GWN: a Framework for Packet Radio and Medium Access Control in GNU Radio

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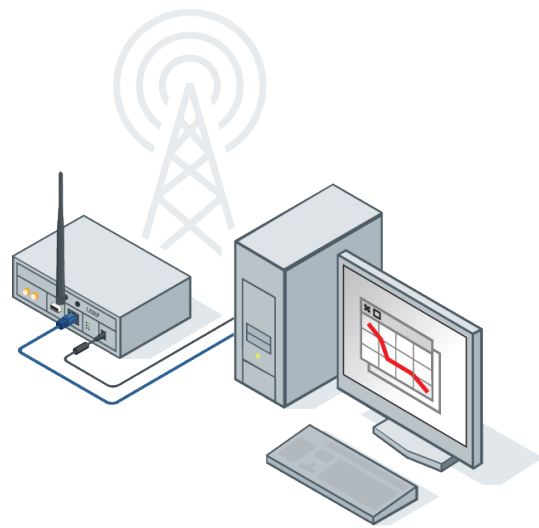
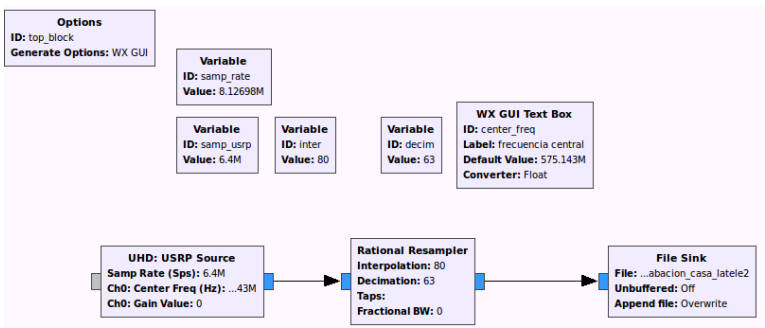
Software Defined Radio (SDR)

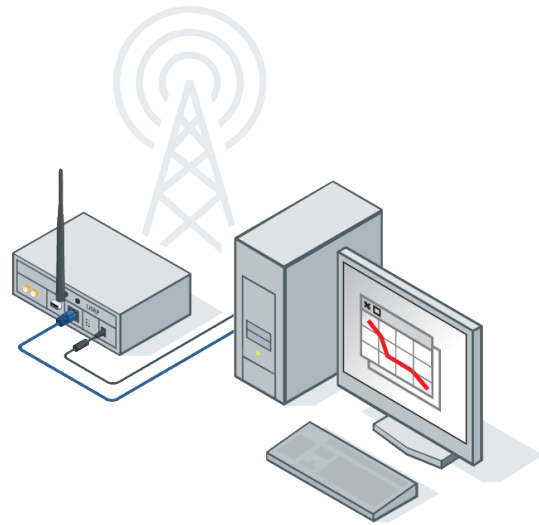
- Basic idea: implement as much as possible of receiver and/or transmitter in software
- We focused on PC-based SDRs: enough sampling rate for most applications + only some hundreds dollars



Software Defined Radio (SDR)

- Basic idea: implement as much as possible of receiver and/or transmitter in software
- We focused on PC-based SDRs: enough sampling rate for most applications + only some hundreds dollars
- Software: GNU Radio
  - Free and open-source SDR development toolkit
    - Provides framework to implement and interconnect blocks
  - Extremely popular
    - Supports most (if not all) SDR hardware
    - Growing base of already-implemented blocks





