Time sensitive networks over private 5G

Artur.Wachtel@belden.com
Principal Architect Technology Value @ Belden CTO office
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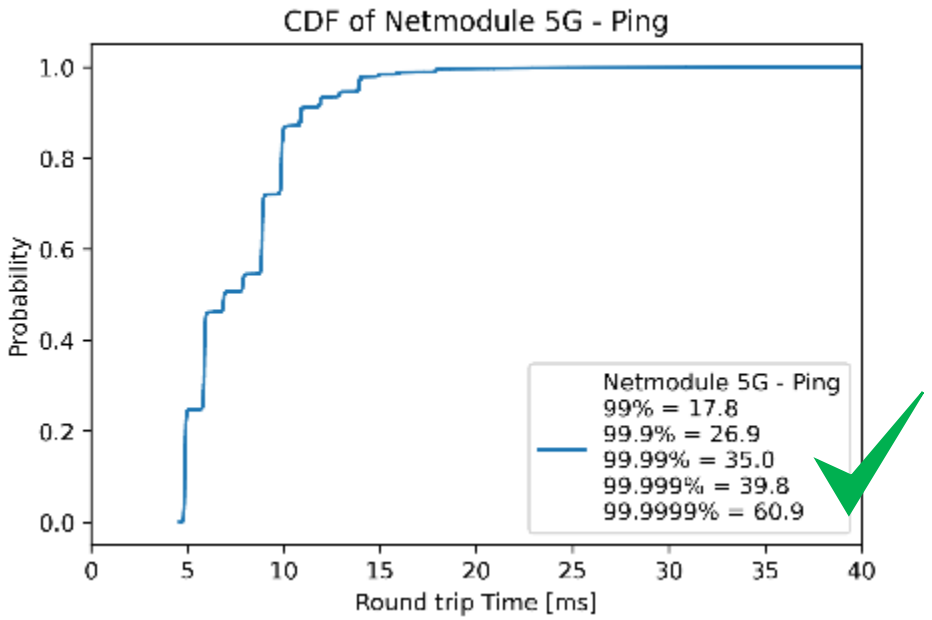
NB1800: NetModule Industrial Router

- ✓ 2x Gigabit Ethernet, 1x SFP
- ✓ 2xLTE, 2x micro-SIM
  - ✓ AP or client mode
  - ✓ IEEE1588v2
  - ✓ IEEE802.1AS (TSN)
  - ✓ IEEE 802.11 a/b/g/n/ac
  - ✓ **VXLAN Layer-2 Tunnel**
- Telit 5G Modem: FN980 (RED certified)
  - **3GPP Release 15**, Qualcomm chipset
  - Stand alone, non-standalone
- Telit 5G Modem: FN990
  - 3GPP Release 16, Qualcomm chipset SDX62
  - Stand alone (SA), non-standalone (NSA)



Why TSN over 5G?

