CHRONOS: A Cloud based Hybrid RF-Optical Network Over Synchronous Links

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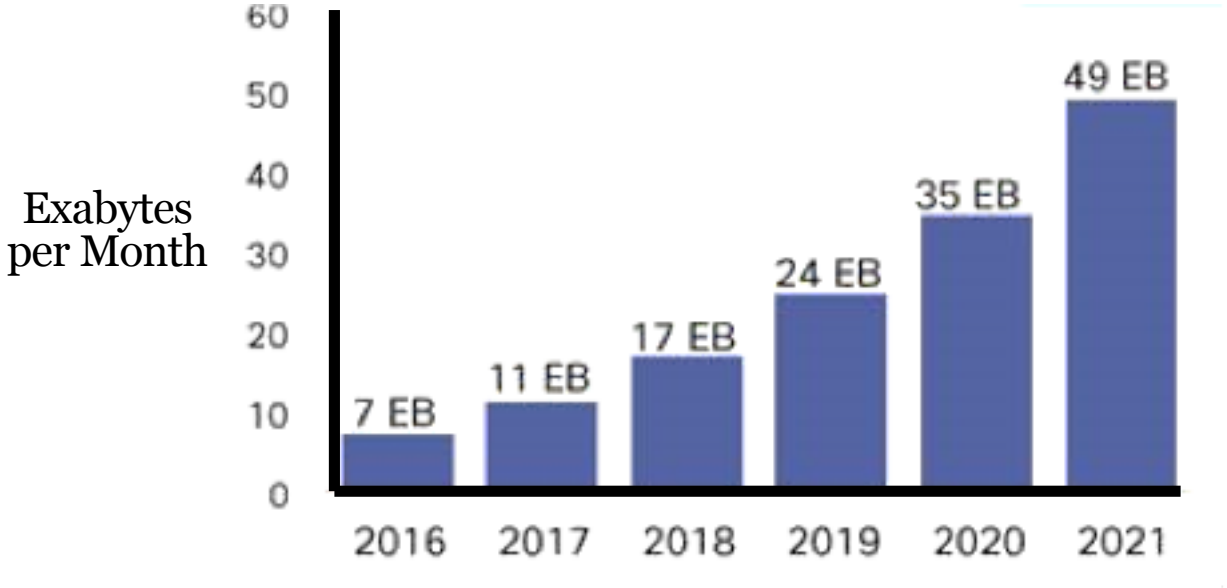
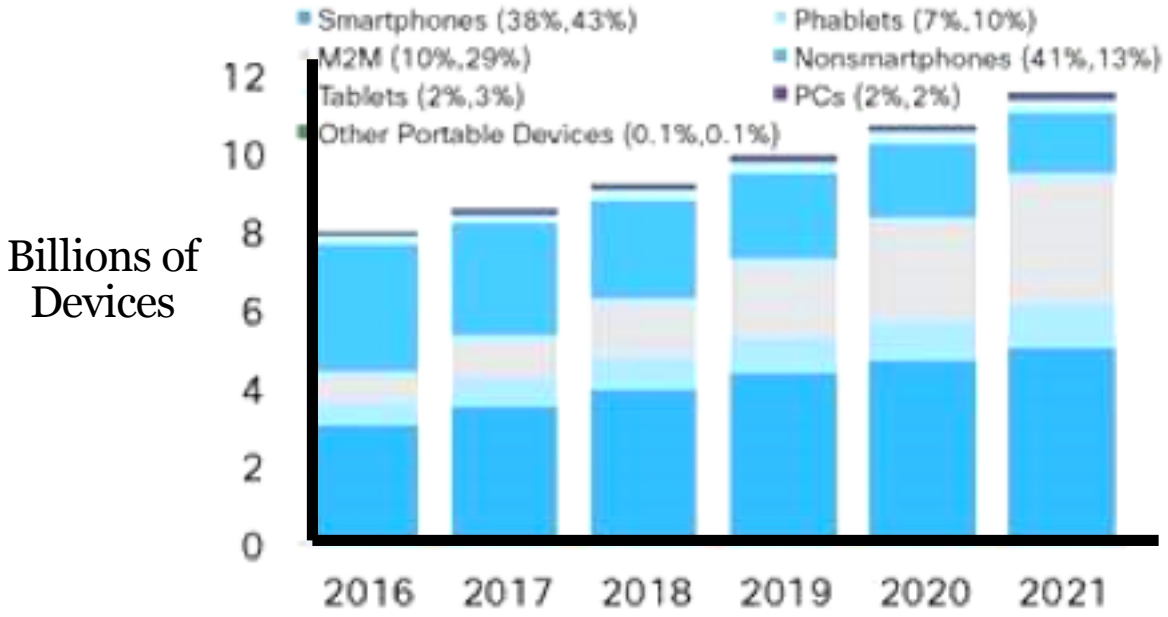
Wireless Trends



Growth in Wireless Data Traffic [1]



Global Mobile Devices Growth [1]

Low Throughput and High Latency

[1] Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update (White Paper)

Higher Frequencies

- High bandwidth → Harsh channel conditions → Less explored
- Research on Isolated bands (sub-6GHz, mmWave and THz)

Solution

- Integrated, seamless and complementary communication across multiple bands
- Needs a complete rethinking and redesigning of network architecture
- CHRONOS: A *Cloud based Hybrid RF Optical Network Over Synchronous Links* to virtualize the Radio Access Network