GNU Radio and Wireless Networks

- GNU Radio was originally conceived for stream-oriented communications

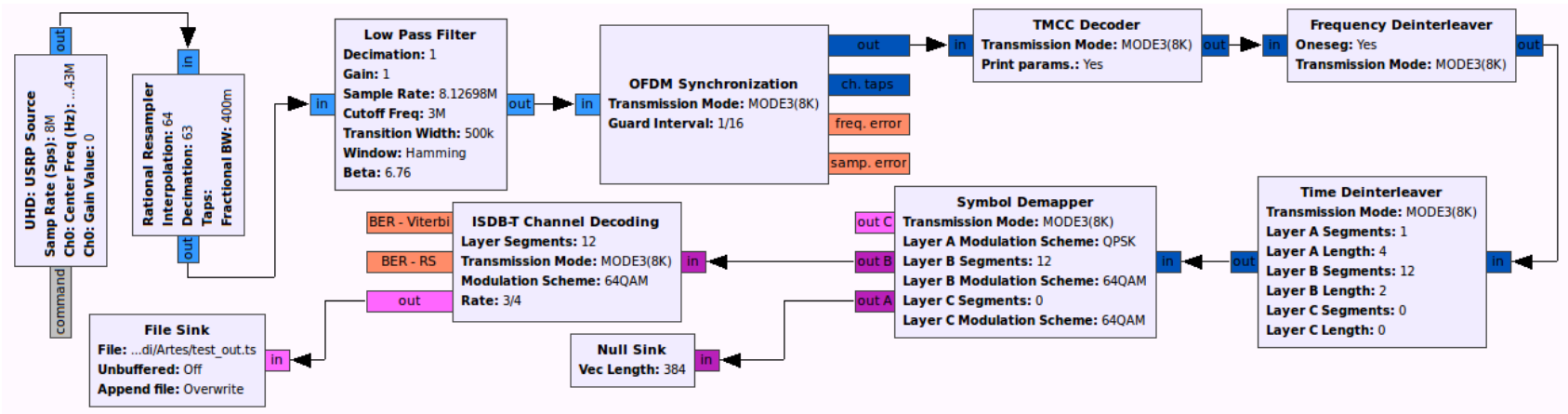


Fig: An example flowgraph of gr-isdbt, our ISDB-T (DTV) receiver

- What if I want to work with packets?

GNU Radio and Wireless Networks

What if I want to work with packets on GNU Radio?

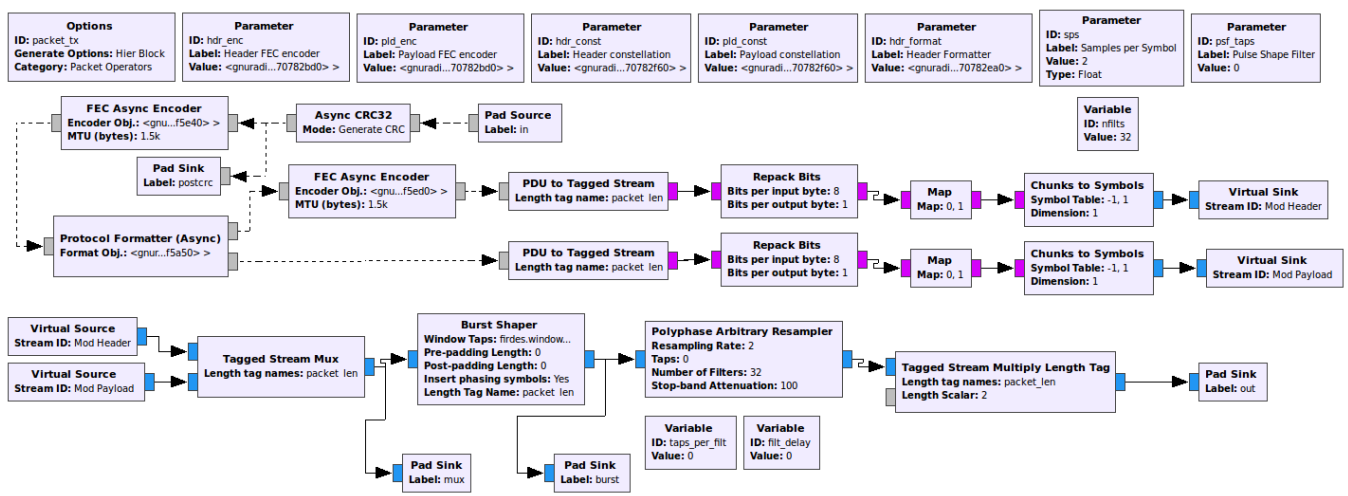
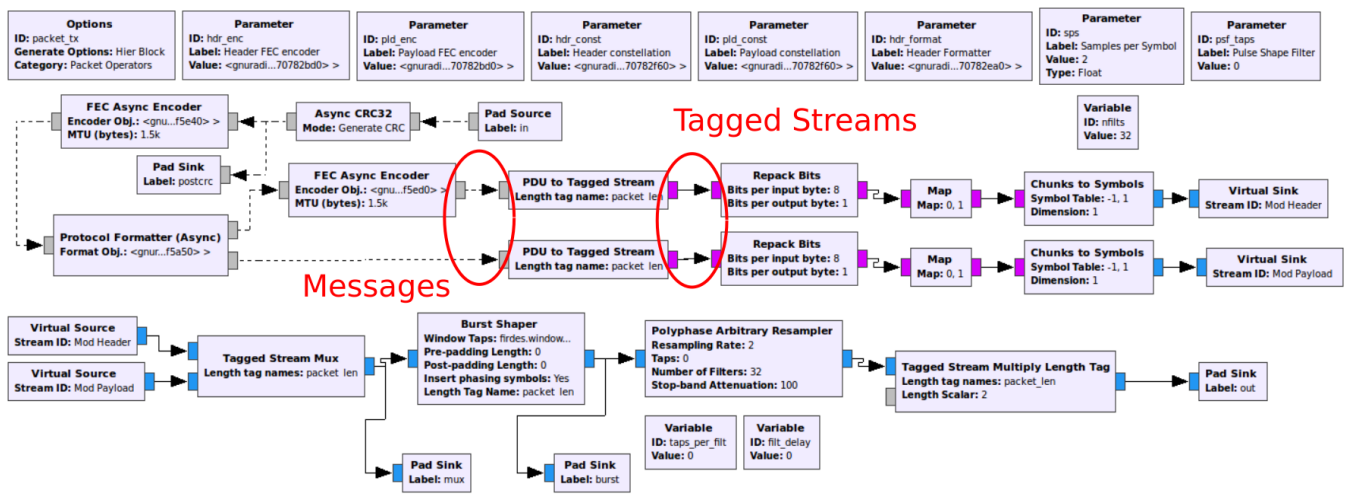


