Indian 5G Testbed

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Winter Fog School

Major Goals of 5G testbed

- Encourage existing telecom product startups in India
  - New startups
- Multiply R&D capability to develop 5G solutions for Indian markets
  - Hugely enhance capacity in 5G technology skills
- Demonstrate solutions for India
  - LMLC for Rural network deployments
  - Smart city applications
- Increase India's participation in global forums (3GPP, ITU, IEEE) - present test results for Indian use cases
- Helping government agencies with the correct technical information

Indigenous 5G testbed project

- First proposed by Prof. A. Paulraj
- Funded by Department of Telecommunications (DOT)
- Three-year duration

Build and demonstrate an end-to-end 5G testbed

5G Test Bed Team

IITB

IITH

IITM

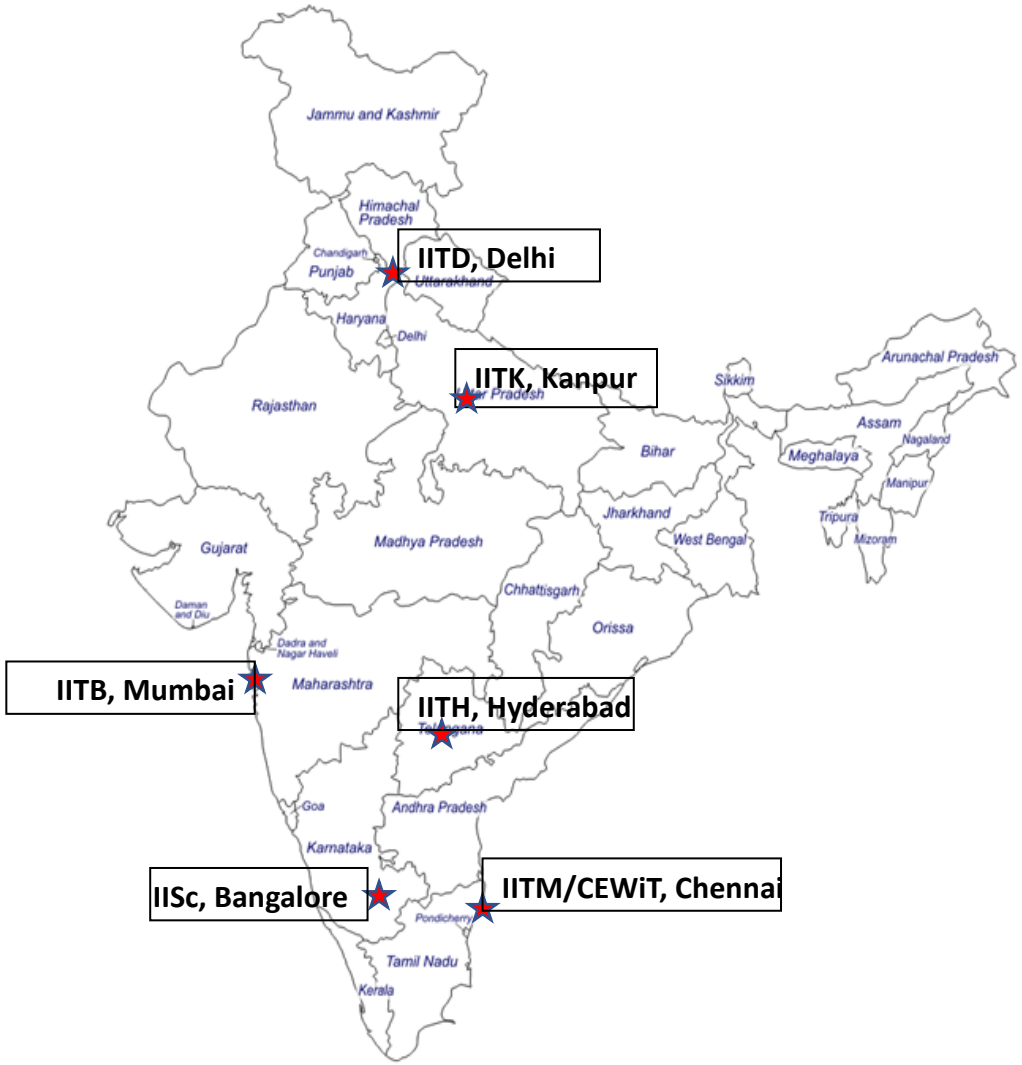
IITD

IISc

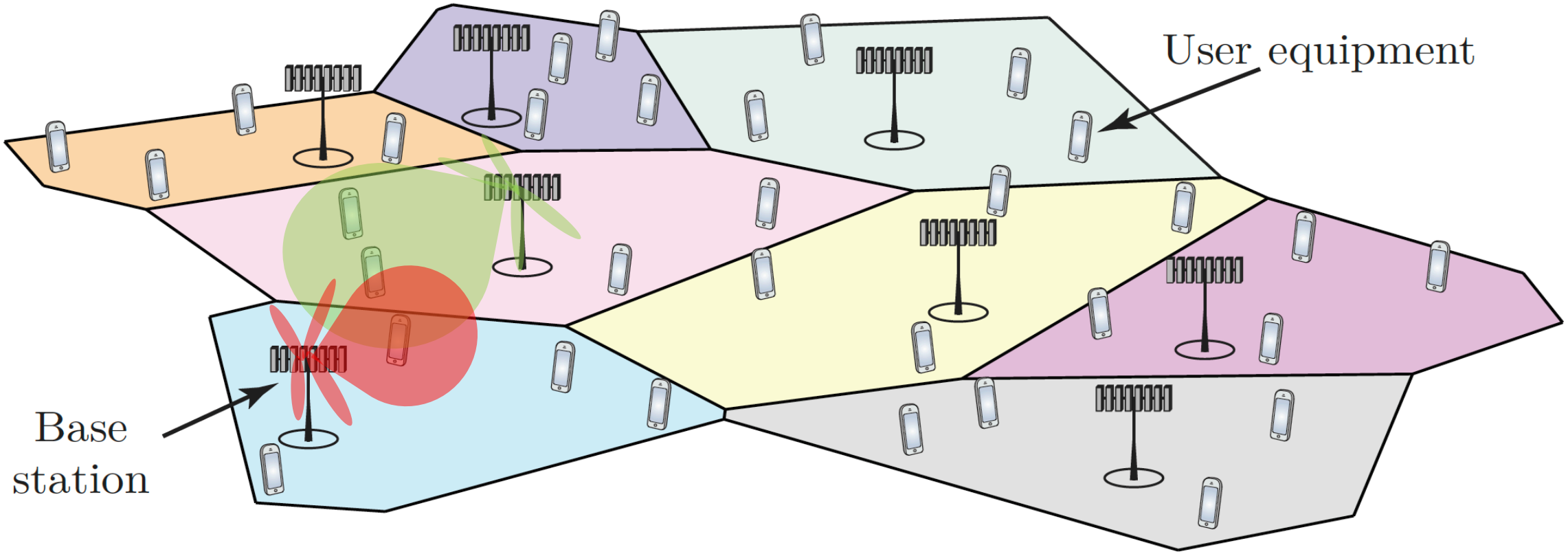
IITK

- 40 Investigators (faculty members/Senior researchers) from 8 institutes
- **Currently 260 employees working on the testbed**
- Engaging with Indian telecom startups for various sub-systems

