IIA Project GF3
Audio Modem

Dr Jossy Sayir
`js851@cam.ac.uk`

Easter Term 2020

1   Introduction

The aim of this project is to implement an audio modem to transmit data files from one computer and to receive them on another computer using audio, i.e., from the loudspeaker of the transmitting computer to the microphone of the receiving computer.

The technical constraints on the system are the following:

- the system must use Orthogonal Frequency Division Multiplexing (OFDM) or its baseband equivalent Discrete Multi-Tone (DMT)

- transmitters and receivers of all groups must be *inter-operable*, meaning that a file transmitted using one group's software must be recoverable using another group's software, provided the two groups involved have been able to implement a full modem that can transmit as well as receive files.

The scope of the project excludes the following desirable features:

- the transmitter does not adapt its coding and modulation to the channel, other than perhaps having a selection of operative modes and data rates which can be set manually by the user

- no feedback link is to be implemented and no corresponding feedback mechanisms such as Automatic Repeat reQuest (ARQ) are possible

- the system must not support mobility (moving users, significantly changing channel conditions, Doppler effect). It is OK to ask everyone to hold their breath and not move so as not to affect the audio channel during one transmission

While these features would be nice to have, I have limited the scope of the project because there is more than enough work without the above to occupy you for a 4 week project. Should you feel like continuing the project over the summer, extensions beyond these limitations would of course be fun to implement and you are more than welcome to send me software that goes beyond the scope defined above.

2   Platforms

The project will operate remotely on the following platforms:

- `slack` will be used for chat-based exchange of information and as the backup communication channel (if `slack` crashes, please resort to email.)

- `zoom` will be used for all meetings with the project leader. Newnham College has kindly made an education license for `zoom` available to me. For meetings set up and hosted by unlicensed (free) users, a time limit of 40 minutes applies.

- `Google Meet`, `Microsoft Teams` and other tools can be used for meetings between project participants in order not to run into the 40 minute limit if no participant has a paid `zoom` license[1]. The university has site-wide licenses for `Google Suite` and for `Microsoft Teams` so you are able to access those as long as you log into `http://google.com` or launch the `Microsoft Teams` software using your university email address[2].

While you are free to use other tools for your group meetings, I would encourage you to use `slack` to agree and start meetings and publish the meeting access details on `slack`, as this will allow me to monitor your exchanges and pop into your meetings offering help, which mimicks closely the situation we would experience if you were doing your project live in the DPO instead of having to do it remotely.

In all cases, please observe guidance from the University Information Services concerning safe use of all those tools, in particular `zoom`[3] as there were recently cases of meetings disrupted by malicious hackers.

The moodle site will be used for dissemination of lecture slides, relevant papers and for submissions of deliverables (reports, software, white papers, etc.)

3   Groups

You have been arranged into groups of 3 with the following constraints:

- you are operating mostly in similar time zones (with one exception)

- each group has participants that have taken 3F1, 3F3, 3F4, 3F7, 3M1, all of which can be relevant for the project

- each group has participants that self-described as good programmers

Make sure you use all those skills and keep all 3 group participants involved. Do not let the project turn into a solo venture by the "programming guru" in the group: you all have something to offer, even if it may look from the outside as if the programmer is doing all the work. A good group will have regular meetings, distribute the workload and facilitate the exchange of knowledge and information, so that lessons learned by one participant are disseminated to other group members.

---

[1]although the quality of video, audio, and document presentation options is significantly superior on `zoom` than it is on those other paltforms, as far as I was able to observe during supervisions and the IA Microprocessor lab in early Lent term.

[2]I am aware that Group 2 is operating in a country where some of those tools may be blocked at times. Feel free to use a tool that works for you but please try to make your meetings accessible for me so that I can offer support as described.

[3]`https://help.uis.cam.ac.uk/service/security/wfh-security/zoom-security`

4 Group supervisions

Each group will get a minimum of two 20 minute sessions of direct supervision allocated per week. An indicative timetable for those meetings is, Thursdays and Mondays,

9:20 - 9:40 Group 1

9:40 - 10:00 Group 2

11:00 - 11:20 Group 3

11:20 - 11:40 Group 4

14:00 - 14:20 Group 5

14:20 - 14:40 Group 6

with all times stated in Cambridge time (British Summer Time). Meetings may have to be rescheduled depending on my own constraints or on yours. Please let me know as soon as you become aware of such constraints. Attendance of all 3 members at supervisions is compulsory, and decuctions will be made for unexplained absences. Given the context of the COVID19 pandemic, there is no expectation that you be able to fully participate in a supervision at all times and we will all understand if you have to turn off your mic because working in a noisy environment with family members interfering, etc. (indeed, this is very likely to happen to me during our meetings as I am homeschooling primary-school age children!)

5 Standardisation

In order to ensure inter-operability of all modems, we will be running a standardisation activity: each group is to name one delegate to represent it in standardisation. The standardisation body will meet *every weekday* at 10 a.m. Cambridge time. Participation of each group at all standardisation meetings is compulsory, but it is acceptable for a delegate to be replaced by another group member occasionally if the delegate is unable to attend.

