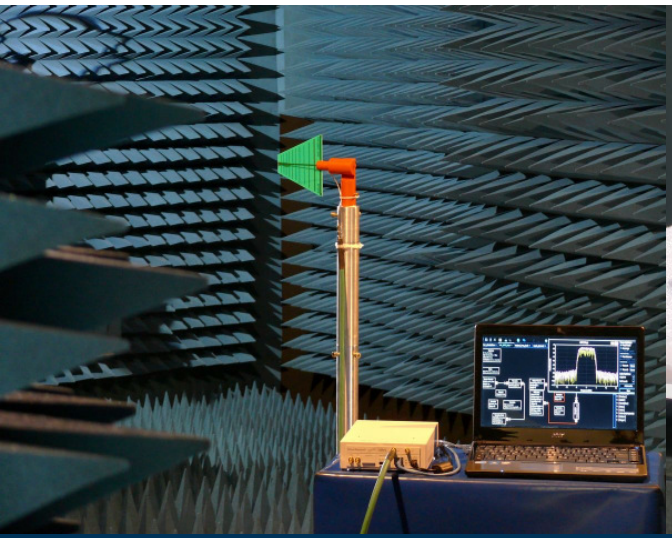
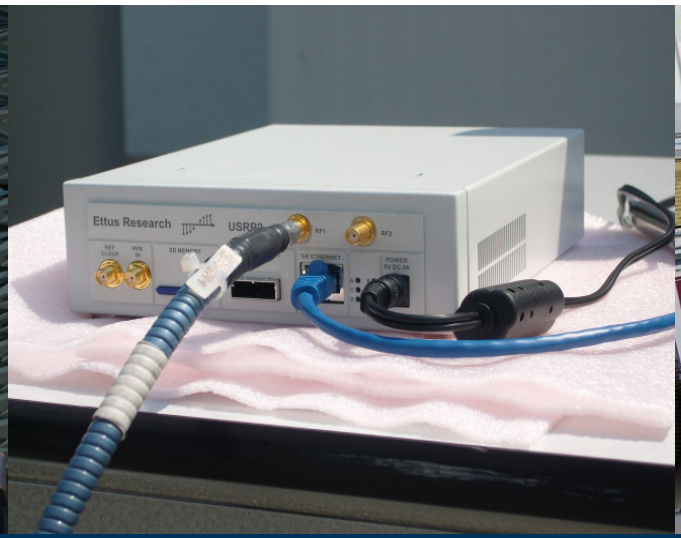
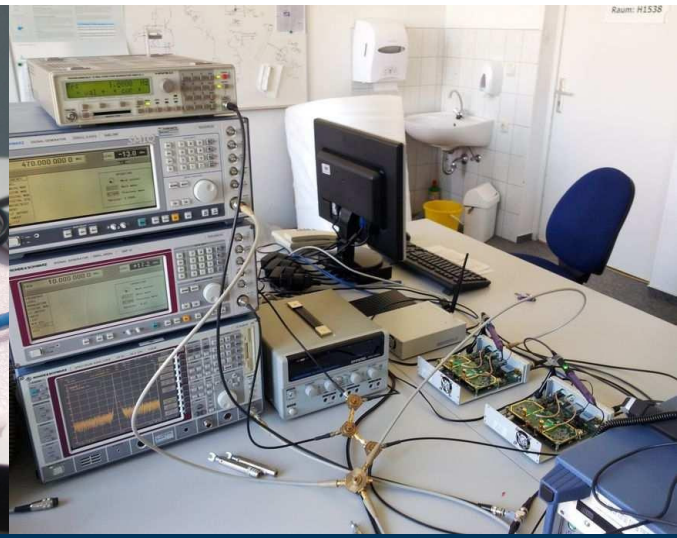
Building Link-Layer Protocols in a Lego-like Fashion

André Puschmann







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International Graduate School on Mobile Communications

