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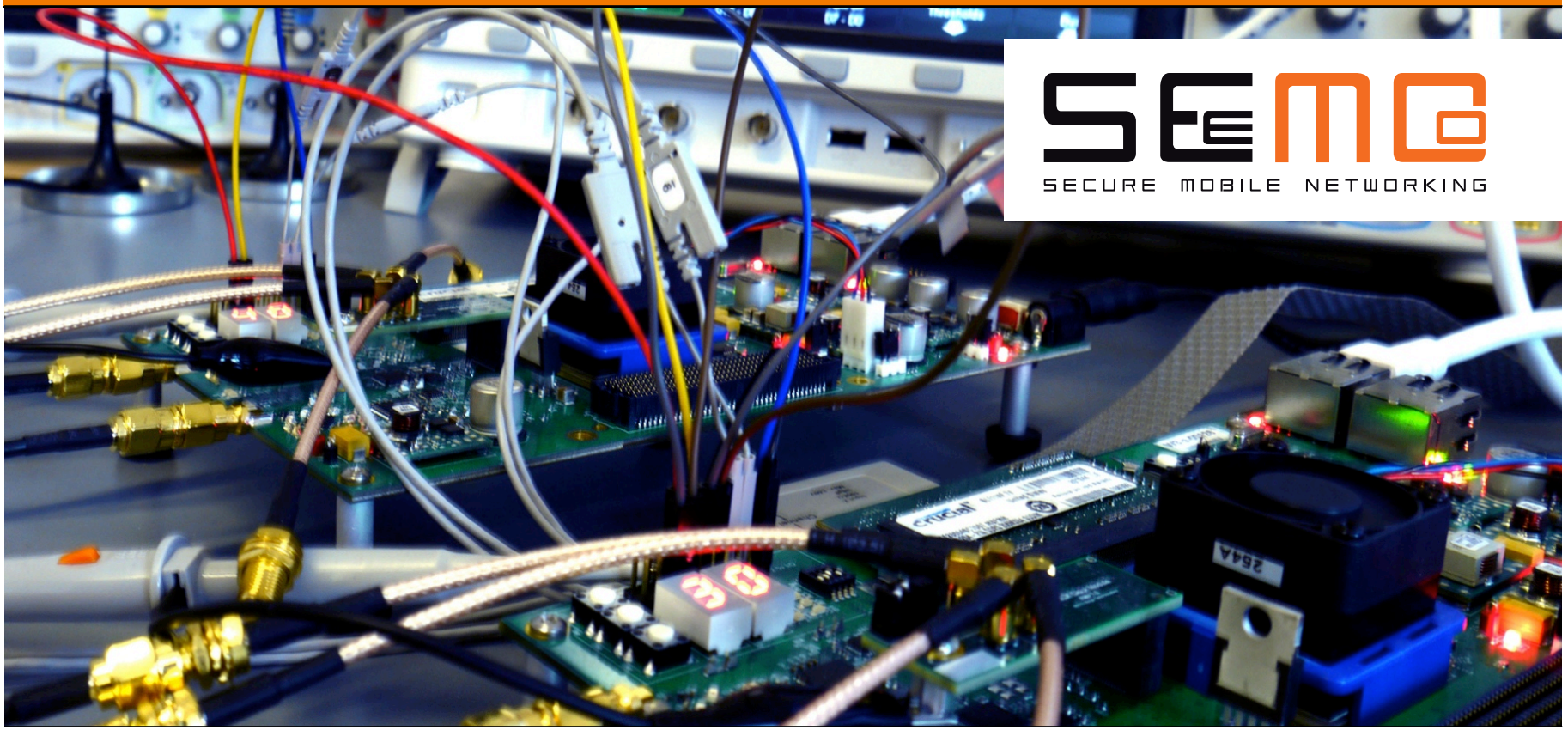
An Object-oriented Framework to Speed Up WARP-SDR Development

TECHNISCHE UNIVERSITÄT DARMSTADT

Scandinavian workshop on testbed based wireless research
Stockholm, November 27th, 2013