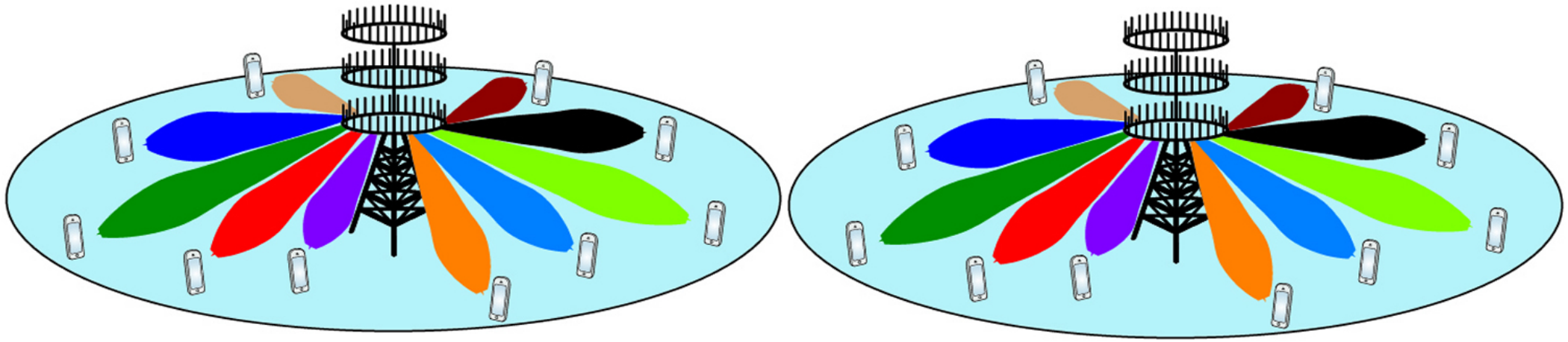
Test Bed Locations



Cellular system layout

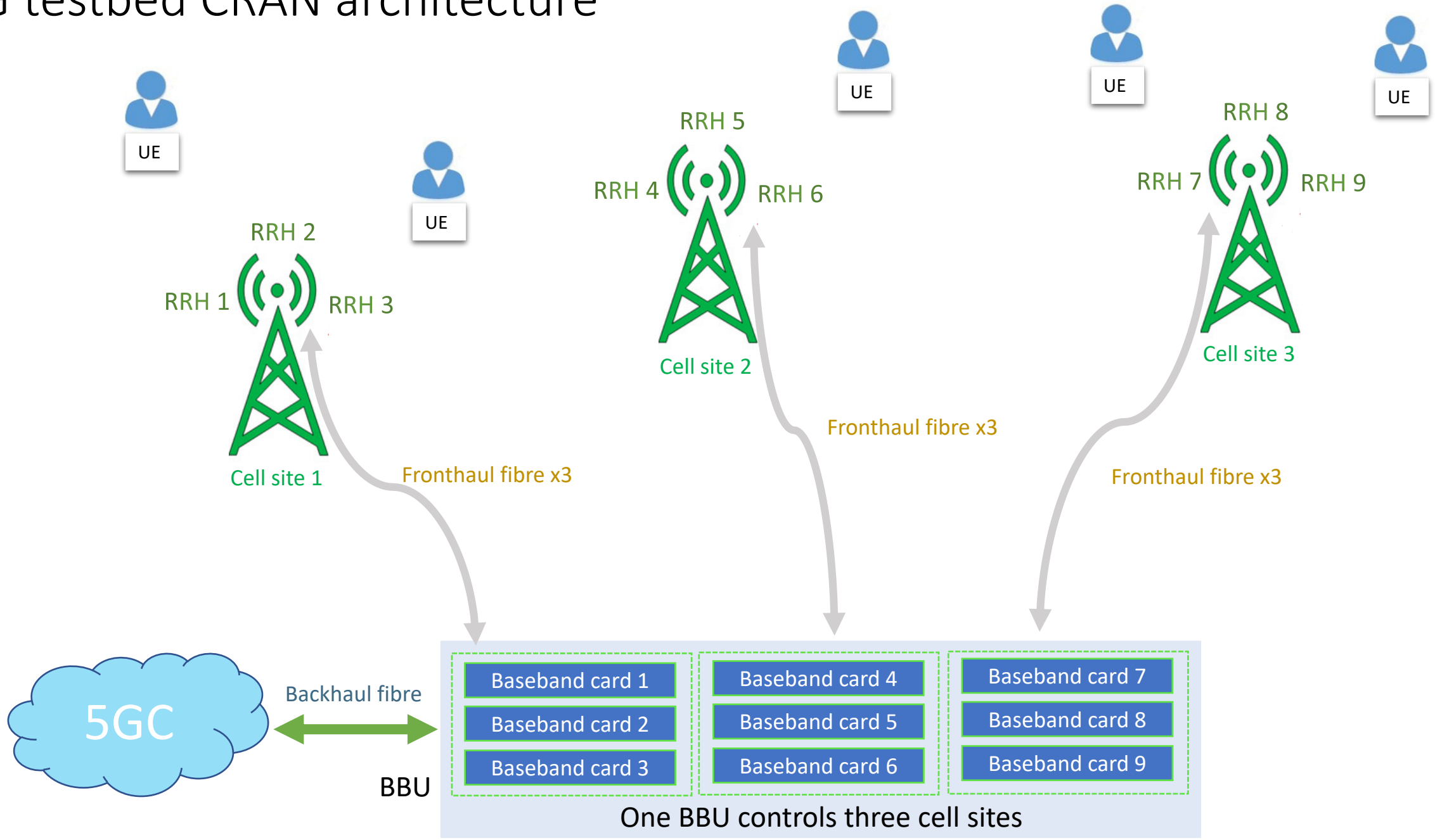


Massive antennas at the BS

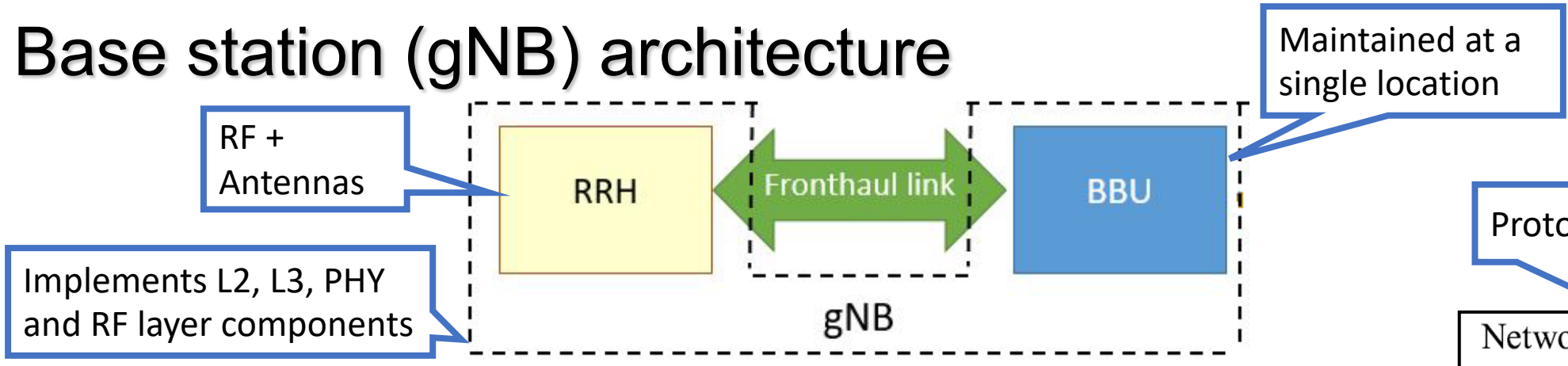


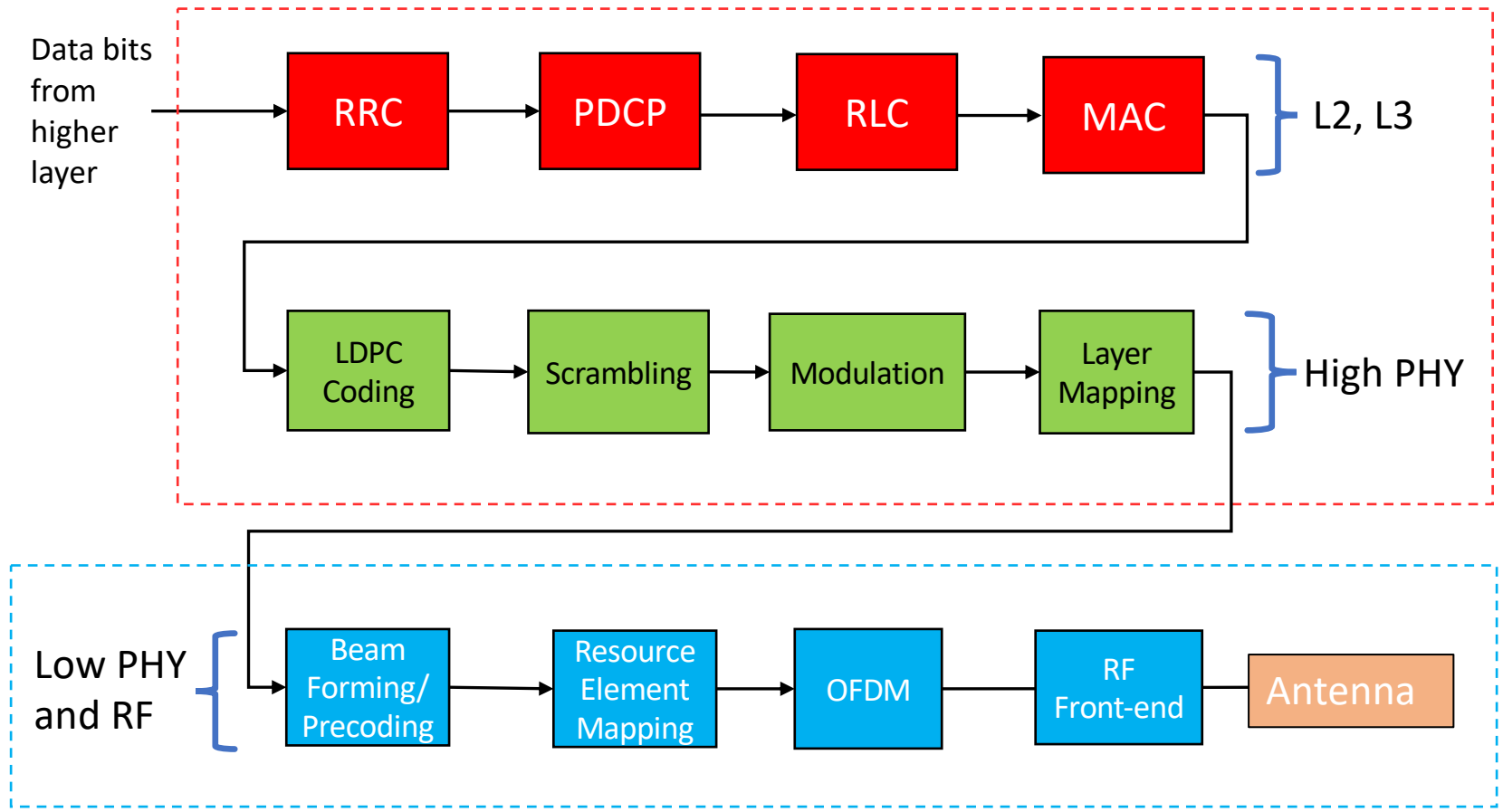
- Large number of antennas help in forming pointed beams towards the users
  - Reduces inter-cell interference