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Outline

1 Introduction

2 State of the Art

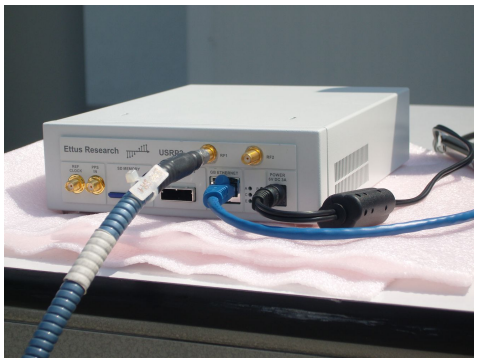
3 Component-based Link Layer Protocols

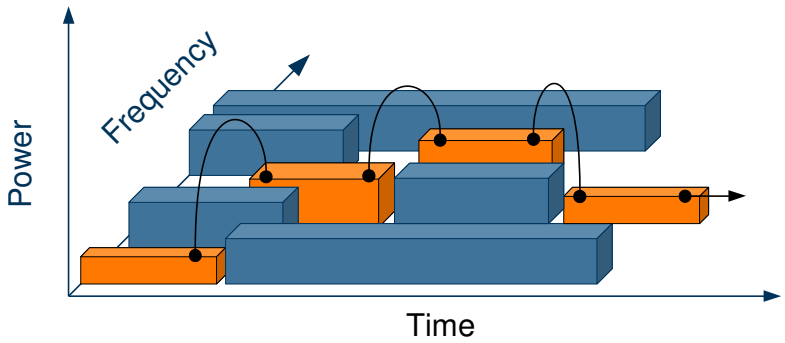
4 Practical Examples

5 Summary

Motivation

- PHY: Flexibility mostly here, e.g.
  - Antennas
  - Waveforms
  - Spectrum sensing
- Higher layer: Mostly individual and application specific, e.g.
  - Energy-efficiency
  - Delay tolerant networking
  - Cognitive Radio (CR)
  - Dynamic Spectrum Access





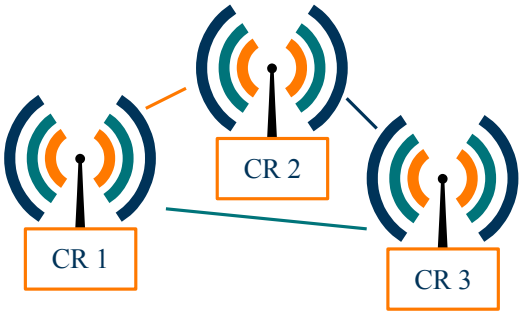
Key question:

Can higher layer components benefit from flexibility, too?

The CR link layer: What remains? What changes?

Requirements:

- Basic link layer functions
- Management of PHY resources
- Application specific, e.g.:
  - Link establishment
  - Link maintenance



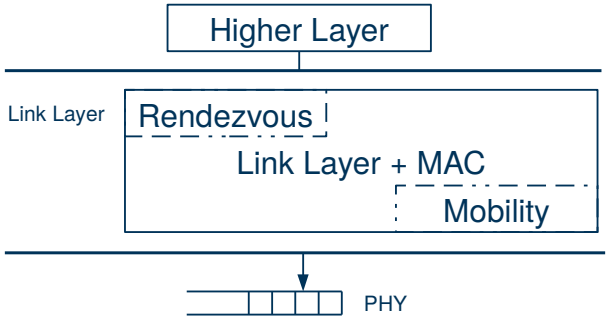
Challenges:

- How to address heterogeneous system requirements?
- Data transfer vs management functions?
- How to facilitate reuse of existing protocols?

