GNU Radio 3.10

and other technical updates
FOSDEM 2022
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GNU Radio 3.10

- Released Jan 14, 2022 → 3.10.0.1 ~Jan 24
  - Packaging window for Ubuntu 22.04
- Much smaller 'irritation factor' 3.9-3.10 (than 3.7 or 3.8 to 3.9)
  - API changes, but likely little OOT rework
- Two new Modules
  - gr-pdu
  - gr-iio
- Support for Hardware Accelerators
- Updated Logging Infrastructure
- 92 Unique Contributors since v3.9.0.0

Getting 3.10

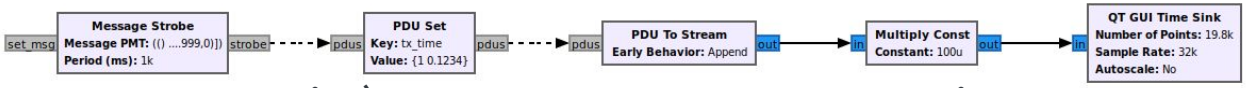
- maint-3.10 branch of https://github.com/gnuradio/gnuradio
- Radio Conda
  - https://wiki.gnuradio.org/index.php/CondaInstall
- Ubuntu PPA (for 20.04)
  - `sudo add-apt-repository ppa:gnuradio/gnuradio-releases`
  - `sudo apt-get update`
  - `sudo apt install gnuradio`

NOTE: PPA doesn't play well with apt install other OOTs - install OOTs from source

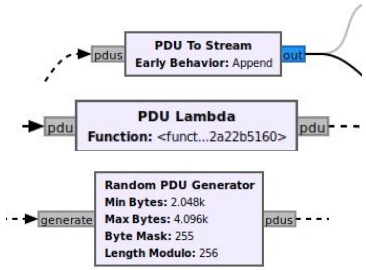
- The goal is that for Ubuntu 22.04, should just be (thanks @mait)
  - `sudo apt install gnuradio`
  - Of course, Conda or the ppa will be better to get maintenance releases
- → Always looking for more help with packaging maintenance

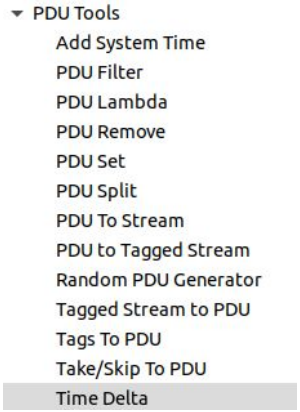
gr-pdu

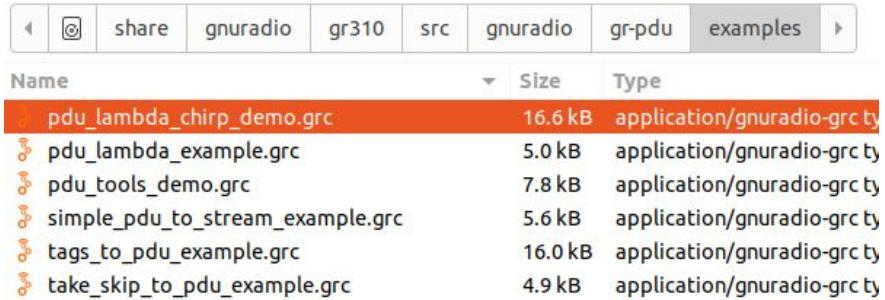
https://www.youtube.com/watch?v=bT60hVVte48
https://www.youtube.com/watch?v=YPfkjWtIFXs



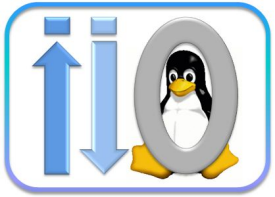
- PDUs (protocol data units) are the standard GNU Radio way for dealing with packetized data
  - Special PMT type with metadata and data
- Upstreamed from **Sandia National Labs (Jacob Gilbert)**
  - Tools for manipulation of PDU objects





