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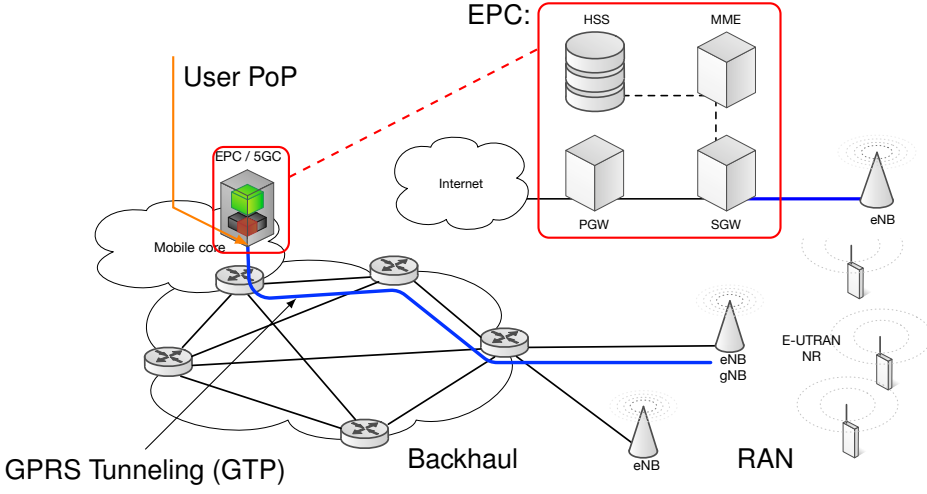
# Modern Wireless Systems - 5G and Beyond

## Mobile core networks

STEFAN HÖST

# Network topology – Mobile network



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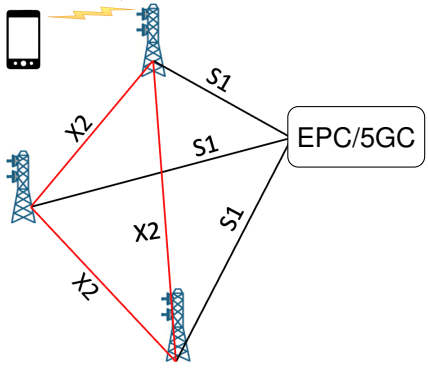
# EPS interfaces




EPC/5GC ↔ gNB

- S1 interface
- Split in S1-MME and S1-U (Control plane and data plane)
- No centralised gNB

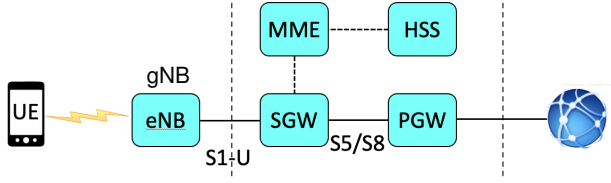
gNB ↔ gNB

- X2/Xn interface
- Coordination and positioning
- Hand over
- Load balancing

UE ↔ gNB

- NR

# EPC – Data plane



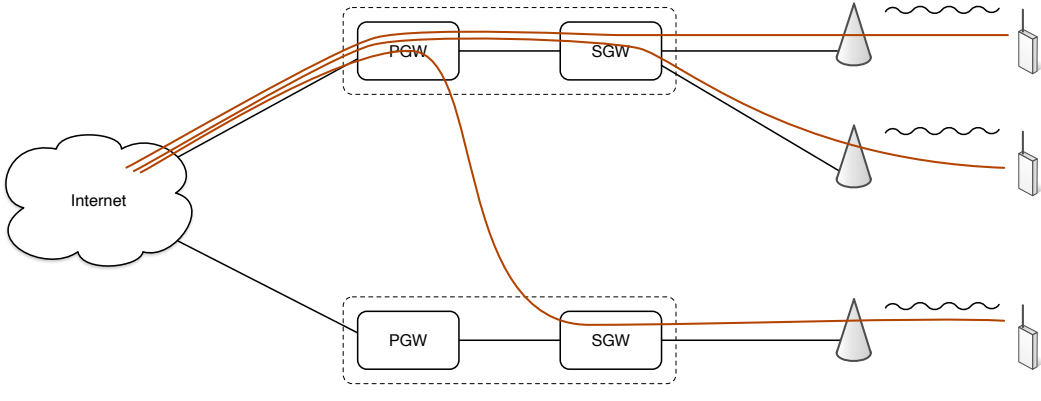

Packet GW

- IP address allocation to UE
- User IP edge
- QoS filtering
- Mobility anchor
  Does not change during session.
  Preserves IP address