State of the Art

Approaches:

- Stand alone or extended protocols
  - ⊖ Limited feature set
  - ⊖ Monolithic design, tight integration
- Flexible MACs with fine-grained components
  - ⊖ Off-the-shelf 802.11 HW or FPGA-only
- Flexible MACs with coarse-grained components



Conclusion:

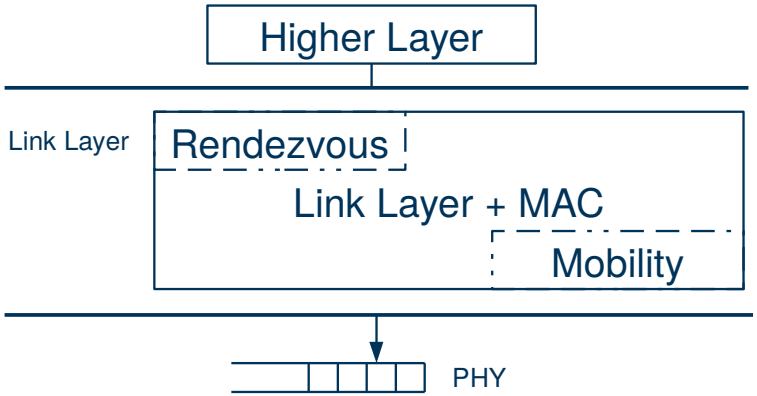
- Protocols complex and difficult to implement/maintain
- Reduced re-usability due to tight integration
- Mix of data transmission and management functionality

Lego-like Link Layer Architecture

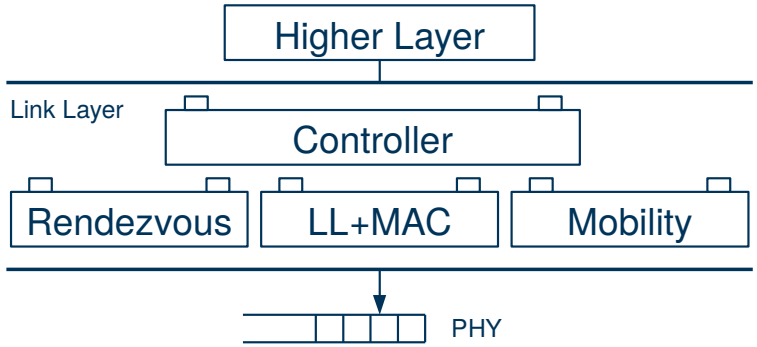
Logical components:

- Core blocks:
  - → Basic LL+MAC
- Optional apps:
  - → Rendezvous
  - → Spectrum Mobility
  - ..
- Controller:
  - → Manage PHY capabilities
  - → FSM to model dynamics
  - → Events to allow interactions

