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ANSIAN - ANDROID SIGNAL ANALYZER

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AnSiAn - Android Signal Analyzer
SEEMOO Secure Networking Lab

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CONTENTS

ACRONYMS

AM	Amplitude Modulation
AnSiAn	Android Signal Analyzer
FM	Frequency Modulation
GC	Garbage Collector
GUI	Graphical User Interface
LSB	Lower Side Band
MVC	Model–View–Controller
PSK31	Phase Shift Keying, 31 Baud
RDS	Radio Data System
SDR	Software-Defined Radio
USB	Upper Side Band

1 INTRODUCTION

Android Signal Analyzer (AnSiAn) is an Android application by the Secure Mobile Network Lab (SEEMOO) at Technische Universität Darmstadt. It features a graphical signal analyzer that can be used with common Software-Defined Radios (SDRs) like the HackRF and the RTL-SDR. The project is based on RF Analyzer, an application by Dennis Mantz. AnSiAn currently extends RF Analyzer by the following features:

- Time Domain Signal Graph (Waveform)
- Morse Decoder
- Scanner
- Codebase structured according to the Model–View–Controller (MVC) pattern

This lab aims to further extend the feature set of AnSiAn while also making the app more stable and refining existing features. The description of the project goals are listed in Section 1.1.

1.1 PROJECT DEFINITION

This section defines the features that will be implemented throughout the project and schedules them into three sprints.

1.1.1 *Features*

The new features can be divided into mandatory features, that will have high priority within this project, and optional features, that will be implemented if time permits. As can be seen in Section 1.1.2, the third sprint is reserved for either optional features or completing mandatory features and the documentation.

1.1.1.1 *Mandatory Features*

The following features are scheduled for implementation during the first and second sprint:

- Radio Data System (RDS) demodulation
  If the user selects the existing wide-band Frequency Modulation (FM) demodulation option, the app shall try to detect and

demodulate any existing RDS signal along with the audio demodulation. The extracted information shall be displayed on the screen.

- Phase Shift Keying, 31 Baud (PSK31) demodulation
  If the user selects either of the single side band demodulation modes (Upper Side Band (USB) and Lower Side Band (LSB)), he or she shall have the option to enable PSK31 demodulation along with or instead of the audio demodulation. The demodulated text string shall appear and scroll through the analyzer window.

- Extraction of RDS-, Morse- and PSK31-data to logfiles
  If the user selects to demodulate any digital mode, the demodulated text shall be written to a log file specified by the user.

- Support for the rad1o badge
  The rad1o badge, which is a modified low-cost replica of the HackRF, shall be supported as a signal source by AnSiAn.

- Transmission support for HackRF and rad1o
  If AnSiAn is used with an SDR capable of transmitting signals, it shall offer options to send signals in the following ways:
  - Replay I/O samples from a file
  - Generate and send Morse code from text
  - FM-modulate and send audio from a file

1.1.1.2 *Optional Features*

The optional features are scheduled in the third and last sprint. However, they will only be added to the feature set if the last sprint is not needed in order to compensate for delays on the mandatory features. The optional features are listed in the order of priority:

- Walkie-Talkie Mode
  The user shall have the possibility to put AnSiAn into a Walkie-Talkie mode. In this mode, the application will demodulate an FM channel and the user can quickly switch between demodulation and transmission of audio recorded from the internal microphone.

- Packet Radio demodulation
  A new mode *Packet Radio* shall be added to AnSiAn. Once selected, it shall allow the user to tune to a Packet Radio channel and display information about demodulated packets on the screen. If time permits, it might even be possible to implement a transmission feature for Packet Radio.

1.1.2 *Time Schedule*

The project will have two developers, Dennis Mantz and Max Engelhardt, working in three sprints. There are three milestones corresponding to the sprints, labeled Alpha, Beta and Final Version. They each add an independent and self-contained set of features to the application:

- Software Design (due 12.05.)
- Sprint 1: Alpha Version (due 09.06.)
  - RDS demodulation
  - PSK31 demodulation
  - Extraction of RDS-, Morse- and PSK31-data to logfiles
- Sprint 2: Beta Version (due 21.07.)
  - Support for the rad1o badge
  - Transmission support for HackRF and rad1o
    - Replay I/O samples from a file
    - Generate and send Morse code from text
    - FM-modulate and send audio from a file
- Sprint 3: Final Version (due 25.08.)
  - Complete leftovers from previous sprints
  - Walkie-Talkie Mode (optional)
  - Packet Radio demodulation (optional)

1.2 SOFTWARE DESIGN

The software design for each sprint is done ahead of the respective sprint. This procedure goes along well with the Agile Manifesto which encourages the design of a complex system in small incremental parts.

