Tarana G1 Advanced Training

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G1 Platform Summary - Base Node (BN)

Integrated Base Node

Baseband
Massive MIMO antenna array
Multi-TFLOPs computation
Carrier ethernet switch
GPS receiver

- Dual Carrier 2x40 MHz
- Distributed Massive MIMO — with antenna arrays on both ends
- 6 spatial planes (MU-MIMO)
- Up to 256 users per sector
- Full Tx/Rx digital beamforming with interference cancellation
- 4D Scheduler
- Range : NLoS up to 3 km, LoS 15 km

G1 Platform Summary - Remote Node (RN)

Dual Carrier 2x40 MHz

2x2 MIMO

Max DL:UL 640/140 Mbps (2x2 MIMO) (DL/UL 4.5:1)

Full Tx/Rx digital beamforming with custom silicon IC

Auto antenna alignment (5000/sec)

PoE powered

G1 Platform Summary - Tarana Cloud Suite (TCS)

TCS Overview

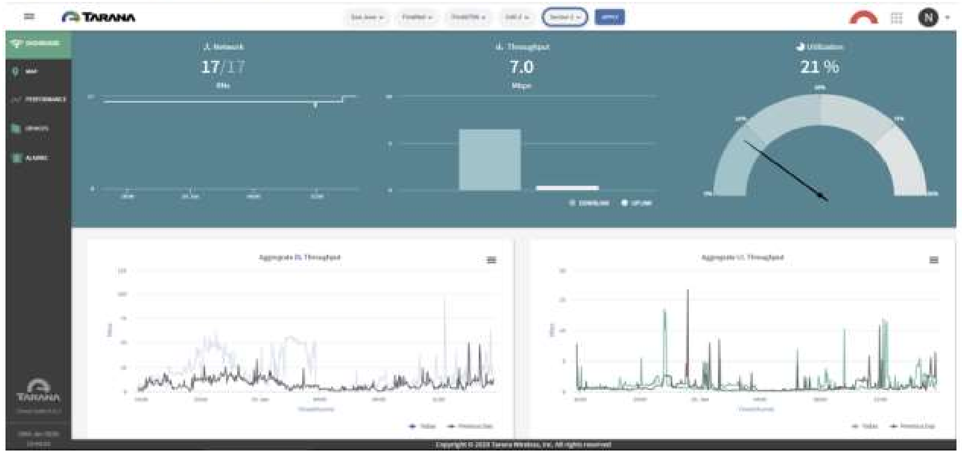
Subscriber Service Activation
– Zero-Touch Deployment

Management and Maintenance Features
KPI monitoring and management
Fault logging, correction and reporting Firmware and configuration management

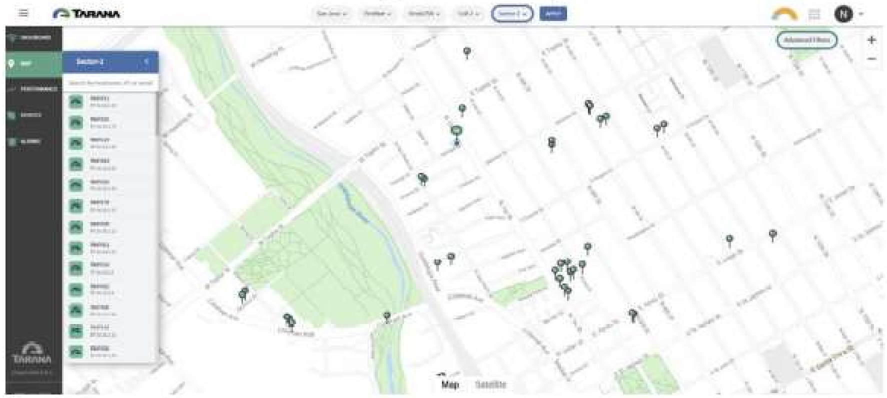
Network Analytics

Northbound Interface for the Carrier's System Integration

Dashboard

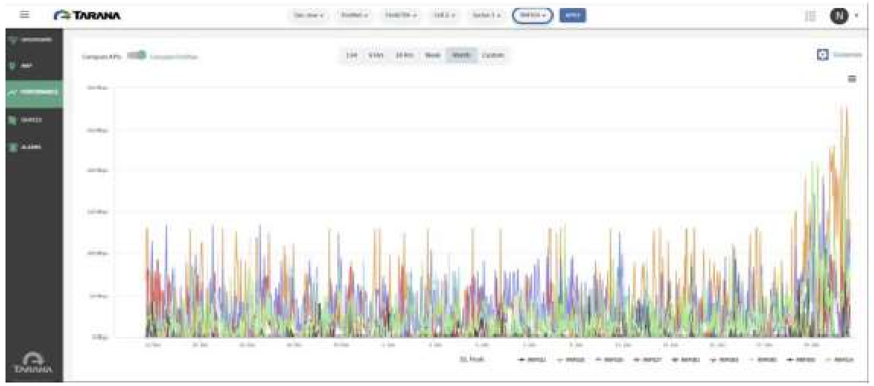


Integrated Google Map



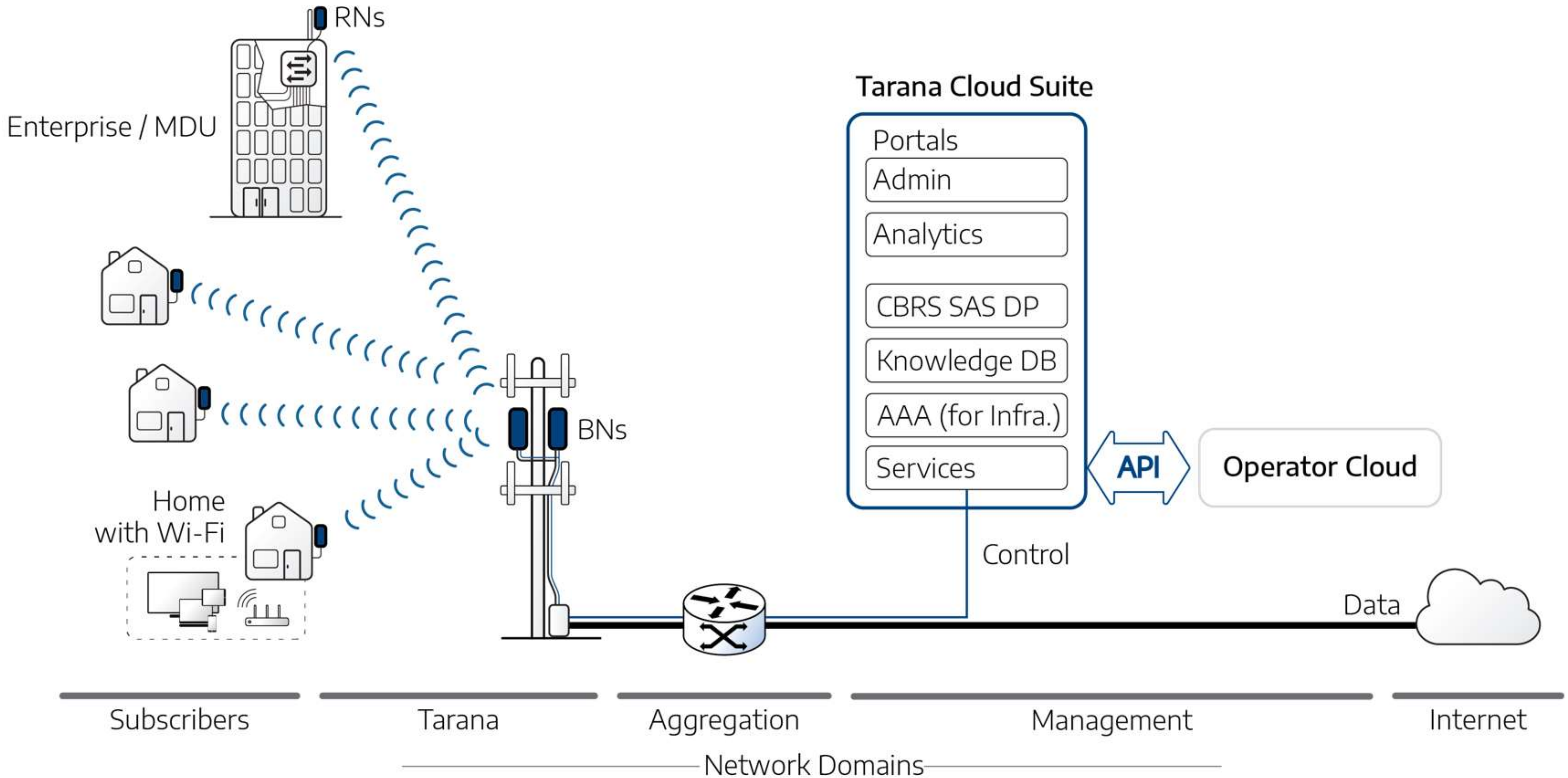
Alarms

KPI Charts



Inventory / Live Stats

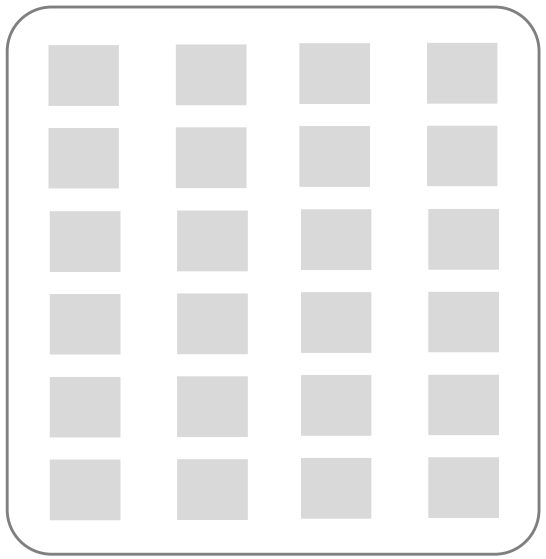
G1 Platform Summary – E2E System Architecture



