Investigation and Improvements to the OFDM Wi-Fi Physical Layer Abstraction in ns-3

Workshop on ns-3 **June 15, 2016**

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Goals of this Research

- Why Investigate the Physical Layer Abstraction?
  - Improve accuracy of system simulations
  - Keeping up with standards
- Research objectives
  - Examine the accuracy of existing implementation
  - Identify gaps
  - Enhance fidelity

Presentation Overview

- Preliminaries
  - Network Simulators
  - Related Work
  - Motivation
- Error Models
  - UW Link-Sim
  - ns-3 PHY Error Models
  - Comparison
- Wi-Fi Multistage Reception
  - Results
- Discussion
- Next Steps

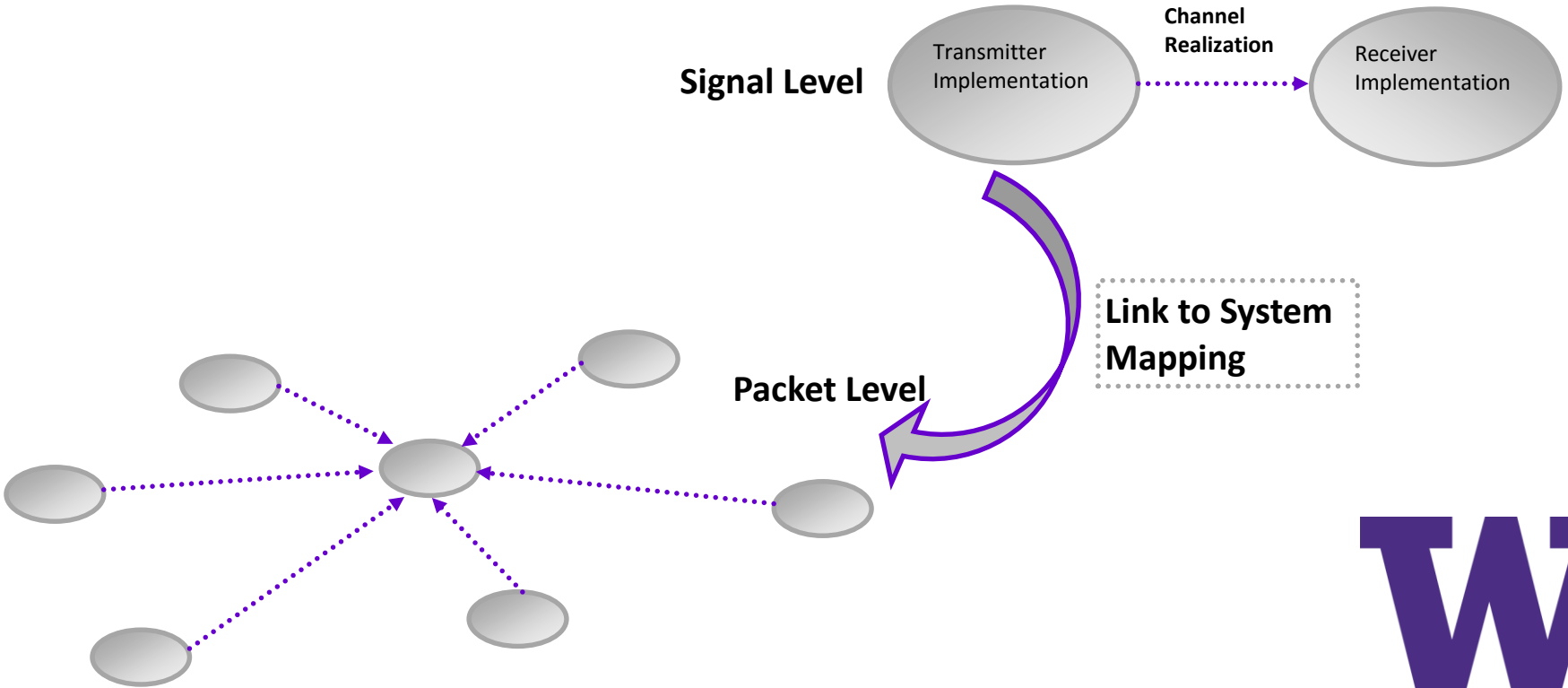
Preliminaries

Network Simulation

- Link Layer Simulators
  - Focus on the physical layer
  - Single link signal level emulation
- System Simulators
  - Packet level simulation
  - Generally scalable to large scenarios
  - Tools for evaluating the entire network stack

