Integrating an 802.11 physical layer simulator in NS-3

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Outline

Physical layer abstractions in network level simulators

- Network simulators typically abstract the physical layer
- They use frame-level statistics
  - What happens to the frame?
  - (c.f. what happens to the signal?)
- Approach works well enough if the abstraction is reasonable
  - Ok in wired, not so well in wireless

Reasonable abstractions

- Not always clear what to abstract and what not to
- It is not easy to extrapolate “general” characteristics
- Scenario-specific minute measurements may matter
- May want to examine network performance of PHY techniques
  - Receiver structure (Interference cancellation)
  - Synchronisation
  - Channel estimation

Typical channel model development

- Channel Measurements→Channel Model→BER→PER
- Lost in translation? BER to PER conversion not trivial
- Would be useful to utilise Channel Model or Measurements directly
  - Expediency (no need to make PER calculations)
  - Accuracy (no compromises)

Big picture - Layer division

- Network vs physical layer communities
- Packet vs signal time samples
- Coarse vs fine grained
- Network vs Link
- **Join the two perspectives in a single simulation tool**

An idea (with KIT)

Integrate physical layer simulator for OFDM-based IEEE 802.11 communication in a network simulator

CHALMERS

Karlsruhe Institute of Technology

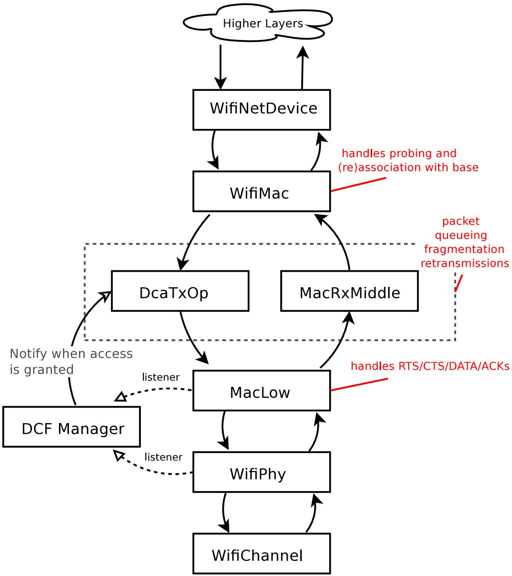
Course of action

1. Use NS-3 – a popular, well maintained simulator
2. Develop and validate a physical layer simulator
   - Based on well-established signal processing library (IT++)
   - May have value as a standalone deliverable
3. Integrate the two – release to community for feedback

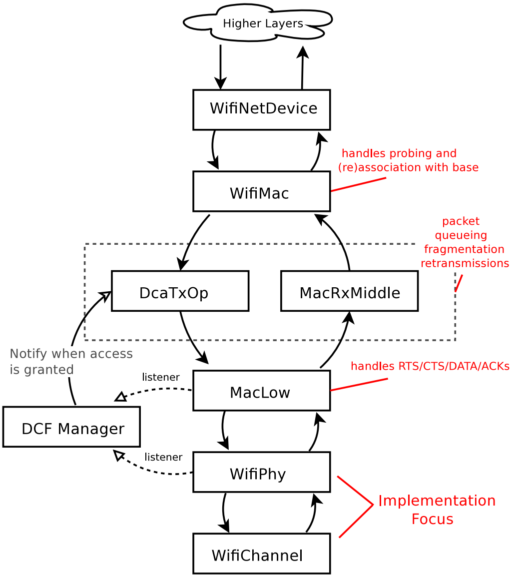
Why use NS-3

- Very well maintained
- Open source (GPL)
- Speed and accuracy are a priority for maintainers
- Flexible architecture and very good documentation
- Actively used for research