G1 Hardware – Antenna Array

5 GHz RN Antenna

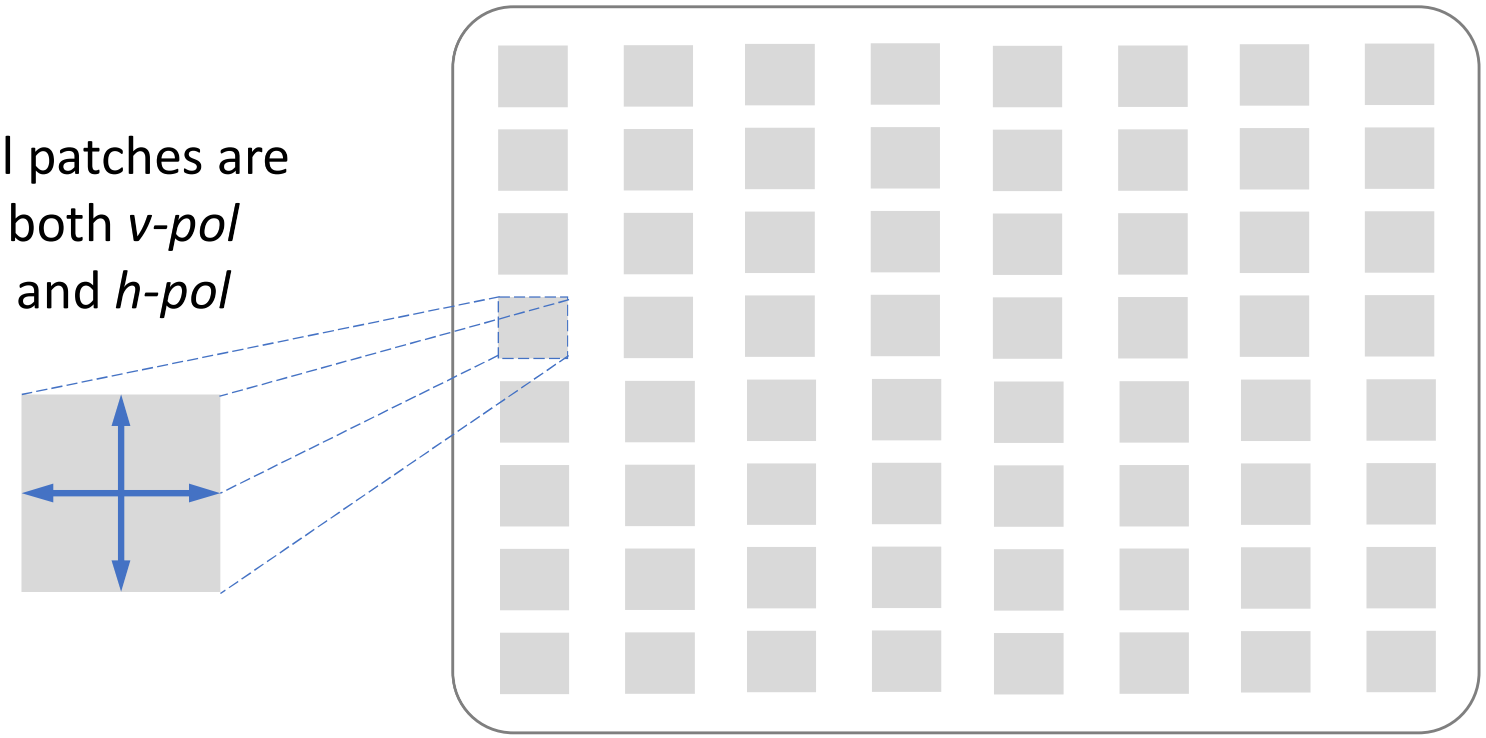
4 x 6 patch array



5 GHz BN Antenna

8 x 8 patch array

All patches are both *v-pol* and *h-pol*

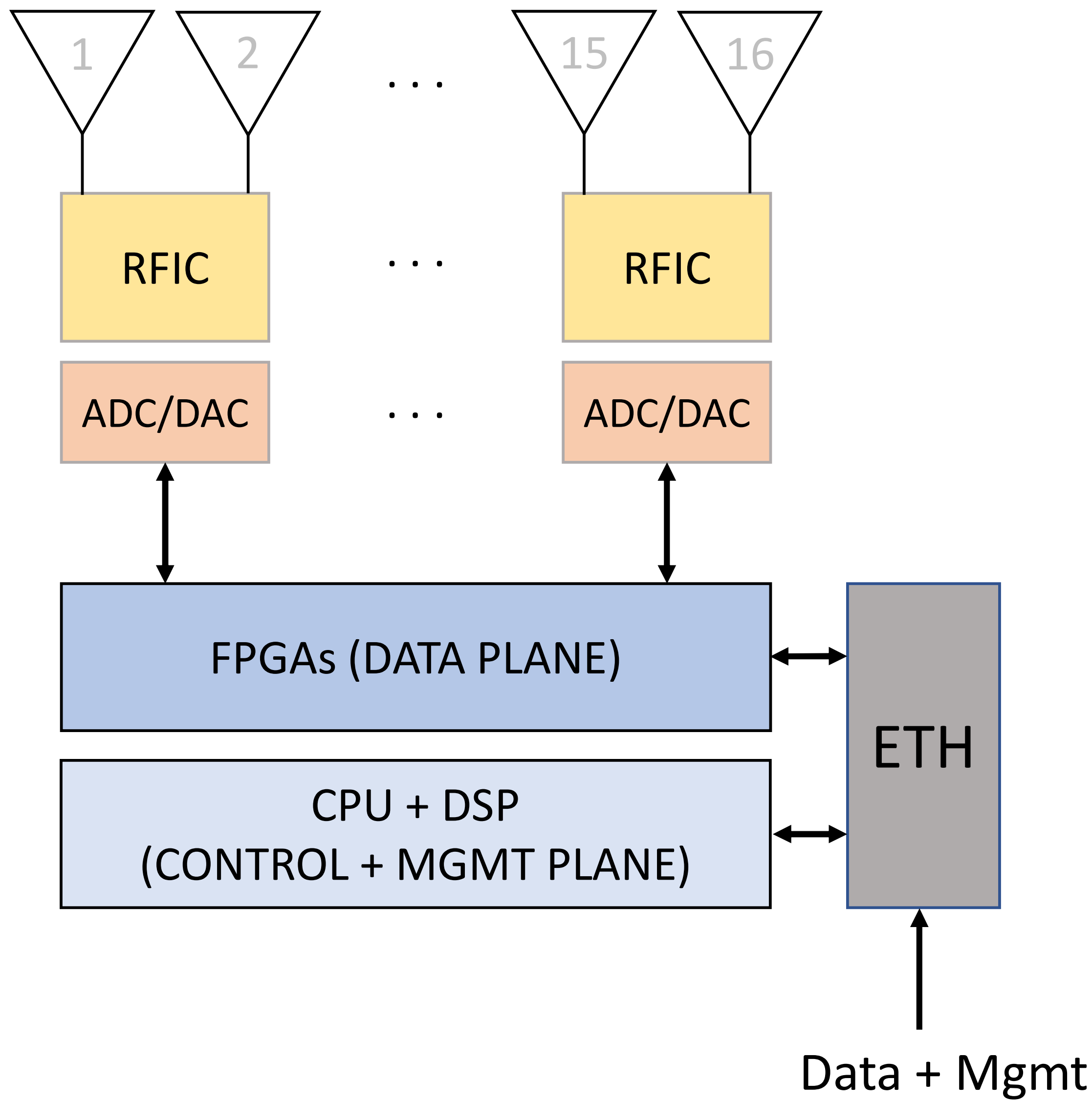


G1 Hardware - BN Architecture

The BN is a highly integrated unit consisting of a radome, antenna array, RF processing assembly, digital processing assembly and enclosure.

The BN uses a 16T16R architecture and has a PA, LNA, and RF bandpass filtering for each antenna feed.

The digital processing assembly is FPGA based.

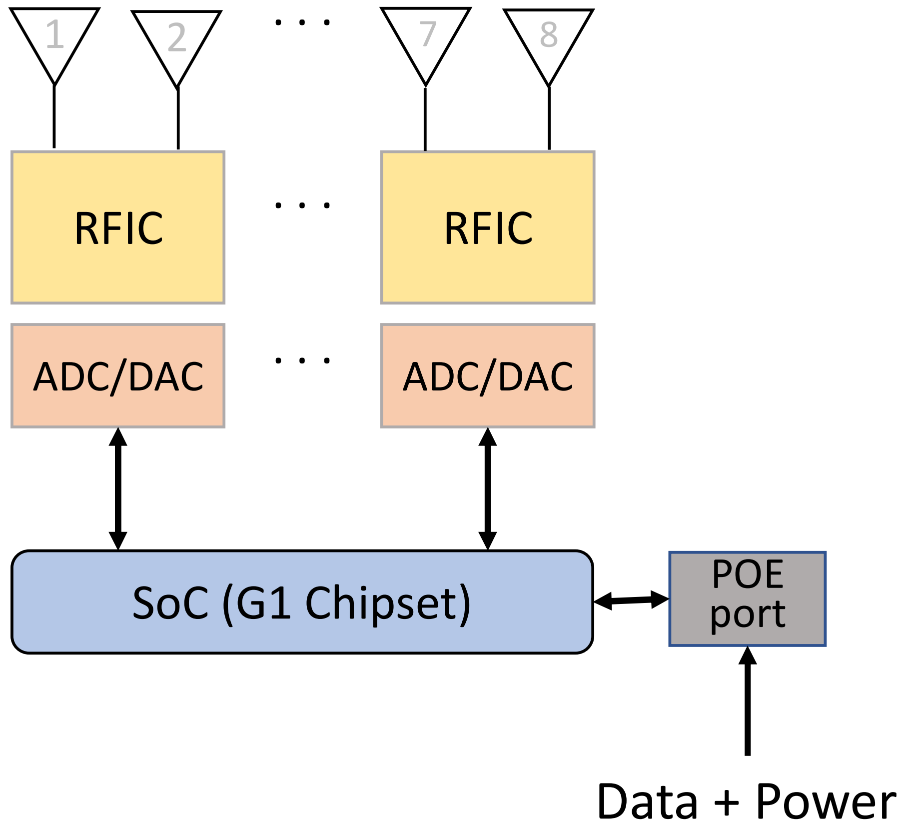


G1 Hardware - RN Architecture

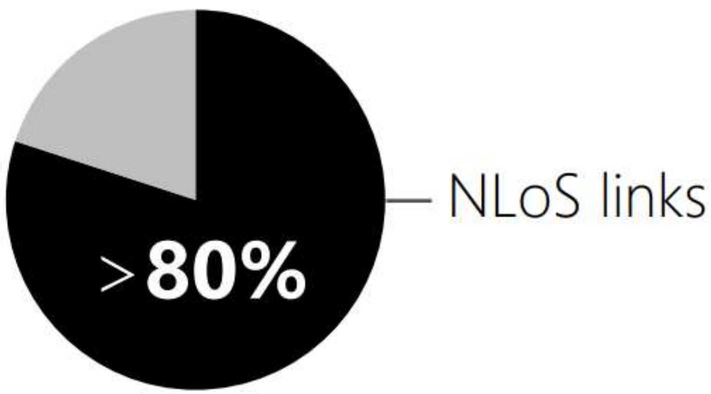
The RN is a highly integrated unit consisting of a radome, antenna array, RF and Digital processing assembly and enclosure.

The RN uses an 8T8R architecture supporting beam-forming toward the intended base station and null steering in the direction of other adjacent cell BN interference.

The RF and Digital processing assembly incorporates the Tarana G1 chipset.



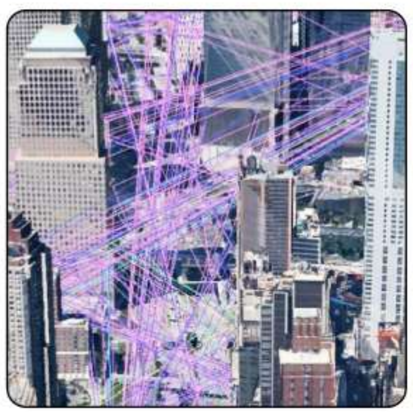
Principals of Operations - Technical Challenges in Wireless Access Networks



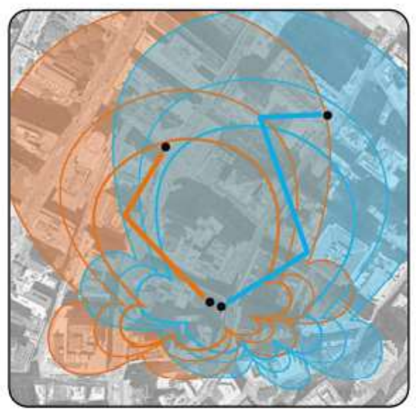
1. Very limited spectrum

Physics work, but oversubscribed for mobile access
3.5GHz (CBRS in US)
5GHz unlicensed, very crowded

2. Multipath



3. Co-Channel Interference

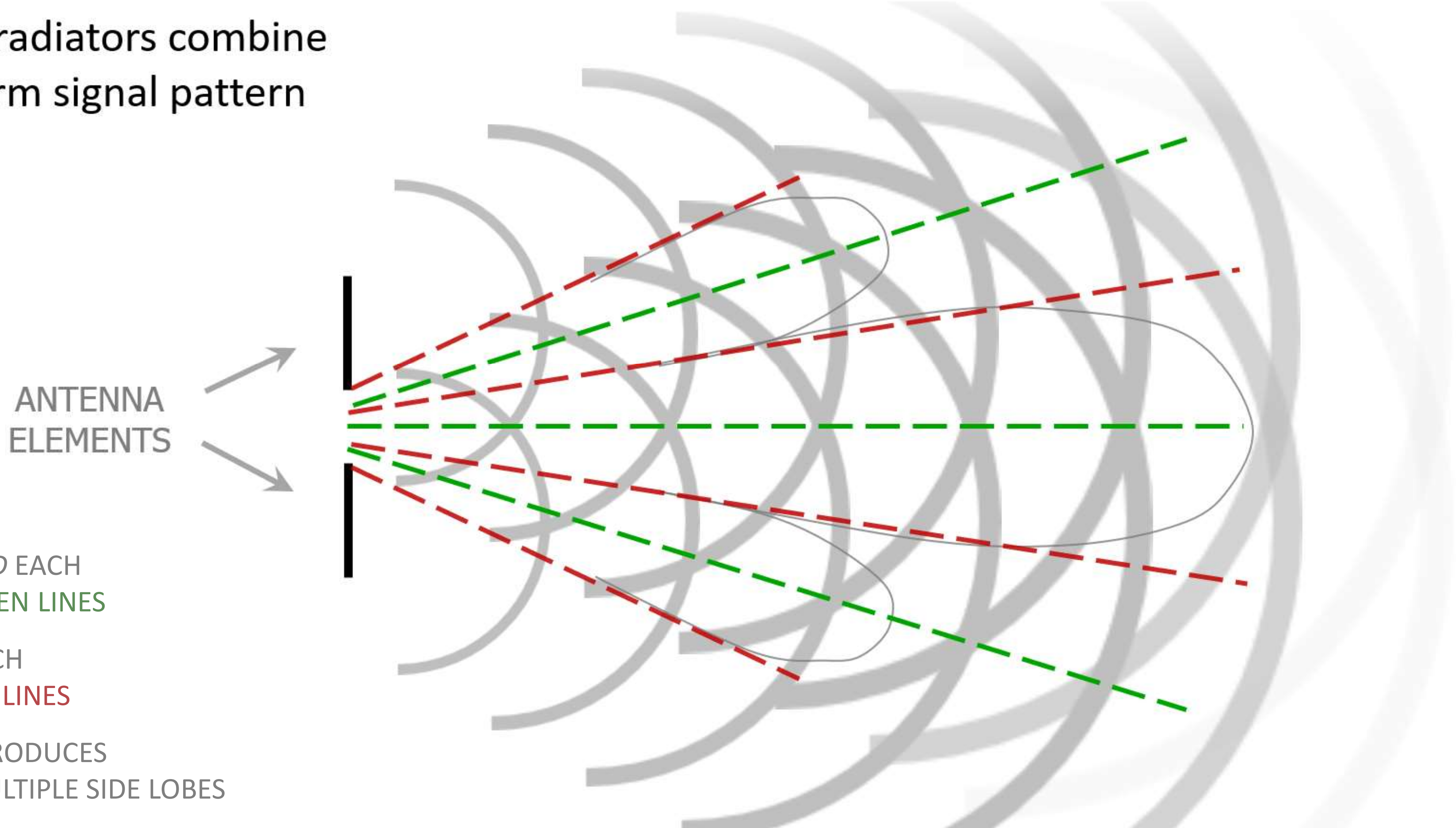


4. Wi-Fi Interference

5. Changing Conditions

Principles of Operations– Beamforming (Tx Signal Pattern)

