On the Role of Timing and Synchronization for 5G-Phase II Industrial Internet of Things (IIoT): Challenges and Opportunities

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work accomplished by Orange Labs in coordination with Orange France

Reminder of the Context - 5G Phase I First deployments (3.5 GHz TDD)

- 5G is becoming a reality in Asia, Americas, as well as in Europe
- 5G Phase I targets Enhanced Mobile BroadBand (eMBB) services.
- Phase/time synchronization is mandatory for TDD based eMBB services (e.g. 3.5 GHz band in TDD mode)
- 2 recommended solutions to distribute phase/time synchronization (for Orange networks); via GPS or via PTPv2.
  - where SyncE in addition to frequency delivery, is also used for backing-up phase/time
- Orange France: successful PTPv2 trial in 4G context (18Q1), on-going project to deploy PTPv2 for Orange Cities.
- Distribution of accurate time synchronization creates new challenges for an operator
  - Anticipation of the transport equipments upgrade (SyncE + PTPv2 support)
  - Handling of asymmetries (calibration at set up and during operation)
  - Planning of proper redundancy for long time holdover to avoid service degradation

Mobile networks roadmap (radio features) is a key input to determine the target architectures and the migration paths of synchronization networks in countries.

Where does 5G Phase II stand today? An Evolution or a Revolution ?

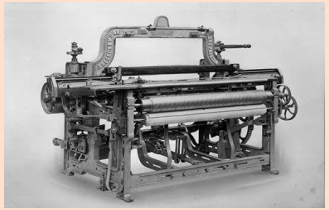
- 5G Phase II is part of 3GPP release 16 (Freeze date (March 2020) and completion (June 2020))
- 5G Phase II targets (among others) URLLC (Ultra Reliable and Low Latency Communications) use cases also.
- Key URLLC business opportunities: smart factory/industrial automation; remote diagnosis and surgery for healthcare professionals; entertainment; transportation; manufacturing and smart grid.
- Industrial IoT (IIoT) , aka, Industry 4.0 needs URLLC component of 5G.

5G Phase I compared with 4G/4G+ is an evolution. But 5G Phase II compared to 5G Phase I is a revolution.

Manufacturing Revolution- From Industry 1.0 to Industry 4.0

Industry 1.0
FIRST Industrial Revolution

Key Change:
Introduction of Mechanical Production Equipment driven by Water and Stream Power



18th Century Mechanical Loom

End of 18th Century

Industry 2.0
SECOND Industrial Revolution

Key Change:
Introduction of mass Manufacturing Production lines powered by Electric Energy

Vintage Electric Conveyor Belt

End of 19th Century

Industry 3.0
THIRD Industrial Revolution

Key Change:
Introduction of Electronics, PLC Devices, Robots and IT to automate Production

PLC Driven Robots

Q4 of 20th Century

Industry 4.0
FOURTH Industrial Revolution

Key Change: Everything everywhere connected!
(Introduction of IoT and Cyber-Physical Systems driven by Augmented Reality & Real Time Intelligence)

