Poster: VoIP System for Bicycle Platoons

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***Abstract*—For communications, in certain scenarios, the spatial proximity between nodes obviates the need for a cellular connection, and MANETs can provide better solutions. An example is audio communication in bicycle platoons: cyclists ride in a cluster, but may be spread over hundreds of meters and their spatial arrangement can vary, leading to volatile links. In this work, we showcase a novel implementation of VoIP that was tailored for a MANET composed of embedded devices installed in bicycles, operating over multicast. We describe the architecture of our system, which builds on off-the-shelf hardware and software, and list the parameter values that result in reasonable audio quality. Preliminary results show that high packet delivery ratios (above 70%) can be attained with our system in platoon-riding conditions, despite no link (or network) retransmissions.**

I. Introduction

Mobile Ad-Hoc Networks (MANETs) are decentralized networks (i.e. no single node coordinates the network) composed of mobile nodes, independent of infrastructural nodes. These characteristics make them a good solution for scenarios where an infrastructured network could be impossible or infeasible to deploy [1], to trust [2], or to provide the required service [3].

Additionally, in a scenario in which mobile nodes are in spatial proximity, a MANET-based communication system can constitute an inexpensive alternative to cellular for audio chat applications. This is the case of a bicycle platoon, in which members remain in the vicinity of the group, but environmental and wind noise make it impossible to sustain spoken communication over long periods. Providing Voice over Internet Protocol (VoIP) over a MANET of embedded or personal devices installed in bicycles faces the challenge of low latency, a Quality of Service (QoS) requirement difficult to ensure in an uncoordinated network.

In this work, we describe the system design and implementation of a VoIP solution that operates over a MANET and is tailored to operate in the particular scenario of bicycle-platoon riding. Alongside describing the system, which is based on off-the-shelf software libraries and was tested on commodity hardware, we report the parameter values required to attain acceptable usability of voice in a bicycle platoon scenario.

II. System Architecture

The architecture of our VoIP communication system for a bicycle platoon is shown in Fig. 1. It includes software modules that handle the audio capture and reproduction, configure the network and transmit the packets to all receivers. For this, we developed an application that controls these modules.

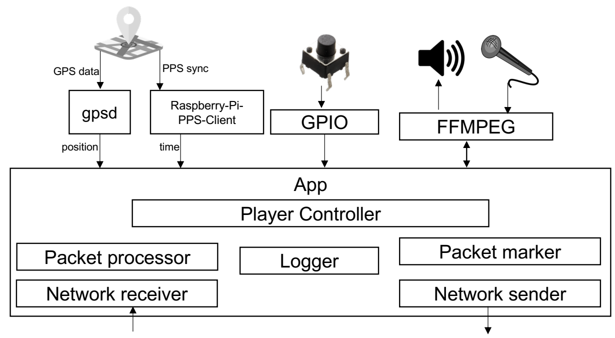

Figure 1: Architecture of the prototype

The GPIO module is used for a button to start/stop the audio capture and transmission. The *gpsd* and PPS client are used to extract position and accurate time from the GPS.

A. Audio Capture

For audio capture, we installed and configured *bluez*, *pulseaudio* and used *FFmpeg* to perform the recording, encoding and packaging. Opus was chosen for audio encoding as it is one of the renowned codecs for voice encoding [4]. This audio was then packed in *mpeg-ts* packets and sent to our local application, which adds metadata for posterior metrics calculation. It then adds a sequence number and the 24 less significant bits of the timestamp truncated to the millisecond. This resolution was chosen due to size limitations. On the receiver side, our application receives these data packets, unpacks the metadata, logs it and sends the rest of the data to the player controller. This module controls multiple players, one per audio source. The player controller sends the data to the correct player, which in turn sends to its respective *FFmpeg* that decodes the audio to the headset and to a local file.

B. Network Transmission

For the network transmission of each data packet, we use multicast transmissions, despite the problems documented in the literature [5]. The main advantage of this communication pattern is the support for multiple communication groups given by the network layer. We can also obtain an efficient and scalable transmission, since a single successful transmission would be listened by any nearby node independently of the number of neighbours.

Multicast does not adapt bit-rates according to the medium, since there is no built-in feedback. Thus transmissions use the basic service set bit-rate. In the configured Independent Basic

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Service Set (IBSS) 802.11 protocol *b* network, the bit-rate of broadcast and multicast packets was 1 Mbit per second. This limits how fast we can send data, trading off bandwidth for a better transmission range. In preliminary tests, we observed VoIP communication between two users at 130 meters.

