniques are applied for both kind of

measurement setups individually for amplitude and phase data. Extensive experimental evaluation in typical car environment validates noteworthy performance of this approach in case of various transmitter-receiver (Tx-Rx) configurations and sitting positions. Performance is evaluated by comparing results of single Rx antenna, two Rx antennas, and three Rx antennas cases for all Tx-Rx configurations at different sitting positions. Results are further verified with real-time counting of breathing rates.