Link to System Mapping

- Enabling packet level simulation for system simulators
- Requisite for efficient system simulations



ns-3 OFDM PHY Layer Abstraction

- What is currently modeled in ns-3?
  - AWGN channel via analytical models
- Features yet to be implemented
  - Frequency selective fading
  - MIMO
  - PLCP Preamble reception
- Lack of comprehensive contributes to under-development
- Has not kept up with changing standards

Related Work

- **Analysis of ns-3 physical layer abstraction[1]**
  - **Accuracy of ns-3 error models**
  - **A look at bounds on error probability**
- **NIST[3] Error model: too pessimistic?**
  - **Nature of errors for coded bits[2]**

1. C. Hepner, et al. SINCOM 2015
2. L. Deutsch, et al. Technical Report May 1981
3. G. Pei et al. Technical report, 2010.

Motivation

- Existing physical layer implementation in ns-3
  - Independence assumption for bit errors
  - Lack of PLCP preamble reception
- Physical layer fidelity for ns-3
  - Emulate the actual Wi-Fi reception process
  - Lay the framework for all existing and upcoming technologies
- Analytical ns-3 models
  - AWGN models only
- Developing a framework for frequency selective fading

OFDM PHY Error Models (AWGN)

Wi-Fi Frame Format

- Physical layer frame format
  - PLCP Preamble
    - Short training field
    - Long Training field
  - L-Sig Field
  - Payload

SNR

- **For the link sim: power transmitted divided by the noise over 52 occupied sub-carriers**

$$SNR = \frac{P_{tx}}{N_0 B}$$

- **For analysis: bit SNR γ_b**

$$\gamma_b = \frac{E_b}{N_0} = \frac{P_{tx} * 3.2\mu * \frac{1}{52k}}{N_0} * \frac{B_{sub-carrier} * 52}{B_{sub-carrier} * 52}$$

$$= \frac{P_{tx}}{N_0 B} * B_{sub-carrier} * \frac{3.2\mu}{k}$$

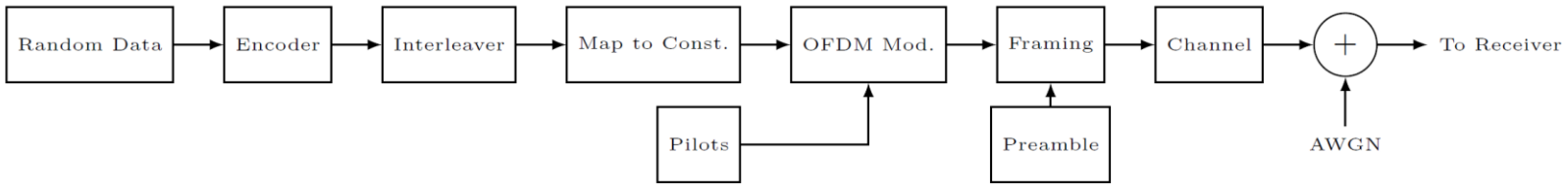
$$\gamma_b = SNR \; B_{sub-carrier} T_b$$

UW Link Sim

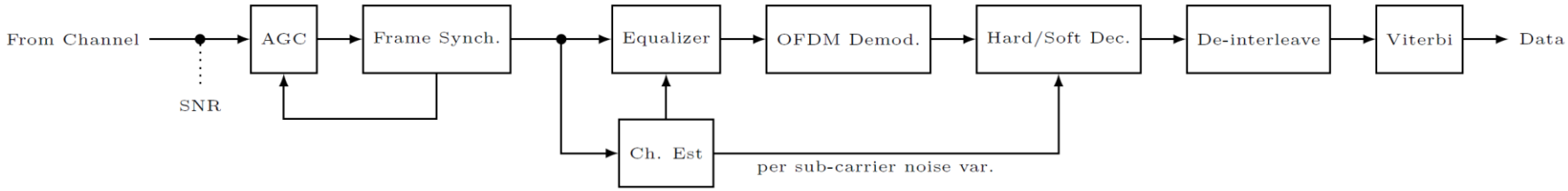
- MATLAB based Link simulator for Wi-Fi
- 20MHz OFDM SISO system
- AWGN channel
- Channel Estimation: Ideal (AWGN)
- Decoder: Viterbi
- Noise Figure 0dB

UW Link Sim (Cont.)

