18ECO127T
5G Technology – An Overview

OPEN ELECTIVE (by ECE)
SEM:7
B.TECH

MODULE 3:
Radio Access Technologies in 5G

- Introduction to Radio Access Technologies
- New Radio (NR) Interface: Overview and Features
- New Radio (NR) Interface: Key Technologies
- Massive MIMO in 5G
- Beamforming in 5G
- Beamforming Types
- Small Cells in 5G
- HetNets in 5G
- Millimeter wave Communication;

MODULE 3:
Radio Access Technologies in 5G

M3 S1 & S2

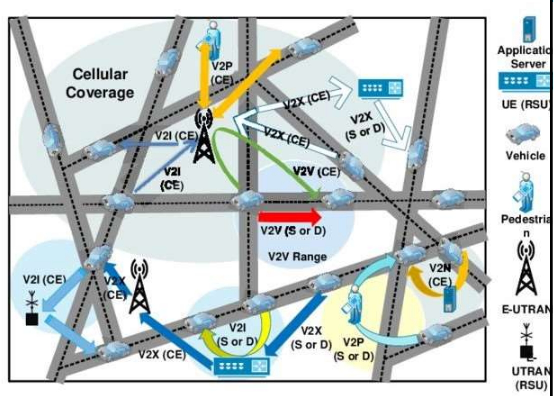
Introduction to Radio Access Technologies

New Radio (NR) Interface: Overview and Features

Introduction to Radio Access Technologies

What is radio access network?

- A radio access network (RAN) is a major component of a wireless telecommunications system that connects individual devices to other parts of a network through a radio link.

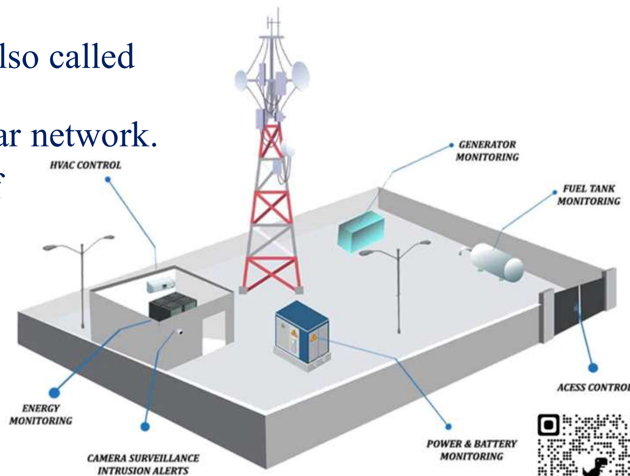


- The RAN links user equipment, such as a cellphone, computer or any remotely controlled machine, over a fiber or wireless backhaul connection.
- That link goes to the core network, which manages subscriber information, location and more.

Introduction to Radio Access Technologies

What is radio access network?

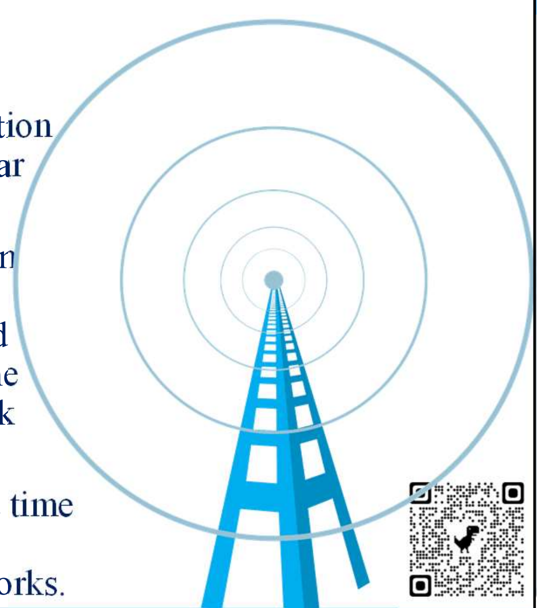
- The RAN, which is sometimes also called the access network, is the radio element of the cellular network.
- A cellular network is made up of land areas called cells.
- A cell is served by at least one radio transceiver, although the standard is typically three for cell sites.



Introduction to Radio Access Technologies

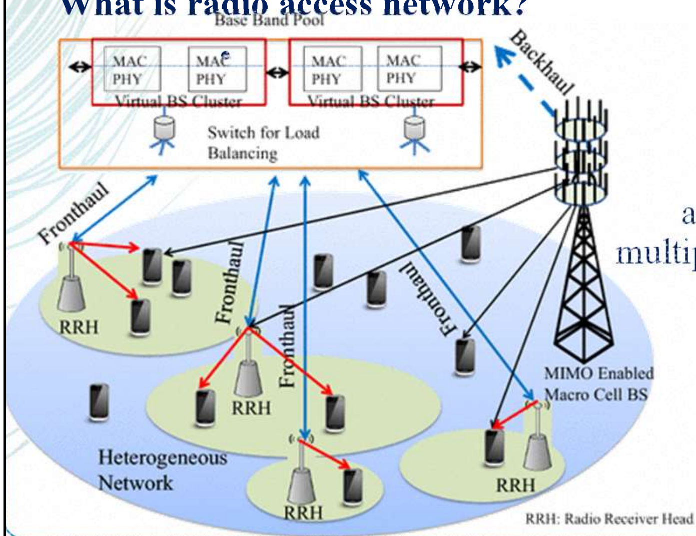
What is radio access network?

- RANs have evolved from the first generation (1G) to the fifth generation (5G) of cellular networking.
- With the development of fourth generation (4G) technology in the 2000s, the 3rd Generation Partnership Project introduced Long-Term Evolution (LTE) RAN, and the radio access network and the core network changed significantly.
- With 4G, system connectivity for the first time was based on the Internet Protocol (IP), replacing the previous circuit-based networks.



Introduction to Radio Access Technologies

What is radio access network?

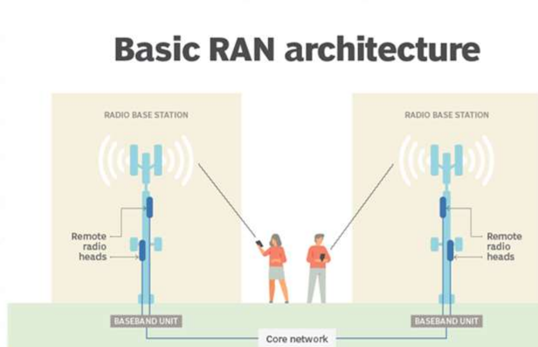


Now, with LTE Advanced and 5G, improvements are coming in the form of centralized RAN, also called cloud RAN (C-RAN), and multiple antenna arrays, such as multiple input, multiple output (MIMO).

Introduction to Radio Access Technologies

What is radio access network?

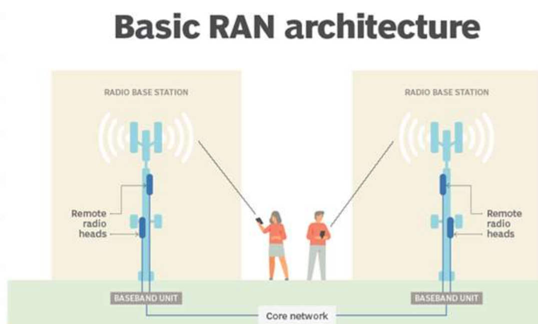
- Since the first cellular networks were introduced, the capabilities of RAN have expanded to include voice calls, text messaging, and video and audio streaming.
- The types of user equipment using these networks have drastically increased, including all types of vehicles, drones and internet of things devices.



Introduction to Radio Access Technologies

What components make up a RAN?

- RAN components include base stations and antennas that cover a specific region, depending on their capacity.
- Silicon chips in both the core network and the user equipment provide RAN functionality.



Introduction to Radio Access Technologies

What components make up a RAN?

- A RAN is made up of three essential elements:

1. **Antennas** convert electrical signals into radio waves.
2. Radios transform digital information into signals that can be sent wirelessly and ensure that **transmissions** are in the correct frequency bands with the right power levels.
3. Baseband units **(BBUs)** provide a set of signal processing functions that make wireless communication possible.
   Traditional baseband uses custom electronics combined with multiple lines of code to enable wireless communication, typically using the licensed radio spectrum.
   BBU processing detects errors, secures the wireless signal and ensures that wireless resources are used effectively.

