5G Network Deployment for CAM – Challenges & Lessons Learned

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5G Networks Deployed in 5G-MOBIX

SA networks with roaming
SA network slicing
Service continuity with multiple edges
5G Localisation

SA networks + multi-SIM functionality
Service discovery
Edge computing

Multi-SIM modem for increased reliability and preventing cross-border HO latencies
Intelligent routing for coverage gaps & service continuity
Satellite network integration

SA network and NSA network (multi-SIM service migration)
n1 Band operation (+n78)
Near Edge + Far Edge computing

NSA networks with roaming
Edge computing
NSA roaming in hard-border conditions

 NSA networks with roaming
Edge computing (MEC)
Possible SA network with NSA roaming
Cross-Border Issues (& Solutions)

**X-Border Issues**
- Roaming Interruption (NSA & SA)
- Inter-PLMN interconnection latency
- Low coverage areas
- Session & Service Continuity
- Data Routing
- Insufficient GPS positioning accuracy
- Data & Protocol stack interoperability
- Geo-dissemination of information
- Law enforcement interaction
- Security & Safety

**Considered Solutions/Features**
- Inter-PLMN HO with extra interface
- Release with redirect
- Application steered connectivity
- Multi-SIM (DSDA)
- SA based HO
- Internet-based & direct inter-PLMN connectivity
- Use of common message format (CAM, DENM, MCM, CPM)
- Satellite connectivity
- Adaptive service degradation
- S1 based HO
- 5G core and EPC based HO
- Predictive QoS
- SSC mode 2 and 3
- Home Routing (HR)
- Local break-Out (LBO)
- MEC/Edge broker interconnection
- PC5/Uu hybrid networking
- Predictive HO & App state transfer
- mmW location services
5G Network Deployment – Challenges and Lessons Learned

- **Equipment availability and readiness**
  - Challenges with Core and RAN equipment availability early in the deployment phase
  - Feature sets very much incomplete – especially early on
  - Availability of advanced 5G features remains an issue to some extend

- **Chipset and device availability and readiness**
  - Chipset availability was a major issue early on (especially SA)
  - Engineering samples not at the level required for integration/trialling
  - Feature sets, specifications & KPIs may not be firm – and definitions differ between vendors
  - Limited availability can cause high vendor dependence

- **Stability and compatibility can be an issue**
  - Stability of devices and connectivity is not assured
  - More stable versions of 5G chipsets should help boost reliability and performance
  - Compatibility issues are frequent (especially with early/pre-commercial samples/equipment)

- **Firm-/software and support are critical**
  - Firmware is not yet long- or medium-term stable (bugfixes, feature & performance updates)
  - Firmware upgrades may need special tools or root access to devices
  - Driver and OS compatibility and stability can be an issue
  - Manuals and documentation are critical (and may be incomplete)

- **SA support remains limited**
  - SA mode may require firmware updates/experimental firmware
  - Stability of SA devices not yet sufficient
  - Regional differences between SA support for commercial devices exist (e.g., Samsung S20 has SA in US, but not in EU)

- **Chipset integration vs commercial devices**
  - Performance will differ between chipsets in custom integration (specialized OBUs/self-integrated chipsets) and commercial devices (handsets/modems)
  - Processing and timing in modems may not yet be optimized => needs to be considered when developing software to handle modems
5G Network Deployment – Challenges and Lessons Learned

- **Spectrum availability and assignment**
  - Spectrum re-assignments (e.g., transition from test to commercial licenses etc.) can cause significant delays or re-works
  - Spectrum access for testing can be very limited (especially for non-MNOs or during auction phases)
  - LTE spectrum for NSA mode can be critical & coverage of existing LTE and new NR may differ
  - Cross-border spectrum coordination may be required

- **Network configuration complexity**
  - Networks in SA mode present configuration complexity => new characteristics and issues arise
  - Support from ecosystem for SA is still limited, as is the number of players able to tackle issues (unlike NSA)

- **PLMN ID availability/allocation and support**
  - Increase in number of private 5G networks seems to add to scarcity of PLMN-IDs
  - Test PLMN IDs may not be supported by modems/devices

- **Restrictions on TDD frame structure**
  - Allowable/acceptable TDD frame structures may be restricted => testing of different structures is limited
  - Restrictions on frame structure may limit ability/freedom to increase UL capacity
  - Added synchronization requirement for adjacent cells/networks – incl. cross-border
  - Cross-border coordination/selection of compatible frame structures

- **Impact of fixed network links & logical policies**
  - Insufficient fixed links may cause unexpected bottlenecks
  - Logical policies or firewalls may limit connectivity/need to be carefully considered especially when integrating test installations with existing networks

- **Virtualized components and network**
  - Virtualized components can be easier to deploy – careful design of the deployment is critical though
  - VM external access solution/architecture should be defined in extreme detail: such applications, protocols and related open ports requirements
  - Common understanding, terminology and language for virtualized components is still evolving

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5G Network Deployment – Challenges and Lessons Learned