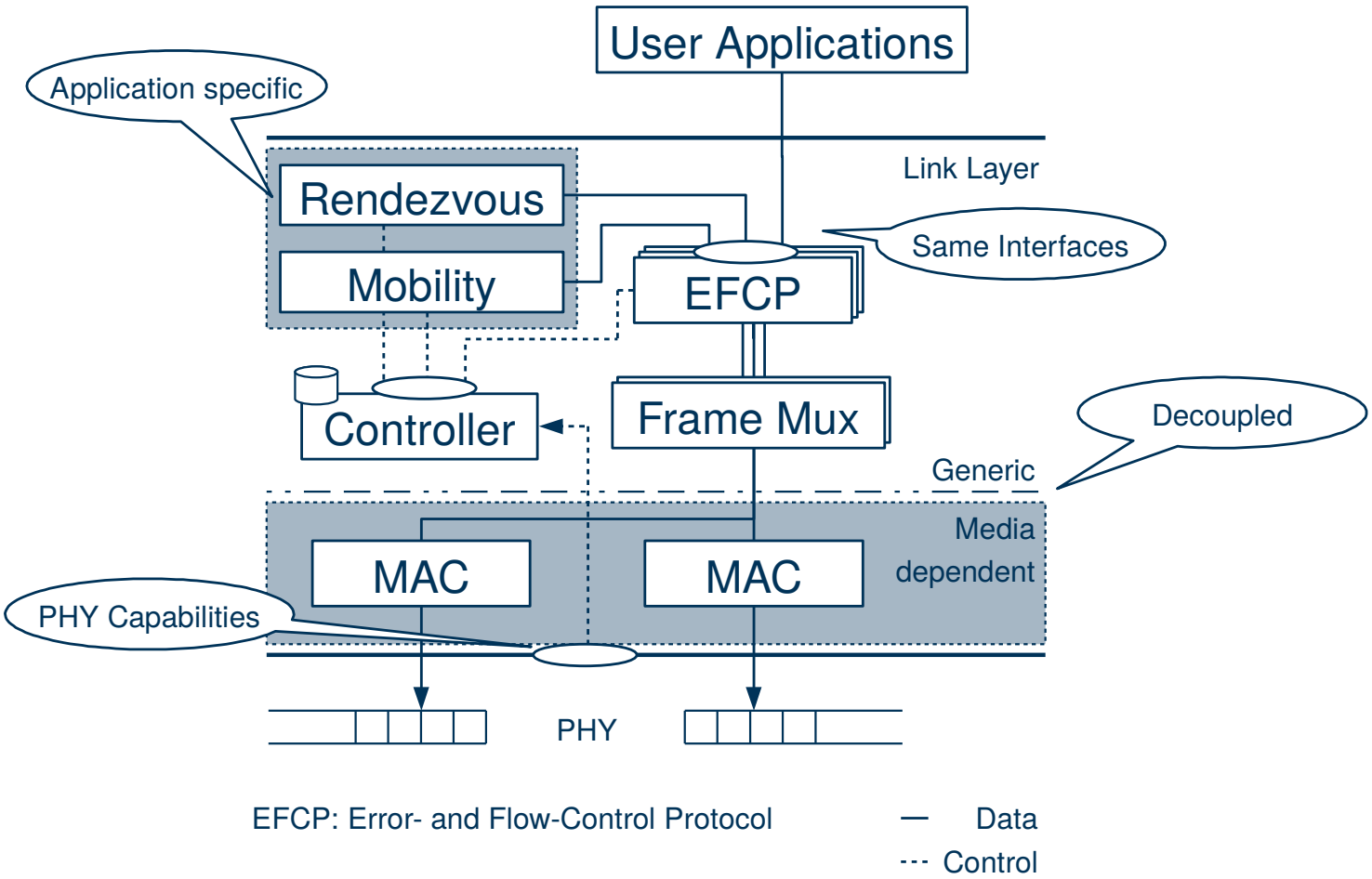
Legacy Architecture:



Component-based Architecture:



Details of Link-Layer Architecture



Let's Play Protocol Lego

Rendezvous

- Blind (Random, JS, ..)
- Coordinator-assisted

Basic Link Layer

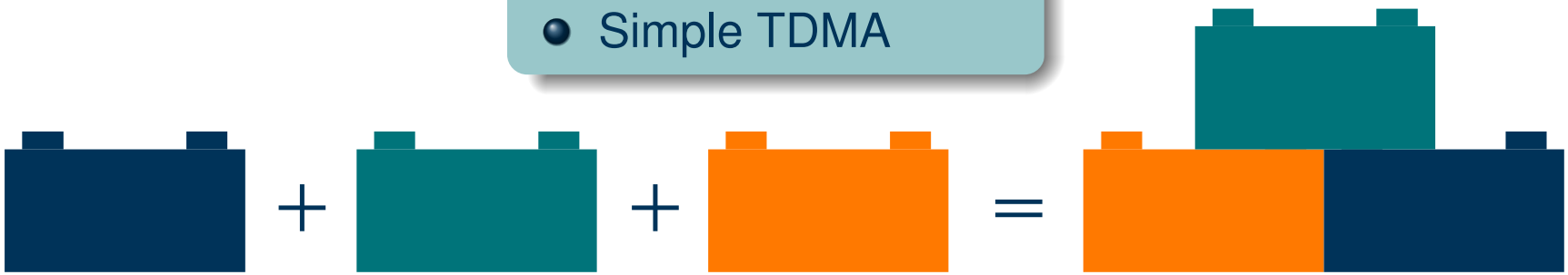
- Stop and Wait
- Block Acks
- Flow ID with prios