Introduction to Radio Access Technologies

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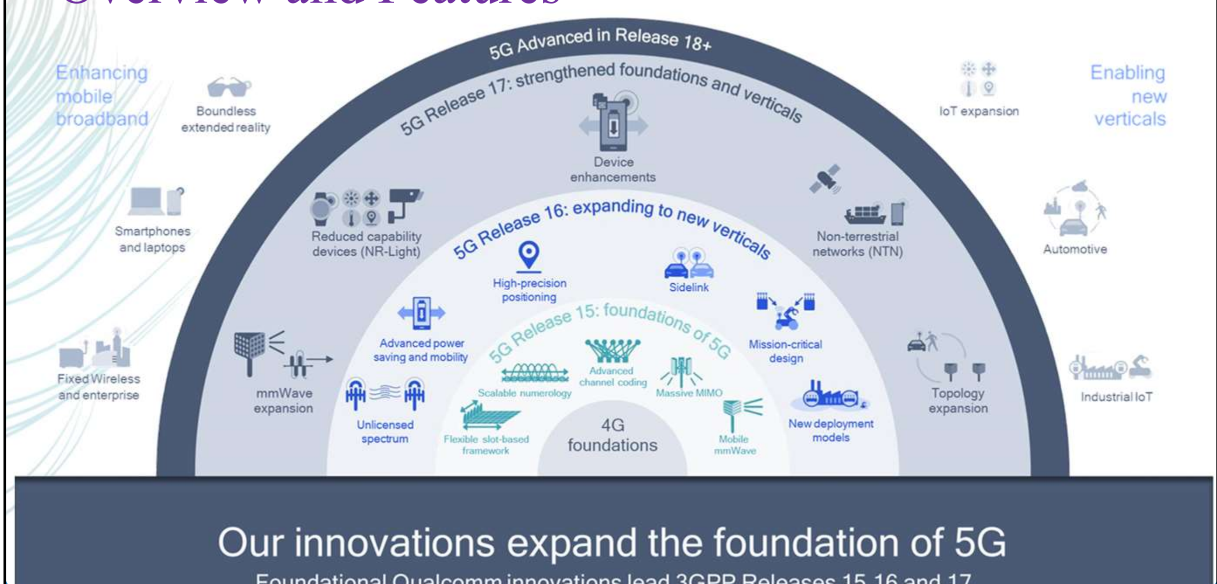
Introduction to Radio Access Technologies

What is RAN in 5G?

- The 5G New Radio (5G NR) standard is the latest radio interface and radio access technology for 5G cellular technology.
- The interface supports multiple frequency bands, including sub-6 gigahertz bands and millimeter wave (mmWave) bands, such as 24 GHz, 28 GHz and higher.
- The mmWave bands offer 1+ gigabits per second download speeds, but they have reduced ranges compared to sub-6 GHz services.

New Radio (NR) Interface: Overview and Features

New Radio (NR) Interface: Overview and Features



New Radio (NR) Interface: Overview and Features

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mmWave expansion
For more capacity, new use cases and deployments
Licensed and unlicensed spectrum operations in 52.6-71 GHz

Reduced capability devices (NR-Light)
For expanded IoT: wearables, sensors, surveillance cameras
Lower complexity devices with 20 / 100 MHz max bandwidth in sub-7 / mmWave with 1 or 2 Rx antennas

Device enhancements
For enhanced device user experience and performance
More antennas, higher throughput, battery life, mobility, coverage, positioning accuracy, multi-SIM

Non-terrestrial networks (NTN)
For ubiquitous coverage and expanded use cases
Satellite communications for mobile devices and IoT, leveraging 5G NR framework

Topology expansion
For more efficient deployments, public safety, and others
Enhanced IAB, repeater, C-V2X with vulnerable road users

Early R&D investments | Cutting-edge prototypes | Fundamental contributions to 3GPP

New Radio (NR) Interface: Overview and Features

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5G
3GPP Release 17

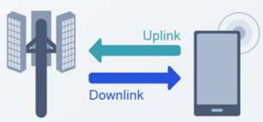
A key 5G milestone: 3GPP Release 17 Completion

Functional freeze in March 2022 and ASN.1 freeze expected in June 2022

New and enhanced 5G system capabilities
- Further enhanced massive MIMO
- Coverage enhancements
- Device power savings
- Spectrum expansion (60 GHz)
- Enhanced IAB and RF repeater
- Further enhanced URLLC, private networks, others...

Expansion to new 5G devices and applications
- Sidelink expansion
- Broadcast/ multicast expansion
- NR-Light (RedCap), enhanced mIoT
- Non-terrestrial networks (NTN)
- Enhanced precise positioning
- Boundless XR study, others...

New Radio (NR) Interface: Overview and Features



Further enhancing 5G massive MIMO performance

Focus areas for Release 17 Work Item

Enhanced multi-beam operation
- Unified TCI[1] framework in DL/UL[2] to reduce latency and overhead
- UL beam selection for multi-panel devices
- More efficient L1/L2[3] intra-and inter-cell mobility

SRS[7] improvements
- More flexible triggering of aperiodic SRS and DCI[8] overhead reduction
- SRS switching for up to 8 antennas
- Improved SRS reliability such as repetitions and time bundling

SRS: Sounding Reference Signal
DCI: Downlink Control Information

Enhanced multi-TRP[4] deployment
- Improved reliability for DL control, UL control and data channels
- QCL[5] for inter-cell multi-TRP reusing L1/L2 mobility measurements
- Beam management for multi-panel Rx
- High-speed SFN[6] enhancements

CSI[9] measurement & reporting
- DL/UL reciprocity of angle and delay for FDD[10]
- More dynamic channel/interference hypotheses for non-coherent joint transmission

Source: RP-212535 (Further enhancements on MIMO for NR)
1 Transmission Configuration Indicator; 2 Downlink/Uplink; 3 Layer-1/Layer-2; 4 Transmission and Reception Points; 5 Quasi Co-Location; 6 Single Frequency Network; 7 Sounding Reference Signal; 8 Downlink Control Information; 9 Channel State Information; 10 Frequency Division Duplex

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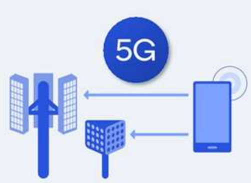
New Radio (NR) Interface: Overview and Features

Improving 5G uplink coverage

Targeting urban and rural deployments using sub-7 GHz and mmWave, also applies to satellites (NTN[1]) communication



Coverage enhancements Work Item
3GPP Release 17

- **Uplink data channel (PUSCH[2]) enhancements**
  Increasing the maximum numbers of repetitions, supporting transport block processing over multiple slots, and enabling joint channel estimation across multiple transmissions and frequency hopping
- **Uplink control channel (PUCCH[3]) enhancements**
  Supporting dynamic repetitions for better reliability, DMRS[4] bundling across repetitions based on similar mechanisms for enabling joint channel estimation for PUSCH
- **Message 3 enhancements**
  Supporting Type A PUSCH repetitions for capability signaling, barring, and early indication

Source: in RP-211566 (NR coverage enhancements)
1 Non-terrestrial Network; 2 Physical Uplink Shared Channel; 3 Physical Uplink Control Channel; 4 Demodulation Reference Signal

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New Radio (NR) Interface: Overview and Features

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Further enhancing device power efficiency

For idle/inactive mode

Techniques to reduce unnecessary device paging reception (false alarms) without impacting legacy devices

Providing potential TRS[1]/CSI-RS[2] to devices in idle/inactive mode with minimized system overhead impact

Supporting PDCCH[3]-based permanent equipment identifier (PEI)

Rel-17 power saving enhancements

Building on Rel-16 device power saving design

For connected mode

Extending to Rel-16 DCI[4]-based power saving adaptation for an active BWP[5], including PDCCH monitoring skipping during C-DRX[6]

Relaxing device measurement for RLM[7] and/or BFD[8] for low mobility devices with short DRX[9] cycle

Source: RP-212630 (UE Power Saving Enhancements)
1 Tracking Reference Signal; 2 Channel State Information Reference Signal; 3 Physical Downlink Control Channel; 4 Downlink Control Information; 5 Bandwidth Part; 6 Connected Discontinued Reception; 7 Radio Link Monitoring; 8 Bidirectional Forwarding Detection; 9 Discontinued Reception

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New Radio (NR) Interface: Overview and Features

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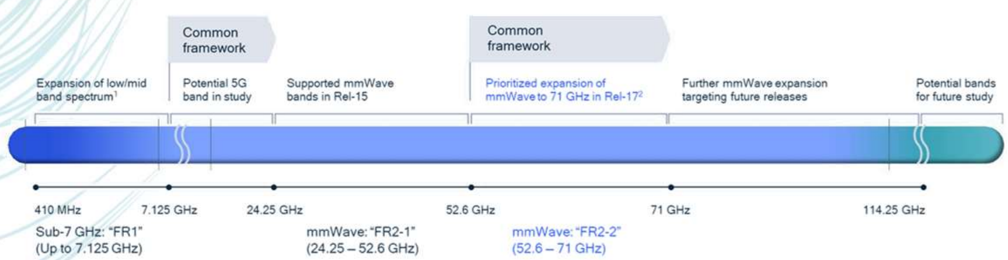
Scaling 5G NR design to support 60 GHz unlicensed band



Design Principles

SCS[3] for control/data channels
Leveraging existing design of 120 kHz, and scaling to wider numerology of 480 kHz and 960 kHz

SSB[4] numerology
Supporting 120 kHz (480 kHz optional) for initial access, 120 kHz (480 kHz, 960 kHz optional) for non-initial access, and 64 SSB beams

Channel access mechanisms
Supporting flexible deployment in unlicensed spectrum utilizing LBT[5], directional LBT, or no LBT

Beam management
Reusing designs based on existing mmWave frequency range (FR2-1) established in Release 15 and 16