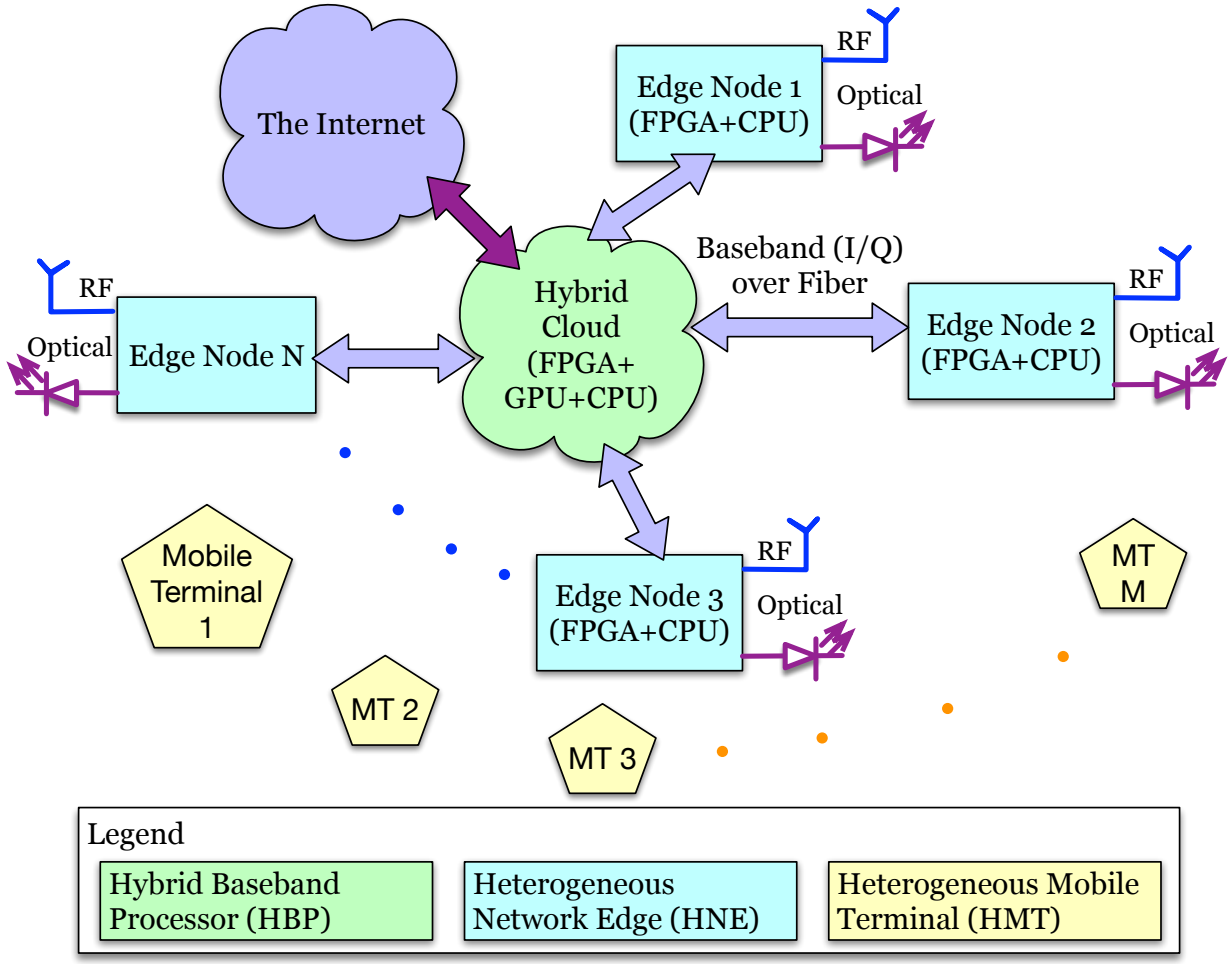
CHRONOS

- A Multi-node, heterogeneous, wideband, scalable, hybrid and synchronous Cloud Radio Access Network (C-RAN)

- Enhancing core capabilities of C-RAN by integrating synchronous RF and Optical links (heterogeneity).

CHRONOS: Architecture

- 1) Hybrid Baseband Processor (HBP) (cloud platform)
- 2) Heterogeneous Network Edge (HNE) (Edge node)
- 3) Heterogeneous Mobile Terminal (HMT) (User Equipment)



Novelty

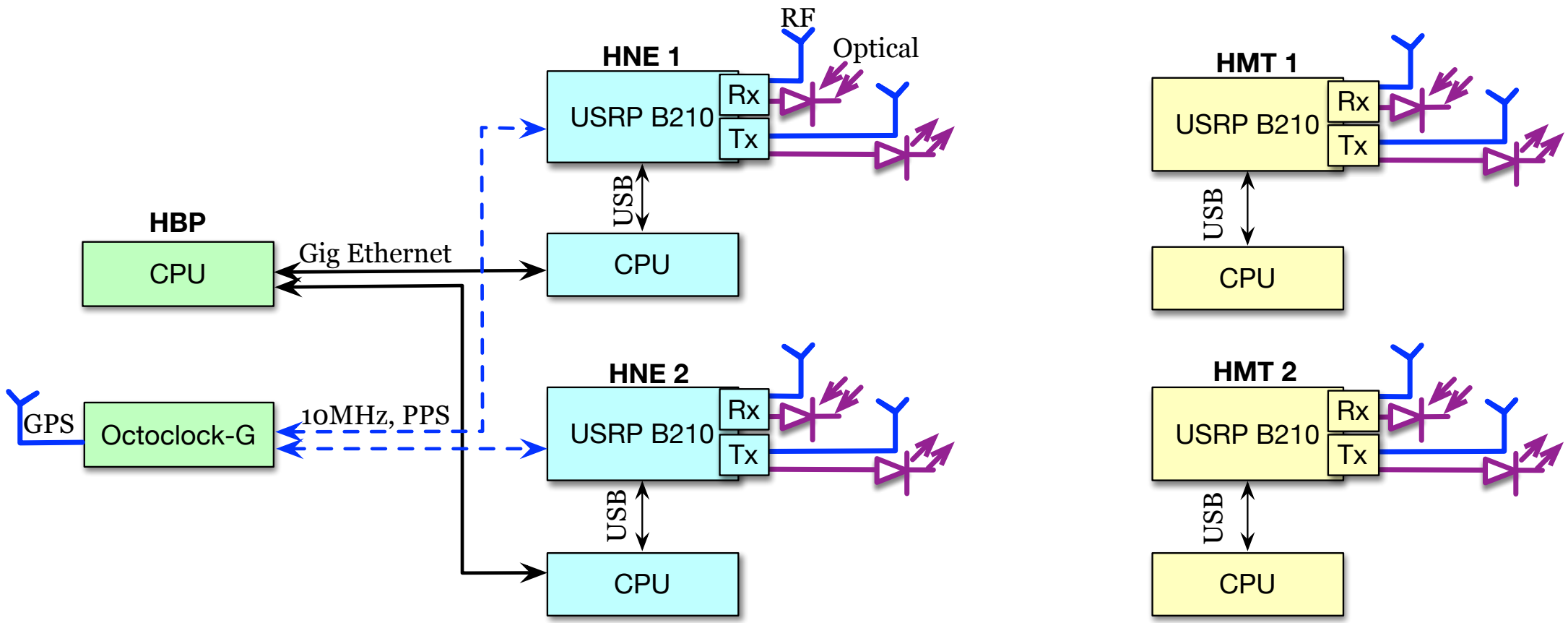
1) Heterogeneous (RF-Optical) Edge:

2) Hybrid Cloud based DSP:

