5G Air Interface

Course Description

The 5G air interface is a key part of the 5G system which will facilitate Enhanced Mobile Broadband and Ultra Reliable Low Latency Communication, as well as the support of Massive IoT (Internet of Things). This course focuses on 5G Phase 1. In so doing, both SA (Standalone) and NSA (Non Standalone) operation are discussed. The course details all aspects, from the physical layer channel and reference signals, through to scheduling and analysis of NR RRC signalling utilized to configure the NR air interface.

Prerequisites: 5G System Engineering and LTE Air Interface, or equivalent knowledge.
This course will contain the following sections:

1. 5G NG-RAN

**Topic areas covered include:**

- **5G Phases:**
  - NR (New Radio) Phases:
    - R15 Phase 1 and R16 Phase 2.
  - 5G NR Roadmap:
    - Early Drop, Main Drop and Late Drop.

- **5G RAN Architecture:**
  - 5G RAN Deployment Options:
    - Option 3, Option 3x, Option 3a, Option 2, Option 7 and Option 4.
    - EN-DC, NGEN-DC, NE-DC.
  - Standalone Architecture.
  - Non-Standalone Architecture.

- **C-RAN Concepts:**
  - C-RAN Architecture for 5G.
  - Separation of gNB-CU.
  - F1 Protocol Stack Split.
  - EN-DC Configuration for 5G C-RAN.

- **Managing 5G QoS:**
  - QoS Flow Parameters.
  - 5QI (5G QoS Identifier).

- **5G Bearers:**
  - MCG and SCG Cell Terminology.
  - RRC Considerations.
  - MCG Split SRB.
  - User Plane Splitting.

2. 5G Physical Layer

**Topic areas covered include:**

- **5G Waveform: CP-OFDM and DFT-s-OFDM:**
  - OFDM Subcarriers.
  - Orthogonal Frequency Division Multiplexing.
  - Cyclic Prefix.

- **5G NR Duplexing:**
  - FDD and TDD Duplexing Modes.
  - Supplementary Downlink.
  - Supplementary Uplink.

- **5G Frequency Bands:**
  - Definition of Frequency Ranges.
  - 5G NR Bands.
  - EN-DC Band Combinations.
  - Baseband Processing Combination.
  - Harmonics and Intermodulation.
  - 5G Carrier Numbering.

- **NR Numerology and Frame Structure:**
  - Numerology in 5G.
  - Frame Structure.
  - NR Slots.
  - 5G NR Time Unit.
  - NR Cyclic Prefix.
  - NR Physical Resource Block and Resource Grid.
  - 5G NR Transmitted Signal.
  - Slot Format Configuration.
  - Uplink Timing.

- **Channel Bandwidth:**
  - Maximum Transmission Bandwidth.
  - Carrier BWP (Bandwidth Part).
3. 5G Massive MIMO and Beamforming

Topic areas covered include:

• What is Massive MIMO?
  - Requirement for Massive MIMO.
  - Antenna Elements.
  - Antenna Arrays.

• MIMO in 5G:
  - MIMO Spatial Multiplexing.
  - SU-MIMO vs MU-MIMO.
  - Summary of Transmission Path in 5G NR:
    - Codewords, Layers and Antenna Ports.

• Beamforming (Massive MIMO):
  - Spatial Multiplexing vs Beamforming.
  - Creating a Beam.
  - Narrow Beams and Beam Steering.
  - Beamforming Nulls:
    - Null Beam Steering.
  - Massive MIMO Antennas.
  - MIMO in a Handset.
  - Multiple Panel Antenna.

• NR Beam Management:
  - Beam Sweeping.
  - SS Block:
    - NR SSB, PSS, SSS, PBCH and DMRS.
  - Beam Management Reference Signals:
    - CSI-RS and SRS.
  - Single and Multiple CSI-RS:
    - CRI (CSI-RS Resource Indicator).
  - PMI (Precoding Matrix Indicator).
  - Transmission Based on SRS.

• Synchronization Signal Block Location:
  - SS Burst and Burst Set.
  - SS Block Locations.
  - SS/PBCH Block Index Indication.
  - GSCN (Global Synchronization Channel Number).
  - Beam Measurement, Determination and Reporting.

4. 5G Physical Layer and Channels Introduction

Topic areas covered include:

• NR Channels:
  - Logical Channels.
  - Transport Channels.
  - Mapping Logical Channels into Transport Channels.
  - Physical Channels.
  - Mapping Transport Channels to Physical Channels.
  - Synchronization and Reference Signals.