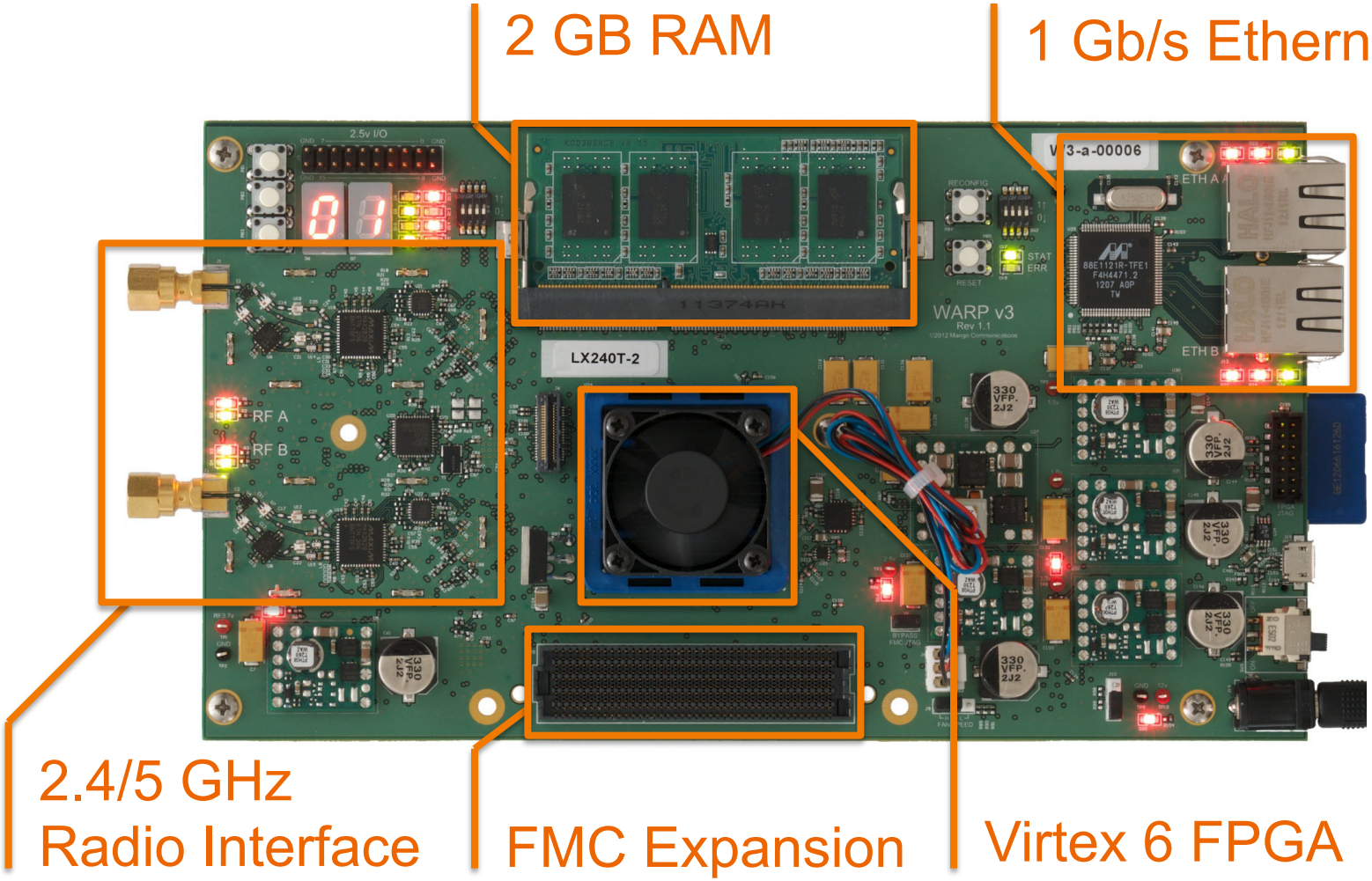
SEEMO
SECURE MOBILE NETWORKING

CASED

Content

- Introduction to WARP and WARPLab
- Scenario/Motivation
- Object-Oriented WARPLab Framework
  - Coding Examples
  - Channel Model
  - Abstraction from Physical Nodes
- Wrap-Up

Introduction to WARP



Introduction to WARPLAB

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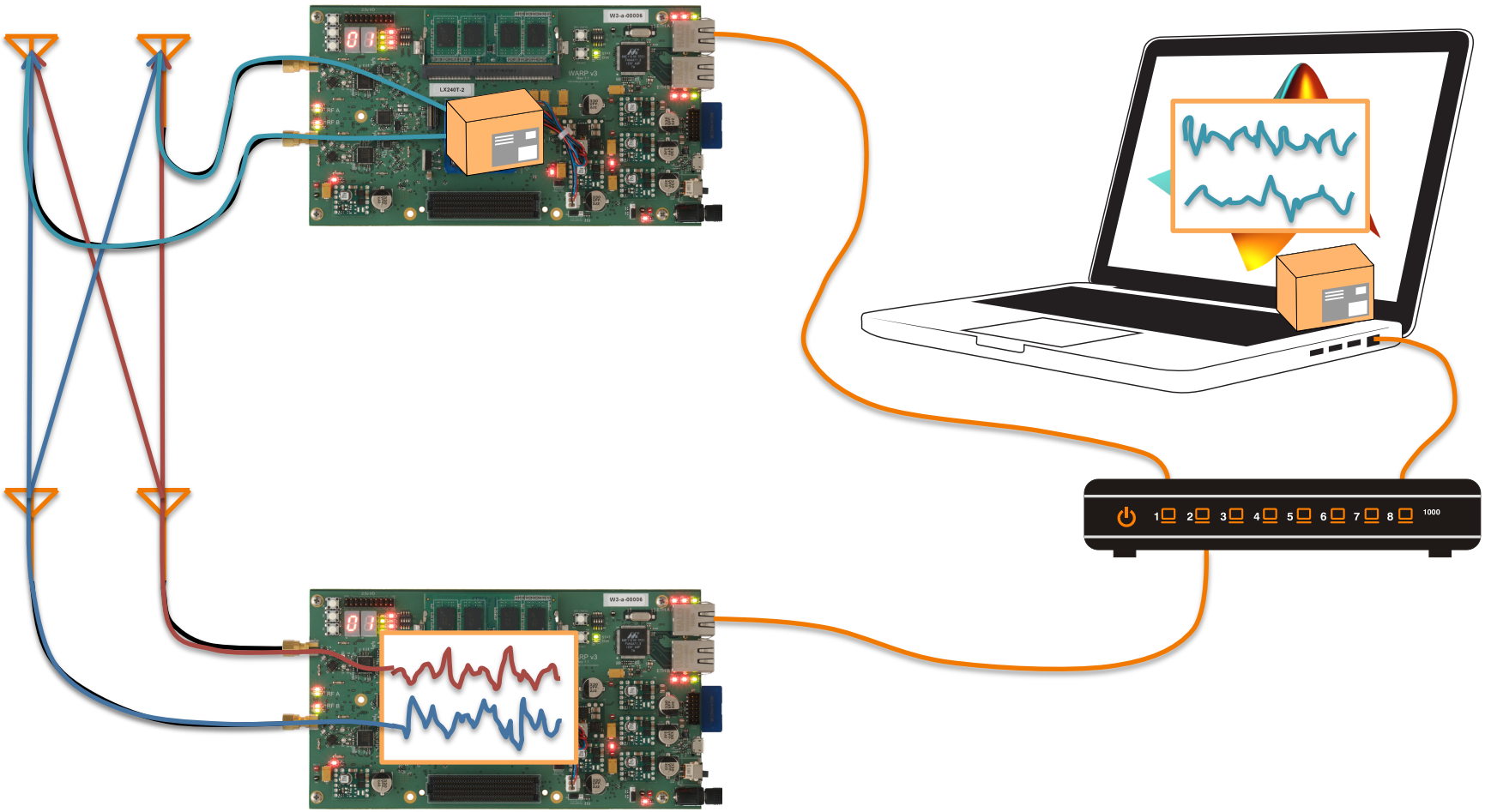