> Transmitter



> Receiver



IEEE 802.11n MCS

MCS	Modulation	Coding Rate	Constraint Length	Data Rate
0	BPSK	½	6	6.5Mbps
1	QPSK	½	6	13Mbps
2	QPSK	¾	6	19.5Mbps
3	16QAM	½	6	26Mbps
4	16QAM	¾	6	39Mbps
5	64QAM	2/3	6	52 Mbps
6	64QAM	¾	6	58.5 Mbps
7	64QAM	5/6	6	65 Mbps

ns-3 PHY Error Models

- **Default model: NIST**
  - **Application of error bound on PER**

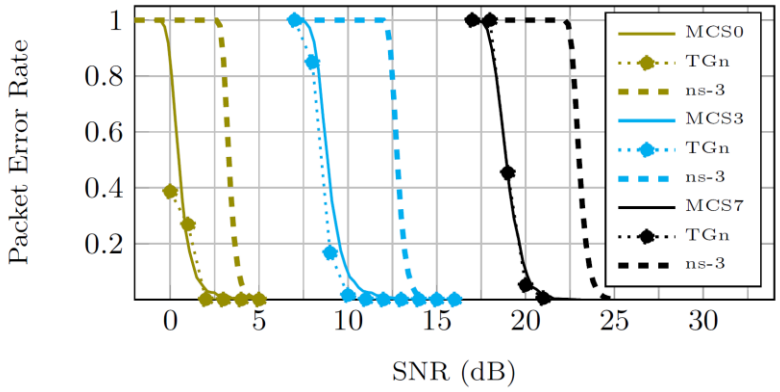
$$P_e = 1 - (1 - P_b)^N$$

  - P_b **is the bit error probability**
  - **Pessimistic performance prediction**
  - **Incorrect assumption of independent bit errors[2]**
- **Divergence from link sim results**
  - **Effect of payload size**
- **Can we work with the independence assumption?**

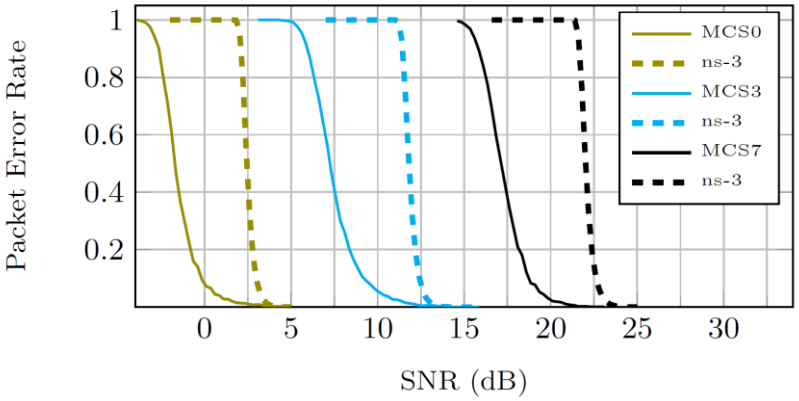
2. L. Deutsch, et al. Technical Report May 1981

Comparison: Analytical Models and Link-Sims

> Link sim, NIST[3] and TGn[7] results (1000 bytes)



> Greater divergence at smaller payloads (50 bytes)



Multistage Reception

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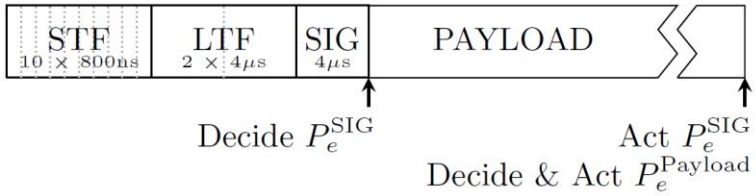
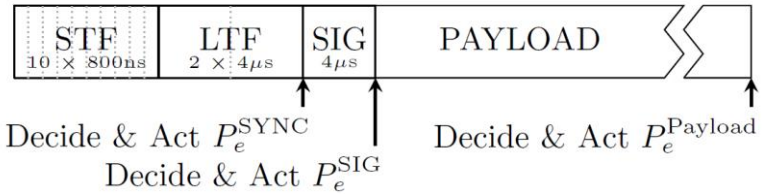
Multistage Reception

