Vehicle-Driver Communication using Off-The-Shelf Transceivers

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***Abstract*—Almost all modern cars can be controlled remotely using a personal communicator (keyfob). However, the degree of interaction between currently available personal communicators and cars is very limited. The communication link is unidirectional and the communication range is limited to a few dozen meters. However, there are many interesting applications that could be supported if a keyfob would be able to support energy efficient bidirectional longer range communication. In this paper we investigate off-the-shelf transceivers in terms of their usability for bidirectional longer range communication. Our evaluation results show that existing transceivers can generally support the required communication ranges but that links tend to be very unreliable. This high unreliability must be handled in an energy efficient way by the keyfob to car communication protocol in order to make off-the-shelf transceivers a viable solution.**

I. Introduction

Modern cars can be controlled remotely using a personal communicator (keyfob). However, the degree of interaction between currently available personal communicators and cars is very limited. The communication link is unidirectional and control messages can only be sent from the keyfob to the car. In addition, the communication range is limited to a few dozen meters. Thus, application scenarios that are currently supported are very limited. For example, keyfobs are used to lock/unlock a car from a short distance. However, there are many more interesting keyfob applications that could be supported if the aforementioned technical limitations are overcome. A longer range two-way communication channel would allow us to support a range of interesting applications. For example, the keyfob could be used to receive status messages such as burglar alarm notifications from the car. The keyfob could also be used to query the vehicle and request information such as the current fuel level.

Communication systems for vehicle-driver interaction can be classified according to the communication distance at which they work. Available technology generally fits into one of the following three classes:

- *Close range communication system:* These systems are used when the driver is not more than $30m$ away from the vehicle. Almost all available keyfob systems can be classified as such close range communication systems.
- *Medium range communication system:* The driver is between $30m$ and $1km$ away from the vehicle. This class of communication system is not widely used as appropriate transceiver hardware and communication protocols are not yet adapted for vehicle-driver communication [3]. This paper targets this class of vehicle-driver interaction.
- *Long range communication system:* The driver is at a distance of more than $1km$ from the vehicle. This type of system is generally supported through the existing GSM network by using a mobile phone/PDA as keyfob.

Beside their communication range keyfobs can be categorized according to the communication pattern they support: *unidirectional or bidirectional*. Unidirectional (one-way) keyfobs are only able to transmit information to the vehicle. These keyfobs are not able to receive data. Bidirectional (two-way) keyfobs are more capable as they allow us to send data to the vehicle and to receive data. There are two modes of operation of a bidirectional keyfob that have to be distinguished: *synchronous and asynchronous*. Synchronous communication allows the driver to send a request to the vehicle which responds immediately. For example, the driver might send a request to the car to inform him of the current fuel levels. With asynchronous communication the vehicle may send data to the driver at any time. For example, the driver may configure the car to transmit a message when a theft is detected.

Nowadays close range, unidirectional keyfobs are mostly used as they are simple to construct. Only a transmitter but no receiver element is required and communication protocols can be kept simple. It is our goal to construct a medium range, bidirectional keyfob for asynchronous communication. This is a challenging task as an efficient transceiver must be used and combined with a suitable communication protocol. In this paper we describe the performance of a an off-the-shelf transceiver. The obtained results will allow us in a next step to construct a matching communication protocol. As the evaluation results show, such communication protocol must handle high message loss rates while achieving energy efficiency for the keyfob.

II. Transceiver Selection

For a car manufacturer it is important to keep costs low. Thus, it is desirable to use off-the-shelf transceivers for keyfobs that are already on the market and used in large quantities for other purposes. Furthermore, a keyfob must be usable in all countries as car manufacturers do not want to adapt systems for different countries whenever possible. Thus, a transceiver should use frequencies and power levels that are acceptable in all countries. A bidirectional keyfob that supports asynchronous communication needs to conserve

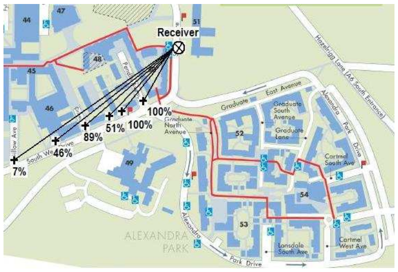

Fig. 1. Achieved packet reception rate PRR in Experiment 2.