The standardisation body will aim to do the following:

- evaluate and compare proposals from groups and agree on the technical implementation details of the transmitter (e.g. synchronisation protocol, OFDM symbol and cyclic prefix length, etc.

- compile all agreed details into a written standard document with contributions from all groups

- issue white papers for guidance and advice to all groups on aspects relevant to the implementation. White papers could for example summarise relevant publications on an implementation-relevant topic such as synchronisation, offer a compilaton of best practice in software implementation such as a list of relevant libraries and functions or guides to using Git or other version control systems. White papers can be co-authored jointly by members of more than one group.

The first and constituent meeting of the standardisation body will be Friday, 8 May at 10 am and its first task will be to pick a name for the standard (such as "802.11", or "5G", or "UMTS"). We will aim to take all decisions by concensus, but when concensus cannot be reached decisions will be taken by majority vote with one vote per group and I hold the casting vote.

Other group members are welcome to attend standardisation meetings as observers if a topic of interest is being discussed, but only one group member can vote.

"Plugfests" will be organised as implementations progress in various groups. Wikipedia decribes a plugfest as follows:

> A plugtest or plugfest is an event based on a certain technical standard where the designers of electronic equipment or software test the interoperability of their products or designs with those of other manufacturers. It could be literally plugging company A's cable into company B's socket, or a more elaborate test resembling a realistic scenario.

The final standardisation meetings on 1 and 2 June 2020 will be plenary meetings where groups will be able to demo their modems. An external audience may be invited to attend those meetings, and those meetings will be recorded. Please let me know if you objected to being recorded and I will edit out and delete any parts of the video recording where you appear. The recording will be accessible only to those signed up on the moodle course and we would get in touch with you to request separate permission if there was ever an intention to use the recording for any other purpose such as outreach or material for this project in future years.

6   Initial steps

By 4 pm on the project kick-off day Thursday 7 May 2020, I would like to receive from each group:

- a group name (something more evocative than "Group 1"),

- the name of the group's designated standardisation delegate,

- a proposal for the name of the audio modem standard to be discussed at the consituent standardisation meeting on Friday.

The standardisation delegate must have a good understanding of the communication theoretic aspects of the project, so it is preferable for it to be a person who has taken the relevant courses, but it is also important that they be strongly involved in the programming aspects, or at least spend a lot of time discussing and understanding the detailed challenges the group faces in the implementation.

7   Software

No guidance is issued on what programming language or system to use this year. I have some code in Python and Matlab that can be offered to support groups who are struggling, but experience from last year shows that groups who wrote their own software from scratch ended up writing far better software than the skeleton implementation I had provided.

You are *not* allowed to use libraries that implement modulation, synchronisation or error control coding. These parts you are expected to write yourself.

8   Theory

I will give regular theory lectures during standardisation meetings, starting with the kick-off meeting on Thursday 7 May 2020. All slides used during presentations will be made available on moodle for future reference.

8.1   Assessment and reporting

The project will be assessed based on:

- the group's contributions to the standardisation process

- the quality of the group's final implementation of the modem

- indivdual reports.

Each group is expected to contribute at least two technical standards proposals[4], and author or co-author at least one white paper.

Individual interim reports of no more than two A4 pages should be submitted via Moodle by 4 p.m. on Wednesday, 20 May 2020. These reports should give a brief overview of the tasks undertaken so far by the group, the group's plans to complete the work, a description of the individual's role within the group, and a more detailed account of achievements so far and future plans related to the individual's specific activities within the group.

Individual final reports of no more than 6 A4 pages should be submitted via Moodle by 4 p.m. on Thursday, 4 June 2020. These report should give a comprehensive overview of the group's and indivdual's achievements and lessons learned during the project. It is highly recommended though not compulsory to submit a draft of your report by Wednesday, 27 May 2020: during the supervisions on the subsequent Thursday and Monday, I will offer feedback to help you improve your report. I will be focussing on the structure of the report and pick an individual paragraph that I will read with you to help you learn how to transfer from your writer's perspective to the reader's perspective. Hence, it is OK to submit a very early draft on 27 May as long as the report structure (titles, bullet points) is in place and there are at least a few paragraphs of technical text for me to pick a suitable paragraph for joint proofreading.

A summary of deadlines and marks awarded is in Table 1. All reports are to be submitted electronically on Moodle.

---

[4]the proposal for the name of the standard that every group has to submit on day 1 does not count as a technical standards proposal.

Table 1: Deadlines and marks awarded

Item	Due date	Marks	Marking mode
Standardisation contributions	Throughout project	20	group
Final software and demo	1&2 June	10	group
Interim report (2 pages)	Wednesday, 20 May, 4 pm	20	individual
Draft final report	Wednesday, 27 May, 11 pm	0	-
Final report (6 pages)	Thursday, 4 June, 4 pm	30	individual