- Synchronization requirements
  - Synchronization across the core, network, MEC, RSU and UE/OBU is essential to ensure performance and for testing
  - Low latency levels of 5G require much tighter synchronization to obtain accurate measurements
  - Asymmetric latency paths between UL/DL make network based sync more difficult => increased need for GNSS references close to nodes (especially OBU)

- Reliability and performance
  - 5G chipset compatibility and performance are tightly coupled with firm-/software used => latest is not always best/best combination of HW and SW must be found
  - Reliability is hard to test as chipsets themselves sometimes are not reliable enough

- Readiness for testing & testing complexity
  - Increased E2E testing complexity when including MEC
  - RAN testing solutions for SA mode networks are still a work in progress
  - Testing of advanced 5G features remains challenging and depends on standardization progress & equipment availability
  - Equivalent tests and workarounds needed where features are not ready or testing solutions are lacking => to be considered early and included in planning

- 5G QoS measurements when CCAM traffic is used
  - Testing unloaded 5G base stations, with only CCAM applications may not be conclusive
  - Realistic loading of 5G cells with other/background traffic can be challenging (especially where multiple slices are involved)

- 5G CBC/Multi PLMN measurements
  - Testing cross-border with multiple PLMNs for elaborate scenarios add substantial complexity to testing
  - Need to develop testing procedure/platform for multiple observation of network levels and nodes, CCAM protocols/application and different use cases/scenarios
  - Determining/controlling handover point/area between networks is not trivial

- Static vs mobile performance
  - Performance with mobility substantially lower than for a static user and highly variable – especially uplink
  - Dedicated optimization required to get max performance under mobility

- Security of networks directly impacts safety of road traffic
  - New level of requirements on networks
  - System complexity increases number of attack vectors

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Seamless Roaming

- Disconnect on crossing borders on minute scale => not acceptable for CAM
- Fast reconnect (few seconds) & dual modem require user domain application
- Seamless handover using N14 interface (or S10)
  - How to steer selection of next VPLMN?
  - Data exchange required between networks: availability of inter-PLMN handover, RAN data at gNB level, preferred/allowed VPLMNs, CAM services available, data network name (DNN), slice identifiers to be used in N-VPLMN
  - UE should be informed of possible/upcoming handover – take preparatory/preventive measures

Seamless handover using N14 interface

- Scalability is an issue
  - ~100 HPLMNs in EU (~30 countries x 3-4 PLMNs)
  - ~10 N-VPLMNs at any time (~3 bordering countries x 3-4 PLMNs)
  - For any given C-VPLMN in a country => 1k PLMN combinations!

Required steps to achieve seamless roaming

- Enable N14 as roaming interface
- Make PLMN selection possible from current NW
- Fast reselection support from NW
- Implement RAN data sharing solution at borders
- Share where seamless roaming is supported
- Share what CAM services are available
- Share how to connect to closest service
- Share roaming options per subscription
- Research possible extension of ANR cross border

Home network (HPLMN)
- UDM
- PCF
- AUSF
- AMF

Current visited network (C-VPLMN)
- PCF
- AMF

Next visited network (N-VPLMN)
- UDM
- PCF

Policy from HPLMN extended to C-VPLMN

Country A

Other candidate network Cy-B

Country B

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TDD Selection and Synchronization

Network synchronization required to avoid interference – also at int'l. level across borders
- Common phase clock reference
- Selection of compatible frame structures
  - DDDDDDSUU (8+2), DDDSUUDDD (4+2+4)
  - Recommended CBC frame structures (ECC 2003)
  - DDDSU (4+1), DDDSUUDDD (4+2+4)
- Minimum distances between unsynchronized macro base stations/networks (ECC Rep. 296)
  - 60km co-channel, 14km adjacent channel

Options for co-existence of non-synchronized networks
- Localized frame structures

FDD
- Different frequencies for UL & DL
- Less BSs, less cost
- Spectrum waste due to guard band

TDD
- Same frequency for UL & DL
- Efficient spectrum usage
- Requires phase/time sync

- Downlink blanking
- Use of alternative bands at borders
- Use of adjacent channels
- Club licenses, spectrum & infrastructure sharing

Observations & lessons learned
- No performance impact observed when operating common TDD frame structure
- Coexistence following GSMA and ECC recommendations is feasible
- Limited choice of TDD frame structures reduces flexibility and possible UL rates
- Downlink blanking and cross-link interference cancellation should help push performance
Further Recommendations

Network oriented

- National strategies and plans by EU Member States, available national data on 5G deployment including coverage and quality
- Preparation and execution of spectrum assignments by public authorities as well as 5G public funding for network deployment and R&I
- Reduce the cost and increase the speed of deployment of very high-capacity networks, notably by removing administrative hurdles
- Common message sets/protocols dedicated to police interactions shall be standardized at international level for suspicious events

CAM oriented

- Develop common European understanding on necessary digital infrastructure quality/coverage for Level 3
- Joint approach between telecom and vehicle industries to support CAD
- Common European understanding on safety & security validation (when are the systems safe enough)
- Adaption of road traffic rules in Member States
- Align General Data Protection Regulation within the European member states to ensure privacy
Thank you

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