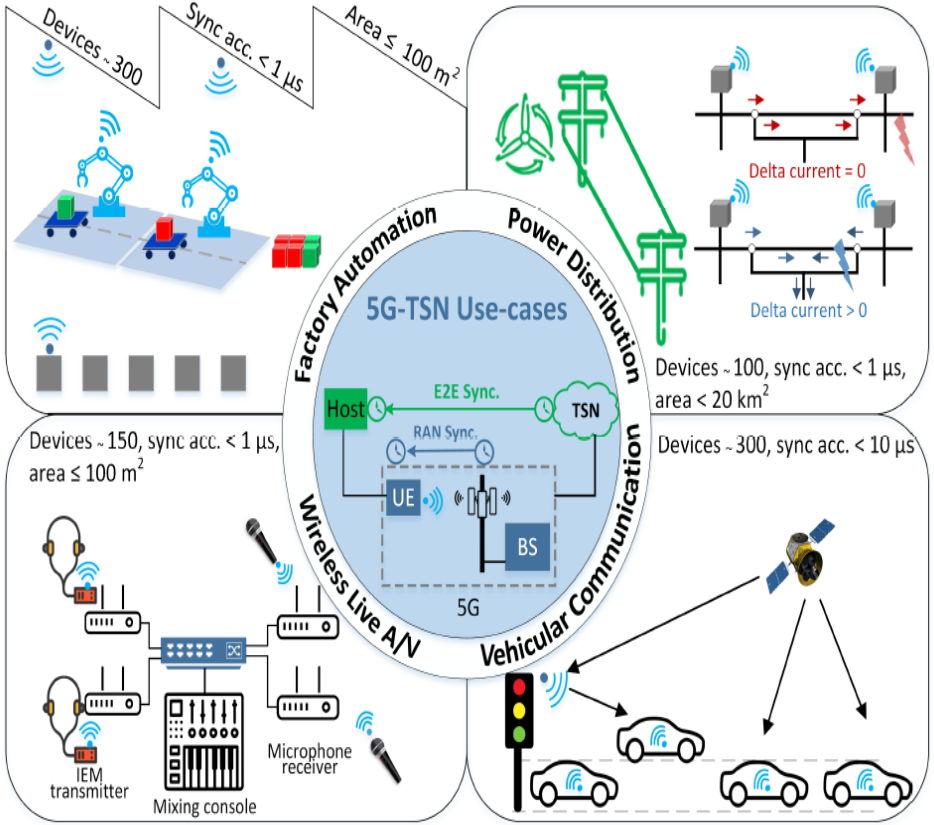
Augmented Reality Driven CPS

Start of 21th Century

Level Of Complexity

Do not confuse between Latency and Synchronization. We need both for certain uRLLC use cases!

Where does timing and Synchronization stand today for 5G Phase II



4 Reasons Why Synchronization is Critical to IIoT

- **Synchronization** — the way an IoT device adjusts its internal clock in order to align with the clocks of other devices in a network — lies (surprisingly) at the center of many of today's IoT challenges, particularly for low-power IoT.

1. Communication
   - e.g. V2V communications, etc.
2. Géolocalisation
   - e.g. Indoor positioning, etc.
3. Coordination
   - e.g. Robots, machines, etc.
4. Distribution
   - e.g. Power distribution, etc.

The clocks on the IIoT devices are way more important than you think!

5G Time Synchronization Requirements for Smart Factories

clock synchronicity accuracy level	Number of devices in one Communication group for clock synchronisation	Clock synchronicity requirement	Service area	scenarios
1	Up to 300 UEs	< 1 µs	≤ 100 m x 100 m	Motion control (Control-to-control communication for industrial controller)
2	Up to 10 UEs	< 10 µs	≤ 2500m^2	High data rate video streaming
3	Up to 100 UEs	< 1 µs	< 20km^2	Smart Grid: synchronicity between Phase Measurement Units

Table 1. Time synchronicity requirements in typical industrial automation scenarios/ **3GPP TS 22.104 Service requirements for cyber-physical control applications in vertical domains**

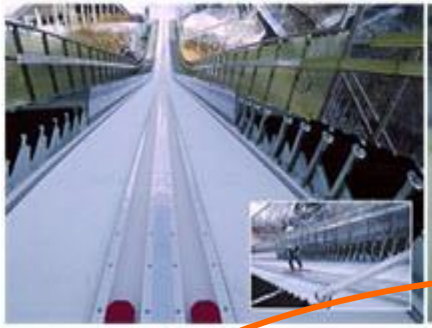
Clock synchronicity is defined as the **maximum allowed time offset** within a synchronization domain between the master clock and any individual device clock.

There are different industrial applications in the factory automation domain, which depend on the clocks to be tightly synchronized

1. e.g. High accuracy demand (in the order very few microseconds) is put forth by factory deployments of mobile robots, which aid, e.g., transportation of materials or manufacturing of products.
2. e.g. building on simultaneous communication under few tens of microseconds, a motion control system requests that up to 100 actuators and sensors are guaranteed clock synchronicity in the order of one microsecond, or even below

Many aspects of every-day operation of a network rely on its devices to have a common timescale, such as for the fault management purposes, robot coordination, etc.