MAC

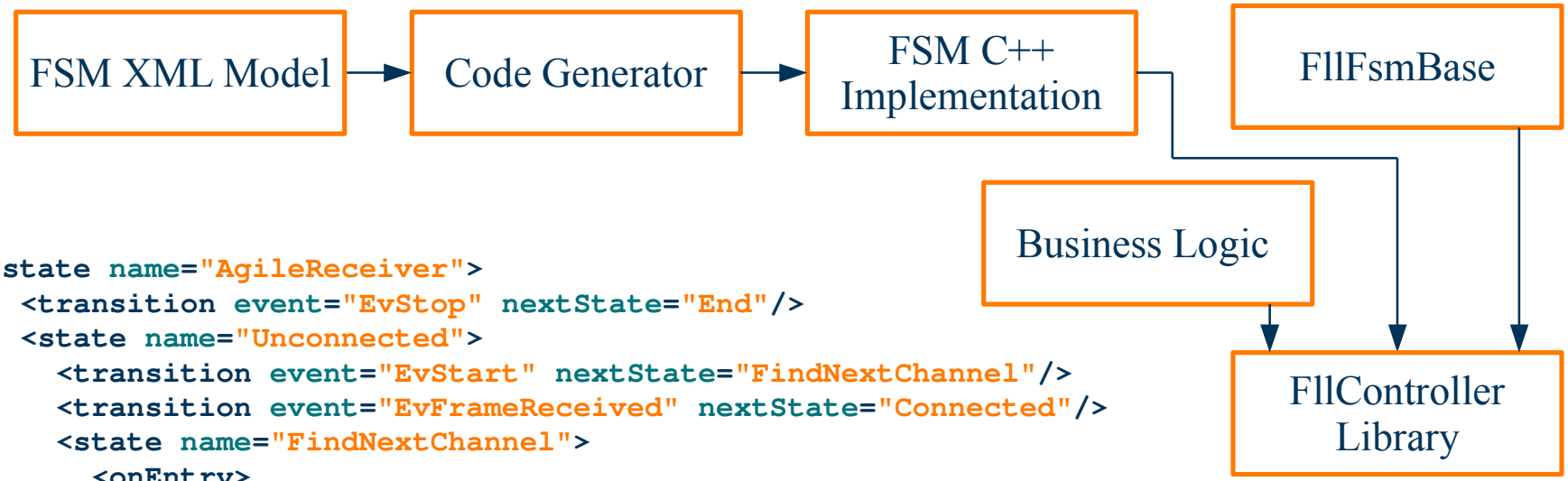
- Pure Aloha
- Soft/FPGA CSMA
- Simple TDMA

Mobility

- Individual
- Coordinator-assisted
- Cluster-based



How does the protocol interaction work?



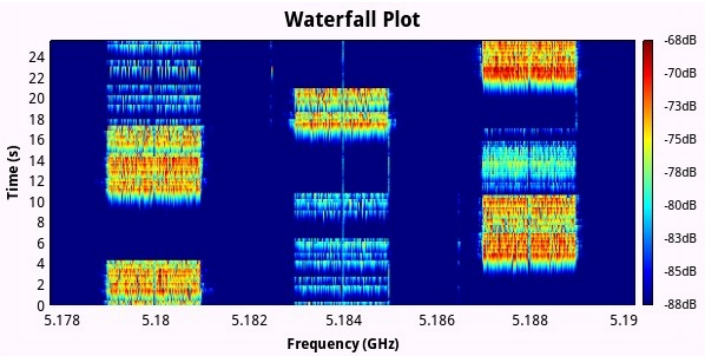

```
<state name="AgileReceiver">
  <transition event="EvStop" nextState="End"/>
  <state name="Unconnected">
    <transition event="EvStart" nextState="FindNextChannel"/>
    <transition event="EvFrameReceived" nextState="Connected"/>
    <state name="FindNextChannel">
      <onEntry>
        <action>fsm.FindNextChannel()</action>
      </onEntry>
      <transition event="EvChannelFound" nextState="ReconfigureRadio">
        <action>fsm.reconfigureChannel(channel)</action>
      </transition>
    </state>
    <state name="ReconfigureRadio">
      <transition event="EvReconfDone" nextState="WaitForFrame"/>
    </state>
    ..
<state/>
```

