Modern Wireless Networks

5G Multipoint Coordination & Transmission

ICEN 574– Spring 2019

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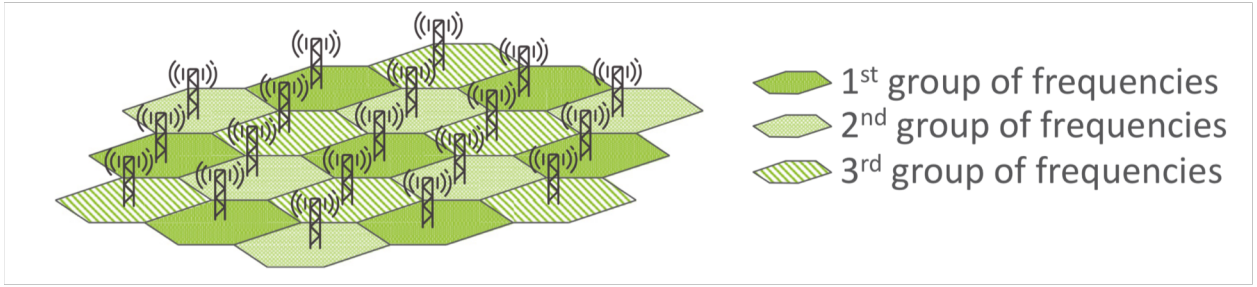
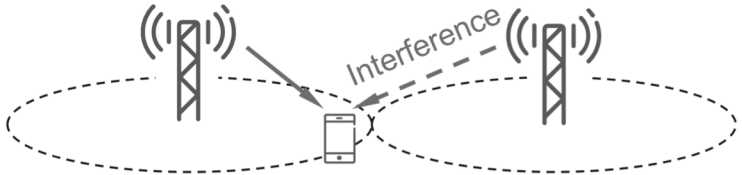
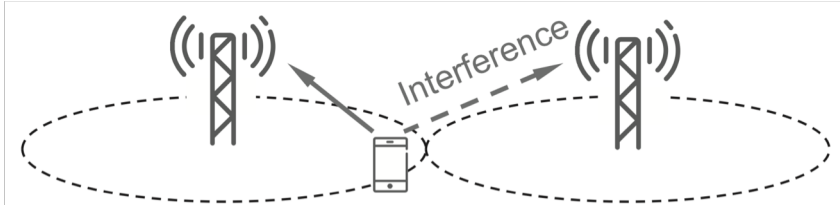
Frequency Reuse and Interference

- Earlier cellular deployments do not use frequencies efficiently



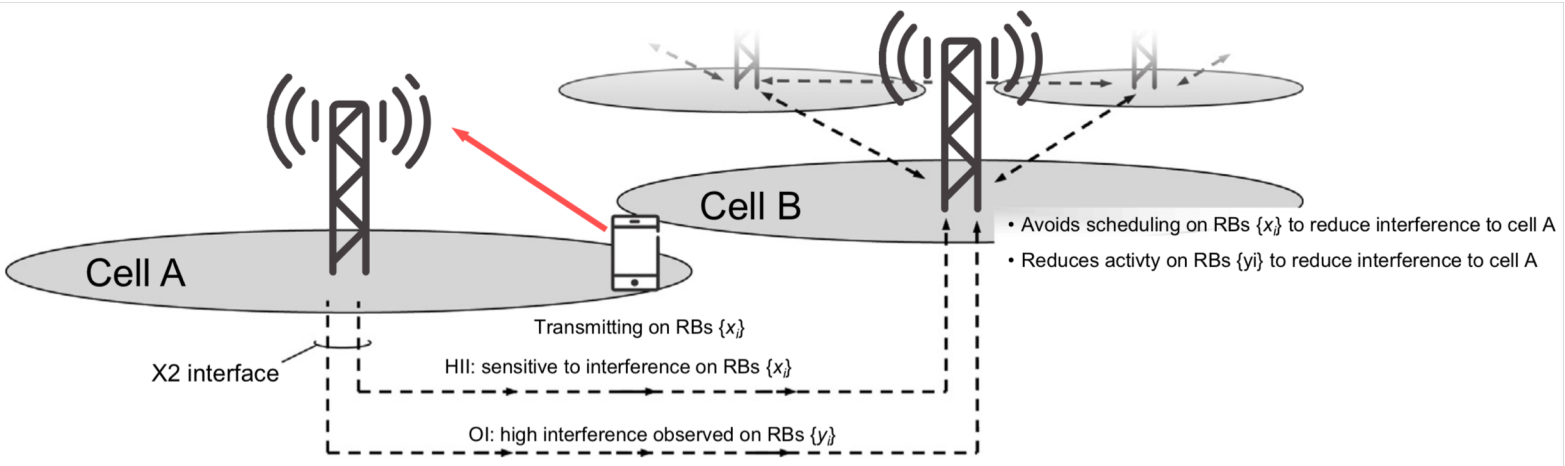
- LTE: all frequency resources are available for use at each transmission point
  - Instead of "cell" we here use the more general term "(network) transmission point."
- Interference in Cell Edge if not coordinated





