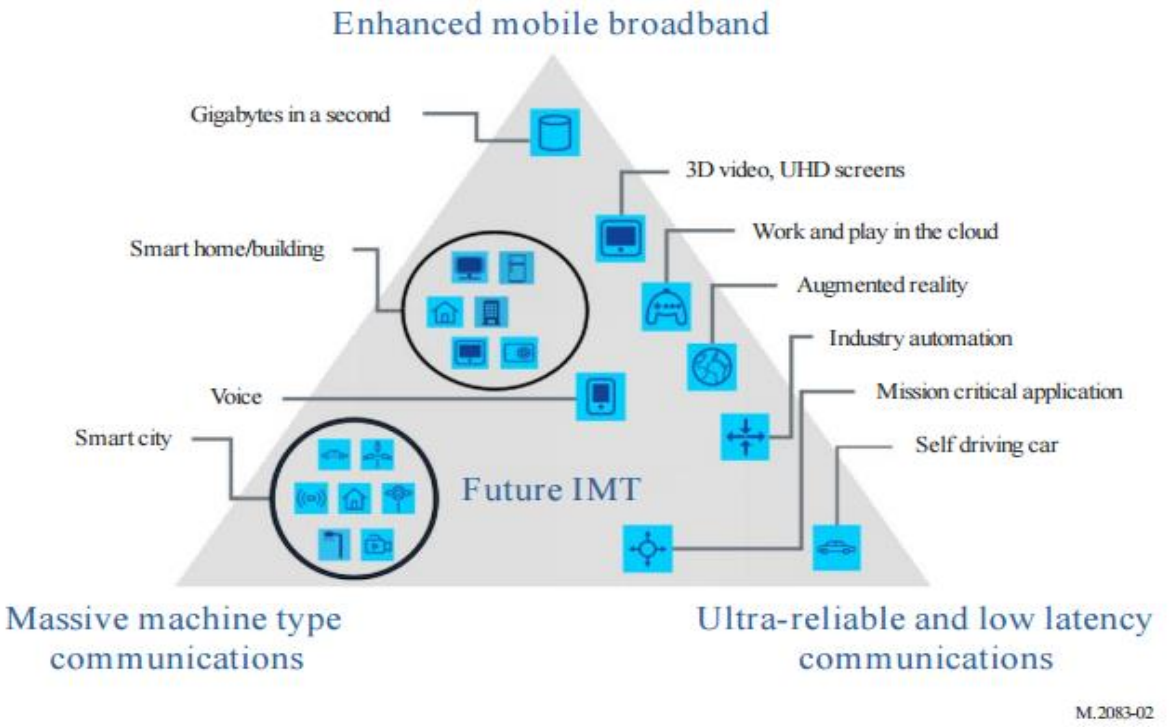
5G Network Architecture, Design and Optimisation

Andy Sutton
Principal Network Architect
Architecture & Strategy, TSO
24th January 2018

Contents

- ITU-R IMT-2020 requirements
- 5G network architecture
- Functional decomposition of the RAN
- Network latency
- Developing a 5G network architecture
- Review a 5G conceptual network architecture
- Optimising 5G network architecture for services
- Network densification
- BT/EE 5G trials - a few highlights
- Summary

Usage scenarios of IMT for 2020 and beyond

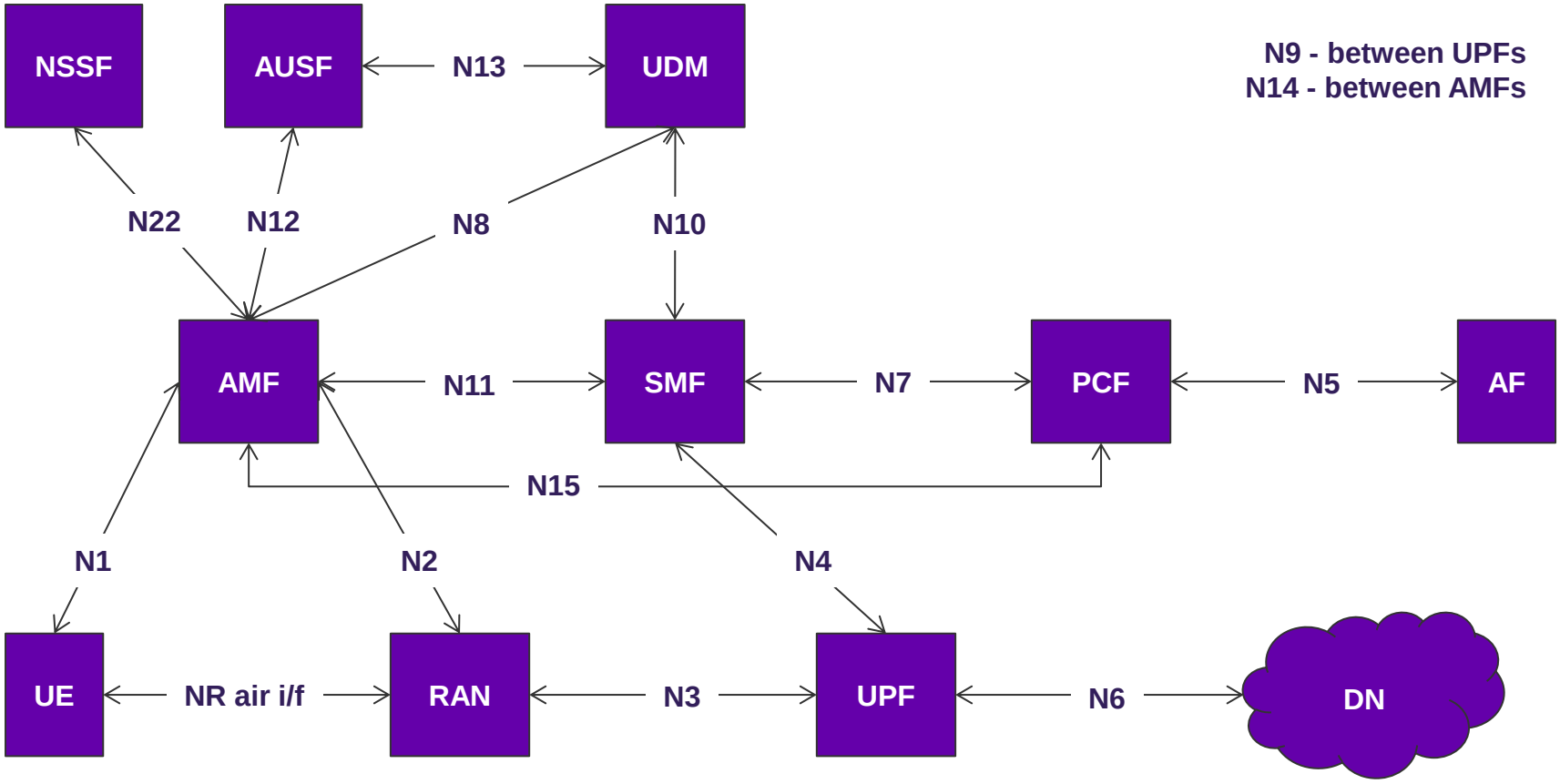


Source: https://www.itu.int/dms_pubrec/itu-r/rec/m/R-REC-M.2083-0-201509-I!!PDF-E.pdf

