Enabling Communication Services for Vertical Industries through Network Slicing and Mobile Edge Cloud

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Peter Rost
Peter.m.rost@nokia.com
Nokia Bell Labs, Munich, Germany
5G Introduction

Mobile Internet will be the first relevant commercial application

Machine markets will start to develop 2022+
- Need for coverage layer and low cost devices
- Verticals not expected to be early adopters for 5G (low expertise)
- Earlier trials to test technology and define business models

E2E solutions for all three markets
- High capacity and coverage
  - Megacity capacity densification
  - 3 to 6GHz ~100MHz BW
  - Dense urban grid

Ultra high capacity
- Ultra dense use cases
- cm/mmWave
- Short range, LOS preferable

5G Fixed Wireless Access
- Extension of fiber access
- cm/mmWave
- Line of Sight (LOS)

Extreme mobile broadband market starts
- High capacity and coverage
- Ultra high capacity
- 5G Fixed Wireless Access

2018 2019 2020 2021
5G Added Value for other industries ("Verticals")

Relevance

Declining profits from eMBB, but strong growth in new markets

**Industry 4.0**: distributed organization of production, connected goods, low energy processes, collaborative robots, integrated manufacturing and logistics, ....

**Automotive industry**: autonomous and cooperative vehicles (V2X)

**E-health**: personalized Healthcare and transition from hospital to distributed patient centered models

....

Vertical industries for **more** and especially **better** bits
Industry 4.0
The 4th industrial revolution

From Industrie 1.0 to Industrie 4.0

First Industrial Revolution
through the introduction of mechanical production facilities with the help of water and steam power

Second Industrial Revolution
through the introduction of a division of labor and mass production with the help of electrical energy

Third Industrial Revolution
through the use of electronic and IT systems that further automate production

Fourth Industrial Revolution
through the use of cyber-physical systems

Source: DHL (2011)
Industry 4.0
Multi-Domain Technologies
Industry 4.0
Range of applications
The Automation Pyramid
Still State of the Art

Source: M. Bajer, “Dataflow In Modern Industrial Automation Systems. Theory And Practice"
Connectivity Overlay
Tailored solutions per application and layer

Value Chain
Company
Factory
Cell/Line
Field Equipment
Actuators/Sensors
Operational Technology / Automation Domain

Enterprise Information Technology Domain

Public Domain

Existing Automation Hierarchy
- Production Control
- Logic Control
- Motion Control
- Drive Control

IoT Overlay
Industrial and Tactile Communication
Technology Building Blocks

URLLC & mMTC
- URLLC: utilizing multi connectivity, punctured transmission.
- mMTC: connectionless access, energy efficient solutions, like NB-IoT, IoT proxy for further optimization.

Industrial (Edge) Cloud
- Local processing of data cooperatively & relevance-based
- Time critical applications (tactile and deterministic)
- Outsourcing of latency-critical control algorithms

Network Slicing
- Enables application specific implementations using shared infrastructure

Technology Building Blocks
Industrial and Tactile Communication

Flexible, programmable infrastructure
Security
Autonomous operation of industrial network
Latency requires e2e analysis

**Example functions:**
- Sensor data acquisition & processing
- User input acquisition
- Pre-analysis & encoding
- Receive/decode
- Rendering/display
- Actuation

**Example functions:**
- Decode/buffer
- Image recognition
- Big database search
- Correlation/analysis
- Event recognition
- Control cycle logic
- Rendering
- Encode/buffer

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**UE/Endpoint Application Processing**

**Cloud Application Processing**

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**E2E network latency**
E2E latency counts

The content should preferably be close to the radio to get full benefit from the 1-ms round trip time in the radio
⇒ Mobile Edge Computing (MEC) and Local break out will be needed
5G Architecture: Key to flexibility

5G NORMA

Exposure of control
- Service management
- Mapping of customer-facing services and procedures to resource-facing services and procedures
- Access control and integrity

Network slicing
- SDM-O: Service and Resource Orchestration
- Inter-slice and intra-slice

Network programmability
- Differentiation into common and dedicated functions
- SDM-X and SDM-C
5G Architecture: Key to flexibility

