5G and the growing need for higher accuracy in Time

Tommy Cook

What is 5G?

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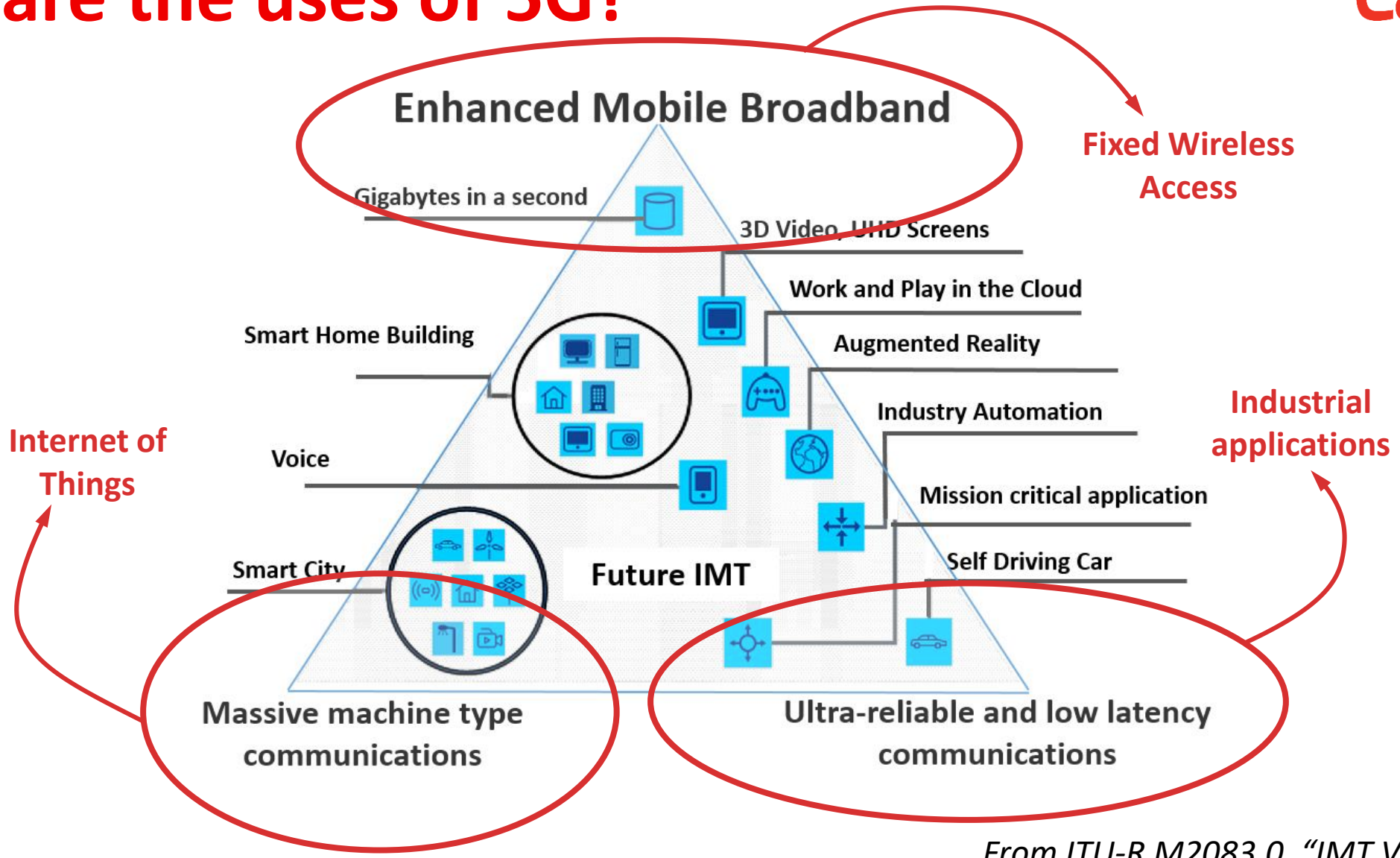
- ***"A wireless infrastructure to connect the world" ****
  - Enhanced mobile broadband
  - Ultra-reliable and low latency communication (URLLC)
  - Massive machine-to-machine type communications (i.e. the "internet of things")
- Mobile Operators' vision:
  - Anything better than the current offering that can be branded as "5G"
    - Current LTE-Advanced offering is just carrier aggregation, branded 4.5G in some markets
  - Quite likely that anything beyond Carrier Aggregation (CA) will be marketed as 5G
    - e.g. eICIC, CoMP, MBMS, MIMO
  - Starts with enhanced mobile broadband, IoT and URLLC will follow later