ITU-R IMT-2020 Requirements – selected parameters

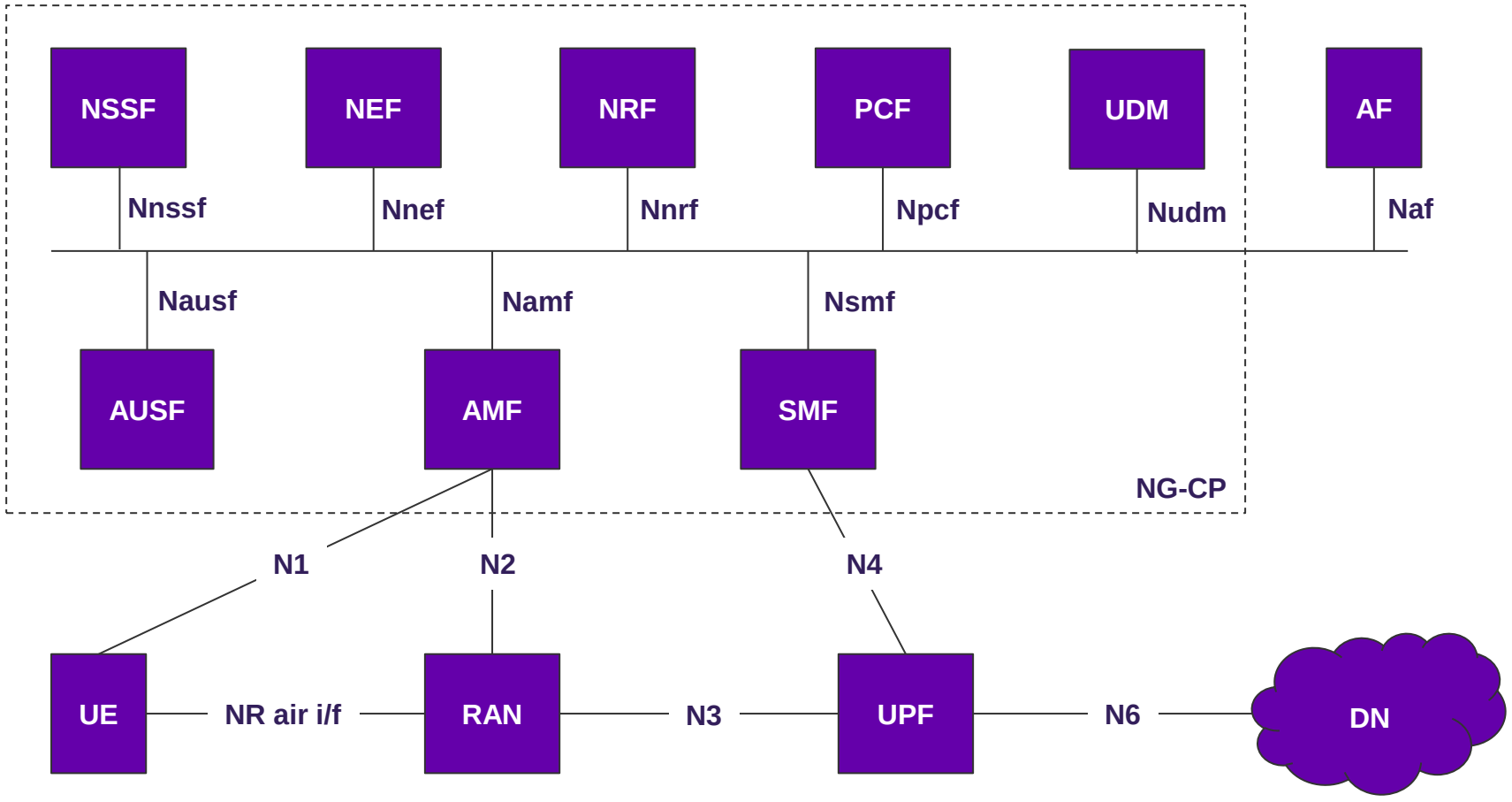
- The minimum requirements for eMBB peak data rate are as follows:
  - Downlink peak data rate is 20Gbps
  - Uplink peak data rate is 10Gbps
- The minimum requirements for eMBB peak spectral efficiencies are as follows:
  - Downlink peak spectral efficiency is 30 bit/s/Hz
  - Uplink peak spectral efficiency is 15 bit/s/Hz
- The target values for the user experienced data rate are as follows in the Dense Urban – eMBB test environment:
  - Downlink user experienced data rate is 100Mbps
  - Uplink user experienced data rate is 50Mbps
- The minimum requirements for 1-way user plane latency over the radio interface are:
  - 4 ms for eMBB
  - 1 ms for URLLC (3GPP target = 0.5ms)
- The minimum requirement for control plane latency is 20ms (Proponents are encouraged to consider lower control plane latency, e.g. 10ms) 3GPP target = 10ms)
- The minimum requirement for mMTC connection density is 1,000,000 devices per km^2
- The minimum requirement for eMBB and URLLC mobility interruption time is 0ms

3GPP 5G network architecture



Note: Focus on mobile however Access Network (AN) could be fixed

3GPP 5G Service Based Architecture



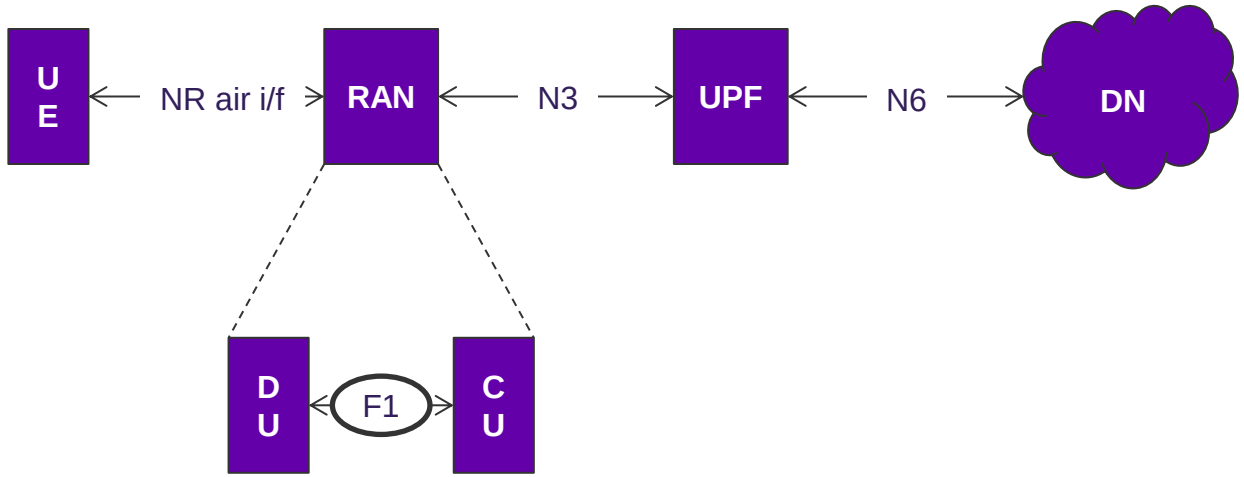
Functional blocks within 5G network architecture

1. AUSF = Authentication Server Function
2. UDM = Unified Data Management
3. NSSF = Network Slice Selection Function
4. NEF = Network Exposure Function
5. NRF = Network Repository Function
6. AMF = Core Access and Mobility Management Function
7. SMF = Session Management Function
8. PCF = Policy Control Function
9. AF = Application Function
10. UE = User Equipment
11. RAN = Radio Access Network
12. CU = Centralised Unit
13. DU = Distributed Unit
14. UPF = User Plane Function
15. DN = Data Network, e.g. operator services, Internet or 3rd party services

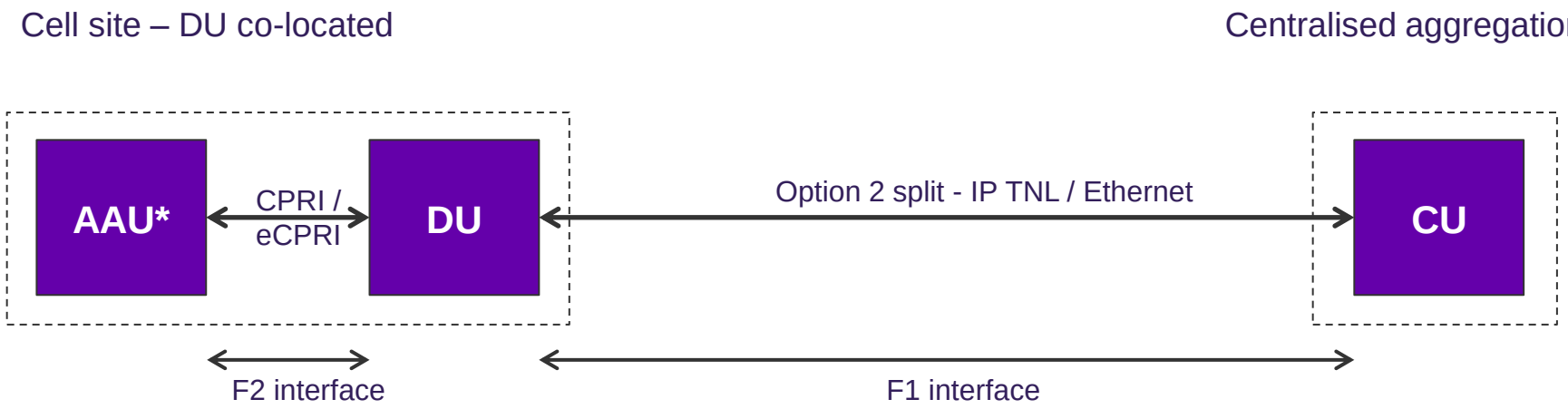
5G interfaces (reference points)