Scenario/Motivation

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Development of a new algorithm

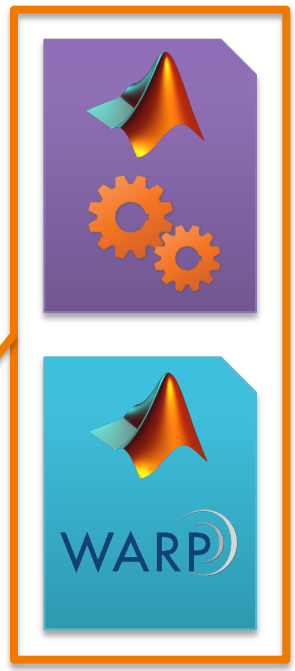
- Theory on paper
- First prototype in MATLAB
- Simulation in MATLAB
- Iterative improvements
- Evaluation on real channels with WARP and WARPLAB
- Iterative improvements
- *optional:* Real-time implementation in FPGA

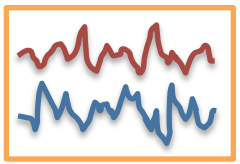
$e = mc^2$

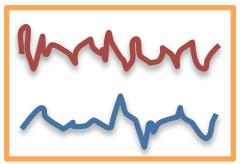
$\alpha \in [-\beta; \pi]$

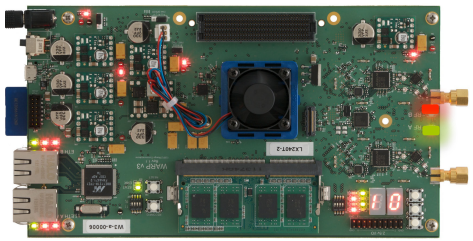
$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2}$$

$$X_k = \sum_{n=0}^{N-1} x_n e^{-j2\pi k \frac{n}{N}}$$









Two separate scripts/programs

Design of our Object-Oriented WARPLab Framework

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Experiment	Simulation
OO WARPLab Framework	Channel Model
WARPLab	
WARP Hardware	

WarpLab 6 Example

Transmission using Radio 2 of WARP Node 1

SECURE MOBILE NETWORKING

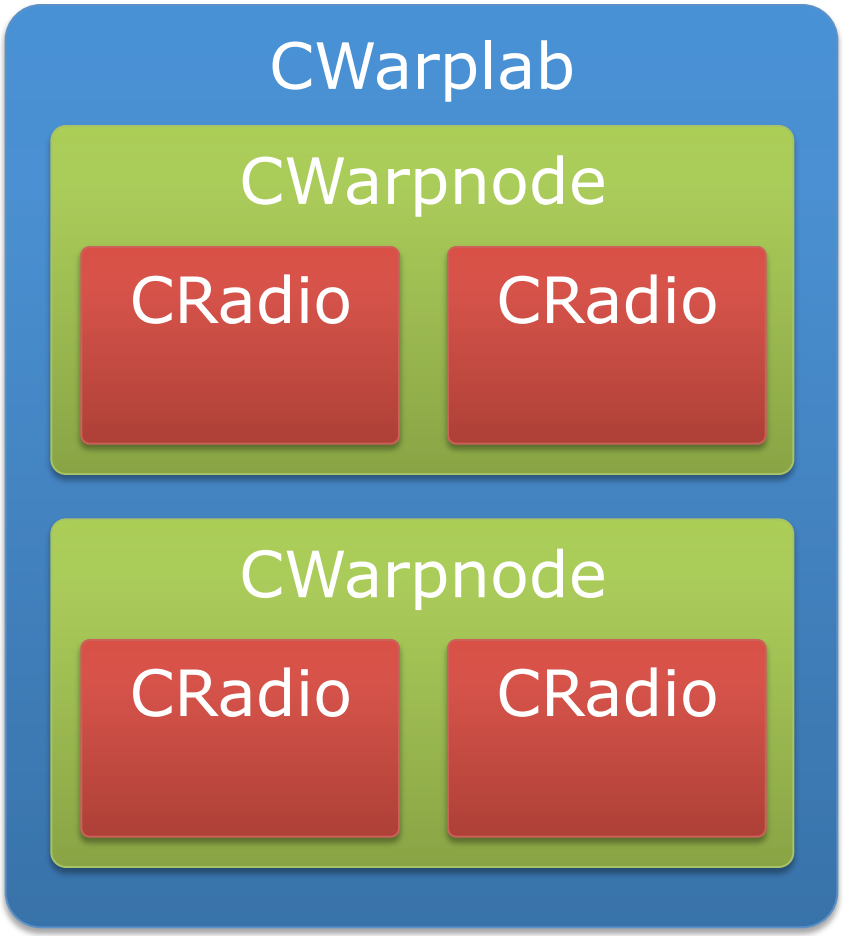
```
warplab_defines
[socketHandles, packetNum] = warplab_initialize;
udp_Sync = socketHandles(1); udp_node1 = socketHandles(2);
warplab_writeRegister(udp_node1,TX_LENGTH,2000);
warplab_setRadioParameter(udp_node1,CARRIER_CHANNEL,14);
warplab_setRadioParameter(udp_node1,RADIO2_TXGAINS,(40 + 3*2^16));
TxData = exp(linspace(0,2000/40e6,2000)*j*2*pi*1e6);
warplab_writeSMWO(udp_node1, RADIO2_TXDATA, TxData);
warplab_sendCmd(udp_node1, RADIO2_TXEN, packetNum);
warplab_sendCmd(udp_node1, RADIO2TXBUFF_TXEN, packetNum);
warplab_sendCmd(udp_node1, TX_START, packetNum);
warplab_sendSync(udp_Sync);
warplab_sendCmd(udp_node1, RADIO2TXBUFF_TXDIS, packetNum);
warplab_sendCmd(udp_node1, RADIO2_TXDIS, packetNum);
pnet('closeall');
```

