Simple TDMA + ARQ MAC using GNURadio and USRPs

Presentation and framework - Josh Blum

MAC layer and protocol blocks – John Malsbury

@ Ettus Research

Intro to John's MAC work

- TODO Introduce Malsbury...
- Motivation:
  - Want a cool two-way comms example for USRP
  - Demonstrate proper usage (tags, timed bursts etc)
  - Easy to comprehend and change (all in python and GRC)
- Note to self:
  - Say bad things about tunnel.py if we didn't already

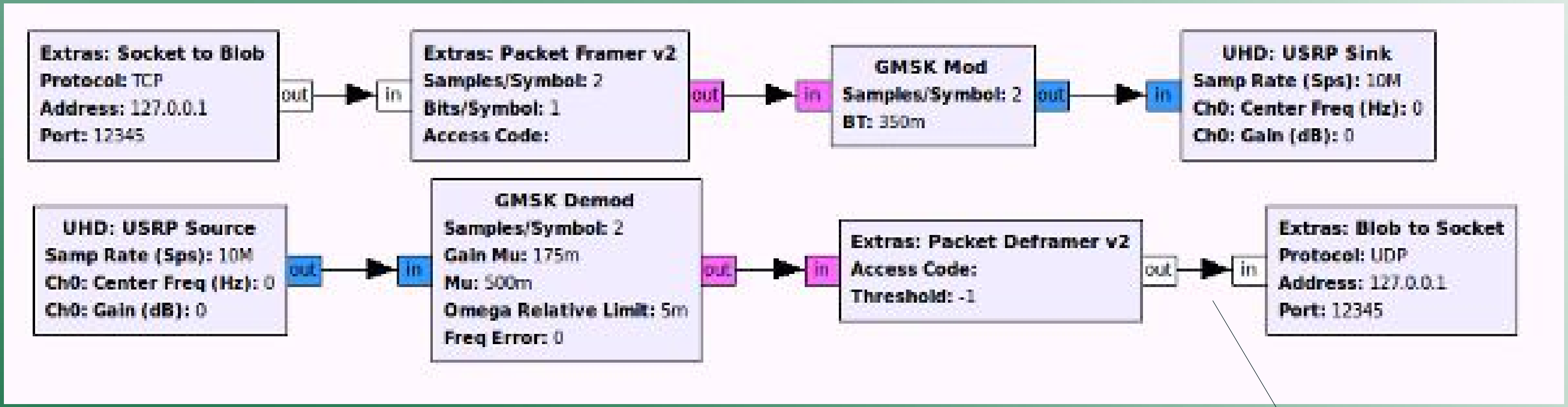
Now, lets build this presentation up one layer at a time – I promise that it will all make sense

The GR Extras Project

- Message passing API
  - Implemented on top of stream tags/builds on a stock gnuradio
  - Use messages to preserve packet boundaries (aka pmt_blob)
  - Use messages for a control plane or MAC layer
- Write blocks in python
  - Overload work function in python!
  - Bridges the gap between python/C++
- Misc blocks in Extras
  - May make use of the message passing feature
  - (can totally make a templated adder with a volk specialization)
- See wiki page below and link to coding guide

https://github.com/guruofquality/grextras/wiki

Message passing, a quick visual



Extras: Socket to Blob
Protocol: TCP
Address: 127.0.0.1
Port: 12345

Extras: Packet Framer v2
Samples/Symbol: 2
Bits/Symbol: 1
Access Code:

GMSK Mod
Samples/Symbol: 2
BT: 350m

UHD: USRP Sink
Samp Rate (Sps): 10M
Ch0: Center Freq (Hz): 0
Ch0: Gain (dB): 0

UHD: USRP Source
Samp Rate (Sps): 10M
Ch0: Center Freq (Hz): 0
Ch0: Gain (dB): 0

GMSK Demod
Samples/Symbol: 2
Gain Mu: 175m
Mu: 500m
Omega Relative Limit: 5m
Freq Error: 0