Fig: An example flowgraph of gr-digital (packet_tx.grc)

GNU Radio and Wireless Networks

What if I want to work with packets on GNU Radio?

- **Tagged Streams**
  - Specific samples may be "marked" with extra data (i.e. where a new packet begins)
- **Message passing**
  - Blocks may send and receive **messages**
  - They work asynchronously and separated from the data stream
  - Blocks may even receive messages from external apps
  - Messages are actually PMTs: generic data containers which may contain mostly anything, and in particular packets



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GNU Radio and Wireless Networks

Natural next step: What if I want to implement the Data Link Layer on GNU Radio?

- What's necessary?
  - TX: Packets have to be sent when certain conditions are met (e.g. free channel, slotted time), acknowledgements waited for a certain time, packets re-sent, etc.
  - RX: As packets are received, error checking/correction is performed, re-ordering may be necessary, (n)acknowledgments sent, etc.
  - The above includes the **Medium Access Control** mechanism

GNU Radio and Wireless Networks

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What's necessary?

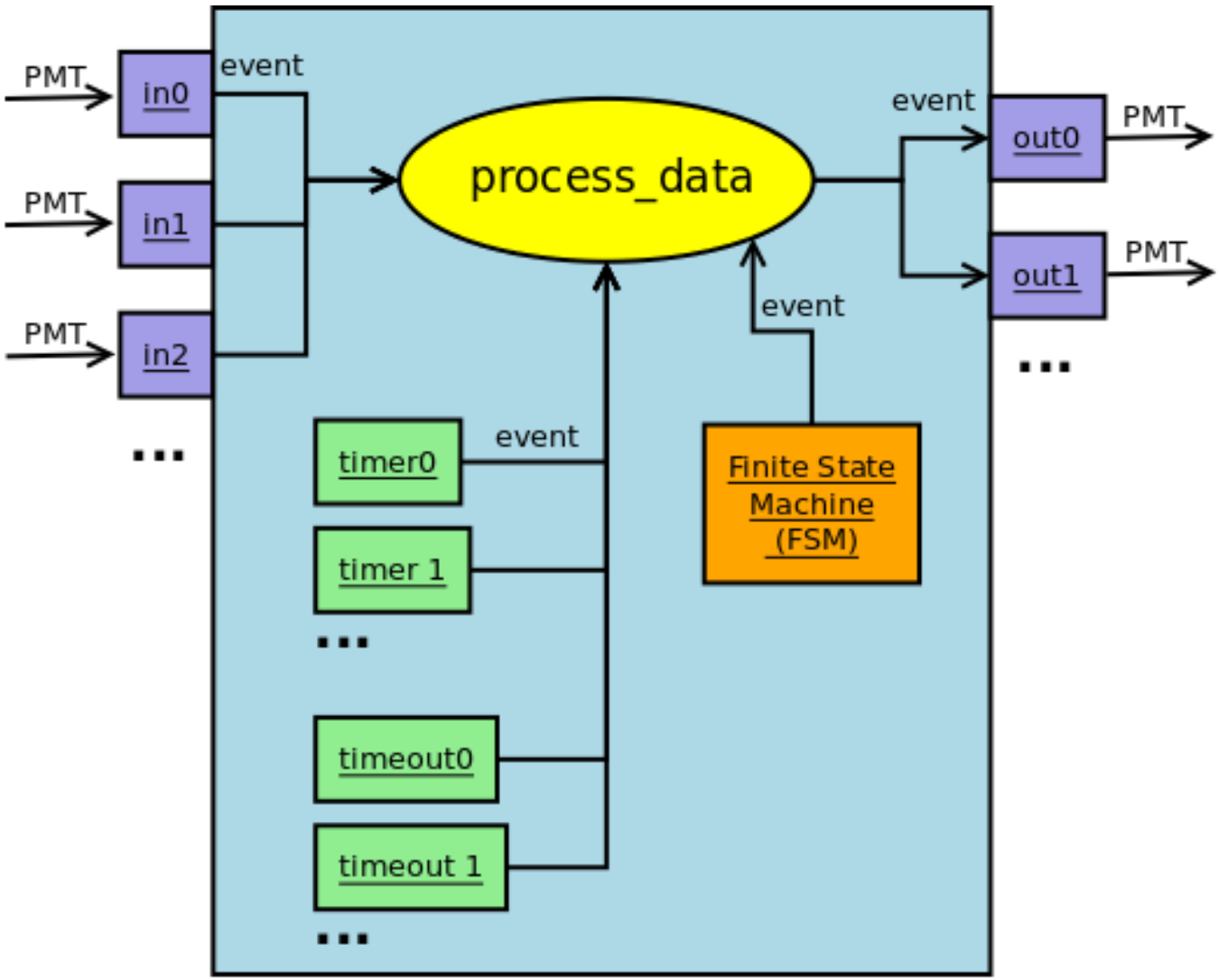
1. A Finite State Machine (FSM) to implement the protocol's logic
2. Events to drive the FSM
3. Timing