TSN makes uRLLC usable for operation technologies

Sensor Data: FFT of ultra sound

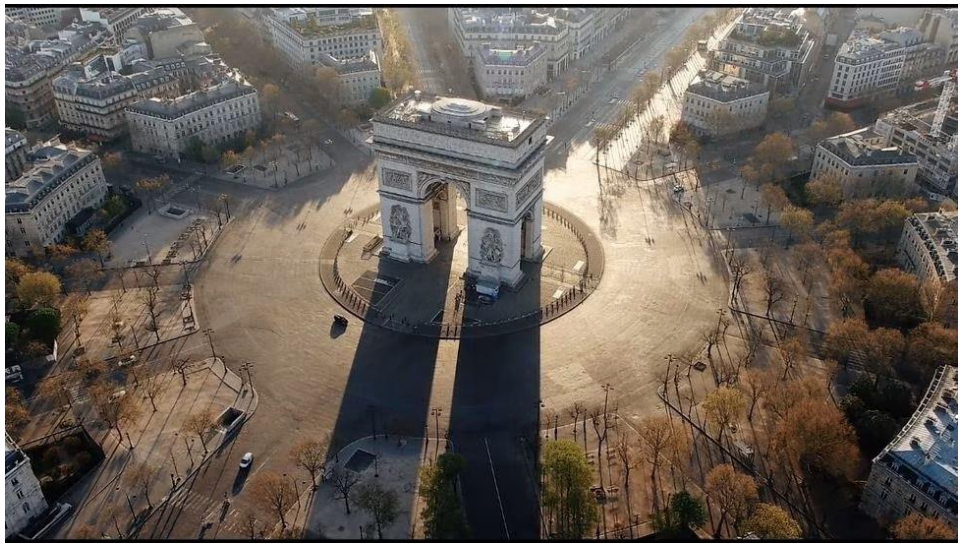
Position of the 5 axis milling

5G Use Cases versus Business Case or Value Proposition

- **Use Case**
  - Manufacturing: high precision alignment of sensor data in time and space
  - Next generation of sensors: 4k, ultrasound, lidar
- **Time to market:**
  - we are still in the early adopter phase – 5G needs to solve a problem
  - Full feature set and business volume is for later
- **Economic viability**
  - High material cost – titanium blisk ~ 100k€
  - High tool cost, 10 – 20k€

Use case : preventive maintenance

Motivation for Time Sensitive Networks



Brown Field

- Ethernet functions like place Etoile in Paris
- Industrial Ethernet requires determinism which led to proprietary solutions
  - Profinet
  - Ethercat
  - CC-link

  Based on non standard Ethernet hardware

TSN

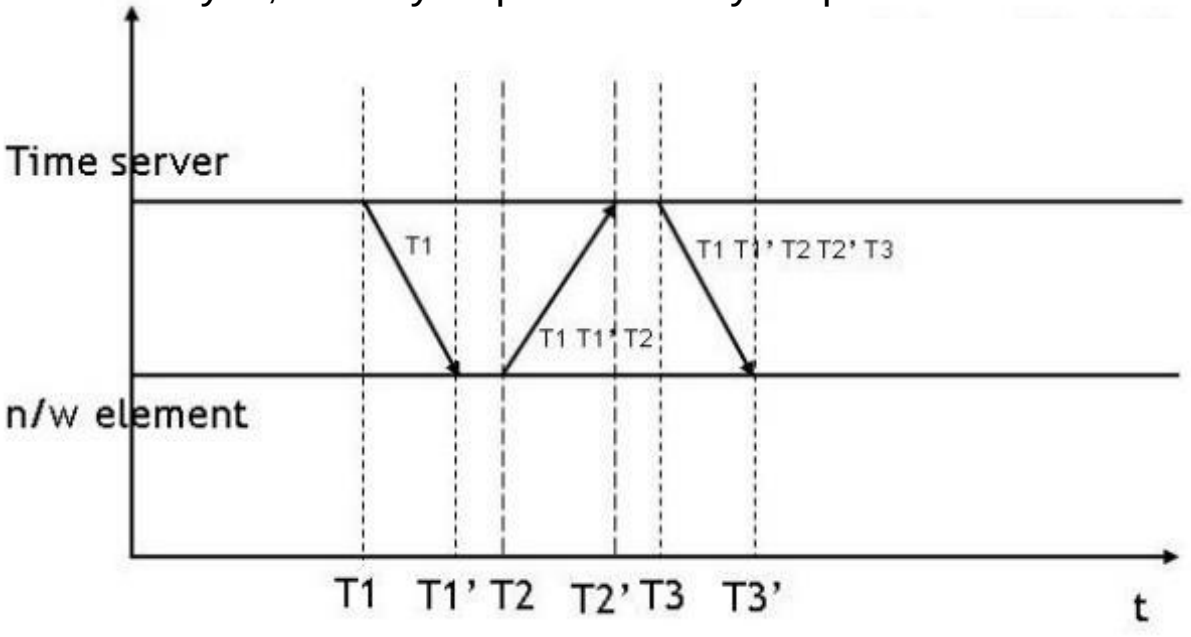
- Time Sensitive Networks is a set of standards
- IEEE802.1AS provides time synchronization
- TSN Layer 2 has been incorporated in Profinet, EtherCat, CC-link, etc.
- TSN leads to more economic (standard) hardware