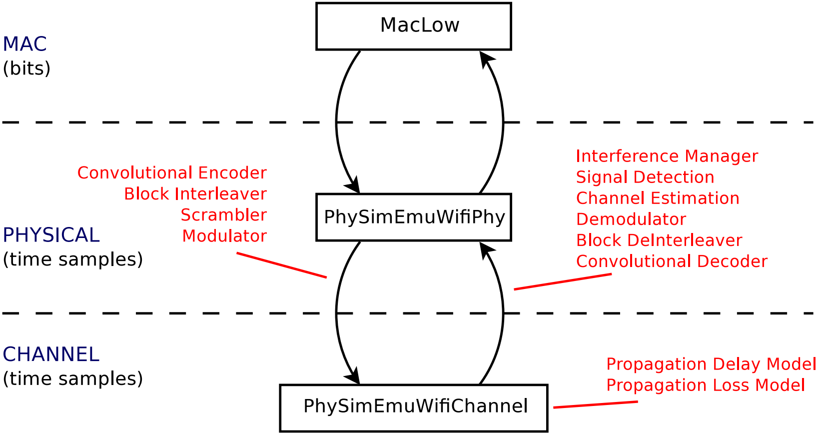
NS-3 architecture



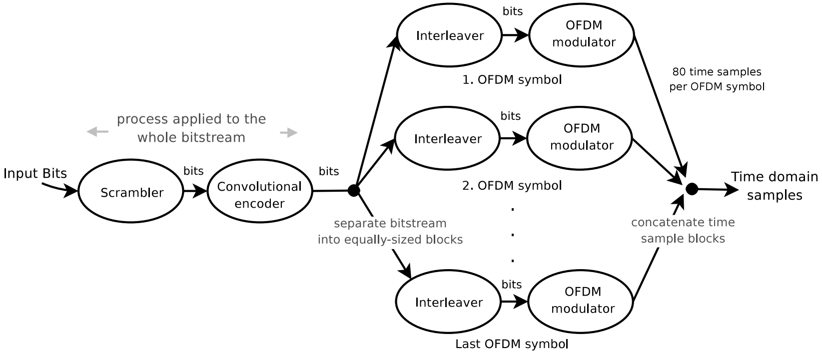
NS-3 architecture (implementation)



A new physical layer for NS-3

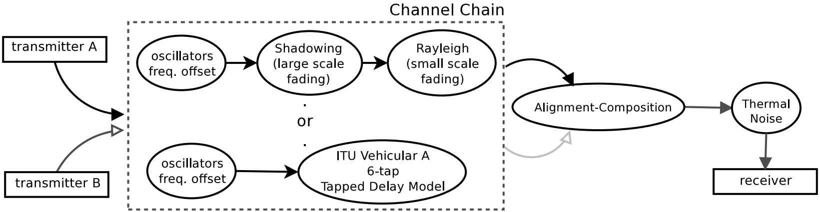


Frame construction



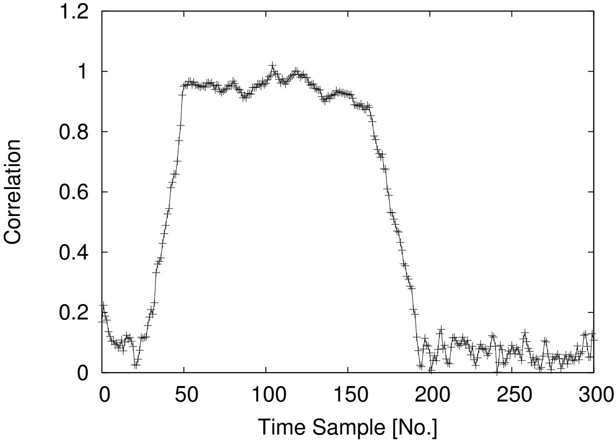
Channel modelling

- Channel models operate on time sample level
- Several have been implemented already
- Channel models can be "chained" in sequence



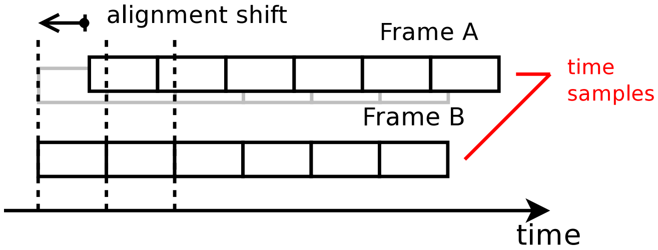
Frame reception

- Frame reception handled realistically
- Signal detector tries to “lock-on” to frame
- Header is decoded and if successful the payload is examined too

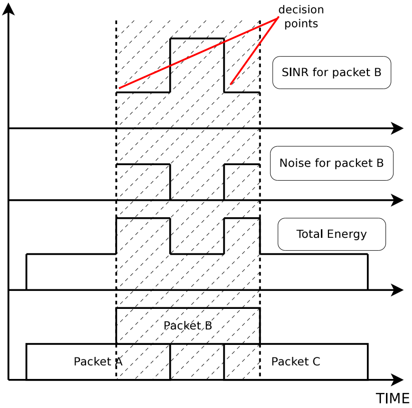


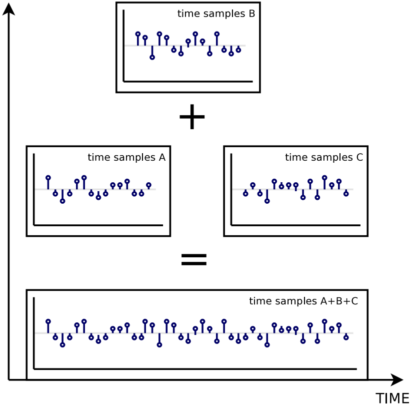
Frame reception (2)