1. Rel-15 supported 450 MHz to 6 GHz; 2 To support global unlicensed 60 GHz bands, SCS scaling from 24.25-52.6 GHz band with same characteristics (e.g., waveforms);
3 Subcarrier Spacing; 4 Synchronization Signals Block; 5 Listen-Before-Talk

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New Radio (NR) Interface: Overview and Features

Further enhancing ultra-reliable, low-latency communications

Release 17 Work Item targeting to meet more stringent requirements of Industry 4.0 applications

Enhanced physical layer feedback

- Improved device feedback for HARQ-ACK[1]
- New mechanism triggered aperiodic CSI[2] and SRS[3] for more accurate MCS[4] selection
- Improved reliability with uplink control[5] on two carriers
- Subband CQI[6] with more granularity

Improved compatibility for unlicensed spectrum

- Supporting device-initiated COT[7] for FBE[8]
- Harmonizing uplink configured-grant enhancements in Rel-16 NR-U[9] and URLLC[10] to be applicable for unlicensed spectrum

Intra-device multiplexing and prioritization

- Handling low-priority traffic on eMBB without impacting data flow in case of URLLC concurrency
- Parallel PUCCH and PUSCH[11] transmissions on different component carriers for inter-band CA[12]

Enhanced time synchronization

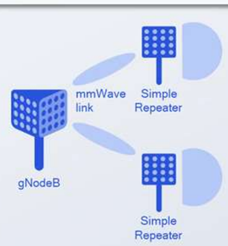
Supporting uplink RTT[13]-based method for TSN[14] and improved propagation delay compensation

Network enhancements

Based on new QoS[15] related parameters such as survival time, burst spread

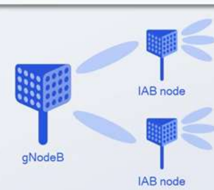
Source: RP-210854 (Enhanced Industrial Internet of Things and ultra-reliable and low latency communication support for NR)
1 Hybrid Automatic Repeat Request Acknowledge; 2 Channel State Information; 3 Sounding Reference Signal; 4 Modulation and Coding Scheme; 5 PUCCH - Physical Uplink Control Channel; 6 Channel Quality Indicator; 7 Channel Occupancy Time; 8 Frame Based Equipment; 9 NR Unlicensed; 10 Ultra Reliable Low Latency Communication; 11 Physical Uplink Shared Channel; 12 Carrier Aggregation; 13 Round Trip Time; 14 Time Sensitive Networking; 15 Quality of Service

New Radio (NR) Interface: Overview and Features



RF Repeaters

Introduced RF repeaters (without adaptive beamforming) that can operate in sub-7 GHz (FDD/TDD) and mmWave, leveraging IAB and LTE repeaters work; "Smart" network-controlled repeater in Rel-18



Integrated Access & Backhaul (IAB)

Enhanced Rel-16 IAB design by adding support for simultaneous Tx and Rx (spatially separated full duplex), inter-donor migration / handover, and multi-hop efficiency enhancements

Efficiently expand 5G mmWave coverage

New mmWave infrastructure options introduced as part of Release 17

!!THANK YOU!!
!! Have a Nice Day!!

Today we learned about

Introduction to Radio Access Technologies
&
New Radio (NR) Interface: Overview and Features

MODULE 3:
Radio Access Technologies in 5G

M3 S3

New Radio (NR) Interface: Key Technologies

New Radio (NR) Interface: Key Technologies

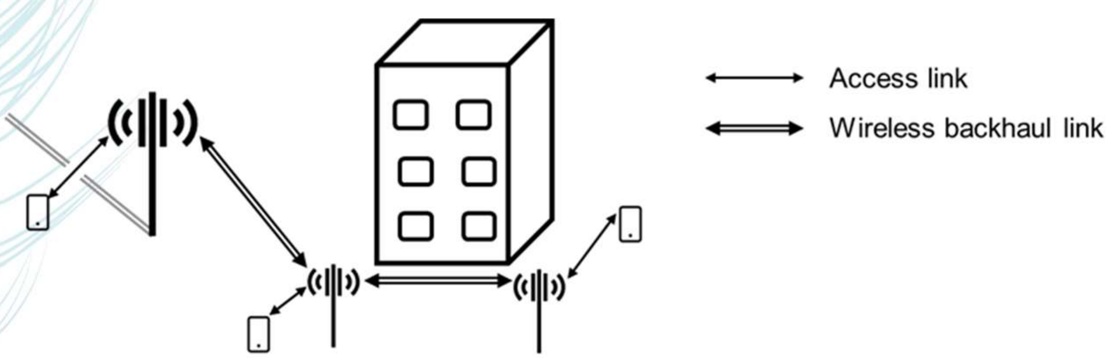
- **Single-DCI-based vs. multi-DCI-based multi-TRP transmission**

Carrying the information to schedule (allocate physical resources) for Downlink Data (PDSCH)
Carrying the information to schedule (allocate physical resources) for Uplink Data (PUSCH)

Single-DCI-based multi-TRP transmission **Multi-DCI-based multi-TRP transmission**

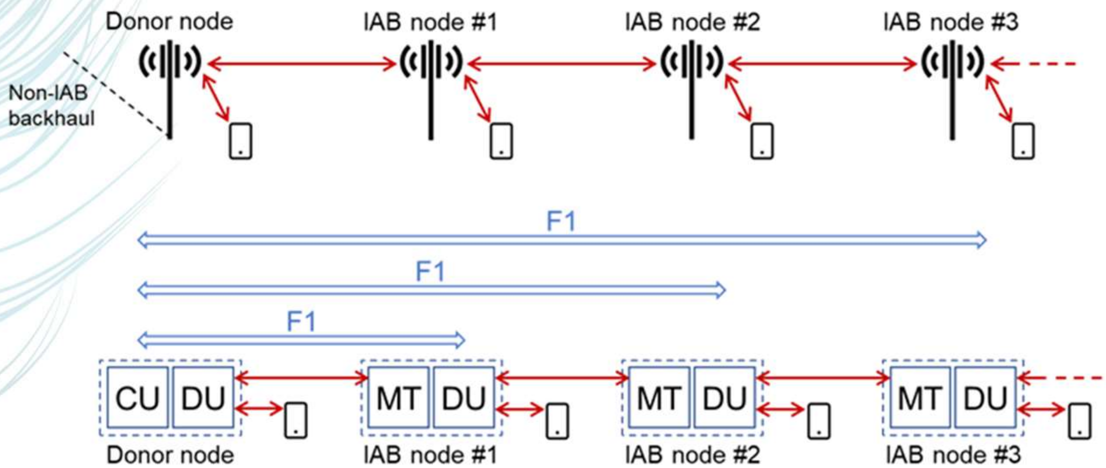
New Radio (NR) Interface: Key Technologies

- **Integrated Access Backhaul (IAB)**



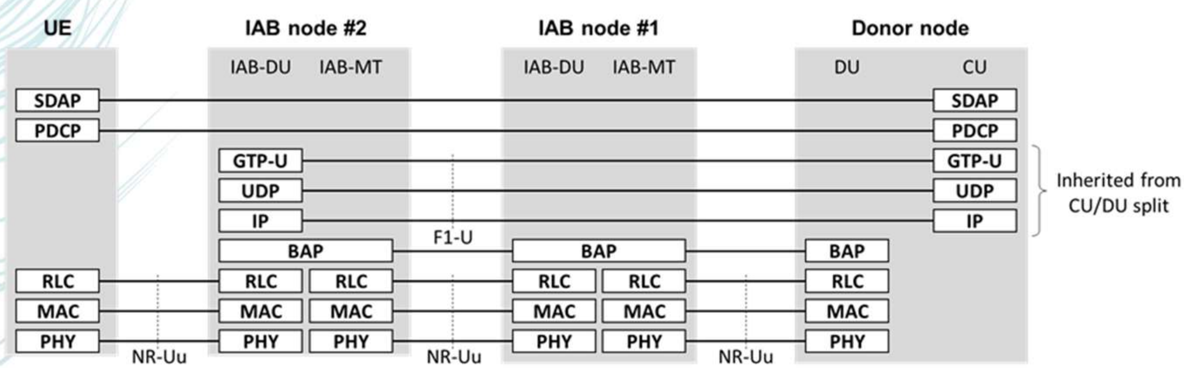
New Radio (NR) Interface: Key Technologies