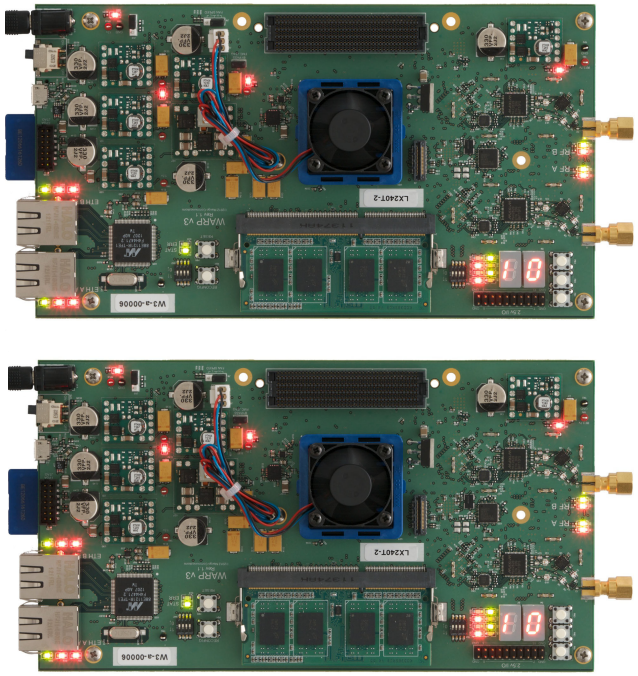
What do we need to change to transmit using radio 1?

Design of our Object-Oriented WARPLab Framework

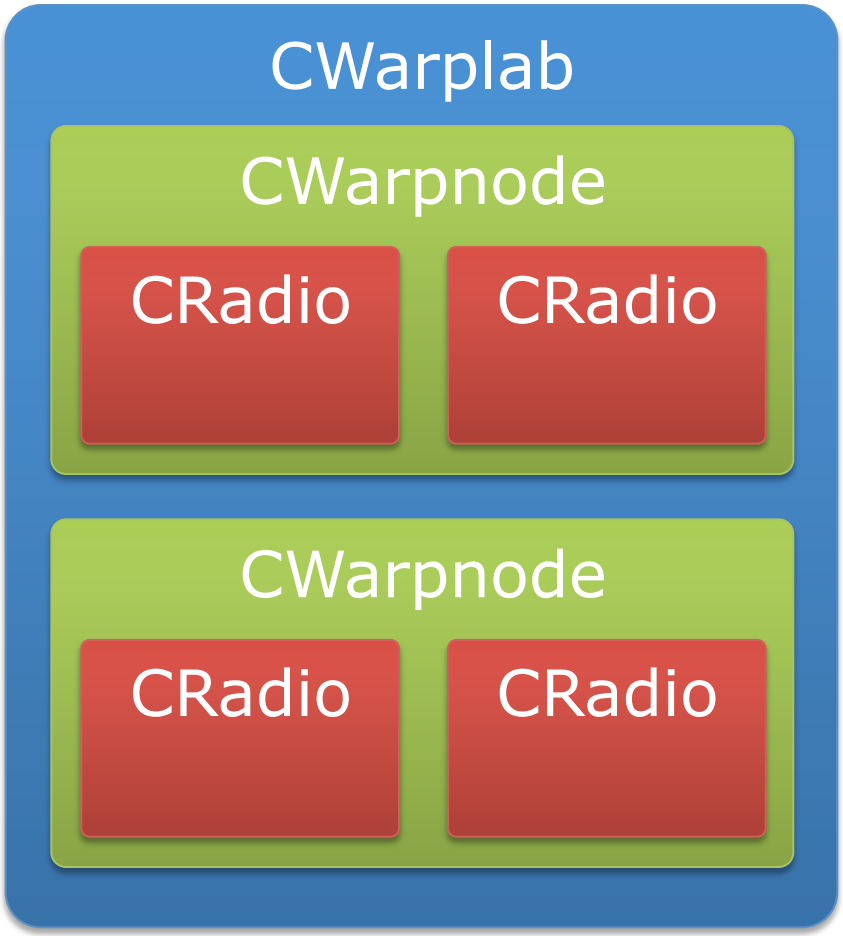
Experiment	Simulation
OO WARPLab Framework	Channel Model
WARPLab	
WARP Hardware	

OO WARPLab Framework





OO WARPLab Framework




```
warplab = CWarplab( ...
  CWarpnode( ...
    'radio1', CRadio(), ...
    'radio2', CRadio(), ...
  ), ...
  CWarpnode(...
    'radio1', CRadio(), ...
    'radio2', CRadio(), ...
  ) ...
);
```

WarpLab 6 Example
Transmission using Radio 2 of WARP Node 1

SECURE MOBILE NETWORKING

```
warplab_defines
[socketHandles, packetNum] = warplab_initialize;
udp_Sync = socketHandles(1); udp_node1 = socketHandles(2);
warplab_writeRegister(udp_node1,TX_LENGTH,2000);
warplab_setRadioParameter(udp_node1,CARRIER_CHANNEL,14);
warplab_setRadioParameter(udp_node1,RADIO2_TXGAINS,(40 + 3*2^16));
TxData = exp(linspace(0,2000/40e6,2000)*j*2*pi*1e6);
warplab_writeSMWO(udp_node1, RADIO2_TXDATA, TxData);
warplab_sendCmd(udp_node1, RADIO2_TXEN, packetNum);
warplab_sendCmd(udp_node1, RADIO2TXBUFF_TXEN, packetNum);
warplab_sendCmd(udp_node1, TX_START, packetNum);
warplab_sendSync(udp_Sync);
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warplab_sendCmd(udp_node1, RADIO2_TXDIS, packetNum);
pnet('closeall');
```

What do we need to change to transmit using radio 1?