- At all times surrounding interference is accounted for
- For the superposition of signals some alignment is needed



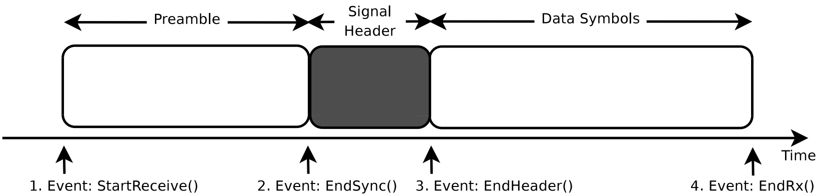
Frame reception (Old vs New)





Integration into NS-3 state machine

- Reception process represented by 4 events
- Computations performed at each event
- Possibilities of computational “shortcuts”



Example usage (standard model)

```
YansWifiChannelHelper wifiChannel;
YansWifiPhyHelper wifiPhy = YansWifiPhyHelper::
    Default();

wifiPhy.SetChannel(wifiChannel.Create());

WifiHelper wifi = WifiHelper::Default();
NqosWifiMacHelper wifiMac = NqosWifiMacHelper::
    Default ();
wifiMac.SetType ("ns3::AdhocWifiMac");

NodeContainer nodes;
nodes.Create(2);
// Install WifiPhy and set up mobility
wifi.Install (wifiPhy, wifiMac, nodes);
```

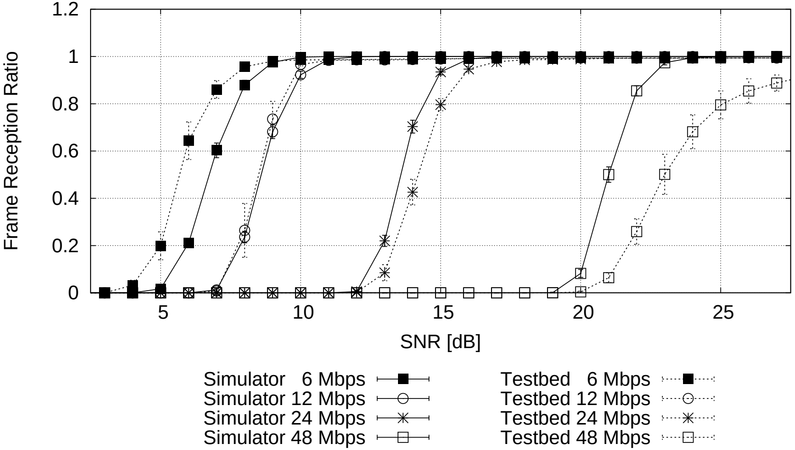
Example usage (new model)

```
PhySimWifiChannelHelper wifiChannel;
PhySimWifiPhyHelper wifiPhy = PhySimWifiPhyHelper::
    Default();

wifiPhy.SetChannel(wifiChannel.Create());

WifiHelper wifi = WifiHelper::Default();
NqosWifiMacHelper wifiMac = NqosWifiMacHelper::
    Default ();
wifiMac.SetType ("ns3::AdhocWifiMac");

NodeContainer nodes;
nodes.Create(2);
// Install WifiPhy and set up mobility
wifi.Install (wifiPhy, wifiMac, nodes);
```

Validation

- Validate produced samples against 802.11 Annex G.
- Common-sense cases (BER vs SINR)
- Verification against Octave/Matlab simulator and theoretical BER curves
- Against real transceivers done by KIT at CMU

Validation (2)



Static pathloss, 500 bytes frame size, 10 Hz transmission freq.

What is the tradeoff?

- Simulation becomes much more demanding
- Computational costs + memory overheads
  - Preliminary results indicate slowdown factor of 200 for simple pathloss
  - ...for complex channel slowdown factor increases to 10^3
  - Have to store whole frame representation in memory
- Work underway at Karlsruhe to increase speed for single user systems (OpenCL)

Future work

- Integrate several new channel estimators (sometime in October/November)
- Implement more channel/frontend effects (phase noise, antenna diversity etc...)
- Implement environment/node geometry effects

Where can I get all this?

- All items are open source (GPL) and available online
- Standalone physical layer simulator available
- ...as well as full NS-3 implementation
- Code is under review for inclusion in NS-3 in the near future

Thanks

Thank you for your attention

Questions?

- **Standalone physical layer simulator**
  Does not include high-level protocols, mobility, etc...
  http://physlayersim.sourceforge.net
- **NS-3 simulator with new physical layer model**
  Ported to the latest version of NS-3 (3.9)
  http://www.lefrog.at/NS-3.9-PhySimWiFi-1.0.tar.bz2