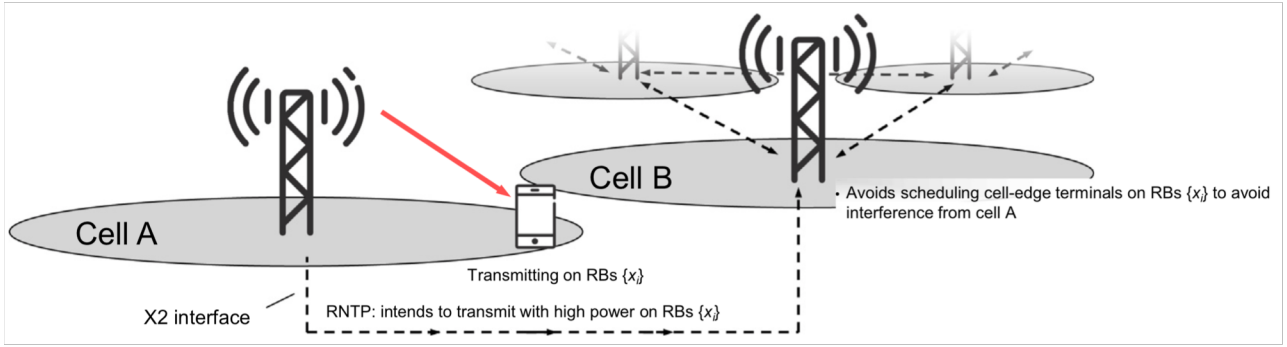
Inter-Cell Interference Coordination (ICIC)

- X2 Messages for Uplink Interference Indicator
  - high-interference indicator (HII): set of resource blocks within which an eNodeB has high sensitivity to interference; proactive
  - overload indicator (OI): indicates at three levels (low/medium/high), the uplink interference experienced by a cell on its different resource blocks; reactive
  - How to react to ICIC is not part of the standard



Inter-Cell Interference Coordination (ICIC)

- X2 Messages for Downlink Interference Indicator
  - relative narrowband transmit power (RNTP): provides information, for each resource block, whether or not the relative transmit power of that resource block is to exceed a certain level; proactive