GNU Radio Wireless Networks

- We present GNU Radio Wireless Networks (GWN)
- It introduces `gwnblock`: an extension of GNU Radio's basic block which includes
  - An implementation of a FSM, which may be specified very easily
  - Events
  - The possibility to handle time
- It is thus fully compatible with GNU Radio and integrates seamlessly
- We demonstrate it by discussing an ARQ (Automatic Repeat ReQuest) implementation

GWN Architecture

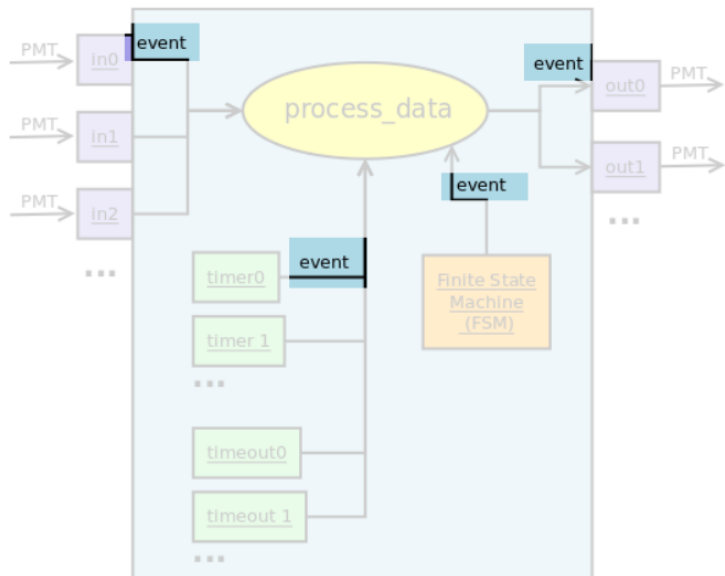
A typical GWN block:



GWN Architecture

Events

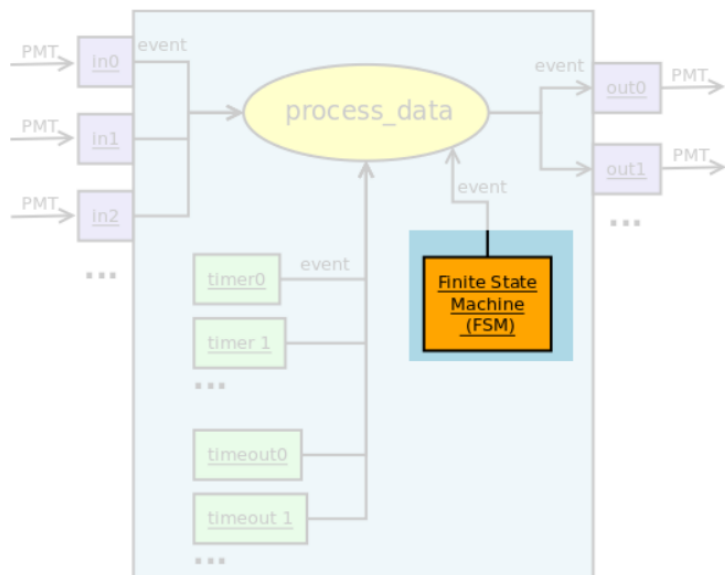
- Events are characterized by:
  - a `Nickname` which indicates the type of Event
  - a `Dictionary` with additional information
- Specialized Events are provided: `EventConfig`, `EventTimer` and `EventComm`, along with constructor functions
  - example: `EventComm` represents an incoming packet, and as such includes source/destination addresses and payload



