Synchronization Challenges on URLLC Networks

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Contents

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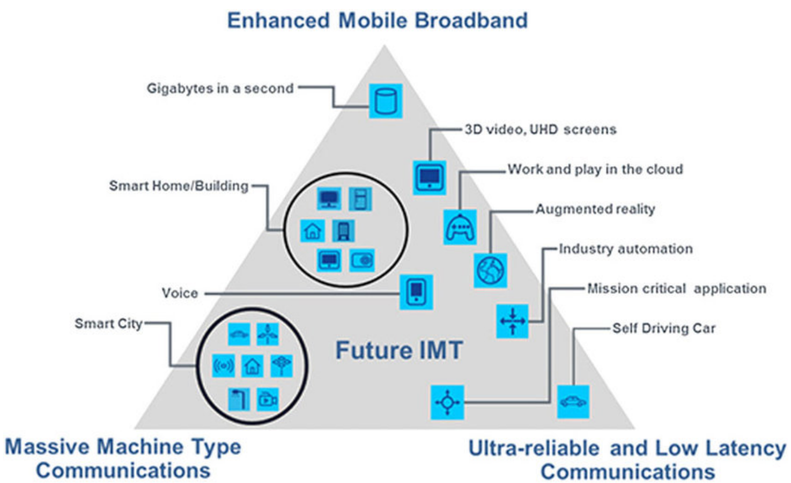
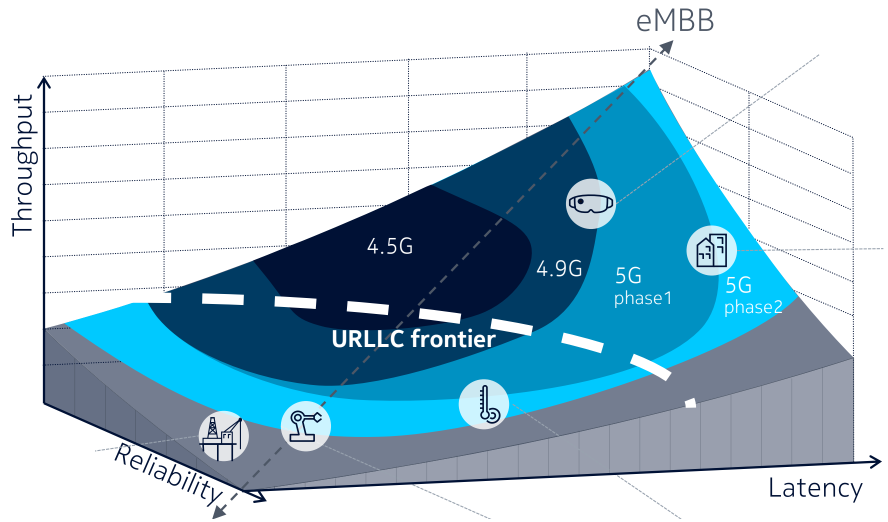
Focus of 5G

- Usage scenarios of IMT for 2020 and beyond (source: ITU-R 3)





Source: Nokia 5G future X – exploring the URLLC frontier

URLLC Key applications

- **Mission Critical / Factory Automation Applications**
  - Remote factory controls
- **Remote operation / Telemedicine**
  - Remote surgery (telesurgery)
- **Autonomous Vehicles**
  - 10s of “visibility” is critical (assuming 100km/h)

URLLC Key Parameters

- **Latency**
  - One-way delay until successful reception
- **Reliability - Packet Transmission success rate**
  - Function of many aspects – distance, visibility, SNR, packet size etc.
- **Throughput**
- **Range**
- **Connection density**
- **Connectivity conditions**
  - Mobility, Weather

Performance Targets

- Performance Targets

	Scenario	Latency Targets (ms)	Reliability Targets (%)
1	Motion Control	1	99.9999
2	Discrete Automation	10	99.99
2	Process Automation	50	99.9999
3	Monitoring	50	99.9
4	Intelligent Transport systems	10	99.9999
5	Tactile Interactions	0.5	99.999
6	Remote Control	5	99.999