** From ITU-R M2083.0, "IMT Vision"*

What are the uses of 5G?



From ITU-R M2083.0, "IMT Vision"

Fixed Wireless Access

- 1Gbit/s to the handset? That's 20x better than my home broadband…
- Major operators proposing to use 5G for fixed wireless access
  - Looking at the 28 or 39GHz bands (millimetre wave), 500m range
  - Principal target is dense urban environments, but some carriers investigating it for rural last mile
  - Estimated to be 40% cheaper deployment than FTTP*
  - $40B market by 2025*
- Another form of convergence
  - Home/office and mobile infrastructure merge
    - Cost savings for operators on infrastructure
    - More opportunities to compete with the incumbent supplier
  - Backhaul capacity will have to increase massively
    - Move to 100G and beyond accelerated

*SNS Research report: "5G for FWA: 2017 – 2030"

Wireless Industrial Networks and IoT

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- 5G aiming at unifying a wide range of hitherto diverse networks
- Examples:
  - Sensor networks for smart buildings, environmental monitoring
  - Smart cities and transport networks
  - Warehouse management and stock tracking
  - Automotive networks and autonomous vehicles
  - Healthcare and wearable devices

What are the expected capabilities of 5G?

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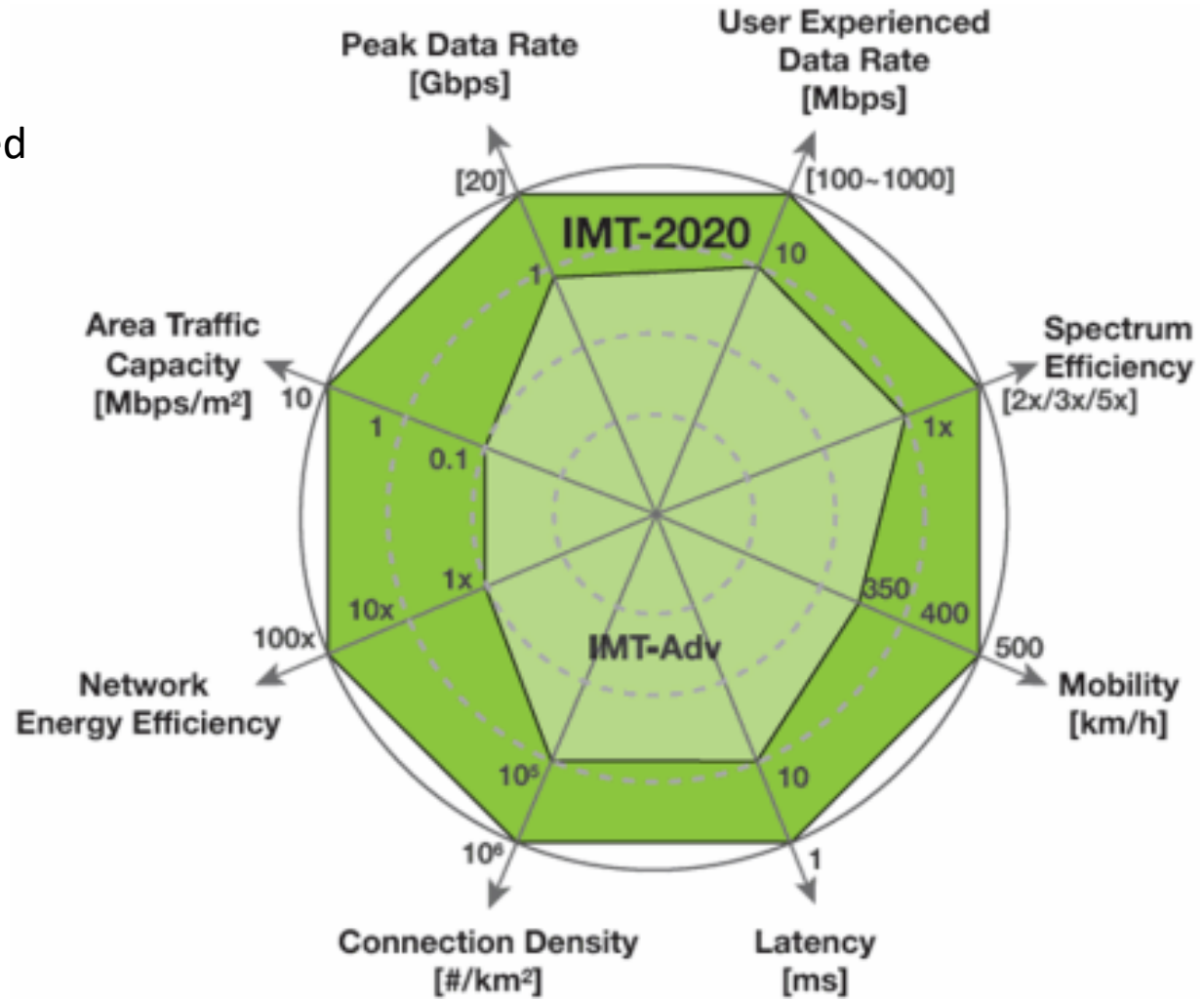
- IMT-Advanced (LTE, 4G)
- IMT-2020 (5G), relative to IMT-Advanced



What are the implications?