Two dipole radiators combine waves to form signal pattern



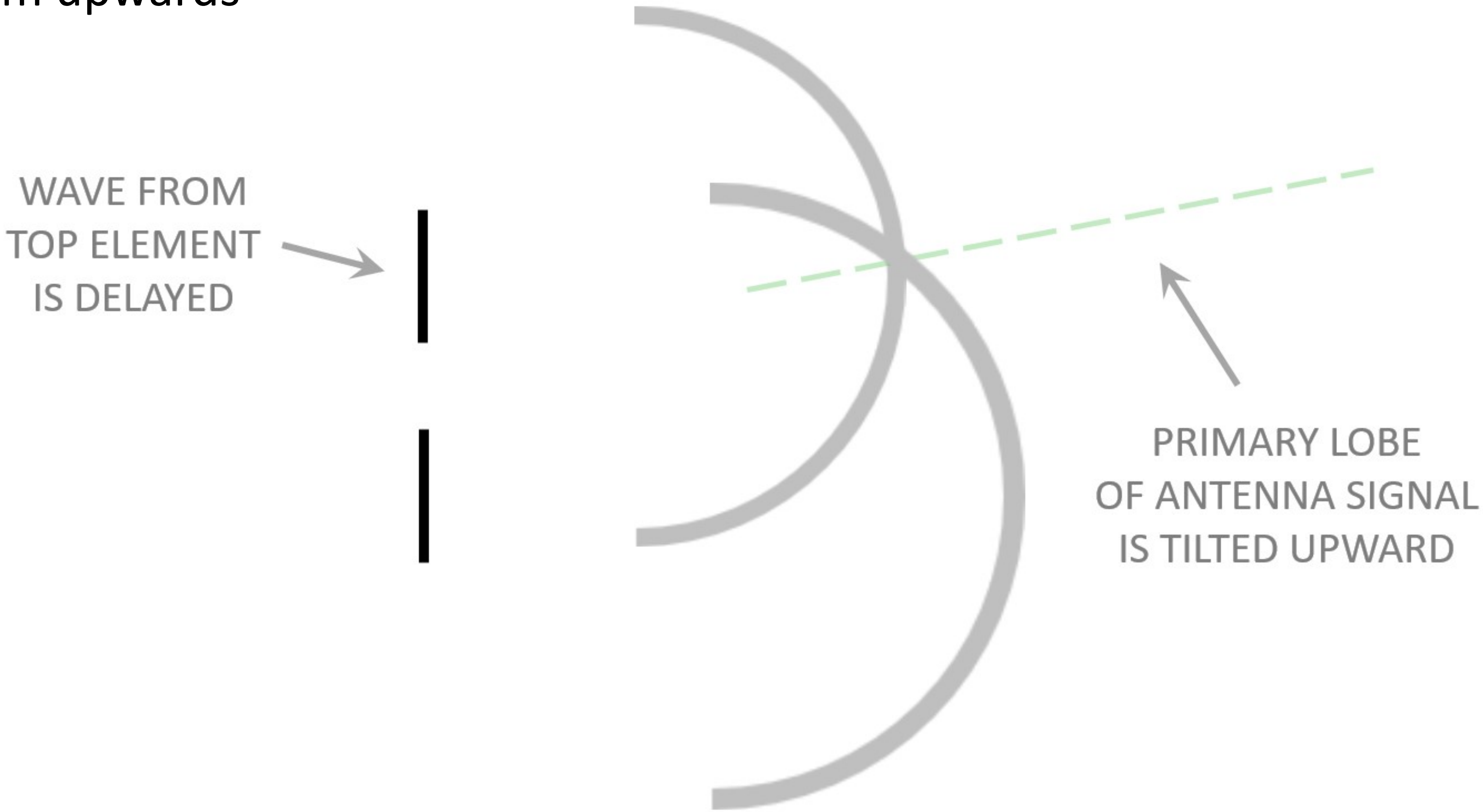
WAVES *COMPOUND* EACH OTHER ALONG GREEN LINES

WAVES *CANCEL* EACH OTHER ALONG RED LINES

OVERALL EFFECT PRODUCES PRIMARY LOBE, MULTIPLE SIDE LOBES

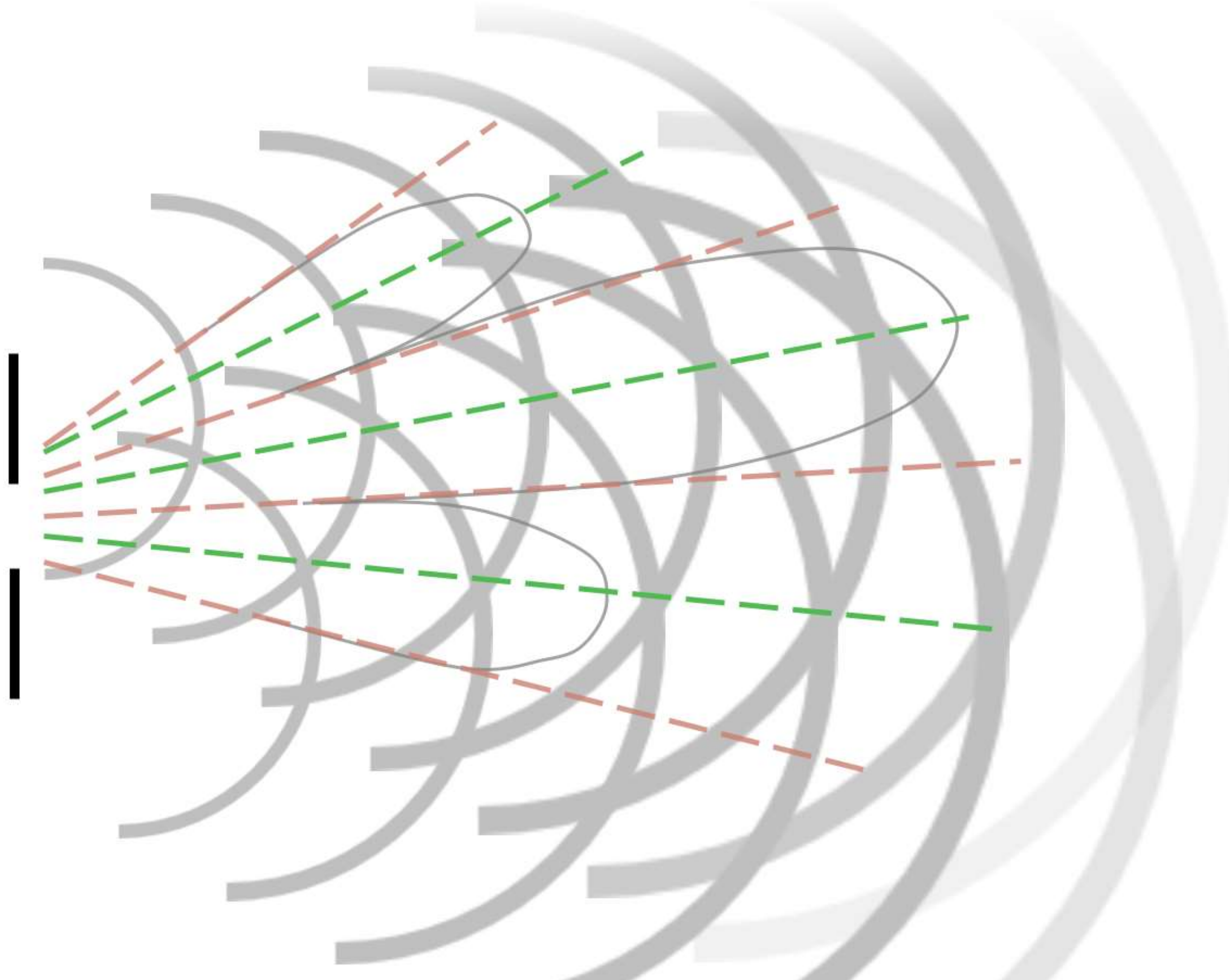
Principles of Operations– Beamforming (Tx Signal Pattern)

Timing delay element is used to beamform upwards



Principles of Operations– Beamforming (Tx Signal Pattern)

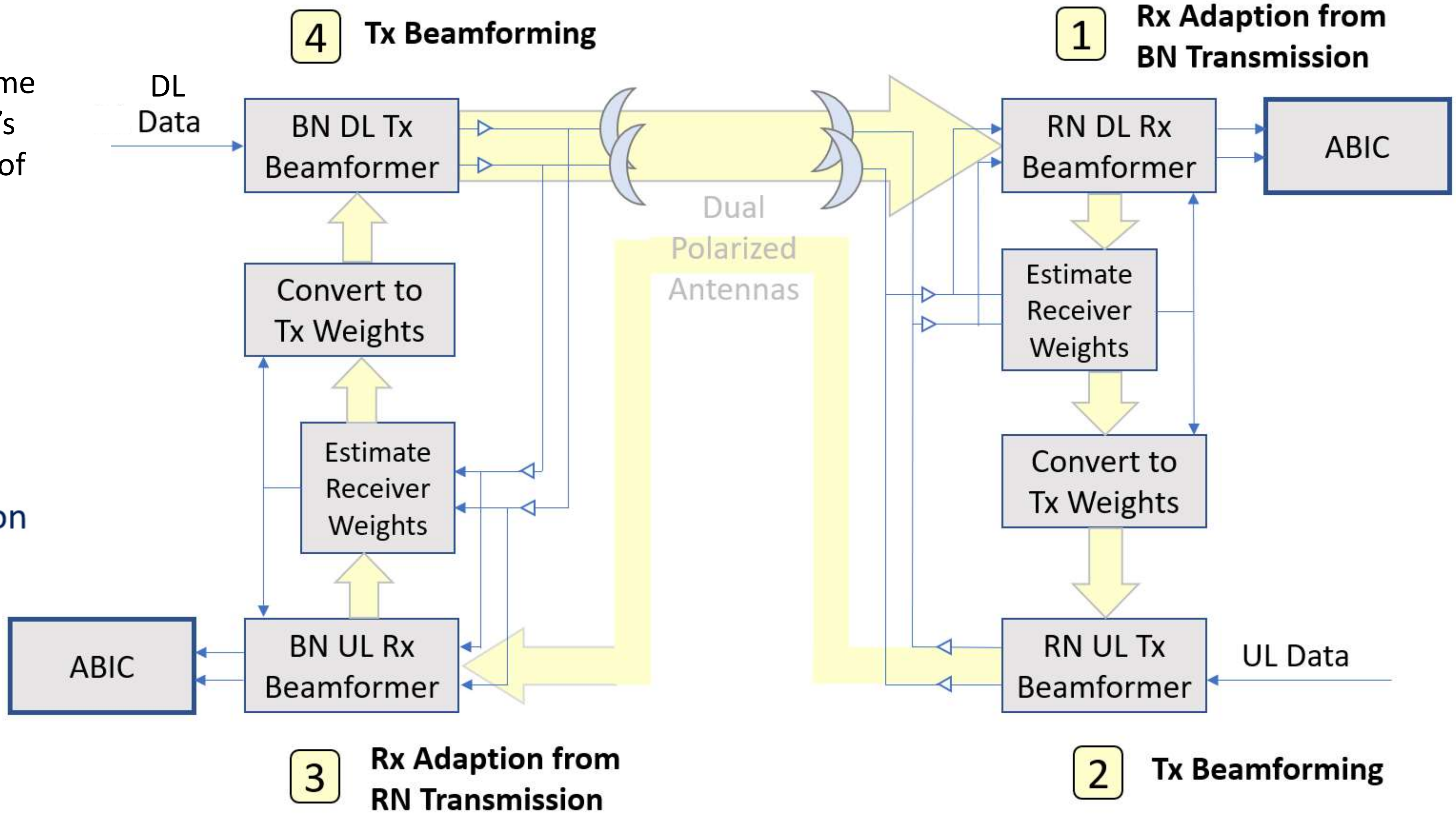
Entire signal pattern
is tilted upward
(both lodes and nulls)



Principles of Operations – Auto-Convergent Retro-Directive Beamforming

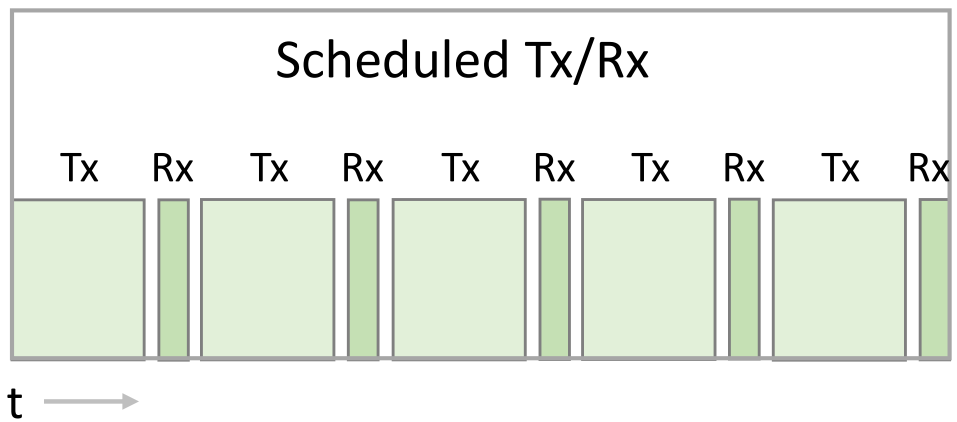
The RN and BN independently become aware of each other's respective direction of location