Source: TIM

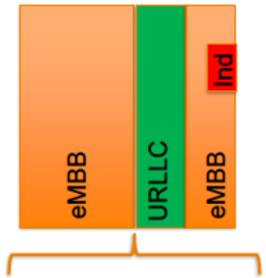
- LTE-A networks achieve 20-30ms Latency

Latency & Reliability of URLLC

Scheduling mechanisms

- Pre-emption and free PUSCH data transmission

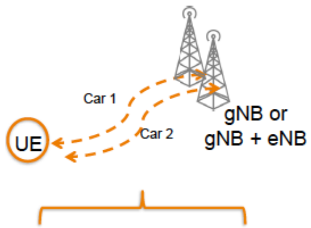
Credit : Ericsson



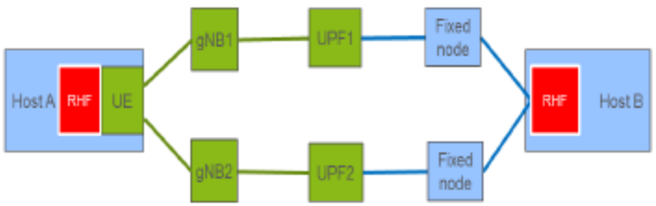
PDSCH eMBB slot with URLLC pre-emption

Redundant transmission

- Carrier Aggregation or dual connectivity



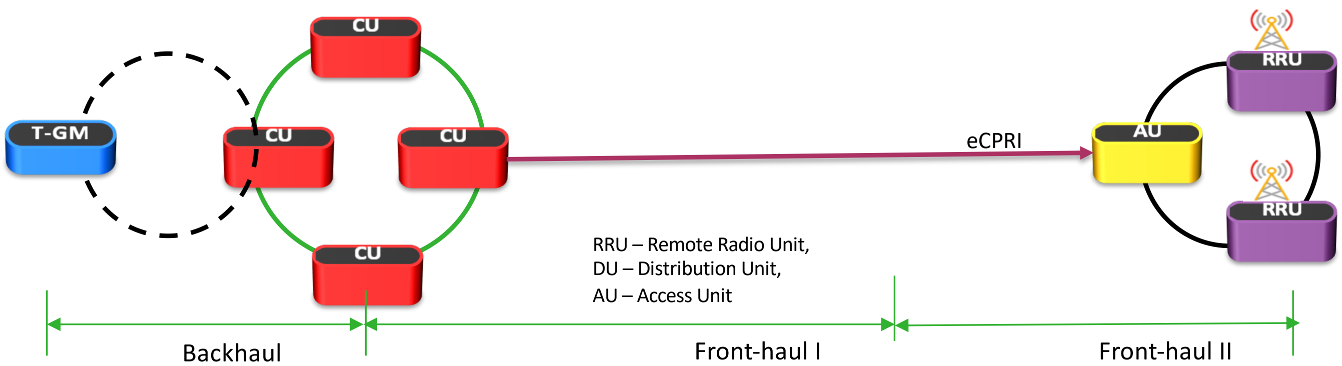
Redundant transmission via Carrier Aggregation or Dual Connectivity