Coordinated Multi Point (CoMP) Tx/Rx

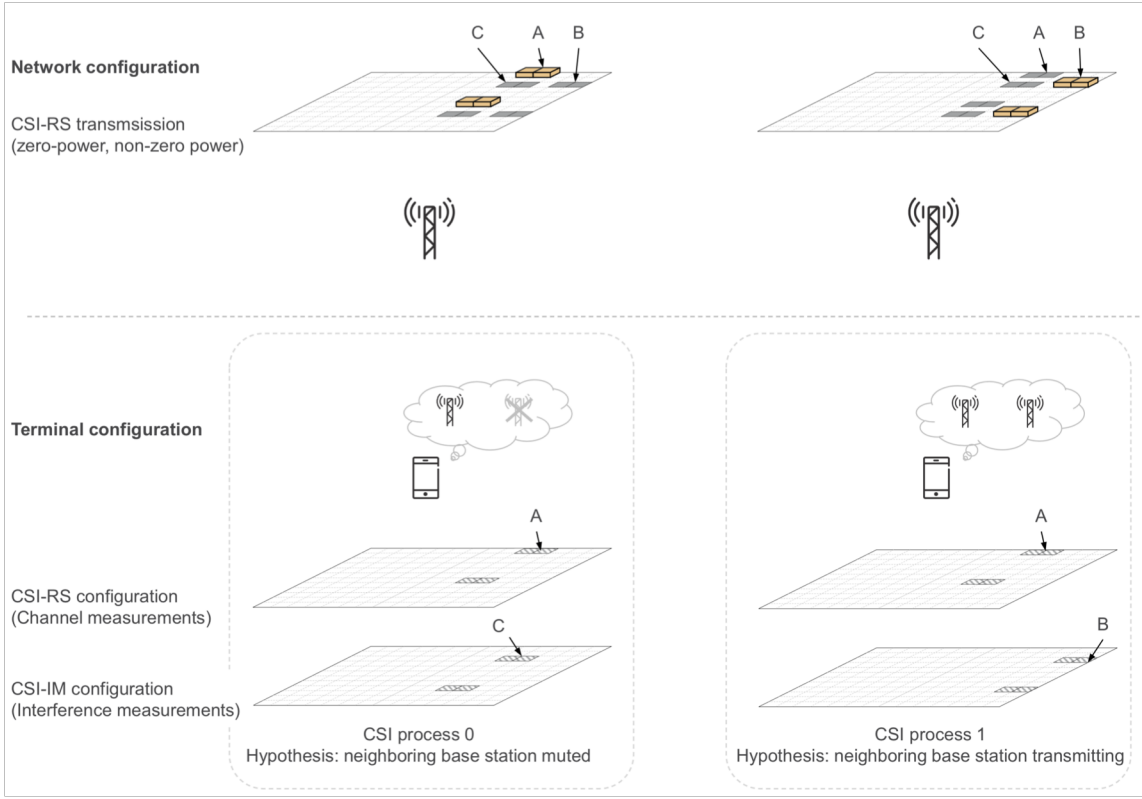
- Downlink Multi-point coordination
  - transmission to a device is carried out from *a specific transmission point*
  - scheduling and link adaptation may be coordinated between transmission points
- Downlink Multi-point transmission
  - transmission to a device is carried out from *different transmission points*
  - transmission can either *switch dynamically* between the different transmission points or be carried out *jointly* from multiple points
  - requires coordination between transmission points
- Uplink Multi-point coordination
  - uplink scheduling is coordinated between different reception points
- Uplink Multi-point reception
  - reception may be carried out at multiple points

Coordinated Link Adaptation

- *Link Adaptation*: dynamic selection of data rate based on predictions of the channel conditions
  - Highly dynamic traffic condition results in change in interference level from neighboring transmission point
- *Coordinated Link Adaptation:* uses information related to transmission decisions of neighboring transmission
  - transmission points carry out transmission decisions in a given subframe
  - this information is shared between neighboring transmission points
  - neighboring transmission points transmission decisions are fed as input to the link-adaption decision
- How much interference from Neighboring Tx Points?

Multiple CSI Processes

- Process 0
  - Reports channel state under the hypothesis that there is no transmission from the neighboring transmission point
  - CSI-RS corresponding to resource A
  - CSI-IM corresponding to resource C (configured as *zero-power CSI-RS* at the neighboring transmission point)
- Process 1
  - Reports channel state under the hypothesis that there is transmission from the neighboring transmission point
  - CSI-RS corresponding to resource A
  - CSI-IM corresponding to resource B (configured as *nonzero-power CSI-RS* at the neighboring transmission point)