- N1: Reference point between the UE and the Access and Mobility Management function (AMF).
- N2: Reference point between the (R)AN and the Access and Mobility Management function.
- N3: Reference point between the (R)AN and the User plane function (UPF).
- N4: Reference point between the Session Management function (SMF) and the User plane function (UPF).
- N5: Reference point between the Policy Function (PCF) and an Application Function (AF).
- N6: Reference point between the UP function (UPF) and a Data Network (DN).
- N7: Reference point between the Session Management function (SMF) and the Policy Control function (PCF).
- N7r: Reference point between the vPCF and the hPCF.
- N8: Reference point between Unified Data Management and AMF.
- N9: Reference point between two Core User plane functions (UPFs).
- N10: Reference point between UDM and SMF.
- N11: Reference point between Access and Mobility Management function (AMF) and Session Management function (SMF).
- N12: Reference point between Access and Mobility Management function (AMF) and Authentication Server function (AUSF).
- N13: Reference point between UDM and Authentication Server function (AUSF).
- N14: Reference point between 2 Access and Mobility Management function (AMF).
- N15: Reference point between the PCF and the AMF in case of non-roaming scenario, V-PCF and AMF in case of roaming scenario.
- N16: Reference point between two SMFs, (in roaming case between V-SMF and the H-SMF).
- N22: Reference point between AMF and Network Slice Selection Function (NSSF).

Functional decomposition of the 5G RAN

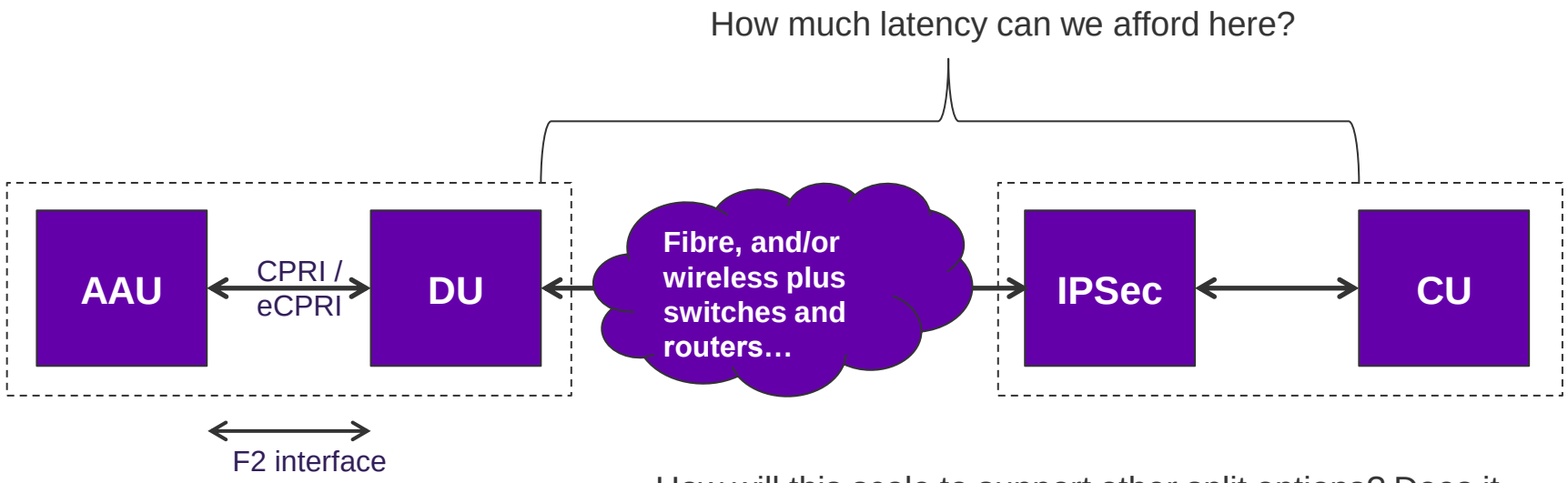


5G RAN architecture – DU co-located with RF



*AAU illustrated, actual implementation could be AAU or passive antenna with RRU

Latency requirements



How will this scale to support other split options? Does it need to?
Alternative splits in uplink/downlink?
Alternative splits as subs move from cell centre to cell edge?
…

5G Latency Requirements – Industry Targets

NGMN 5G Requirements

- 5G E2E Latency (eMBB) = **10ms** (i.e. RTT from UE-Application-UE)
- 5G E2E Latency (URLLC) = **1ms** (i.e. RTT from UE-Application-UE – or just UE-UE)

In both cases, the values are defined as capabilities that should be supported by the 5G System.

GSMA 5G Requirements

- 5G E2E Latency = **1ms** (again, defined as a capability target, not as a universal requirement)

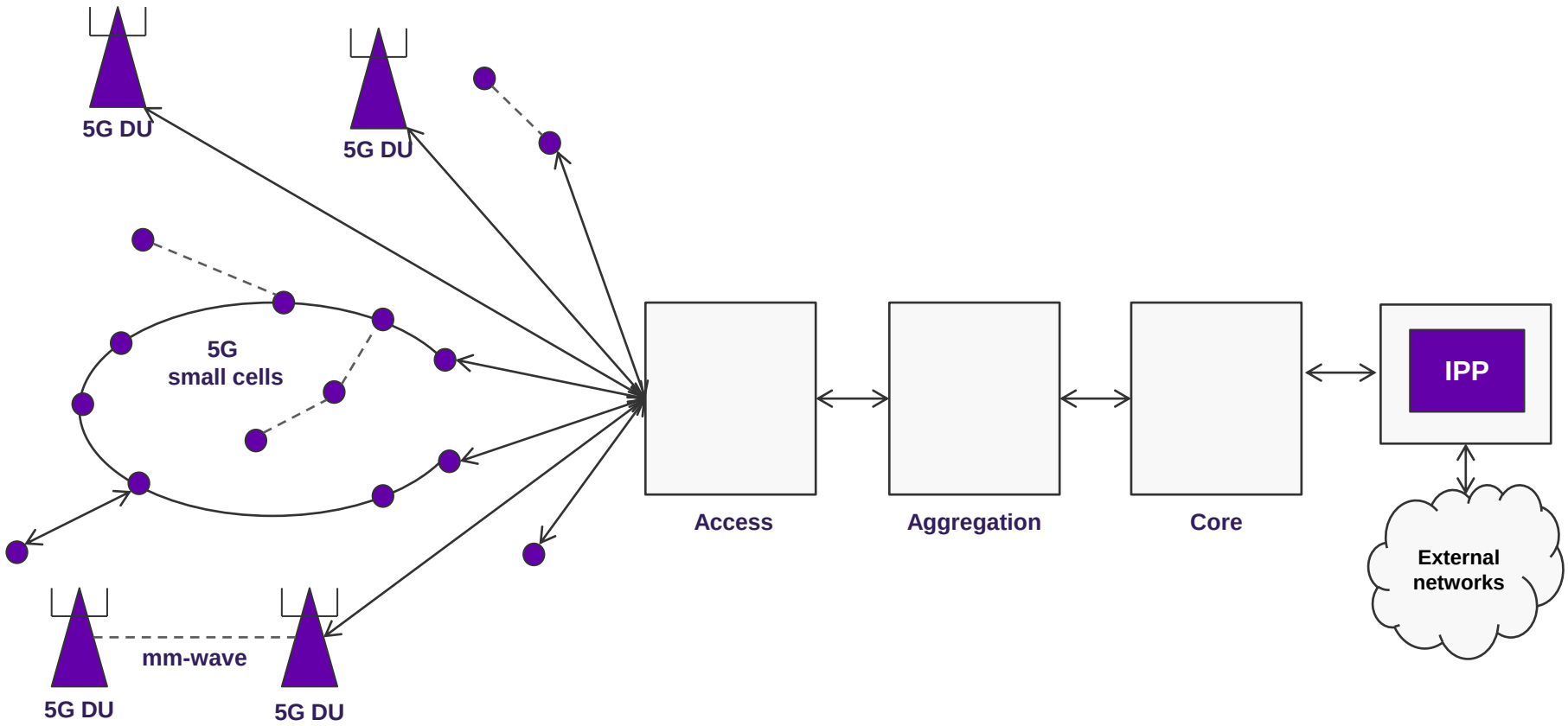
ITU-R IMT-2020 Requirements

- eMBB User Plane Latency (one-way) = **4ms** [radio network contribution]
- URLLC User Plane Latency (one-way) = **1ms** [radio network contribution]
- Control Plane Latency = **20ms (10ms target)** [UE transition from Idle to Active via network]

Low Latency Use Case Requirements (various sources)

- Virtual Reality & Augmented Reality: **7-12ms**
- Tactile Internet (e.g. Remote Surgery, Remote Diagnosis, Remote Sales): < **10ms**
- Vehicle-to-Vehicle (Co-operative Driving, Platooning, Collision Avoidance): < **10ms**
- Manufacturing & Robotic Control / Safety Systems: **1-10ms**

Developing a 5G Network Architecture



5G Network Latency modelling

We have done significant analysis of network latency and cost to underpin the 5G Architecture (this work is ongoing but the figures below provide initial results).

