There is an on-going discussion in working groups about unification of Fronthaul and Backhaul network infrastructure. Main drivers are:

- Reduce Bandwidth **CPRI is unsustainable**.…
- Enable Resource Pooling (Cloud Infrastructure, RAN sharing) Huge Cost and Performance Driver

- Ethernet will also cover Fronthaul networks.
- However time requirements of Fronthaul networks are stringent, so **Ethernet has to do some homework ➔ TSN (time sensitive networks)**
Front-Haul Split – TSN Implications

Key Is Time Sensitive Ethernet

Rates indicate peak throughput on a single 20MHz LTE carrier (2Tx, 2Rx)
What is Time Sensitive Ethernet (TSN)?
Old wine in new bottles?

- Back when almost flawless streaming QoS was required ...
  -- we had land-line *circuit-switched telecom networks*,
  -- connections were based on “circuits” (nailed-up paths from end to end with deterministic characteristics).

- The internet changed this model to “connections”
  -- highly adaptive, very robust, but timing is very sloppy
  -- use the sloppy timing budget as a way to get the data through (retries, adaptive routing, etc)

- Now the sloppy timing is facing real world, **real time requirements/applications**
  -- Industrial automation, vehicle control, tactile internet require low latency packet forwarding
  -- Mobile Radio Fronthaul has stringent delay, continuous throughput and synchronization demands (e.g. CPRI, HARQ loop, carrier frequency accuracy). This is a must for a working mobile radio network infrastructure.

- **Time-Sensitive Networking** (TSN) is the answer to these demands and returns to “circuits”
  -- but we call them “streams” with defined QoS characteristics (e.g. max. latency)
  -- but still this shall seamlessly interoperate with existing models of “the internet”

- How do we do this?
  -- Provide a network-wide **precision clock reference** for scheduling
  -- **Limit network delays** to a well-known (and hopefully small) value
  -- Keep non-time-sensitive traffic from messing things up

⇒ To achieve this, we need to fix the low-level plumbing (transport layer) .....  
⇒ In case of networks based on Ethernet, we use IEEE 802.1Q Time-Sensitive Networking.
What is a Time Sensitive Network – A New Ethernet!

The primary TSN projects include:

- **Time synchronization of TSN components**
  - 802.1AS (based on IEEE 1588)

- **Schedule, Queue & Forward time-sensitive streams**
  - 802.1Qav credit-based shapers, new P802.1Qbu frame preemption, P802.1Qbv time-aware queuing, P802.1Qch cyclic queueing, P802.1Qci input gating and P802.1CB seamless redundancy.

- **Registration & Reservation of time-sensitive Streams**
  - 802.1Qat – a distributed “stream reservation protocol”, extended in new P802.1Qcc to support preemption, scheduling, centralized control, and interaction with higher layer IETF services.

- **Overall system architecture for Mobile Fronthaul**
  - 802.1CM:
    a) The VLAN Bridge specification in IEEE Std 802.1Q.
    b) Interspersing express traffic specification in IEEE 802.3br.
    c) Frame preemption specification IEEE Std 802.1Qbu.
    d) The time synchronization standard IEEE Std 1588, or one of its suitable profiles.
    e) The MAC and PHY standards specified for the various LAN MAC/PHY technologies, such as IEEE 802.3, IEEE 802.11.

The above listed needs test functionality beyond what is currently implemented in our instruments!
TSN UnitTesting
Lab - Testing Frame Preemption, Queuing and Scheduling

Performed tests:

- **Preemption**: Data integrity/frame loss under varying frame size conditions
- **Queuing**: Correct routing of express vs standard packets based on priority/VLAN
- **Scheduling**: Correct timeslot assignment of packet based on SyncE/PTP synchronization. Basic PDV
- **General parameters**: packet delays, packet timing (slot based histogram)
  Check dependency of key parameters on load variation (background traffic) or impairments (timing)

Dual Port 10/100G Test Unit
Testing Next Generation Fonthaul Interfaces (NGFI)

Performed tests:
- Basic protocol functionality/connectivity
- Link Delays
- Loss of frames
- Verification of end to end connectivity/protocol/timing in NGFI (fronthaul link)
- SyncE performance testing
Network Test and SON
Sample SON reconfiguration options

- SON fronthaul levers
  - Change functional split
    - As split point moves IQ to PDCP defined bandwidth requirement decreases
    - Minimum latency requirement increases
    - Split may differ in UL and DL and between different RU
  - Latency provision
    - Different co-operative modes require stricter latency requirements
  - Fronthaul path configuration

- SON reconfiguration options
  A. Impose/remove latency guarantee on existing path to support CoMP vs other traffic
  B. Switch Ethernet path to
    - equalise hops & distribute traffic to facilitate latency to support CoMP vs other traffic
    - Circumvent node failure
  C. Activate small cells and switch-off SON to release resources (bandwidth and latency) for small cells
  D. Change functional split point to reduce bandwidth requirement or, conversely, to exploit available bandwidth
Potential set-up for next steps towards D3.3 and WP5

Radio performance & configuration “OMC”

Legacy BBU(s)

CPRI up to 10G

Mod Split BBU(s) (int.)

CPRioEth

TSN Eth-Switch

IAF Prototype Platform

Mod Split BBU(s) (ext.)

Next-Generation Central Office

Allows investigation of different split options and Eth scenarios

Point-to-point or few node rings (up to 20km)

100GE+ trunks, low cost optics

WEB GUI

System manager + SON

SDN

Front haul cloud

Next-Generation Cell Site

Mod Split OAI RRH (Kent)

60GHz RRH (HHI)

Legacy RRH

TSN Eth-Agg MEC option (ADVA)

Pluggable Probes up to 10GE

Built-in probes up to 10GE

CPRIoEth

Section 6 in ToC of D3.2