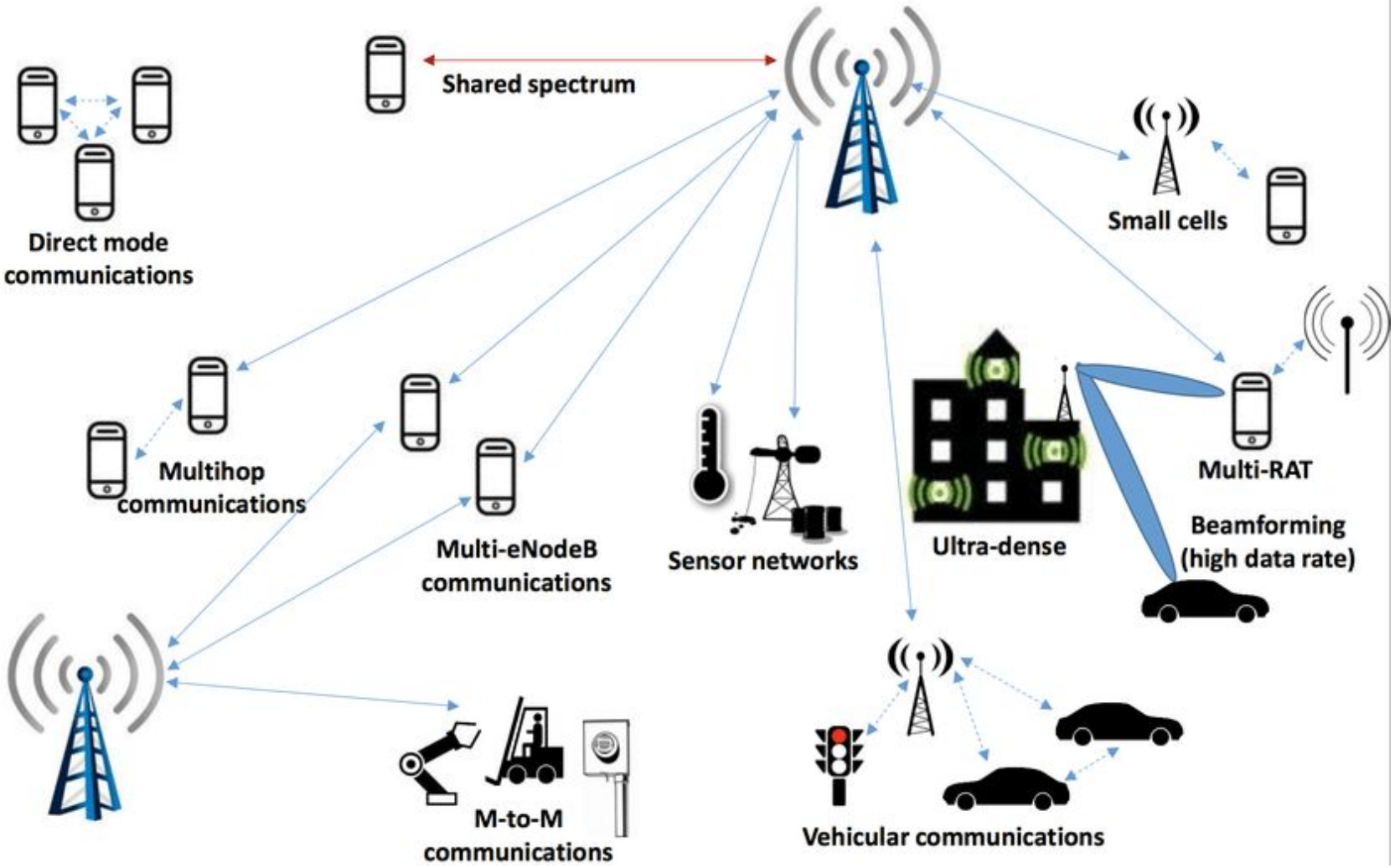
5G New Radio (NR)

Key abbreviations

- UE – User Equipment (User's device e.g. phone, tablet etc.)
- NB – Node B (Cell Tower)
- NR – New Radio (the name given to 5G technology, just like 4G is called LTE)