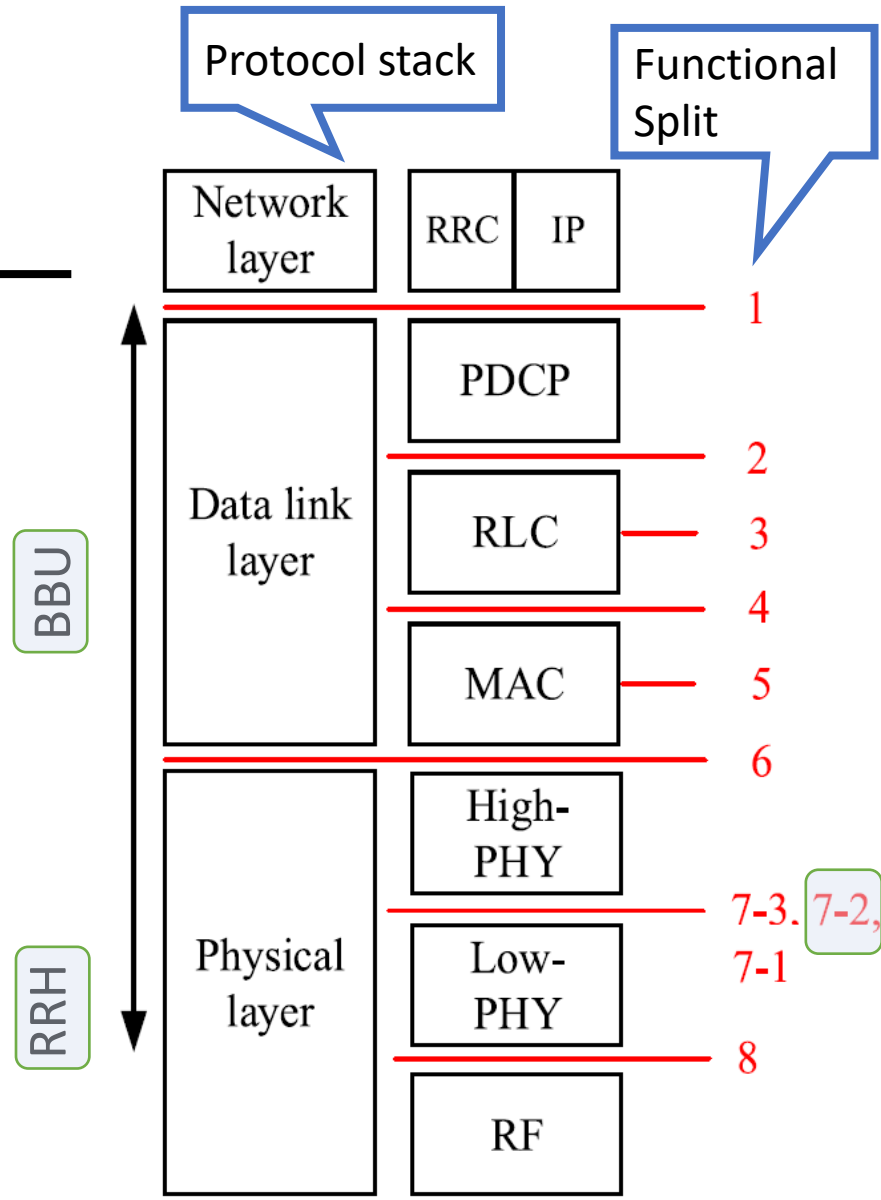
5G testbed CRAN architecture



Base station (gNB) architecture

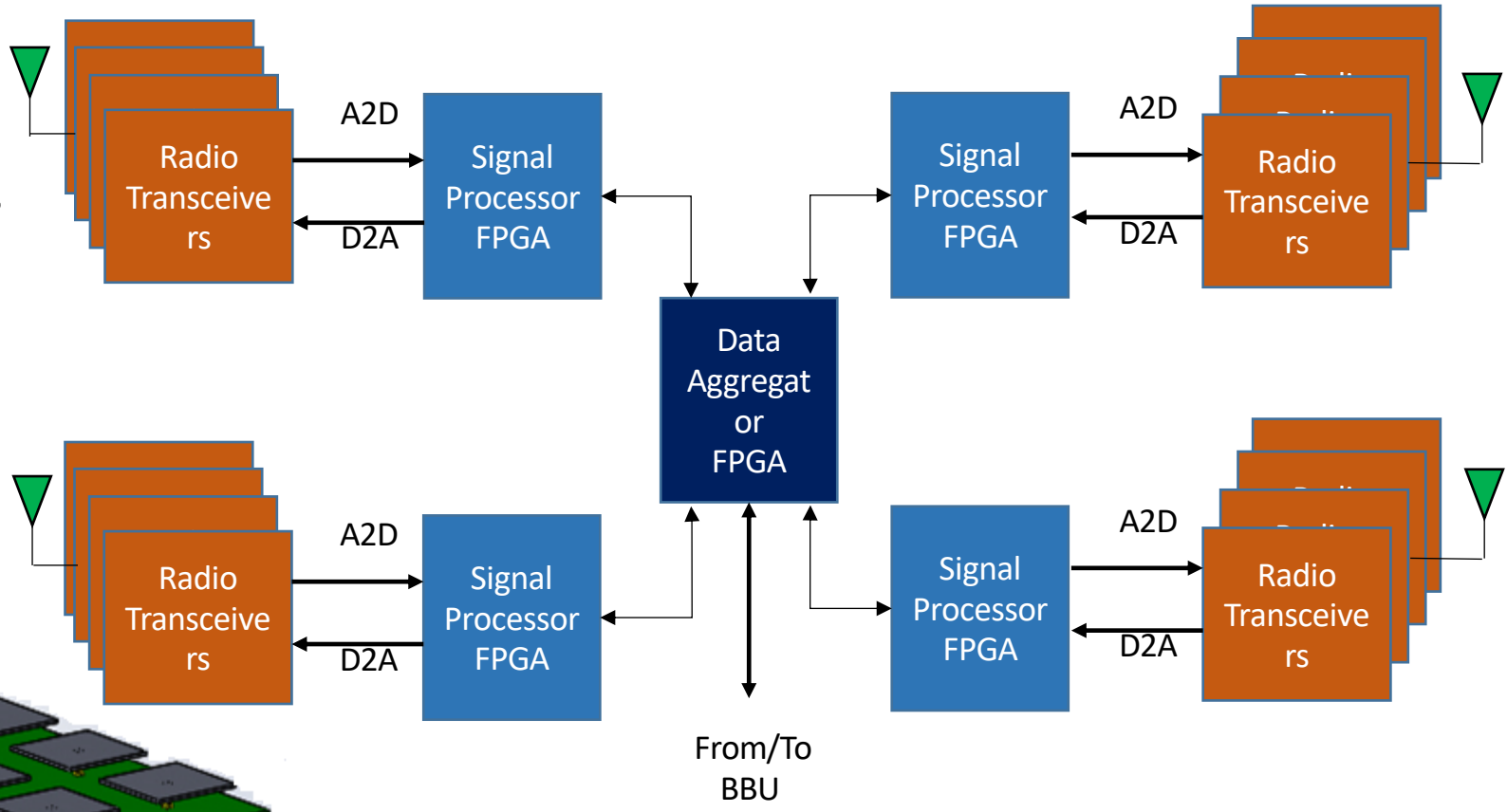


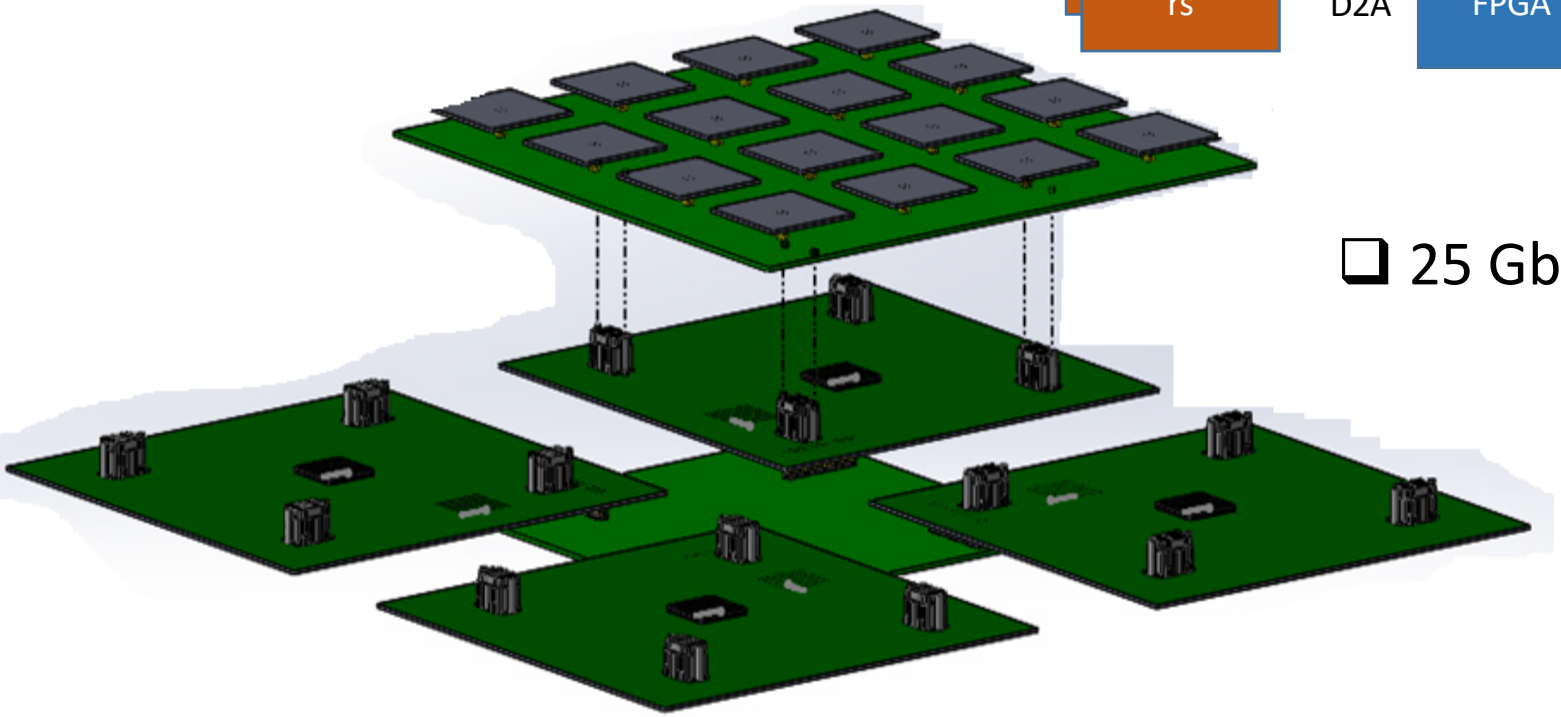




Remote radio head (RRH) for sub 6 GHz

- ❑ Massive MIMO with 64 antennas
- ❑ Each antenna is connected to separate RF chain and ADC/DACs
- ❑ Single FPGA is not sufficient to interface with 64 ADCs/DACs





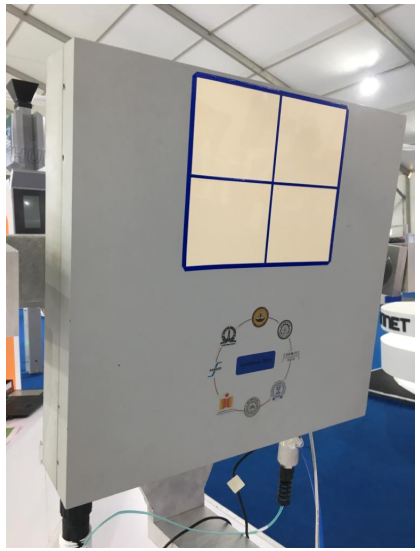
- ❑ 25 Gbps optical ethernet interface to BBU

