

Google Summer of Code 2017: DAB/DAB+ transceiver app

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1 Introduction

The project "DAB/DAB+ transceiver app" aims to produce a DAB/DAB+ transceiver app that is capable of the transmission and reception of audio and data according to the DAB/DAB+ standard. It builds on the existing GNU Radio Out-Of-Tree module `gr-dab`. The goals for this project are the completion of the `gr-dab` module and the creation of a full-fledged application, including a graphical user front end that is capable of transmitting and receiving DAB/DAB+.

2 Digital Audio Broadcasting

Digital Audio Broadcasting (DAB) is a standard for radio broadcasting of audio and data services. With the digital processing of data comes a whole new spectrum of opportunities in providing a large amount of service information to a channel, for example emergency warnings, traffic information and even moving pictures like weather maps. Furthermore a DAB service which is embedded in a DAB ensemble, can supply a diversity of audio and data streams each sent in a separate sub channel that can be optionally shared among services. This flexibility of the system and its service structure demands complex data multiplexing. Therefore the DAB standard provides the Fast Information Channel (FIC) which mainly exists for carrying the multiplex control data safely and quickly.

The digital transmission of the audio data enables error protection and therefore better audio quality with less noise in comparison to FM. To reach a more efficient use of bandwidth the DAB system encodes audio using a modified MPEG Audio Layer II with an additional error protection. Typical data rates are 128 kbit/s or 160 kbit/s which try to achieve the subjective quality of an audio CD. In order to maintain this quality in even more noisy channels, DAB was further developed to DAB+. It contains the audio codec HE AAC v2 which uses spectral band replication and provides a stronger error correction with Reed-Solomon codes that achieves this subjective CD quality with a data rate of 80 kbit/s.

The transmission signal is modulated in D-QPSK and OFDM. There are four different transmission modes in DAB which are each optimized for specific network configurations and different operating frequencies. Besides the common terrestrial transmission, for example transmission mode III is optimized for low frequency cable transmission and also there are specially optimized modes for single frequency networks (SFN) in transmission mode I and IV.

3 Deliverable features

3.1 Out-Of-Tree module gr-dab

A dab module (`gr-dab`) already exists, implemented by Andreas Mueller, which can be found on GitHub [1]. It is compatible with `gr_modtool` and can be modified and extended under GPLv3. The `gr-dab` module contains the implementation of the physical layer including OFDM and error correction. It does not provide any interpretation of the received audio frames due to a missing audio decoding. It can extract basic information, for example service labels, but a lot of features have not been implemented yet. The handling of the specific messages and creation of the data stream which is necessary for a transmission signal is also not existing.

To provide a functional transmission and extended reception of DAB signals including audio coding, I am planning to extend and modify the `gr-dab` module by improving existing blocks and adding new ones. A comprehensive overview of the blocks, existing and planned, is shown in figure 1.

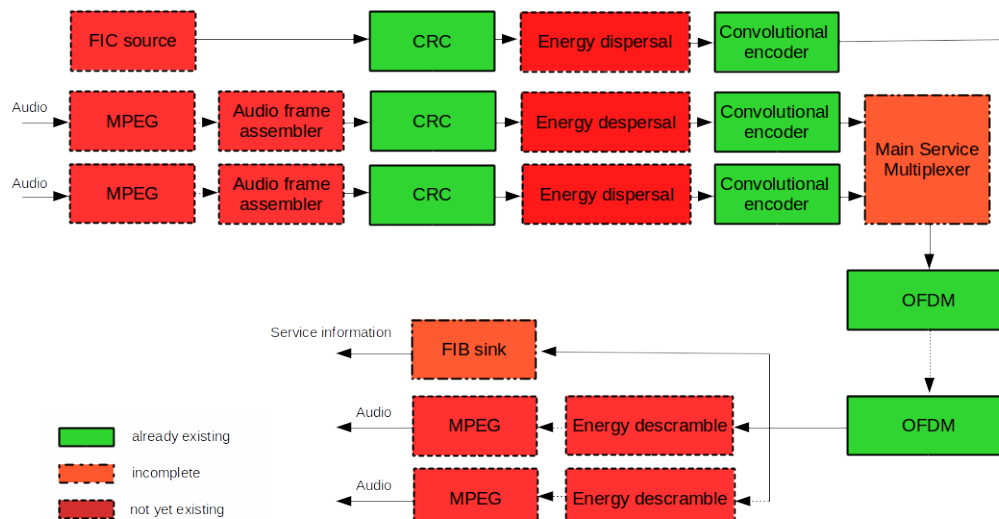


Figure 1: Flowgraph of a DAB transceiver

In detail I am planning to implement the following features (written in C++):