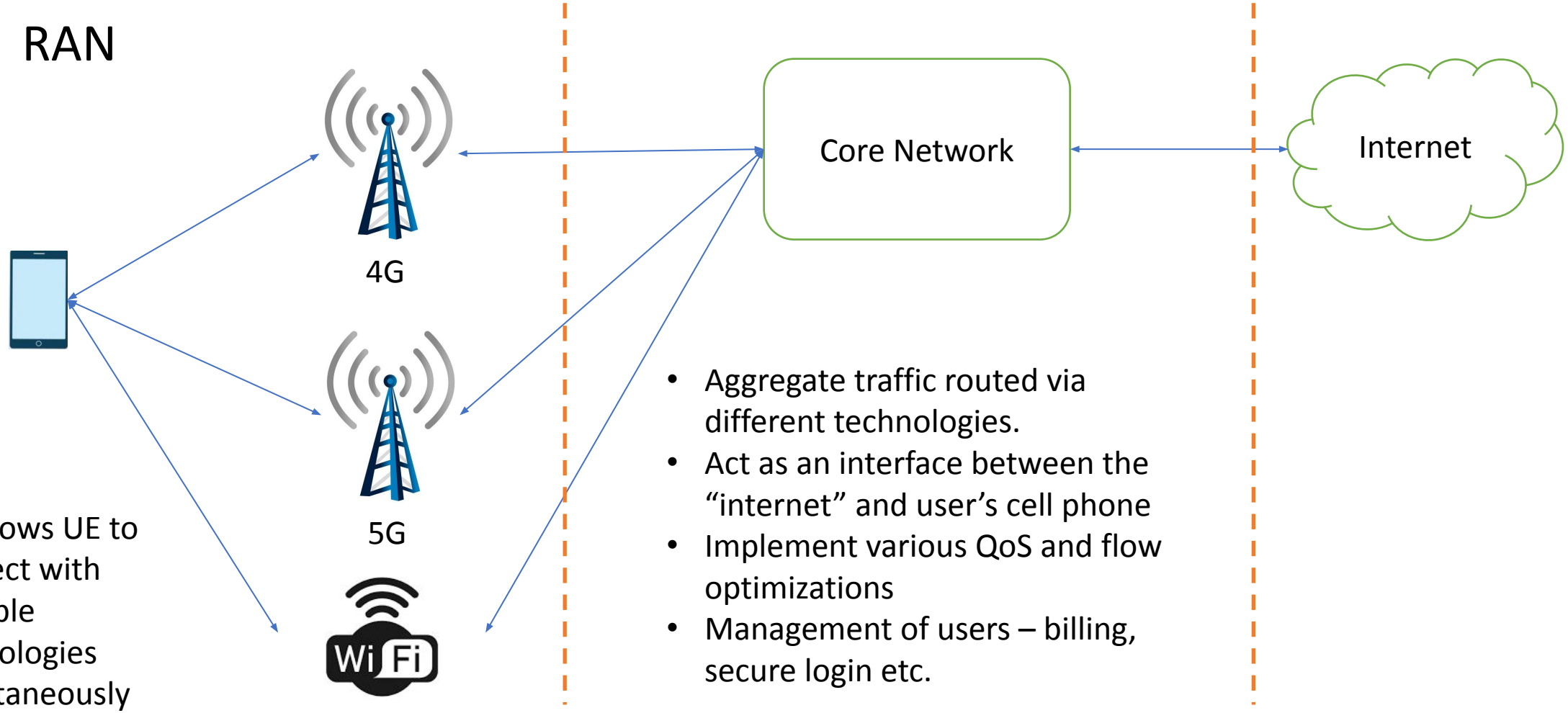
What specialized services does 5G NR provide?



- EMBB (Multi Gbps Tput)
- URLLC (Very low latency)
- MMTC (machine-machine)
- NB-IoT (IoT devices)
- NR-Unlicensed
- Non-terrestrial communication
- V2X – Vehicular communication

5G is much more than just high throughput!!