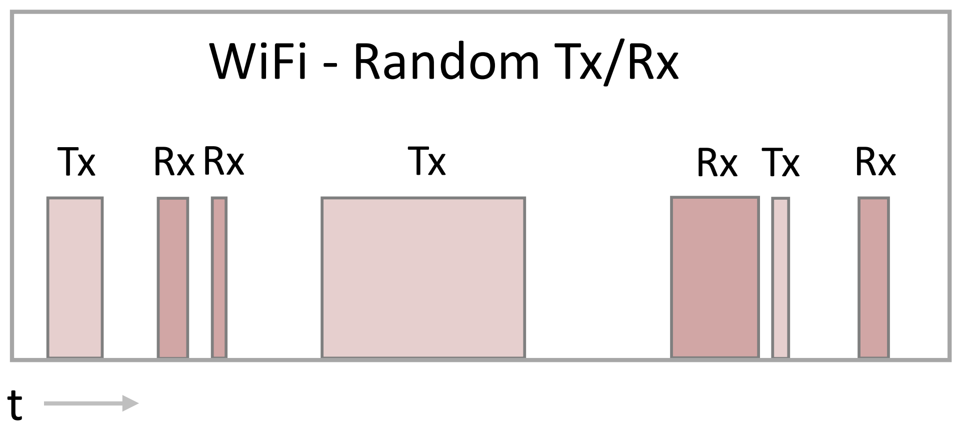
*Real-time BEAMFORMING every 5 ms
*ABIC computation every 100 µs

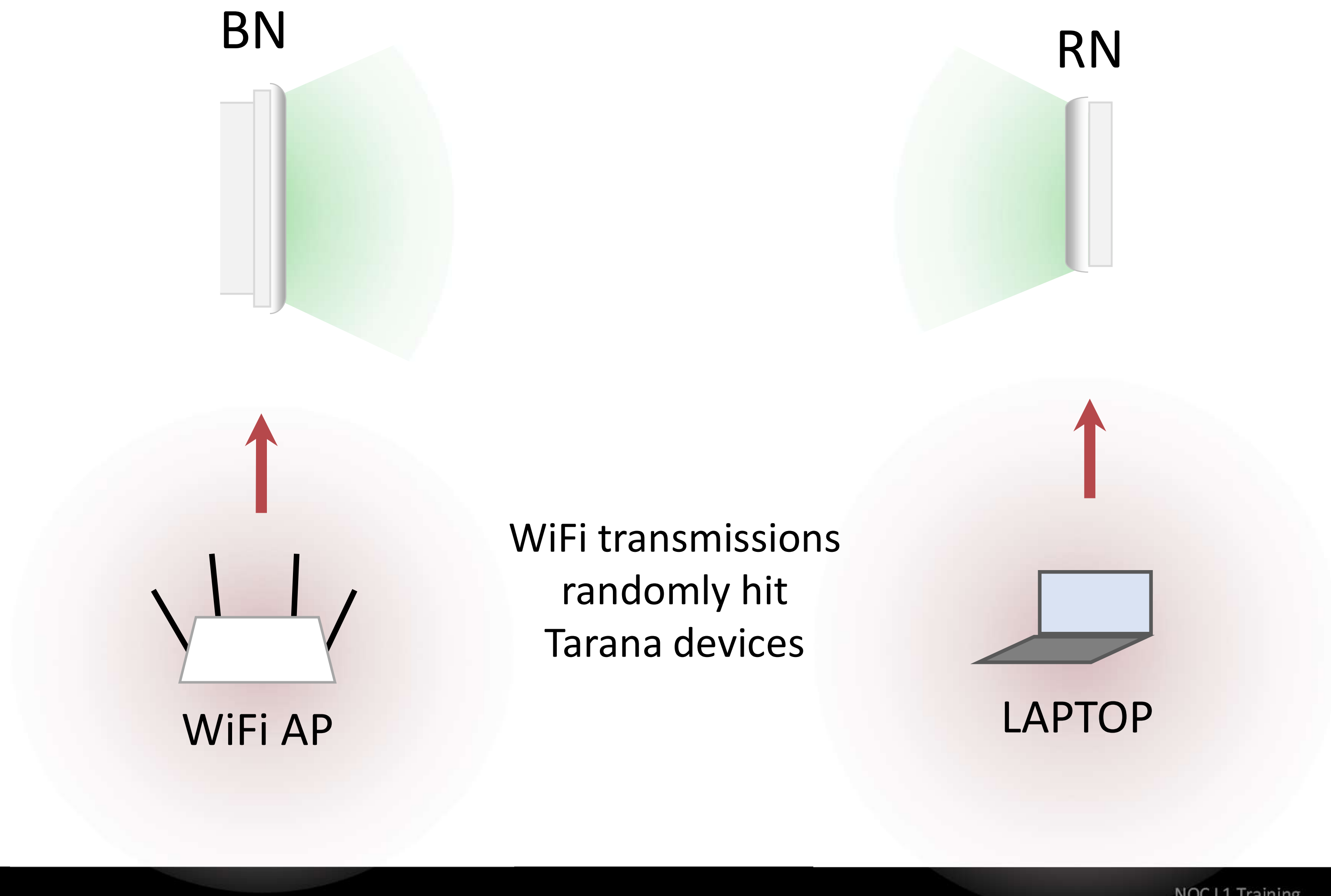


Principles of Operations – The Need For Asynchronous Burst Interference Cancelation

WiFi Transmissions are not predictable, and send randomly-timed interference.

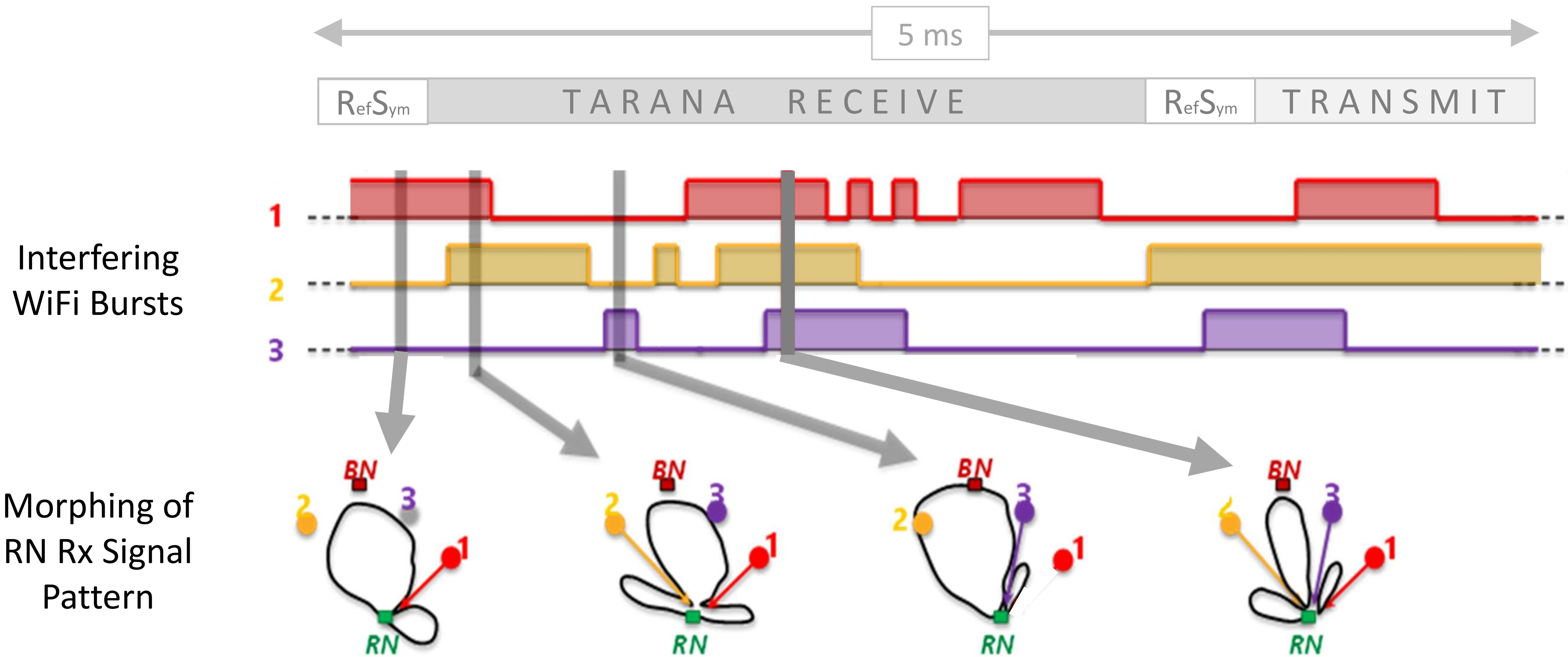






Principles of Operations – The Need For Asynchronous Burst Interference Cancelation

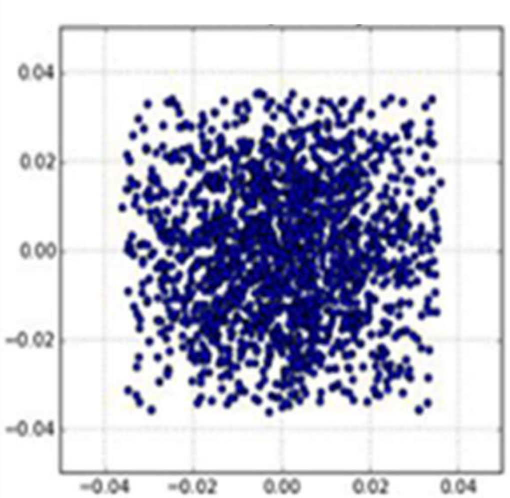
Asynchronous Burst Interference Cancelation (ABIC) allows RN to form "receive nulls" in realtime in the direction of interferers.



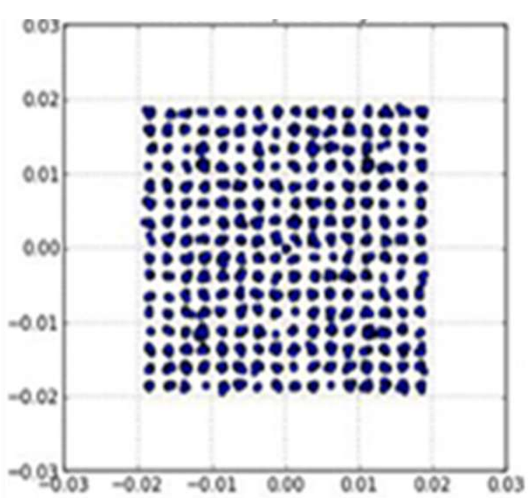
Principles of Operations – The Need For Asynchronous Burst Interference Cancelation

ABIC significantly increases SINR, which allows for higher modulations, leading to higher throughput.

Before

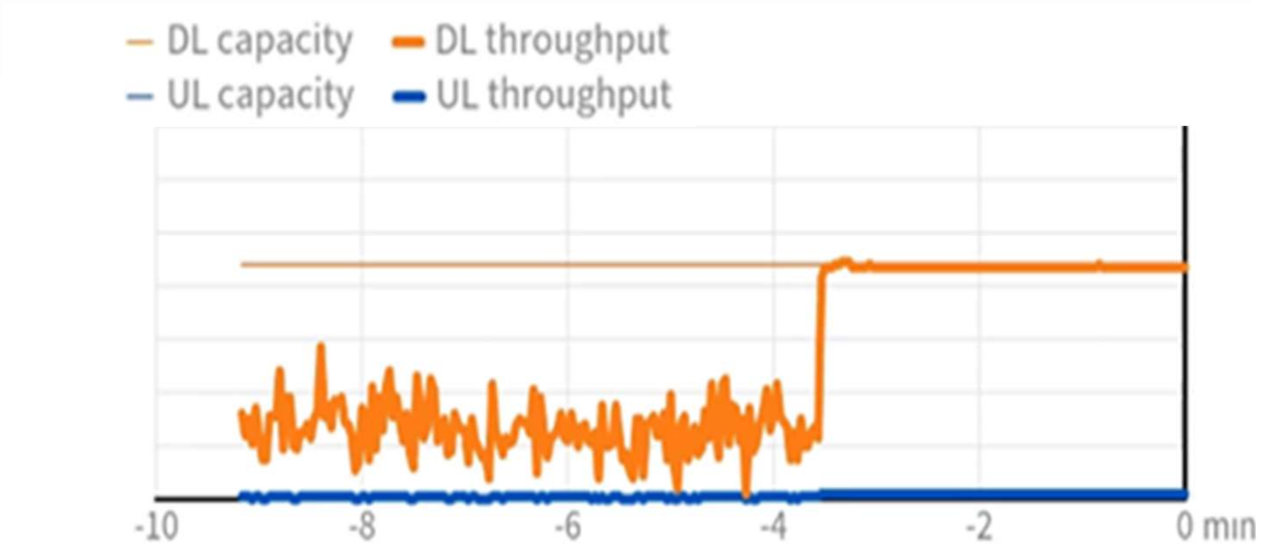


After



Before

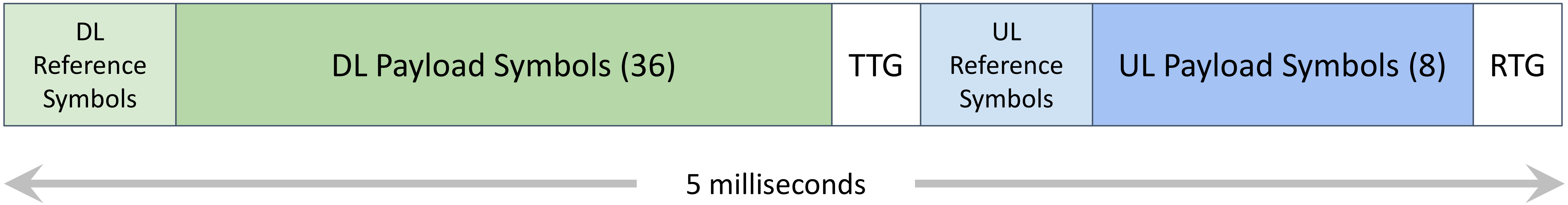
After



System Design – Physical Layer

- Frame Structure
- Control Channels and Network Access Protocols
- Network Entry of RN
- Adaptive Coding and Modulation