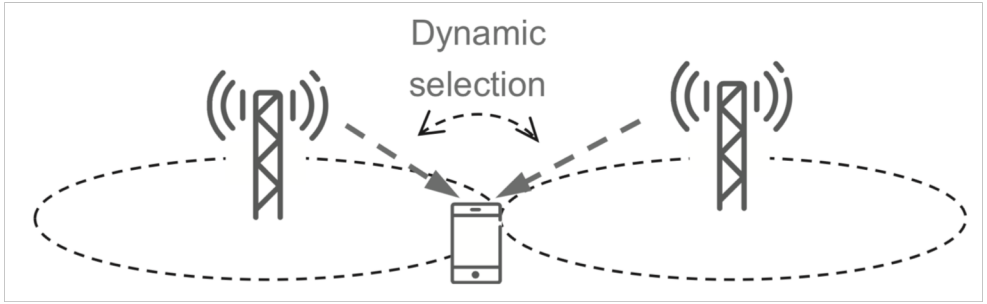


Coordinated Scheduling

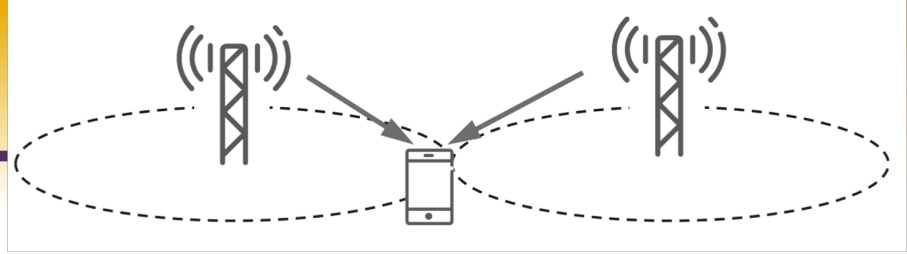
- coordinating the actual transmission decision(s) between transmission points
  - dynamic point blanking: dynamically preventing transmission at certain time-frequency resource
  - coordinated power control: dynamically adjusting the transmit power
  - coordinated beam-forming: dynamically adjusting the transmission direction

Dynamic Point Selection

- the device does not need to be aware of the change of transmission point
- the device will see a PDSCH transmission, instantaneous channel may change abruptly as Tx Point changes
- device transmits based on Uplink grant



Joint Transmission



- Coherent joint transmission
  - network has knowledge about the detailed channels to the device
  - selects transmission weights accordingly
  - a kind of beamforming for which the antennas taking part in the beamforming are not colocated but correspond to different Tx points
- Noncoherent joint transmission
  - Detaied channel knowledge is not required
  - the power of multiple transmission points is used for transmission to the same device, that is, in practice, a power gain

Uplink CoMP

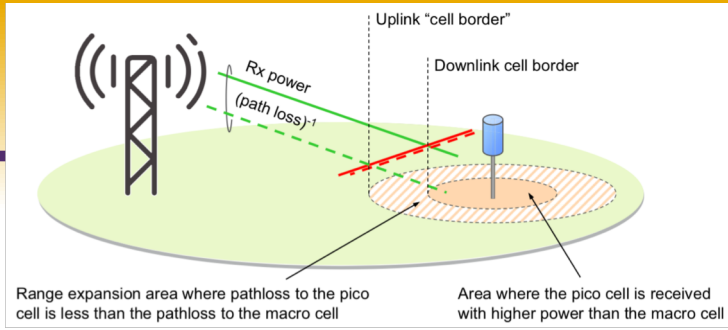
- Basic principles of downlink CoMP
  - uplink multi-point coordination: dynamic coordination of uplink transmissions in order to control uplink interference and achieve improved uplink system performance
  - uplink multi-point reception or uplink joint reception: reception of uplink transmissions at multiple points

Heterogeneous Deployment

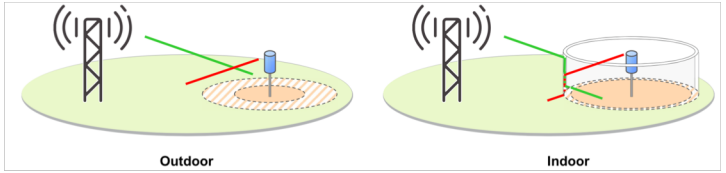
- deploy additional lower-power nodes, or “small cells”, under the coverage area of the macro layer
- low-power nodes provide *very high traffic capacity* and improved service experience (higher end-user throughput) locally
- the macro layer provides full-area coverage

Densification with *complementary* low-power nodes (heterogeneous deployment)