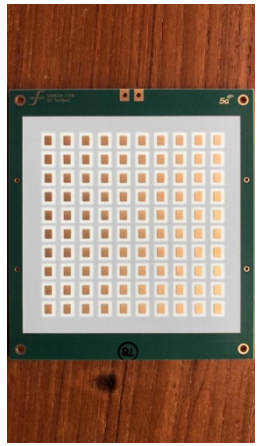
Remote Radio Head (sub 6 GHz)

Designed and built in-house

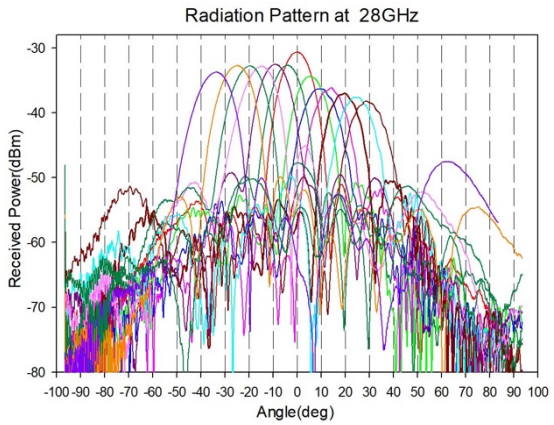
RF Features
• 3.5 GHz • 100 MHz • 64 TRX   • Dual Polarized • 1.5 Watt per Antenna • TDD
Mechanical Features
• IP65 • 33 Kg
Fronthaul
• e-Cpri (10/25G)
Software
• 3GPP (5G NR) • 7.2 split (3GPP)

Remote Radio Head (mmWave)





Designed and built in-house



RF Features

- 28 GHz
- 400 MHz
- 4x 64 element phased array
- TDD

Mechanical Features

- IP65
- 15 Kg

Fronthaul

- e-CPRI (25G)

Software

- 3GPP (5G NR)
- 7.2 split (3GPP)

BBU : Requirements & Architecture

High PHY needs a lot of data crunching at higher clock rates

L2, L3 layer focuses on packets, frames and a lot of decision making

Fronthaul

Baseband card (FPGA)

PCIe

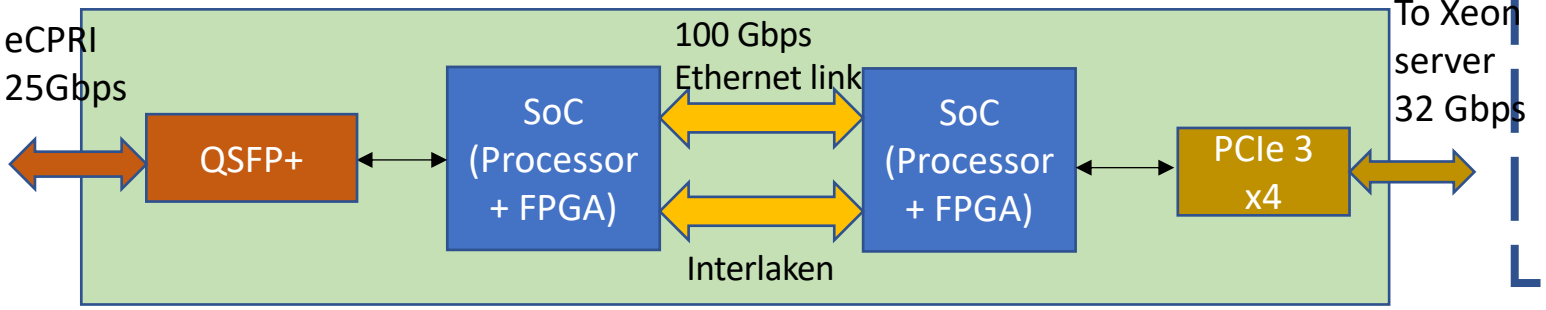
Xeon Server (CPU)

BBU

Backhaul

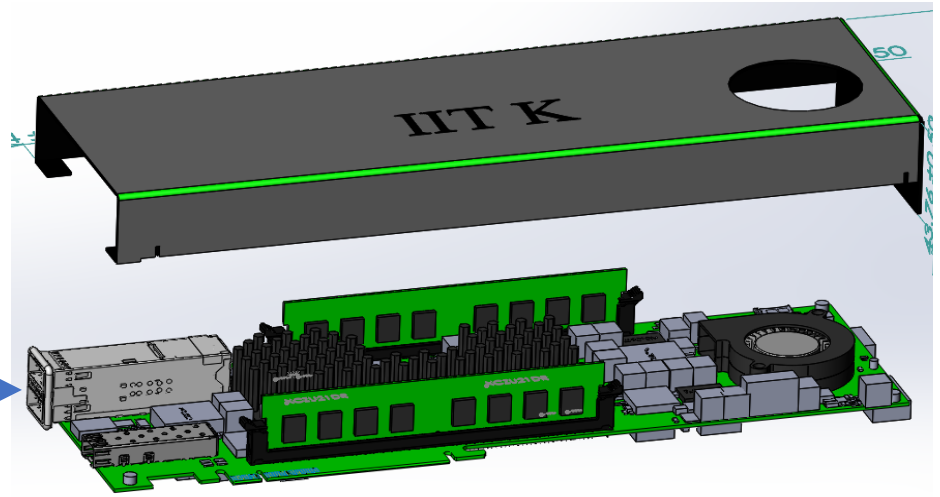
- Channel coding
- Scrambling
- Modulation
- Layer map

- RRC
- PDCP
- RLC
- MAC



BBU = Server + 9 Baseband Cards

Fronthaul



PCIe complaint Baseband card

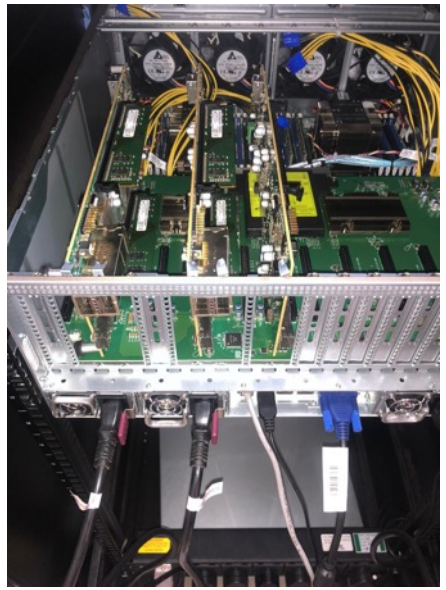
9 Baseband cards

Server with PCIe slots

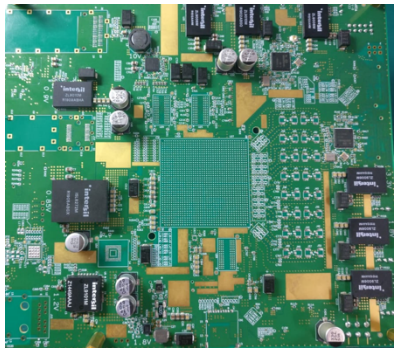
Server rack

Base Band Unit

Features
• PCie • Cloud ready • 4.5 Gbps throughput
Form Factor
Like Tesla card (NVidia)
Front Haul
Like Tesla card (NVidia)
L2/L3 Interface
FAPI
Software
• 3GPP (5G NR)