Typical timing generation, delivery and synchronization mechanisms

Source	Typical Precision	Description
Atomic Clock	1 part per10^{15}	An extremely expensive method of generating very high precision time. The root time reference for all other systems is typically an atomic clock
NTP	<20ms	Network Time Protocol: Dominant protocol for distributing time over Internet. Not suitable for precision time delivery.
PTP (IEEE1588)	<1us	Precision Time Protocol: Requires end-to-end support at all switches. Used in controlled deployments (e.g., factory, radio access network)
GPS / GLONASS	<50 ns	Global Positioning System: Over the air, free and very accurate. Requires outdoor unobstructed antenna.
5G NR+CN TSN-Bridge	±1.5 ns	5G system may provide timing based on several references; Universal Time Coordinated (UTC), GNSS or Local Time. TSN over 5G specified in TS23.501, starting Release 16

Principle of Precission Time Protocol

- Offset = ½ [(T1'-T1) – (T2' – T2)]
- Latenz = ½ [(T1'-T1) + (T2' – T2)]
- Condition : symmetrie ?
- Sync,-> delay request -> delay response



Clock hierarchies 1588

- Grand Master Clock
  transmits synchronization information to the clocks residing on its network segment.
- Transparent Clock
  multiport devices such as bridges
- Boundary Clock
  has multiple network connections and can accurately synchronize one network segment to another
- Ordinary Clock:
  is a device with a single network connection

Clock hierarchies TSN

- Relay Instance ~ Boundary Clock
- End Instance

Profiles: 1AS is a profile of PTP

- Faster clock locking
- Allows for easier / lower cost implementation, L2 Ethernet
- Every device in the path (endpoints and relays) must support 802.1AS

Evolution from IEEE 1588 towards IEEE 802.1AS-20

IEEE	1588-2002	1588-2008 (V2)	802.1AS-2011	802.1AS-2020
Residence time correction	No transparent clocks	Transparent clocks A switch adjusts packet time stamps with residence time		
Bridge	Time or non time aware		Time aware	
Delay calculation	Path delay	Peer delay or path	Peer delay	
Protocols	Layer 2-4, IPv4 multicast	Layer 2-4, IPv4, v6 multicast, unicast	Layer 2 only : Ethernet	
Grandmaster	Multiple domains supported simult.		Single domain	Redundant GM
Asymmetry	none		Correction optional	