Interference Scenarios



- Simultaneous use of the same spectrum in different layers implies interlayer interference
- Homogeneous Deployment:
  - Cell association is based on received signal power (CS-RS) at UE
  - Uplink and downlink pathloss / SNR is similar



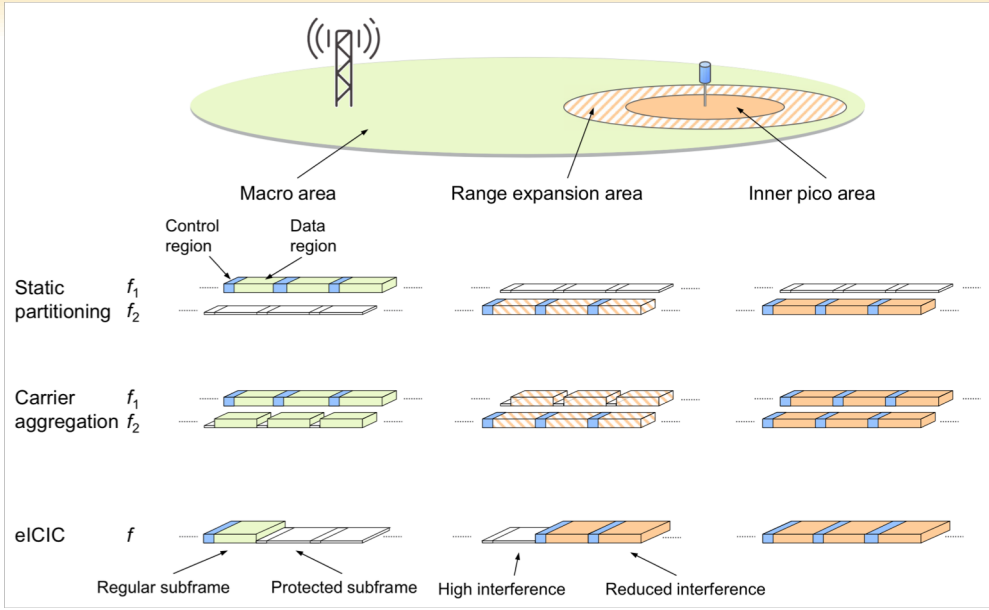
- Heterogeneous Deployment:
  - Large difference in Transmit Power between the layers
  - Uplink reception point and downlink reception point may not be the same
  - Downlink point selection is based on highest received signal strength
  - Uplink point selection is based on lowest pathloss

Approaches to HetNet Deployment

- Release 8 functionality:
  - a medium amount of range expansion
  - No inter-cell time synchronization or coordination is necessary
- Frequency-domain partitioning
  - extensive amount of range expansion is supported through interference handling in the frequency domain, for example, by using carrier aggregation
- Time-domain partitioning
  - an extensive amount of range expansion is supported through interference handling in the time domain
- “Shared cell”
  - using CoMP techniques to support a large amount of range expansion
  - transmission point does not define a unique cell
  - multiple geographically separated transmission points may belong to the same cell

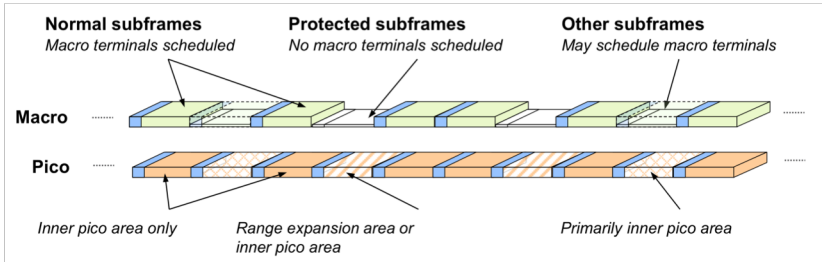
Frequency Domain Partitioning

- Split the spectrum into two parts f_1 and f_2
- Data (PDSCH) transmission:
  - both carriers are available in both layers
  - interference between the layers is handled by ICIC
  - carrier aggregation allows the total available spectrum, to be assigned for transmission to a single device
- L1/L2 control signaling:
  - Semi-static frequency separation