URLLC requires new network Architectures

- **Evolution of networks**
  - LTE -> 5G NR Non Stand alone -> 5G NR

  - CUs -> Re-use the LTE Radios -> Moving to 5G NR



- **The support for CA and guaranteed synchronisation is essential to URLLC**

Frequency & Time Alignment Error Requirements

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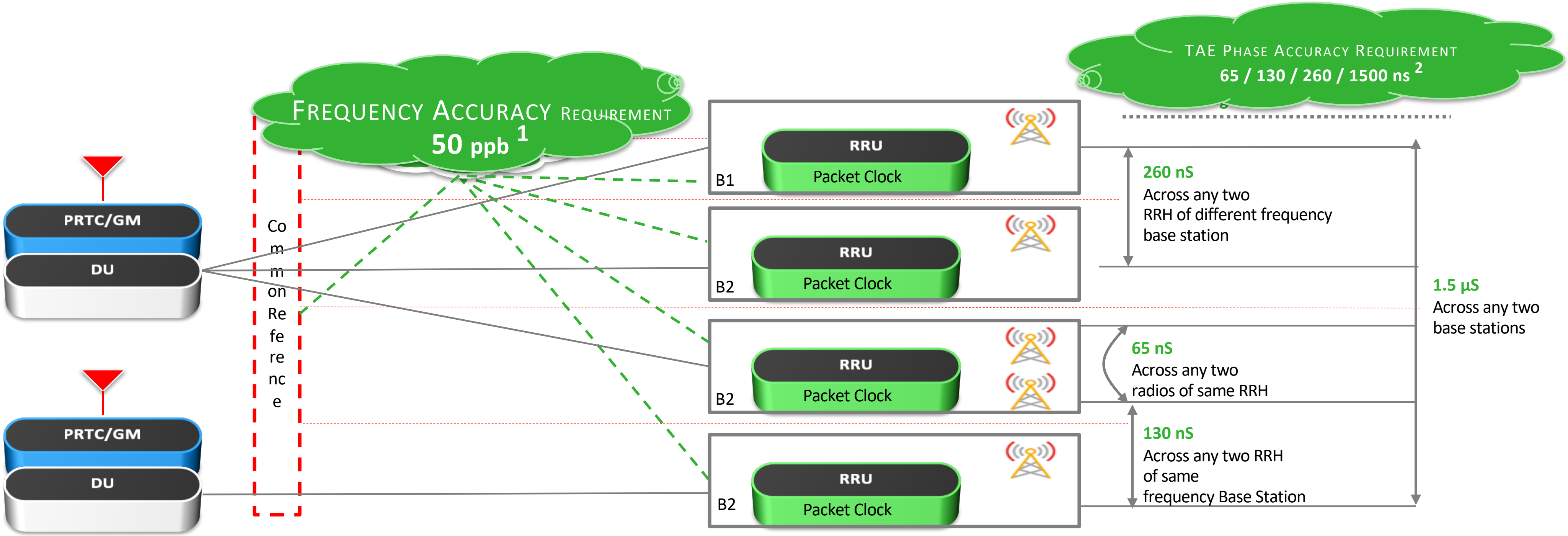
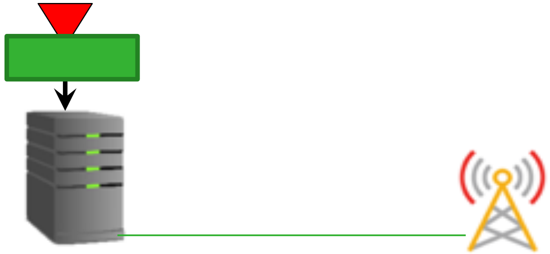


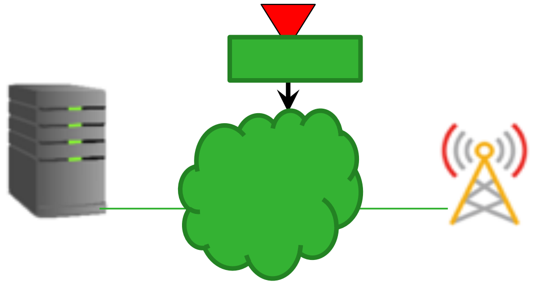
Category	Applications Details	TAE (for Application)
A+	MIMO or TX diversity transmissions, at each carrier frequency	65ns
A	Intra-band contiguous carrier aggregation, with or without MIMO or TX diversity	130ns
B	A & Inter-band carrier aggregation, with or without MIMO or TX diversity	260ns
C	3GPP LTE TDD	1500ns