OO WARPLab Framework Example

Transmission using Radio 2 of WARP Node 1

```
warplab = CWarplab(...
    CWarpnode(...
        'radio2', CRadio(...
            'dir', 'tx'...
        ), ...
        'txlength', 2000 ...
    )...
);

TxData = exp(linspace(0,2000/40e6,2000)*j*2*pi*1e6);
warplab.nodes(1).radio2.txdata = TxData;
warplab.transferDataStartTransmission();
pnet('closeall');
```

What do we need to change to transmit using radio 1?

Design of our Object-Oriented WARPLab Framework

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Experiment and Simulation

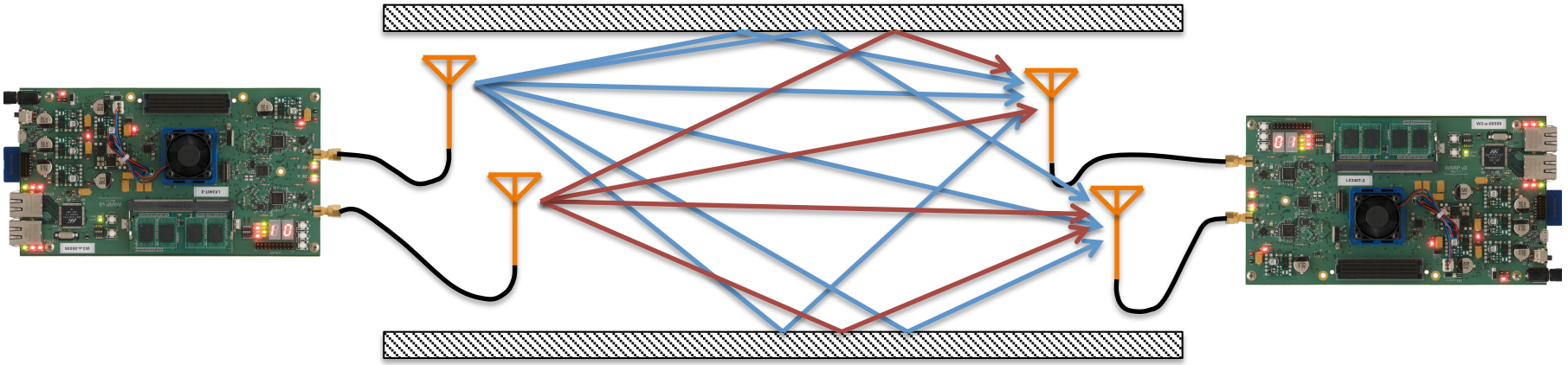
OO WARPLab Framework

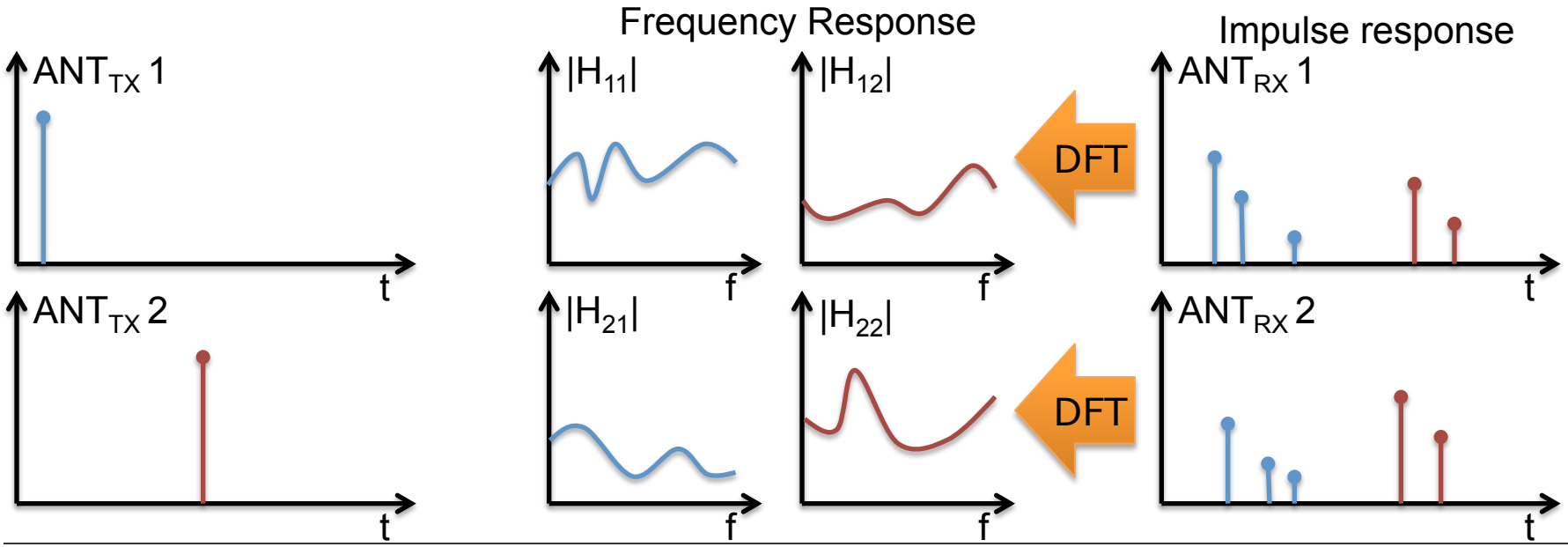
WARPLab 6/7/…

WARP Hardware

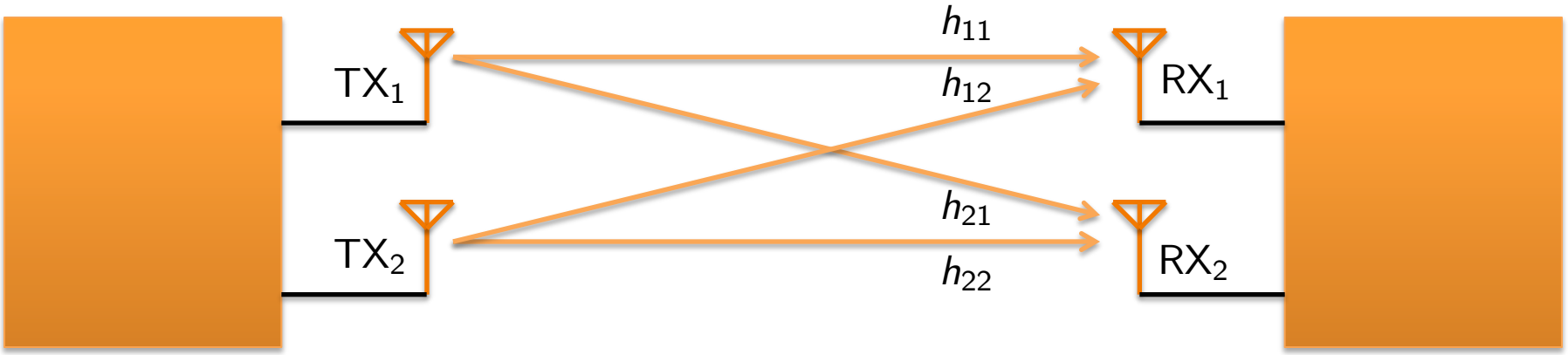
Channel Model

Channel Model





Channel Model



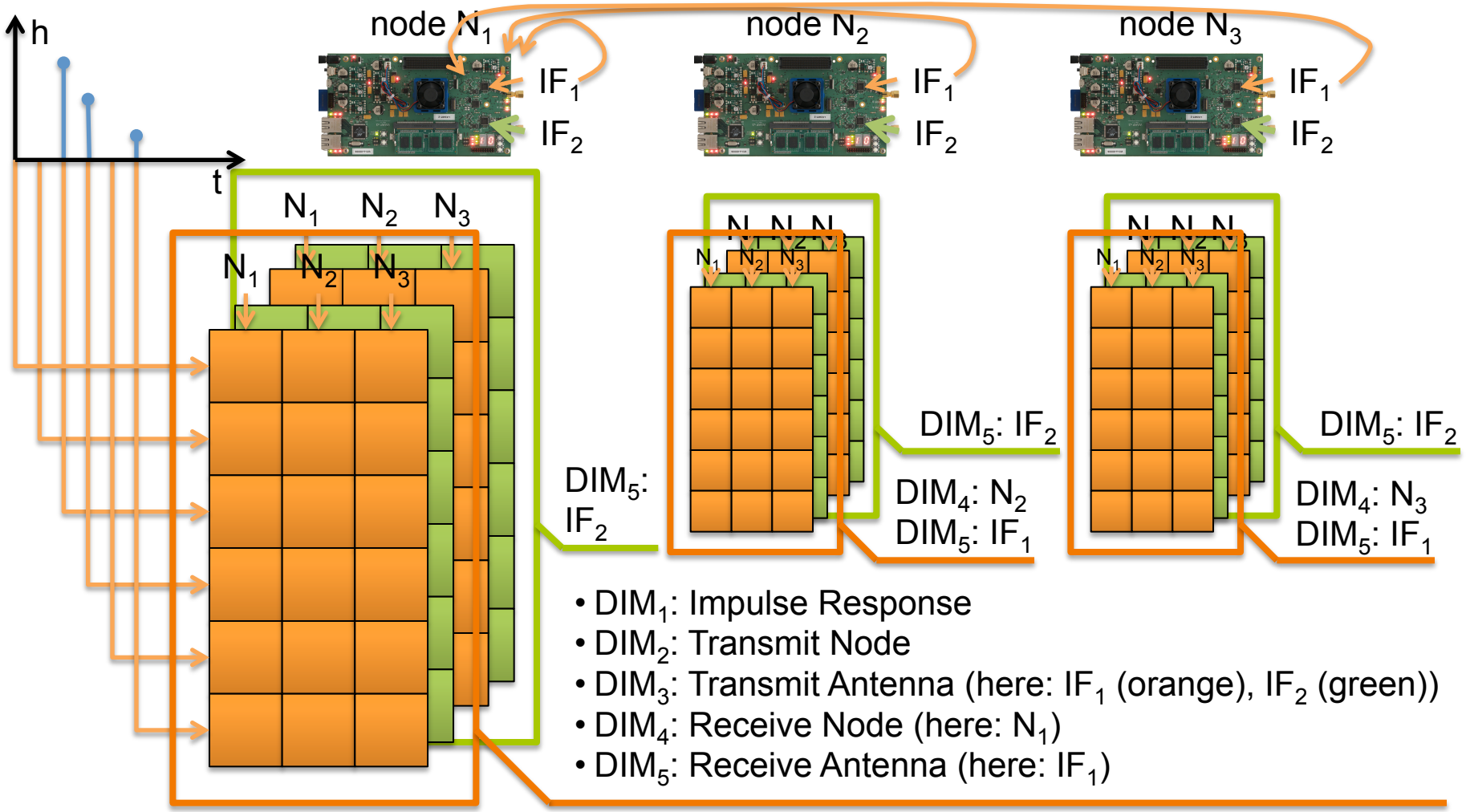
$$RX_1 = TX_1 * h_{11} + \eta_1 + TX_2 * h_{12} + \eta_2$$

$$RX_2 = TX_1 * h_{21} + \eta_1 + TX_2 * h_{22} + \eta_2$$

Convolution of TX signal with channel impulse response

Additive white Gaussian noise (AWGN)