IEEE 802.1AS Pdelay is not compatible with IEEE 1588 Pdelay

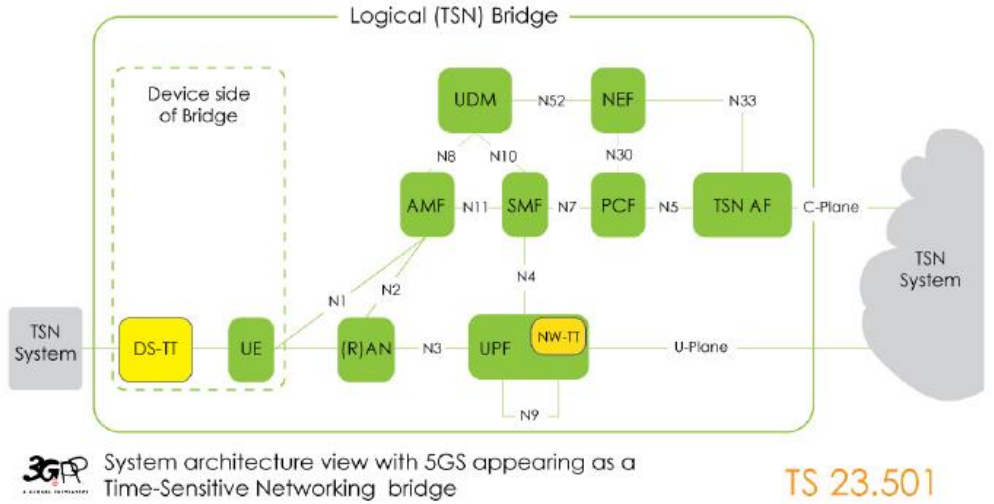
Release 16 – support for TSN

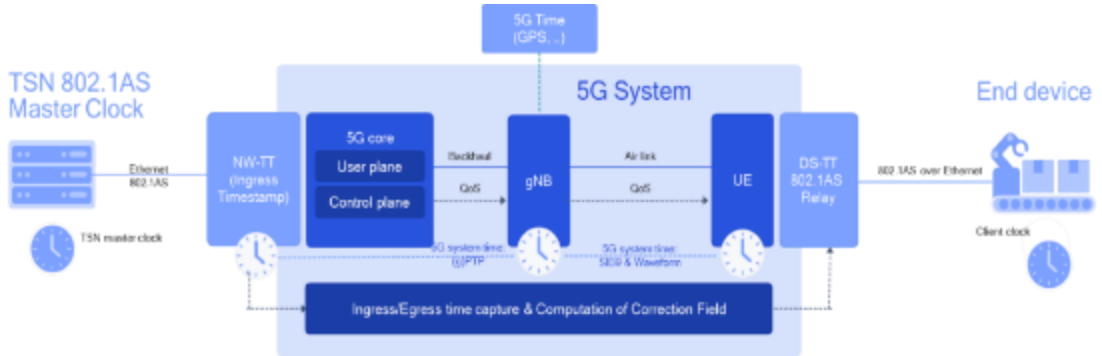
- **IEEE 802.1AS-based time synchronization**. Rel-16 supports only “downlink synchronization” i.e. scenarios with TSN GM clock residing on the network side.

- **Support of the fully centralized IEEE TSN configuration model (IEEE 802.1Qcc).** The 5GS architecture for TSN support is largely over-the-top because the TSN-related functionality is primarily confined to TSN Translator (TT) functions at the 5GS ingress points (AF, UPF, UE).

- **QoS support for TSN traffic**. 5GS supports Time-aware scheduling (IEEE802.1Qbv) and PFSP (Per Stream Filtering and Policing) capabilities (IEEE 802.1Qci).

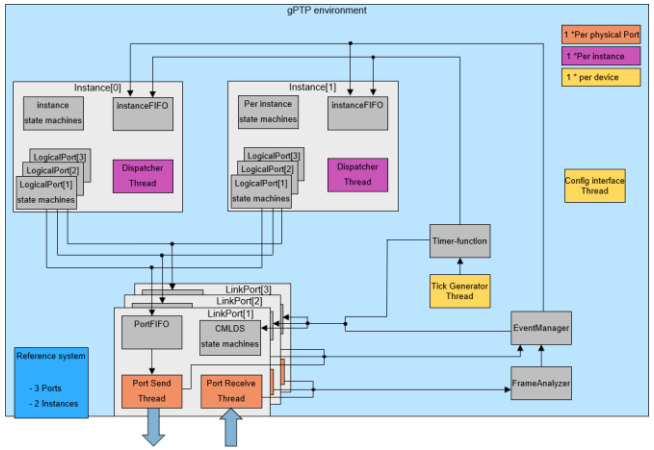
- **IEC/IEEE60802**: Industrial automation profile, enables concurrent support of Profinet, EtherCat, OPC UA