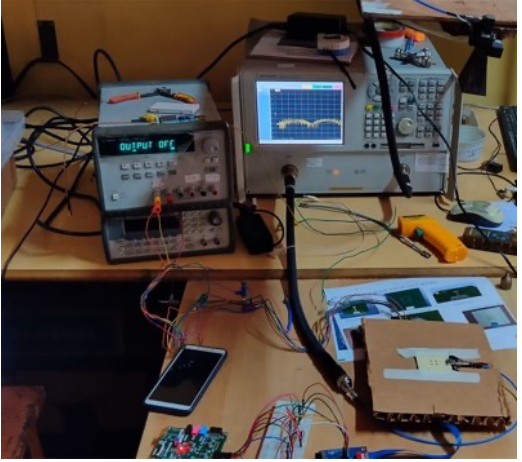


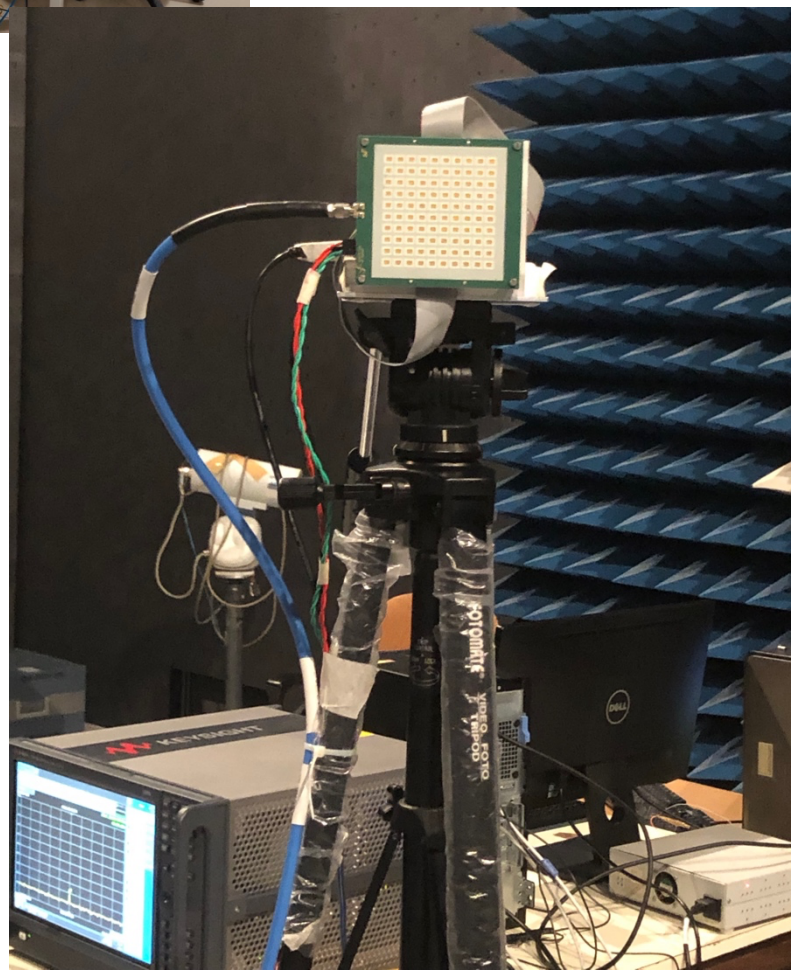
User Equipment



Features

- 2 Antenna
- 3.5 GHz/ 28 GHz
- 100 MHz/400 MHz
- 23 dBm





Labs

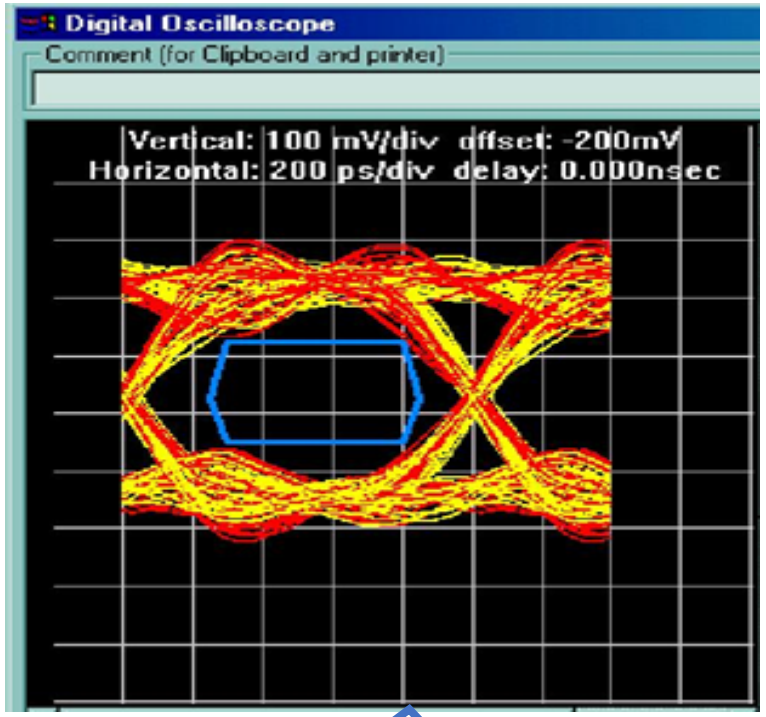
- State of the art 5G Labs have been developed across these institutes
  - 5G test equipment (sub 6 GHz and Mmwave)
  - Requisite Software(s)
  - Protocol testers
- Open to outside companies*

Snapshot of challenges- PCB design

- Impedance mismatch, discontinuities, reflections, ISI, jitter, cross talk and ground bounce

For trace length > 1/10 of wavelength, traces are treated as transmission lines

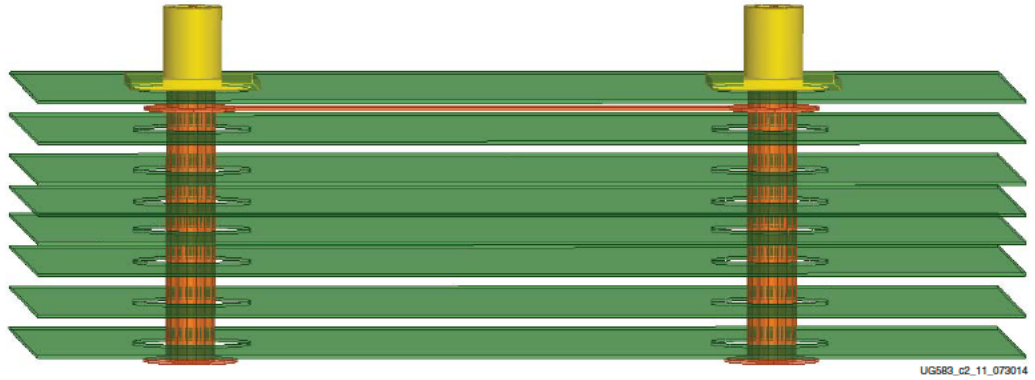
- SI is done for high speed and critical links