System Design – Physical Layer (Frame Structure)



5 ms radio frame

- -Beamformer periodicity
- -TDD frame with 4.5:1 DL:UL split

Reference symbols

- -Used for training the beamformer
- -Helps equalize time-varying channels

Payload symbols

- -Carry user data

System Design – Physical Layer (Frame Structure)

Dual carrier radio architecture

-Each 40 MHz carrier is independently tuneable
-Supports both contiguous and non-contiguous operation

OFDMA modulation scheme

-The subcarriers are grouped into 128 payload sub-bands.
-4 additional sub-bands are used for access and control.
-Pilot subcarriers interspersed between data subcarriers
-Helps equalize frequency selective channels

System Design – Phy Layer (Control Channels and Network Access Protocols)

DL synchronization and broadcast channels

-PSS, SSS, PBCH

UL synchronization and random access

-PRACH, PRACH response (PRACHR)

-Physical UL/DL connection request (PUCRCH/PDCRCH)

Calibration signal (CAL)

-Sounding reference signal (SRS)

UL/DL control channel elements (CCE) (i.e. PUCCH and PDCCH)

-UL/DL payload channels (i.e. PUSCH, PDSCH)

-Reference symbols (RS)

Channel	Frequency	Link Direction
PSS/SSS	All frames	Downlink
PBCH	All frames	Downlink
PRACH	Even frames	Uplink
PRACH-R	Even frames	Downlink
PUCRCH	Odd frames	Uplink
PDCRCH	Odd frames	Downlink
DL-CCE	All frames	Downlink
UL-CCE	All frames	Uplink
PDSCH	All frames	Downlink
PUSCH	All frames	Uplink

Network Entry of RN

The RN undergoes the following process when joining:

1) Search Supported Channels – The RN will listen for BN broadcast on all of its supported channels

2) Identify BNs – Multiple viable BNs may be discovered during this time.

3) Select Optimal BN – Based on received signal strength, the RN will select the best serving BN.

4) Calibration – RN undergoes calibration of its transmit and receive chains.

5) Initiate Random Access – RN will commence connection with selected BN.

6) Connection Established – RN is allocated a CCE and will be allocated RBs based on user demand.

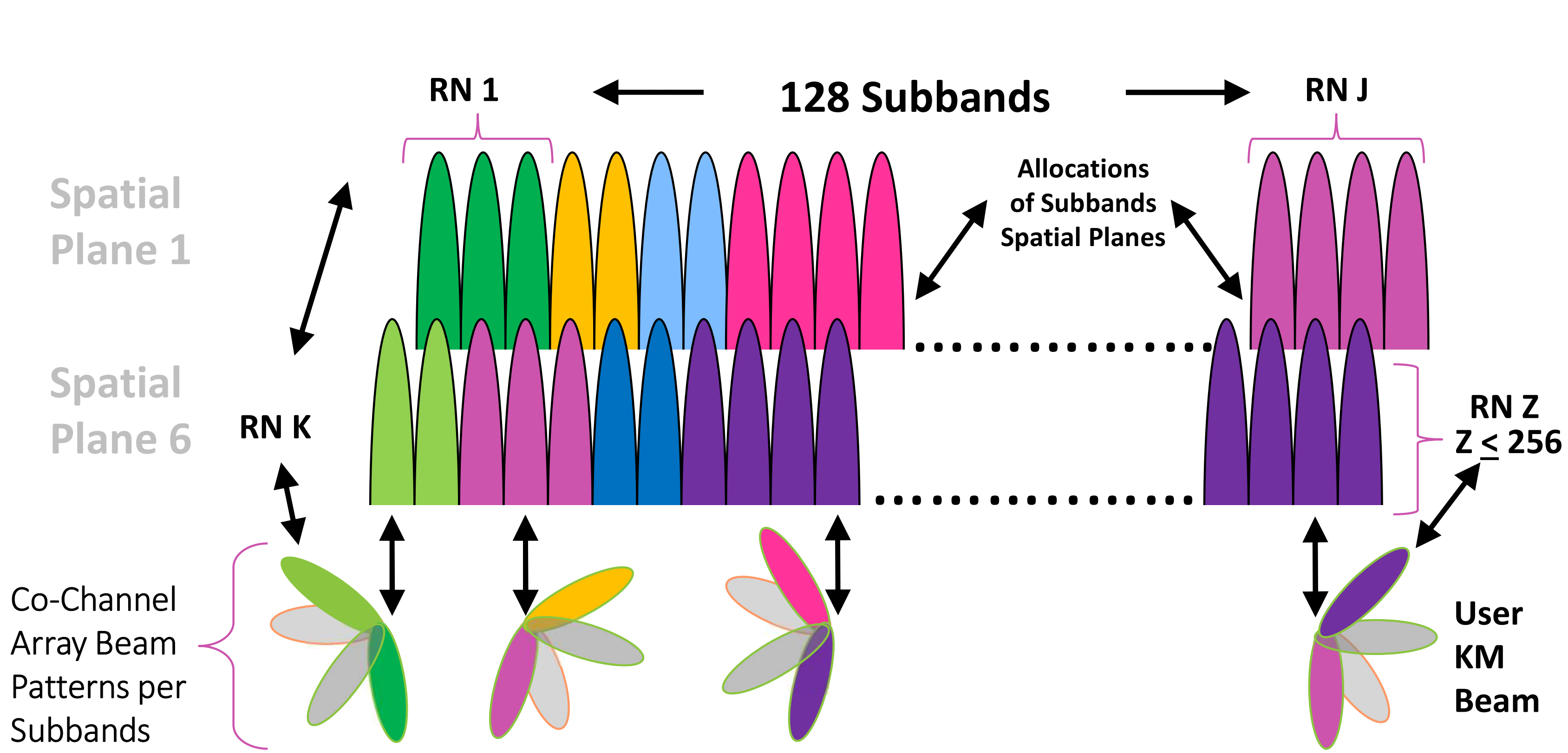
Adaptive Coding and Modulation

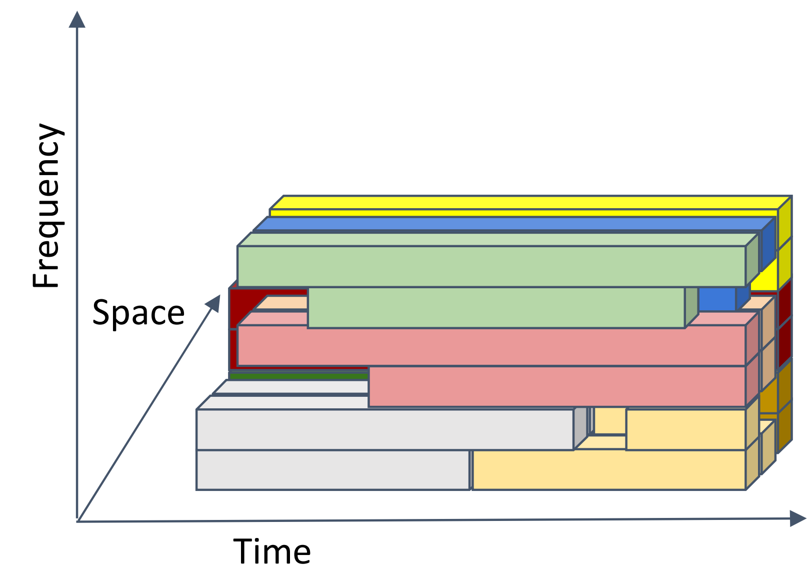
- The baseband uses OFDMA in both the DL and UL.
- The subcarriers are grouped into 128 payload sub-bands of 52 SC each.
- Each subcarrier is modulated using QPSK, 16 QAM, 64 QAM or 256 QAM.
- Link adaption via 16 MCS levels is controlled by the dedicated fast control channel.
- This facilitates frame by frame hitless changes in the MCS.
- The code rate and modulation are adaptive based on SINR, pathloss and error rate.
- Fade margins are adaptive to minimize frequent ARQ re-transmission and to lower packet jitter.

System Design – MAC Layer

- Scheduler
- Packet ARQ

System Design – MAC Layer (Scheduler – Resource Grid)

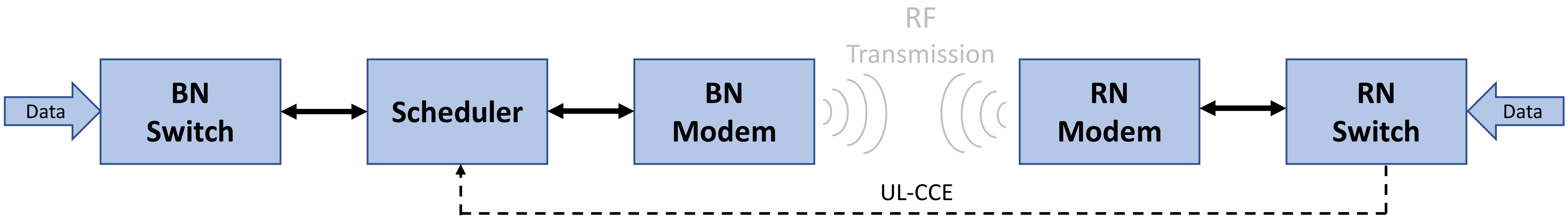




•128 subbands in 80 MHz, 6 Spatial Data Planes/Sector = 768 allocation units per frame.

•1 or 2 spatial planes (streams) plus 1-128 subbands are allocated to an RN by scheduler.

System Design – MAC Layer (Scheduler – Details)

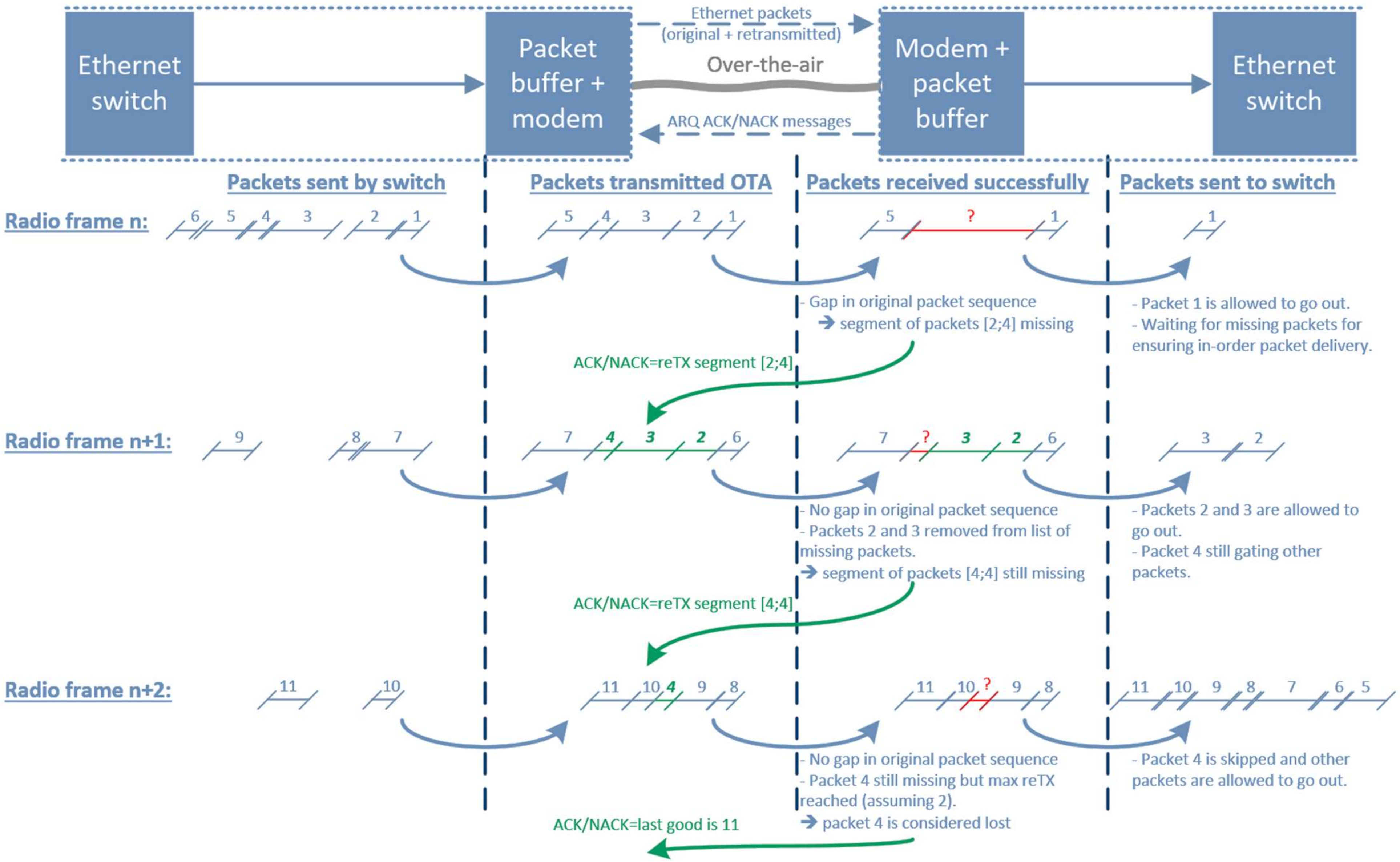


<u>Packet scheduling</u>: Classification and queue scheduling of Ethernet packets.