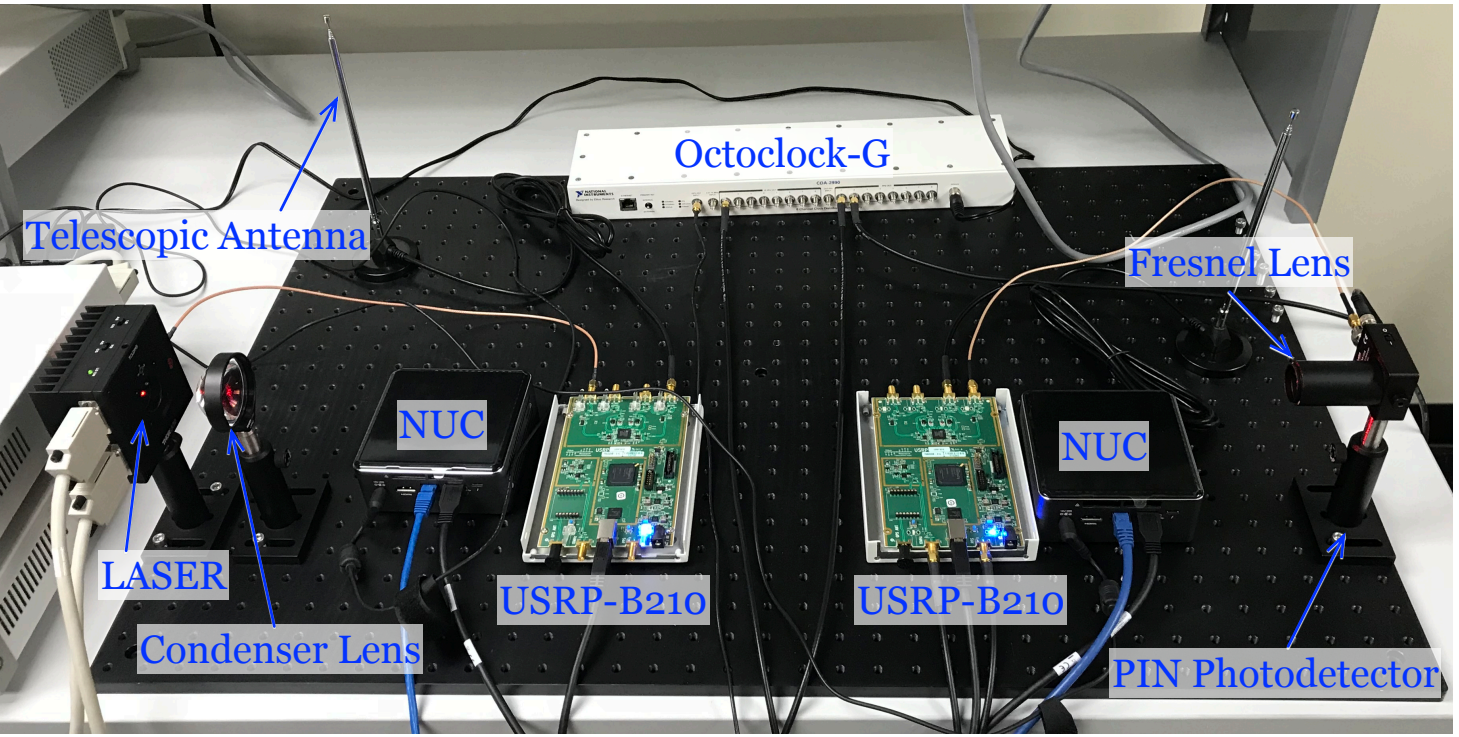
3) On-demand Edge Processing:

4) Synchronous Edge:

Testbed Setup



Testbed



Each HNE and HMT:

- RF & Optical Front Ends
- SDR (USRP B210)
- Intel NUC: i7-7567U, 16GB RAM

HBP (Cloud)

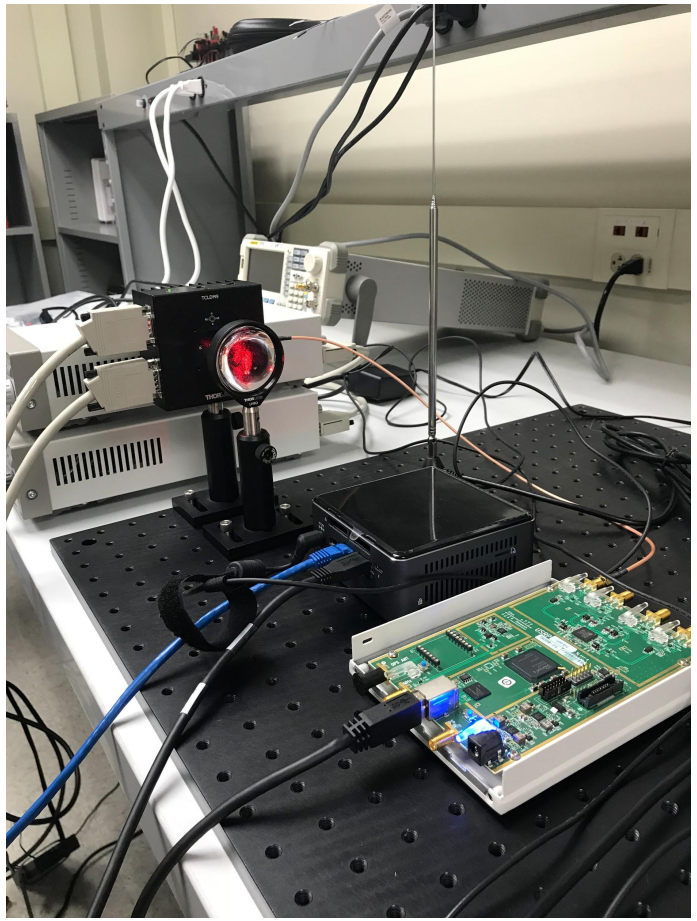
- i7 quad-core processor

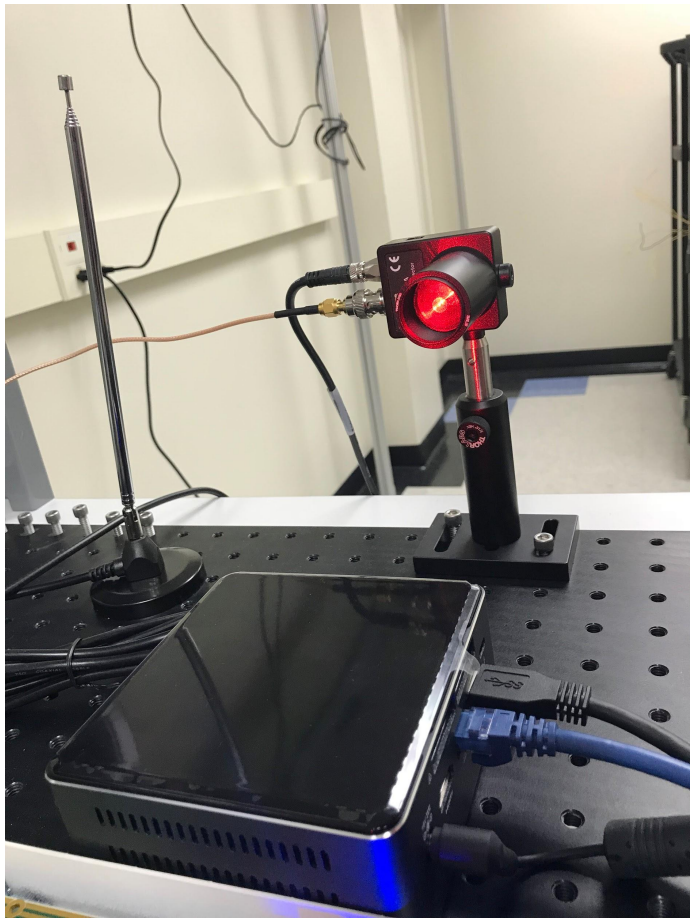
Synchronization

- Clock Distribution – OctoclockG
- Controller in Cloud

Optical Frontends

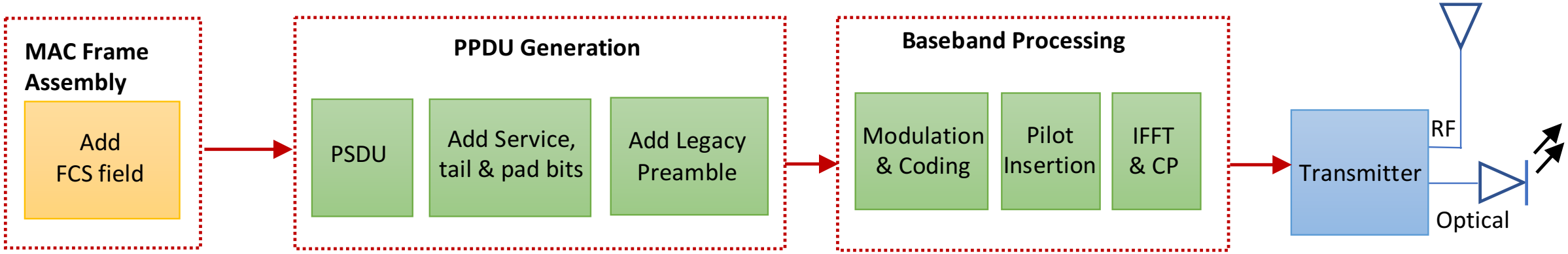
- Optical Front-End:
  - Laser Diode sources
  - Photo Diode Detectors with Amplifiers (TIAs)
  - Collimating Lenses