Extras: Packet Deframer v2
Access Code:
Threshold: -1

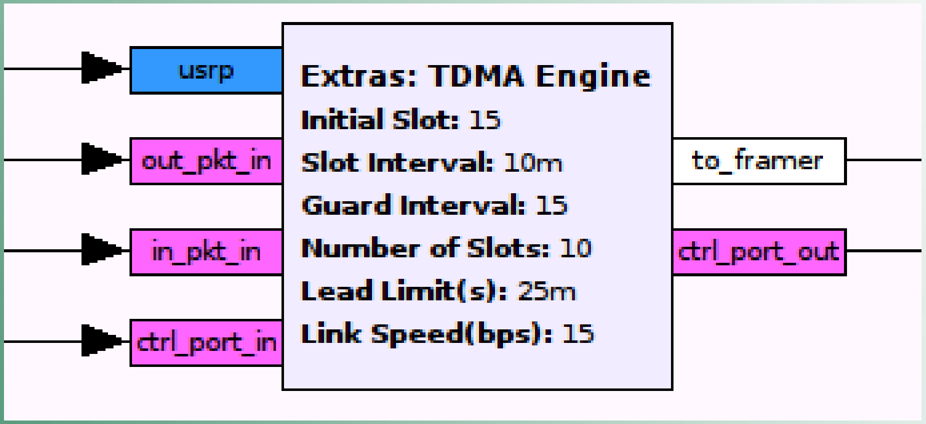
Extras: Blob to Socket
Protocol: UDP
Address: 127.0.0.1
Port: 12345

- Some of these blocks pass PMT "blob" types
- Whats a blob?
  - PMT library primitive
  - Polymorphic type that holds std::vector<char>
  - Its just a memory pointer and a length in bytes

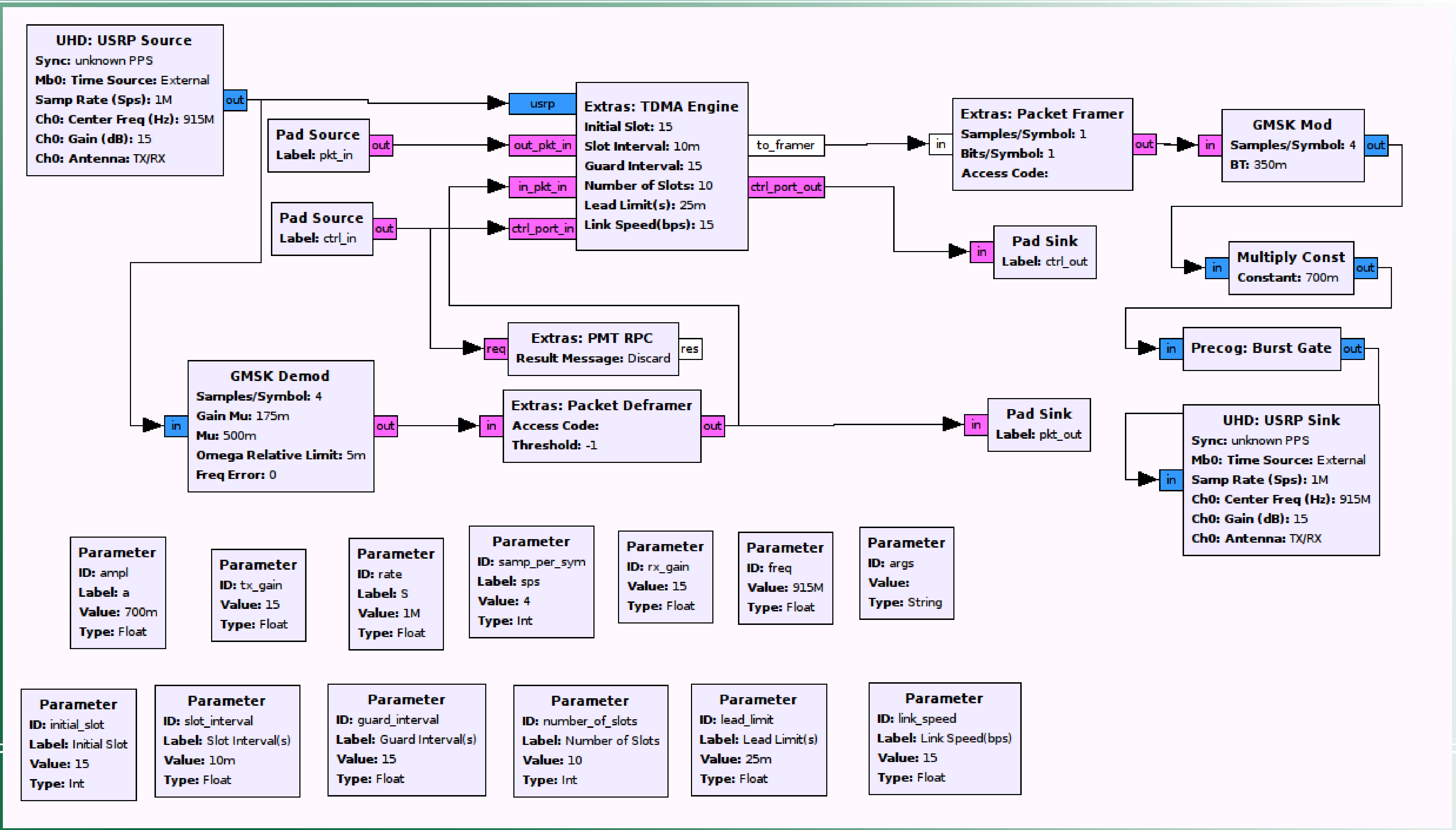
Packet boundaries
are preserved
into the socket!