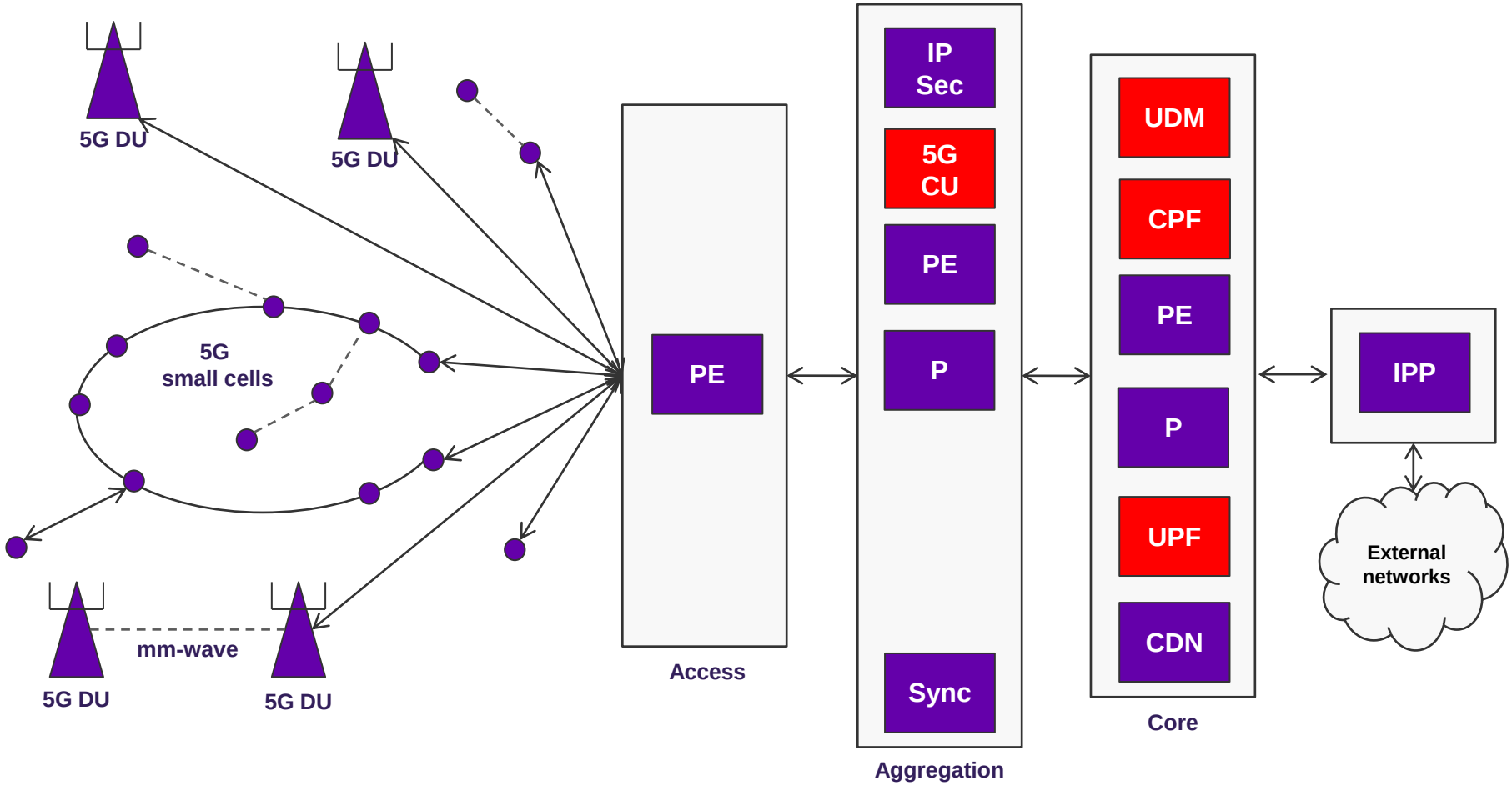
The following figures relate to content served from the same location as the UPF node:

UPF Location	Access	Aggregation	Core
Number of sites	1200	106	10
Transport Latency (1-way)*	0.6ms	1.2ms	4.2ms
Estimated 5G Latency (RTT)*	9.2ms [eMBB]	10.4ms [eMBB]	16.4ms [eMBB]
	2.2ms [URLLC]	3.4ms [URLLC]	9.4ms [URLLC]