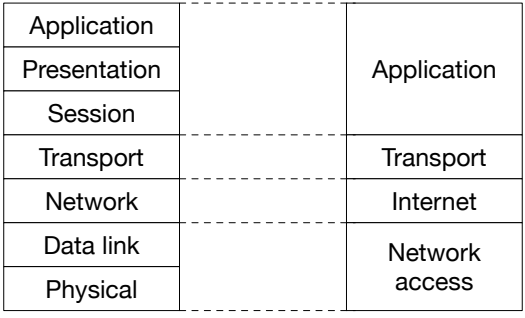
Serving GW

- Collect charging information
- Local anchor towards eNB/gNB
  Can change during session

# User mobility



# Protocol stack – OSI and TCP/IP




Application specific. User interaction

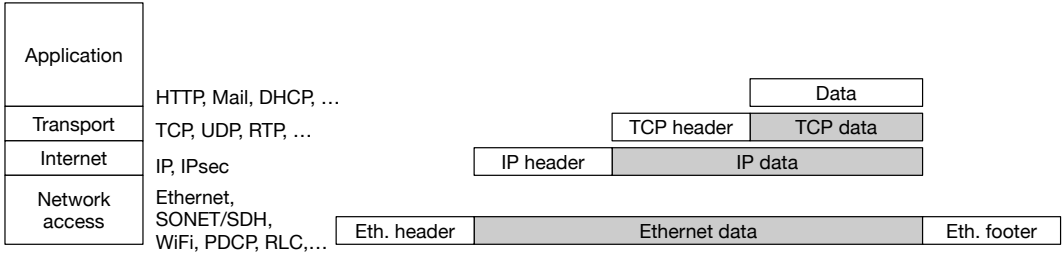
Communication between processes at units

Routing between end units

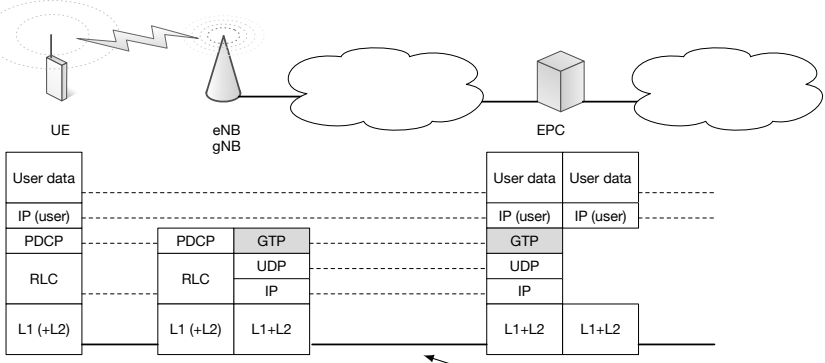
Framing. Error control. Local addressing

Access to media. Signal propagation

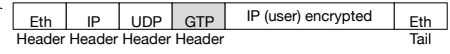
# Protocol stack – Layered traffic and framing



# Tunneling in mobile network




- GTP: GPRS Tunneling Protocol
- PDCP: Packet Data Convergence Protocol
- RLC: Radio Link Control



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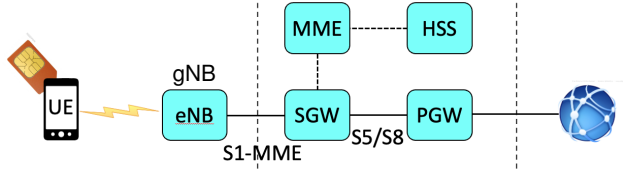
# EPC – Control plane




MME (Mobility Management Entity)

- Communicates with eNB and SGW
- Manages tunnels and encryption

HSS (Home Subscriber Server)

- Subscriber database
- SIM card key exchange
- AAA
  (Authentication, Authorisation, Accounting)