• NR Physical Layer Processing:
  - Key Specifications.
  - Code Block Generation.
  - Code Block Group.
  - Processing Chain.

5. NR Downlink Physical Channels and Signals

Topic areas covered include:

• Downlink Synchronization Signals:
  - PSS and SSS.

• Physical Broadcast Channel:
  - Master Information Block.
  - PBCH Payload.
  - PBCH Physical Layer Processing.
  - DMRS for PBCH.

• Physical Downlink Control Channel:
  - PDCCH Physical Layer Processing.
  - PDCCH Features.
  - CORESET.
  - CORESET Configuration.
  - CORESET Configuration for EN-DC.
  - Other PDCCH Usages:
    - MU-MIMO and Beamforming.

• Physical Downlink Shared Channel:
  - PDSCH DMRS.
6. NR Uplink Physical Channels

Topic areas covered include:

- NR Physical Random Access Channel:
  - Preamble Sequence Generation.
  - Configuring RACH/PRACH.
  - NR PRACH Configuration Index.
  - Preamble Formats.
  - Preamble Sequence.
  - NR PRACH Format 0 Example.
  - NR PRACH Format - CP Size.

- NR Physical Uplink Shared Channel:
  - NR PUSCH Processing Chain
  - Configuring NR PUSCH
  - PUSCH DMRS.

- NR Physical Uplink Control Channel:
  - NR PUCCH Formats.
  - NR PUCCH Location Example.
  - NR PUCCH Configuration.
  - NR PUCCH Format 0 Example.

7. 5G Reference Signals

Topic areas covered include:

- 5G Reference Signals.

- Channel State Information - Reference Signals:
  - CSI-RS Types.
  - CSI-RS Features.
  - CSI-RS Locations in a Slot.
  - CSI-IM Patterns.
  - CSI-RS Configuration.
  - ZP-CSI-RS Configuration.
  - CSI Timing.

- Sounding Reference Signal:
  - SRS Usages.

- Phase Tracking Reference Signal.

8. NR Layer 2 and Layer 3

Topic areas covered include:

- NR Radio Resource Control:
  - NR RRC States.
  - RRC Messages.
  - RRC Critical and Non-Critical Extensions.

NR Layer 2 and Layer 3 (cont.)

- Service Data Application Protocol:
  - SDAP in the RAN.
  - SDAP Functions.
  - SDAP Headers.
  - SDAP Example.
  - RDI Indication.
  - RQI Indication.

- NR Packet Data Convergence Protocol:
  - PDCP Services and Functions.
  - PDCP Profiles.
  - PDCP Protocol Data Units.
  - PDCP Example.

- NR Radio Link Control:
  - Transparent Mode.
  - Unacknowledged Mode.
  - Acknowledged Mode.
  - RLC Protocol Data Units.

- NR Medium Access Control:
  - MAC Services and Functions.
  - MAC Control Elements.
  - NR RNTI Identities.
  - MAC Headers.

9. 5G Scheduling

Topic areas covered include:

- NR Scheduling:
  - DCI (Downlink Control Information).
  - Search Space.
  - PDCCH Aggregation Levels.
  - Resource Allocation.
  - Frequency Domain Resource Allocation.
  - Resource Allocation Type 0.
  - Resource Allocation Type 1.
  - Dynamic Switch.
  - PDSCH and PUSCH Scheduling.

- NR Downlink Resource Allocation:
  - PDSCH Time Domain Resource Allocation.
  - PDSCH/PUSCH MCS.
  - Transport Block Size.
  - Downlink Configured Scheduling.
  - Discontinuous Reception.
5G Scheduling (cont.)

- NR Uplink Resource Allocation:
  - PUSCH Time Domain Resource Allocation.
  - PUSCH MCS Index.
  - Uplink Configured Scheduling.

- NR Feedback:
  - Buffer Status Reporting.
  - Power Headroom Reporting.
  - HARQ-ACK.
  - Scheduling Request.
  - Channel State Information.
  - Channel Quality Indicator.

- Inter-RAN Resource Coordination:
  - Resource Coordination Signalling.
  - Coordination Resource Bitmap.

5G Access Procedures (cont.)

- 5G Network Registration:
  - RRC Setup.
  - 5G Registration Procedure.
  - Device Capabilities.

10. 5G Access Procedures

Topic areas covered include:

- Initial Access:
  - Network Access Procedure.
  - PLMN and Access Network Selection.
  - Scanning.
  - GSCN Number and Raster.
  - SSB Operation.
  - Deriving SSB Index.
  - Downlink Synchronization.
  - SI Acquisition - MIB/SIB1/RMSI.
  - Example of SI Mapping.
  - System Information Block 1.
  - System Information Types.
  - Cell Selection.

