GNU Radio beyond 3.8
A technical outlook

Marcus Müller

17 September 2019
Structure

Introduction

Looking back at the releasing 3.8

GNU Radio 3.8 and on

The Next Big Thing

Questions & Answers
Marcus Müller
Bearer of a couple of roles

- **Research assistant at** CEL
  - Exercise classes for KIT EEs’ *Probability Theory* and *Communications Theory I* courses (> 300 students) and *Applied Information Theory, Advanced Radio Communications II, Communications Theory II* (ca 13 dB fewer students), also computer lab and a couple of advised B.Sc./M.Sc. theses
  - PhD on LDPC on non-stationary $P_e$ / short packet channels

- **Freelancing Engineer**
  - Technical Consulting
  - Contract Development
  - Customer-Specific Training Courses

- **Ettus Support Grumpiness supplier**

- **Maintainer of the GNU Radio project**

---

Really, Really Short Introduction

GNU Radio beyond 3.8

17 September 2019
Marcus Müller
Bearer of a couple of roles

- Research assistant at CEL
  - Exercise classes for KIT EEs’ Probability Theory and Communications Theory I courses (> 300 students) and Applied Information Theory, Advanced Radio Communications II, Communications Theory II (ca 13 dB fewer students), also computer lab and a couple of advised B.Sc./M.Sc. theses
  - PhD on LDPC on non-stationary $P_e$ / short packet channels
- Freelancing Engineer
  - Technical Consulting
  - Contract Development
  - Customer-Specific Training Courses
- Ettus Support Grumpiness supplier
- Maintainer of the GNU Radio project
Depending on what you want to talk to me about, contact me using

- University Research & Teaching: mueller@kit.edu
- GNU Radio aspects: Preferably, discuss-gnuradio@gnu.org, for confident matters mmueller@gnuradio.org
- Ettus support: support@ettus.com (ask for Marcus The Younger)
- Freelancing & Private: mueller@hostalia.de
Looking back at the releasing 3.8

Superficially (I’ve been doing this way too often):

- Python2 → Python2 ^ 3
- C++03 → C++11
- All-around source formatting
- Qt4 → Qt5
- XML → YAML
- Vintage CMake → Modern CMake
- Pixelized Canvas → Vector GRC
- Boring straight connectors → curves
Looking back at the releasing 3.8

Things learned from this release

- Maintenance branch mergeback model without definite dates for the future leads to stalling
- Not doing a larger release for six years hurts...
  - a lot.
- Actually working towards a release unleashes a lot of energy
  - Super happy that we didn’t lose a lot of developers, it seems
  - See Ben’s slide on Year-to-Year comparison of participation metrics
- Release publicity is a lot based on copy & paste
GNU Radio 3.8: What now?

Git branches now consistently reflect new development:

- **master** will become 3.9
- **maint-3.8** is from where 3.8.x.x releases are made from
- **maint-3.7** is from where 3.7.x.x releases are made from

Use this correctly: Submit patches / Pull Requests against the right branch!

- You’ve got a feature to merge? → **master**
- You’ve got a bug to fix that applies to both master and 3.8? → **master** (and tell us you want us to backport/cherry-pick to maintain-3.8)
- You’ve got a bug that’s specific to a specific release series? → **maint-Release**
GNU Radio 3.8++

GNU Radio 3.9: confirmed features

- Upstream gr-iio: libiio – Standard Linux sampling device interface (e.g. Pluto)
- Upstream gr-soapy: hardware-abstracting universal SDR driver interface
- Python 3 only

But when?

- Regular release cadence
- Tentatively:
  - Release shortly before GRCon (late August)
  - Release a month after FOSDEM (mid-March)
- As Ben said: GNU Radio can now legally order booze (in Germany)
- Scheduling is actually pretty primitive
- Let’s look at current scheduling to learn what needs to improve
Current Signal Flow Architecture

- GNU Radio is a backpressure-driven parallel signal processing architecture.
- Blocks produce as much output as they can at once, given:
  - available input data ready at the start of processing
  - available output data memory
- Every block runs in its own thread.
- Asked to produce \(\min(\text{buffer size} / 2, \text{available output buffer})\).
- Block can start working again while downstream block is still consuming.
- High parallelism.
Current Scheduling Mechanism – Abstracted