- Existing ns-3 reception model
  - Lack of preamble reception
  - Decision at the end of the frame



- Implemented reception model



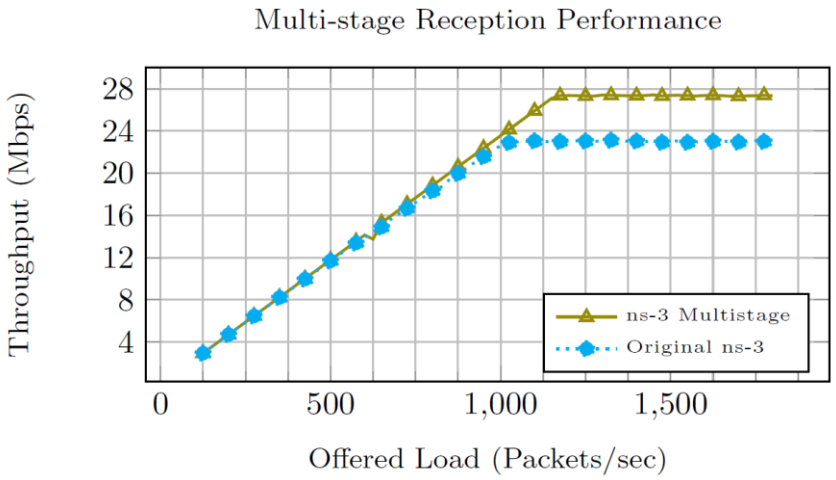
PLCP Preamble and Header Decode

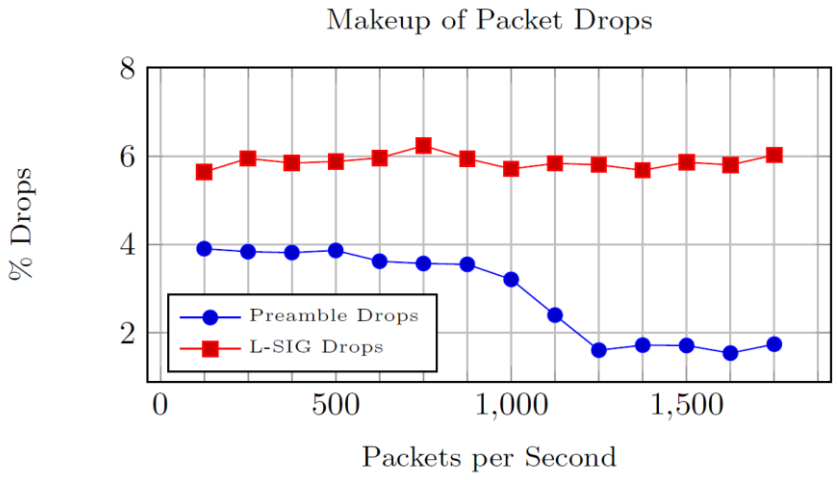
- Why do we need multistage reception?
  - Frame capture
  - Potential frame drops at PLCP preamble and header stage
    - Low SNR/SINR
    - Significant in coexistence studies
  - Example: Ad-hoc network with 25 nodes

Flows	Frequency of Occurrence	
	$< 2dB$ SINR	$< 5dB$ SINR
2	1.5%	2.4%
5	2.47%	4.04%
10	3.56%	5.71%

Results for Multistage Reception

> Increased throughput for hidden node scenario





Discussion

- Validation needed for analytical error models
  - Via link-sim and test beds
  - Correct application of bound on error probability
- Working towards better analytical models
  - AWGN Channel
- Can we match emulator error results?
  - Noise figure

Next Steps

- Moving towards frequency selective fading
  - Effective SNR mapping
  - Using AWGN analytical results
- Implementation of capture model for Wi-Fi

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Questions

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