1. **FIC source:** This block creates the Fast Information Groups (FIGs) of the incoming parameters (transmission mode, number of subchannels and strings of labels of the ensemble) containing multiplexing information (MCI) and service information (SI). In addition it handles the assembling of the Fast Information Blocks (FIBs) made out of the FIGs. It prefers

those FIGs containing essential MCI and subsequently filling the FIBs with optional SI. Finally tags are added to the stream to mark the beginning of each FIB for the following cyclic redundancy check (CRC).

2. **Energy dispersal and energy descramble:** An energy dispersal scrambler ensures the appropriate energy dispersal of the transmitted audio frames and the transmitted FIBs. It can be derived from the existing energy dispersal of the DVB-T module, changing the pseudo-random binary sequence and the polynomial. The class accepts the transmission mode as an input argument according to change the length of the vector that is being scrambled which depends on the number of FIGs which are included in one transmission frame. The descrambling in the receiver follows the same process.
3. Audio services are coded in **MPEG Audio Layer II** in DAB, and **HE-AAC v2** in DAB+. For this issue mp2/mp4 encoding and decoding blocks are added, integrating an existing implementation of the GPLv3 licensed project `welle.io` [9],[10]. To preserve the flexibility of easily changing the audio coding, for example to switch between DAB and DAB+, and possibly try new codecs in the future, the audio frame assembler is implemented separately.
4. **Audio frame assembler:** The block accepts the encoded audio stream and adds header information and zero padding. Finally it tags the stream for the following CRC.
5. **Main service multiplexer:** It combines all of the sub channel streams to a common interleaved frame (CIF). This class is fractionally implemented in `gr-dab` (`dab_concatenate_signals`) with a comment that samples of the input vector get lost in some cases. I am planning to solve the problem of long input vectors using tagged streams instead.

I am planning to use several existing blocks of GNU Radio and `gr-dab` without modifying:

1. The **convolutional coding** which completes the coding process has already been included in GNU Radio (`gr-fec`) and can be used.
2. A **CRC** block already exists in GNU Radio in the component `gr-fec`. In `gr-dab` exists a convolutional coding (`crc16`) as well which seems to have the identical functionality like the one in GNU Radio.
3. **OFDM** has already been implemented in `gr-dab` and is going to be used.

3.2 Graphical user interface

To provide comfortable usage of the transceiver module, a user front end is implemented with the PyQt5 framework. It displays the received service information and lets the user select the transmission mode and the channel out of the ensemble. In addition it offers certain information for developers with interest in the physical transmission, for example a waterfall plot, in a special developer mode. A draft of how the GUI could look like, is given in figure 2.

3.3 Documentation

A detailed documentation is an essential requirement especially for an open-source project that is likely to be continued and extended after GSoC. Therefore a doxygen documentation is written for the `gr-dab` module. In addition I am going to comment my source code in order to make my thoughts easily comprehensible for everyone interested.