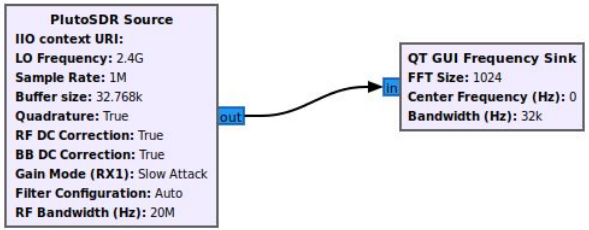


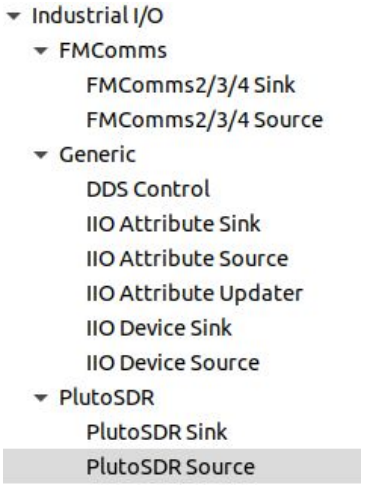
gr-iio



https://www.youtube.com/watch?v=2gKbollW6wg

- Upstreamed from **Analog Devices**
- IIO is an industry standard for interacting with a wide range of devices
- Source/Sinks for iio based devices
  - PLUTO SDR
  - FMCOMMS 2/3/4





Logging Infrastructure Overhaul

Revamped Logging Infrastructure (**Marcus Müller**)

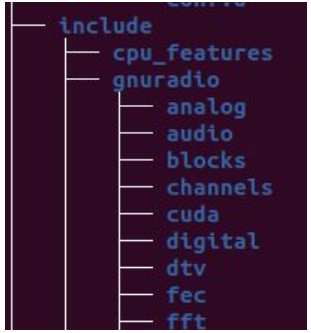
spdlog replaces Log4Cpp - which had become an unwieldy dependency

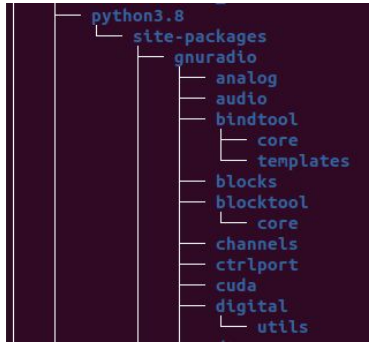
- Persistently difficult dependency to maintain and use
- **spdlog** provides much nicer and more modern logging facilities
- **libfmt** for boost::format string formatting replacement
  - Instead of GR_LOG_DEBUG(d_logger, boost::format("logging value %d") % x)
  - ... d_logger->debug("logging value {}", x)

https://github.com/gnuradio/greps/blob/main/grep-0024-oots-same-as-modules.md

gr_modtool OOT restructuring

- OOT structure more closely resembling the in-tree structure
- OLD:
  - import myoot
  - #include <myoot/myblock.h>
- NEW:
  - from gnuradio import myoot
  - #include <gnuradio/myoot/myblock.h>
- WHY?
  - We were being very presumptuous about package naming
  - Losing the association of an OOT with GNU Radio
  - Consistency
- OOTs created with 3.9 modtool (old structure) should be handled as normal with 3.10 modtool (the reverse is not true)





OOTs now installed *same level* as in-tree modules

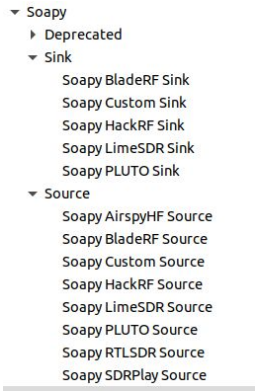
Active Backporting

3.9.5.0 and 3.8.5.0 available now!!!

