Transport Network Requirements and Architecture for 5G

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Metro Networks Architecture 2015

- Increased bandwidth
  - 1G to >100G
  - 100G Accelerates
- Dynamic architectures
  - L0 to L3
  - Fast moving towards SDN architectures
  - Fronthaul/Backhaul/FTTx
  - Cloud based services
- Cost optimized solutions
  - Purpose build hardware
  - White label boxes
  - Management solutions
- Scalability
  - Platform and commercial aspects
- Multi Layer Management
  - Ability to manage L0 to L3

1G → 10G → 100G → >100G
Mobile - 5G Requirements

- 1-10 Gbps connections to endpoints in the field (i.e., not theoretical maximum)
- 1 millisecond end-to-end round trip delay (latency)
- 1000x bandwidth per unit area
- 90% reduction in network energy usage

Source: GSMA
5G Scenarios…

• Key Scenarios to be Addressed by 5G

Mission Critical Service
• Full reliability & high availability
• Real-time responsiveness
• On-the-fly coverage scalability for disaster situations

Fixed Broadband
• Next-generation broadband
• Multi-Gbps peak throughputs
• Alternative to costly fibre
• New VAS possibilities for fresh revenue generation

Requirements
• 10x bandwidth per connection
• Low-ms latency
• Five 9’s reliability
• 100% coverage
• >10x connections
• 50Mbps per connection everywhere
• 1000x bandwidth/area
• 10 year battery life
• Reduction in TCO

Massive IoT
• Connectivity for a new wave of device types
• High density deployments
• Networks-as-a-Service to meet each service provider’s needs
• Robust QoE / QoS management
• New revenue opportunities

Mobile Broadband
• Multi-Gbps peak throughputs
• Universal gigabit connectivity
• Unparalleled mobility support
• New service / application enablement
• Advanced big data analytics

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Different Context of the same environment

<table>
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<tr>
<th>Requirements</th>
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| • 10x bandwidth per connection  
• Low-ms latency  
• Five 9's reliability  
• 100% coverage  
• >10x connections  
• 50Mbps per connection everywhere  
• 1000x bandwidth/area  
• 10 year battery life  
• Reduction in TCO | • Enhanced Mobile BB  
• Connected vehicles  
• AR/VR  
• S-UHD/3D Video  
• Haptics/Sensing  
• Massive IoT  
• Remote machine control  
• Mission critical services  
• Fixed-wireless access  
• … | • Consumer  
• Auto industry  
• Health  
• Industry 4.0  
• Agriculture  
• Smart City/Public sector  
• Smart building  
• Utilities  
• Education  
• Transport  
• … | • B2C  
• B2B  
• B2B2C |

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5G Service Enablers

- **mmWave System/RFIC/Ant.**
  - Legacy Bands: 700 MHz, 3 GHz
  - New Bands: 18-27 GHz, 30 GHz
  - mmWave RFIC, Wide Coverage Antenna

- **New Channel Coding**
  - LDPC (Low-Density Parity-Check)

- **Network Slicing**
  - Global Mobility/Delay-Tolerant
  - Low Latency

- **< 6 GHz Massive MIMO**
  - Half Wavelength

- **Massive Connectivity (IoT)**
  - Grant-based Multiple Access: 3-4 Step
  - Grant-Free Multiple Access: 1 Step

- **Low Latency NW**
  - Mobile Data
  - BS (Base Station)
  - Server
  - ① Radio Information
  - ② TCP Rate Control
5G Topology Flexibility…?

‘Softwarisation’ of the network

**C-RAN** – removal of functionality from cell sites to consolidation point in the network

**NFV and SDN** – enabling flexibility in where functions are deployed and scaled

**MEC** – pushing Core Network functions and content ingress to cell sites

**CP/UP split** – decoupling of user plane traffic from control plane functions
5G Network Slicing

Orchestration Layer
- RAN Orchestration
- CN Orchestration
- Transport Orchestration

Inter-orchestration system interface

Enterprise Customer (or SI)
- Orchestration (Network Slicing)
- Data Centre
- Apps
- VNF vCPE

UE
- MEC (RAN, CN)

MEC (RAN, CN)

C-RAN
- CN, Policy VNF
- Transport VNF
- CN, Policy VNF

(V)UPF

One (or more) 5G slice per enterprise customer

Potentially multiple other network slices per network customer

Network Slices:
- 2G, 3G, 4G Slice
- NB-IoT, LTE-M slice
- Wi-Fi Slice
- Fixed Line Slice
5G Transport is More Than a Necessary Cost...

- It is an investment in critical assets that enables customers to interact with services

- It is an architecture that will underpin the long-term development of the 5G commercial offer

- Part of a “universal edge” based on packet/optical integration, SDN, and etc, etc.
4G to 5G Network Evolution Challenges

- **Latency budget**
  - FH: 4G is 75μs to 100μs while ultra low latency requires under 50μs
  - MH: New for 5G @ 1ms to 3ms max
  - BH: Unchanged

- **Connectivity**
  - 4G using CPRI is P2P and P2MP
  - 5G is Cloud based and will also need MP2MP

- **Synchronization**
  - 4G using GPS
  - 5G using PTP and SyncE

- **Massive MIMO transport rate impact**

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**5G RAN Model**

- SDN Control
- Core
- Backhaul: Carrier Ethernet
- Midhaul: Low latency Ethernet
- DU
- Fronthaul: RoEeCPRI
- RU

**4G Central RAN Model**

- MSC
- Backhaul: Carrier Ethernet
- BBU
- Fronthaul: CPRI
- RRH

Max latency values based on IEEE 1914.3

100μs or 50μs for URLLC

10ms

1-3ms

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TSN (Time Sensitive Networking)

- TSN is part of the 802.1Q family of standards and is designed to provide deterministic messaging on standard Ethernet networks.