<u>Sub-band scheduling</u>: Allocation of sub-bands (SBs) and spatial streams, at the BN, for uplink and downlink transmissions to RNs

<u>SPA</u>: Semi-persistent allocation of one or more allocation units for a number of frames for a given RN

System Design – MAC Layer (Packet ARQ)



System Design – Network Layer

- Network Interfaces
- Ethernet Features
- Life of Packet

System Design – Network Layer (Network Interfaces)

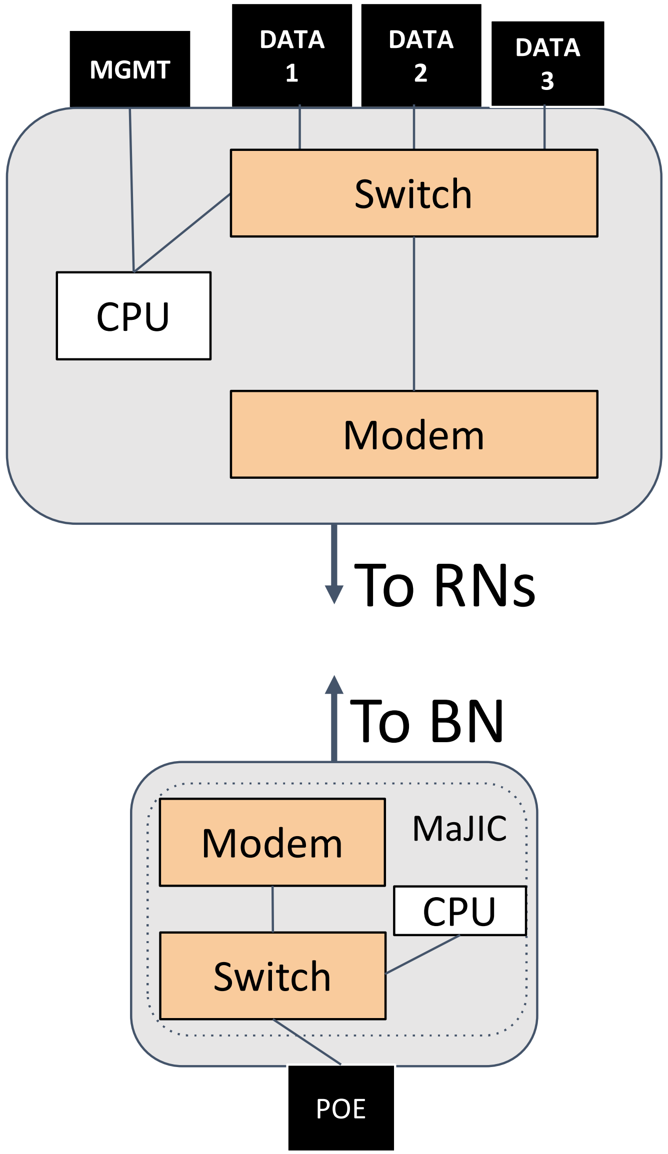
BN

-Two 10 Gbps SFP+ and one 1 Gbps data interfaces.

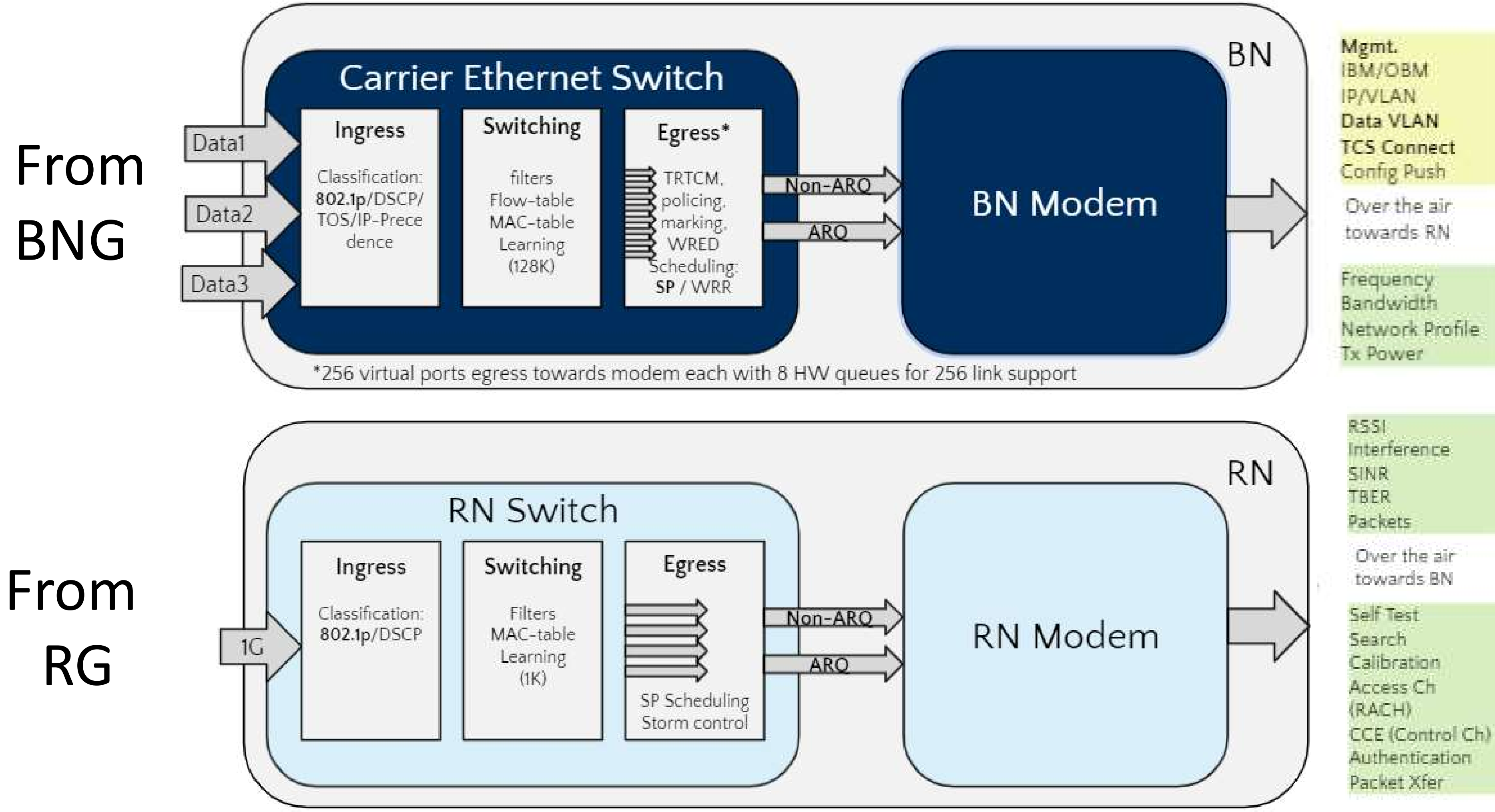
-Additional 1 Gbps mgmt Ethernet interface.

RN

-1 Gbps Ethernet interface, with PoE support.



System Design – Network Layer (Ethernet Features)



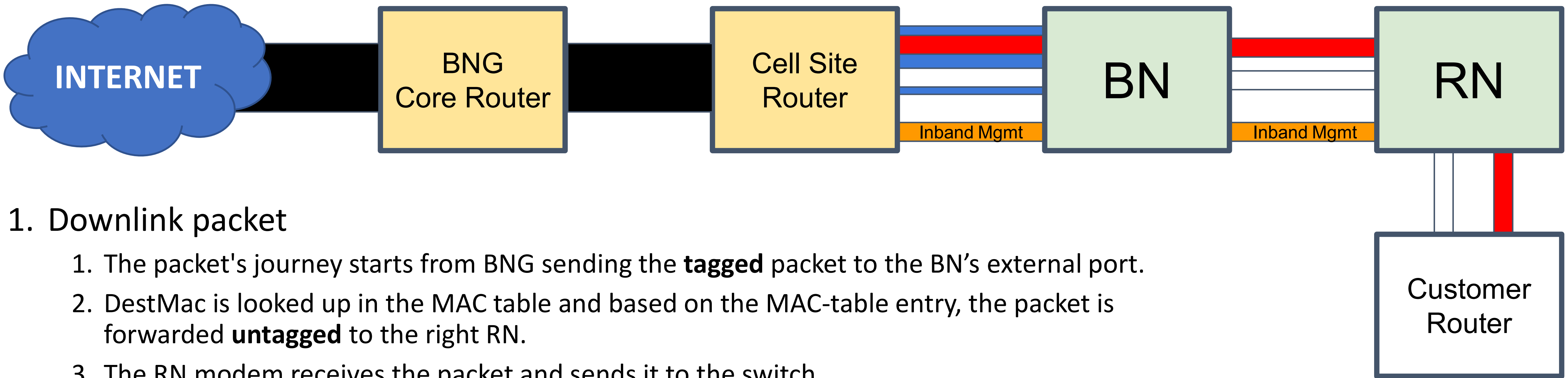
Classification can be based on 802.1p/ DSCP/ TOS/ IP-Precedence and mapped to 8 HW queues in BN

CoS	Traffic
7	NETWORK CONTROL
6	INTERNETWORK CONTROL
5	VOICE (Non-ARQ)
4	VIDEO
3	CRITICAL APPs
2	EXCELLENT EFFORT
1	BACKGROUND
0	BEST EFFORT

DSCP	Traffic
56-63	NETWORK CONTROL
48-55	INTERNETWORK CONTROL
40-47	EXPRESS FORWARD (Non-ARQ)
32-39	CS4
24-31	CS3
16-23	CS2
8-15	CS1
0-7	CS0

Classification can be based on 802.1p/ DSCP and mapped to 4 HW queues in RN

System Design – Network Layer Life of a (Data) Packet

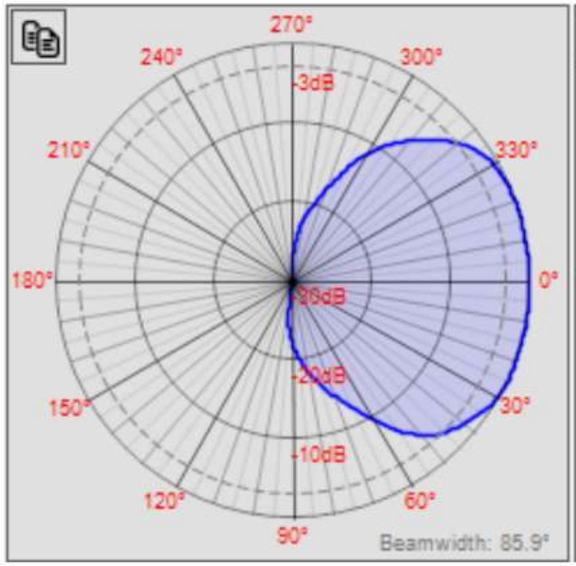


1. Downlink packet
   1. The packet's journey starts from BNG sending the **tagged** packet to the BN's external port.
   2. DestMac is looked up in the MAC table and based on the MAC-table entry, the packet is forwarded **untagged** to the right RN.
   3. The RN modem receives the packet and sends it to the switch. .
   4. This **untagged packet** is sent to the customer router through RN's external port.
2. Uplink packet
   1. The packet's journey starts from Customer Router sending the **untagged** packet to the RN's external port.
   2. The packet is forwarded to the BN **untagged**.
   3. The BN modem receives the **untagged** packet and sends it to the switch.
   4. The packet is assigned to the appropriate virtual port for the specific user.
   5. This packet is **tagged** and sent to the BN's external port.