- **Types of Network Nodes**



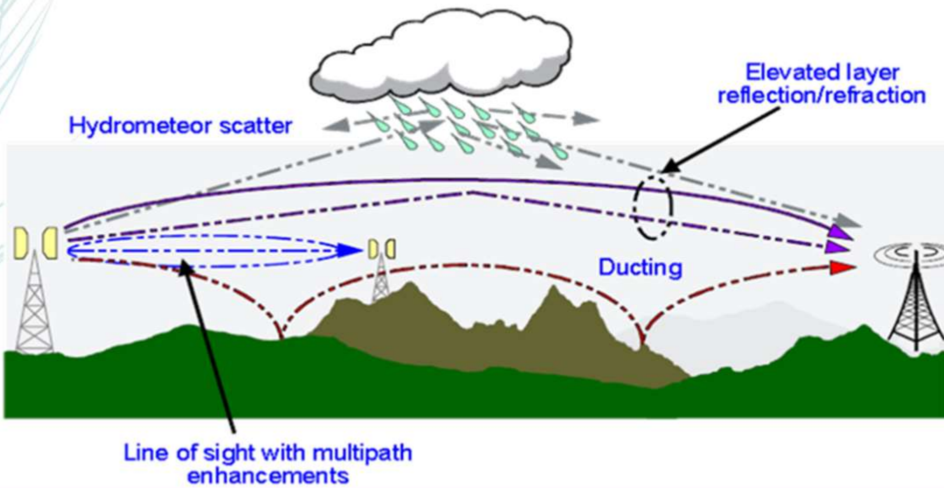
New Radio (NR) Interface: Key Technologies

- **IAB protocol stack – U-plane**



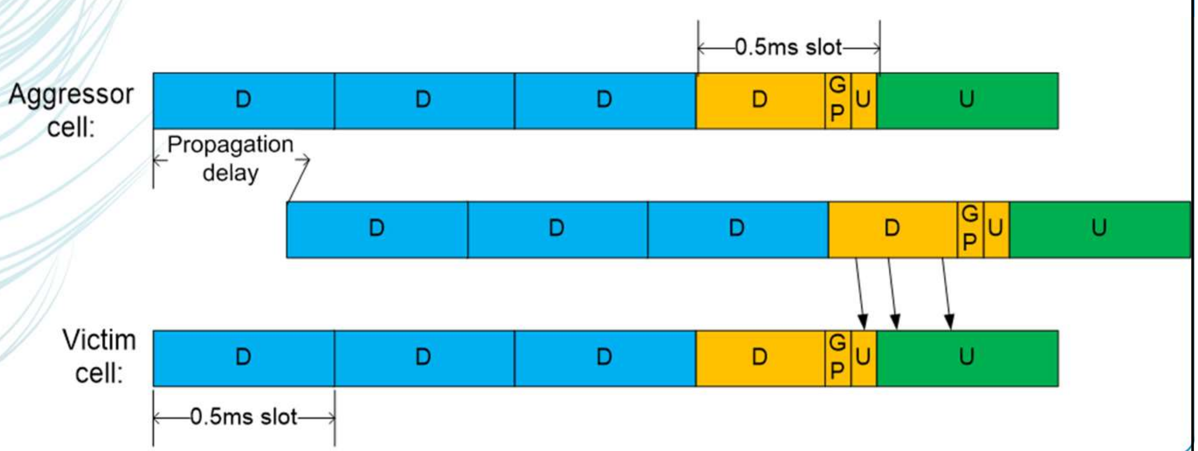
New Radio (NR) Interface: Key Technologies

- **Remote interference 100's of kms away caused by ducting**



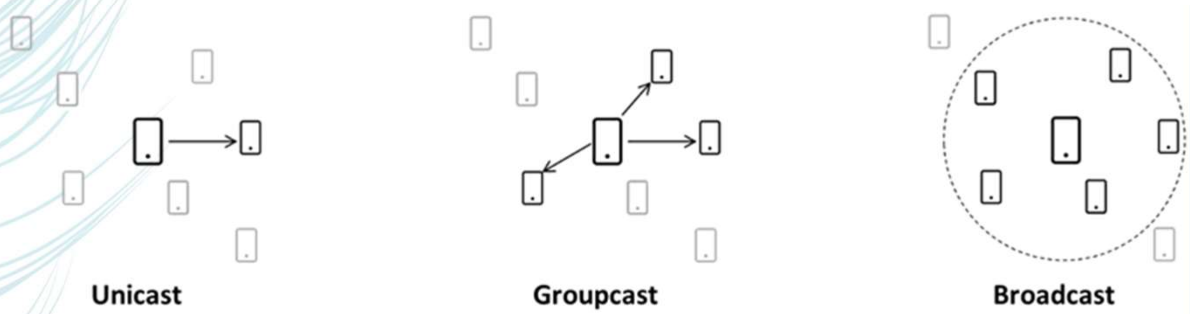
New Radio (NR) Interface: Key Technologies

- **Single of aggressor cell arriving delayed at victim cell such that downlink of aggressor cell interferes with uplink of victim cell**



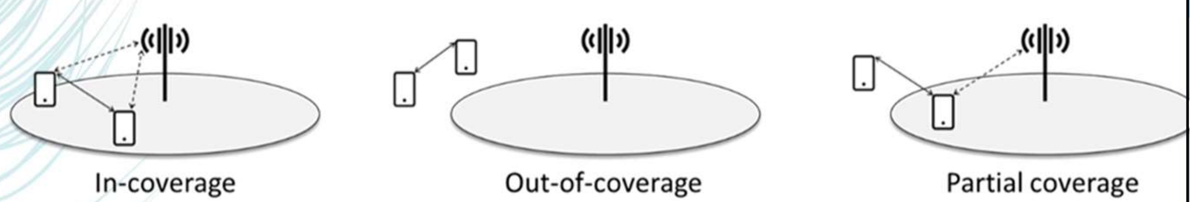
New Radio (NR) Interface: Key Technologies

- **Basic sidelink transmission scenarios**

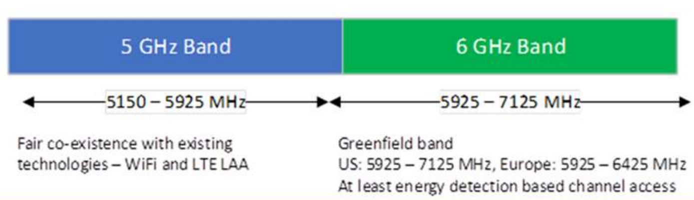


New Radio (NR) Interface: Key Technologies

- **Sidelink deployment scenarios**

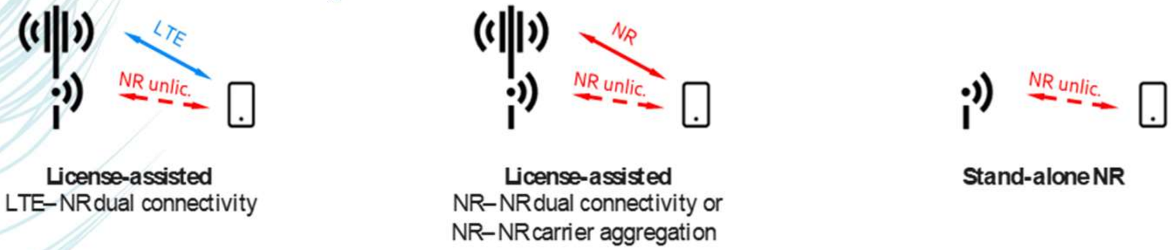


- **Spectrum priorities for NR-U**



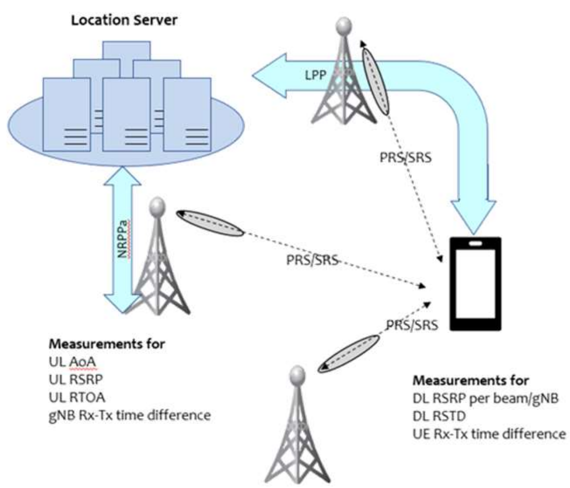
New Radio (NR) Interface: Key Technologies

- **License-assisted (left and middle) and stand-alone (right) operation of NR in unlicensed spectra**



New Radio (NR) Interface: Key Technologies

- **NR RAT-dependent positioning schemes**



!!THANK YOU!!
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Today we learned about

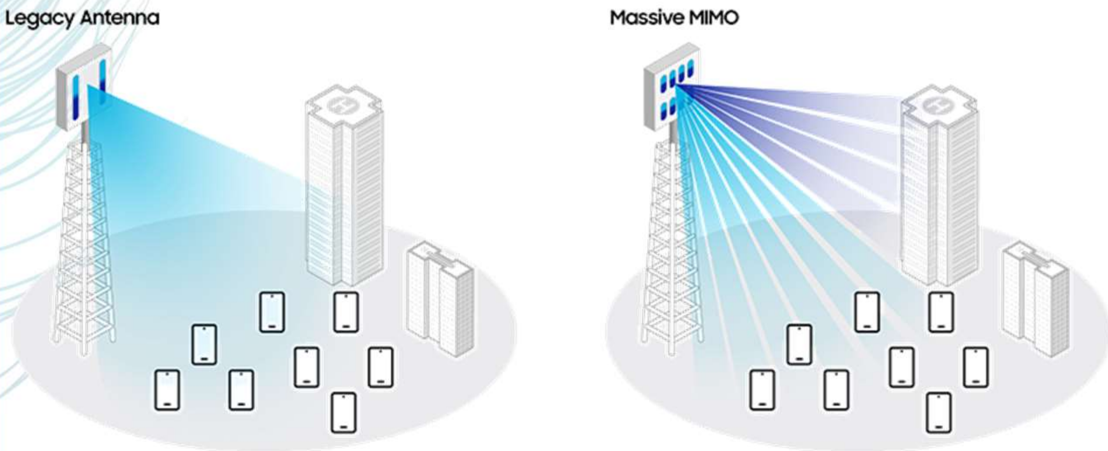
New Radio (NR) Interface: Key Technologies