5G NR Architecture



5G allows UE to connect with multiple technologies simultaneously

- Aggregate traffic routed via different technologies.
- Act as an interface between the “internet” and user’s cell phone
- Implement various QoS and flow optimizations
- Management of users – billing, secure login etc.

5G NR RAN (Radio Access Network)

What all functionalities need to be performed at RAN level?

- Transmit and receive radio signals (because wireless!!!)
- Converting bits to physical signals (modulation)
- Error coding

What can happen to a packet transmitted wireless channel?

- It can get lost/corrupted – Retransmissions/Recovery
- Packets can be delivered out of order - Reordering
- Packet might be too large to fir the wireless resources – segmentation and reassembly
- Someone might try to decode your data – Ciphering
- Someone might try to spoof configuration messages – Authentication
- Move from one cell tower to another - Handover

5G NR RAN

Control Plane

NAS
RRC

- Configuration of Data path parameters for scheduling, security etc.
- Control of interaction between RAN and core network

Data Plane

SDAP	Mapping IP Flows to RAN Packet Data Units
PDCP	Ciphering and Security, Handovers
RLC	Segmentation, Retransmissions , Reordering
MAC	User Scheduling, Control signaling, concatenation
PHY	Modulation, coding etc.
RF	Responsible for transmission AND reception of radio signals

5G NR RAN

SDAP – Service Data Adaptation Protocol

- MAP IP flows to Radio Bearers (Data flows corresponding to users at RAN level)

PDCP – Packet Data Convergence Protocol

- Cipher user data
- Cipher and authenticate control messages between UE and NB
- Manage data recovery/retransmission during movement of UE from one cell tower (NB) to another

5G NR RAN RLC (Radio Link Control)

- Responsible for ensuring reliable data delivery between UE and NB

- Has two operation mode for data:
  - UM : Unacknowledged mode – Data is sent without worrying about whether it gets lost or corrupted (similar philosophy as UDP)
  - AM : Acknowledged mode – Guarantees reliable delivery of data from UE to NB. It uses selective retransmission, where RLC maintains sends a set of packets and receives a list of missing packets as NACK's, which are then retransmitted.

- RLC is given wireless resource allocation for each user by MAC layer. If the data packet is larger than the allocation then RLC is responsible for segmenting the packet on the transmitter and reassembling the packets at the receiver.

- Both RLC or PDCP can be configured to performing reordering of packets to ensure packets are processed further in-order.

5G NR RAN MAC (Medium Access Control)

- Responsible for wireless resource allocation and scheduling.
- Responsible for concatenating various flows corresponding to the same users into a single MAC packet that can be transmitted to the user.
- Responsible for various control signaling (Timing advance etc.) --- Exact details beyond the scope of this precept.