1.2.1 *Sprint 1: PSK31 and RDS demodulation*

The existing architecture of AnSiAn features individual threads for scheduling, downsampling, demodulation and audio output. The `Demodulator` thread demodulates quadrature samples by calling the `demodulate()` method on an instance of `Demodulation`. `Demodulation` is an abstract class that is implemented by concrete demodulation methods such as `AM`, `FM` and `Morse`.

AnSiAn utilizes the EventBus library in order to pass demodulated Morse text to the Graphical User Interface (GUI). Demodulated audio

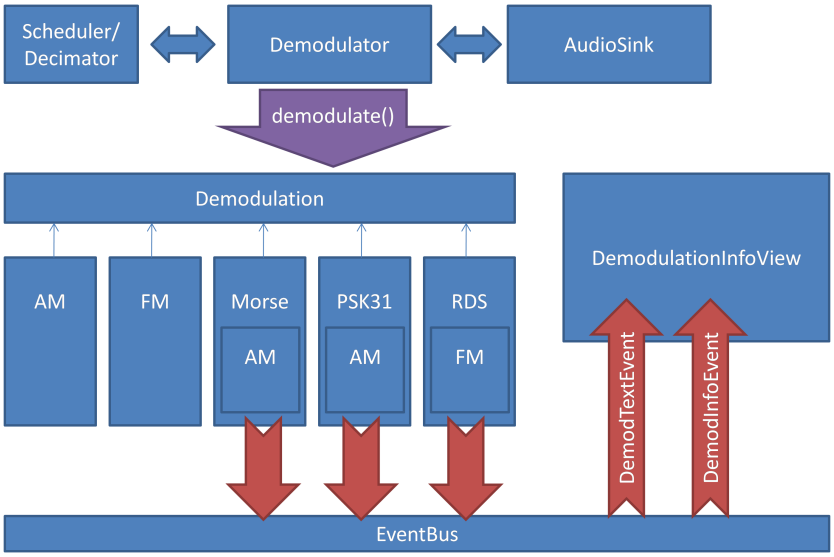

Figure 1: Architecture of the extended demodulation logic and communication with the GUI

data is passed to the `AudioSink` thread by enqueuing it into its input queue. This mechanism is explained in more detail in Section 1.3.1.

In order to extend AnSiAn with demodulation functionality for PSK31 and RDS, the existing architecture needs to be extended. The extended architecture is depicted in Figure 1 and explained in the following.

Two new classes `PSK31` and `RDS`, that inherit from `Demodulation`, need to be implemented to represent the new demodulation mechanisms.

As PSK31 demodulation works on the envelope of the received signal and Amplitude Modulation (AM) demodulation essentially performs envelope detection, `PSK31` uses an instance of `AM` for envelope detection.

RDS transmits metadata for FM radio channels. It is therefore desirable for the RDS demodulation mode to not only display this metadata, but to also play the FM-modulated audio at the same time. The `RDS` class uses an instance of `FM` for this purpose.

Like the existing architecture, the new architecture will use the EventBus library to pass the demodulated text to the GUI. The existing View `MorseReceiveView` is refactored into a universal `DemodulationInfoView` that displays the text output of any selected demodulator. Demodulators pass `DemodTextEvents` and `DemodInfoEvents` via the EventBus to the `DemodulationInfoView`, which contain demodulated text and further information (e.g. baud rates or raw dits and dahs) and are displayed in separate lines.