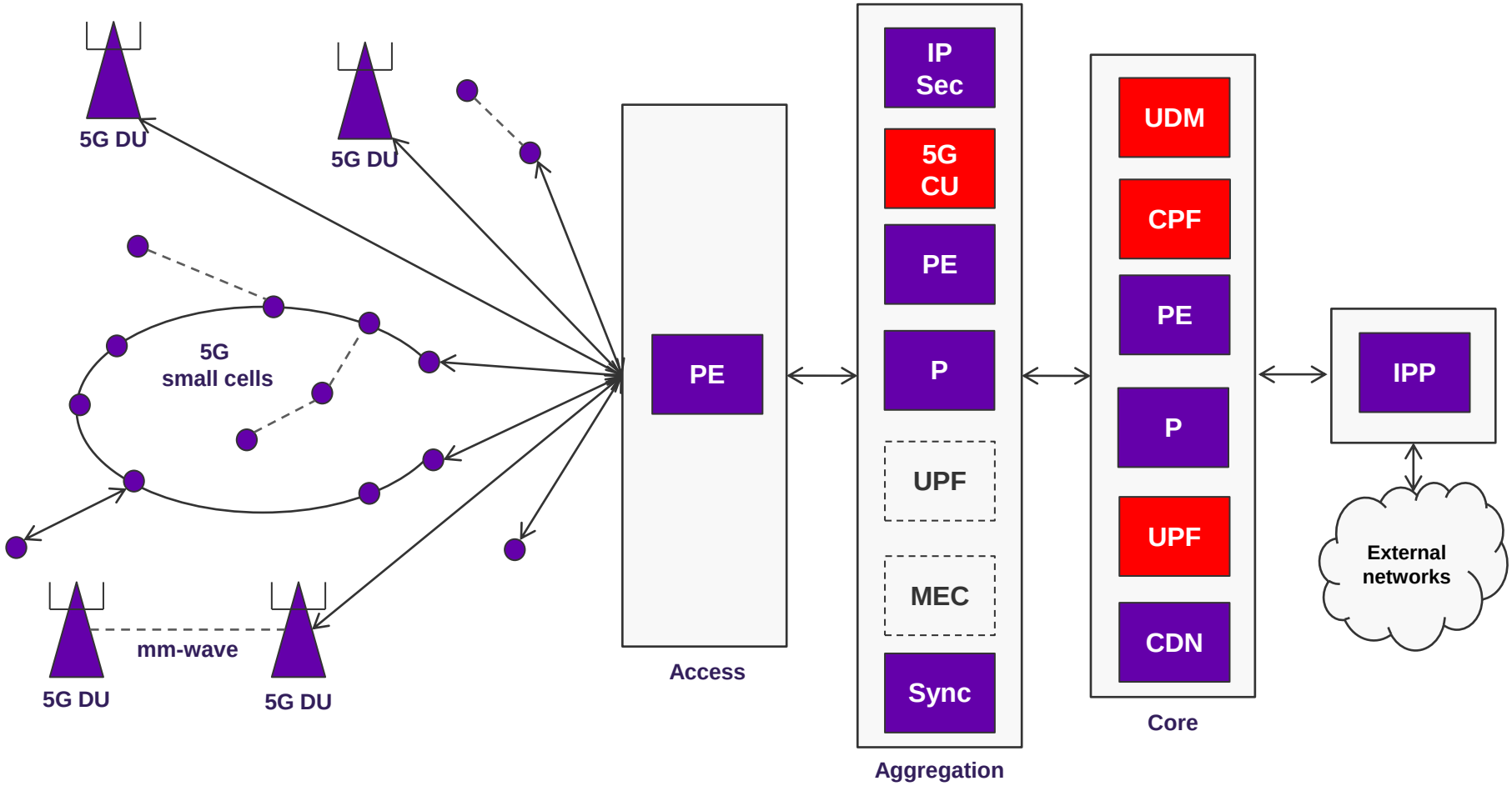
* *Assumptions:*

- *Latency figures based on 95th-percentile of transmission delay (i.e. 95% of cell sites are within this) + overhead for IP*
- *5G RTT assumes 8ms overhead for 5G New Radio & Next-Gen Core (eMBB case) - 1ms for URLLC (as per 3GPP 5G)*

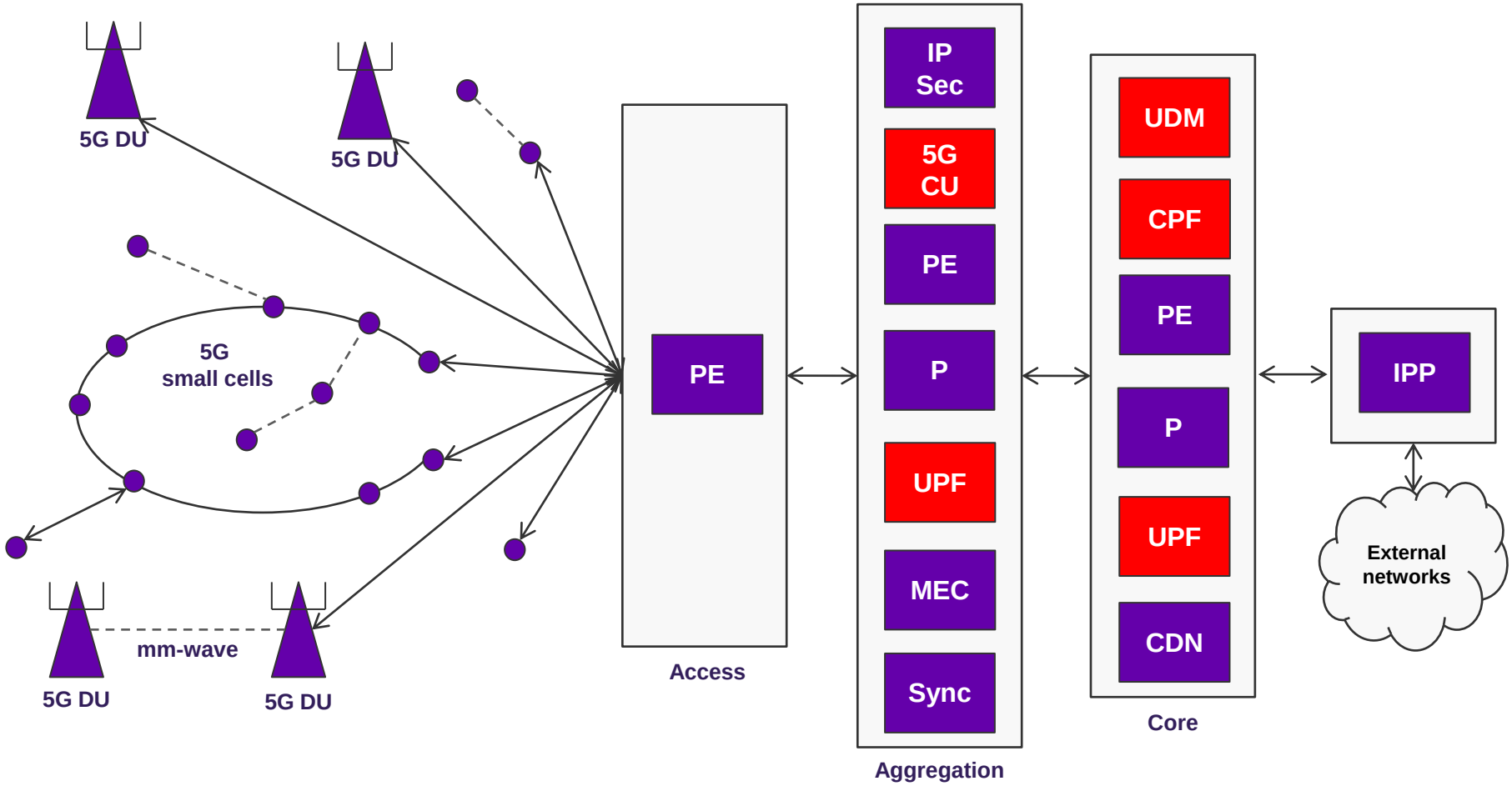
Conceptual 5G Network Architecture (1)



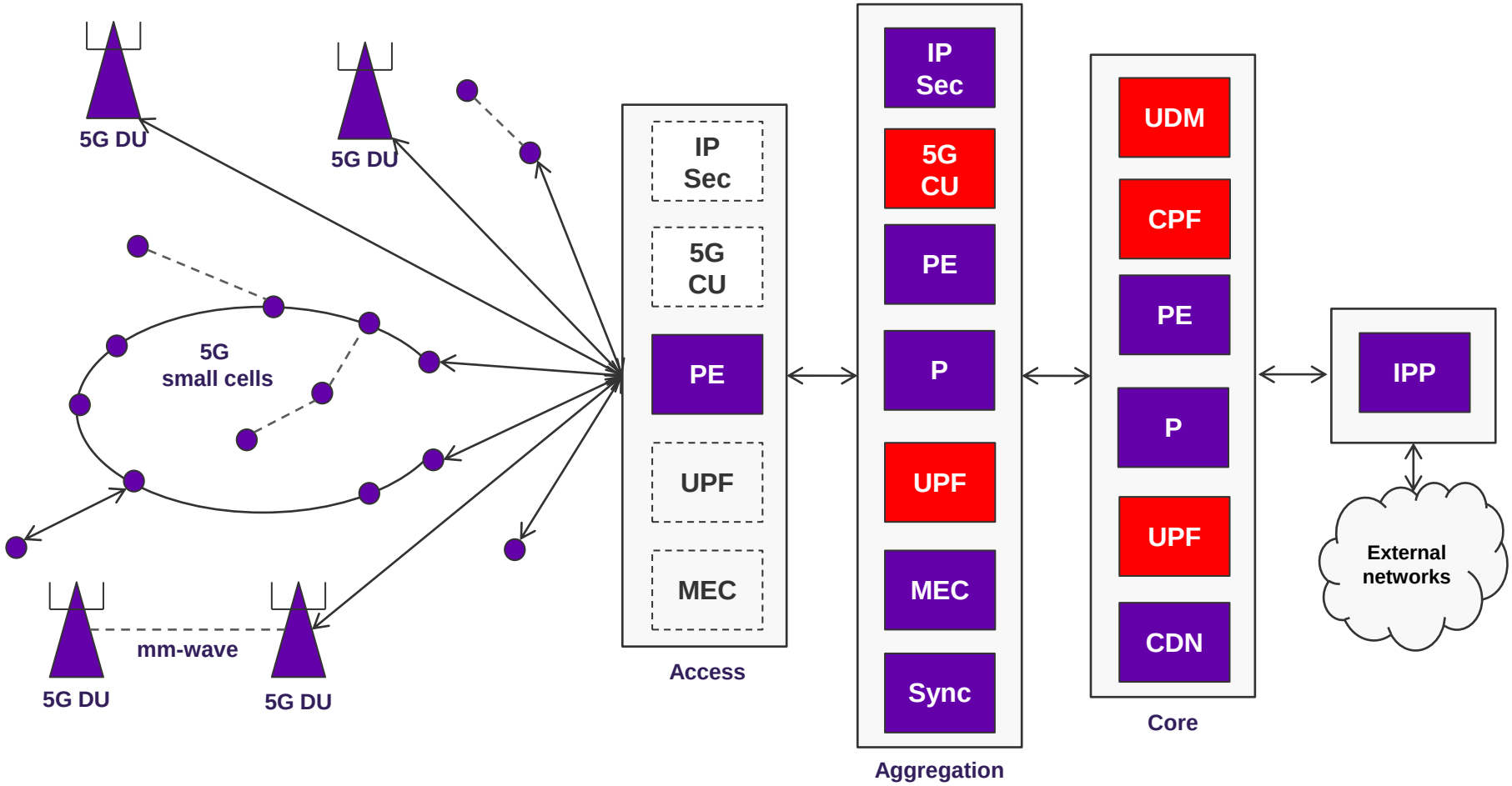
Conceptual 5G Network Architecture (2)