Simple TDMA Engine

- TDMA Engine - this block will monitor a USRP receiver stream to determine the time. Based on the assigned slot, specified guard interval, and number of slots in the TDMA frame, this block will hold back all incoming blobs until it's assigned slot (plus guard interval) approaches. It will output these msg's as blobs after its next slot interval - lead limit passes.


Extras: TDMA Engine
Initial Slot: 15
Slot Interval: 10m
Guard Interval: 15
Number of Slots: 10
Lead Limit(s): 25m
Link Speed(bps): 15

Integrating the TDMA Engine w/ Mod and Demod chains



UHD: USRP Source
Sync: unknown PPS
Mb0: Time Source: External
Samp Rate (Sps): 1M
Ch0: Center Freq (Hz): 915M
Ch0: Gain (dB): 15
Ch0: Antenna: TX/RX

Pad Source
Label: pkt_in

Pad Source
Label: ctrl_in

Extras: TDMA Engine
Initial Slot: 15
Slot Interval: 10m
Guard Interval: 15
Number of Slots: 10
Lead Limit(s): 25m
Link Speed(bps): 15

Extras: Packet Framer
Samples/Symbol: 1
Bits/Symbol: 1
Access Code:

GMSK Mod
Samples/Symbol: 4
BT: 350m

Pad Sink
Label: ctrl_out

Multiply Const
Constant: 700m

Extras: PMT RPC
Result Message: Discard

Precog: Burst Gate

GMSK Demod
Samples/Symbol: 4
Gain Mu: 175m
Mu: 500m
Omega Relative Limit: 5m
Freq Error: 0

Extras: Packet Deframer
Access Code:
Threshold: -1

Pad Sink
Label: pkt_out

UHD: USRP Sink
Sync: unknown PPS
Mb0: Time Source: External
Samp Rate (Sps): 1M
Ch0: Center Freq (Hz): 915M
Ch0: Gain (dB): 15
Ch0: Antenna: TX/RX