MODULE 3:
Radio Access Technologies in 5G

M3 S4 & S5

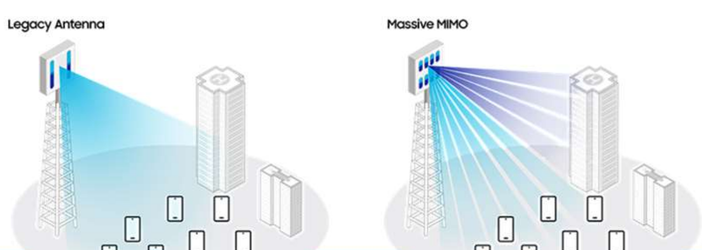
Massive MIMO in 5G
Beamforming in 5G

Massive MIMO in 5G



Massive MIMO in 5G

- Massive MIMO is a multi-user MIMO (multiple-input multiple-output) technology that can provide uniformly good service to wireless terminals in high-mobility environments.
- The key concept is to equip base stations with arrays of many antennas, which are used to serve many terminals simultaneously, in the same time-frequency resource.
- The word "massive" refer to the number of antennas and not the physical size.



Massive MIMO in 5G

- MIMO systems require a combination of antenna expansion and complex algorithms.
- It's multifaceted, but MIMO has been used in wireless communications for a long time now — it's common for both mobile devices and networks to have multiple antennas to enhance connectivity and offer better speeds and user experiences.
- MIMO algorithms come into play to control how data maps into antennas and where to focus energy in space.
- Both network and mobile devices need to have tight coordination among each other to make MIMO work.
- Now, with the design of new 5G NR networks, MIMO becomes "massive" and crucial for 5G NR deployments..

Massive MIMO in 5G

- Massive MIMO — which is an extension of MIMO — expands beyond the legacy systems by adding a much higher number of antennas on the base station.
- The "massive" number of antennas helps focus energy, which brings drastic improvements in throughput and efficiency.
- Along with the increased number of antennas, both the network and mobile devices implement more complex designs to coordinate MIMO operations.
- That's all to say, these advancements are all aimed at achieving performance improvements needed to underpin the 5G experiences consumers expect in this new era.

Massive MIMO in 5G

- Minimum Antenna Height = ??
- For efficient radiation and reception, the height of transmitting and receiving antennas should be comparable to a quarter of wavelength of the frequency used.
- So for efficient transmission of signals of wavelengths λ the minimum length of antenna should be **λ/4.**
- Find out the minimum antenna height

1. F= 3 GHz
2. F= 6 GHz
3. F= 60 GHz
4. F= 90 GHz

Massive MIMO in 5G

- What is the distance between each antenna in the MIMO = ??
- The most important thing in MIMO antenna design we have take care about the mutual coupling, So, the antennas structure has to be small enough to accommodate the space between the two patches with distances between them of about λ/2 (λ is the free space wavelength),.
- So for efficient transmission of signals of wavelengths λ the minimum space between the two patches of antenna should be **λ/2.**
- Find out the minimum space between the two patches of antenna height

1. Two antenna of F= 3 GHz
2. Two antenna of F= 6 GHz
3. One antenna of F= 6 GHz & Other one is of F= 3 GHz

Massive MIMO in 5G

- Find out the minimum dimension (in terms of area) of an antenna unit which uses 9 antenna unit of 3GHz frequency and 3 antenna unit of 9GHz frequency??

Massive MIMO in 5G

- **Benefits of massive MIMO**

- Increased Network Capacity

Network Capacity is defined as the total data volume that can be served to a user and the maximum number of users that can be served with certain level of expected service. Massive MIMO contributes to increased capacity first by enabling 5G NR deployment in the higher frequency range in Sub-6 GHz (e.g., 3.5 GHz); and second by employing MU-MIMO where multiple users are served with the same time and frequency resources.

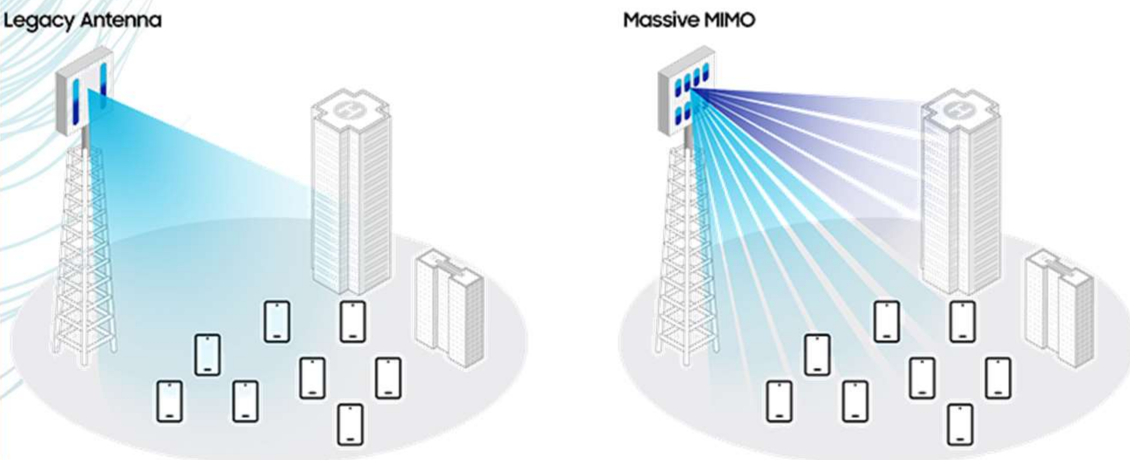
- Improved Coverage

With massive MIMO, users enjoy a more uniform experience across the network, even at the cell's edge – so users can expect high data rate service almost everywhere. Moreover, 3D beamforming enables dynamic coverage required for moving users (e.g., users traveling in cars or connected cars) and adjusts the coverage to suit user location, even in locations that have relatively weak network coverage.

- User experience

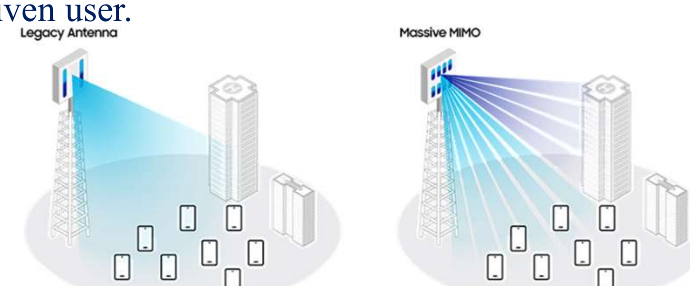
Ultimately, the above two benefits result in a better overall user experience —
users can transfer large data files or download movies, or use data-hungry apps on the go, wherever life takes them.

Beamforming in 5G



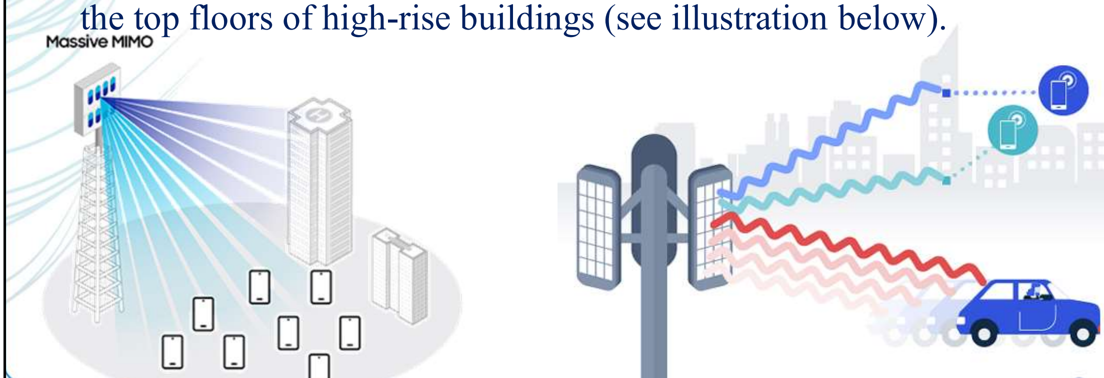
Beamforming in 5G

- Beamforming is another key wireless technique that utilizes advanced antenna technologies on both mobile devices and networks' base stations to focus a wireless signal in a specific direction, rather than broadcasting to a wide area.
- Think of the difference between using a flashlight — which kind of floods everyone in the room — versus a laser pointer, which can pinpoint and continuously track a given user.



