Network Synchronization Challenges in 5G

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Time?

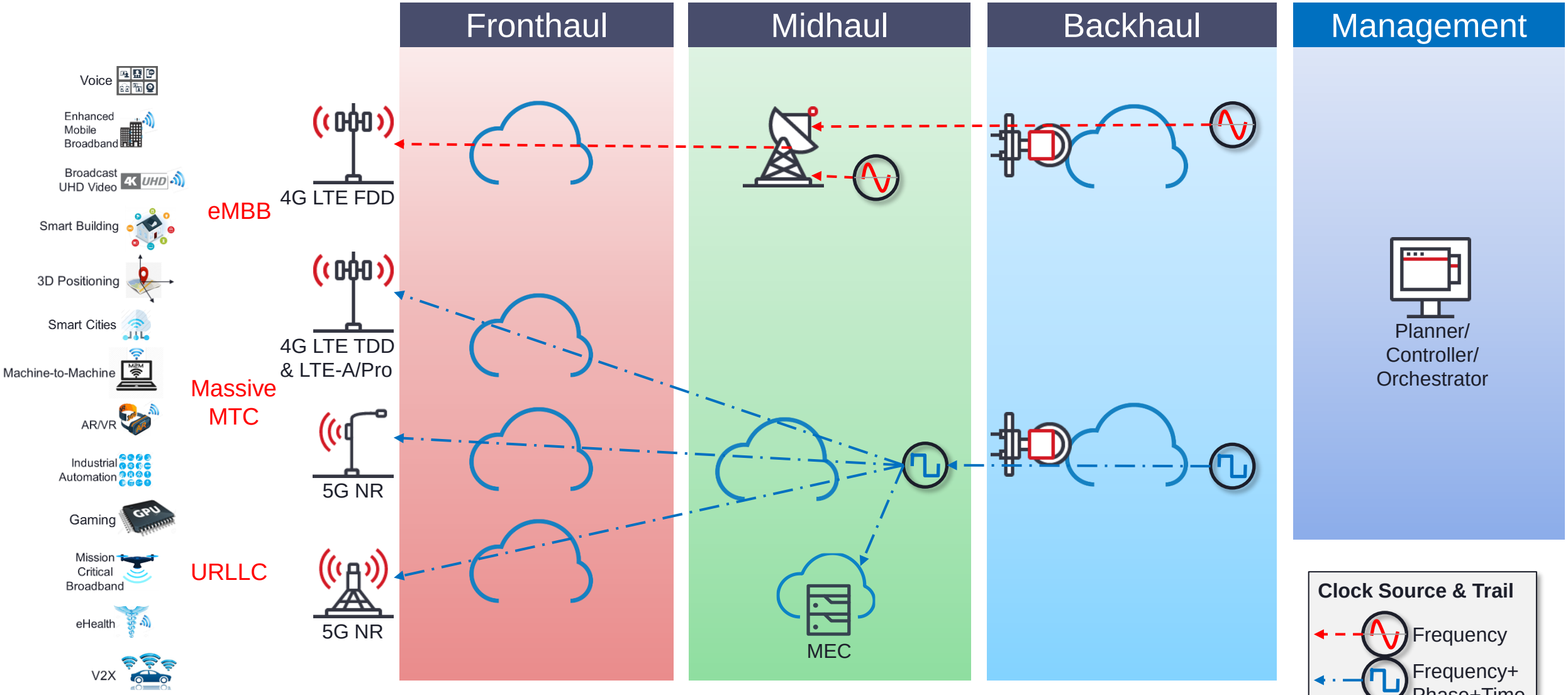
Time is a complex measure, guide and standard that has laymen and experts, spanning many disciplines, defining, understanding and applying it. It is therefore not surprising that its representation and interpretation may change meaning depending on its context and application.

– Bashar Abdullah

Agenda

1. 5G Packet Network Synchronization Overview
2. Synchronization Landscape for the next generation
3. Synchronization Architecture Evolution
4. Challenges Facing the 5G Synchronization Network
5. Summary

5G Packet Network Synchronization Overview



Synchronization Landscape for the Next Generation

Frequency Only

- G.8262 SyncE
- G.709
- G.8265.1
- IEEE 1914.3
- CPRI
- 10MHz
- BITS

✓ RU and BBU reference
✓ For phase holdover

Frequency, Phase & Time

- ePRTC (GNSS trained atomic)
- PRTC (GNSS only)
- G.8275.1 Full Timing Support (FTS)
- G.8275.2 Partial Timing Support (PTS)
- 802.1AS Time Sensitive Networking PTP (TSN PTP)
- Proprietary Profiles

- GNSS & G.8275.1 Assisted Full Timing Support (AFTS)
- GNSS & G.8275.2 Assisted Partial Timing Support (APTS)