Some more 5G use cases with Time Synchronization requirements



Sync view

360° VR

Interactive multi-view

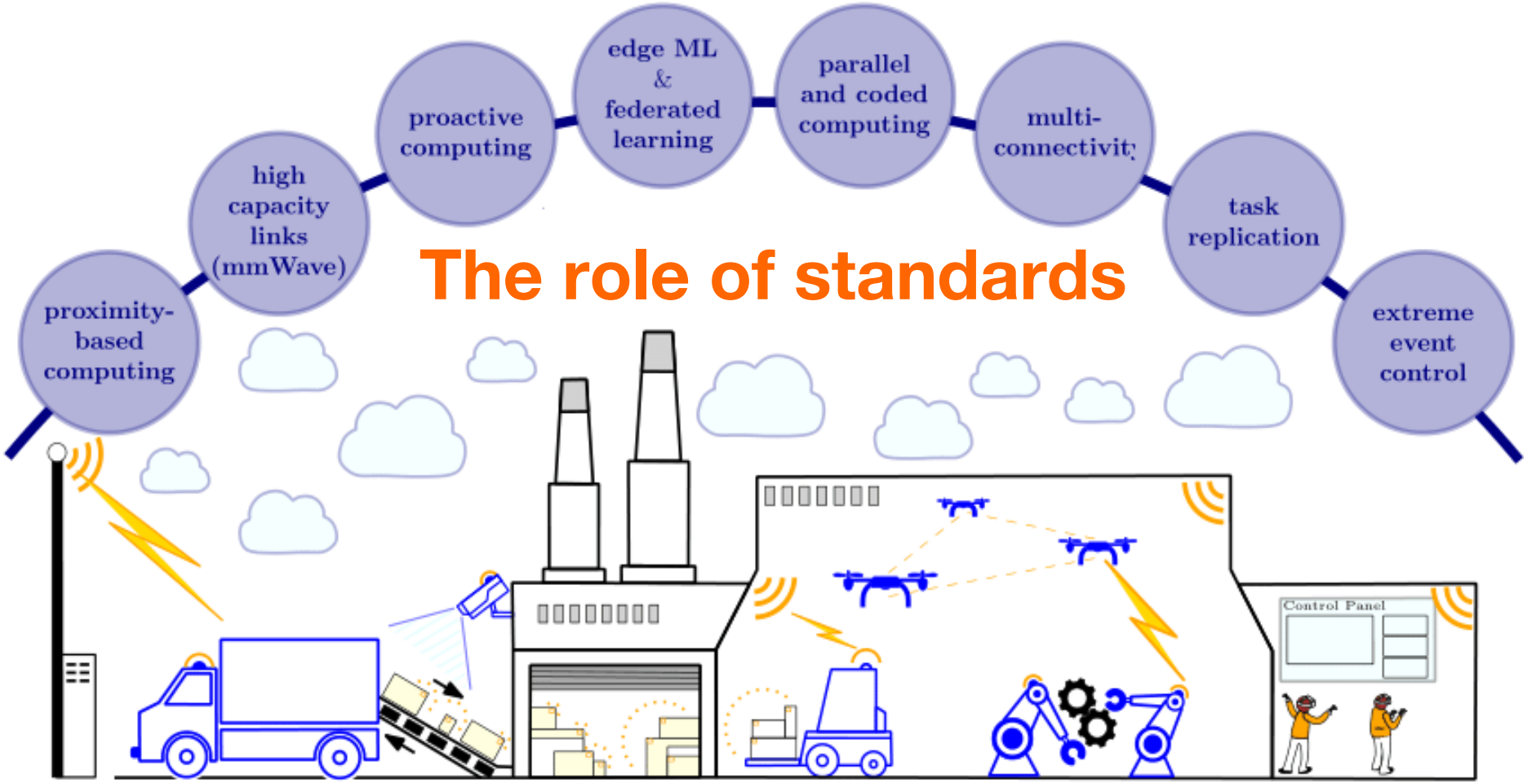
Hologram live

5G safety

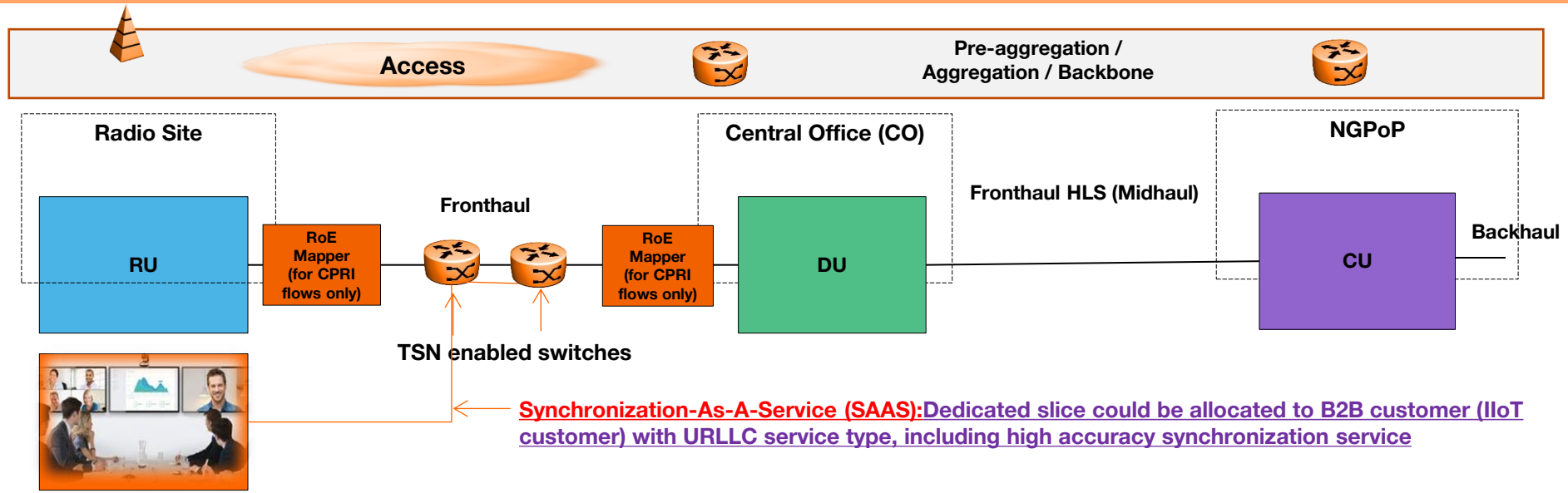
- Sync view - Streaming events from the perspectives of players
- 360° VR - Live streaming of events in real time through multi-channel
- Interactive multi-view - e.g. Can be used in video replay by referees
- Hologram live
- 5G safety - Drone featuring face recognition solution integrated with AI system

Infotainment, Entertainment, etc. needs very high latency as well as very accurate synchronization.

The role of standards



The role of Time Sensitive Networking for Mobile Network Operators