Thanks to the active backporting efforts of **Jeff Long** (co-maintainer), we are seeing many bug fixes and even large features show up in maintenance releases

https://github.com/gnuradio/gnuradio/blob/maint-3.9/CHANGELOG.md

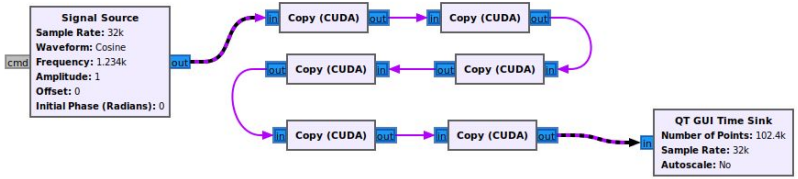
- gr-soapy
  - provides access to Soapy hardware drivers using the SoapySDR driver framework
  - https://wiki.gnuradio.org/index.php/Soapy
  - "out of the box" (if SoapySDR installed) support for
    - rtl-sdr
    - hackrf
    - limesdr
    - bladeRF
    - SDRPlay
    - Airspy
    - ...



https://www.youtube.com/watch?v=VO1zMXowezg

Custom Buffers

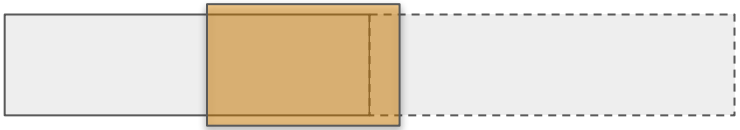
- Feature introduced by **David Sorber** at **Black Lynx** via the **DARPA SDR 4.0** project
  - Working Status presented last year at FOSDEM
  - https://archive.fosdem.org/2021/schedule/event/fsr_improving_gnu_radio_accelerator_device_dataflow/
- Device compatible buffer structure (single mapped)
  - https://wiki.gnuradio.org/index.php/Custom_Buffers
- Data able to remain in accelerator memory
  - Streamlined data movement



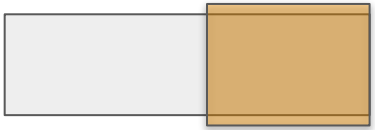
Prior to 3.10 using custom buffers, each connection between CUDA enabled blocks would require ingress/egress to/from device memory (expensive)

Single vs Double Mapped Circular Buffers

- GNU Radio Double Mapped Buffers



  - Contiguous read/write for the entire buffer size
  - Simple pointer arithmetic
- Device (e.g. DMA) Memory - Single Mapped



  - Readers/Writers need to handle wraparound
  - Shuffle the data when necessary

CUDA Block Example

Old way to write CUDA enabled GR blocks (pre 3.10)

constructor()

```
check_cuda_errors(cudaMalloc((void**)&d_dev_in, d_max_buffer_size));
check_cuda_errors(cudaMalloc((void**)&d_dev_out, d_max_buffer_size));
```

Allocate CUDA Device memory in the constructor (or worse, in the work function if necessary)

work()

```
check_cuda_errors(cudaMemcpyAsync(d_dev_in,
                                  in,
                                  noutput_items * d_itemsize,
                                  cudaMemcpyHostToDevice,
                                  d_stream));

load_cu::exec_kernel(d_dev_in,
                     d_dev_out,
                     gridSize,
                     d_block_size,
                     noutput_items * d_itemsize,
                     d_iterations,
                     d_stream);
check_cuda_errors(cudaPeekAtLastError());

cudaMemcpyAsync(out,
                d_dev_out,
                noutput_items * d_itemsize,
                cudaMemcpyDeviceToHost,
                d_stream);
```

Copy from the GNU Radio buffers (input_items) to the device memory

Execute kernel and check for errors

Copy from the device memory back out to the GNU Radio buffers (output_items)

Custom Buffers Example

NEW WAY to write CUDA enabled GR blocks in 3.10

https://github.com/gnuradio/gr-cuda

- Contains CUDA Buffer Class that can be re-used in your OOT
- Similar custom buffers available for AMD HIP (https://github.com/BlackLynx-Inc/gr-hip_buffer)

constructor()

```
#include <gnuradio/cuda/cuda_buffer.h>
```

```
gr::io_signature::make(1, 1, itemsize, cuda_buffer::type),
gr::io_signature::make(1, 1, itemsize, cuda_buffer::type)),
```

Use the cuda_buffer class as part of the io_signature - the details of ingress/egress happen behind the scenes

work()