Eye diagram is used for SI analysis

❑ Layer stack-up

- specifies the arrangement of circuit board layers



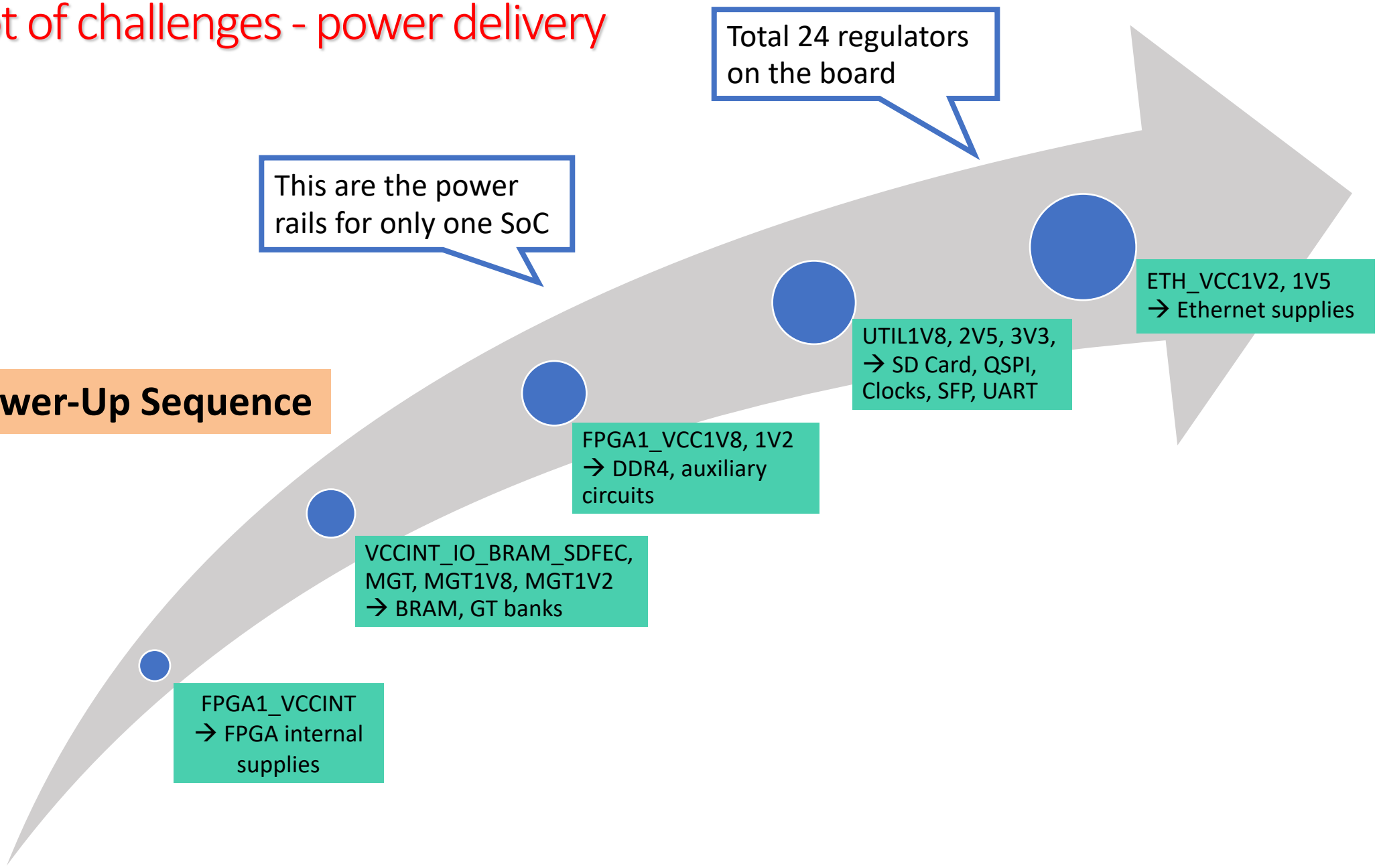
PCB Stack-up -1

PCB stack-up is done, before SI analysis

Makes routing easier

PCB Stack-up -2

Snapshot of challenges - power delivery



Snapshot of testing: Step - 1

❑ Design of board support package

- BSP: OS + device drivers (hardware dependent)
- Allows kernel to communicate with hardware