Radio Synchronisation Scenarios

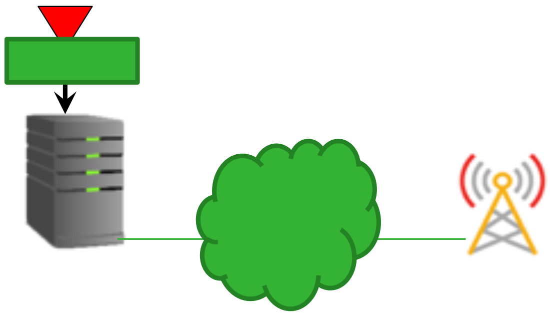
- Point to point



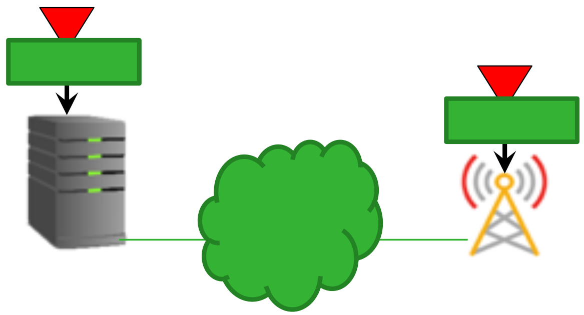
- From Network



- Through Network



- Independent



Synchronization Challenges

- **Time Grand Master Clocks**
  - Performance Improved Clocks
  - Located close to end nodes
- **Transport Network Clocks**
  - High Performing Clocks
  - Shorter Chains
- **Radio Clocks**

Synchronisation Challenges on Radio Clocks

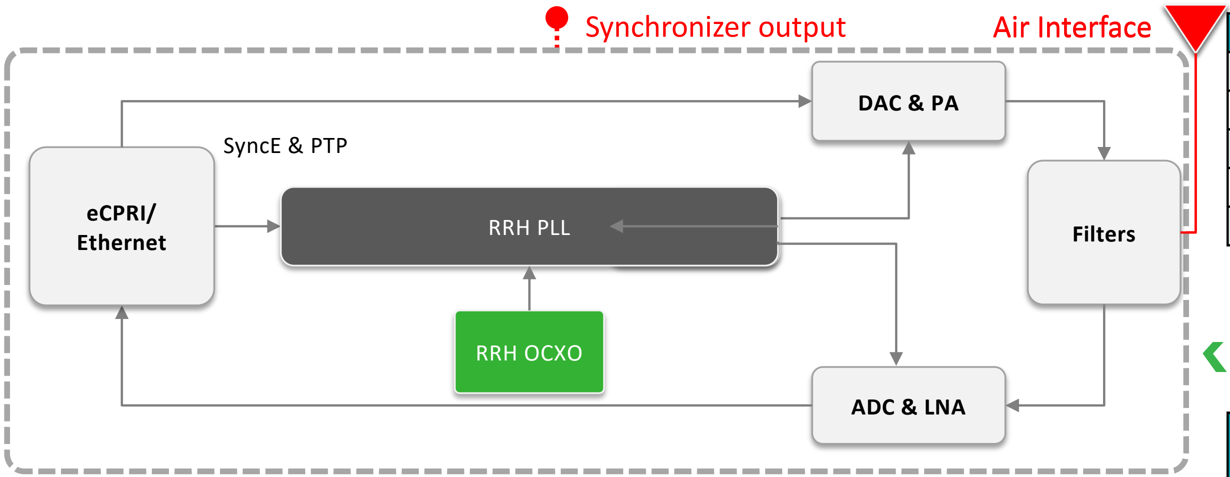
- **Meeting 50ppb frequency accuracy**
  - Defined in 1ms
  - Depends on the network noise into the Radio
  - Depends on the filtering on the Radio
- **Meeting 130ns/260 phase error depends on**
  - The synchronization sources
  - The servo architecture
  - The reference clock performance
- **Meeting holdover depends on**
  - The servo features
  - The thermal conditions
  - The reference clock performances
- **Filtering**
  - 30ppb/75mHz proposed by ORAN
  - System may choose other values
- **Time Alignment Error**
  - GNSS-> PTP-> SyncE-> Oscillator
  - Thermal behavior of oscillator
- **Holdover**
  - Performance of Servo
  - Thermal, ageing & random behavior of oscillators