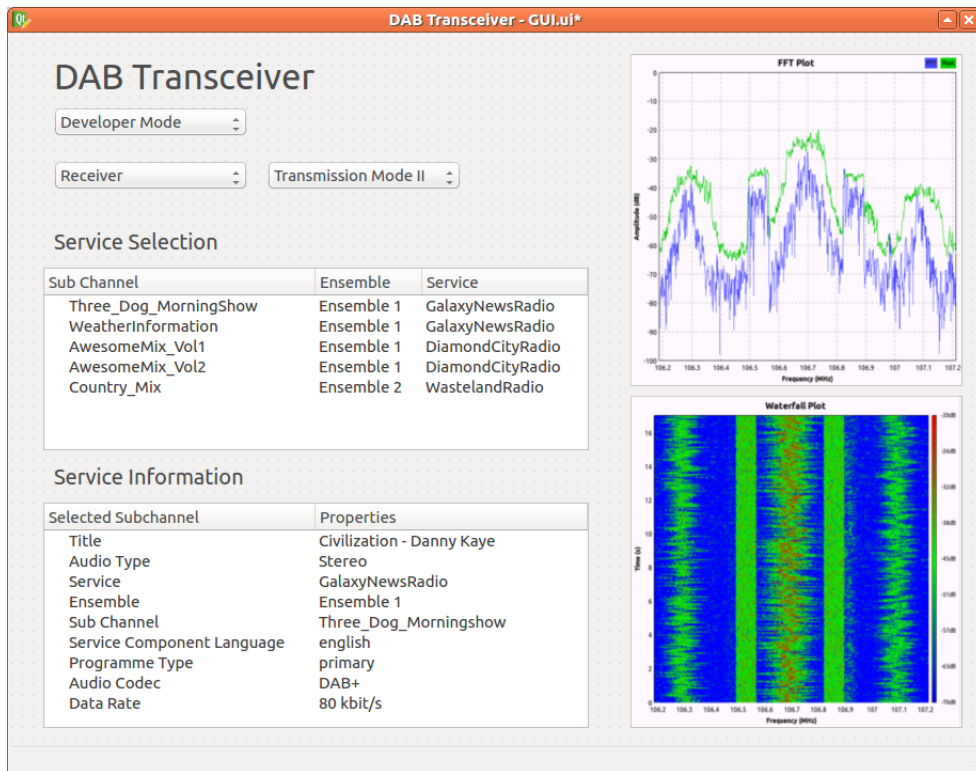


Figure 2: Draft of the graphical user interface

4 Timeline

I am a third-year Bachelor student at Karlsruhe Institute of Technology (KIT), Germany and I am planning to write my bachelor thesis in fall 2017. I have got the possibility to write the thesis at Communications Engineering Lab (CEL) about DAB/DAB+ which would include the implementations coded in GSoC. Therefore I could work full-time on the GSoC project DAB/DAB+ and write my Bachelor thesis afterwards. At CEL I have got access to SDRs for transmission and reception of DAB signals. Furthermore the GSoC mentor Felix Wunsch also works at CEL which would ensure an intense communication while GSoC. The CEL fully supports the open-source idea. Therefore the whole project is going to be open-source available on GitHub, included the GPLv3 licensed code of GSoC and the thesis written after GSoC. I am planning to fork the **gr-dab** repository on my GitHub and submit a pull request to the original repository after each completed milestone. I am also planning to publish my weekly progress in an internet blog in order to keep my work transparent.

According to the timeline of GSoC 2017 there are 13 weeks of coding period including three evaluation periods. I scheduled the deliverables into 1- to 2-week periods, planning to work full-time (40 hours a week) from Monday to Friday and using the weekends as additional time buffers. The timeline is shown in table 1. I will not have any exams this summer and I am planning to skip my job at CEL for the time during GSoC. Therefore I can focus perfectly on GSoC.

Table 1: Timeline GSoC 2017

May 5 - May 29	Community Bonding - coordinate the project with the mentor. Investigate the current version of gr-dab and discuss questions with the author and the GNU Radio community.
May 30 - June 11	Coding, 2 weeks - implement transmitter blocks in C++ and QA tests in Python and write documentation.
June 12 - June 18	Coding, 1 week - add MPEG Audio Layer II and HE-AAC v2 encoder and decoder block and optimize transmitter.
June 19 - June 25	Coding, 1 week - implement receiver blocks in C++ and QA tests in Python.
June 26 - June 28	Phase 1 evaluation , 3 days - prepare results for evaluation including the transmitter and QA tests.
29 June - July 16	Coding, 2.5 weeks - implement receiver blocks in C++ and QA tests in Python and write documentation.
July 17 - July 23	Coding, 1 week - wrap up the gr-dab module and create QA tests for transceiver in Python and examples for GRC. Complete the documentation of the module.
July 24 - July 26	Phase 2 evaluation , 3 days - prepare results for evaluation.
July 27 - Aug 13	Coding, 2.5 weeks - GUI implementation in Python and documentation.
Aug 14 - Aug 20	Coding, 1 week - final bug fixes and optimization.
Aug 21 - Aug 29	Final evaluation - 1 week, submission of the final code and evaluation.

