5G Network Architecture: An overview

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5G shall enable a Connected, Controlled, and Flexible Network as a service.

5G Promises:
- Digital Society
- Value Creation
- Consistent experience
- Sustainable business model
LT → Driving Forces of 5G
Communication-Oriented

Today’s 4G is designed for a limited number of UCs

- Throughput-optimized
- Fixed
- Rigid

Is 4G enough?
Monolithic BS
Stateful network entities
Transactional communication mode
Certain level of CP and UP separation
Common entity for user mobility and session management

Communication-oriented 4G
**Multi-operator RAN (MORAN)**
Shared RAN nodes, dedicated spectrum, but separated CN per operator

**Multi-operator CN (MOCN)**
Shared RAN nodes and spectrum, but separated CN per operator with proprietary services

**Gateway CN (GWCN)**
shared RAN and part of core networks

**Dedicated core (DECOR)**
Deploy multiple dedicated CNs (DCNs) within a single operator network
One or multiple MMEs and SGWs/PGWs, each element

**Evolved DECOR (eDECOR)**
UE assisted DCN selection
Network Node Selection Function (NNSF) at RAN to select directly the proper DCN towards which the NAS signaling needs to be forwarded
Congestion control and load balancing among multiple DCN with shared MME
Mindful about

3GPPP facts and figures

514 Companies from 45 Countries
50,000 delegate days per year
40,000 meeting documents per year
1,200 specifications per Release
10,000 change requests per year
Evolution from 4G to 5G

- One-size-fit-all
- Bottom-up
- Communication-oriented
- Multiple logic networks
- Top-down
- Service-oriented

4G → 5G
Dimension in increasing capacity

Bandwidth

Spectral Efficiency

densification

Overall 5G Components

Business Applications

Management and Orchestration

IP Layer
Convergent Layer

LTE Evolution
New Radio
WiFi WiGig

Network Service and App

Cloud Infrastructure

Below 6GHz  Above 6GHz  Specific bands

5G is not just a new radio/spectrum, but also a new architecture and business helper

5G : A Paradigm Shift
5G Technology Enablers

- Software Defined Networking
- Fog Computing Edge Computing
- SDN/NFV Orchestration
- Network Function Virtualization
- Cloudification Virtualization
- Contextual Networking
- Heterogeneous Networking
- Self Organization Networking
- Ultra dense network
- Advanced MIMO
- Carrier Aggregation of discontinuous bands
- Advanced waveforms
- Flexible and high capacity backhaul
- Millimeter Wave
- Single channel full duplexing
- New Spectrum Allocations
- More Flexible Spectrum
Turn physical infrastructure into multiple logical networks, one per service instance: **One-Network, Many-Service**

**NOT** a one-size fits all architecture **NOT** a Dedicated Network

Network Slicing
Multi-service multi-tenant network

© Ericsson WP

**Service-oriented 5G**
5G novel usage scenarios: eMBB, uRLLC, mMTC

Multi-disciplinary approach with the fusion of computing, communication, information, and IT
Network Slicing evolves the value-chain of telecom industry:

Decoupling of Players, but the reality might be different
## 3GPP Re-Architects Mobile Network