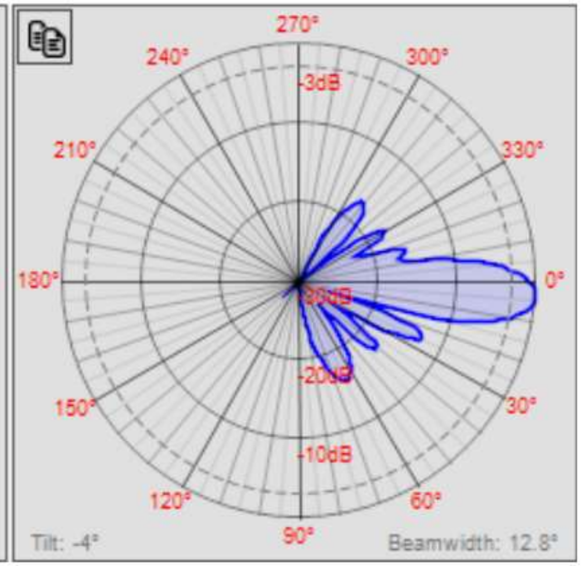
Color	**VLAN/Type**
White	UNTAGGED
Red	Passthru
Blue	Data
Orange	Management

RF Planning – Antenna Parameters

Transmit Parameters (Base Node)



Azimuth Pattern



Elevation Pattern

- Carrier bandwidth: 40 MHz
- Tx Power: 15.35 dBm
- Tx Gain: 17.65 dB

Receive Parameters (RN)

- Carrier bandwidth: 40 MHz
- Antenna pattern: Isotropic
- Rx antenna gain: 14.1 dBi
- Rx miscellaneous gain: 7.8 dB

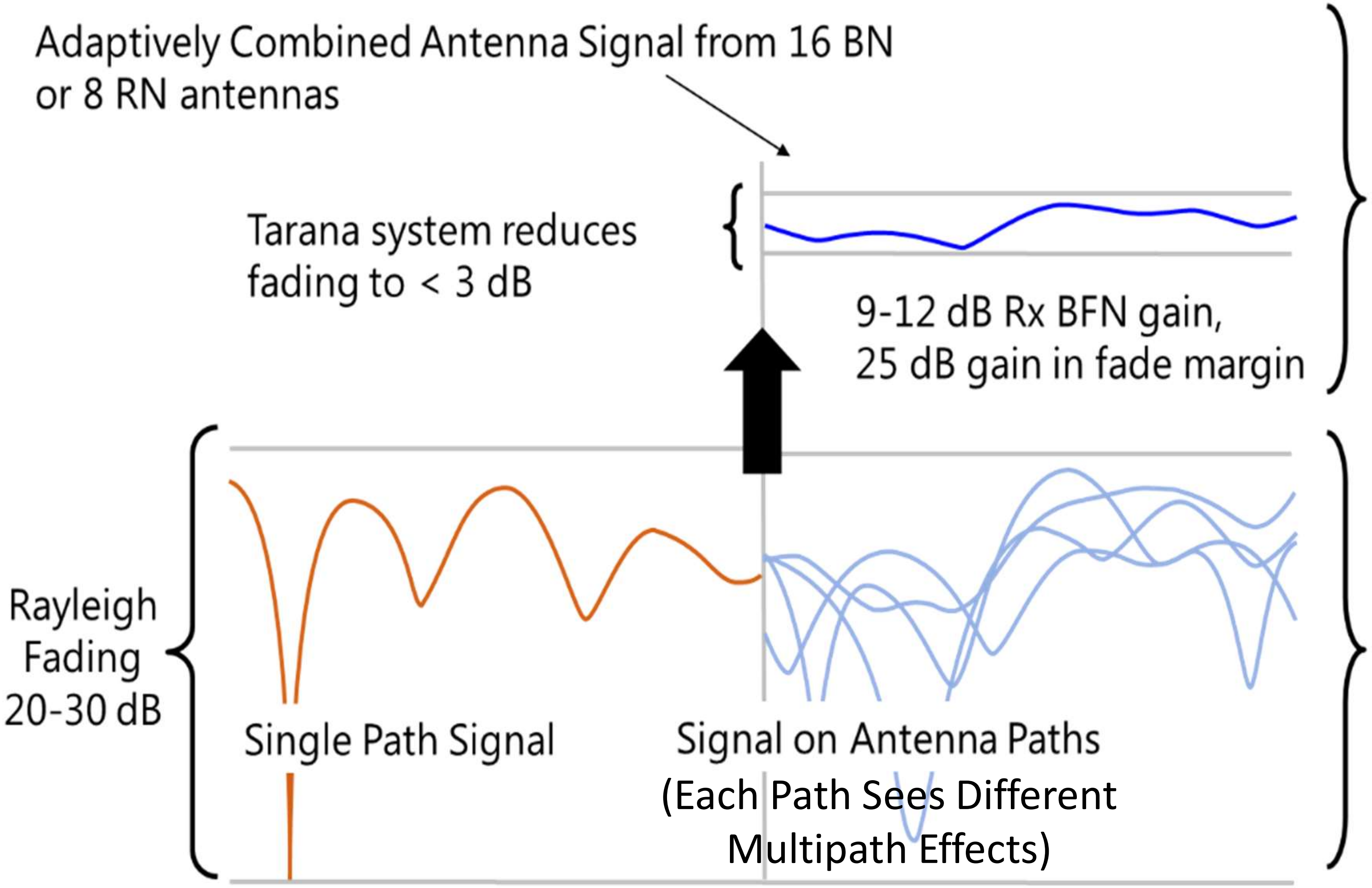
(beamforming & spatial processing gain)

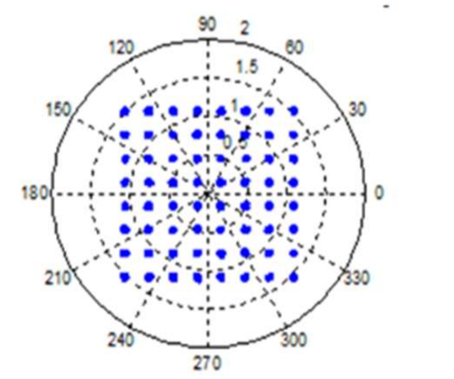
- Noise figure: 5 dB

RF Planning – Antenna Parameters

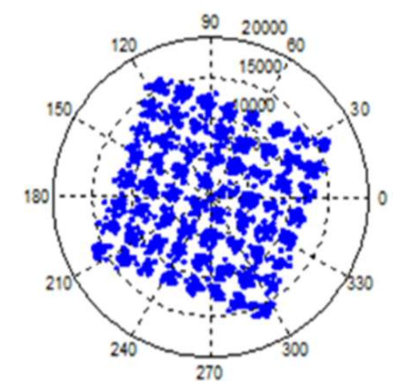
- Recommended 4 Sectors/BNs per Site for 90-degree coverage

RF Planning – Link Budget Impairments (Handling Multipath)





3D Beamforming Gives Dramatic Improvement



Multipath Destroys Constellation

Adaptive fade margin adjusts for target PER rate automatically

RF Planning – MAPL Table

Reference Table							
MCS Index	MCS	bits per symbol	Maximum Available Path Loss (dB)	DL Capacity per Carrier (Mbps)	UL Capacity per Carrier (Mbps)	DL Total Link Capacity (Mbps)	UL Total Link Capacity (Mbps)
16	256QAM-7.375/8	7.35	120.0	321	71	**641**	**143**
15	256QAM-7.25/8	7.25	121.4	315	70	**630**	**140**
14	256QAM-7/8	7	122.3	304	68	**608**	**135**
13	256QAM-6.5/8	6.5	123.6	282	63	**564**	**125**
12	256QAM-6/8	6	125.3	260	58	**520**	**116**
11	64QAM-5.5/6	5.5	127.1	238	53	**476**	**106**
10	64QAM-5/6	5	128.8	216	48	**431**	**96**
9	64QAM-4.5/6	4.5	130.3	194	43	**387**	**86**
8	64QAM-4/6	4	131.8	171	38	**343**	**76**
7	16QAM-3.5/4	3.5	133.2	149	33	**299**	**66**
6	16QAM-3/4	3	134.6	127	28	**254**	**57**
5	16QAM-2.5/4	2.5	137.1	105	23	**210**	**47**
4	16QAM-2/4	2	138.7	83	18	**166**	**37**
3	QPSK-1.75/2	1.75	139.8	72	16	**144**	**32**
2	QPSK-1.5/2	1.5	140.7	61	14	**122**	**27**
1	QPSK-1/2	1	141.8	39	9	**77**	**17**

Fading Margin………………………………………………………………**3 dB**
Interference Margin…………**2 dB** for rural, **5 db** for suburban
***All capacities mentioned above are at layer 2

RF Planning – Co-location Guidelines

Spatial nulling is performed dynamically to cancel all active interferers

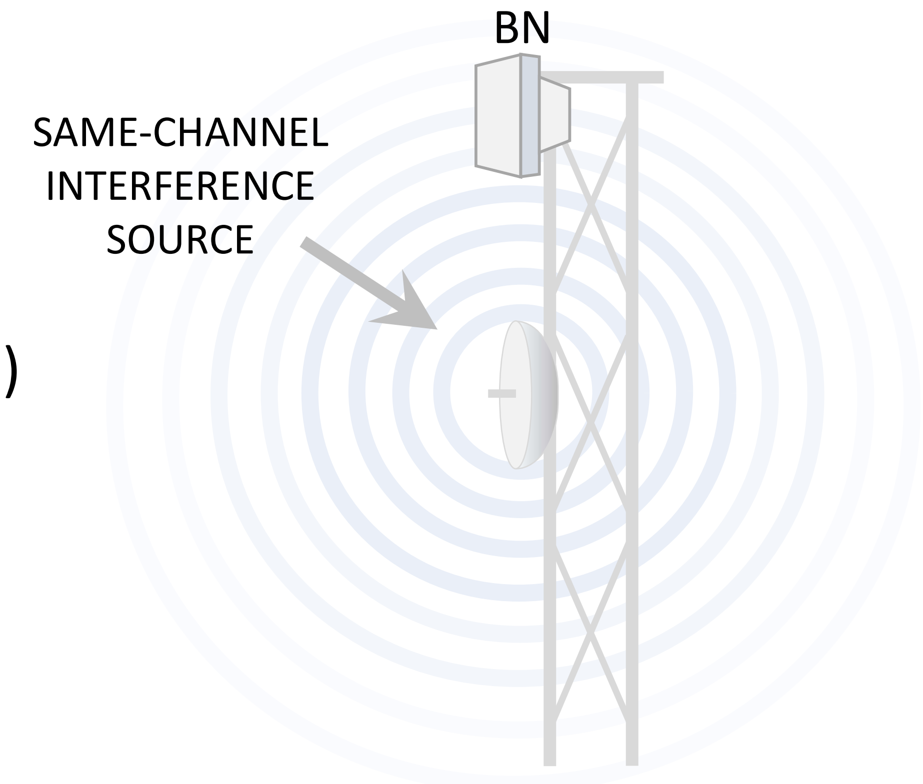
-Covers the vast majority of interference sources

-Without this approach link reliability is extremely poor

Extreme cases where interference can still result in performance degradation:

-Some 5GHz base-stations co-located on the same tower

-Co-linear interference along the path of a LoS/near-LoS link (this is accounted by interference margin in link budget)

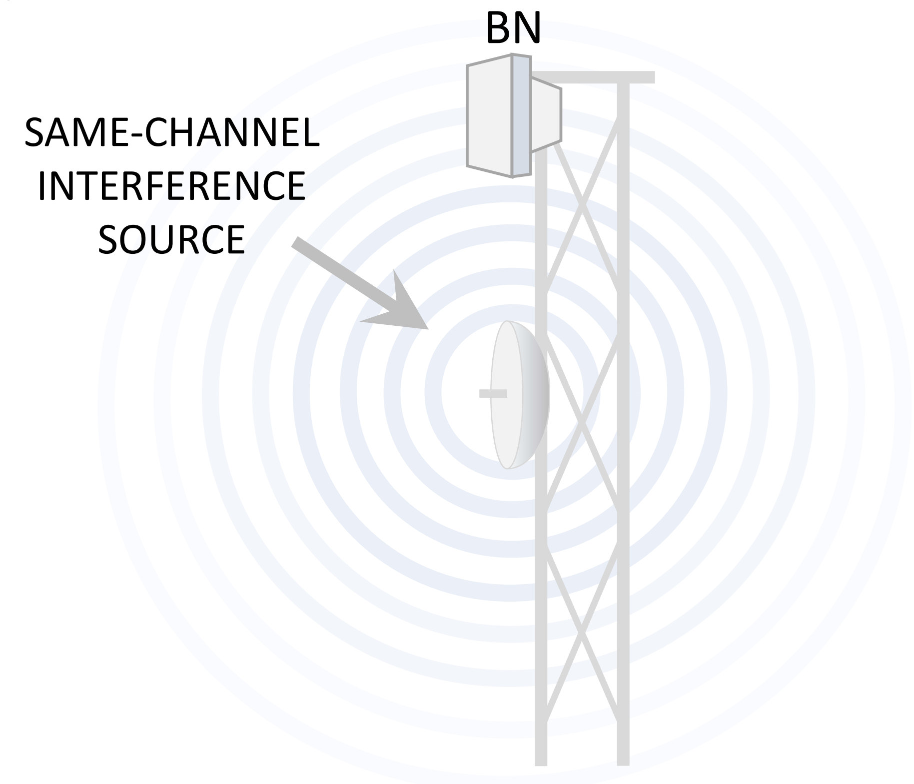


RF Planning – Co-location Guidelines

When Tarana BN receives, *and* local interferer transmits, interference can be much stronger than BN's desired receive signal.