Fig. 2. Achieved packet reception rate PRR in Experiment 3.

energy to achieve an acceptable lifetime. Such keyfob must be able to receive permanently as the car could send a message at any time. Thus, the transceiver must be power efficient.

To comply with the previous outlined requirements we decided to select the AVR AT86RF212 transceiver [1]. The transceiver adheres to the IEEE 802.15.4 standard and is widely used for industrial process monitoring and control. It supports the Chinese WPAN Band, the European SRD Band and the North American ISM Band. The transceiver requires $9mA$ for listening operations and $18mA$ during transmission. Thus, the transceiver can be operated in listen mode for $4.6days$ if a typical AA battery with a charge of $1000mAh$ is used. An acceptable lifetime of a month can be achieved by operating a communication protocol that duty cycles the transceiver chip (see [2]).

III. Transceiver Evaluation

For evaluation we used a sender and a receiver with AVR AT86RF212 transceiver with standard half wavelength antenna. A keyfob antenna will obviously have a slightly different design, however, our setup is still useful for initial evaluation. The transceivers use the European SRD Band from $863MHz$ to $870MHz$ with a power level of $10dBm$. The sender transmits for each measurement point a sequence of 100 packets of size $20byte$ with an inter packet spacing of $5ms$. The transmission speed is set to the lowest transmission speed of $20kb/s$ using BPSK as reliability and not data rate is of interest (See Section IV). At each measurement point the packet reception rate (PRR) that the receiver is recorded.

Experiment 1: For a first experiment sender and receiver are placed in line of sight; no buildings or other obstacles obstruct the transmission path. In this case a packet reception rate of $PRR = 100\%$ up to a distance of $5km$ is successfully measured. Obviously, reliability and achievable range are acceptable. However, in a real application scenario line of sight between keyfob and vehicle are unlikely.

Experiment 2: In a second experiment the receiver is placed on a car park alongside a road on Lancaster University Campus. A measurement is taken at different locations along the same road with an increasing number of multi story buildings between sender and receiver. The evaluation scenario and results are shown in Figure 1. As expected, a much smaller distance can be bridged if a large number of buildings is between sender and receiver ($327m$ maximum communication distance). Interestingly, a large number of measurement points observe very low PPR values (below 80%). Communication does not drop suddenly from high PPR values to zero. A large zone exist in which communication is possible but packet loss rates are high.

Experiment 3: In a third experiment a built-up area with smaller two story buildings is used for evaluation. The receiver is placed in the center of the area and measurement points are set in a grid pattern (see Figure 2). The measurement is taken as close as possible to the center of the grid box. Again, it is observed that a large number of measurement points have very low PPR values.

IV. Findings and Conclusion

The transceiver can achieve easily the required communication range of up to $1km$ if there are no obstacles between sender and receiver. In more realistic urban environments a range of $250m$ is feasible which falls short of the desired range of $1km$. However, this distance would still be sufficient to enable communication between a driver at home with his nearby roadside parked car.

The evaluation shows that communication situations with very low packet reception rates are common. However, these situations are acceptable for the intended application scenario as data throughput and data transport delay are not critical. Enough bandwidth and time is available to retransmit lost messages a number of times. For example, to transmit a car alert indicating a theft only a few bytes need to be transmitted and the message can be delayed for a few seconds. Thus, it is important that the communication protocol using the transceiver is able to handle necessary retransmissions well. In particular, the protocol must integrate power saving functionality with retransmission functionality. To achieve this goal we plan to modify the existing power efficient FrameComm communication protocol described in [2] such that observed high loss rates can be managed as well.

References

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