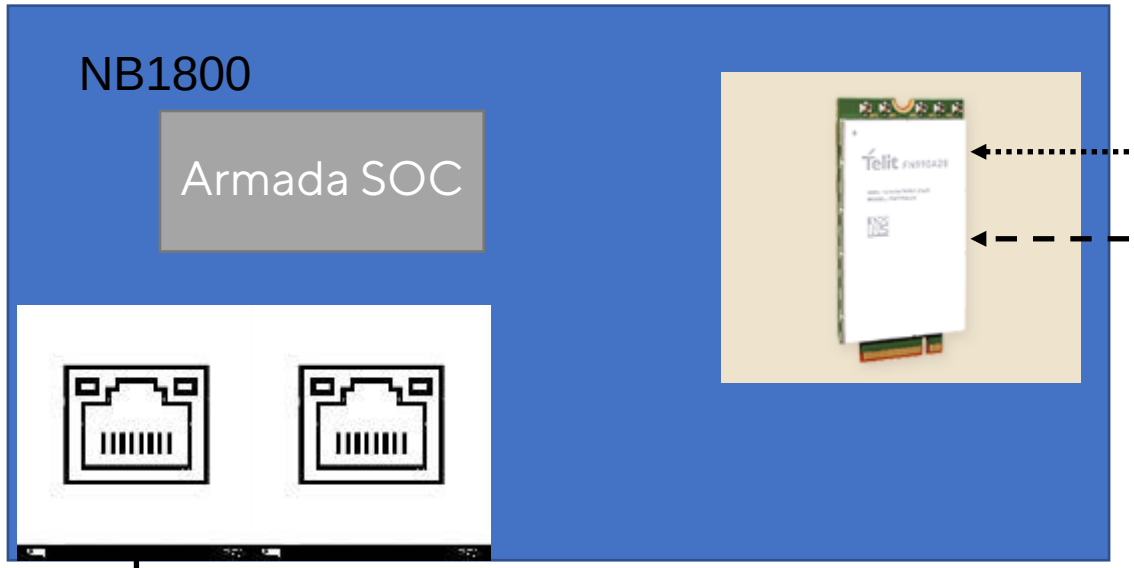




Overview 802.1AS in NB1800

1. Ethernet TSN stack between two Marvel PHYs Δ ~ 338 ns
2. TSN stack between Marvel PHY and virtual Ethernet Port
3. TSN Stack between Marvel PHY and ETH PDU on FN990





Control Plane
SIB9

User Plane
L2 Ethernet

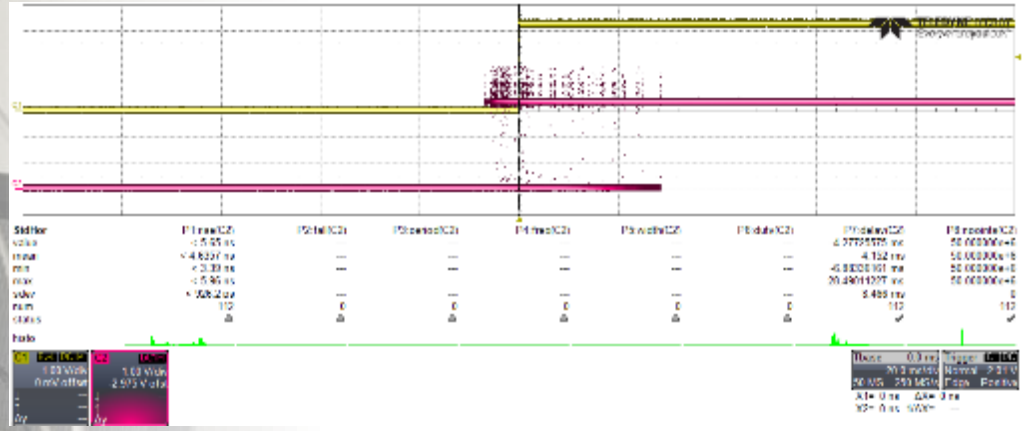
Extract ingress timestamps for Sync and pDelay messages