Time Domain Partitioning

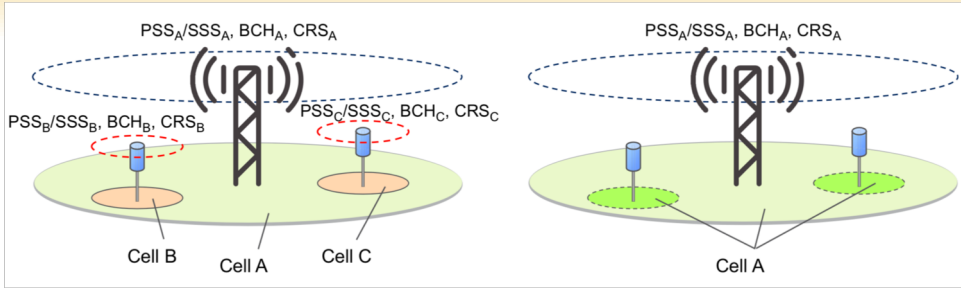
- restrict the transmission power of the macro cell in some subframes
- In *reduced-power subframes or protected subframes*, devices in pico cell will experience less interference from macro cell for both data and control
- pico cell schedules devices in the:
  - range expansion area using the protected subframes
  - inner part of the pico cell using all subframes
- macro cell schedules devices in the:
  - mostly outside protected area
  - some control signaling in protected area

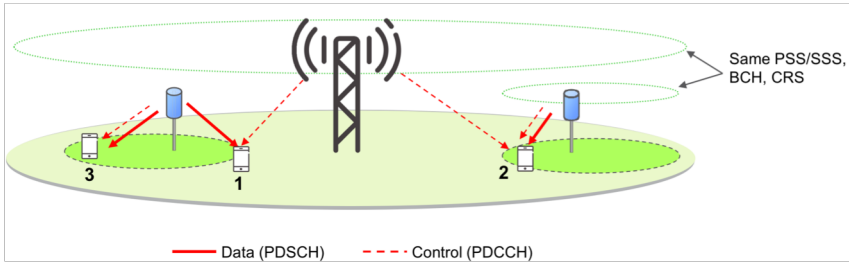


- The gain from deploying the pico cells must be larger than the loss incurred by the macro cell reducing power in some subframes

Shared Cell

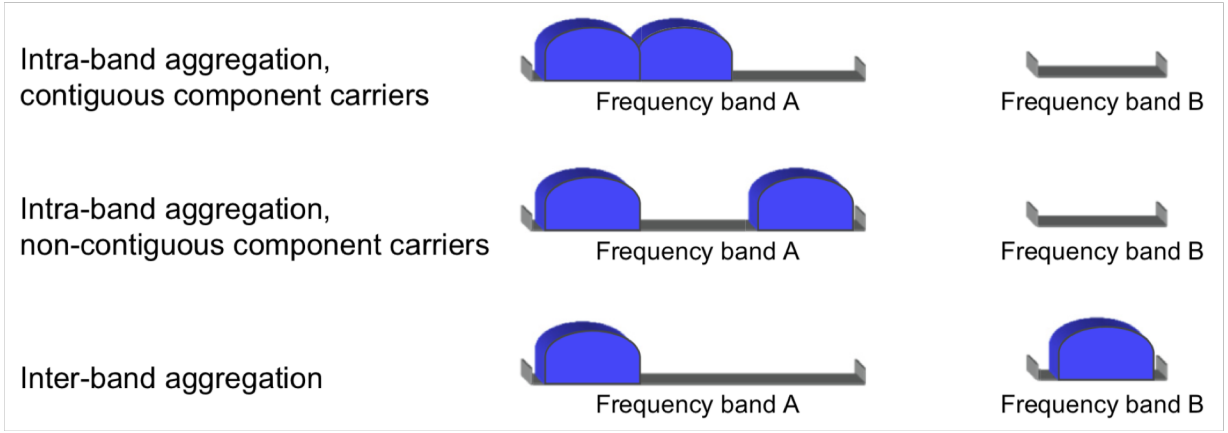
- Distinction between a cell and a transmission point
- Pico-transmission points do not transmit *unique* cell-specific reference signals, nor system information
- Device 1: control from macro, data from pico, network power consumption is reduced
- Device 2: same control from both macro and pico, data from pico, increased SNR of control
- Transmission point can be changed quickly without handover procedure