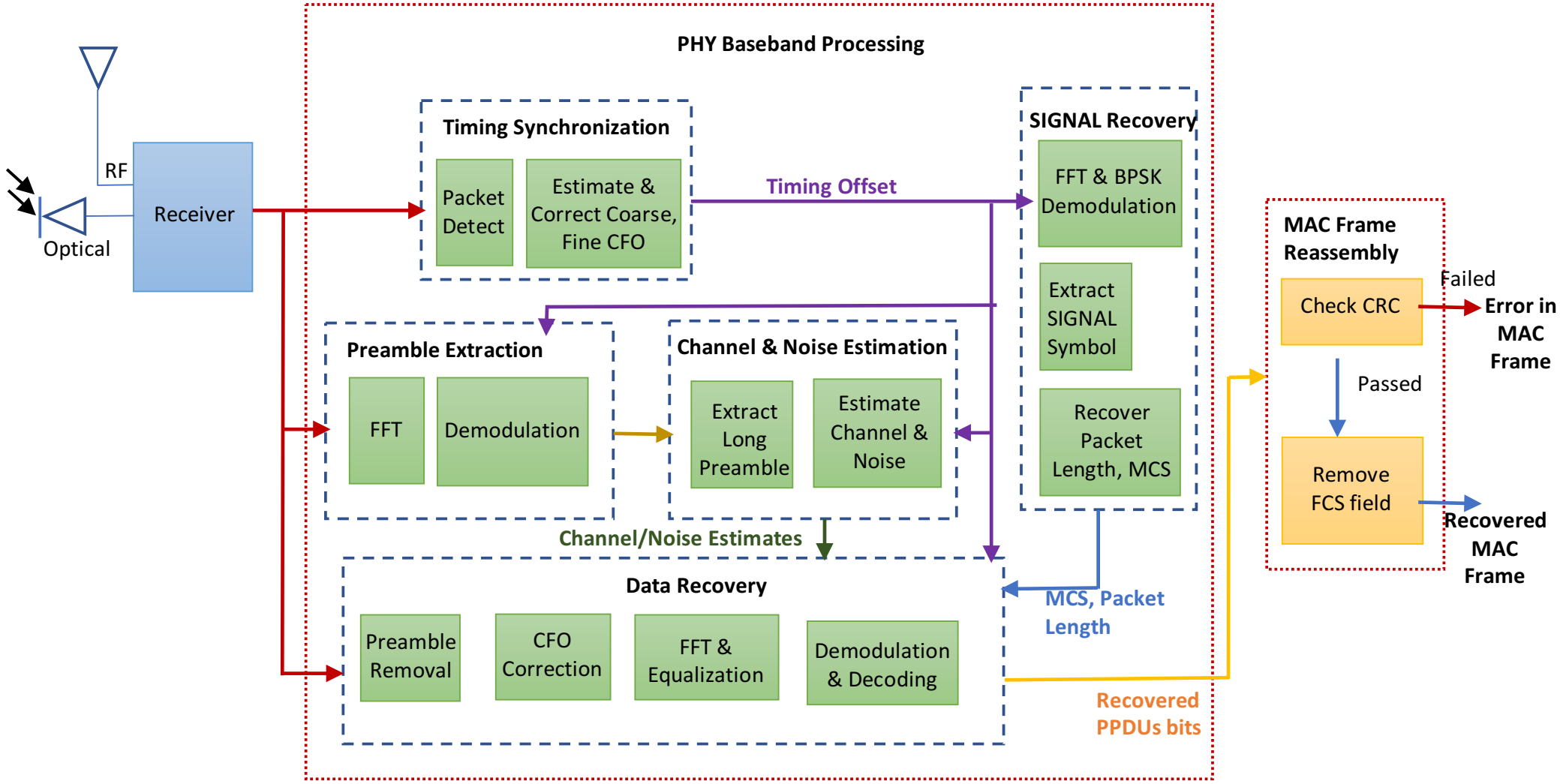


Baseband Transmitter

- Currently postprocessing in MATLAB



Baseband Receiver

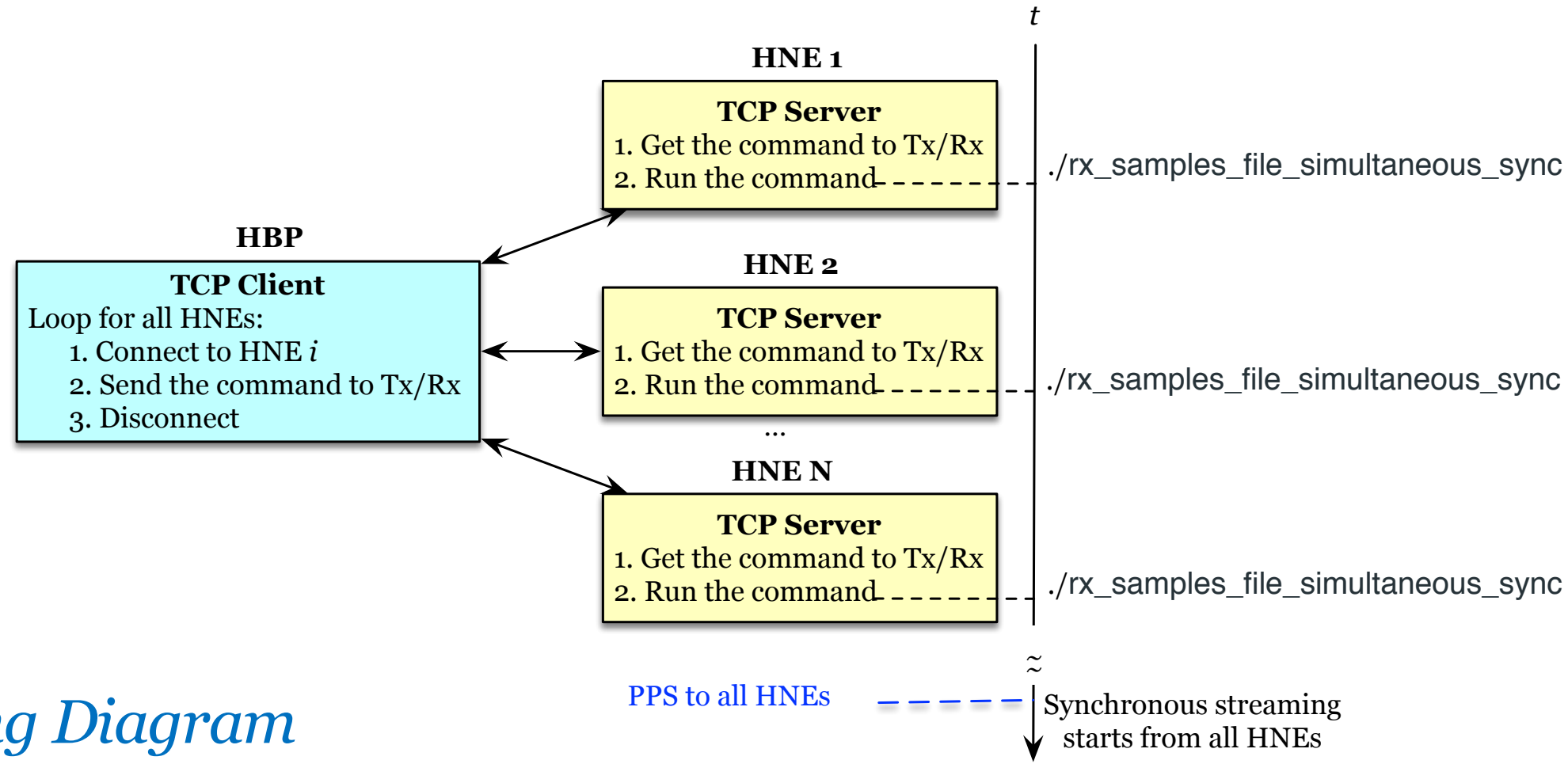


Simultaneous Transmissions

```
$ ./tx_samples_file_simultaneous --freq1 80e6
--freq2 80e6 --rate 5e6 --gain1 80 --gain2 60
--subdev="A:A A:B" --channel=0,1 --ant TX/RX
--ref=internal --repeat --spb 10000
--file1 /media/ramdisk/RF/RFTx.dat
--file2 /media/ramdisk/Opt/OptTx.dat

Creating usrp device with: serial=310733F...
-- Setting master clock rate selection:'automatic'
-- Setting clock rate 16.000000 MHz...
Using Device: Single USRP: Device:B-Series B210
Setting TX Rate: 5.000000 Msps...
-- Setting clock rate 40.000000 MHz...
Setting TX Freq of channel 0: 80.000000 MHz
Setting TX Freq of channel 1: 80.000000 MHz
Setting TX Gain of channel 0: 80.000000 dB
Setting TX Gain of channel 1: 60.000000 dB
Detecting which channels to use --successful
-- Setting clock rate 20.000000 MHz...
Buffer Size: 10000