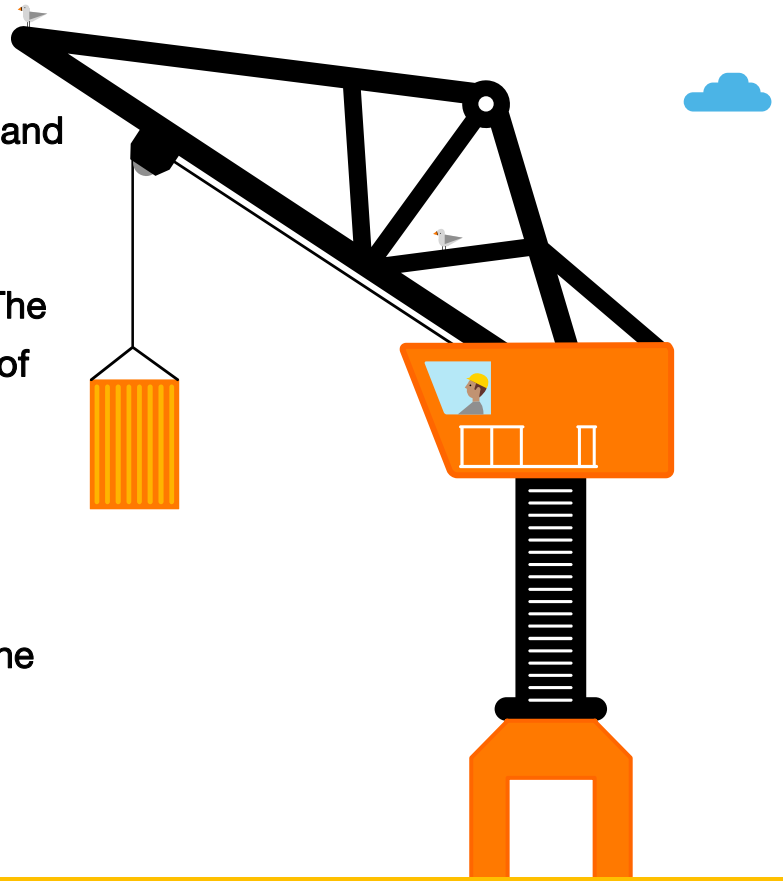


- TSN synchronization is provided through the IEEE 802.1AS standard, which allows automatic synchronization between compliant Ethernet-based L2 switches and end stations.
- One use case is when a B2B customer (IIoT customer) requests for dedicated slice for URLLC service, including high accuracy synchronization service.
- In this scenario, TSN enabled Ethernet switches would allow a dedicated slice, over the same “RU-DU” FH transport network.

Operators who deploy ITU-T G.8275. x series for phase/time sync in their transport networks, need not upgrade their transport again to support TSN specs for synchronization purposes only.

What 3GPP has for us?

