EE6143: Advanced Topics in Communications
Assignment 5a
Radio Interface Protocols

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November 27, 2024

5G sparked of changes in the structure of the *Radio Access Network (RAN)* as well as the core network (*EPC: Evolved Packet Core*) [1].

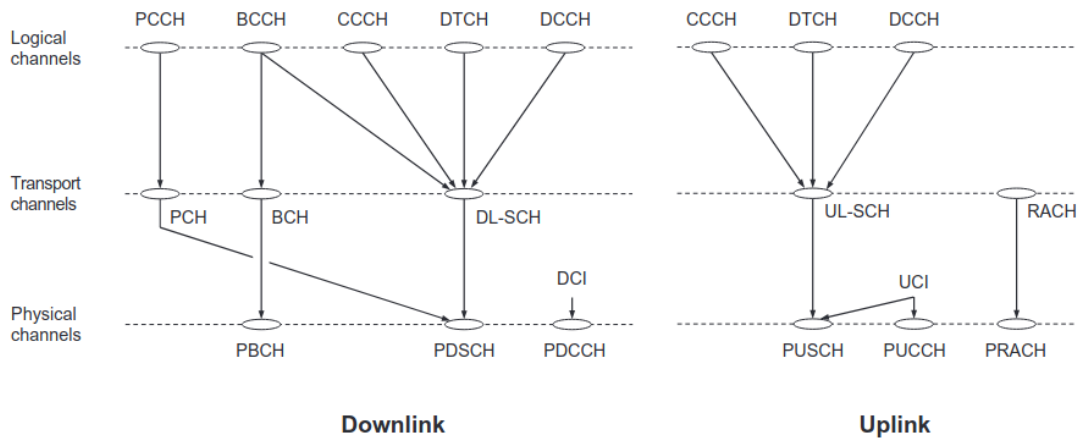
- **Radio Access Network (RAN):** It is responsible for all radio-related functionality of the overall network, like scheduling, resource handling, retransmission protocols (like ARQ), coding, and MIMO schemes.
- **Core Network:** The 5G core network is used for functions not related to the radio access like authentication, charging functionality, and setting up of end-to-end connections.

The *user plane* is where the actual user data is transmitted, while the *control plane* is used for establishing, maintaining, and terminating connections between the `UE` and the `gNB`.

1 Channels

There are different types of channels:

- **Logical Channel:** Defined by the *type* of information that the channel carries, i.e. whether it is *control* information or *traffic*.
- **Transport Channel:** Defined by how the information is transported over the radio interface (i.e. whether it is broadcast, paging, or shared-channel).
- **Physical Channel:** Corresponds to the set of time-frequency resources used for transmission of a particular transport channel.



Logical channels use underlying Transport channels to transmit information, and Transport channels in turn pass the information to the Physical layer channels.

1.1 Physical Channels

The various downlink physical channels are:

1. **Physical Downlink Shared Channel (PDSCH):** This is the channel mostly used to send the user data downlink. But, it is also used for other things like sending paging information, and random-access responses.
2. **Physical Downlink Control Channel (PDCCH):** This channel is used for providing downlink control data, mainly scheduling decisions, to the `UE`s. *Note: This channel is elaborated in further assignments.*
3. **Physical Broadcast Channel (PBCH):** This channel broadcasts some parameters that will be used by `UE`s for access.

Likewise, the various uplink physical channels are:

1. **Physical Uplink Shared Channel (PUSCH):** This is the channel used to send the user data uplink.
2. **Physical Uplink Control Channel (PUCCH):** This channel carries UCI (Uplink Control Information) and ARQ acknowledgements from the `UE` to `gNB`.
3. **Physical Random Access Channel (PRACH):** This is used by `UE`s for initial access and request an allocation from the base station.

1.2 Transport Channels

The various downlink transport channels are:

- **The Broadcast Channel (BCH):** Used for transmission of parts of the BCCH system information- the Master Information Block (MIB), which contains the DL Bandwidth, number of transmit antennae, and so on.
- **The Paging Channel (PCH)** is used for transmission of paging information from the PCCH logical channel.

- **The Downlink Shared Channel (DL-SCH)** is the main transport channel used for transmission of downlink data in NR.