-Tarana gear can cancel interference signals ~10 dB stronger

-With co-located, higher-power transmitter, interference can be significantly stronger



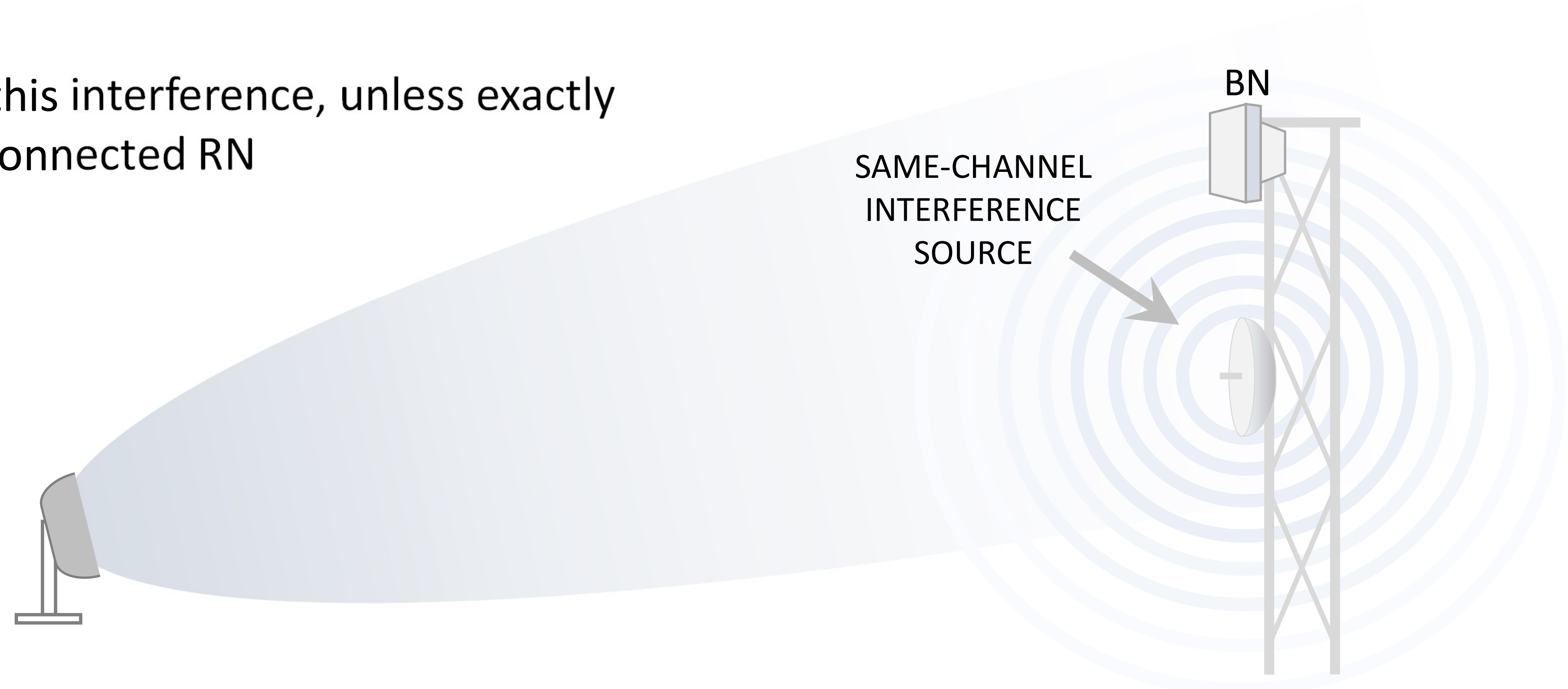
RF Planning – Co-location Guidelines

There can be one or more radios paired with interferer on the tower.

-Radio could be pointed straight at BN, LoS and at close range.

-BN can mitigate this interference, unless exactly co-linear with a connected RN

Co-located interference at tower can degrade UL



RF Planning – Co-location Guidelines

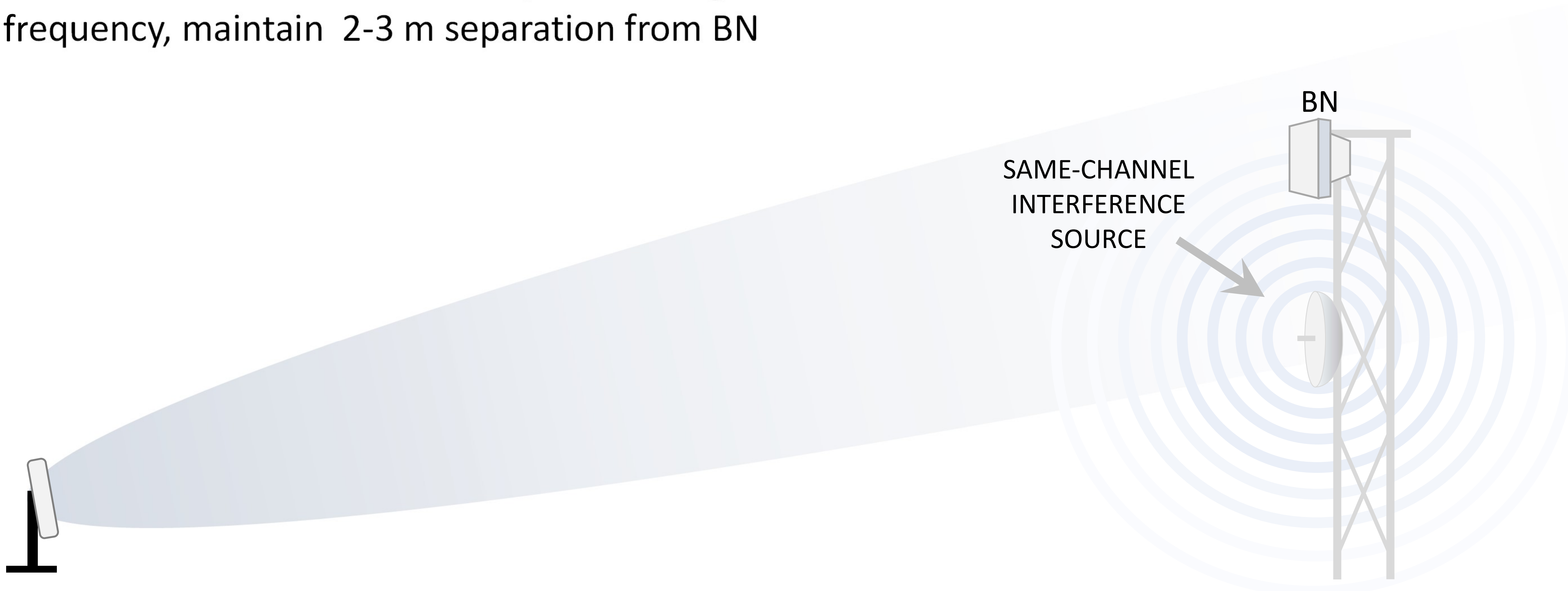
A distant RN will see its BN and interferer as co-located, and will not be able to spatially remove interference.

RF Planning – Co-location Guidelines

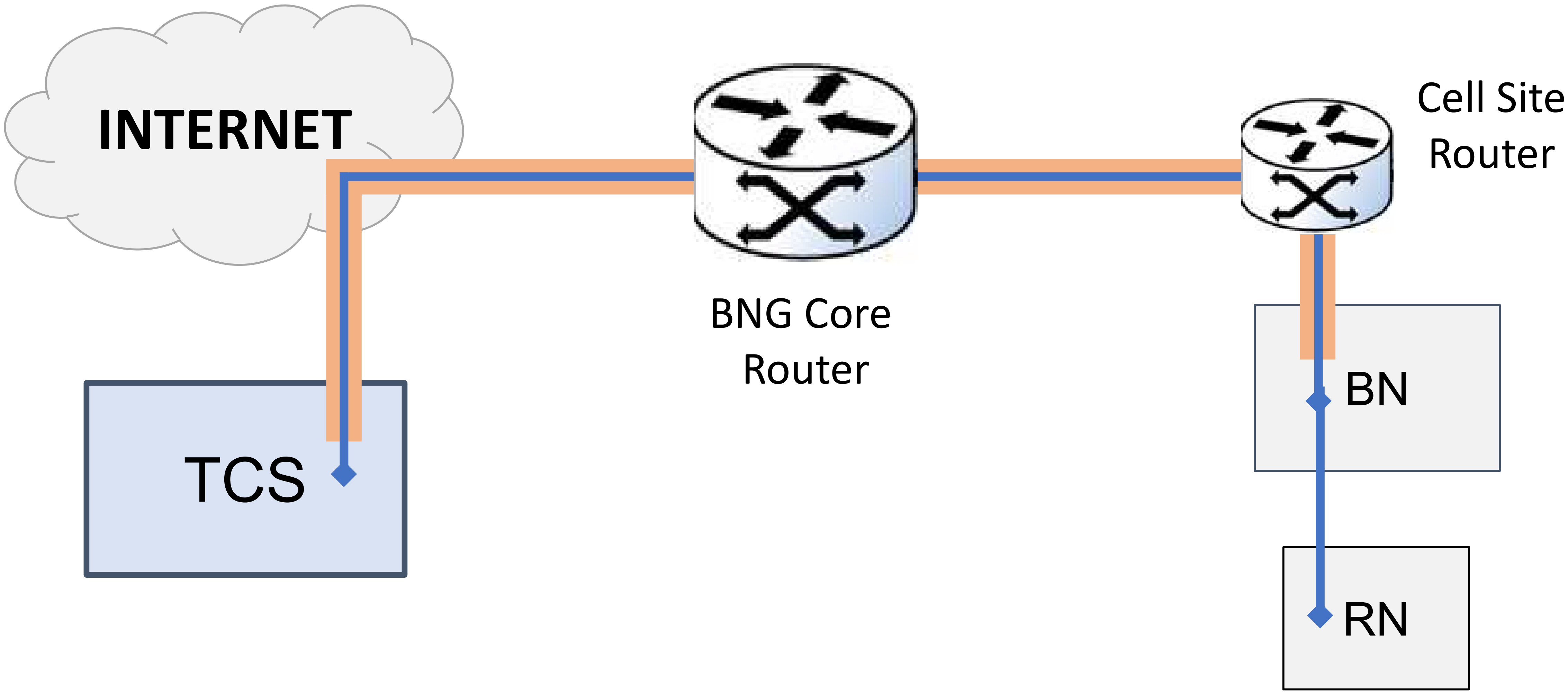
Recommendations regarding co-located interference:

-Avoid using towers with UNII-3 gear on them

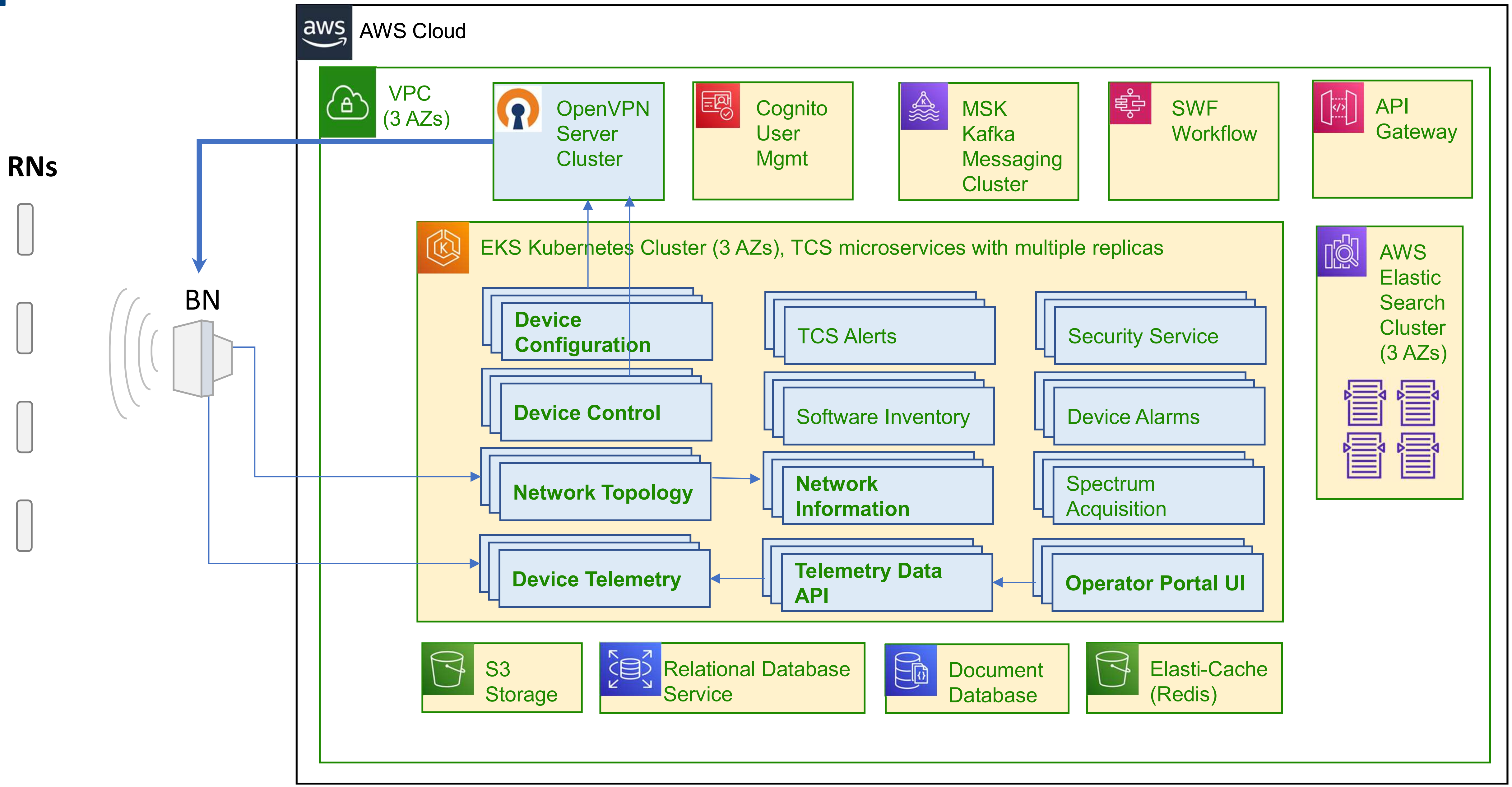
-If towers do have UNII-3 devices, avoid using same frequency, maintain 2-3 m separation from BN



Tarana Cloud Suite – Management Plane Connectivity



Tarana Cloud Suite – Cloud Architecture



END