- **Radio-interface Based Synchronization** (RIBS).
- Standardized in R12 for small cell (TR 36.922 section 6.4.2.1) and 3GPP TR 36.872, section 6.3).
- RIBS uses wireless **network listening for synchronization**. The target cell monitors the network listening RS (e.g, CRS, PRS) of the source cell directly to maintain synchronization with the source cell.
- When the target cell monitors the source cell, the target cell mutes its own transmission at least when the target cell and the source cell are in the same frequency.
- Period Configuration: The period of RIBS is less than 10s.



3GPP RIBS solution is needed when the client (time receiver) can not be connected through Wired network.

Opportunities for operators in the IIoT domain wrt Synchronization

Smart Industries

eHealth

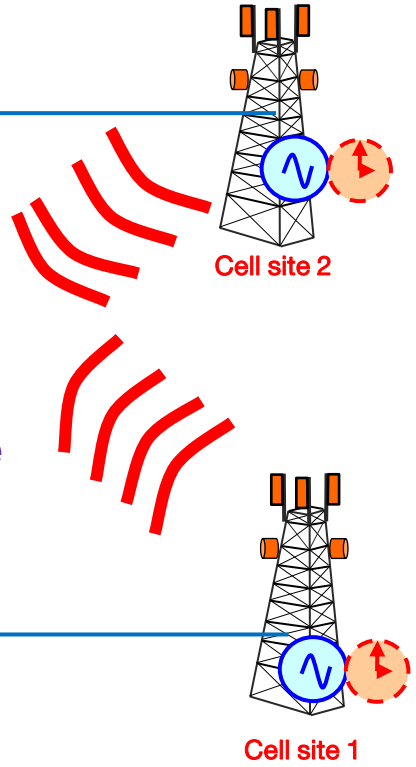
PTP GateWay

V2V communicatio

Power distribution

Connected homes

Re-use the time received from the backhaul to re-distribute to the UEs/IIoTs domain



Synchronization-As-A-Service (SAAS)

Re-use OTA solutions from 3GPP to transfer time from cellular domain to IIoT domain and reuse IEEE TSN to transfer time within the IIoT domain.

Challenges for Operators in deploying Synchronization for IIoTs (1/2)