GWN Architecture

Finite State Machine

- In addition to states and transitions, GWN's FSM includes:
  - `Action`: a function to be executed on a transition
  - `Memory`: which may be handled in the action functions
  - `Conditions`: a function which, if evaluates to False, the Action and the transition are not executed



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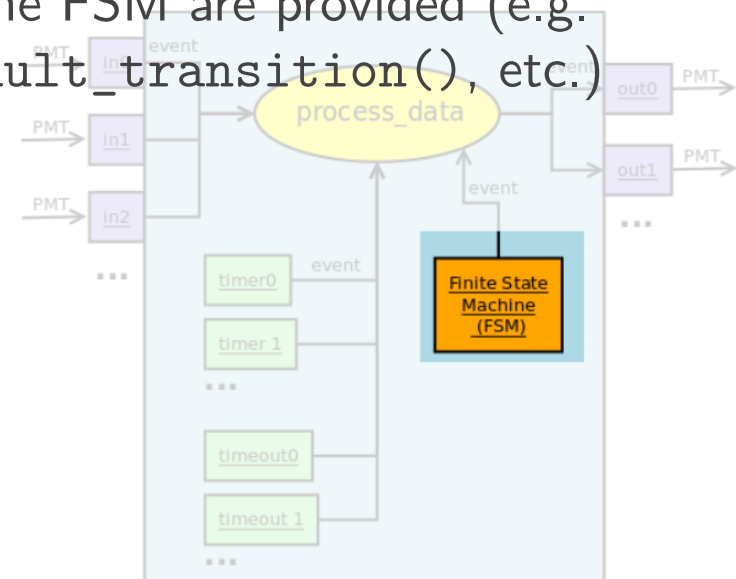
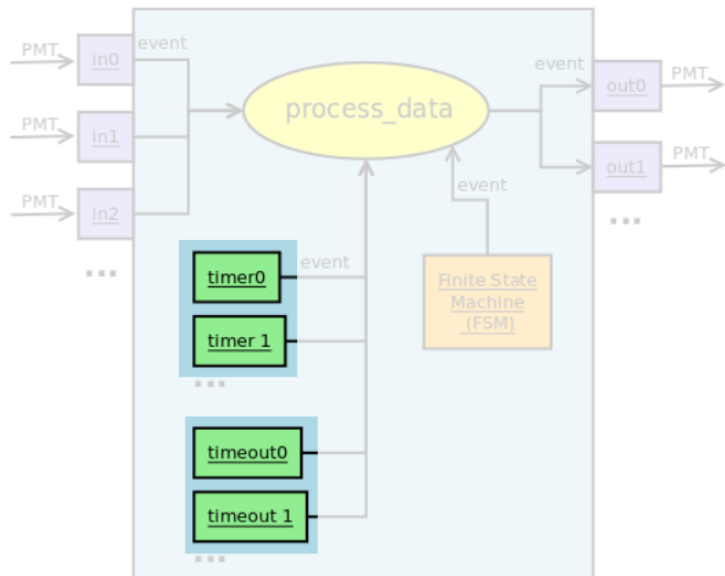
- FSM is actually a table of transitions with entries as: `(input,current_state)->(action, next_state, condition)`
- Several methods to modify the FSM are provided (e.g. `add_transition`, `add_default_transition()`, etc.)



GWN Architecture

Handling of Time

- GWN timers generate `Events` (which are processed as any other `Event` by the `process_data()` function)
- An arbitrary number of timers may be attached to a block
- Two timing mechanisms are provided in GWN's current form:
  1. `Timers`: Events are generated periodically for a number of times
  2. `Timeout`: A single Event is generated after a certain time
- All timers may be stopped, reset or interrupted



Creating a new block

Let's do a simple example: `Data Source` (it generates data events periodically and sends them out as GNU Radio messages)

1. New blocks are generated (as usual) through `gr_modtool`:

```
gr_modtool add -t sync -l python
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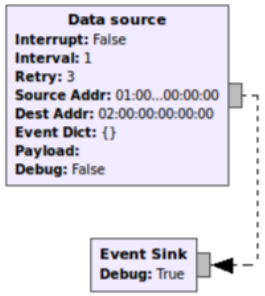

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2. Modify the code so that it inherits from `gwnblock`

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class data_source(gwnblock):
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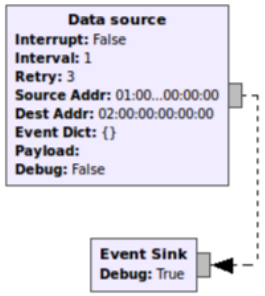

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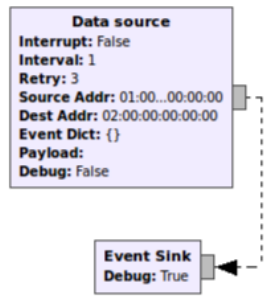

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```
class data_source(gwnblock):
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3. Write the constructor (note that the number of timers is specified here):

