A Software Defined Radio 802.11 Infrared Transmission System

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Abstract

We present a 802.11 infrared packet transmission system built around GNU Radio and homemade infrared front-ends. The communication system is validated by a demonstration of audio transmission.

1 Introduction

Optical wireless transmission is of great interest in many critical environments due to the confinement of optical beams (higher level of security) and the lack of interference of existing radio frequency connections. This is particularly true for aeronautical contexts. As part of the Aircraft Light Communication (ALC) project (European project Clean-Sky2 H2020), our goal is to design a multi-user optical communication system in an aircraft cockpit. Since the brightness inside the cockpit must be greatly reduced during the critical phases of flight, the visible band is not appropriate. Therefore, the optical wavelengths in the infrared (IR) domain are used.One of the most successful IR standard (IrDA) is not applicable due to small operating distance and the need for directed Line-Of-Sight (LOS) links with strong alignment. Because of growing interest in visible light communications, there is today a lot of activities on optical wireless communication standards. This includes different groups such as IEEE802.11bb, IEEE802.15.7r1, IEEE802.15.13, and the ITU G.vlc. We decided to follow the IEEE 802.11 standard and adapt it to our study using IR technology. To enable interoperability with the 802.11 radio-frequency standards that dominate the market and thus facilitate light communication penetration, the future standard should be as close as possible to existing 802.11 specifications.Particularly in the ALC project, the interoperability of the system with the 802.11 standard is important because it guarantees a system evolution and the ease of adaptation of this system to the future 802.11bb standard. The standardization effort consists of the data link control layer (subdivided into two sublayer namely: the Logical Link Control (LLC) and the medium access control (MAC)) and physical (PHY) layer.We choose a multi-step work: firstly we implement the On-Off-Keying (OOK) modulation which is one of the most used modulations in optical wireless transmission systems, and second we will study other modulations used in 802.11 versions. In order to cope with the design challenges involved, we found it practical and efficient to develop our solution using the SDR technology and in particular with USRP radios and GNU Radio. Indeed, the GNU Radio platform already provides a large library of digital communication blocks and allows implementing rapidly design modifications in software. One can find several research works dealing with the implementation of the 802.11 standard for SDR applications. These implementations are focused on RF communications. As far as optical communications are concerned one can find several Visible Light Communications (VLC) implementations focused on the 802.15.7 standard. The rest of this paper is organized as follows. Section 2 discusses the main characteristics of the developed communication chain. Section 3 presents an infrared packet transmission system using homemade IR front-ends before concluding in Section 4.

2 Communication chain

The developed chain uses the classical MAC/PHY layer model. We focus in particular on the transmission and the reception of packets for the LLC sub-layer and the frames of the IR PHY physical layer.The LLC sub-layer is, among others, in charge of building 802.11 compliant packets. One can find an existing GNU Radio transmission chain which includes this compliant packet forming scheme [1]. The 802.11 compatibility can be verified by using the network analyzer tool Wireshark. The LLC blocks are: WIFI MAC in charge of the packetizing operation at the transmission side and WIFI PARSE MAC in charge of the packet analyze at the reception side. The packetizing operation has the structure presented in Fig.1.

The WIFI PARSE MAC block is able to distinguish and list the different fields of the received packet. In the Bloessel implementation [3], the block in charge of this operation is part of the OFDM physical layer. This is the reason why we could not use it in our IR PHY implementation and

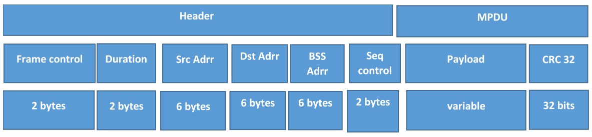

Figure 1: IR PHY packet structure.

had to develop a MAC packet data unit (MPDU) Parse block. This block is in charge of recovering the payload.The LLC sub-layer packets are then aggregated in a frame compliant with the 802.11 IR PHY standard specification [2], shown in Fig.2. This is a starting point because this specification is no longer present in the latest versions of the standard. One of our goals is to adapt it to the constraints of the ALC project.

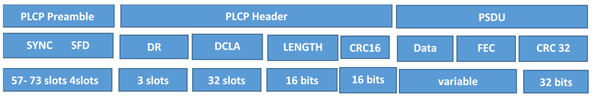

Figure 2: LLC packet structure.

We have worked with the available GNU Radio tutorials and documentation. We have developed a PHY Formatter block dealing with the insertion of the synchronization fields and the transmission header forming a frame. The Parse PHY block at the reception side analyzes the frame and returns the length field to the Demux Header/Payload block which then demultiplexes the header and the payload. For simplification reasons, as a first step, we fix the time slot value to the bit time instead of 8s as specified in the 802.11 IR standard. Us PHY layer implements an OOK modulation by adding an offset to the BPSK modulation scheme. This offset is required by the IR front-ends. OOK modulation is one of the most used in wireless optical communication systems.The main GNU Radio tools for packet communication systems design are the tags and the messages.These tools use polymorphic type (PMT) data. Several blocks of our chain use PMT. For example the convolutional code ECC block specified by the 802.11 standard, the packetizing blocks WIFI MAC, WIFI Parse, PHY Formater, PHY Parse and Header/Payload Demux.

3 Front-ends & demonstration

The 802.11 PHY IR specification recommends data rates of 1 Mbps and 2 Mbps. In a multi-user context, it is essential to have a high data rate to ensure good communications of all users. For that purpose, we designed RX and TX front-ends [3] having a 10MHz bandwidth. Due to the constraints of IR technology, the link has to work in baseband (OOK,L-PPM modulations). To comply with this requirement, Ettus LFTX and LFRX daughterboards have been selected as they allow communications between 0 and 30MHz. The designed TX IR front-end converts the LFTX board voltage ranging between 0 and 3.3V to a 0-100mA current into the IR LED thanks to a high speed video op amp. The role of the RX front-end is to convert the very low PIN photodiode current (in the order of 1uA) into a voltage value of around 1V. This is accomplished by a special type of op amp called a transimpedance amplifier (TIA).The demonstration is made of two parts: first, we send a file from the IR transmitter and analyze the frame received at the receiver side using Wireshark. Secondly, a user directly speaks in a microphone connected to the PC of the IR transmitter and it is possible to listen the sound recorded by the computer connected to the IR receiver.

4 Conclusion

As part of the H2020 ALC project we are developing a multi-user infrared system for communications in a cockpit. To ensure scalability, the system should be as close as possible to the 802.11 standard currently under development for optical wireless communications. Our approach is based on the implementation of an 802.11 packet transmission system developed with GNU Radio, tested with USRP radios including specifically manufactured optical front-ends. Currently, our system is able to transmit 802.11 packet data with an OOK-modulated PHY IR. Our future work will focus on the integration of other modulation schemes such as OFDM used in 802.11 a/p/n and the implementation of the DCF access method.

References

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[2] *Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications p1491 2012.*

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