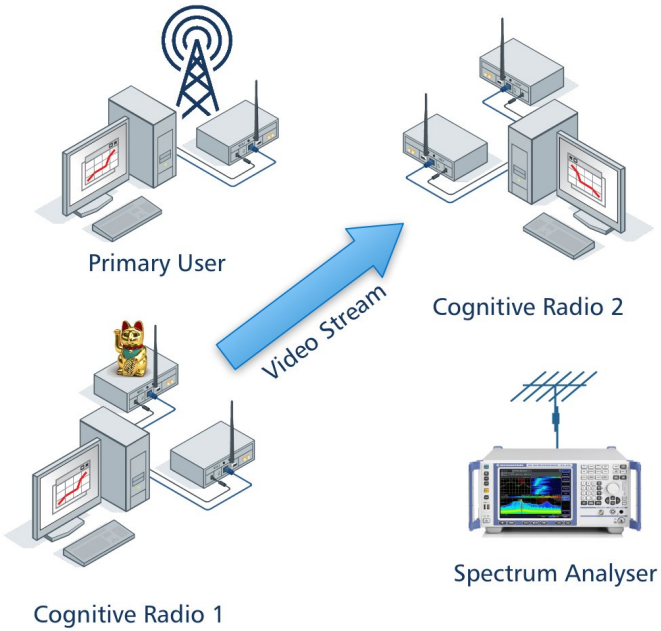
[1] StateBuilderCpp, http://www.stateforge.com/

Database-assisted Dynamic Spectrum Access

Features:

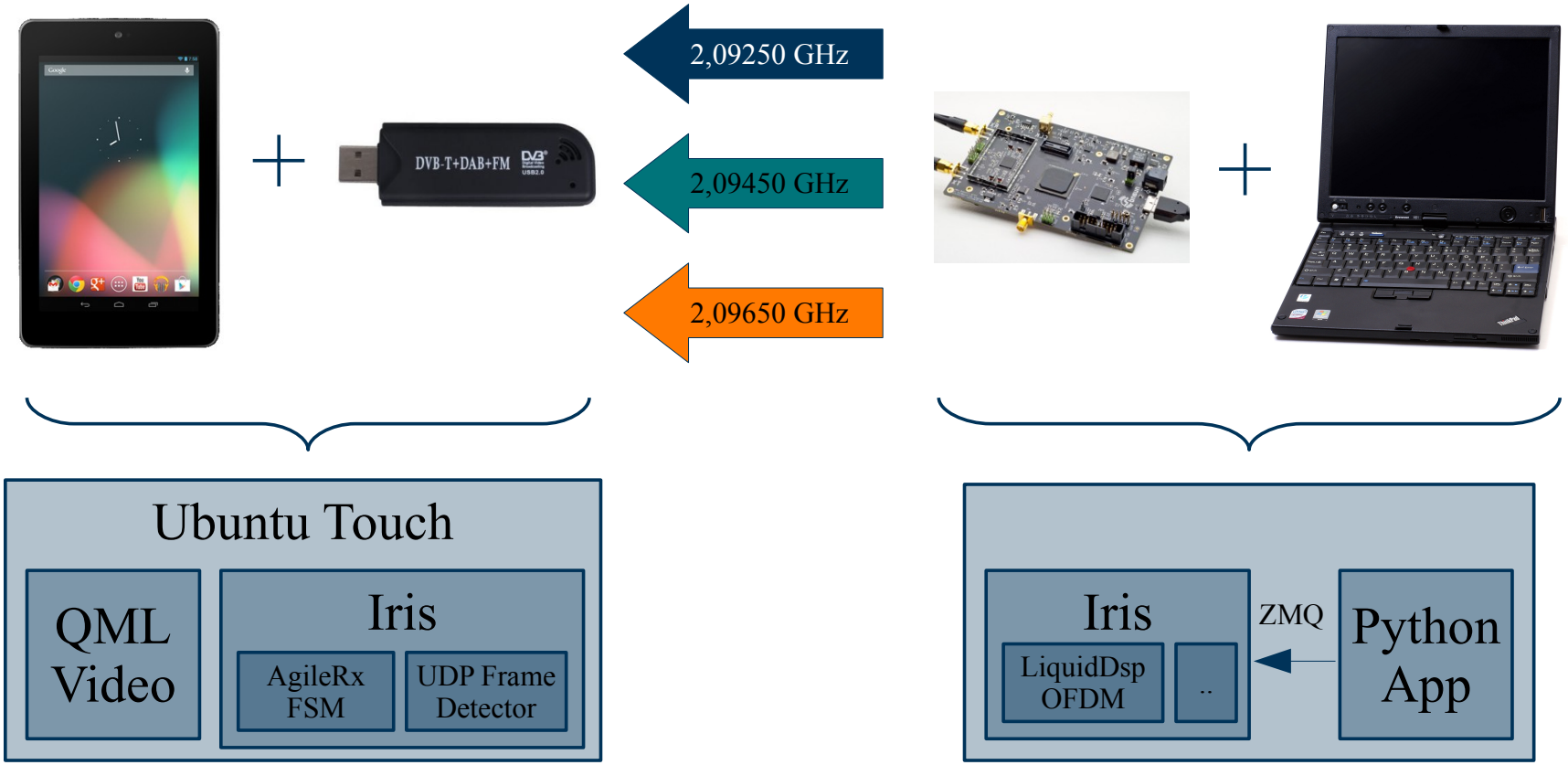
- Spectrum opportunity detection
- Dynamic channel allocation
- Database for predictive PU modelling
- Link adaptation and PU resilience