```
def __init__(self, interrupt=False, interval=1.0, retry=5,
     src_addr='', dst_addr='', payload='', ev_dc={}, debug=False
      ):
    # invocation of ancestor constructor
    gwnblock.__init__(self, name='data_source', number_in=0,
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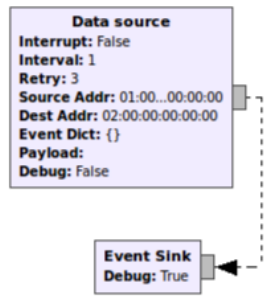

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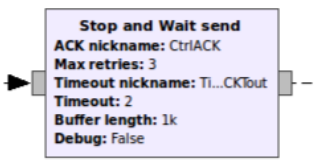
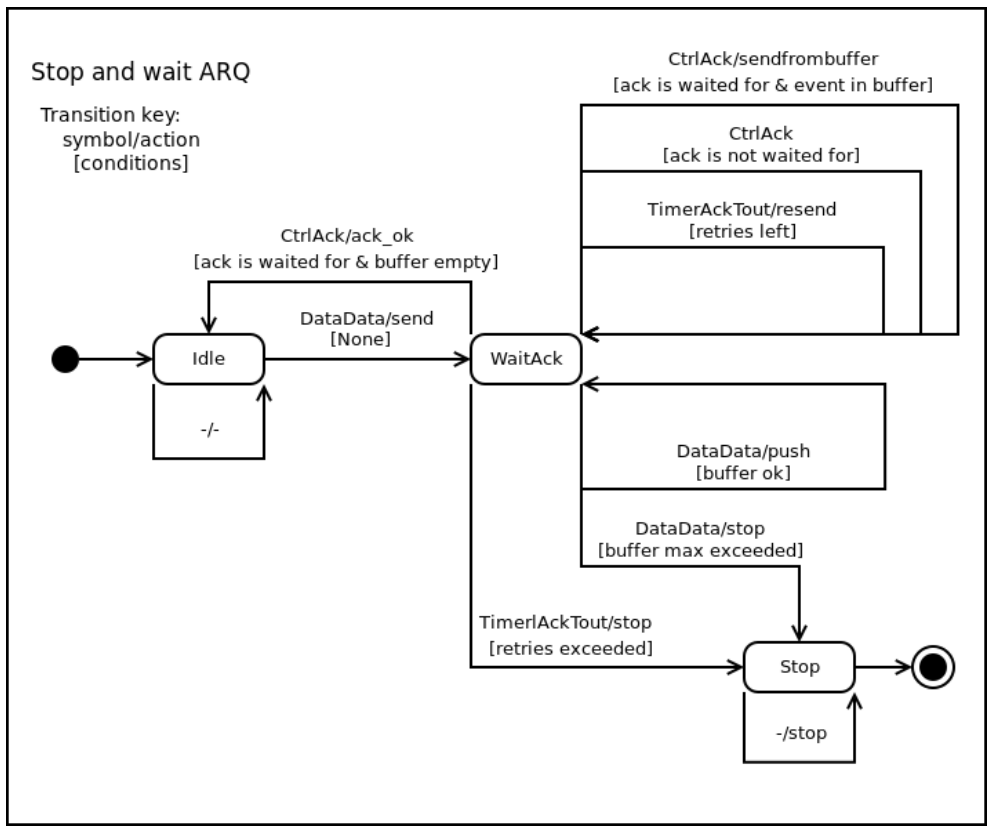
4. Write the `process_data` function to generate a new `Data Event` and write it on the `Event Port`

Creating a new block

Let's do a more advanced example: an ARQ Stop and Wait transmitter (it doesn't send a new packet until an acknowledgement for the previous one was received, and a timeout generates a re-transmission)