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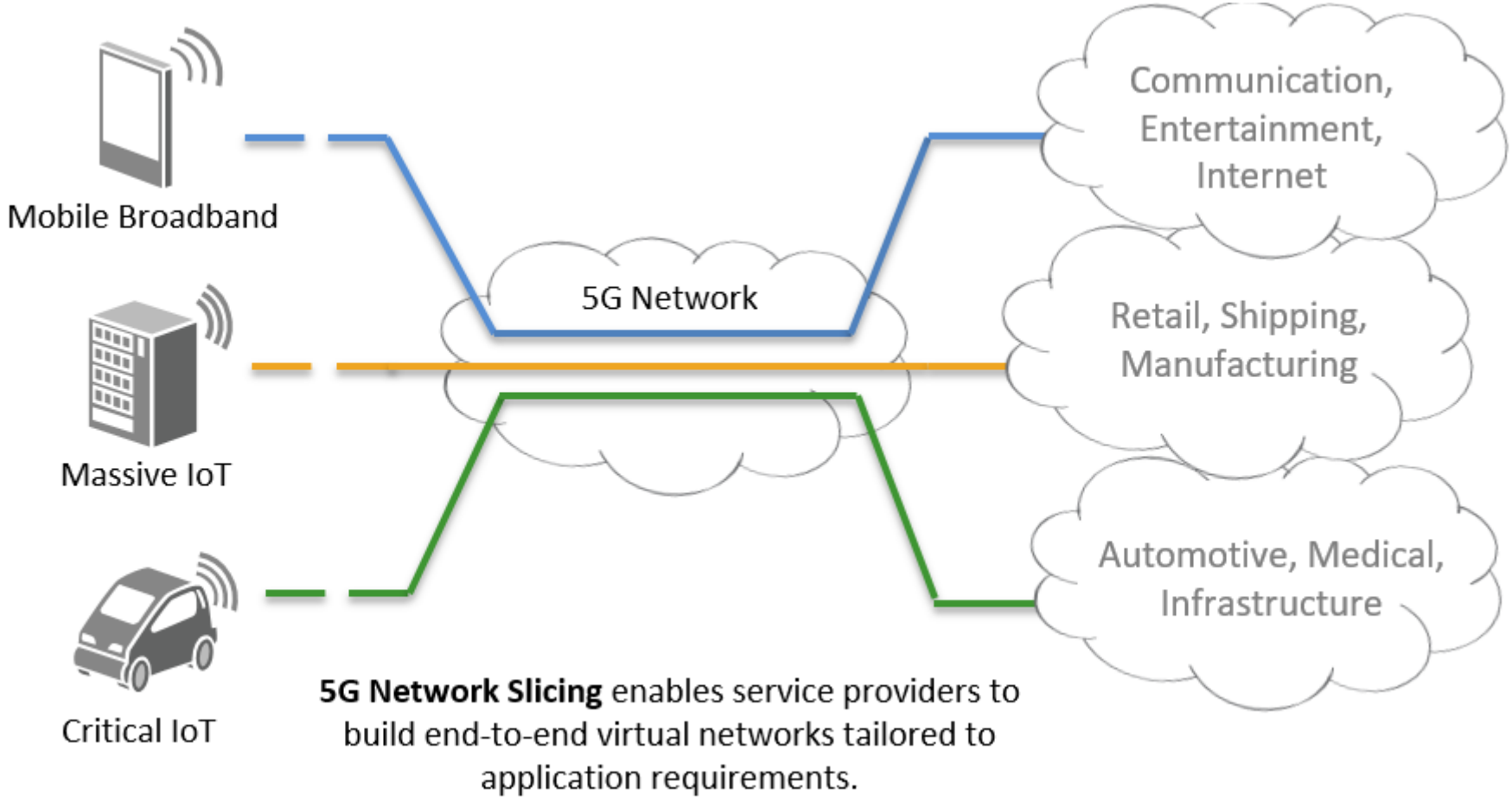
- Peak data rate of 20Gbit/s
  - eNodeB connections at least 25Gbit/s
  - Backhaul networks will require 100Gbit/s or more
- User experienced data rate of 100-1000Mbit/s
  - Co-operative processing and interference management
  - These techniques typically require very accurate synchronization
- Connection density of 1M connections/km^2
  - Requires dense small cell or remote radio unit (RRU) deployment
  - Small, cheap RRU's preferred due to the number of devices required
- Latency < 1ms
  - Distributed architecture, data processing and switching at the edge
  - Fronthaul architecture with distributed radio units and co-located baseband and switching in the core