SIB9

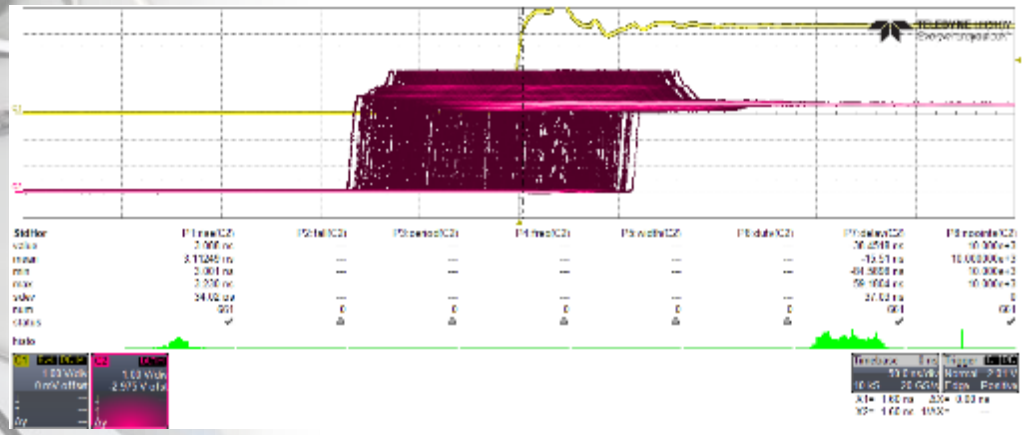
: Carries GPS time and UTC(Coordinated Universal Time)

```
SIB9 ::= SEQUENCE {
    timeInfo SEQUENCE {
        timeInfoUTC             INTEGER (0..549755813887); SFN boundary
        dayLightSavingTime      BIT STRING (SIZE (2)) OPTIONAL,
        leapSeconds             INTEGER (-127..128) OPTIONAL,
        localTimeOffset         INTEGER (-63..64) OPTIONAL
    } OPTIONAL, -- Need R
    lateNonCriticalExtension OCTET STRING OPTIONAL,
    ...
}
```

802.1AS over public 5G



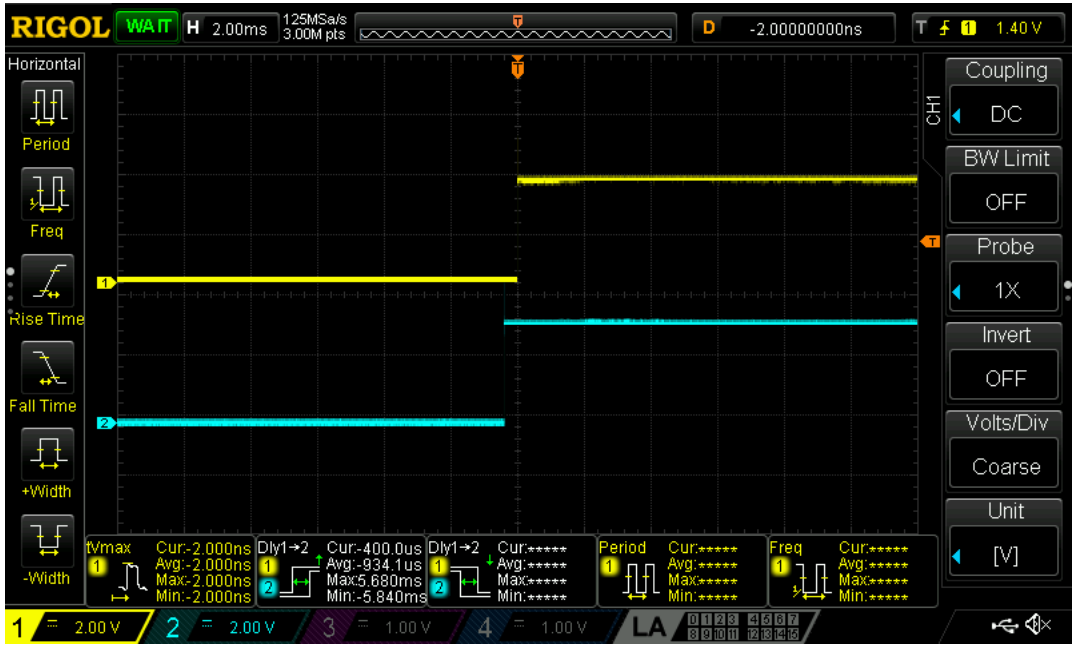
Without SIB9: mean 5,19 ms, min -6.4 ms, max 30 ms