Channel Representation in MATLAB



Channel Representation in MATLAB

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```
ntap = 5; online = 0;
warplab = CWarplab(...
    CWarpnode(...
        'radio1', CRadio(), ...
        'radio2', CRadio(), ...
        'radio3', CRadio(), ...
        'radio4', CRadio(), ...
        'txlength', 2000 ...
    ),...
    'offline_channel', (randn(ntaps,1,4,1,4) + ...
        1j * randn(ntaps,1,4,1,4)), ...
    'awgn_matrix', 25 * ones(1,1,4,1,4), ...
    'online', online ...
);
```

No. of TX Nodes
No. of TX Antennas/Node
No. of RX Nodes
No. of RX Antennas/Node

0 = simulation; 1 = use WARPs

Design of our Object-Oriented WARPLab Framework

Experiment and Simulation

OO WARPLab Framework

WARPLab 6/7/…

WARP Hardware

Channel Model

Abstraction from Physical Nodes

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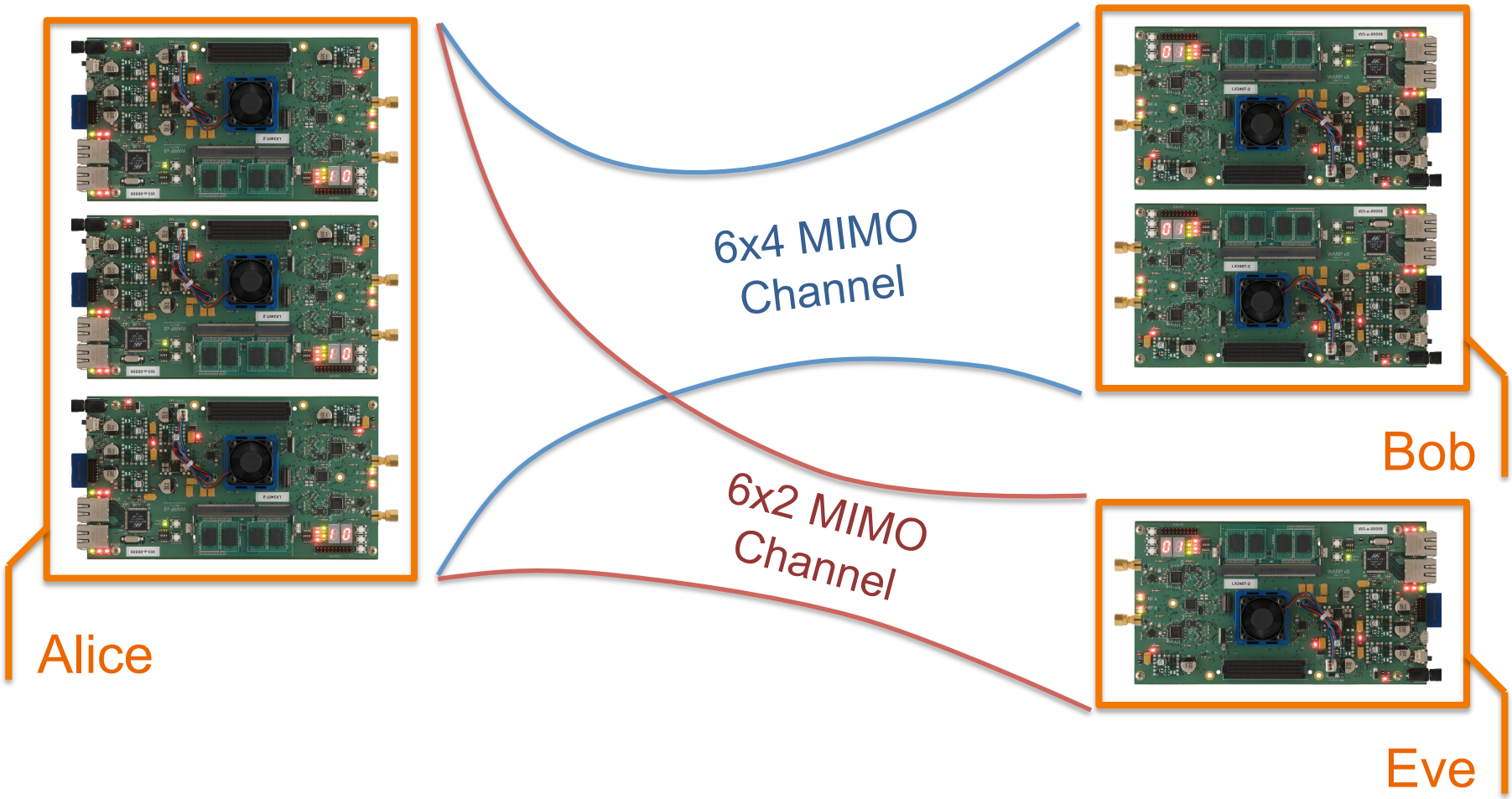

Abstraction from Physical Nodes

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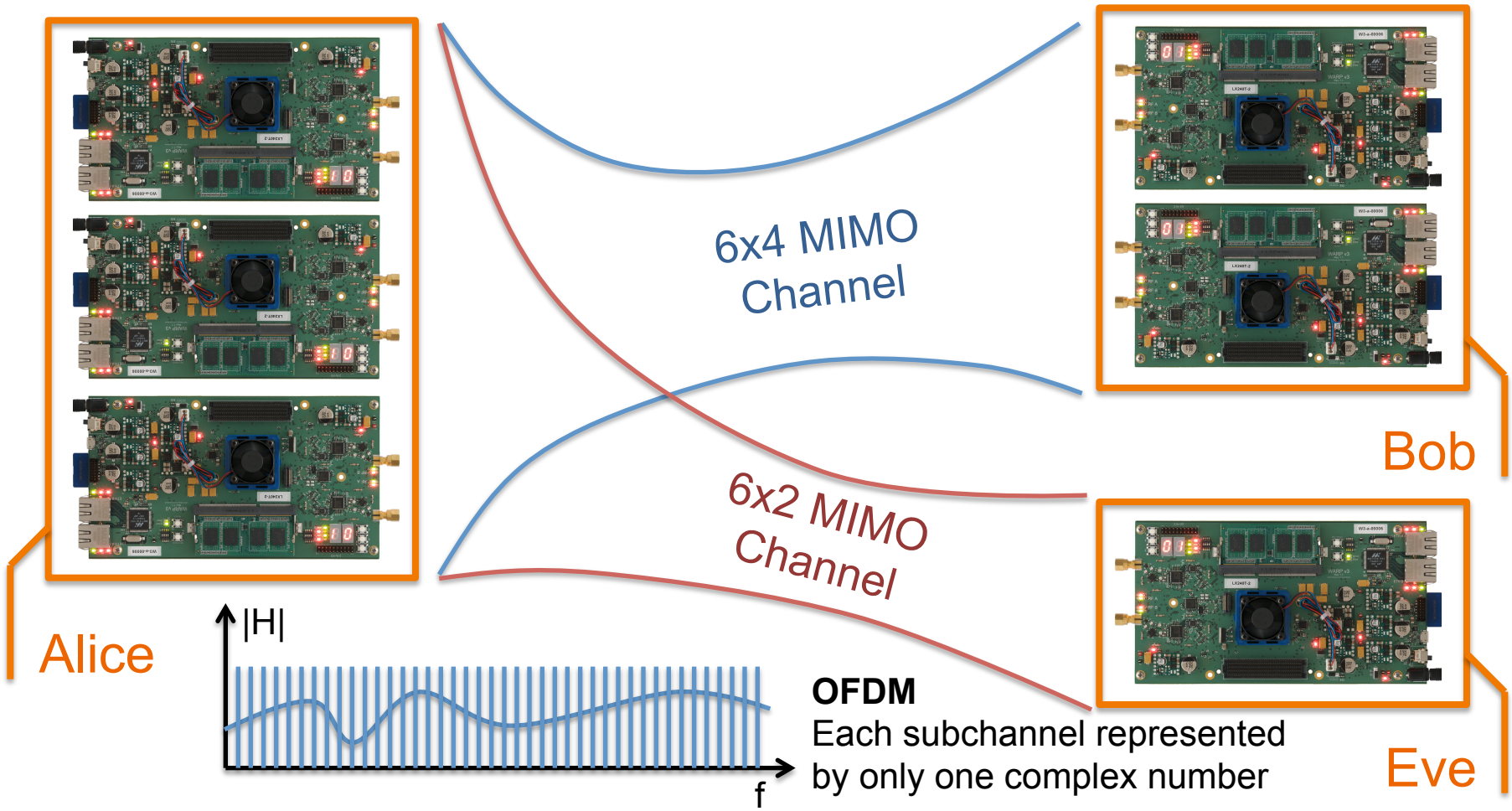
```
alice_if = [ ...
    struct('node',1,'radio',1) struct('node',1,'radio',2) ...
    struct('node’,2,'radio’,1) struct('node’,2,'radio’,2) ...
    struct('node’,3,'radio’,1) struct('node’,3,'radio’,2) ...
]; alice = CNode(warplab, alice_if, 1);