- *Scheduler* might be too strong a word
- *back pressure* limits processing speed
- great for throughput
- not so great for latency
- high parallelism stems from the ability to concurrently execute
- actual scheduling of threads done by OS
- no workload knowledge flows into OS $\rightarrow$ suboptimal . . .
- . . . but works surprisingly well.
- Lots of thread-safety concerns
Introducing: The Next Big Thing (NBT)

- “Scheduling” is actually pretty suboptimal
  - One thread per block: What if number of blocks \(\neq\) cores?
  - Scheduling is actually by the OS
  - no feedback of data flow into the scheduling at all
  - CPU core utilization \(\gg\) not thrashing caches

- Streams and Message are not equal
  - It’s hard to impossible to do no-latency stream-produce-on-async-message blocks (ask Matt!)
  - Way too many states “I’m done”
  - Can’t just apply work to the content of a message (invented TSB for that, not an adequate design)
NBT – Approach

- Thread-per-Block → Worker threads
- Single input queue per worker
- Don’t care whether in- or output buffer is in circular buffer, async message or hardware DMA region
NBT – Approach

- Thread-per-Block → Worker threads
  - can still be 1 worker : 1 block
  - sensible: 1 worker : 1 CPU core (N blocks)
- Single input queue per worker
- Don’t care whether in- or output buffer is in circular buffer, async message or hardware DMA region
NBT – Approach

- Thread-per-Block → Worker threads
- Single input queue per worker
  - No special “blocked” states
  - Migration easy
    - stop-less reconfiguration
- Queue can be clever
  - reorder outstanding items to maximize cache locality
  - signal overload of worker
  - prioritize based on latency constraints . . .
- Receive Workload Items via message passing
  - ZeroMQ: low-overhead transparent, thread-safe message passing
  - Reduction of hidden state: Transparently networkable GNU Radio flowgraphs
- Don’t care whether in- or output buffer is in circular buffer, async message or hardware DMA region
NBT – Approach

- Thread-per-Block → Worker threads
- Single input queue per worker
- Don’t care whether in- or output buffer is in circular buffer, async message or hardware DMA region
  - Obsoletes TSBs
  - Enables Zero-Copy Accelerator, NIC interfacing
NBT – Necessary Changes

- Testing of Scheduler Correctness
- Benchmarking
  - Not only: Throughput, but also
  - Latency constraints (we can track these reasonably with queues!)
  - Number of CPU migrations
  - Cache access failures
  
  can well be done with eBPF
- Refactoring of block_executor
  - Literally among oldest code in GNU Radio
  - Dead code, unused state

Bastian Bloessl has taken the lead on this\(^1\)

\(^1\)Bastian Bloessl, Müller, Hollick: *Benchmarking and Profiling the GNU Radio Scheduler*, Proceedings of the 9th GNU Radio Conference, Sept. 2019
NBT – Necessary Changes

- Testing of Scheduler Correctness
- Benchmarking
  - Not only: Throughput, but also
  - Latency constraints (we can track these reasonably with queues!)
  - Number of CPU migrations
  - Cache access failures
  
  can well be done with eBPF
- Refactoring of block_executor
  - Literally among oldest code in GNU Radio
  - Dead code, unused state

Bastian Bloessl has taken the lead on this\(^1\)

---
\(^1\)Bastian Bloessl, Müller, Hollick: *Benchmarking and Profiling the GNU Radio Scheduler*, Proceedings of the 9th GNU Radio Conference, Sept. 2019
NBT – Workload and Strategy

Immediate yields²:

- Refactored scheduler code to be merged into master (for 3.9)
- Benchmarking shows significant impact of workload size on caching we’ve largely ignored so far
- Benchmarking toolkit gr-sched³
  - Throughput of classical GR under different Linux schedulers / CPU pinning / “emulated” NBT scheduler
  - CPU core migrations
  - Cache hits/misses
  - Pretty specific, doesn’t do automated reports incl. topology (yet)

²https://github.com/bastibl/gnuradio
³https://github.com/bastibl/gr-sched
NBT – Workload and Strategy

- Merge refactoring within 3.9 window
- NBT in GNU Radio 4
Questions & Answers

Ask away!