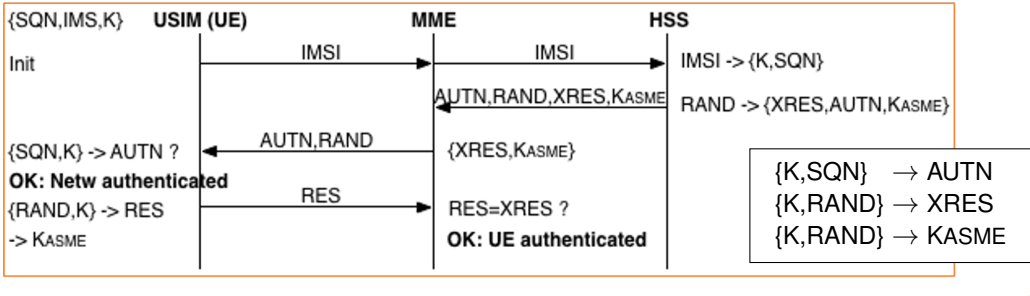
# SIM card

## UMTS Subscriber Identity Module

The (U)SIM card is an application on a smart card and contains:

- IMSI (International mobile subscriber identity) 15 digits
- Authentication key K and sequence number SQN

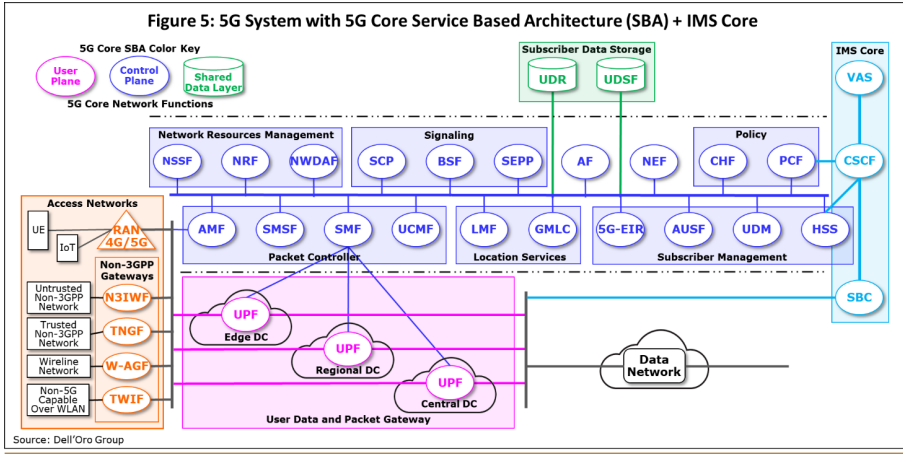
Authentication process:




$K_{ASME}$ is used for encryption of messages

# 5G core

The 5G core (5GC) is by design service oriented and software based
Example:



Source: Dell'Oro Group



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# eNB equipment

BBU (Baseband unit)

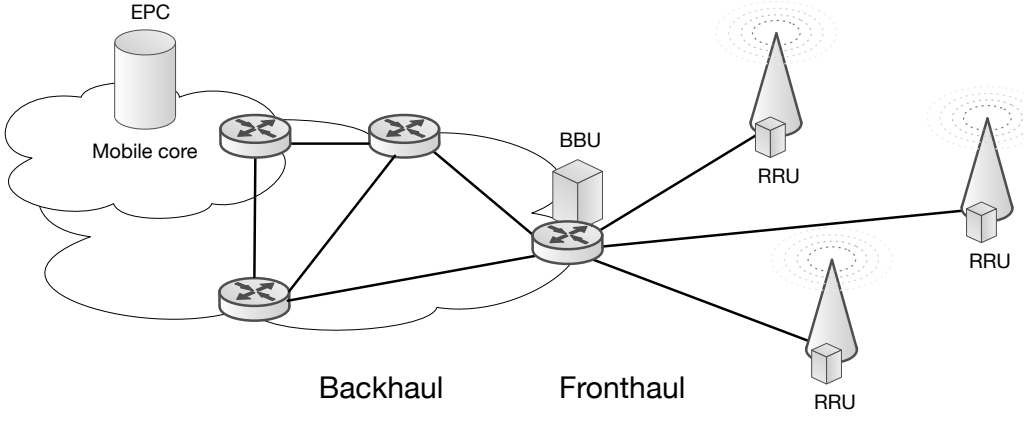
- Coding
- Scheduling
- Rate matching
- Modulation
- Beam forming
- (Rec Equalization)
- IFFT
- Cyclic prefix

RU (Radio unit)