Parameter
ID: ampl
Label: a
Value: 700m
Type: Float

Parameter
ID: tx_gain
Value: 15
Type: Float

Parameter
ID: rate
Label: S
Value: 1M
Type: Float

Parameter
ID: samp_per_sym
Label: sps
Value: 4
Type: Int

Parameter
ID: rx_gain
Value: 15
Type: Float

Parameter
ID: freq
Value: 915M
Type: Float

Parameter
ID: args
Value:
Type: String

Parameter
ID: initial_slot
Label: Initial Slot
Value: 15
Type: Int

Parameter
ID: slot_interval
Label: Slot Interval(s)
Value: 10m
Type: Float

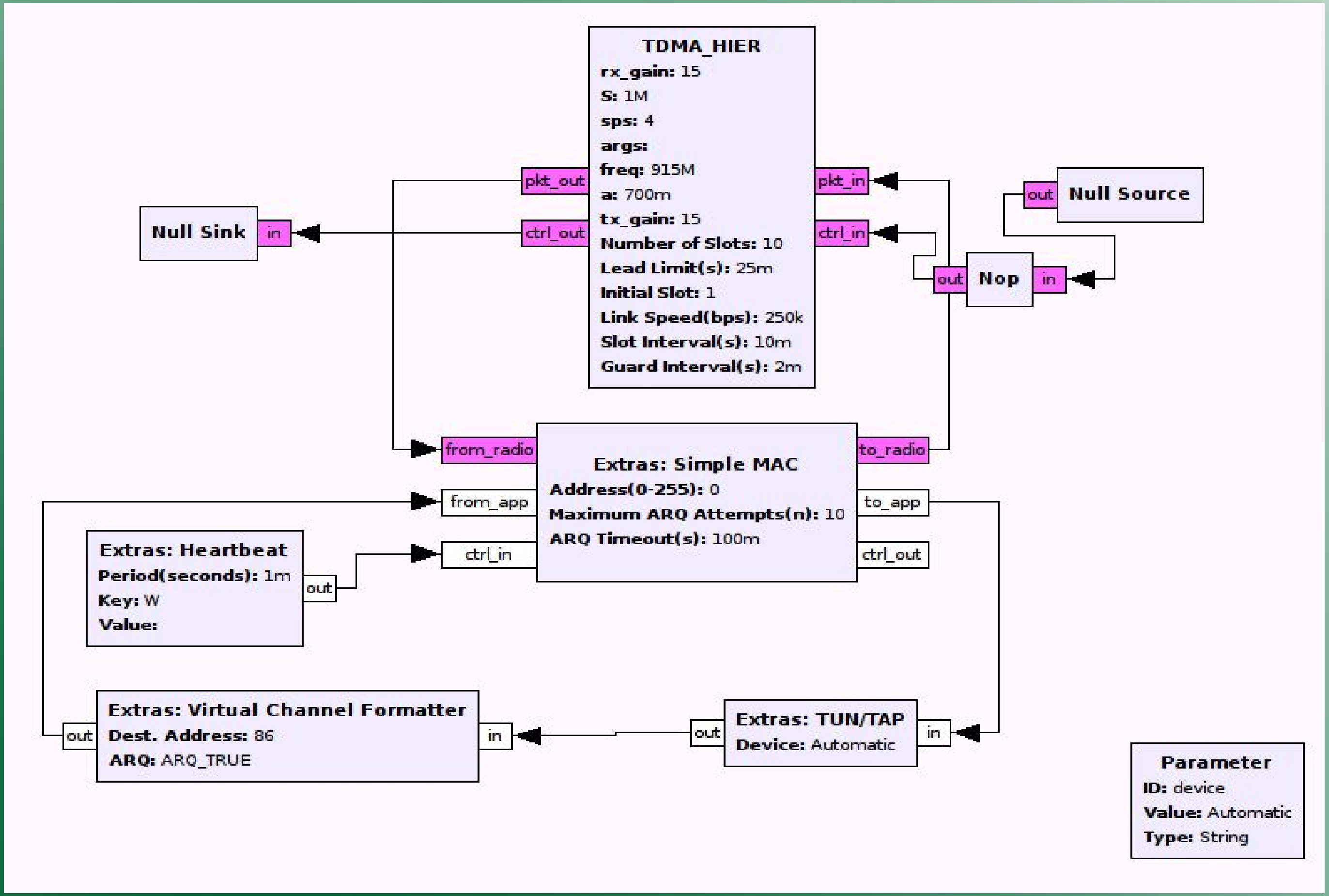
Parameter
ID: guard_interval
Label: Guard Interval(s)
Value: 15
Type: Float