III. Preliminary Performance Results

We tested the system's elements individually in laboratory and the fully integrated solution in a city tour that lasted for about 30 minutes.

The prototype hardware in which the system was deployed consisted of RPi 3 version B with external wireless cards TP-LINK TL-WN722N for better coverage [6]. The antennas where position in the centre of the handlebar, perpendicular to the ground. Audio capture and playback is made through Bluetooth headsets and a remote command installed in the handlebar to start/stop audio transmission. For the external GPS we used an *Adafruit Ultimate GPS* v3 to provide both location and accurate timestamp via the PPS signal. In order to ease deployment, we configured the nodes with static IBSS 802.11b Wi-Fi network configuration. For a more robust network, a solution such as the one in [7] can be used.

For the city tour no instructions were given to the users. As such, the speed, directions and the distance between nodes varied along the route. Multiple audio streams existed almost all the time, with the users doing a normal conversation between each other. The five bicycles moved in the surroundings of the university campus, with multiple buildings and cars passing by. The trajectory can be seen in Fig. 2[1].

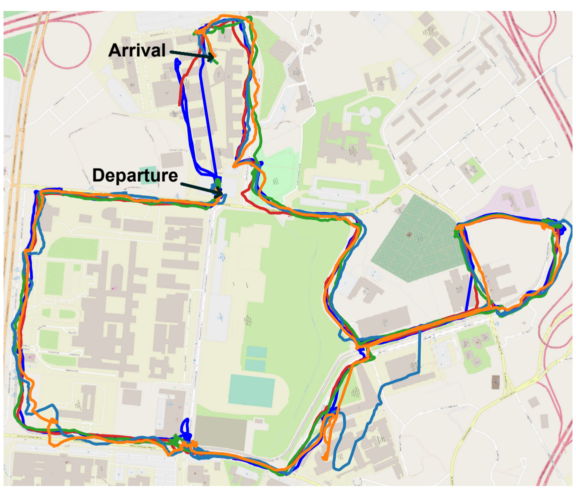
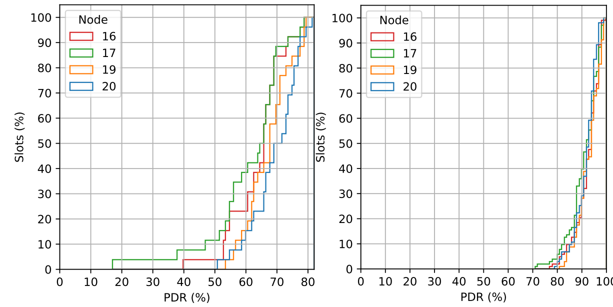


Figure 2: Route of the city tour

In the first trial of the system, we found a low Packet Delivery Rate (PDR), with an average packet loss of 30% in each receiver of an audio stream. This can be seen in Fig. 3a, where The main reason that we identified to account for the high losses was the fact that multicast traffic in 802.11 does not have retransmission mechanisms. Also, we were using a densely populated Wi-Fi frequency, with a large number of external stations accessing the medium.

[1] A small video from the test can be seen in https://youtu.be/b4NwPekct5w



(a) First trial (b) Second trial

Figure 3: Cumulative PDR, measured in 10 seconds' slots

For the second field trial, we changed from wireless channel 1 to 4 and reduced the packet length, increasing however the number of packets. We moved from having 11 packets per second with size distribution of 954 ± 4.8 bytes (95% confid.), to 17 packets per second with a size of 203 ± 0.4 bytes (95% confid.). The average throughput is $\approx$28kbps.

The result of these changes can be seen in Fig. 3b. The results shown are for a single audio source, but similar values were collected in the other audio transmissions.

IV. Conclusion

In this paper we showcased a VoIP system built using off-the-shelf hardware and software that was tailored for application in a bicycle platoon. We report that, in a system-trial campaign in conditions of platoon-like bicycle riding, PDR can achieve a rate of 70% even in multicast mode.

Acknowledgements: The authors would like to thank the help of António Rodrigues, João Mesquita, José Pintor and Miguel Rosa in the measurements. This work is a result of the project Generation.Mobi, reference POCI-01-0247-FEDER-017369, co-funded by the European Regional Development Fund (ERDF), through the Operational Programme for Competitiveness and Internationalisation (COMPETE 2020), under the PORTUGAL 2020 Partnership Agreement.

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