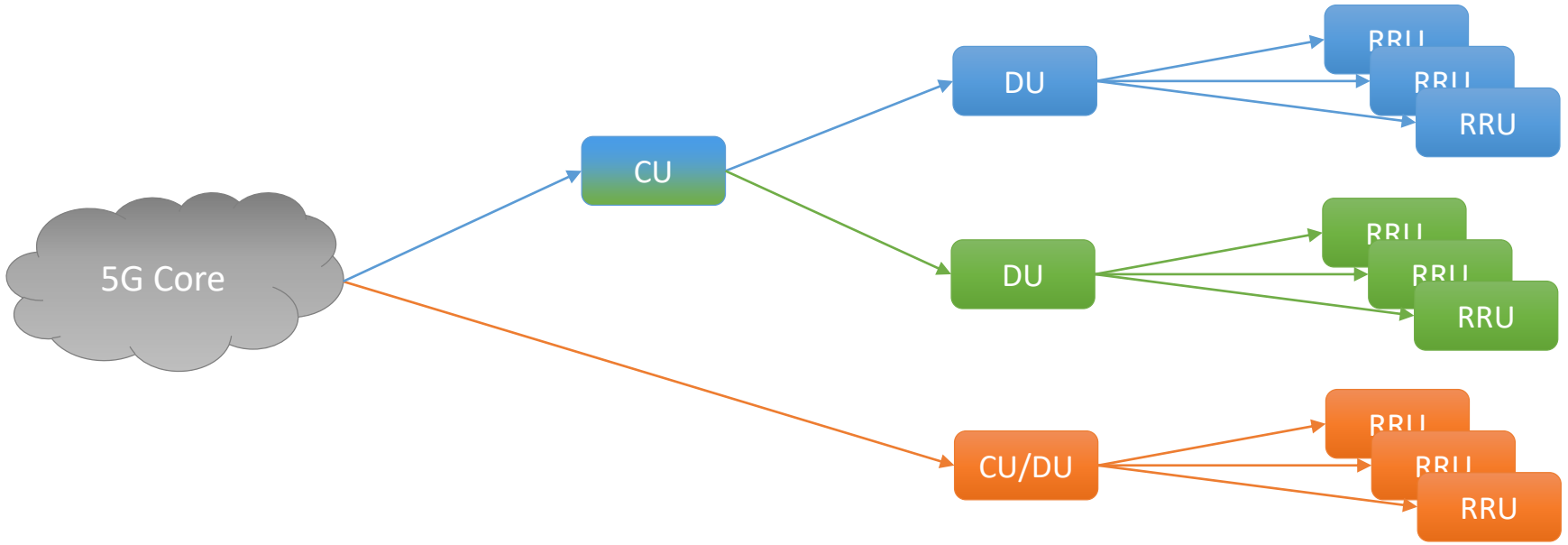
Network Slicing

- Virtual networks created to meet the demands of different applications



https://www.vanillaplus.com/2017/01/31/24983-network-slicing-unleashes-5g-opportunities-service-quality-can-assured-part-2/