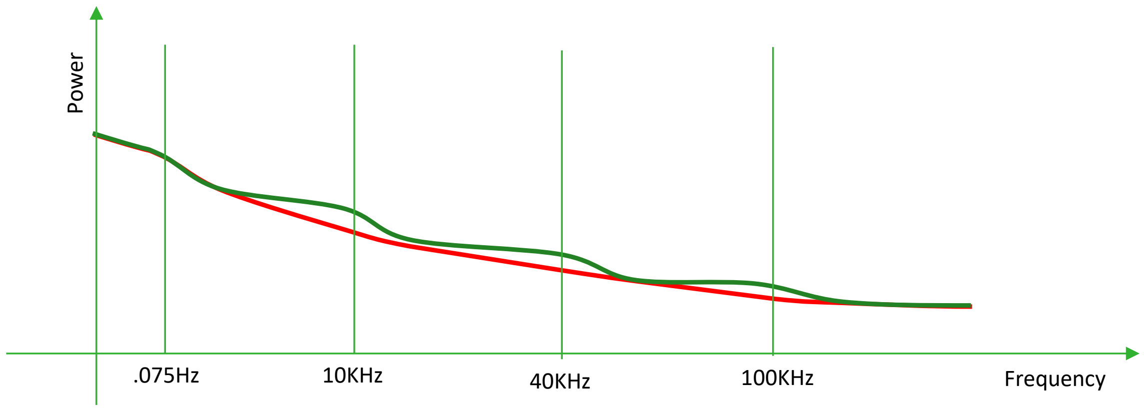
Reference Clocks

- **Medium-Term Stability**
  - Stability in the 5 - 20s duration
  - Temperature sensitivity –> 0.1- 0.5ppb/degC
- **Holdover**
  - Temperature stability -> 1 – 10ppb
  - Ageing -> <1ppb/day
  - Low random noise
- **Shock and Vibration**
  - Contributes to EVM
  - Performance -> ~1ppb/g
- **Other features**
  - Higher operating temperatures -> ~105 deg C
  - Fast Start-up times
  - Low power, Low profile
- **Phase noise performance**
  - Impacts the contribution to EVM

Impact of phase noise on EVM – Better clocks

Phase noise contribution to EVM





EVM limits on QAM modulation

Modulation	Required EVM
QPSK	17.5%
16 QAM	12.5%
64 QAM	8%
256 QAM	3.5%
1024 QAM	1%?

EVM contribution of Clocks

Sub Carrier Spacing	OCXO AT cut 122.88 MHz (simulated)	Ultra Low Noise VCXO 122.88MHz	Traditional VCXO 122.88MHz
1Hz offset	-71		
10Hz offset	-100.3	-85	-70
100Hz offset	-125.8	-121	-100
1kHz offset	-140	-143	-128
10kHz offset	-150.7	-158	-147
100kHz offset	-159.3	-165	-157
1MHz offset	-160.7	-169	-161
10MHz offset	-160.7	-169	-163
EVM Contribution on a 2.4GHz Carrier	0.05%	0.22%	1.38%

Summary

- URLLC requires high performance networks and architectures
- The application cases may be limited – Deployment more centered to cities/industrial areas
- Synchronisation is key – mechanism and methods of synchronization
- Reliable high performance reference clocks are essential to build URLLC networks

Thank you

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