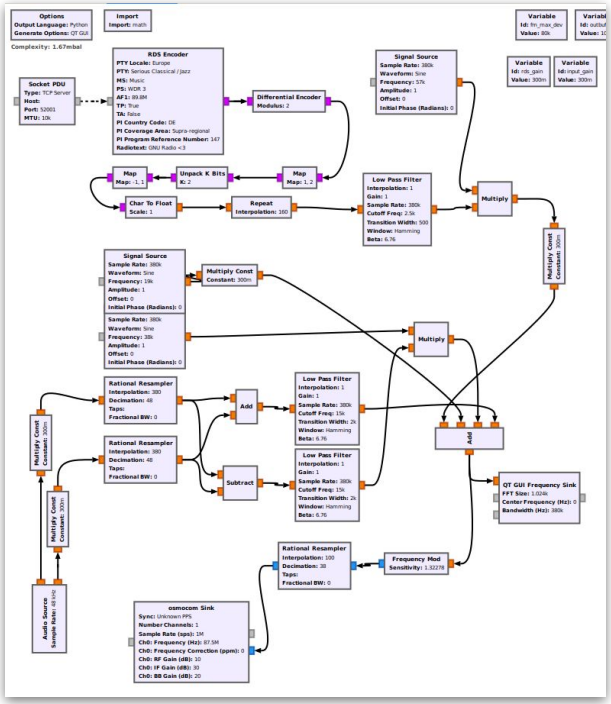
```
load_cu::exec_kernel(in,
                     out,
                     gridSize,
                     d_block_size,
                     noutput_items * d_itemsize,
                     d_iterations,
                     d_stream);
check_cuda_errors(cudaPeekAtLastError());
```

Execute kernel and check for errors
(in and out pointers are ***already in device memory*** due to cuda_buffer)

```
cudaStreamSynchronize(d_stream);
```

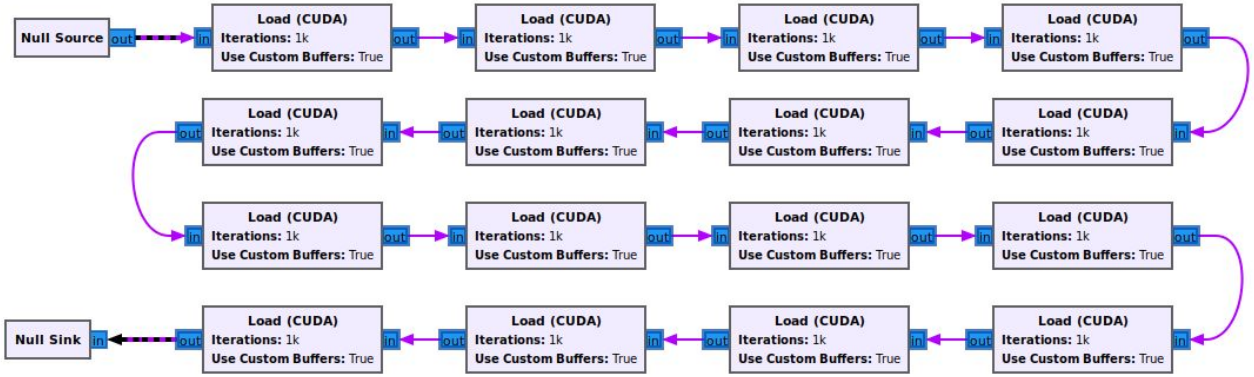
For both old and new, we need to block on the stream used for this block

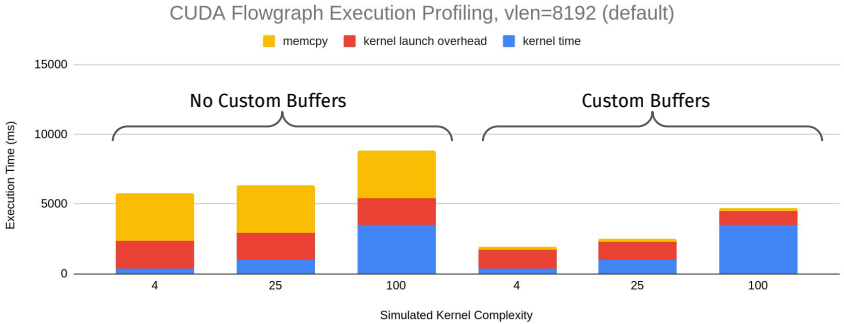
Why is this Important?