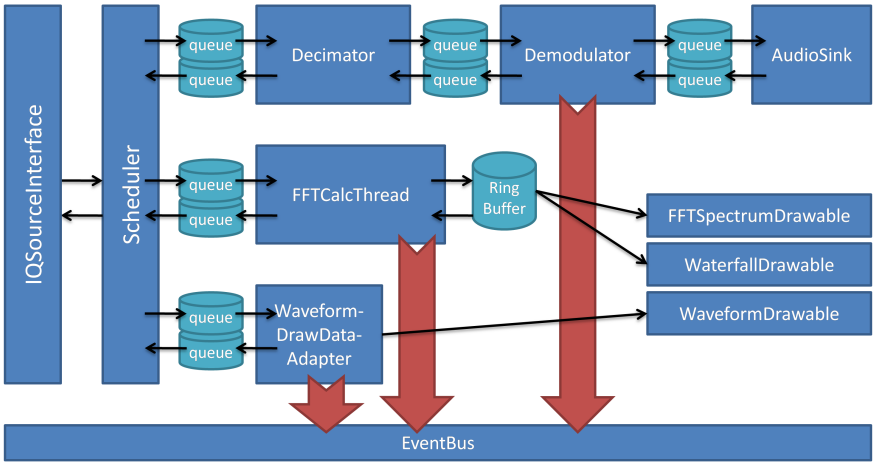

Figure 2: Signal processing architecture with blocking queues

1.3 CLEANUP TASKS

Outside the scope of the planned sprints, some cleanup tasks were necessary to prepare the implementation of the features listed in Section 1.1.

1.3.1 *Memory Optimizations*

The original RF Analyzer application's architecture is based on blocking queues that synchronize the various signal processing threads and efficiently manage memory buffers. Unfortunately, this architecture was partly dropped by the developers of AnSiAn when changing to a new architecture based on the EventBus library. As a result, memory allocation management does not work as efficiently with the current version of AnSiAn.

Instead of using cycling buffers for inter-thread-communication, AnSiAn uses EventBus to deliver data. Buffers are always allocated freshly and discarded after use. This results in a high activity of the Garbage Collector (GC) and therefore in a bad overall performance of the app.

Listing 1 shows a logcat output of the app before any optimizations were applied. The GC runs approximately 8 times per second and the slow performance results in stuttering audio demodulation on older hardware.

Listing 1: Logcat output before memory optimizations

```
05-12 17:55:04.060 D/dalvikvm: GC_FOR_ALLOC freed 4347K, 14% free
     54695K/62984K, paused 28ms, total 28ms
05-12 17:55:04.180 D/dalvikvm: GC_FOR_ALLOC freed 4321K, 14% free
     54737K/62984K, paused 26ms, total 26ms
05-12 17:55:04.300 D/dalvikvm: GC_FOR_ALLOC freed 4507K, 14% free
     54705K/62984K, paused 32ms, total 32ms
05-12 17:55:04.420 D/dalvikvm: GC_FOR_ALLOC freed 4454K, 14% free
     54759K/62984K, paused 30ms, total 30ms
```

In order to fix this performance issue, the architecture is reverted to using blocking queues and cycling buffers in places where large memory buffers are passed between threads. EventBus is still used for delivering information which is not tied to large buffers. A schema of the new architecture is depicted in Figure 2.

In this architecture, the buffers cycle between the threads. The reusage of buffers helps to reduce the memory allocation and garbage collection overhead to a minimum. Listing 2 shows the logcat output after the architecture changes have been applied. The GC only needs to run every 10 to 20 seconds.

Listing 2: Logcat output after memory optimizations

```
05-12 17:27:29.230 D/dalvikvm: GC_FOR_ALLOC freed 3233K, 15% free
     19706K/23000K, paused 32ms, total 33ms
05-12 17:27:40.780 D/dalvikvm: GC_FOR_ALLOC freed 3528K, 16% free
     20235K/23824K, paused 30ms, total 31ms
05-12 17:28:00.110 D/dalvikvm: GC_FOR_ALLOC freed 4130K, 18% free
     20338K/24528K, paused 36ms, total 37ms
05-12 17:28:24.520 D/dalvikvm: GC_FOR_ALLOC freed 4263K, 18% free
     20341K/24664K, paused 49ms, total 49ms
```

ERKLÄRUNG

Hiermit versichere ich gemäß der Allgemeinen Prüfungsbestimmungen der Technischen Universität Darmstadt (APB) § 23 (7), die vorliegende Masterarbeit ohne Hilfe Dritter und nur mit den angegebenen Quellen und Hilfsmitteln angefertigt zu haben. Alle Stellen, die aus den Quellen entnommen wurden, sind als solche kenntlich gemacht worden. Diese Arbeit hat in gleicher oder ähnlicher Form noch keiner Prüfungsbehörde vorgelegen.

Darmstadt, 28. April 2016

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