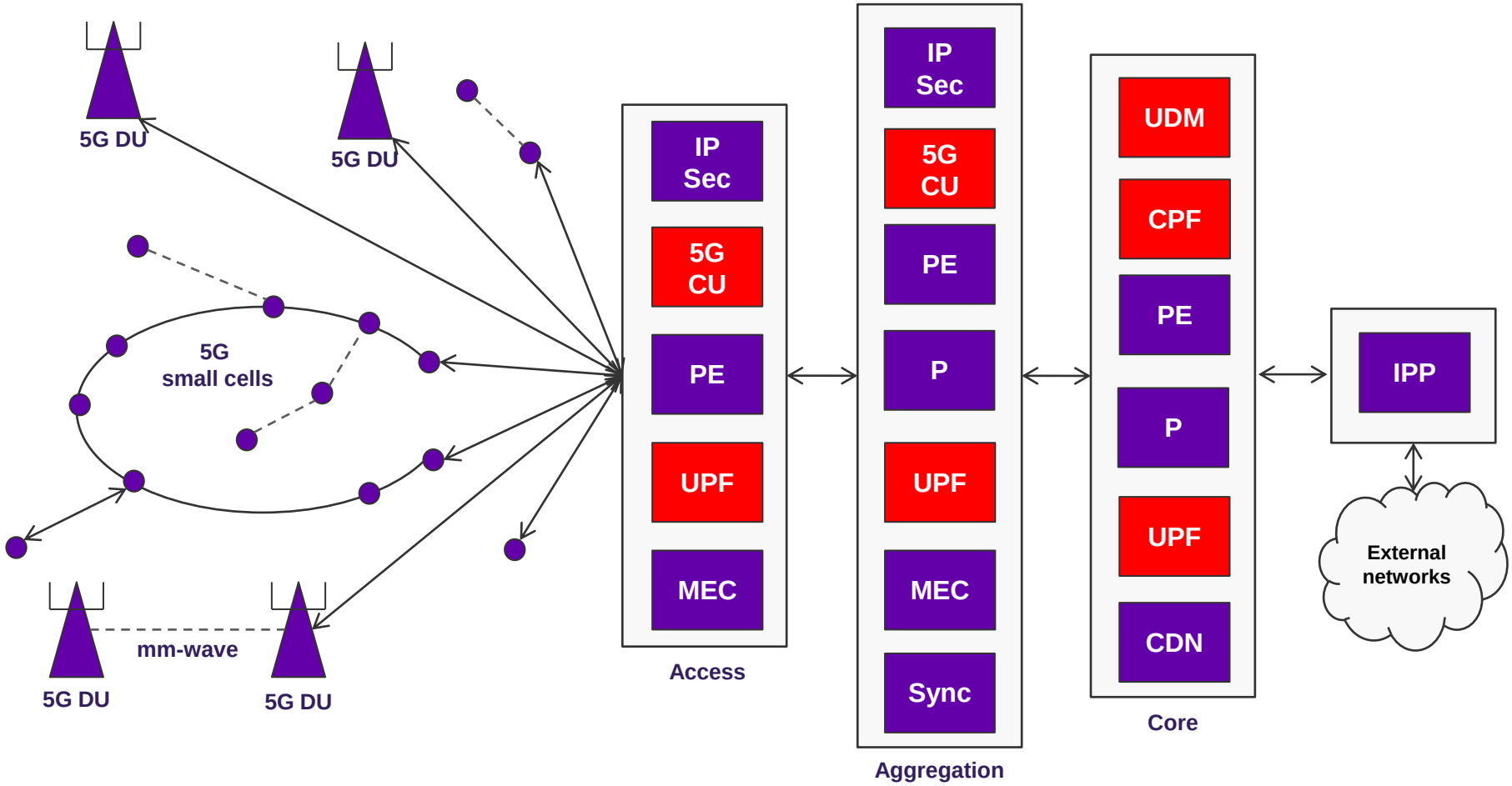
Conceptual 5G Network Architecture (3)



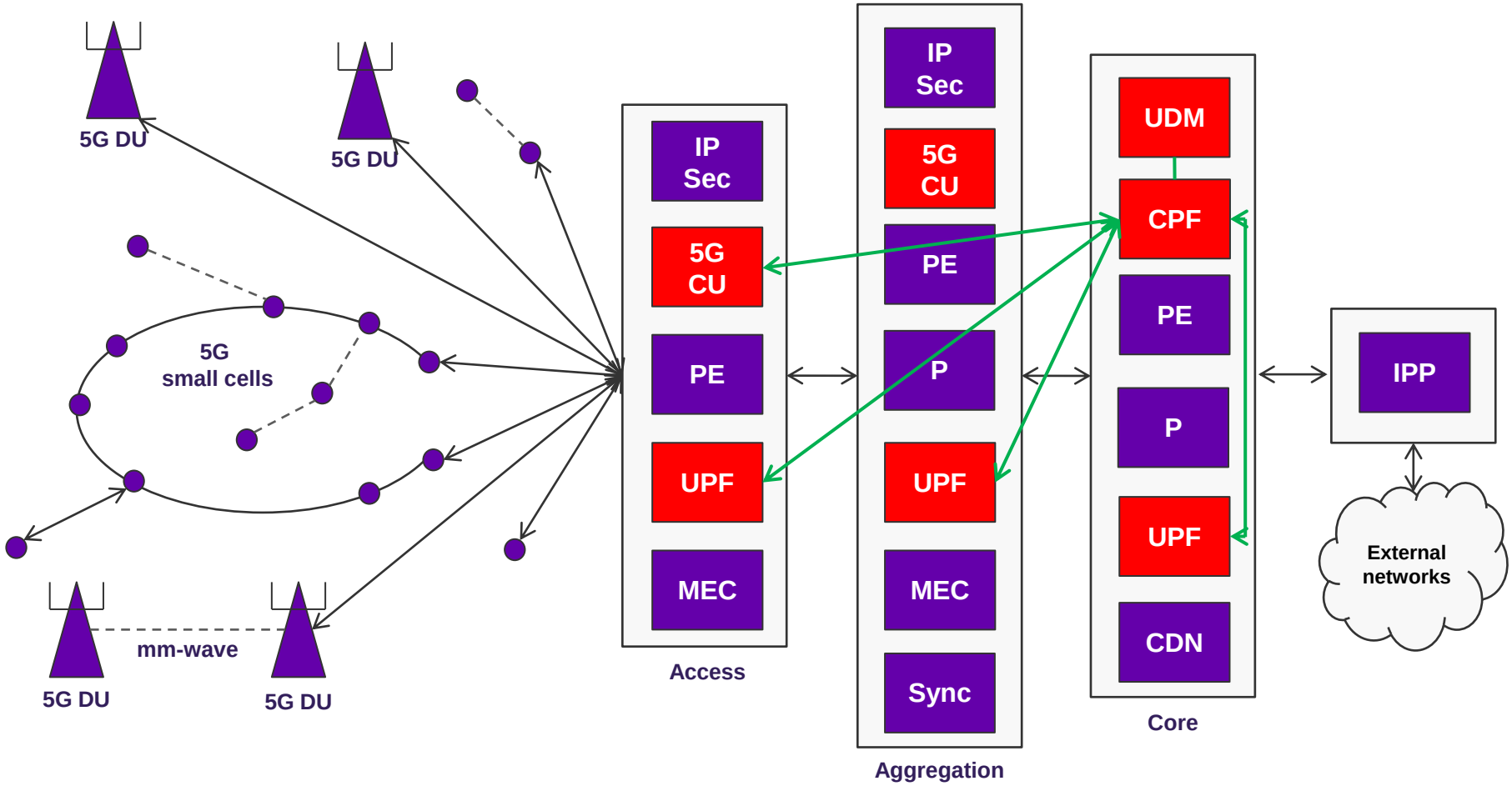
Conceptual 5G Network Architecture (4)