- BSP contains

Connected peripherals

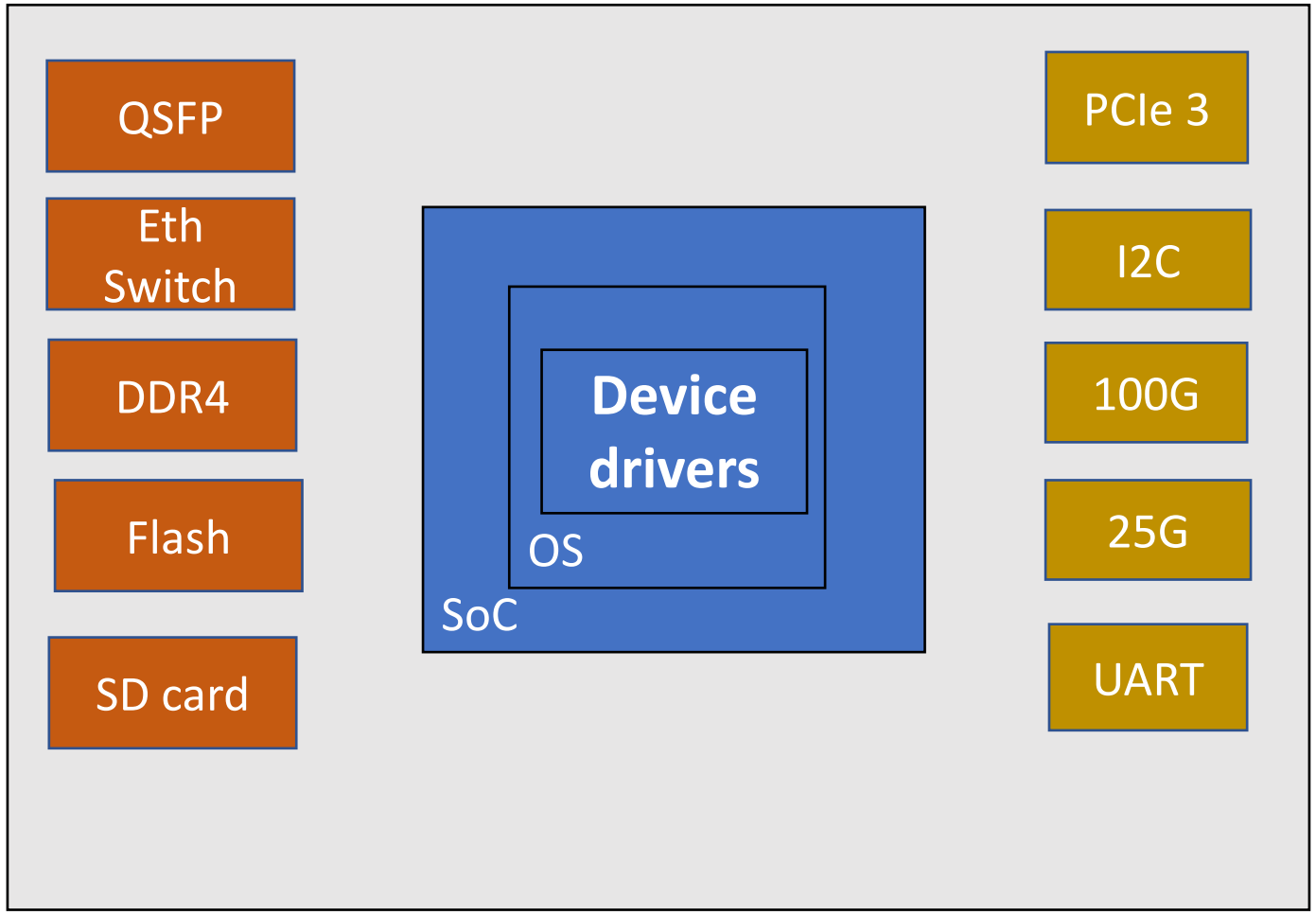
Clock frequency

Connection details

IO pin information

Link speed

IO standard

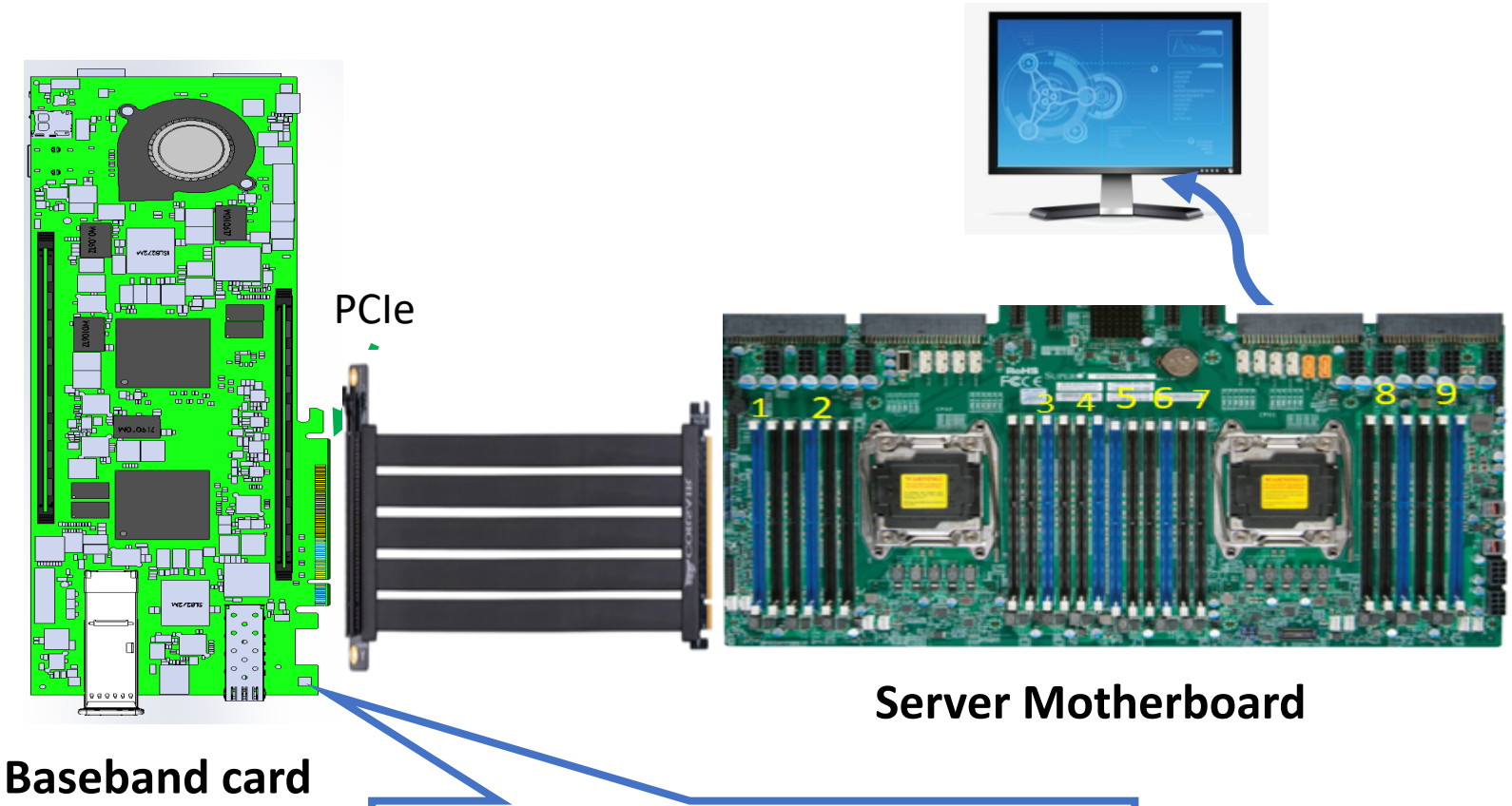


Baseband processing card (only one SoC is shown here)

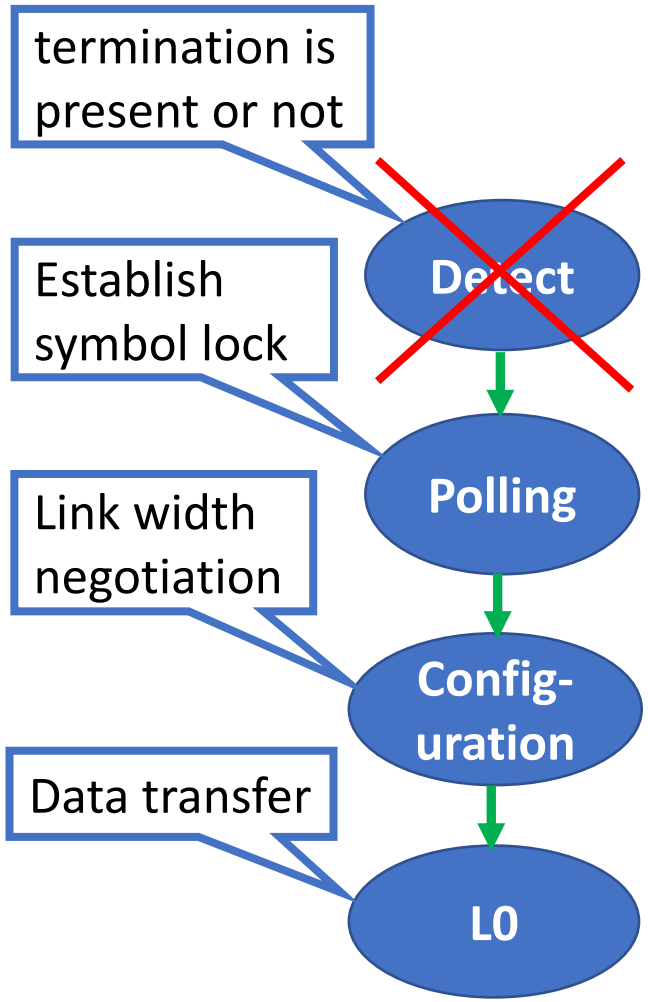
Board testing: Step - 2

❑ Physically testing the board

- Link training for different interfaces e.g., PCI express, 100G Ethernet, eCPRI



Issue: Tx/Rx of PCIe was connected to Tx/Rx of GTY instead of Rx/Tx



Major subsystems that are being developed

- Sub 6 GHz full-digital mMIMO remote radio head (RRH)
  - 64 Antenna systems (Sub 6 GHz)
  - Radio, front end
- Integrated mmWave hybrid RRH
  - Development of hybrid analog/digital architectures
  - 256 Antenna (with 4 streams)
- 5G Base band unit (BBU)
  - 5G NR (3GPP 38 Series) compliant
  - SA mode
  - Supporting lower bands (< 6 GHz) and higher bands (> 6 GHz).
- 5G Core Network
  - SDN based
  - Multi-RAT using WiFi etc
- Management layer for test bed management

Major subsystems that are being developed [Contd.]

- IoT (Internet of Things)