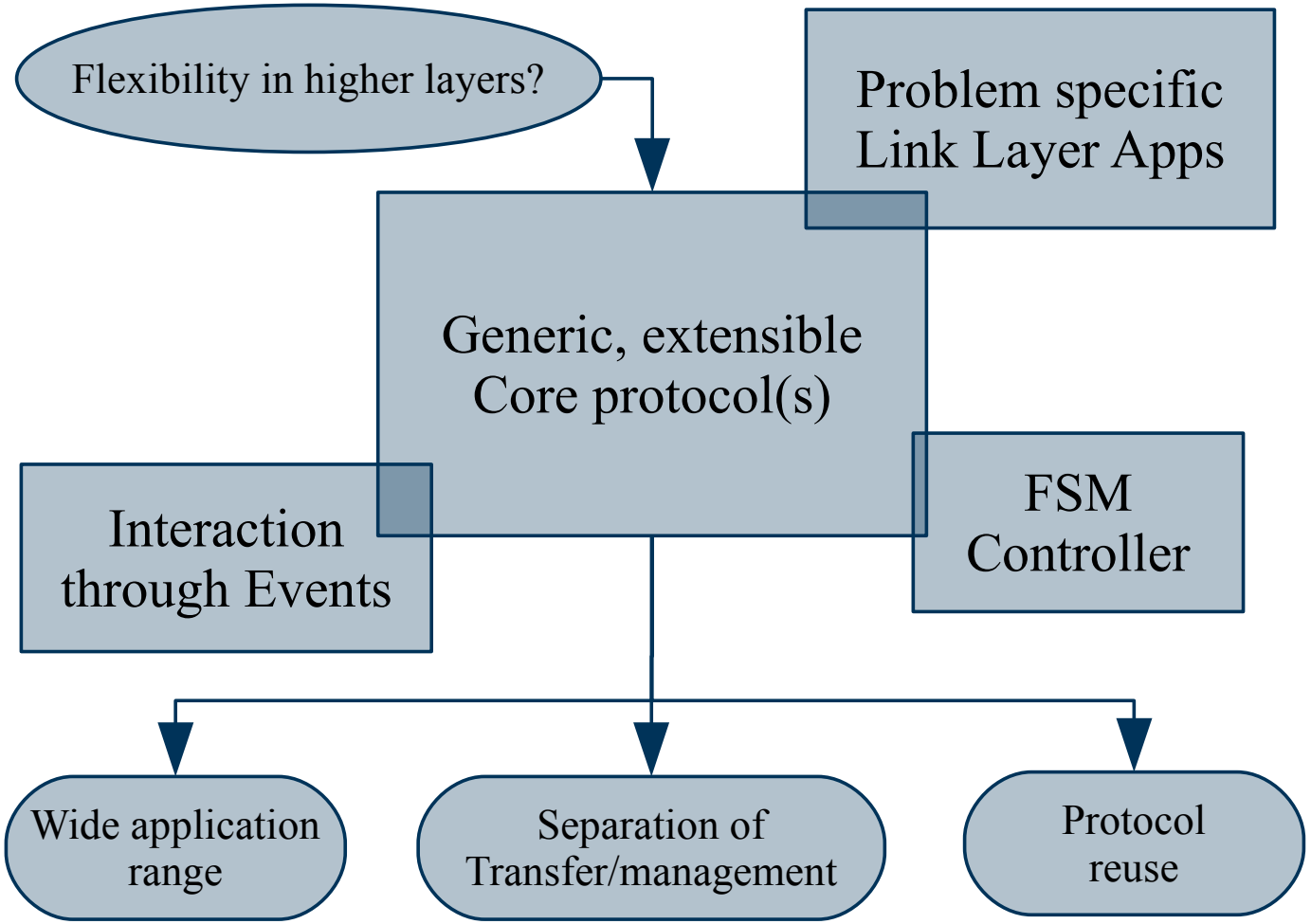


A. Puschmann, et al., “Database-assisted Coordinator-based Spectrum Mobility in Cognitive Radio Ad-hoc Networks"“, *10th International Symposium on Wireless Communication Systems (ISWCS)*, Ilmenau, Germany, August 2013.

Low-cost, Frequency-agile SDR Networking



Summary


Flexibility in higher layers?
Problem specific Link Layer Apps
Generic, extensible Core protocol(s)
Interaction through Events
FSM Controller
Wide application range
Separation of Transfer/management