- Interworking between profiles

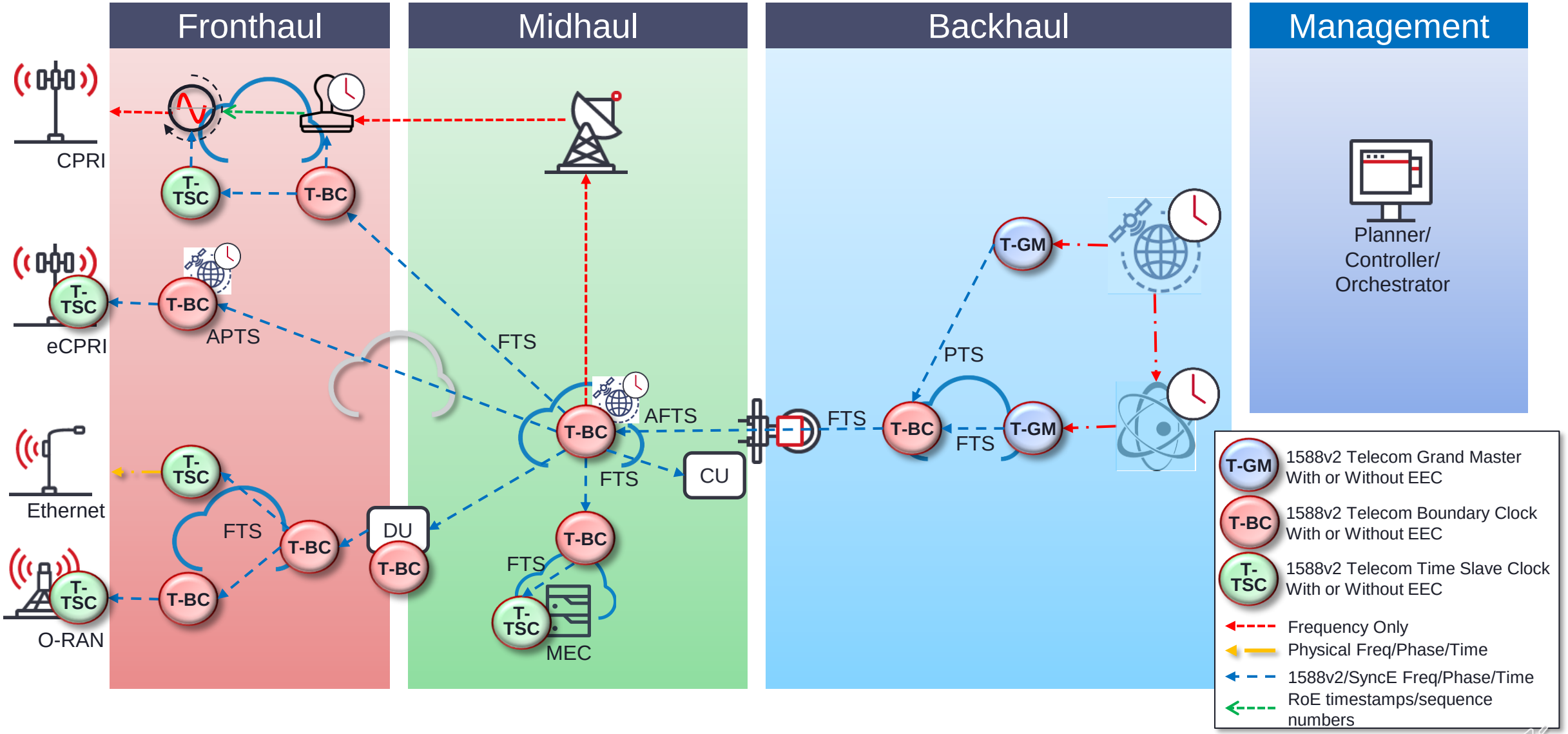
- G.703 1pps (phase only)
- G.703 ToD (e.g., NMEA 0183) (time only)

✓ RU, BBU/vBBU, DU/vDU and CU/vCU reference
✓ For 1914.3 reference

Controller/Orchestrator

Synchronization Network Management & Planning

Synchronization Architecture Evolution



Challenges Facing the 5G Synchronization Network
(1/3)

Network Architecture, Dimension & Scale

CHALLENGES

- 5G disaggregated architecture with shared infrastructure
- Fronthaul
  - O-RAN to CPRI interworking
  - CPRI RoE emulation
  - Increased RU density
- Midhaul
  - MEC with vDU/vCU/vBBU
  - Increased RU density will expand MEC scale
- Backhaul
  - Network dimension with a packet fronthaul can easily exceed engineering limits for SyncE and telecom profiles
  - Network re-arrangements can exacerbate network dimensioning challenge