  - End-to-end IoT network using a mix of commercial and prototype components
  - ASIC
- Security
  - Security for IoT will be a special focus
  - Security for SDN and NFV architectures will be a new challenge to address
- Li-Fi
  - Giga bits range high-speed Li-Fi system
- Devices
  - Mix of devices developed and commercially available

5G testbed work breakup

CEWiT	UE L1/L2/L3, Baseband Algorithms, Core Network
IIT Bombay	Core Network
IIT Hyderabad	NB-IoT ASIC, gNB L1/L2/L3
IIT Madras	gNB/UE Hardware Platforms, gNB L1, Core Network
IIT Kanpur	gNB BBU Hardware Platform, gNB L1
Sameer	Antennas, RF modules
IISc Bangalore	Baseband Algorithms, gNB L1 (open stack) IoT, LiFi
IIT Delhi	Baseband Algorithms, LiFi, Security

Conclusions

- 5G Testbed being built from scratch
  - Remote radio head hardware and software for sub 6 GHz and mmWave bands
  - Baseband unit hardware and software
  - UE hardware and software
  - Core network
- Extreme hardware engineering
  - Design of 20+ layers of printed circuit boards with 100 Gbps interfaces
  - 64 RF transceiver sub 6GHz fully-digital hardware
  - Mmwave hybrid RF transceivers

Thanks