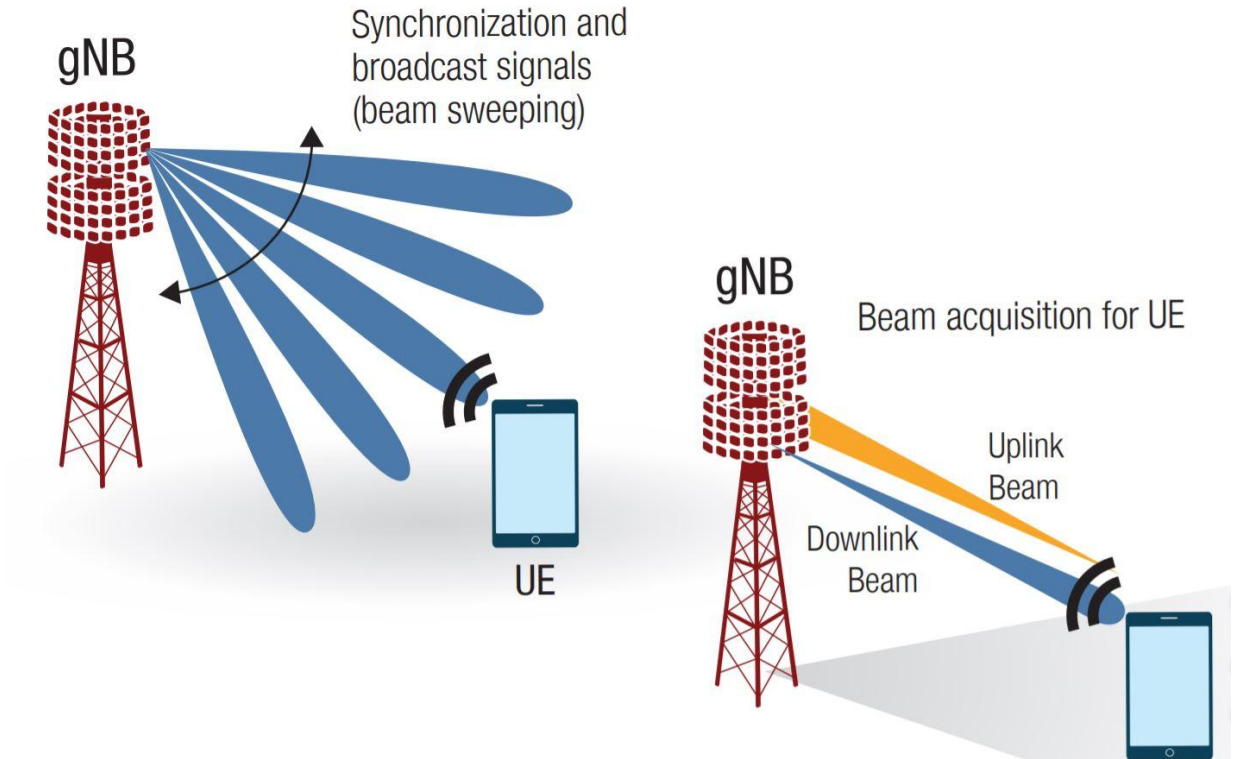
- Responsible for initial connection procedure of UE to NB – Random Access (RACH)

What happens when you turn on your phone?

- Step 1 – Phone searches for available NB, by scanning a broadcast signal.
- Step 2 – After finding the NB, phone initiates a procedure to connect to it – RACH
  - It includes calculating the timing shift between UE NB (propagation time) to decode signals properly
  - Initiating a connection to NB and informing about your identity – We will skip the details of this, but this is a very complicated procedure, that requires managing collisions between different users and exchange of UE unique identities.
- Step 3 - Establish data flows from core network to UE to carry IP data (multiple data flows can be set up with various configurations (e.g. AM/UM) for different types of IP data)
- Step 4 – Securely exchange ciphering and authentication keys between UE and NB
- Step5 – Now you can start browsing the internet!!

5G NR RF

- Use mm Waves for transmitting data (28 GHz) + OFDMA (out of scope)
- Using a large number of antenna elements to create highly directed beams towards the users rather than an omni-directional transmission.



Some interesting properties of millimeter waves

- High attenuation while propagation
- Mostly get absorbed by walls/objects and doesn’t reflect much.

- In the breakout room, you guys need to think about what is a major challenge of 5G arising from these properties of mmWaves.
- Possible solutions to these problems?

5G NR vs older technologies

- Use of mm Waves
- There are a lot of other ingenious changes in 5G compared to previous generations of cellular technologies which can’t be covered in such a short time.
- Some interesting changes at PHY layer include:
  - OFDMA with Multi-numerology
  - Bandwidth part operation
- Interested students can look at the 3GPP specifications for 5G NR (series 38.xxx) or come to office hours.

Breakout room discussion

- Due to lack of reflections, there needs to be a strong line of sight path between UE and NB, which is not always possible due to movement of UE and obstacles. Its like you can play hide-and-seek with cell tower.
- If radio waves cannot penetrate, then how do you receive 5G signals indoors?

Possible solutions:

- Having a large number of NB's serving a small area (referred to as micro/nano cells). But it requires NB to be very compact in size, so you can place them along with road lights, on top of trees etc.
- For indoors, a possible solution is to have a 5G receiver outside which relays and re-transmits the 5G signals indoor. The indoor and outdoor unit can be connected via fiber.
- It is also possible to use 5G as a backhaul for your Wi-Fi connections instead of usual ethernet. So a 5G receiver outside will connect to the cell tower, which will provide a backhaul connection for the indoor WiFi routers.