Beamforming in 5G

- With the massive number of antenna elements in a massive MIMO system, beamforming becomes "3D Beamforming."
- 3D Beamforming creates horizontal and vertical beams toward users, increasing data rates (and capacity) for all users — even those located in the top floors of high-rise buildings (see illustration below).



Beamforming in 5G

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- Mobile feedbacks to the network, allow the network's beam to find any point in space, so a mobile user can always be served by a focused beam to their devices, as they are moving on the street or between different floors in a building.
- Also having such narrow, direct beams reduces interference between beams directed in different directions.

Beamforming in 5G

- **Benefits of beamforming**

- Beamforming effectively uses the science of electromagnetic interference to enhance the precision of 5G connections, working in tandem with MIMO to **improve throughput and connection density of 5G network** cells.
- The resultant highly directional transmissions are particularly beneficial with mmWave transmissions, which suffer heavily from **path loss** and do not propagate well through obstacles such as walls. The improved Signal-to-Noise Ratios (SNR), enabled by beamforming, **increase signal range for both outdoors and - importantly - indoor coverage**.

Beamforming in 5G

- **Benefits of beamforming**

- Beamforming's **ability to cancel out or "null" interference** is also a significant benefit in crowded, urban environments with high densities of UEs, where multiple signal beams can potentially interfere with each other.
- Overall, by reducing internal and external interference and reducing SNR, beamforming **supports higher-order signal modulation schemes**, such as 64QAM and 16QAM - all of which contribute to a substantial improvement in network cell capacity.

!!THANK YOU!!
!! Have a Nice Day!!

Today we learned about

Massive MIMO in 5G
Beamforming in 5G

MODULE 3:
Radio Access Technologies in 5G

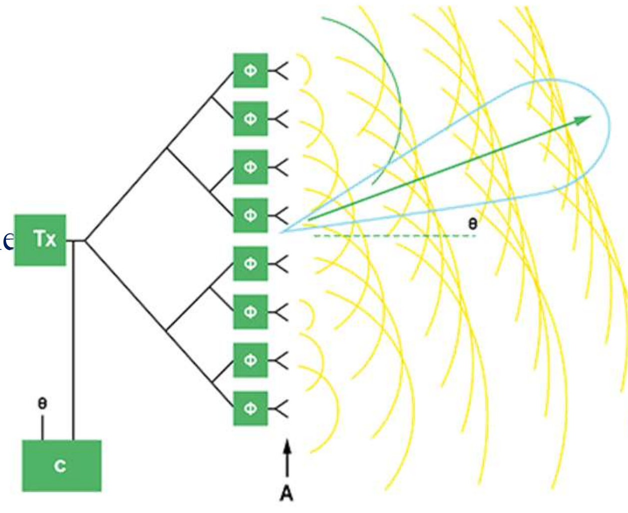
M3 S6

Beamforming Types

Beamforming Types

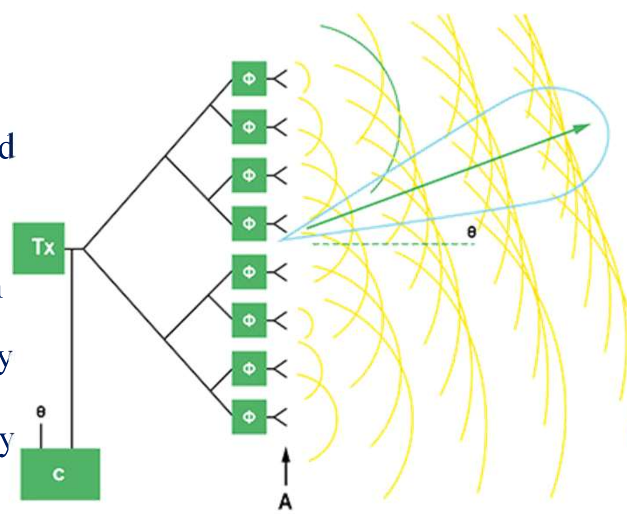
- **Working Principle**

- Beamforming is used with phased array antennae systems to focus the wireless signal in a chosen direction, normally towards a specific receiving device.
- This results in an improved signal at the user equipment (UE), and also less interference between the signals of individual UE.



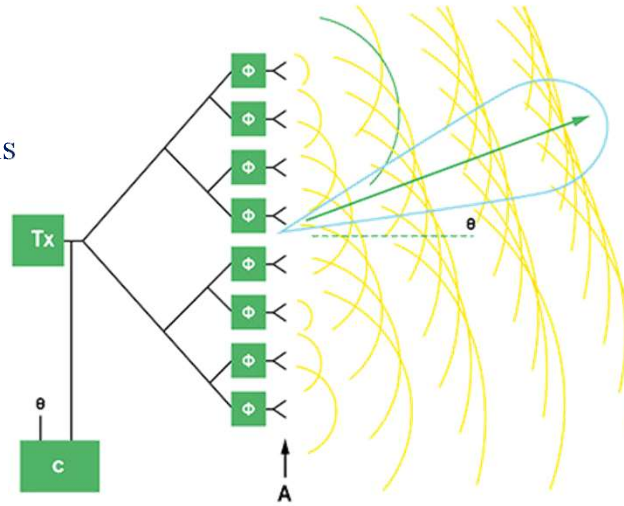
Beamforming Types

- **Working Principle**
- Phased antenna arrays are designed so that the radiation patterns from each individual element combine constructively, with those from neighbouring elements forming an effective radiation pattern - the main lobe - which transmits energy in the desired direction.
- At the same time, the antenna array is designed so that signals sent in undesired directions destructively interfere with each other, forming nulls and side lobes.



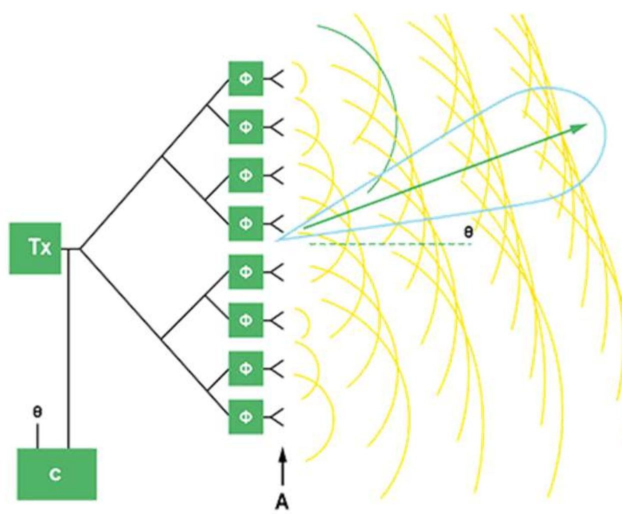
Beamforming Types

- **Working Principle**
- The overall antenna array system is designed to maximize the energy radiated in the main lobe, whilst limiting the energy in the side lobes to an acceptable level.
- The direction of the main lobe, or beam, is controlled by manipulating the radio signals applied to each of the individual antenna elements in the array.



Beamforming Types

- **Working Principle**
- Each antenna is fed with the same transmitted signal but the phase and amplitude of the signal fed to each element is adjusted, steering the beam in the desired direction.
- Fast steering of the beam is achievable since the phase and amplitude of each signal are controlled electronically, allowing adjustments to be made in nanoseconds



Beamforming Types

- **There are three methods of implementing antenna beamforming:**

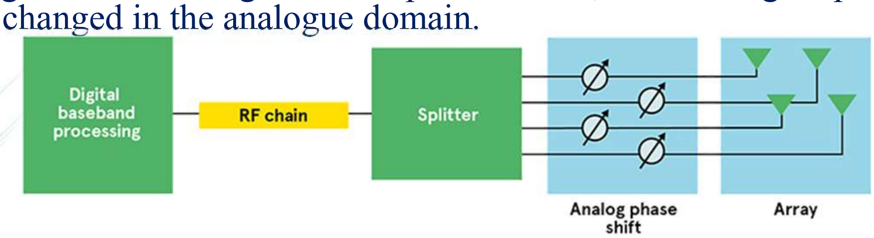
1. Analogue beamforming
2. Digital beamforming
3. Hybrid beamforming

Beamforming Types

- **There are three methods of implementing antenna beamforming:**

1. Analogue beamforming

- Analogue beamforming is the simplest method, with the signal phase being changed in the analogue domain.



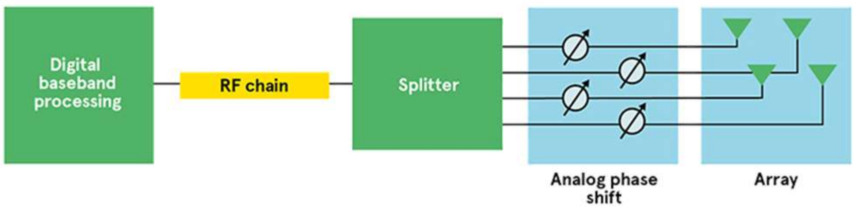
- The output from a single RF transceiver is split into a number of paths, corresponding to the number of antenna elements in the array.
- Each signal path then passes through a phase shifter and is amplified before reaching the antenna element.