SOLUTIONS

- ➢ O-RAN LLS-C1/C2/C3/C4 sync architectures
- ➢ CPRI RRH clock alignment to the O-DU can use 1588v2 re-timing
- ➢ CPRI RoE emulation can make use of 1588v2 as a common reference at the mapper/demapper functions
- ➢ RU densification can leverage more cost efficient 1588v2 distribution
- ➢ MEC can use hardware enabled 1588v2 NICs to achieve 3GPP sync performance requirements
- ➢ MEC scale can expand using switch/router NIC-based 1588v2 T-BCs
- ➢ Position the clock sources in the C-RAN hub or closer to the RUs where AACs are non-viable for clock distribution
- ➢ Network planning and orchestration can facilitate pre-emptive network re-arrangement avoidance

Timing Trail Asymmetry

CHALLENGES

- Fiber deployments
- Transmit and receive paths through synchronization equipment
- OTN transponders, amplifiers & coherent optics

SOLUTIONS

- ➢ Measure the asymmetry and apply compensation to timing trails
- ➢ For coherent optics, leverage the optical supervisory channel (OSC)
- ➢ Design components and devices that exhibit less asymmetry

Challenges Facing the 5G Synchronization Network
(2/3)

Network PDV

CHALLENGES

- Packet network queuing/scheduling/shaping induce PDV
- Clock distribution across AACs for out-of-region access to RUs

SOLUTIONS

- Minimize network PDV by increasing CoS for 1588v2
- Deterministic forwarding
  - Time-based scheduling OIF FlexE/ITU-T G.83xx
  - Time aware scheduling IEEE 802.1bv (up to 25GE only)
  - Frame pre-emption IEEE 802.1bu (up to 25GE only)
- Move clock source closer to the RU site
- Secure sync-as-a-service SLA from AAC

Clock Redundancy

CHALLENGES

- GNSS impairments
- Single point of timing failures

SOLUTIONS

- Use GNSS disciplined atomic clocks in geographically redundant locations
- Maintain multiple geographically dispersed GMs with multiple paths for timing trails to avoid shared fate faults
- Maintain phase holdover for durations that cover maintenance and unexpected sync distribution disruptions

Challenges Facing the 5G Synchronization Network
(3/3)

Phase Holdover

CHALLENGES

- GNSS impairments are frequent and can be regional in impact
- Transport network re-arrangements
- PRTCs require periodic maintenance

SOLUTIONS

- GNSS jamming filters or multi-band receivers
- GNSS disciplined atomic clocks (i.e., ePRTC) in geographically redundant locations
- PRC traceable physical methods (e.g., SyncE)
- PRC traceable packet methods (e.g., G.8265.1)

Planning, Management and Orchestration

CHALLENGES

- Changes in the synchronization network may not correspond to changes in the network topology or status
- Positioning clock sources based on economic, geographic, network technologies, and 3rd party network factors

SOLUTIONS

- Measure and monitor timing trails (e.g., sample longest or highest PDV paths)
  - Measure PDV performance to plan timing trails
  - Monitor the quality of the clock as it traverses the network (timing trail topology) for each of frequency, phase and time-of-day
- Correlate network re-arrangements due to faults or optimizations with timing trail re-arrangements to be able to anticipate synchronization network impairments to minimize their impact

Summary

5G network synchronization inherits many well known challenges from previous generations, and introduces some new ones. The new landscape of synchronization technologies and architectures are enabling the ability to advance the 5G network evolution.

Thank You

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Abbreviations

Abbreviation	Expansion
AAC	Alternative Access Carrier (wholesale service provider)
AFTS	Assisted Full Timing Support (e.g., GNSS primary + G.8275.1 backup)
APTS	Assisted Partial Timing Support (e.g., GNSS primary + G.8275.2 backup)
AR	Augmented Reality
BBU	Baseband Unit
CoMP	Coordinated Multipoint
CU	Centralized Unit (5G architecture)
DCO	Digital Coherent Optics
DU	Distributed Unit (5G architecture)
eMBB	Enhanced Mobile Broadband
FDD	Frequency Division Duplexing carrier signal
FTS	Full Timing Support (e.g., G.8275.1)
GNSS	Global Navigation Satellite System
LLS-C1/2/3/4	O-RAN Low Layer Split – Synchronization Architectures (C1, C2, C3, C4)
LTE	4G Long Term Evolution RRH
LTE-A	4G Long Term Evolution - Advanced RRH
MIMO	Multiple Input Multiple Output
mMTC	Massive Machine-Type Communication
NR	5G New Radio

Abbreviation	Expansion
OSC	Optical Supervisory Channel
OTDOA	Observed Time Difference of Arrival
PTS	Partial Timing Support (e.g., G.8275.2)
RAN	Radio Access Network
REC	Radio Equipment Controller
RRH	Remote Radio Head
RU	Radio Unit
TDD	Time Division Duplexing carrier signal
urLLC	Ultra-Reliable Low Latency Communication
VR	Virtual Reality