Building Link-Layer Protocols in a Lego-like Fashion

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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

- Rendezvous
- Mobility
- Controller
- Frame Mux
- User Applications
- PHY
- EFCP
- MAC
- PHY Capabilities

EFCP: Error- and Flow-Control Protocol

- Data
- Control

- Application specific
- Link Layer
- Same Interfaces
- Decoupled
- Generic
- Media dependent
- PHY Capabilities

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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

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How does the protocol interaction work?

```xml
<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="WaitForKeyFrame"/>
    </state>
  </state>
</state>
...
```


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Database-assisted Dynamic Spectrum Access

Features:

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

Low-cost, Frequency-agile SDR Networking

Ubuntu Touch
- QML
- Video
  - AgileRx
  - FSM
  - UDP Frame Detector

Iris
- Python App
  - LiquidDsp
  - OFDM
  - ..

2.09250 GHz
2.09450 GHz
2.09650 GHz
Summary

Flexibility in higher layers?

- Generic, extensible
- Core protocol(s)
- Problem specific
- Link Layer Apps
- Wide application range
- Protocol reuse
- Separation of Transfer/management
- Interaction through Events

FSM Controller
Questions, comments?

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Sources

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