<table>
<thead>
<tr>
<th>Feature</th>
<th>3G</th>
<th>4G</th>
<th>5G</th>
</tr>
</thead>
<tbody>
<tr>
<td>Downlink waveform</td>
<td>CDMA</td>
<td>OFDM</td>
<td>OFDM, SCFDMA</td>
</tr>
<tr>
<td>Uplink waveform</td>
<td>CDMA</td>
<td>SCFDMA</td>
<td>OFDMA, SCFDMA</td>
</tr>
<tr>
<td>Channel coding</td>
<td>Turbo</td>
<td>Turbo</td>
<td>LDPC (data) / Polar (L1 contr.)</td>
</tr>
<tr>
<td>Beamforming</td>
<td>No</td>
<td>Only data</td>
<td>Full support</td>
</tr>
<tr>
<td>Spectrum</td>
<td>0.8 – 2.1 GHz</td>
<td>0.4 – 6 GHz</td>
<td>0.4 – 90 GHz</td>
</tr>
<tr>
<td>Bandwidth</td>
<td>5 MHz</td>
<td>1.4 – 20 MHz</td>
<td>Up to 100 MHz (400MHz for ≥6GHz)</td>
</tr>
<tr>
<td>Network slicing</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>QoS</td>
<td>Bearer based</td>
<td>Bearer based</td>
<td>Flow based</td>
</tr>
<tr>
<td>Small packet support</td>
<td>No</td>
<td>No</td>
<td>Connectionless</td>
</tr>
<tr>
<td>In-built cloud support</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>

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(1) Ultra-flexible radio-access configurations
   Higher bandwidth
   Higher spectral efficiency (bits/s/Hz/m2)
   Bandwidth parts: tailor bandwidth to UE class (like eMTC narrowbands/widebands)
   Network slicing: new abstractions for service classification down to L1

(2) Compatibility with 4G/5G cores (NSA & SA mode)
   5G dual-connectivity (non-standalone operation)
   Interconnection of evolved 4G eNodeB (ng-eNB) with 5G core

(3) Service-oriented 5G core with cloud-native architecture

5G Main Objectives
3GPP Ongoing Releases

2017

- TSG# 75
- TSG# 76
- TSG# 77
- TSG# 78

Rel-14 St.3 Extension

Rel-15 Stage 1

Rel-15 Stage 2

2018

- TSG# 79
- TSG# 80
- TSG# 81
- TSG# 82

Release 14

Release 15 (5G Phase 1)

Rel-15 Stage 3

Freezing Non-Stand Alone (NSA) Radio

Rel-15 ASN.1

2019

- TSG# 83
- TSG# 84
- TSG# 85
- TSG# 86

Release 16 (5G Phase 2)

Rel-16 Stage 1

Rel-16 Stage 2

Rel-16 Stage 3

Rel-16 ASN.1 (TSG#87)

3GPP Releases
5G Architecture
Overall 5G Architecture
Overall 5G Architecture
3 Tier RAN Node

CU0 → DU[0-n] → RRU[0-m]

Functions Split
CP - UP split

Service-Oriented CN

service catalog and discovery
Slice selection function
CP - UP split
3GPP Re-Architects Mobile Network

Slicing Functions

- NSSF
- NEF
- NRF
- PCF
- UDM
- AF

Control Plane

- AUSF
- AMF
- SMF

User Plane

- UEs
- DU
- CU
- UPF
- DN

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMF</td>
<td>Access &amp; Mobility Management Function</td>
</tr>
<tr>
<td>AUSF</td>
<td>Authentication Server Function</td>
</tr>
<tr>
<td>NRF</td>
<td>Network Repository Function</td>
</tr>
<tr>
<td>UDM</td>
<td>Unified Data Management</td>
</tr>
<tr>
<td>NSSF</td>
<td>Network slice selection function</td>
</tr>
<tr>
<td>SMF</td>
<td>Session Management Function</td>
</tr>
<tr>
<td>UPF</td>
<td>User Plane Function</td>
</tr>
<tr>
<td>AF</td>
<td>Application Function</td>
</tr>
<tr>
<td>PCF</td>
<td>Policy Control Function</td>
</tr>
<tr>
<td>NEF</td>
<td>Network Exposure Function</td>
</tr>
</tbody>
</table>
Functional Split: RAN & CN

- **gNB or ng-eNB**
  - Inter Cell RRM
  - RB Control
  - Connection Mobility Cont.
  - Radio Admission Control
  - Measurement Configuration & Provision
  - Dynamic Resource Allocation (Scheduler)

- **AMF**
  - NAS Security
  - Idle State Mobility Handling

- **UPF**
  - Mobility Anchoring
  - PDU Handling

- **SMF**
  - UE IP address allocation
  - PDU Session Control

Internet

NG-RAN  5GC
QoS Class Indicator (QCI)

QoS Flow Indicator (QFI)

5G Flow-level QoS FW
Newly introduced SDAP layer
- Reflective QoS
- Explicit Configuration

4G LTE: 1:1 mapping of EPS bearer to DRB
5G NR: One or more QoS flows may be mapped onto one DRB.