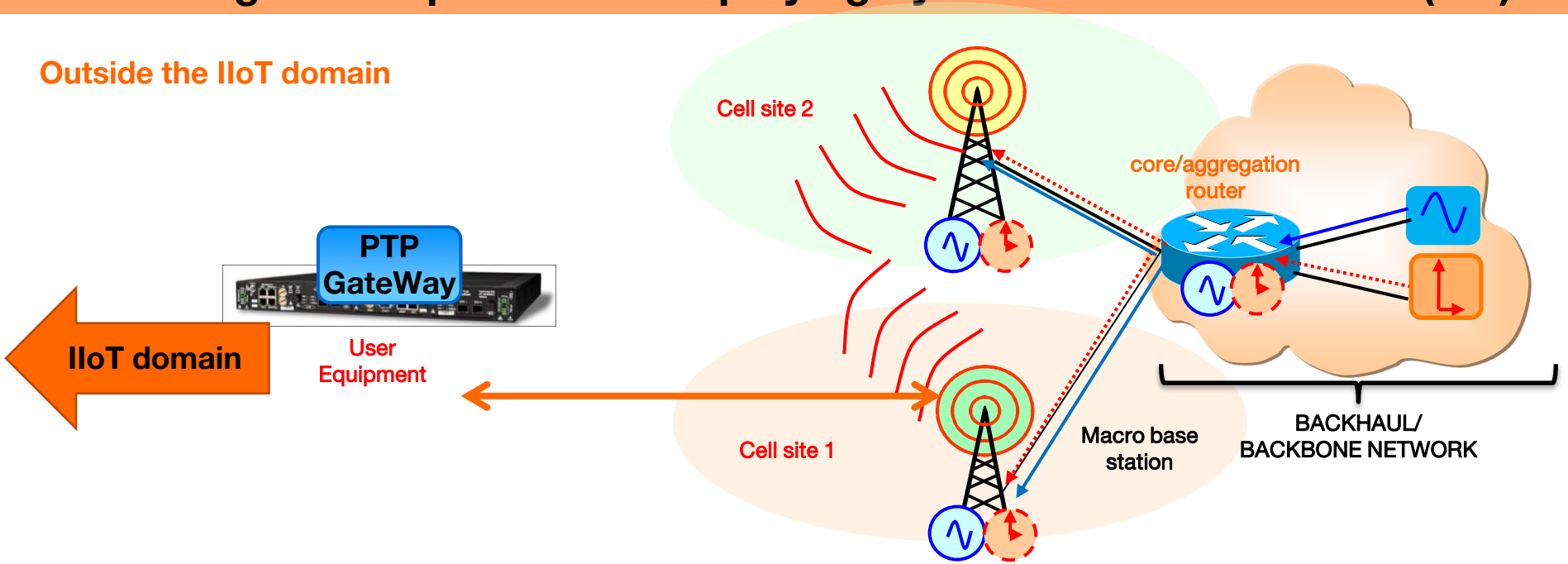
Inside the IIoT domain

- **What is PTP-Gateway ?**
  - A PTP-GW is a “small cell” kind of equipment, that should support IEEE 801.AS also.
  - Should be able to receive time via OTA and/or wired source.
  - Should be able to transmit time via OTA and/or wired source.
  - Possible implementation of Integrated Backhaul Access (IBA), c.f. 3GPP TR 38.874.

- **PTP-Gateway Design**
  - Should be able to serve several clients inside the Industrial domain.
  - No of hops inside the Industry domain needs to be taken into account.
  - Should be designed as per the clients needs and clients size/topology (star, tree, mesh, linear, etc).
  - If more than one PTP-GW is present with the identical clock quality, traceability, and priority inside the IIoT domain, the PTP-GW with the highest MAC address should be chosen.

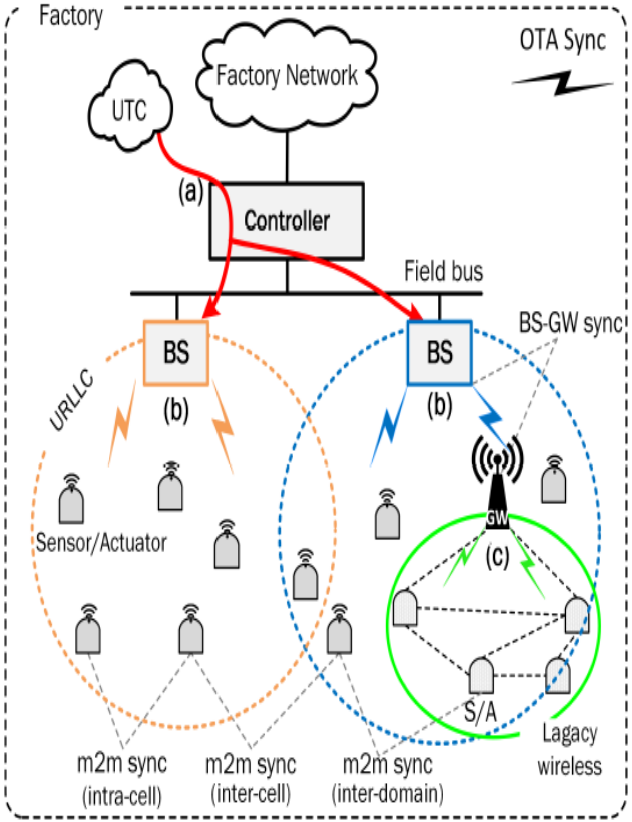
Challenges for Operators in deploying Synchronization for IIoTs (2/2)

Outside the IIoT domain



- Evaluation of the distance between eNodeB (time source) and PTP-Gateway via OTA solutions.
- Care should be taken that PTP Gateway should be able to function even under mobility conditions.
- PTP-GW should be designed by studying the traffic model of the respective Industry domain should be studied.
- Care should be taken that the topology had the maximum amount of bridges participating in synchronization.

Conclusion and summary



- **5G Phase II synchronization requirements would be mainly based on Industrial Internet of Things use cases (URLLC-related use cases).**
- **Accuracy requirements for URLLC-related use cases are not yet fully standardized in SDOs but under study values indicate up to 1µs.**
- **Needless to say, mobile backhaul must be synchronized with SyncE and PTPv2 protocol (± 1.5 µs absolute accuracy with respect to UTC) to transport the synchronization to the URLLC domain.**
- **Operators who do not have G.8275.x series in their backhaul, could go ahead and deploy IEEE 802.1AS Rev for Synchronization purposes only.**
- **When the URLLC domain is isolated from the transport network, Over-The-Air (OTA) based mechanisms are recommended.**
- **Radio Interface Based Synchronization (RIBS) or Network Assistance for Network synchronization are some examples of OTA synchronization solutions.**

Thank you