5G NG Transport Network

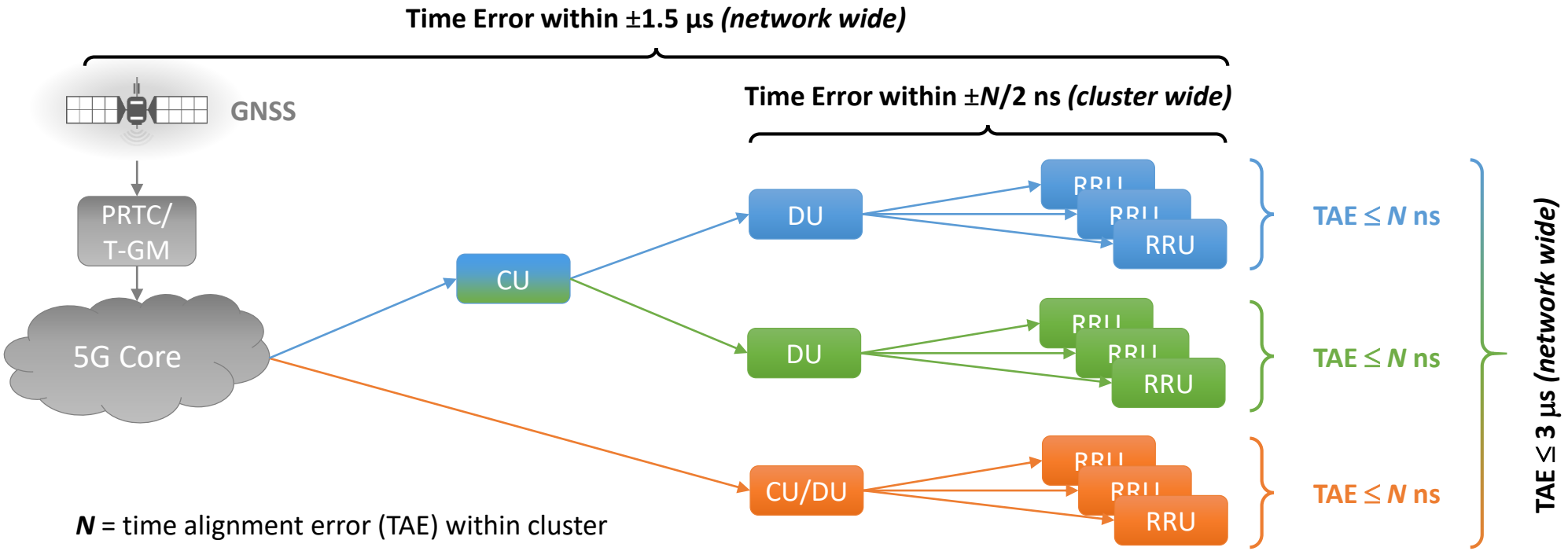


CU: Centralized Unit
DU: Distributed Unit
RRU: Remote Radio Unit

- RAN Split into Fronthaul, Middlehaul & Backhaul (CU, DU, RRU)
- Transport migrating from CPRI to CPRI, Ethernet, FlexE, FlexO, etc.

5G Synchronization Requirements

- Standard 5G TDD networks require ±1.5µs end-to-end (same as 3G and 4G)
- Co-operative radio techniques (e.g. inter-site CA, CoMP, MIMO) require much tighter synchronization when deployed
  - Consensus seems to be around ±130ns, but only between RRUs connected to the same DU
  - This permits “sync clusters” of very tightly synchronised elements



N = time alignment error (TAE) within cluster

End2End or Clusters?