- DA / AD
- Frequency mix
- Analog front-end (amplifiers)
- Antenna connection

Communication between BBU and RU over fibre most often using CPRI/eCPRI

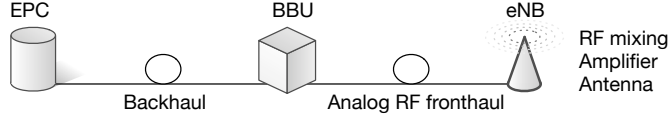
# Mobile network and C-RAN (Cloud RAN)



# Possible splits

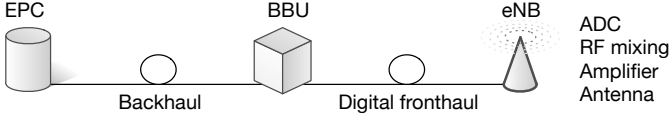
- Analog fronthaul

  Analog RF split




- Digital fronthaul

  Digital split



# CPRI

CPRI: Common Public Radio Interface
Defined by: Ericsson, Huawei, NEC and Nokia

A protocol intended for transport of mobile digital baseband samples.

- Frames are containers for radio frames
- Supports GSM/EDGE (2G), UTRA (3G), E-UTRA/LTE (4G), WiMAX
- Normally point-to-point, but also support for (physical) multiplexing
- Can operate over at least 10 km
- At most 5 $\mu$s delay (excl. propagation delay) and at most $10^{-12}$ BER

# CPRI framing

Hierarchical framing structure

- Basic frame: samples for 260.416 ns radio signal
- Hyper frame: 256 basic frames $\Rightarrow$ 66.7 $\mu$s
- CPRI frame: 150 hyper frames $\Rightarrow$ 10 ms (one LTE frame)

Line coding: 8B/10B or 64B/66B
Sampling 8-20 b/real sample. Normally 15 b/real sample ($\Rightarrow$ 30 b/sample)
$\Rightarrow$ data expansion by a factor of about 10-14

# Number antenna signals and required bitrates

| Option | Rate[Mbps] | Line coding | $W_{LTE}$[MHz] / $R_b$[Mbps] 1.25 77 | 2.5 154 | 5 307 | 10 614 | 15 921 | 20 1 228 |
|---|---|---|---|---|---|---|---|---|
| 1 | 614 | 8/10 | 8 | 4 | 2 | 1 | — | — |
| 2 | 1 228 | 8/10 | 16 | 8 | 4 | 2 | 1 | 1 |
| 3 | 2 457 | 8/10 | 32 | 16 | 8 | 4 | 2 | 1 |
| 4 | 3 072 | 8/10 | 40 | 20 | 10 | 5 | 3 | 2 |
| 5 | 4 915 | 8/10 | 64 | 32 | 16 | 8 | 5 | 4 |
| 6 | 6 144 | 8/10 | 80 | 40 | 20 | 10 | 6 | 5 |
| 7 | 9 830 | 8/10 | 128 | 64 | 32 | 16 | 10 | 8 |
| 8 | 10 138 | 64/66 | 160 | 80 | 40 | 20 | 13 | 10 |
| 9 | 12 165 | 64/66 | 192 | 96 | 48 | 24 | 16 | 12 |

# CPRI

Problems with CPRI

- Point-to-point connection, not routable
- Very high traffic load (Major problems for 5G)
- Not traffic dependent
- Not settings dependent, e.g. number of bits / carrier
- Very high demands on clock synchronisation
- Up- and down-link must have the same latency (max diff 8 ns)

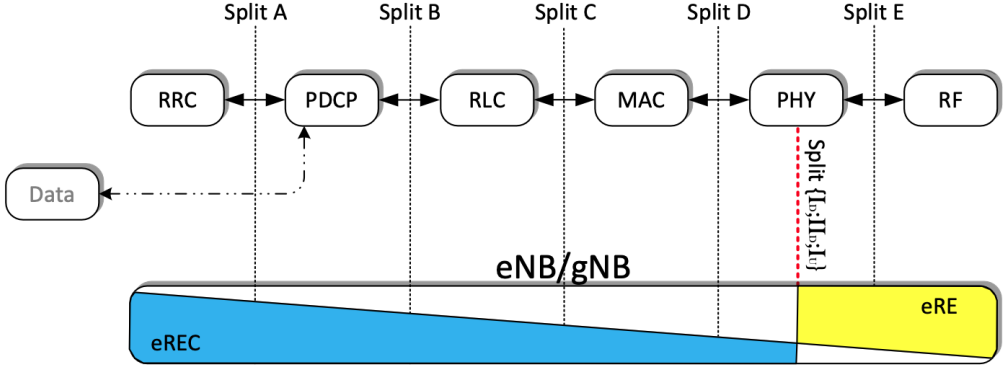
# Packet based fronthaul and eCPRI

eCPRI: Evolved CPRI (V1.1 2018-01-10)