I have read the rules of conduct for GSoC of GNU Radio and acknowledge the three strikes rule. Therefore I am going to intensively communicate with my mentor and keep the work transparent and my working progress up to date for everyone.

5 About myself

I firstly came in touch with programming when I participated in the inventors competition “MikroMakro – kleine Köpfe große Ideen” of the foundation “Landesstiftung Baden-Württemberg”. Together we were a team of six classmates. We got an amount of 5000 € to execute our project idea - “Mamas Voice”, a little humanlike interactive speaking device that reminds students of deadlines and to do’s – like a mother does, including the interaction with the human. We implemented the project on the electronics platform Arduino – using the Arduino microcontroller and software. Here I could gain first experience in programming.

In 2013 I collected geodata from roads and trails for hiking and biking with a gps device and the geographic information system GeoMedia working for the department of environment of Leinfelden-Echterdingen. In order to grant the outdoor community public access of the data, I managed to read the geodata together with metadata like road conditions out of geoMedia. I additionally implemented a front end that displays the tracks on a georeferenced aerial photograph and offers the user the possibility to create a route by selecting certain track sections and automatically generating a gpx file which can be used to navigate through the route with a gps device. I used the open-source environment Processing (based on java) in order to easily deal with graphical issues.

Since 2014 I have been studying electronics and information technology at KIT in Karlsruhe. I have improved my coding skills attending lectures in information technology (based on C/C++) and successfully completed a practical training. The objective was to implement the hardware abstraction layer for the control software of a segway called TivSeg. This included the control of a microcontroller, excluding the feedback control algorithm for the control of the segway. The code was written in C/C++ containing hardware-near programming.

After visiting several lectures about radio communication I got a job at CEL in 2016 in order to get more in touch with practical telecommunication engineering. I got familiar with GNU Radio and improved my coding skills in C++ and Python. I subscribed to the GNU Radio mailing list to get in touch with the community. So far I had no need to ask questions due to some really helpful colleagues at CEL but I have the intention to enrich the GNU Radio community in the future. I have already dealt with the DAB standard in my job, doing researches and understanding the standard.

You can find the code of the mentioned projects on my GitHub page [2].

6 Conclusion

A DAB/DAB+ module in GNU Radio would not just be a great example of how a worldwide operating broadcasting system can be fully implemented in a software radio environment, but also a very useful basis for future projects with GNU Radio implementing new features or doing research. The developed DAB/DAB+ transceiver app allows a comfortable use of the transceiver for developers as well as for beginners.

Through my projects I have come to realize the importance of open-source and how everyone can achieve more by sharing their ideas and thoughts. Therefore I would like to take this opportunity and participate in a GNU Radio project to contribute to the open-source idea. Finally I want to emphasize: Cyberspectrum is the best spectrum.

References

- [1] <https://github.com/andrmuel/gr-dab> Visited March 13, 2017.
- [2] <https://github.com/MoritzLucaSchmid>
- [3] Digital Audio Broadcasting; DAB+ audio coding (ETSI TS 102 563 V2.1.1 (2017-01))
- [4] Radio Broadcasting Systems; Digital Audio Broadcasting (DAB) for mobile, portable and fixed receivers (ETSI EN 300 401 V2.1.1 (2017-01))
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- [6] GNU Radio Documentation <http://gnuradio.org/doc/doxygen/modules.html> Visited March 10
- [7] W. Hoeg, T. Lauterbach, "Digital Audio Broadcasting; Principles and Applications of Digital Radio", Wiley 2003
- [8] Waterfall and FFT plot <http://www.stargazing.net/david/GNURadio/RTLFMstations.html>
- [9] <https://www.welle.io/> Visited March 23, 2017
- [10] <https://github.com/AlbrechtL/welle.io/> Visited March 23, 2017