- Random Access:
  - Random Access Triggers.
  - Contention Based Random Access Procedure.
  - PRACH Preambles.
  - RACH Configuration Common.
  - Preamble Options.
  - Preambles per SSB per PRACH Occasion.
  - SS/PBCH Index Mapping to PRACH Occasion.
  - Random Access Response Window.
  - Random Access Response Message.
  - PRACH Power.

11. EN-DC Operational Procedures

Topic areas covered include:

- Attaching and EN-DC Operation:
  - Initial E-UTRA Attach.
  - UE Capabilities.

- E-UTRA Measurements for EN-DC:
  - EUTRA Measurement Configuration Options.
  - Measurement Objects.
  - Report Configuration.
  - LTE Events Summary.
  - Measurement Identities.
  - NR Measurement Timing Configuration.
  - Identifying Suitable NR Cell.
  - Measurement Report.

- PSCell Addition:
  - SgNB Addition Request and Request Acknowledge.
  - RRC Connection Reconfiguration.
  - Reconfiguration with Sync.
  - PSCell Split SRB.
  - PSCell Split DRB.
  - Secondary Node Release.

- EN-DC Radio Link Failure:
  - RLF Configuration.
  - Out-of-Sync and In-Sync.
  - Failure Report.

12. 5G Connected Mode Procedures

Topic areas covered include:

- Radio Link Failure:
  - RLF Configuration.
  - Out-of-Sync and In-Sync.
  - NR RRC Reestablishment Procedure.
  - EN-DC SCG Failure.
5G Connected Mode Procedures (cont.)

• Beam Failure:
  - Beam Failure Parameters.
  - Beam Failure Detection.
  - Beam Failure Recovery.

• Power Control:
  - Downlink Power Allocation.
  - Uplink Power Control.

13. 5G Paging

Topic areas covered include:

• Paging:
  - SA RRC States.
  - Network Paging Procedure.
  - Paging Identity.

• Scheduling Paging:
  - Paging Frame and Occasion.
  - DCI Paging.
  - Discontinuous Reception for Paging.

• RRC Inactive State and Paging.

14. 5G Measurements

Topic areas covered include:

• NMeasurement Quantities:
  - SS-RSRP.
  - SS-RSRQ.
  - SS-SINR.
  - CSI-RSRP.
  - CSI-RSRQ.
  - CSI-SINR.

• NR Measurements Configuration Options:
  - Measurement Configuration Options.
  - Measurement Objects.
  - Report Configuration.
  - Periodic Measurements.
  - NR Measurement Events.
  - Measurement Gap Configuration.
  - EN-DC Measurement Gap.

15. 5G Carrier Aggregation

Topic areas covered include:

• NR Carrier Aggregation:
  - Component Carriers.
  - Contiguous and Non-Contiguous CA.
  - Intra-Band and Inter-Band CA.
  - PCell and SCell.
  - Downlink and Uplink Carrier Aggregation.
  - Carrier Allocation Specifications.

• Configuring Carrier Aggregation:
  - Buffer Based SCell Activation.
  - Configuring CA SCells.
  - MAC CA Activation.
  - MAC Buffer Status and Power Headroom Reports.

• Releasing Carrier Aggregation:
  - SCell Release Procedure.

16. 5G Dual Connectivity

Topic areas covered include:

• Dual-Connectivity:
  - New Radio Dual Connectivity.

• NR-DC Secondary Node Procedures:
  - NR-DC Secondary Node Addition.
  - Determining the Bearer Configuration.
  - NR Dual Connectivity Mobility.
  - Secondary Node Release.

17. 5G Mobility

Topic areas covered include:

• NR Idle Mode Mobility:
  - Multi-Beam Measurement Quantity.
  - NR Cell Reselection.
  - Priority Based Inter-RAT Cell Reselection.
  - NR System Information Messages.
  - Reselection to a Higher Priority Frequency or RAT Cell.
  - Reselection to a Lower Priority Frequency or RAT Cell.
  - Deleting NR Priorities.
  - Registration Area Update.
5G Mobility (cont.)

- **Xn Based Handover:**
  - Handover Procedure.
  - RRC Connection Reconfiguration.
  - Path Switch Procedure.

- **RRC Inactive Mobility:**
  - I-RNTI.
  - RAN Notification Area.
  - RRC Resume Procedure.

- **Inter MeNB Handover with EN-DC:**
  - MeNB Handover Procedure.
  - RRC Connection Reconfiguration.

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