Num of simultaneous transmissions : 2
```

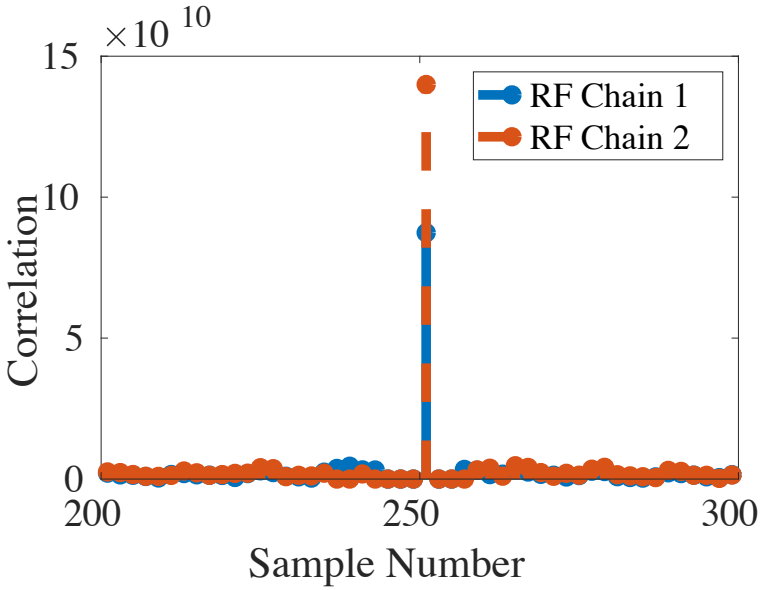
```
$ ./rx_samples_file_simultaneous_sync --freq1 80e6
--freq2 80e6 --rate 20e6 --gain1 20 --gain2 20
--subdev="A:A A:B" --channel=0,1 --ref=external
--nsamp 1000000 --sync=pps --secs=2.5
--file1 /media/ramdisk/file_13.dat
--file2 /media/ramdisk/file_23.dat

Setting master clock rate selection: 'automatic'.
-- Setting clock rate 16.000000 MHz...
Setting RX Rate: 20.000000 Msps...
-- Setting clock rate 20.000000 MHz...
Setting device timestamp to 0...
--1) catch time transition at pps edge
--2) set times next pps (synchronously)
External 10 MHz clock locked++++++
Setting RX Freq of channel 0: 80.000000 MHz...
Setting RX Freq of channel 1: 80.000000 MHz
Setting RX Gain of channel 0: 20.000000 dB
Setting RX Gain of channel 1: 20.000000 dB
Begin streaming 1000000 samples, 2.500000
seconds in the future...
Done!
Buffer Size: 10000
Num of simultaneous transmissions : 2
```