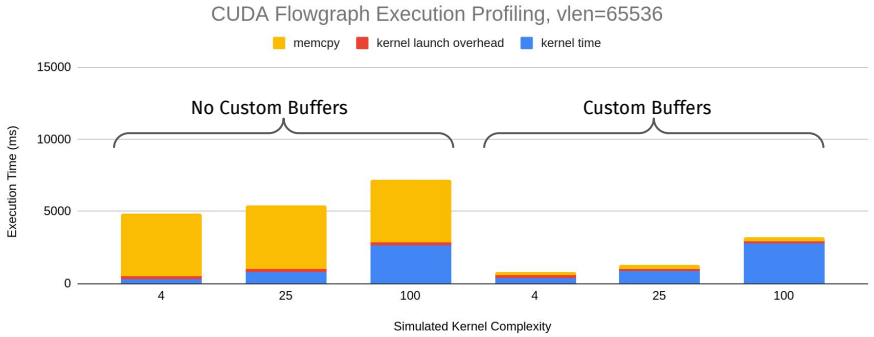


- One of the value propositions of GNU Radio is the ability to accomplish a complex signal processing task by connecting a bunch of general purpose blocks together
- Don't always want to program a special purpose block, though this can be computationally efficient
- For accelerators, this paradigm means a lot of data movement in and out of devices unless handled properly
- GRC already has the concept of "domains" to represent ingress/egress - applied effectively to RFNoC

Profiling

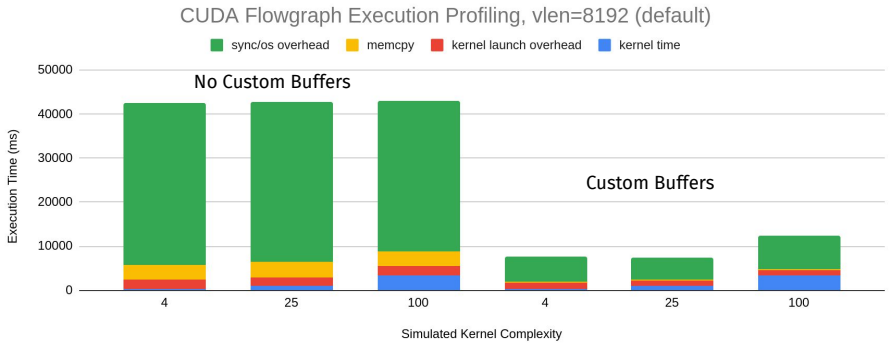

Null Source
Null Sink
Load (CUDA)
Iterations: 1k
Use Custom Buffers: True
in
out

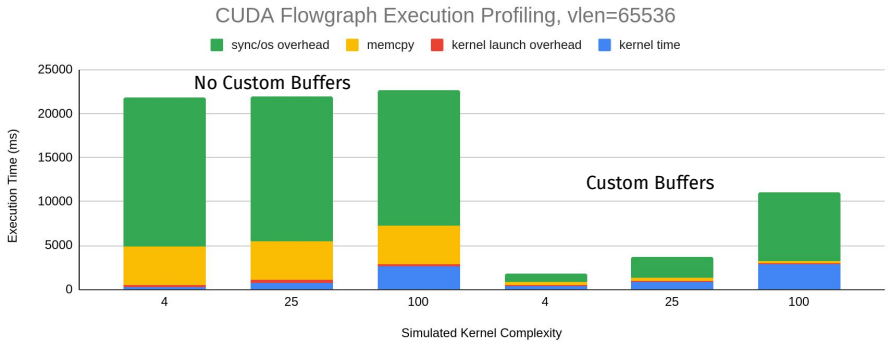

CUDA Flowgraph Execution Profiling, vlen=8192 (default)
memcpy
kernel launch overhead
kernel time
No Custom Buffers
Custom Buffers
Execution Time (ms)
15000
10000
5000
0
4
25
100
Simulated Kernel Complexity


CUDA Flowgraph Execution Profiling, vlen=65536
memcpy
kernel launch overhead
kernel time
No Custom Buffers
Custom Buffers
Execution Time (ms)
15000
10000
5000
0
4
25
100
Simulated Kernel Complexity