- Main alternative for future C-RAN
- New functional splits
- Required data rate scales with user data
- Physical layer from IEEE 802.3 Ethernet
- Layer 2: Ethernet, MPLS (IP address routing on L2)

# eCPRI – Functional splits

## From documentation V2.0



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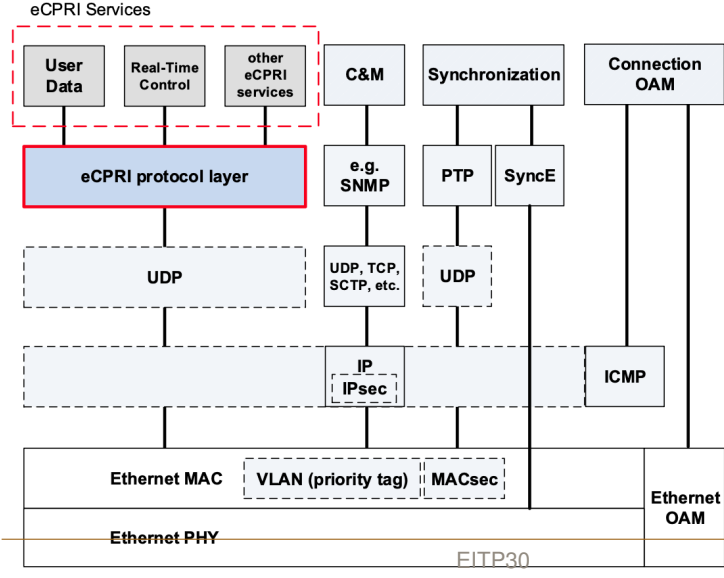
# eCPRI – Protocol transport

## From documentation V2.0



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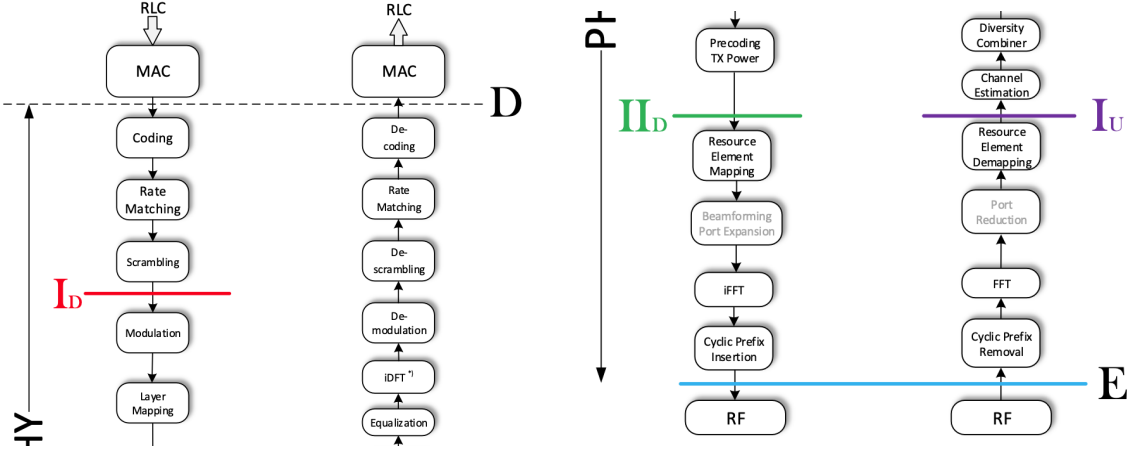
# eCPRI – Phy layer splits (I)