Synchronization

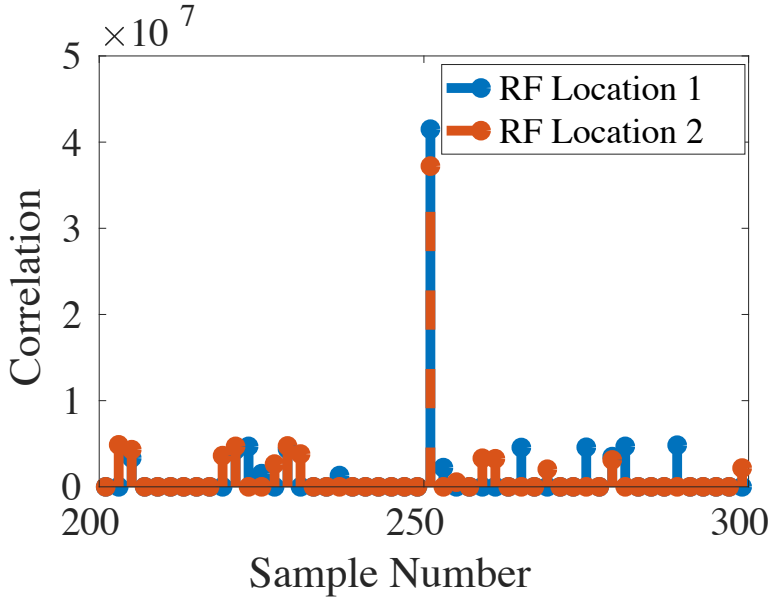


Timing Diagram

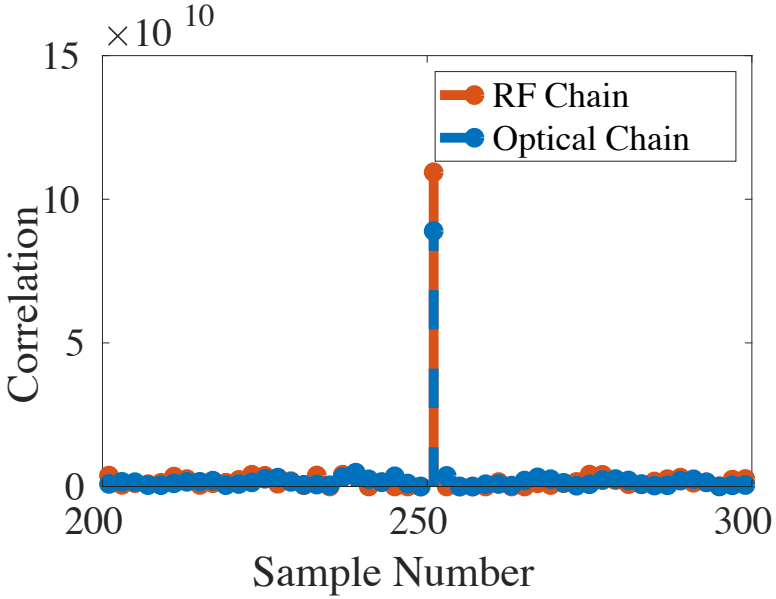
Synchronous Transmission Output



Two RF chains in the same board



RF from 2 different boards, synced using PPS signal

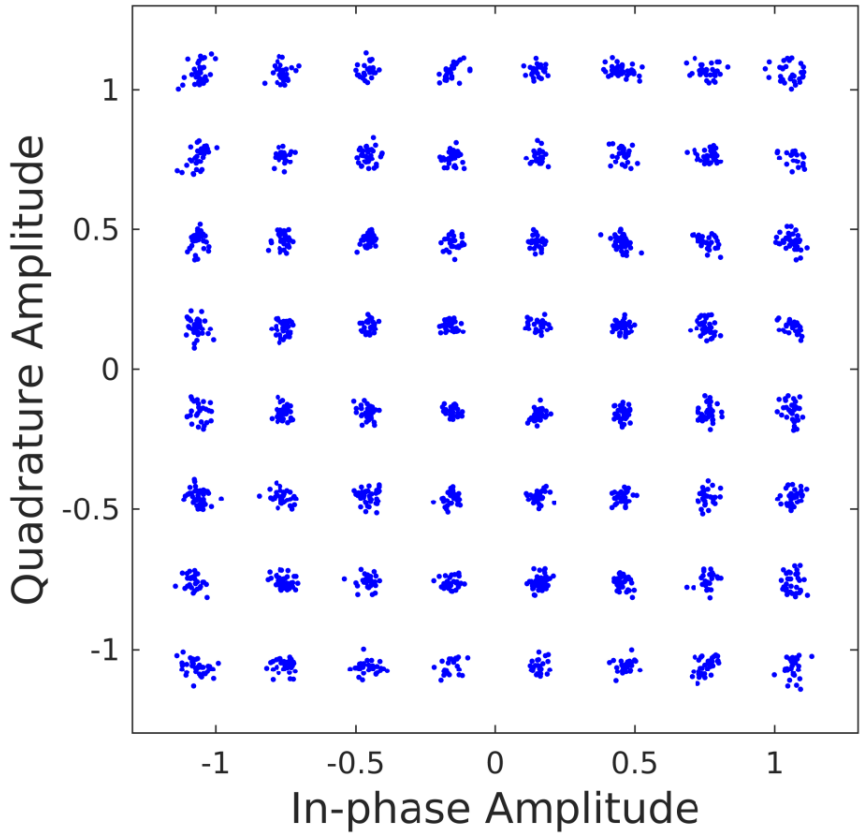


RF and & Optical path in same board

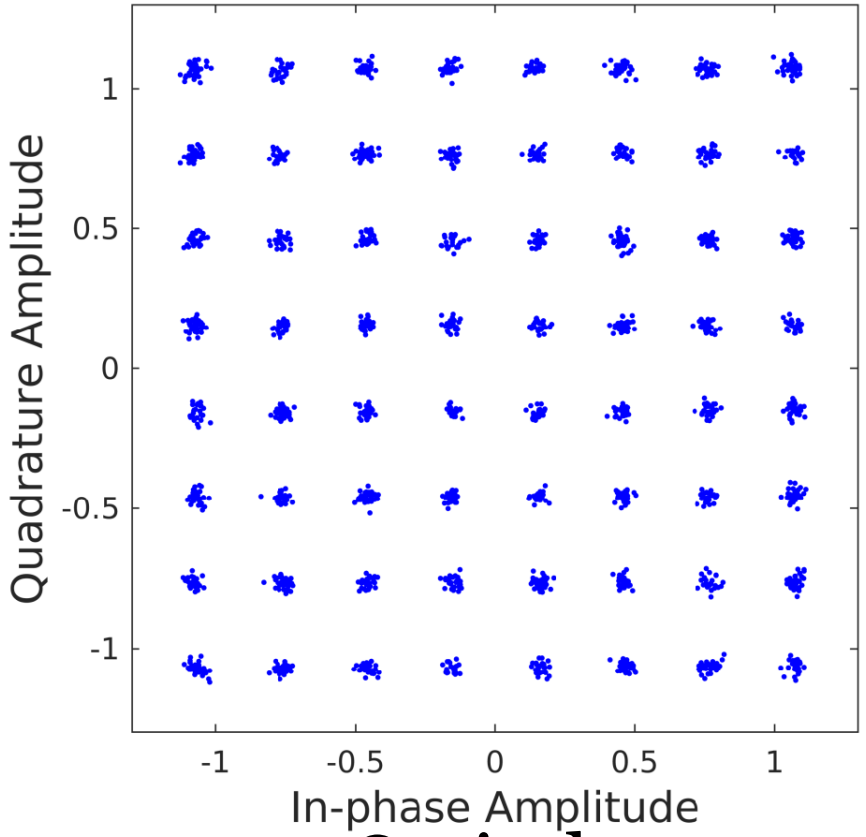
Benchmarking Results

- Transmit/Receive simultaneously over RF & Optical links, each spanning upto 20MHz bandwidth.
- Used IEEE 802.11a/g to reach up to 54Mbps PHY data rate in one link.
- Aggregate PHY data rate of 108Mbps over both links