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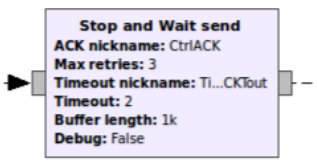


```
def __init__(self, ack_nickname='CtrlACK', max_retries=3,
             tout_nickname='TimerACKTout', timeout=1.0, buffer_len=1000,
              debug=False):
    # invocation of ancestor constructor
    gwnblock.__init__(self, name='stop_wait_send', number_in=1,
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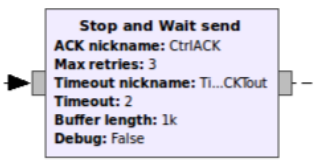


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2. We'll use an FSM this time, so `process_data` may include simply two lines:

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def process_data(self, ev):
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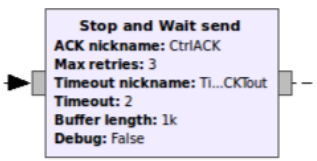


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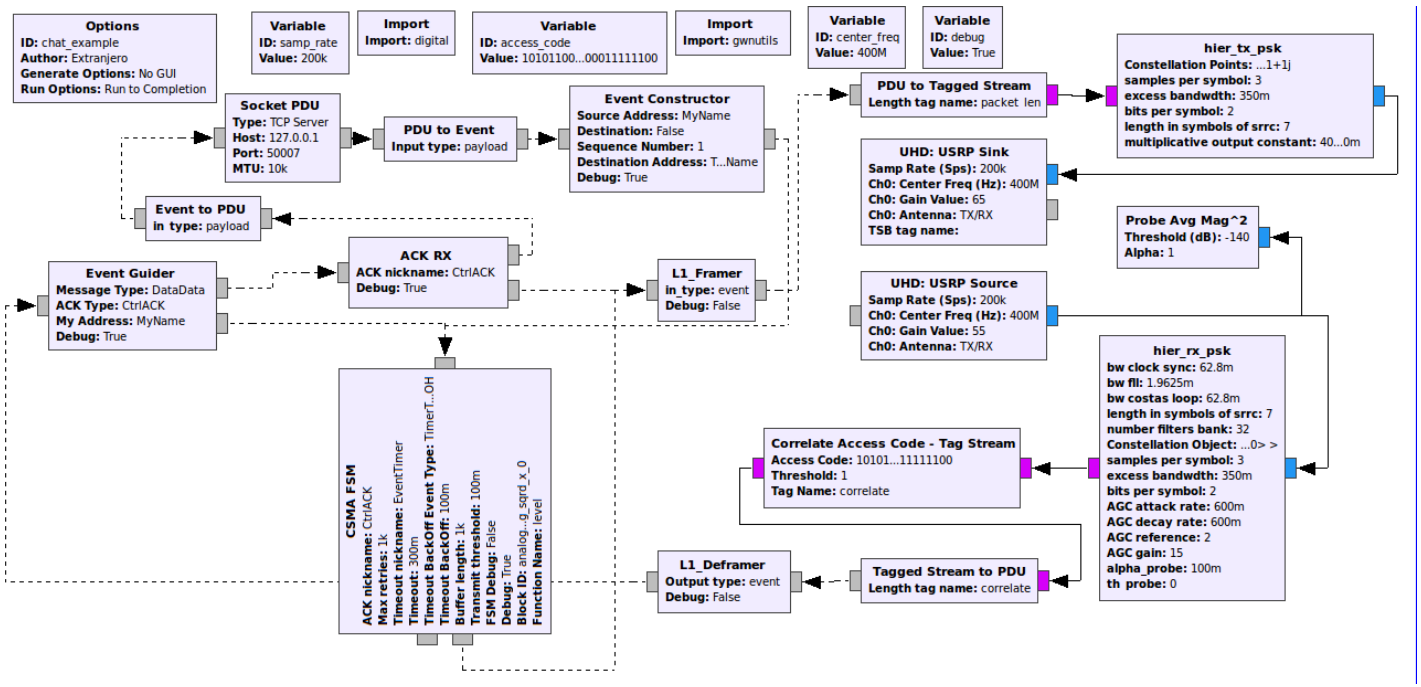
```

3. Write the FSM. For instance:

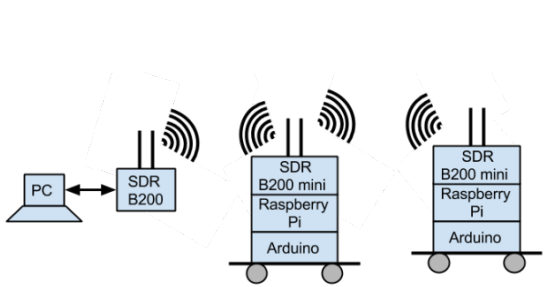
```
def stop_wait_send_fsm(blk):
    # Code to initialize the FSM goes here
    f.add_transition ('TimerACKTout', 'WaitAck', stop, 'Stop', [
        'self.nr_retries > block.max_retries']) # retries
        exceeded
```