The various uplink transport channels are:

- **The Uplink Shared Channel (UL-SCH)** is the uplink counterpart to the DL-SCH, that is, the uplink transport channel used for transmission of uplink data.
- **Random-Access Channel (RACH)** is also defined as a transport channel, and is used by users during initial access.

1.3 Logical Channel

The logical channels are usually not divided into separate uplink and downlink channels. The various channels are:

- **The Broadcast Control Channel (BCCH):** Used for transmission of system information from the network (`gNB`) to all devices in a cell. This is primarily used for initial access.
- **The Paging Control Channel (PCCH):**Used for paging of devices whose location on a cell level is not known to the network. The paging message therefore needs to be transmitted in multiple cells.
- **The Common Control Channel (CCCH):** Used for the transmission of control information in conjunction with random access.
- **The Dedicated Control Channel (DCCH):** Used for the transmission of control information to/from a device. This channel is used for individual configuration of devices.
- **The Dedicated Traffic Channel (DTCH):** Used for transmission of user data to/from a device. This is the logical-channel type used for transmission of all unicast uplink and downlink user data.

2 Protocol Entities

Above is an exploration of the various channels. Now, the various 'layers' or the 'protocol' entities are:

1. **Physical Layer:** Contains all the transport channels described above. This layer takes care of coding, modulation, and multi-antenna mapping.
2. **Medium Access Control (MAC):** Handles multiplexing of logical channels, ARQ, and scheduling.
3. **Radio-link Control (RLC):** Used for segmentation and retransmission handling. In contrast to 4G, 5G does not expect in-order packet delivery.
4. **Packet Data Convergence Protocol (PDCP):** Performs IP header compression, and ciphering.
5. **Service Data Application Protocol (SDAP)** is responsible for mapping QoS (Quality-of-Service) bearers to radio bearers according to their requirements. This protocol layer is not present in LTE.

3 Mobility Management

Mobility is a complicated and involved topic, and might involve handoffs from say LTE to NR base-stations, or something more complicated.

3.1 Network-connected mobility

Assume that the `UE` is connected to the network. There are two subtypes inside this:

- **Beam-level mobility** is essentially beam management, which is implemented in the PHY and MAC layers.
- **Cell-level mobility:** This is the conventional application of mobility. The network is responsible for deciding when we have to change the base-station a `UE` is connected to. There are many events which are triggered in NR.

  For example, if the serving becomes worse than threshold, an A2 event is triggered. This happens in a mobility procedure when a `UE` moves towards cell edge.

The below image describes the various events in cell-specific mobility.

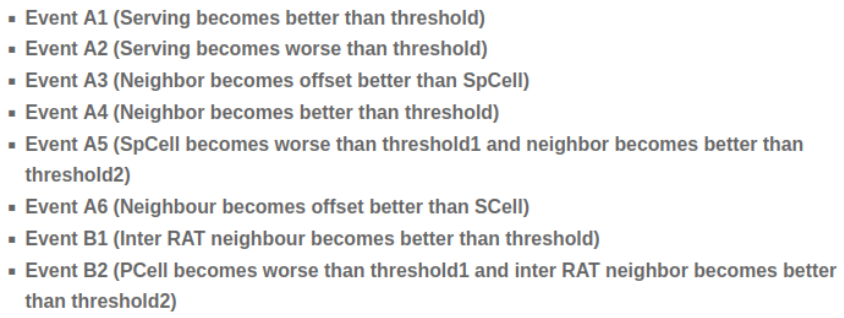


Figure 1: Events in Cell-level Mobility. Abbreviations: SpCell: Special Cell, RAT: Radio Access Technology.

The reason 5G uses events instead of periodic reporting is in accordance with the ultra-lean design principle of 5G.

If the network receives a measurement report after an event, it decides whether to the handover or not, based on if the `gNB`s have sufficient capacity to accommodate, etc. If the target `gNB` accepts the handover request, the source `gNB` requests the device to switch to that corresponding `gNB`.

References

[1] Erik Dahlman, Stefan Parkvall, and Johan Skold. *5G NR: The Next Generation Wireless Access Technology*. Academic Press, Inc., USA, 1st edition, 2018.