Testbed Benchmarking – Fidelity of Links



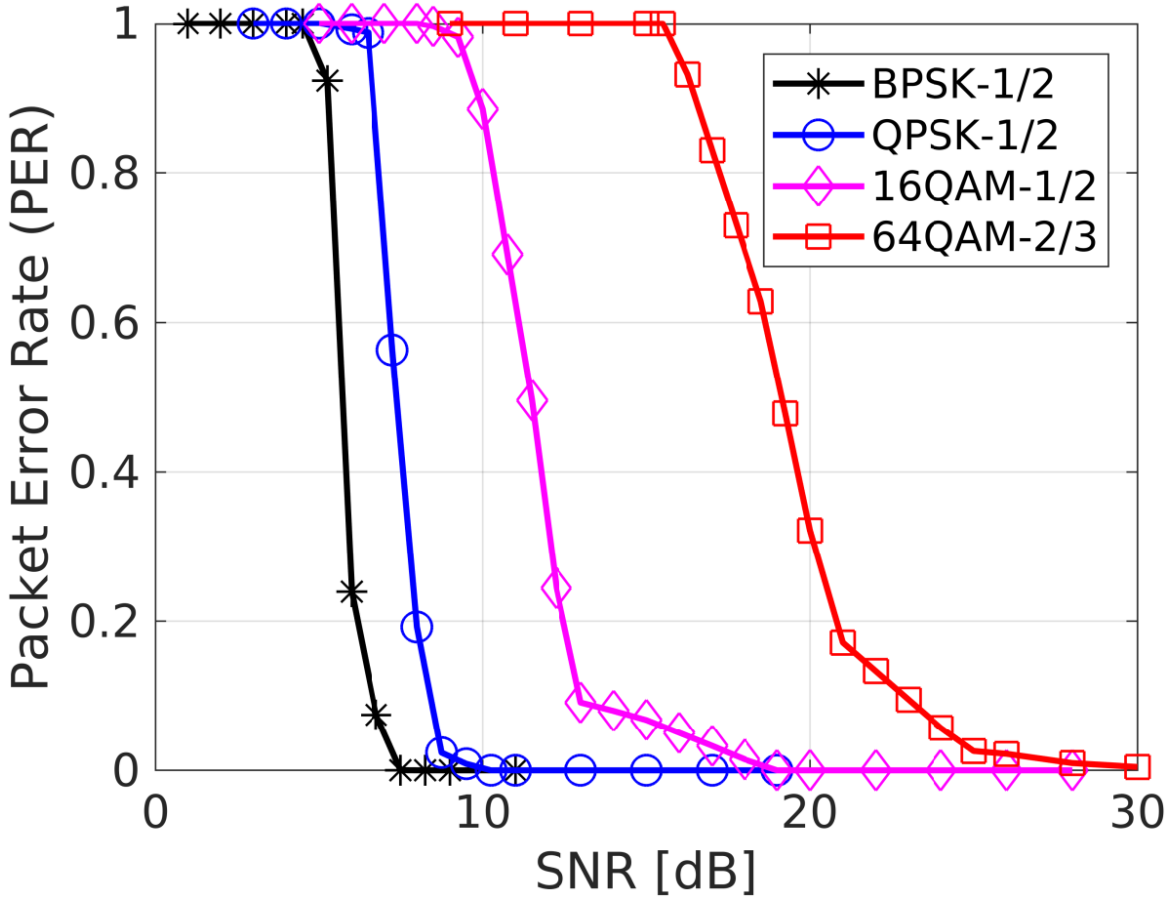
RF



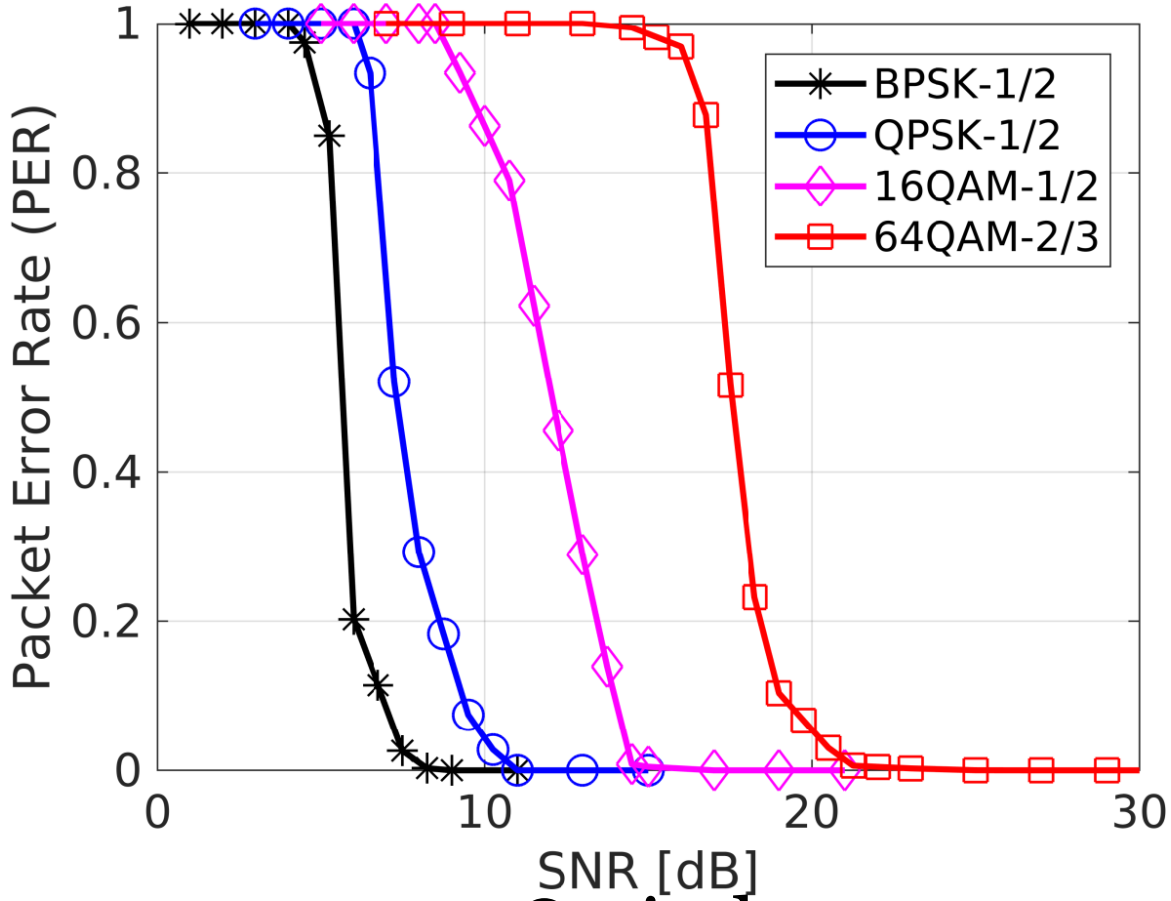
Optical

Can achieve high data rates via higher modulations in both links

Packet Loss & Performance



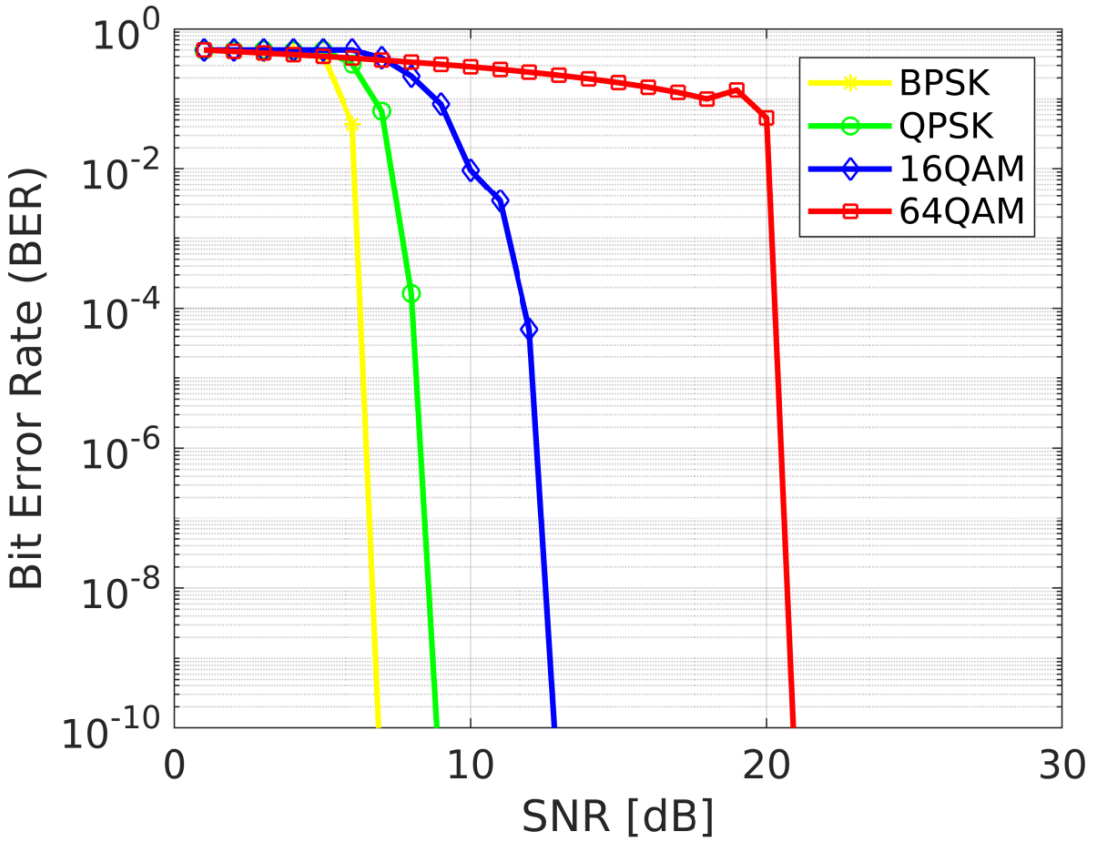
RF



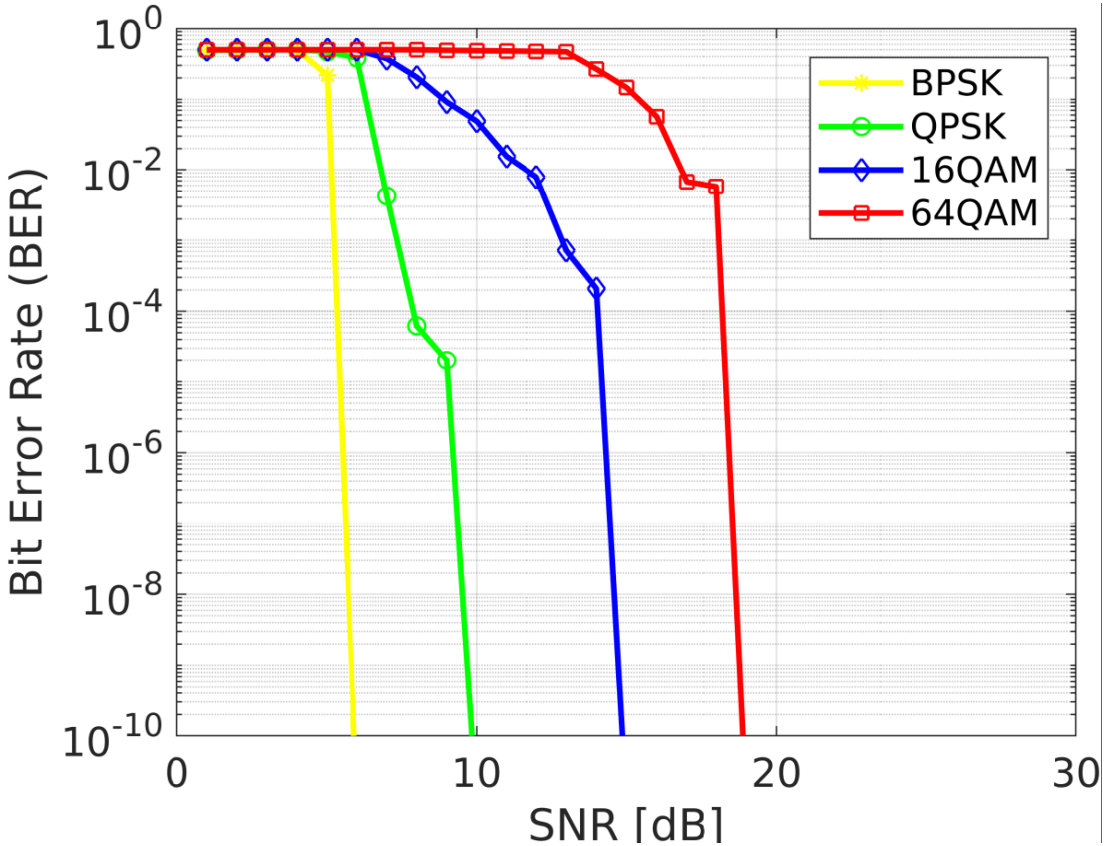
Optical

For the same data rate / MCS the Optical link performs better

Channel Dynamics & Reliability



RF



Optical

Optical link performs better under the same channel as it is directed

Related Work

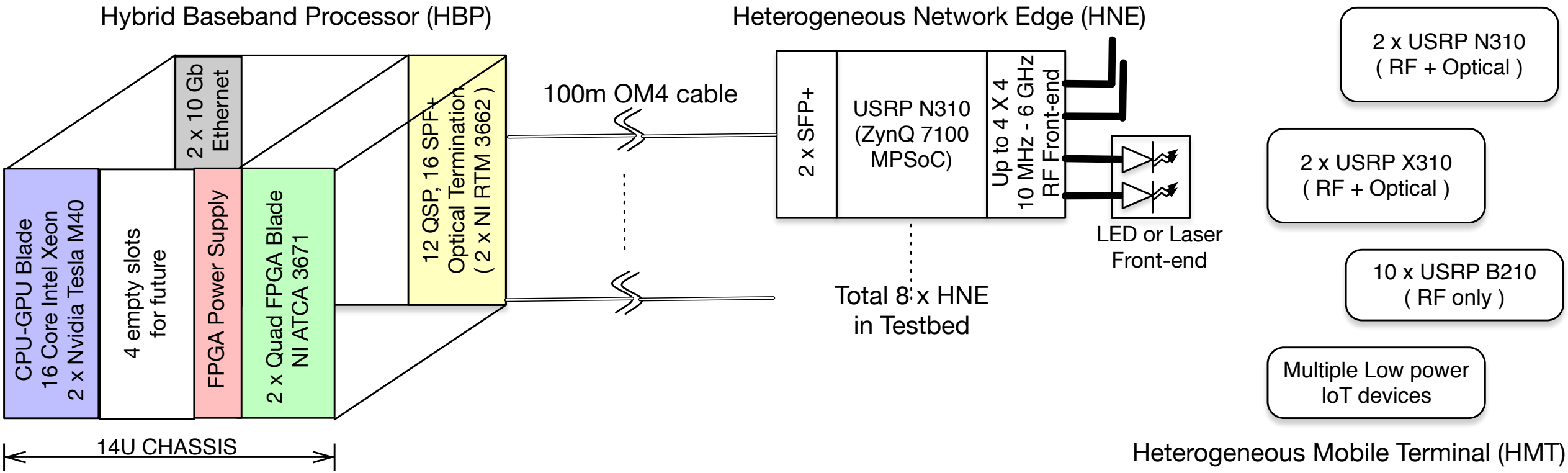
TABLE I: Comparing CHRONOS with existing wireless testbeds

	C-RAN	sub-6GHz	Optical	mmWave & beyond
ORBIT [4]	✓	✓		
TurboRAN [5]	✓	✓		✓
WiSER [6], ROAR [7], WiNEST [8], ArgosNet [9], CORNET [10], Emulab [11]/PhantomNet [12]		✓		
LiRa [13], LESA [14]			✓	
WiMi [15], x60 [16], GigaNets [17], mmVital [18], TeraNova [19]				✓
CHRONOS	✓	✓	✓	work-in-progress

Limitations of Current Setup

- Multiple Tx/Rx chains but single local oscillator.
- Delay between RF & optical paths.
- Coherent detection for Optical transmission

Building a larger testbed



Conclusion

- Explored the features and performance of a next generation RF-optical C-RAN.
- Synchrony opens new avenues of research.
- Realized concrete steps required to scale-up the testbed.