Beamforming Types

- **There are three methods of implementing antenna beamforming:**

1. Analogue beamforming

- This is the most cost-effective way of implementing beamforming, since it uses a minimal amount of hardware, however an analogue beamforming system can only handle one data stream and generate one signal beam, limiting its effectiveness in 5G, where multiple beams are required.

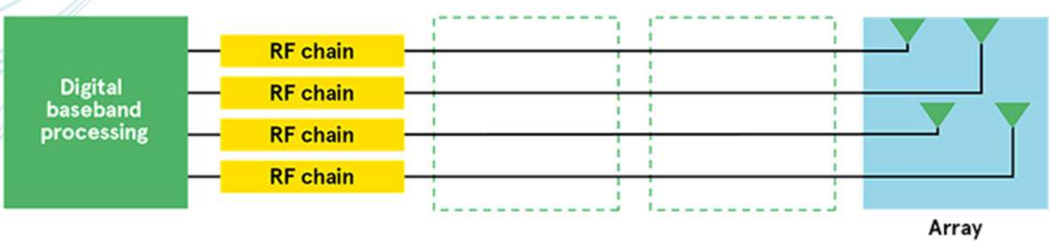


Beamforming Types

- **There are three methods of implementing antenna beamforming:**

2. Digital beamforming

- In digital beamforming, each antenna element is fed by its own transceiver and data converters (see Figure below), and each signal is pre-coded (with amplitude and phase modifications) in baseband processing before RF transmission.



Beamforming Types

- **There are three methods of implementing antenna beamforming:**

2. Digital beamforming

- Digital beamforming enables several sets of signals to be generated and superimposed onto the antenna array elements, enabling a single antenna array to serve multiple beams, and hence multiple users.

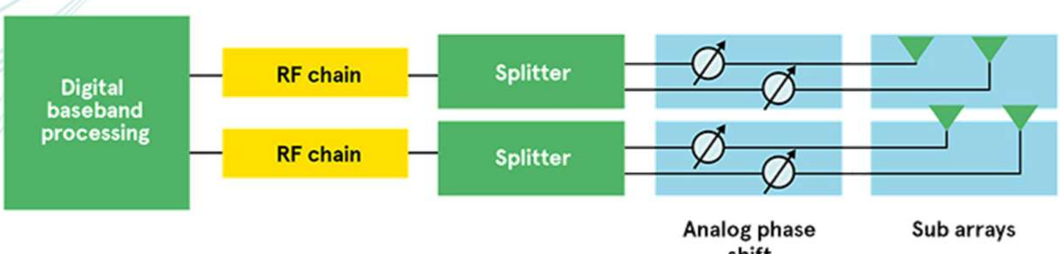
- Although this flexibility is ideal for 5G networks, digital beamforming requires more hardware and signal processing, leading to increased power consumption, particularly at mm Wave frequencies, where several hundred antenna elements are possible..

Beamforming Types

- **There are three methods of implementing antenna beamforming:**

3. Hybrid beamforming

- Hybrid beamforming (see Figure below) - where analogue beamforming is carried out in the RF stage, and digital beamforming in the baseband - offers a compromise between the flexibility of digital beamforming and the lower cost and power consumption of analogue...

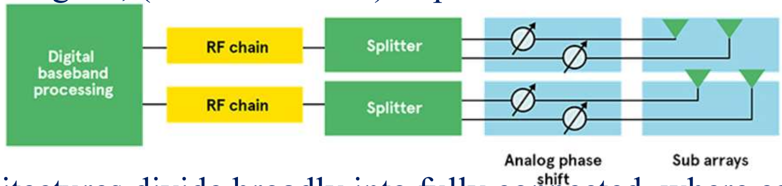


Beamforming Types

- **There are three methods of implementing antenna beamforming:**

3. Hybrid beamforming

- Hybrid beamforming is recognised as a cost-effective solution for large-scale, mmWave antenna arrays and various architectures are being developed for gNB, (5G base station) implementations.



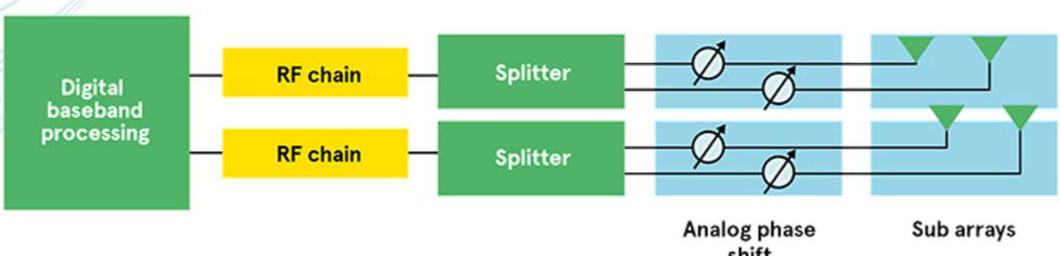
- These architectures divide broadly into fully connected, where each RF chain is connected to all antennas; and sub-connected or partially connected, in which each RF chain is connected to a set of antenna elements.....

Beamforming Types

- **There are three methods of implementing antenna beamforming:**

3. Hybrid beamforming

- Each architecture aims to reduce the hardware and signal processing complexity, while providing near optimal performance: the closest to that of pure digital beamforming.....



!!THANK YOU!!
!! Have a Nice Day!!

Today we learned about

Beamforming Types

MODULE 3:
Radio Access Technologies in 5G

M3 S7 , S8 & S9

Small Cells in 5G

HetNets in 5G

Millimeter wave Communication

Small Cells in 5G

- **What Is Small Cell Technology?**

- Small cells use low-power, short-range wireless transmission systems (or base stations).
- They cover small geographical areas or small-proximity indoor and outdoor spaces.
- Small cells have the same characteristics as base stations used by telecom companies for years.

Small Cells in 5G

- **What Is Small Cell Technology?**

- Small cell can handle high data rates for mobile broadband and consumers, as well as high densities of low-speed, low-power devices for IoT.
- These capabilities make them pivotal for 5G cell planning to deliver:

1. Ultrahigh speeds
2. One million devices per square mile
3. Latencies in the millisecond range

Small Cells in 5G

- **How Small Cell Transceivers Work?**

- Small cells improve leveraging of multiple-input, multiple-output (MIMO), beamforming and millimeter wave (mmWave).
- This concept simplifies transmission station deployment and speeds implementation.
- In addition, these transceivers can mount to the wall for indoor applications.
- For outdoor coverage, small towers and lamp posts are used.
- Backhaul connections are less complicated than before and are usually made of fiber, wired or microwave connections.

Small Cells in 5G

- **How Small Cell Transceivers Work?**

- In 3GPP Release (Rel) 17 and 18, there is also a concept of integrated access and backhaul for mmWave technology.
- Instead of fiber or other means, ultrahigh-speed mmWave signals connect cell sites' backhaul directly over a cellular connection.
- It requires line of sight between the sites but saves capital and operating expenses because no new fiber needs to be installed.

Airtel Xstream AirFiber 5G wireless service

Small Cells in 5G

- **Small Cell Types**
- There are three types of small cells in the industry today:

1. Femtocells
2. Picocells
3. Microcells

- Each type has its distinction based on its coverage capability and the number of individual users it can support.
- Network cell planners and engineers sometimes consider femtocells in a separate class.

Small Cells in 5G

- **Macrocells vs. Small Cells vs. Femtocells**

	MACROCELLS	SMALL CELLS	FEMTOCELLS
Average Size	50-200 feet tall	Pizza box size (18 x 18 inches)	Paperback book size (5 x 8 inches)
Average Coverage Range	A few miles	100 yards (football field)	A home or small business
Average Cost to Install	$200,000	Under $10,000	$100
Deployment	200,00 in the U.S.	Five to 10 times more than macrocells once fully deployed in the U.S.	Anyone can purchase for their home or small business

Small Cells in 5G

- **Small Cell Types**

1. Femtocells

- Femtocells are small mobile base stations that help extend coverage for residential and enterprise-level applications. These are mainly used to offload networks when they become congested. Femtocells can extend coverage and enhance building penetration for indoor consumers.
- **Femtocell Features:**

➢Coverage area: 30-165 feet (10-50 meters) (indoor)

➢100 milliwatts

➢Supports 8-16 users

➢Backhaul: home or enterprise Ethernet

➢Low cost

Small Cells in 5G

- **Small Cell Types**

2. Picocells

- Another type of small cell technology, picocells are small cellular base stations that cover small indoor areas like buildings or aircraft.
- Picocells are great for small enterprises to provide extended network coverage and large data throughput.
- **Applications include:**

➢Offices

➢Hospitals

➢Shopping complexes

➢Schools and universities

Small Cells in 5G

- **Small Cell Types**

2. Picocells

- **Picocell Features:**

❖Coverage area (indoor): 330-820 feet (100-250 meters)
❖250 milliwatts
❖Supports 32-64 users
❖Backhaul: wired, fiber
❖Low cost

Small Cells in 5G

- **Small Cell Types**

3. Microcells

- The microcell is a cell in a mobile network served up by a low-power base station that covers limited areas, such as:

➢Malls
➢Hotels
➢Unique spaces within smart cities or transportation hubs

- Microcells are generally more substantial than picocells, though the distinction is not always clear. Moreover, the microcell can support a more significant number of users in unique geographical areas.