Protocol reuse

Questions, comments?

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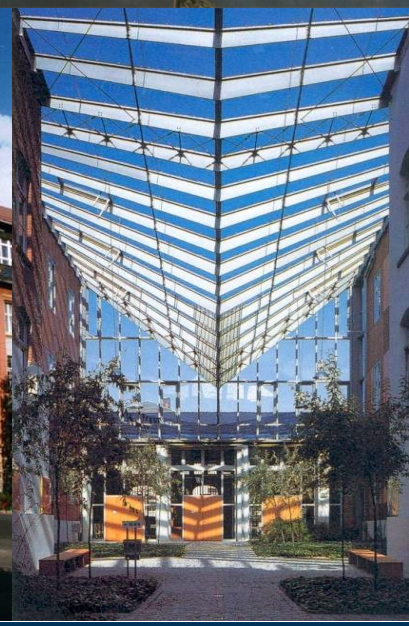

Sources

- Rohde & Schwartz Spectrum Analyser image

  `http://www.rohde-schwarz.de/product/FSVR.html`
- Nexus 7 image

  `http://en.wikipedia.org/wiki/File:Front_view_of_Nexus_7_(cropped).png`
- RTL-SDR

  `http://ecx.images-amazon.com/images/I/41-RmZAq7EL._SY300_.jpg`
- BladeRF image

  `http://www.nuand.com/`
- Thinkpad image

  `http://en.wikipedia.org/wiki/File:Thinkpad-x61-tablet.jpg`