- Important to many industries — e.g. aerospace, automotive, transportation and utilities, and of course, manufacturing — where TSN is emerging as the baseline for real-time networking.

- A wide variety of applications and users, contributing scale to the technology relative to a mobile-only standard.

- A common X-Haul transport network for 5G RAN, serving fronthaul, mid-haul and backhaul, can therefore be developed using TSN.
What is TSN...

- IEEE 802.1CM standard
- TSN enables reliable, deterministic real-time communication over Ethernet (RTCoE)
- Reliable, deterministic RTCoE is achieved using
  - Time synchronization
  - Scheduler shared between network components
  - Frame replication
- Offers
  - Bounded low latency
  - Low delay variation
  - Extremely low loss
Why TSN for 5G RAN?

- Features such as zero congestion loss, bounded ultra-low-latency, hitless 1+1 redundancy, and the ability carry sync accurate to <1μs, make TSN an attractive candidate for 5G RAN transport.

“802.1CM TSN for Fronthaul” is a collaborative effort by the CPRI and IEEE organizations.

- Two profiles are under development
  - Profile A sends user data (IQ data) as high priority traffic
  - Profile B uses “frame preemption”, a TSN feature to prioritize different traffic types (sync, user data, management data, etc.)
5G Transport Platforms and Technology

- **Fronthaul @ 5 µsec to 100 µsec**
  - TSN
  - WDM active and passive
  - Dedicated dark fiber

- **Midhaul @ 1ms**
  - OTN
  - WDM
  - Low latency Ethernet

- **Backhaul @ 10ms**
  - Carrier Ethernet

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**Optical Transport**

- DU
- RU
- CU
- DU
- Core
- CU
5G Model Driven Automation

- The new metro-edge network will be SDN-based, programmable, and open to multi-domain orchestration
- Automation is especially important at the edge because
  - there will be significantly greater number of functions to manage; and
  - equipment may be deployed in locations that are not staffed
- Model-driven, intent-based configuration is of primary importance to lowering opex
- NETCONF/YANG gaining broad-based support as operators migrate away from CLI-based device management to API-driven devices
xRAN Adopts NETCONF/YANG

- Programmatically configure and manage RUs (in LLS architecture)
- Simplify integration between CU and RU, even (especially!) in multi-vendor scenarios
- Model the state of 5G RUs, enabling programmatic control of radio resources across a coverage area
- Lays the foundation for cross-domain orchestration of the RAN with other domains that have already adopted NETCONF/YANG

With a full mesh packet network architecture, cross domain control will allow operators to support end-to-end services, with the appropriate resources allocated in the radio, core, and transport.
Overview of Synchronous Ethernet

- Use the PHY clock
  - Generates the clock signal from "bit stream"
  - Similar to traditional SONET/SDH/PDH PLLs
- Each node in the Packet Network recovers the clock
- Performance is independent of network load
- Uses the OAMPDUs (slow path protocol data units) to pass SSM (synchronization status message).
The IEEE 1588v2 Precision Time Protocol (PTP) defines a packet-based time synchronization method that provides frequency, phase and time-of-day information with sub-microsecond accuracy. PTP relies on the use of carefully time stamped packets to synchronize one or more slave clocks to a master clock. Synchronous time information is distributed hierarchically, with a grand master clock at the root of the hierarchy. The grand master provides the time reference for one or more slave devices. These slave devices can, in turn, act as master devices for further hierarchical layers of slave devices.
IEEE 1588-2008
- Also known as Precision Timing Protocol (PTP)
- 1588-2008 is also referred to as version 2 (v2)
- Intended to synchronize independent clocks to a high
degree of precision on separate nodes over a distributed
network.
- Defines how to transfer precise time over networks. It does
not define how to recover frequency or high precision time
of day.

Message Exchange Pattern
- A) The master sends a Sync message to the Slave and
notes the time t1 at which it was sent.
- B) The Slave receives the Sync message and notes the
time of reception t2.
- C) The Master conveys to the Slave the timestamp t1 by
either
  - Embedding the timestamp t1 in the Sync
    message. This requires some sort of hardware
    processing for highest accuracy and precision.
    This is called as one step clocking.
  - Embedding the timestamp t1 in a Follow_Up
    message. This is called as two step clocking.
- D) The Slave sends a Delay_Req message to the Master
and notes the time t3 at which it was sent.
- E) The Master receives the Delay_Req message and notes
the time of reception t4.
- F) The Master conveys to the Slave the timestamp t4 by
embedding it in a Delay_Resp message.
Extreme Product Portfolio

**EXOS Series**
- Extreme X460/X460-G2
- Extreme X670/X670-G2

**SLX Series**
- SLX 9140
- SLX 9240
- SLX 9560

**Automation**
- Workflow Composer
  - Powered by StackStorm
- Automation Suites

**Product Lines**
- Extreme X460/X460-G2
- Extreme X670/X670-G2
- SLX 9140
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- SLX 9560

**Automation Levels**
- Entry Into Automation
- Begin Customization
- Cross-domain Automation

**Automation Features**
- Network Automation
  - Embedded Fabric Automation
  - RESTful API
  - Automation Suites
- IT Automation
  - Workflow Composer
5G High Level Network Architecture

Source: ITU, 3GPP