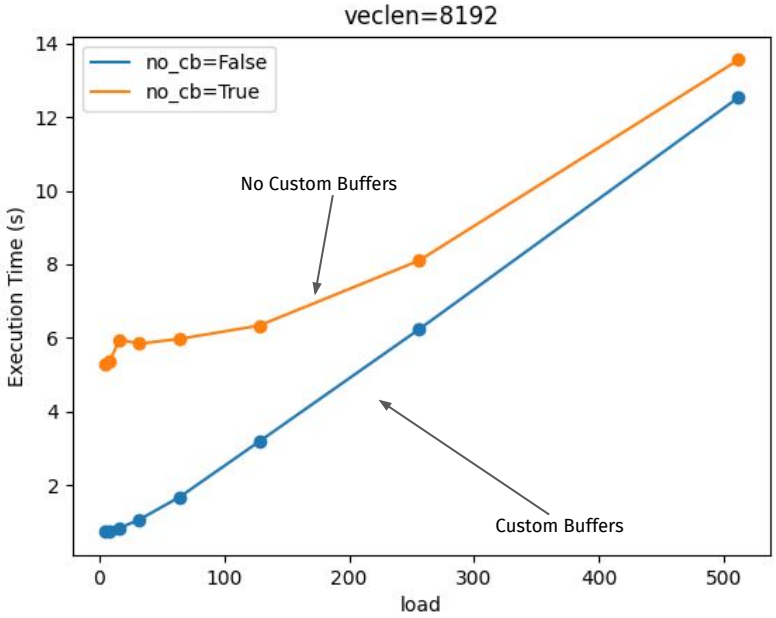
Accounting for CPU Time

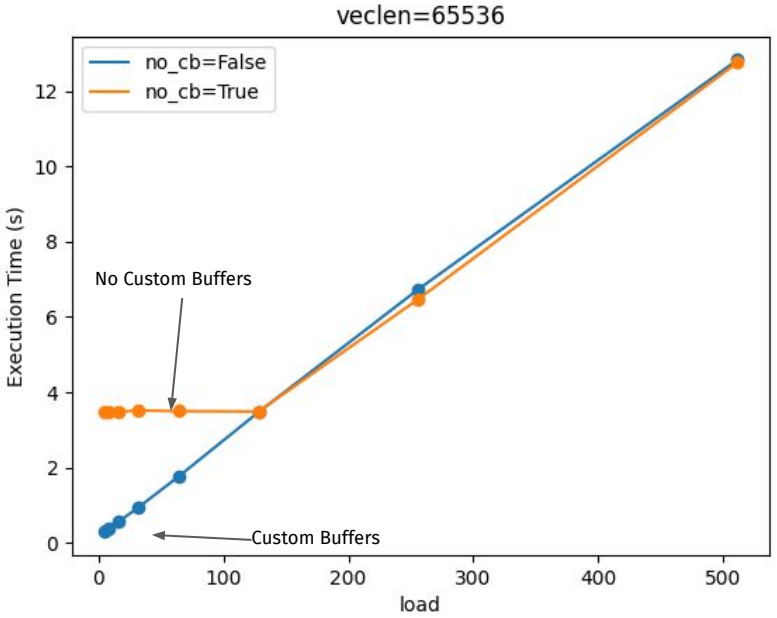
- Compare GPU profile activity in the context of overall available CPU processing time (# of cores * flowgraph execution time)
- Much time is spent either idle - waiting for GPU operations to queue or complete, or synchronization and OS overhead
- Reducing the CPU overhead/idle can come through scheduler advancements → **GR 4.0**