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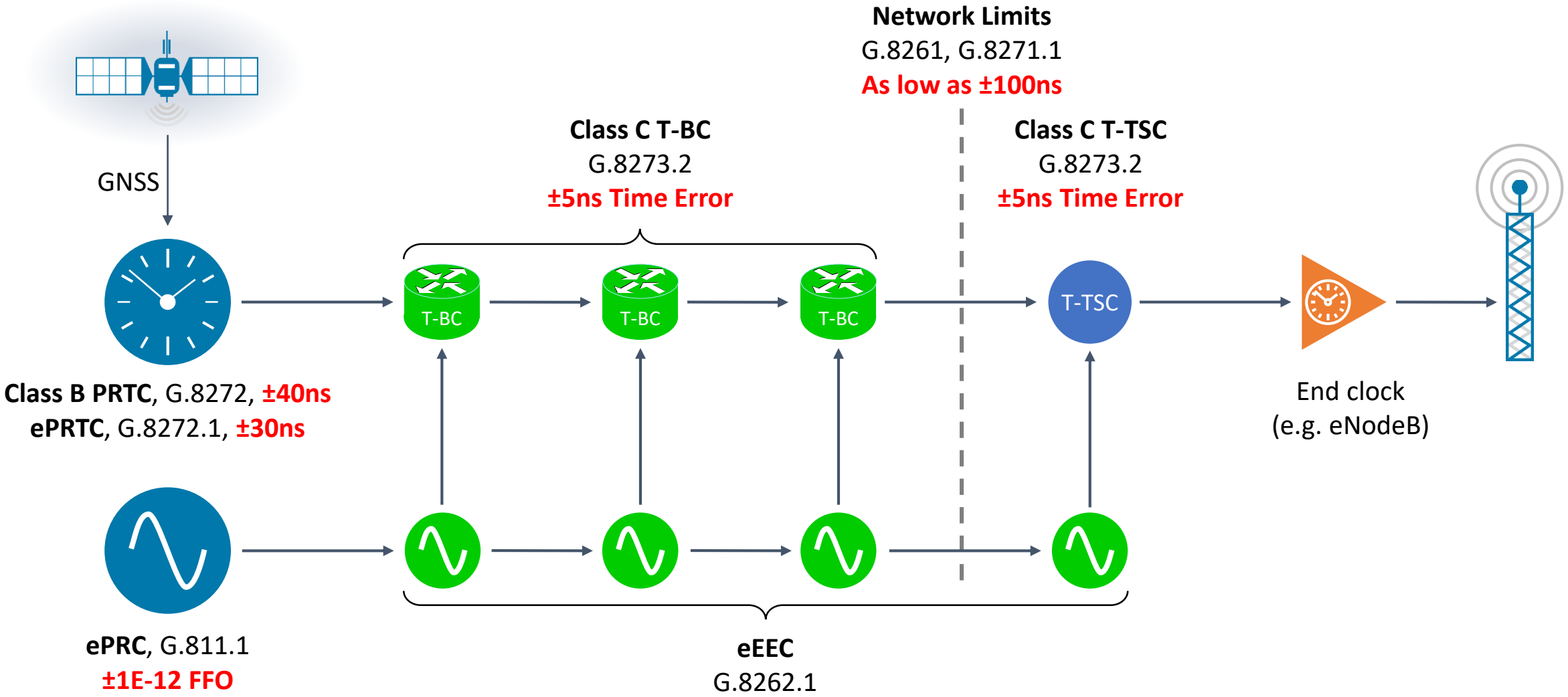
- Networks are dynamic and sometimes fail
- Planned fail-over paths and protection must consider synchronization
  - DU's may be "multi-homed" – connected to more than one CU for protection purposes
  - Not always clear which RRUs are connected to which DUs
  - CloudRAN structure – RRUs may not share the same network section as the DU or CU, especially if dynamic reconfiguration occurs
- In that situation, better to plan for tight end-to-end synchronization, rather than using "sync clusters" **BUT** cost & complexity is greater
- Some operators will require tight end-to-end sync, Some operators will use sync clusters
  - Tradeoff is ease of operation vs. cost and complexity of deployment