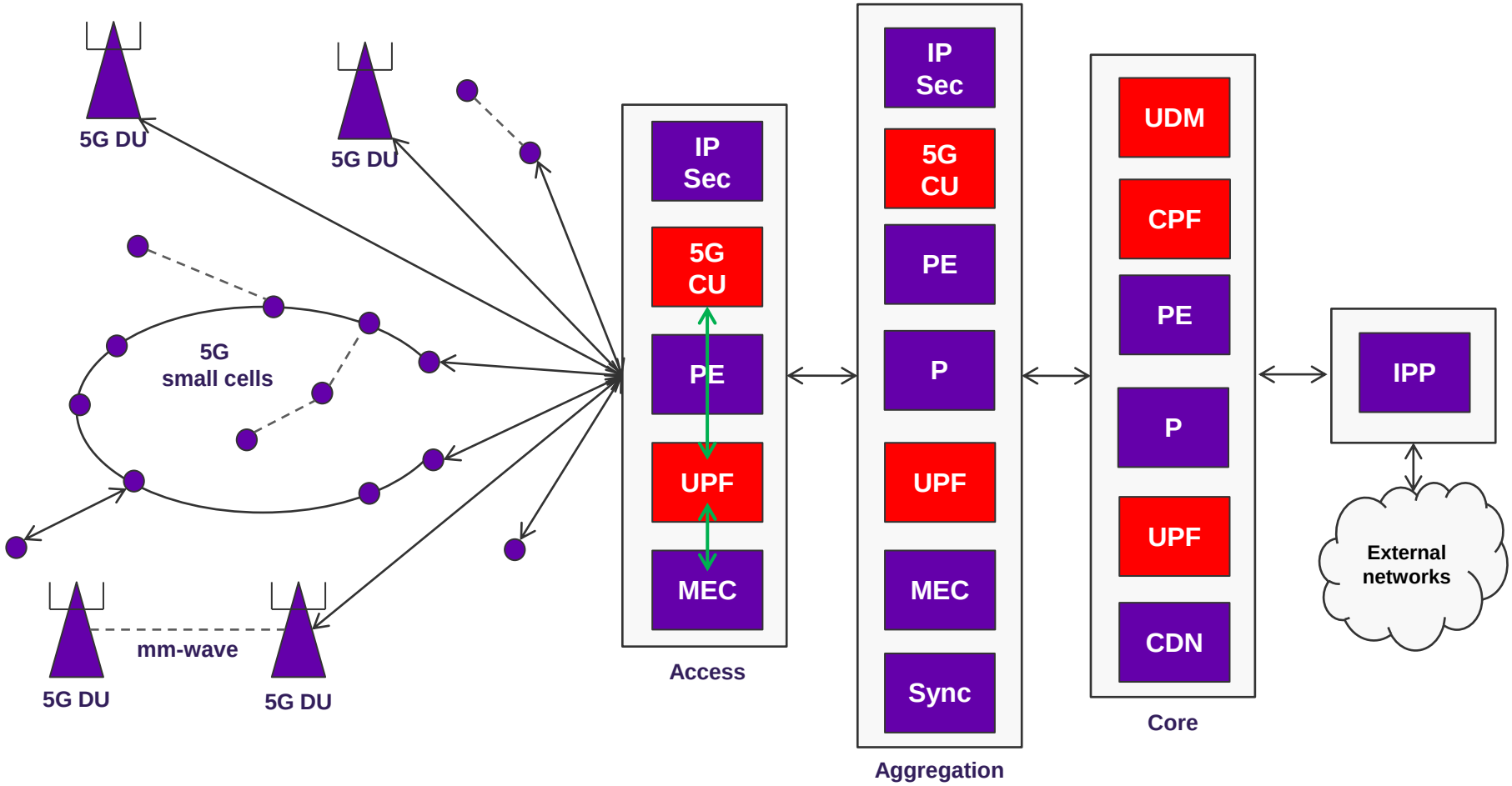
Conceptual 5G Network Architecture (5)



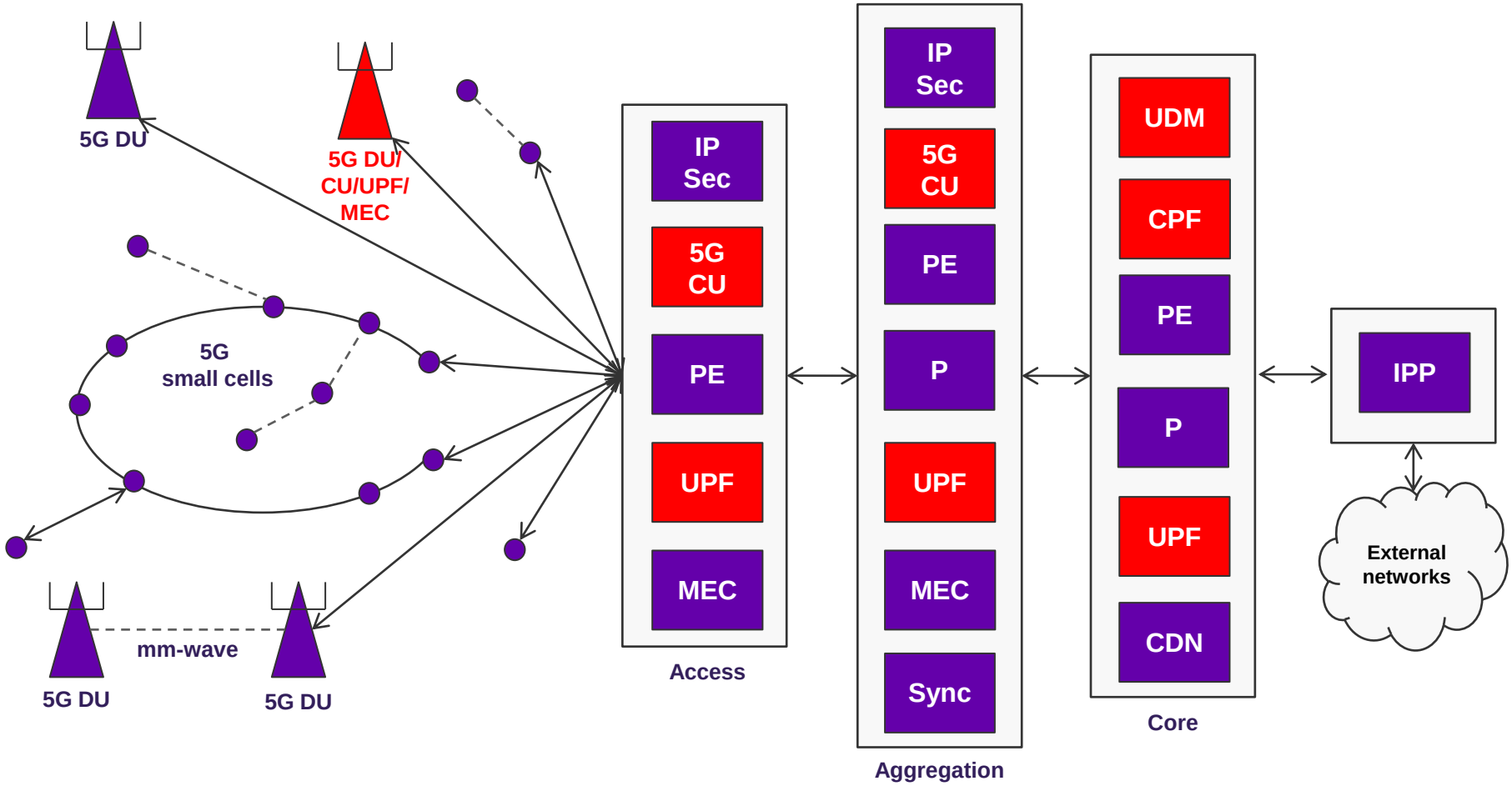
Consider control plane latency – potential for distribution?