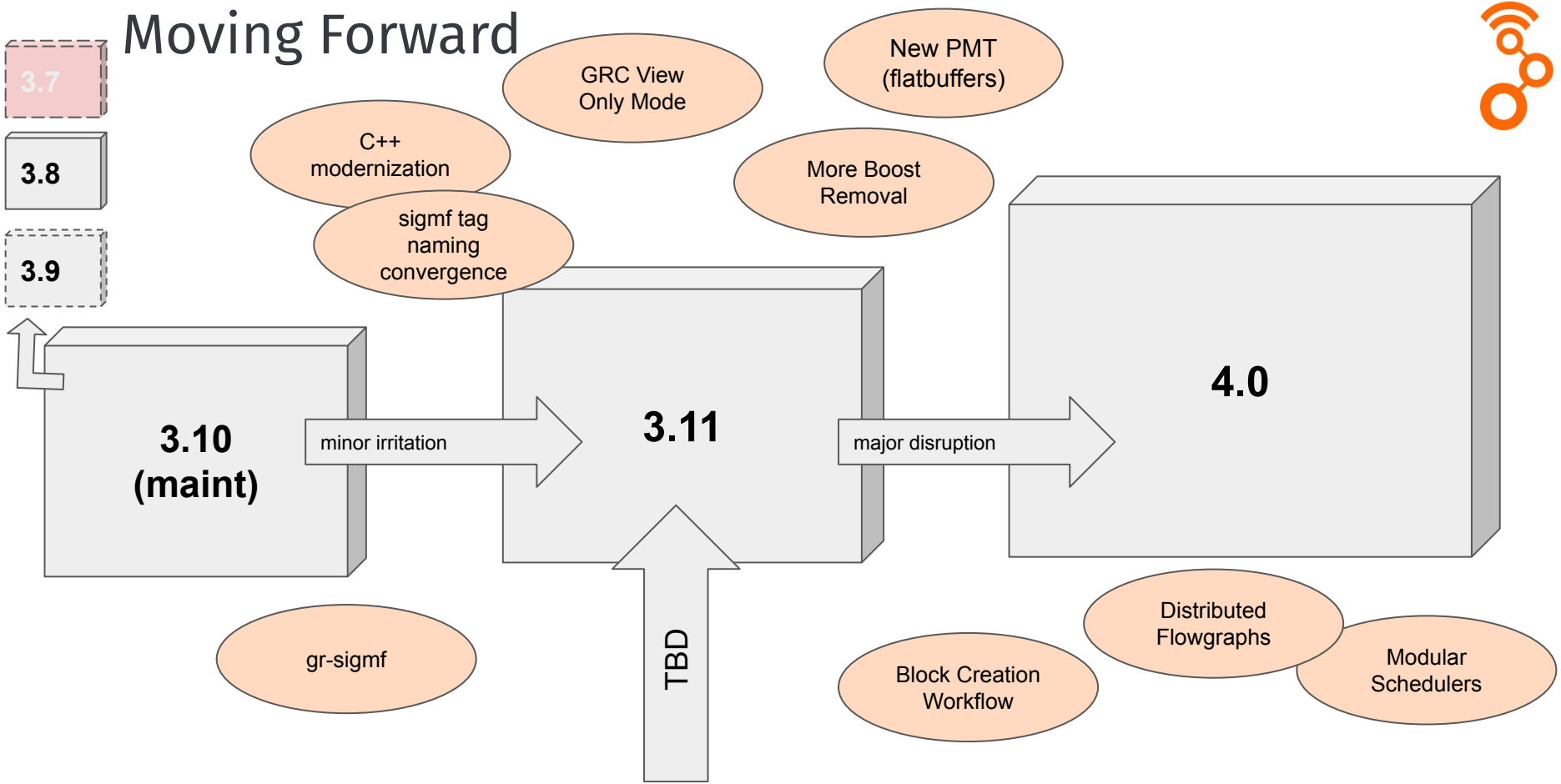
Flowgraph Execution Time





For small kernels, the gains from streamlined data transfer are huge → 90% reduction
Benefit diminishes the more GPU processing that is happening in a single block

Moving Forward



Getting Involved

If there are features you would like to see in GNU Radio, join the conversation

- chat.gnuradio.org (Matrix)
  - #gnuradio - general chat
  - #development
  - #scheduler - discussion of 4.0 / future development
- Monthly Developer Calls
  - 3rd Thursday of Every Month at 12PM Eastern - twitch.tv/gnuradio
- Scheduler Working Group
  - A number of us get together every month or so to discuss more forward looking features and ideas - working towards GNU Radio 4.0
  - Meetings announce in #scheduler