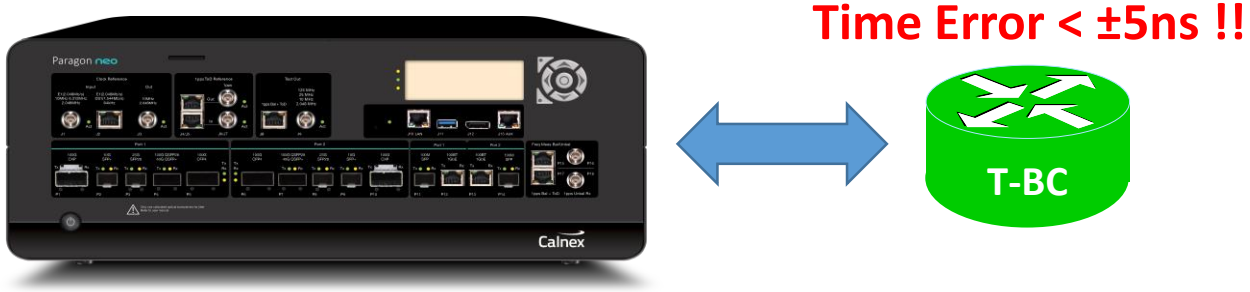
Enhanced Clock Specifications for 5G



ITU-T Recommendations Status

- **G.8272** (Class B PRTC)
  - In progress
- **G.8272.1** (ePRTC), **G.811.1** (ePRC)
  - Published (2017/08)
- **G.8262.1** (enhanced SyncE clock)
  - In progress
- **G.8273.2** (Class C T-BC and T-TSC)
  - In progress (discussion about Class D)

5G: A step change in Timing accuracy



- Tester must be accurate to <1ns
- 1PPS signal skew – difficult to accurately measure to 5ns
  - Even Differential 1PPS, which has ±10ns spec

Insight and Innovation

calnexsol.com

Tommy Cook,
CEO
tommy.cook@calnexsol.com