bob_if = [ ...
    struct('node’,4,'radio',1) struct('node’,4,'radio',2) ...
    struct('node’,5,'radio',1) struct('node’,5,'radio',2) ...
]; bob = CNode(warplab, bob_if, 2);

eve_if = [ ...
    struct('node’,6,'radio',1) struct('node’,6,'radio',2) ...
]; eve = CNode(warplab, bob_if, 3);
```

Abstraction from Physical Nodes



Applying the Abstraction

```
nsym = 100; % 100 OFDM symbols
NFFT = 128; % Number of subcarriers
% Create BPSK symbols
frame1 = randi([0 1], length(alice_if),nsym,NFFT)*2-1;
% Set unusable subcarriers to zero and adjust power
frame1(:,:,[1:6 64:66 124:128]) = 0;
frame1 = frame1 / sqrt(114) / sqrt(length(alice_if));
% Start transmission
alice.transmit_frame(frame1,40,2,0.01);
warplab.transferDataStartTransmission();
alice.clean_transmission();
% Get received frame and estimated channel
[frame, channel] = bob.receive_frame();
```

Bandwidth = 20 or 40 MHz
Preamble repetition
pre-transmission CFO corr.

Wrap-Up

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- Introduction to WARP/WARPLab
- Object-Oriented WARPLab Framework
  - use the same code base for simulation and experimentation
- Abstraction from Physical Nodes
  - Combine multiple nodes into logical named nodes
  - Use OFDM to abstract from the fading channels

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