With SIB9: mean -15.51 ns, min -84.89 ns, max 58,18

SIB9 – UTC time information broadcasted over 5G

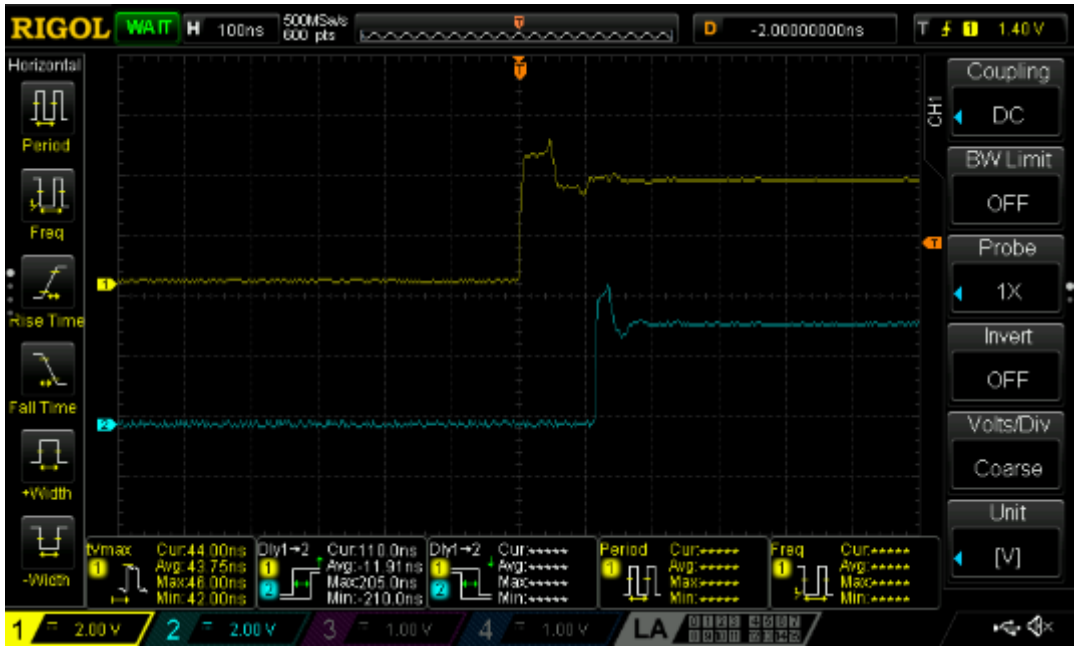
Standalone no SIB9



-> Average 1 milli sec, max 5,7 ms min -5,8 ms

-> significantly better than public 5G networks

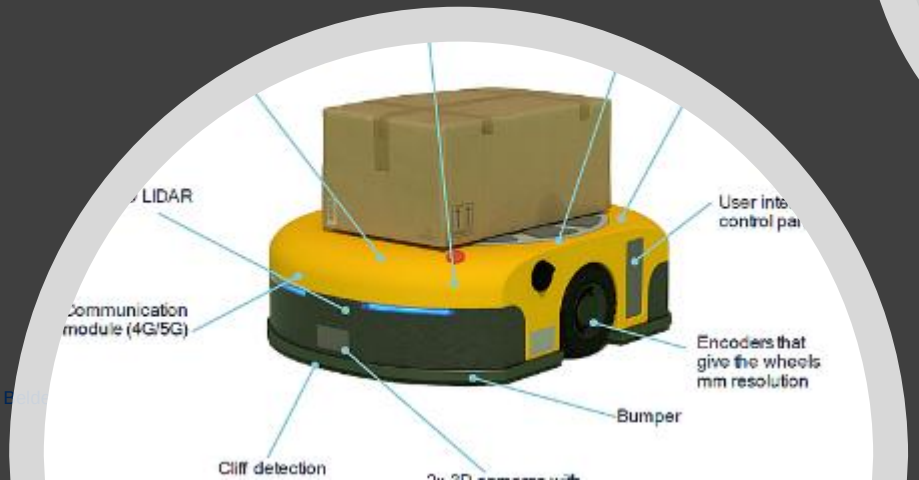
SIB9 activated



-> Average 12 nanosec, max 210 ns min -205 ns

5G use cases

- Collaborative robots.
- Automatic guided vehicles
- Convergence wireline - wireless



Thank You

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