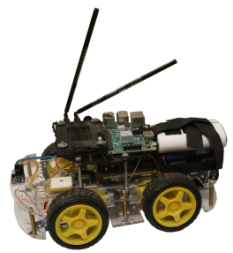
Demo

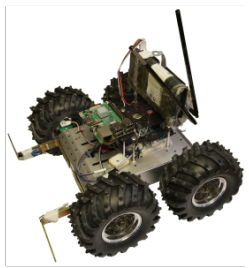

Options
ID: chat_example
Author: Extranjero
Generate Options: No GUI
Run Options: Run to Completion
Variable
ID: samp_rate
Value: 200k
Import
Import: digital
Variable
ID: access_code
Value: 10101100...00011111100
Import
Import: gwnutils
Variable
ID: center_freq
Value: 400M
Variable
ID: debug
Value: True
Socket PDU
Type: TCP Server
Host: 127.0.0.1
Port: 50007
MTU: 10k
PDU to Event
Input type: payload
Event Constructor
Source Address: MyName
Destination: False
Sequence Number: 1
Destination Address: T...Name
Debug: True
PDU to Tagged Stream
Length tag name: packet_len
hier_tx_psk
Constellation Points: ...1+1j
samples per symbol: 3
excess bandwidth: 350m
bits per symbol: 2
length in symbols of srrc: 7
multiplicative output constant: 40...0m
UHD: USRP Sink
Samp Rate (Sps): 200k
Ch0: Center Freq (Hz): 400M
Ch0: Gain Value: 65
Ch0: Antenna: TX/RX
TSB tag name:
Event to PDU
in type: payload
Probe Avg Mag^2
Threshold (dB): -140
Alpha: 1
Event Guider
Message Type: DataData
ACK Type: CtrlACK
My Address: MyName
Debug: True
ACK RX
ACK nickname: CtrlACK
Debug: True
L1_Framer
in_type: event
Debug: False
UHD: USRP Source
Samp Rate (Sps): 200k
Ch0: Center Freq (Hz): 400M
Ch0: Gain Value: 55
Ch0: Antenna: TX/RX
hier_rx_psk
bw clock sync: 62.8m
bw fll: 1.9625m
bw costas loop: 62.8m
length in symbols of srrc: 7
number filters bank: 32
Constellation Object: ...0> >
samples per symbol: 3
excess bandwdth: 350m
bits per symbol: 2
AGC attack rate: 600m
AGC decay rate: 600m
AGC reference: 2
AGC gain: 15
alpha_probe: 100m
th_probe: 0
CSMA_FSM
ACK nickname: CtrlACK
Max retries: 1k
Timeout nickname: EventTimer
Timeout: 300m
Timeout BackOff Event Type: TimerT...OH
Timeout BackOff: 100m
Buffer length: 1k
Transmit threshold: 100m
FSM Debug: False
Debug: True
Block ID: analog...g_sqrd_x_0
Function Name: level
Correlate Access Code - Tag Stream
Access Code: 10101...11111100
Threshold: 1
Tag Name: correlate
L1_Deframer
Output type: event
Debug: False
Tagged Stream to PDU
Length tag name: correlate

Conclusions and Future Work

- We've been using GNU Radio for several years now (both education and research), and wished to extend it to support packet communications
- `Event` objects for inter block communication, conversion to and from GNU Radio PMTs, and the integration of `Event` inputs and outputs in a generic GWN block is the result of some years worth of iterations of GWN
- GWN has been used successfully "on the field"







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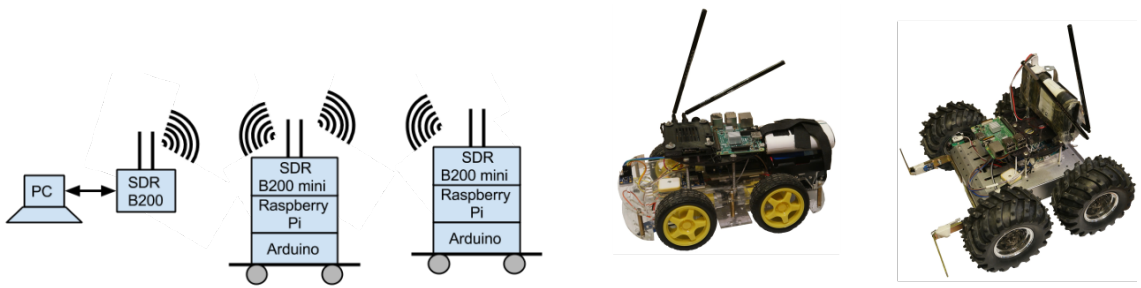

- Although the number of protocols already implemented in GWN is still modest, being open and free we welcome contributions!
- Performance is an issue. We are evaluating a transition to a C++ implementation which should be transparent to users

Thanks for your time!

Any questions?

Federico 'Larroca' La Rocca - flarroca@fing.edu.uy

https://github.com/vagonbar/gr-gwn