Small Cells in 5G

- **Small Cell Types**

3. Microcells

- **Microcell Features:**

❖Coverage area: 1,600 feet-1.5 miles (500 meters-2.5 kilometers)
❖2-5 watts
❖200 simultaneous users
❖Backhaul: wired, fiber, microwave
❖Medium costs (more expensive than femtocells and picocells).

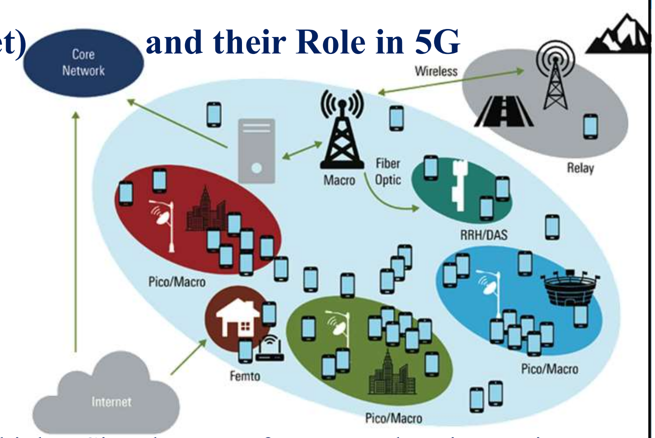
HetNets in 5G

- **Heterogenous Networks (HetNet) and their Role in 5G**

- The term HetNets, or heterogeneous networks, describes the inter-working of different radio network layers
(the macro cell layer and one or more small cell layers).
- HetNets increase network capacity by adding more cell sites;
i.e., radio access networks, macro sites,
in-building wireless and small cell deployments.
- In short, HetNets use a combination of macro, pico, and femto cells to offer network densification.
- HetNets appear as one ubiquitous, seamless network that incorporates different access technologies like 4G, 5G, and Wi-Fi.

HetNets in 5G

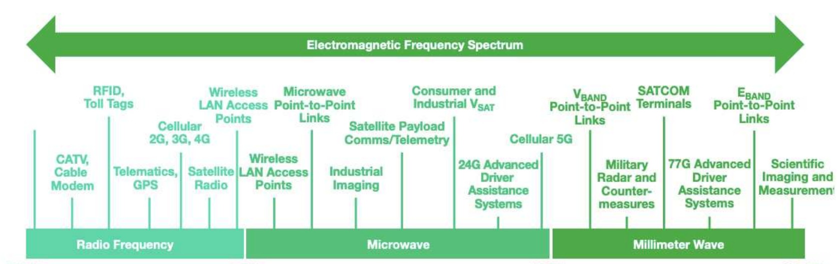
- **Heterogenous Networks (HetNet) and their Role in 5G**



- HetNets significantly improve network coverage, they can also reduce power consumption and improve overall spectral efficiency.
- HetNets offer relief and optimally benefit operators and users alike, but only if their installation is close to where additional capacity is required (i.e., close to the people) and a higher Signal-to-Interference-and-Noise-Ratio (SINR) can be achieved compared to the existing (macro-cell) deployment.
- A high SINR results in high additional indoor capacity created by the new base stations.

Millimeter wave Communication

- Millimeter waves are also known as extremely high frequency (EHF).
- It's a radio frequency that would allow transmission frequencies between 30 GHz and 300 GHz, compared to 5 GHz frequencies used by previous mobile devices.
- It also has wavelengths between 1 mm and 10 mm, compared to the several-dozen centimeter wavelengths possessed by smartphones' current radio waves.



Millimeter wave Communication

- **Millimeter Wave Propagation**

- Millimeter wave signal propagation is characterized by:

1. High free space path loss
2. Significant atmospheric attenuation
3. Diffuse reflections
4. Limited penetration depth

Millimeter wave Communication

- **Millimeter Wave Propagation**

1. High free space path loss

- One limitation of millimeter wave radio frequency (RF) communication is the free space path loss (FSPL) for direct line-of-sight communication between two antennas.
- The FSPL is inversely proportional to the square of the wavelength and is given by the following equation:

$$\textbf{FSPL (dB)} = (4\pi d / \lambda)^2$$

- where: d is the distance between the two antennas in **m** **&&** λ is the wavelength in **m**.
- **As can be seen from equation, a 10X decrease in the wavelength results in a 100X increase in the free space path loss.**
  Thus the attenuation at millimeter wavelengths is many orders of magnitude higher than the attenuation of more traditional communication frequencies like FM radio or Wi-Fi.

Millimeter wave Communication

- **Millimeter Wave Propagation**

1. High free space path loss

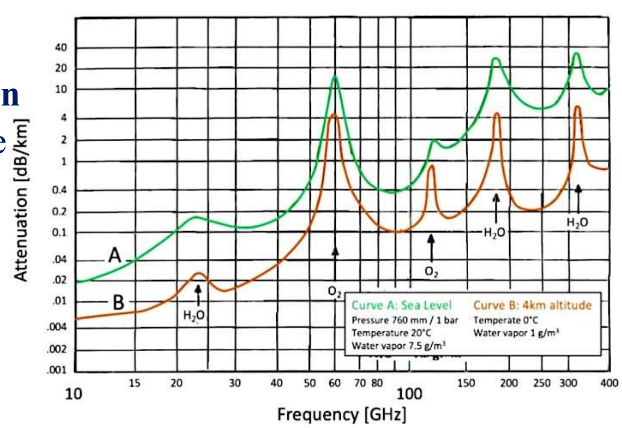
- In RF communication calculations, this loss equation is often converted to provide a result in dB, with the frequency measured in GHz and the distance measured in km. After this conversion, the equation becomes:
- **FSPL(dB)=20∗log10(d)+20∗log10(f)+92.45**
- A free calculator for evaluating the free space path loss is available here..

Millimeter wave Communication

- **Millimeter Wave Propagation**

2. Significant atmospheric attenuation

- Another drawback of millimeter wave transmission is the atmospheric attenuation.
- In this range of wavelengths there is additional attenuation caused by the presence of atmospheric gases – primarily oxygen (O_2) and water vapor (H_2O) molecules.
- As can be seen in Figure, the atmospheric attenuation can be very severe in certain bands...

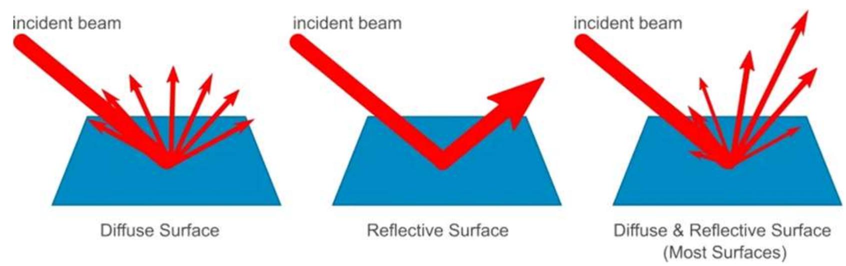


Millimeter wave Communication

- **Millimeter Wave Propagation**

3. Diffuse Reflection

- Longer wavelengths often rely on direct (specular) reflected power to assist in transmission around obstacles (think of mirror-like reflection).
- However, many surfaces appear “rough” to millimeter waves, which results in diffuse reflections that send the energy in many different directions.

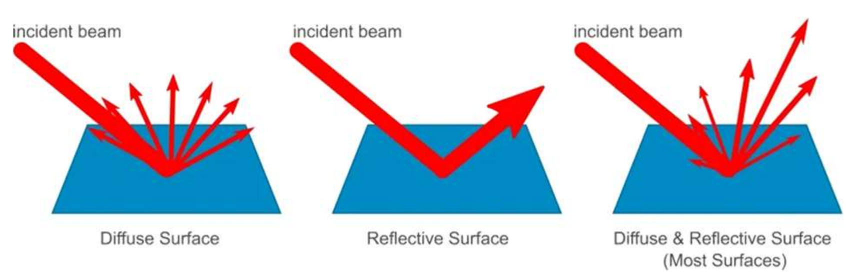


Millimeter wave Communication

- **Millimeter Wave Propagation**

3. Diffuse Reflection

- Thus, less reflected energy is likely to reach a receiving antenna.
- Millimeter wave transmissions are therefore very susceptible to shadowing by obstacles and are typically limited to line-of-sight transmission..



Millimeter wave Communication

- **Millimeter Wave Propagation**

4. Limited penetration depth

- Because of their shorter wavelengths, millimeter waves do not penetrate deeply into or through most materials.
- For example, a study of common building materials found that attenuation ranged from approximately 1 to 6 dB/cm and the penetration losses through a brick wall at 70 GHz may be five times higher than at 1 GHz.
- Outdoors, foliage will also block most millimeter wavers.
- Therefore, most millimeter wave communication is limited to line-of-sight operation...

!!THANK YOU!!
!! Have a Nice Day!!

Today we learned about

Small Cells in 5G
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