Parameter
ID: number_of_slots
Label: Number of Slots
Value: 10
Type: Int

Parameter
ID: lead_limit
Label: Lead Limit(s)
Value: 25m
Type: Float

Parameter
ID: link_speed
Label: Link Speed(bps)
Value: 15
Type: Float

A top level use case



TDMA_HIER
rx_gain: 15
S: 1M
sps: 4
args:
freq: 915M
a: 700m
tx_gain: 15
Number of Slots: 10
Lead Limit(s): 25m
Initial Slot: 1
Link Speed(bps): 250k
Slot Interval(s): 10m
Guard Interval(s): 2m

Null Sink

Null Source

Nop

Extras: Simple MAC
Address(0-255): 0
Maximum ARQ Attempts(n): 10
ARQ Timeout(s): 100m

Extras: Heartbeat
Period(seconds): 1m
Key: W
Value:

Extras: Virtual Channel Formatter
Dest. Address: 86
ARQ: ARQ_TRUE

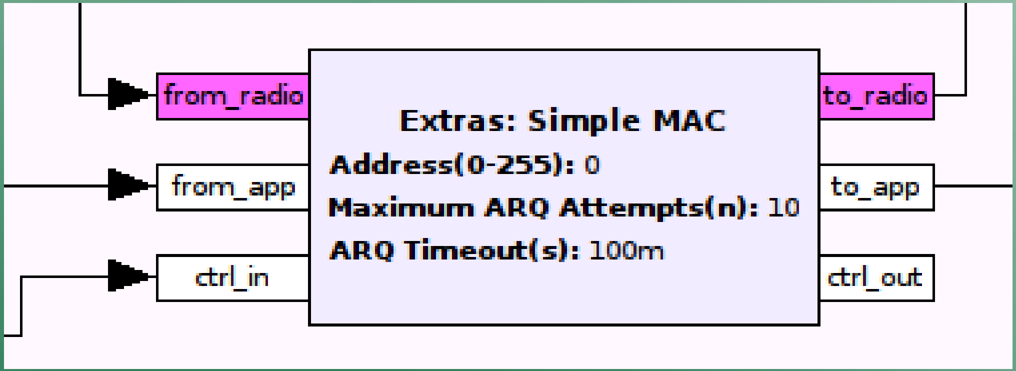
Extras: TUN/TAP
Device: Automatic

Parameter
ID: device
Value: Automatic
Type: String

* Parameter blocks not shown

- External entry and exit points to the flow graph is the tun/tap block. But this can be anything really...

The Simple ARQ MAC



Extras: Simple MAC
Address(0-255): 0
Maximum ARQ Attempts(n): 10
ARQ Timeout(s): 100m

- Simple ARQ - accepts msg blobs on the "app in" msg port. It will add a header that incldues a sequence number, desination address, source address, and a couple of control words. Source address is the address of the MAC itself. The source address is the address of the radio we want to send the message to. This address is encoded into the key of the incoming blob so you can have multiple streams to multiple radios. The ARQ selection is also encoded into the key of the incoming blob. Currently, this block supports simple stop-and-qait ARQ. Blobs with header are exchanged on the "radio" ports. Ctrl ports also provided, but do nothing useful at the moment.

Where is the code?

- GRExtras main wiki page:
  - https://github.com/guruofquality/grextras/wiki
- GitHub URL
  - $ git clone https://github.com/guruofquality/grextras.git
- Check out this branch:
  - $ git checkout pre_cog
- GRC flowgraphs are here:
  - <src dir>/examples/*.grc
- Contact
  - josh@ettus.com
  - john@ettus.com

Conclusion

- TODO
  - Improve/polish code & testing
  - More examples for specific use cases
  - Merged into gr extras master
  - Better/more helpful wiki page
- Questions?