Low-latency access to apps, content and compute

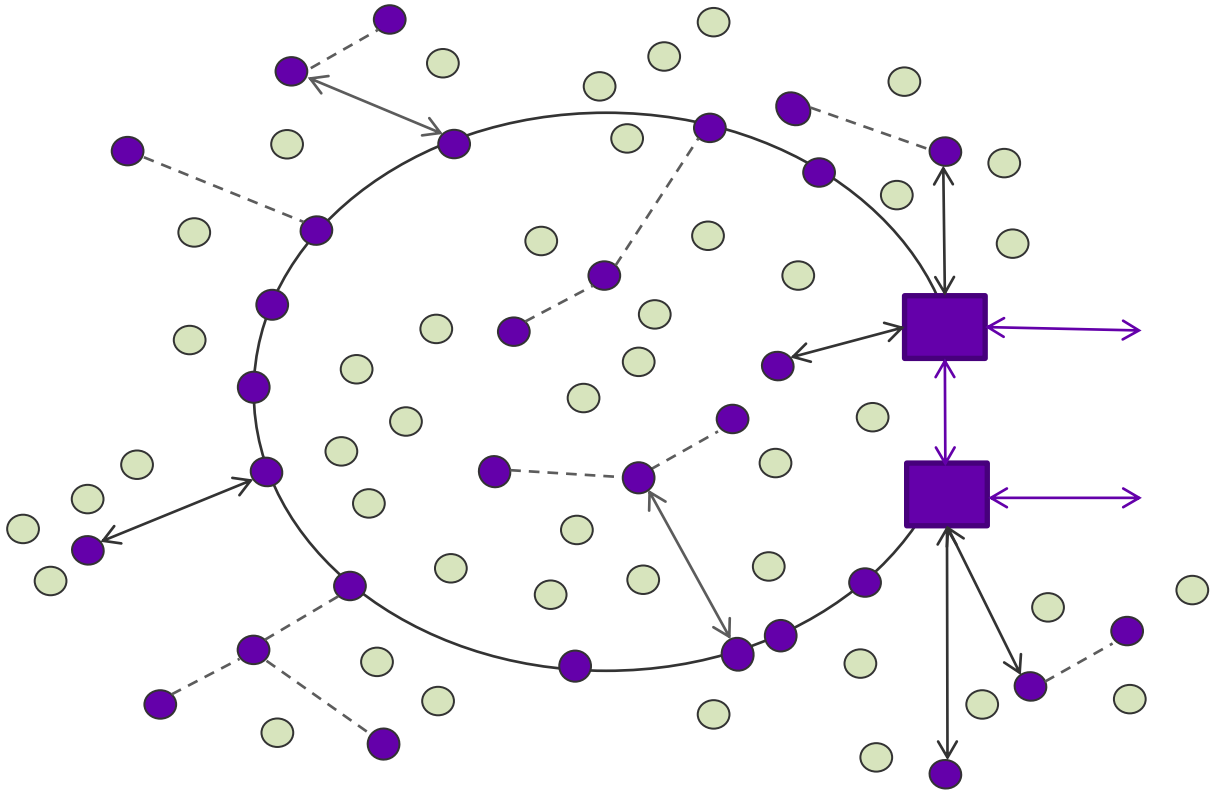


Ultra-low latency service optimisation



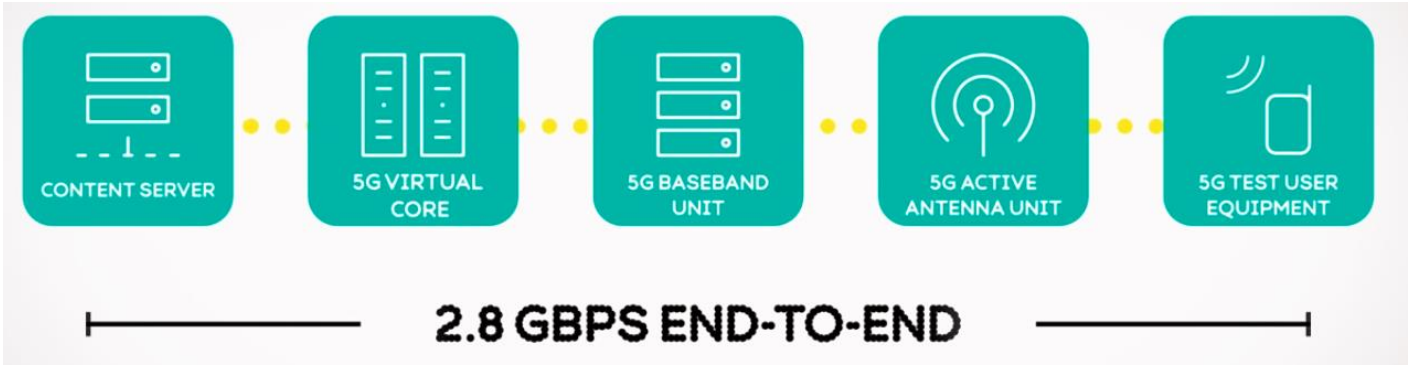
Network densification – a three phased approach

- Base connectivity solution, mainly fibre
- Wireless (+ some fibre) extension from base connectivity solution
- 26 GHz small cells with self-backhaul/in-band backhaul



BT/EE trials

EE hits 2.8Gbps download speeds in UK-first 5G trial

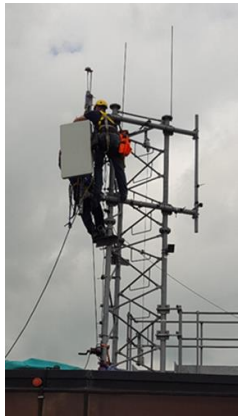


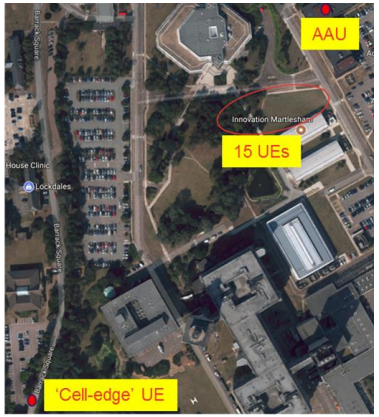
http://newsroom.ee.co.uk/ee-showcases-end-to-end-5g-network-architecture-with-28gbps-speeds/

University, BT and Nokia to conduct joint research into 5G mobile networks in Bristol

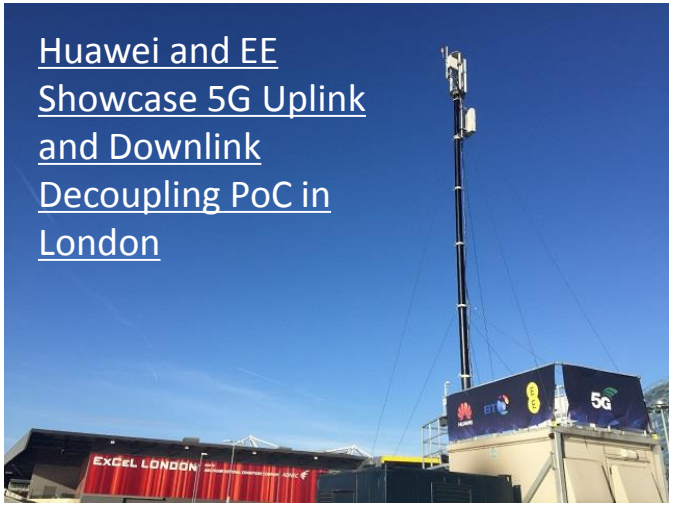
http://www.bristol.ac.uk/news/2017/november/5g-mobile-networks.html

Massive MIMO testing @Adastral Park





Huawei and EE Showcase 5G Uplink and Downlink Decoupling PoC in London



Summary

- 5G will address enhanced Mobile Broadband (eMBB), Ultra-Reliable Low Latency Communications (URLLC) and massive Machine Type Communications (mMTC), use cases
- 5G requires a new network architecture
- The functional decomposition of the RAN results in DU and CU network elements
- Next Generation Core network can be grouped into two functional blocks, CPF and UPF
- Some RAN functionality will move towards the core whilst the core will move towards the RAN
- Small cells are an essential component of 5G
- URLLC is an overlay and requirements will vary based on use cases
- URLLC use cases, UR use cases and LL use cases…
- Initial MTC use cases will be addressed by NB-IoT (4G)

Thank You!
Any questions?