5G Flow-level QoS FW
Network Slicing
Network Slicing

- Efficient and adaptive use of radio resources
- No functional isolation

- Functional isolation
- Inefficient use of radio resources

RAN Sharing
(e.g. [NVS – IEEE/ACM TON 2012])

Full Isolation
(e.g. [FLARE – JIP 2017])

Sharing or Isolation
Network Slicing Concept
Network Slicing

Flexible & Customizable virtual network tailored to each use-cases

Network Slicing Concept

xMBB  uRLLC  mMTC
Dedicated or Shared Functions

Safety/autonomous driving service
URLLC (Ultra Reliable Low Latency)
Infotainment/video streaming
eMBB (Mobile Broadband)
Maintenance/statistics
mIoT, low throughput

UDM  |  NSSF  |  NRF  |  PCF

URLLC Slice
eMBB Slice
Default Slice
mIoT Slice
Multiplexing Gain

Benefit: Efficient use of radio resources
Conclusion
Fusion of Computing, Information and Cellular technologies

(a) 5G and beyond is not only New Radio and verticals, it is also an evolution in General-Purpose computing for wireless networks

(b) More and more software technologies (NFV, SDN, MEC) and Data (mining, analytics) jointly with radio signal processing

Conclusion
3GPP 5G Network started from Rel. 15 phase 1

Flow-level QoS
Heterogeneous and disaggregated spectrum and RAT
Multi-level Network Slicing
Cloud Native Architecture
Open Interfaces and Edge computing

Conclusion
OpenSource tools: OAI and M5G Ecosystem

- JOX Orchestrator
- Store
- FlexRAN Controller
- LowLatency MEC
- OpenAirInterface RAN
- OpenAirInterface CN

http://mosaic-5g.io/
https://www.openairinterface.org/

Conclusion
5G System:
TS23.501 - System Architecture for the 5G System
TS23.502 - Procedures for 5G System
TS29.500 - 5G System, Technical Realization of Service Based Architecture
TS29.501 - 5G System, Principles and Guidelines for Services Definition

5GC components
AMF: - TS29.518 - Access and Mobility Management Services
NRF: TS29.510 - Network Function Repository Services
SMF: TS29.502 - Session Management Services, TS29.508 - Session Management Event Exposure Service
UDM: TS29.503 - Unified Data Management Services

Others:
TS 24.501: Non-Access-Stratum (NAS) protocol for 5G System (5GS)
TS 38.413: NG-RAN; NG Application Protocol (NGAP)
RAN:
3GPP TS 38.401: "NG-RAN; Architecture description".
3GPP TS 37.340: "NR; Multi-connectivity; Overall description; Stage-2".
3GPP TS 38.321: "NR; Medium Access Control (MAC) protocol specification".
3GPP TS 38.322: "NR; Radio Link Control (RLC) protocol specification".
3GPP TS 38.323: "NR; Packet Data Convergence Protocol (PDCP) specification".
3GPP TS 37.324: "NR; Service Data Protocol (SDAP) specification".
3GPP TS 38.331: "NR; Radio Resource Control (RRC); Protocol specification".
3GPP TS 38.133: "NR; Requirements for support of radio resource management".

UE:
3GPP TS 38.304: "NR; User Equipment (UE) procedures in idle mode".
3GPP TS 38.306: "NR; User Equipment (UE) radio access capabilities".
Thoughts
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