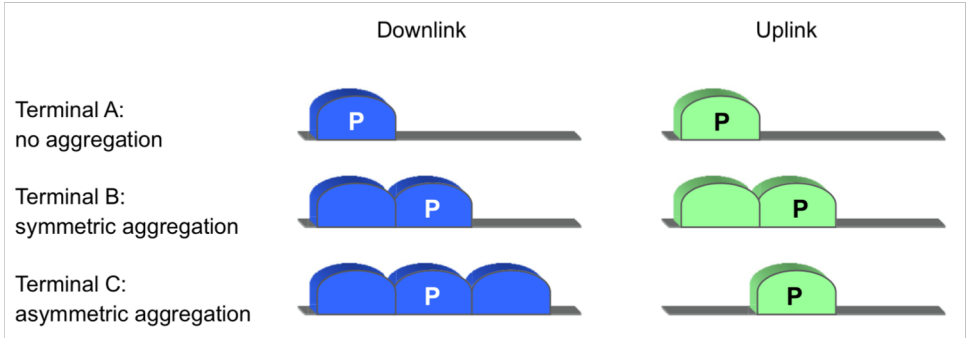
Carrier Aggregation

- operators with a fragmented spectrum can provide high data-rate services
  - Intraband aggregation with frequency-contiguous component carriers
  - Intraband aggregation with noncontiguous component carriers
  - Interband aggregation with noncontiguous component carriers



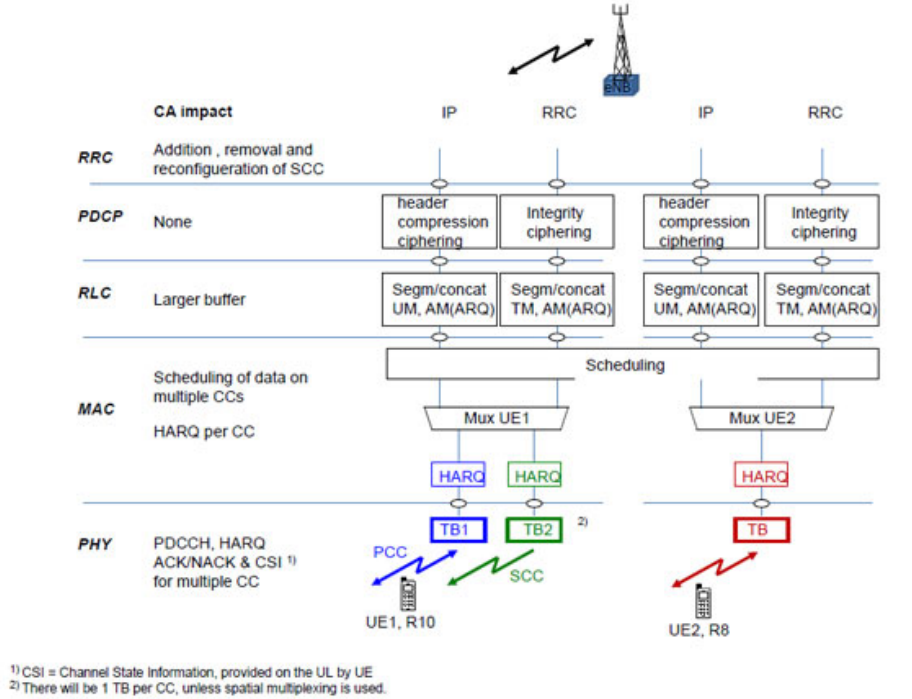
Primary and Secondary Component Carriers

- Each aggregated carrier is referred to as a component carrier
- One downlink primary component & one uplink primary component
- Device specific configuration
- Association of primary carrier is signaled in system information



Protocol

- Aggregation done in Physical layer
- Scheduling can be done:
  - Within same CC
  - In another CC
- CSI measurements performed on all CC



1) CSI = Channel State Information, provided on the UL by UE
2) There will be 1 TB per CC, unless spatial multiplexing is used.