## From documentation V2.0



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# Example – Split ratess

## From documentation V2.0

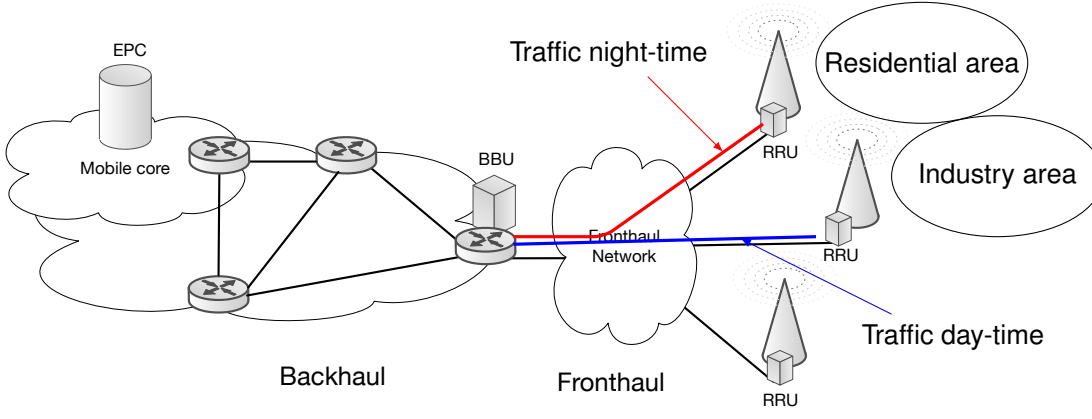
- Utilization 3/1.5 Gbps at 100 MHz
- DL MIMO layers: 8, UL MIMO layers: 4
- Beamforming i eREC
- Code rate: 0.8
- Modulation: 256 QAM
- Sub-carrier spacing: 15 kHz
- IQ sampling frequency: 122.88 Msps
- IQ-quantisation: 30 bits per IQ-sample

# eCPRI – Phy layer split rates

From documentation V2.0

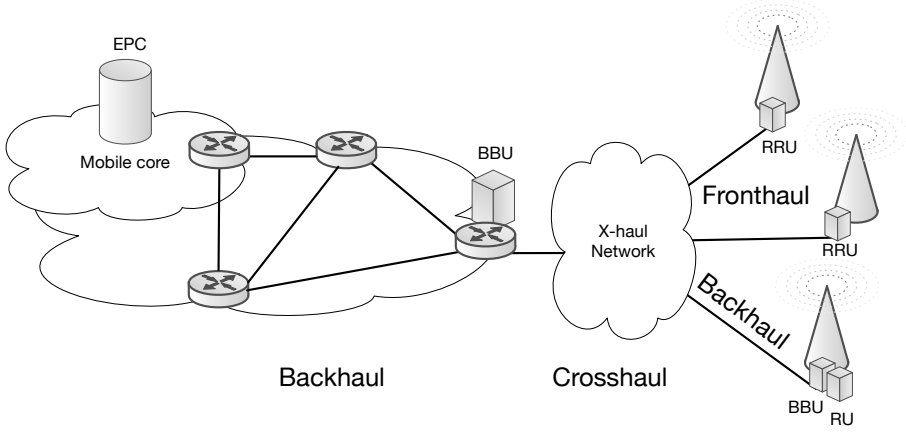
| | Split D | | Split $I_D$ | | Split $II_D$ | | Split E |
|---|---|---|---|---|---|---|---|
| | User Data [Gbps] | Control [Gbps] | User Data [Gbps] | Control [Gbps] | User Data [Gbps] | Control [Gbps] | User Data [Gbps] |
| eREC→ eRE | 3 (assumption) | << 1 | < 4 | < 10 | ~ 20 | < 10 | 236 |
| | | | Split $I_U$ | | | | |
| eRE → eREC | 1.5 (assumption) | << 1 | ~ 20 | < 10 | ~ 20 | < 10 | 236 |

# Packet switched fronthaul



# X-haul

A Crosshaul is a network that transports both backhaul and fronthaul traffic.



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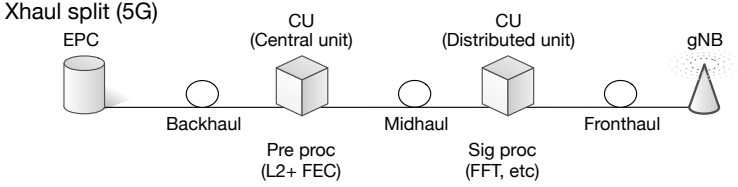
# X-haul splits

Split traffic in backhaul, midhaul and fronthaul at diferent functional splits, e.g.,

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