Major stakeholders

- The 5G NORMA mobile service provider (MSP)
  - is the entity/company that provides Internet connectivity and telecommunication services to subscribers.
  - MSP offers dedicated mobile network instances (i.e., network slices) to 5G NORMA tenants
- The 5G NORMA tenant
  - usually a business entity, buys and levers the 5G NORMA network slice services provided by the MSP.
  - Mobile Virtual Network Operator (MVNO) or an enterprise (e.g. a vertical) requiring a telecommunications service for their operations
- The 5G NORMA mobile subscriber
  - individual who consumes services from the MSP or tenant.
- The 5G NORMA infrastructure provider (InP)
  - entity/company that owns and manages parts of or all infrastructure of the network.
- The mobile network operator (MNO)
  - entity that operates and owns the mobile network (merges the roles of MSP and InP into a single stakeholder)
- The software vendors
  - companies that develop and distribute VNF, management and orchestration, or SDM controller software
5G Architecture: Key to flexibility
How much slicing do we need?

- Shared lower PHY
  - Option 1: RAN slicing with slice-specific RAN stack and shared lower PHY (TP specific)
- Shared up to MAC
  - Option 2: RAN slicing with slice-specific PDCP/RLC and RRC per slice
- Fully shared RAN
  - Option 3: RAN slicing with shared RAN (similar to 3GPP MOCN)
Industrial Internet Network Slicing
Resilient, secure, and very fast communication

- 5G modem
- Sensor
- Control room

Private edge cloud network slice for discrete manufacturing and process automation

Cyber physical system – virtual copy of physical system

Public slice for non-business critical and public applications

- Camera at public site
- AR-enhanced maintenance

Public MNO slice

- 55%
- 45%

Customized for the factory needs
Industrial Internet Network Slicing
Demos at MWC’17 and Hannover Messe
5G for Industrial Use Cases
Benefits und Business Potential

Benefits

Advantage

- Ultra-low latency at scale
  <1ms; 99.999% reliability
- Inherent security by dedicated network slices
- Single company network for all kinds of industrial applications

Wireline connections today
>90%

Wireline connections today

- Resilient, secure low-latency comms
- Manufacturing and process automation

- Critical comms
- Intrusion detection

- AR-enhanced maintenance
- Public MNO slice

Benefits

- Overall costs for greenfield 2-5 times lower
- # of sensors = Payback period
- Break even for wireline replacement 1 year
- Reconfiguration cycle = Payback period
- Removing cost of cabling installation and maintenance
- Less reconfiguration time
- Less production capacity overprovisioning

Business case

https://networks.nokia.com/innovation/5g-use-cases
5G NORMA Evaluation

London Sample Area

Evaluation cases*

1. Baseline evaluation case
   a. MBB deployment
   b. Determination of needed capacity extensions
   c. Comparison of legacy (LTE-A pro) vs 5G NORMA

2. Multi-tenant evaluation case
   a. MBB deployment
   b. Check for suitability of 5G NORMA interfaces
   c. Key benefits of multi-operator networks

3. Multi-service evaluation case
   a. MBB + mMTC + V2X deployment
   b. Comparison of 5G NORMNA multi-service networks with single service stovepipes
   c. Assessment of 5G NORMA functional concepts (mobility, reliability, security, protocols, interfaces,...)
5G Applications will go far beyond initial use cases
“Limited only by our imagination of the human possibilities”

https://networks.nokia.com/innovation/5g-use-cases
TACNET 4.0
BMBF Project

• Volume: 10,33 Mio. EUR
• Duration: 04/2017 - 03/2020
• Leadership team: Prof. Hans Schotten (DFKI), Dr. Peter Rost (Nokia)
• Scope: Highly reliable, real-time 5G network for the digitized industry
• Contact: schotten@dfki.de and peter.m.rost@nokia.com
5G-MoNArch
5G-PPP Phase 2

- Duration: 07/2017 – 06/2019
- Leadership team:
  - Coordinator: Nokia, Germany
  - Technical Management: Universidad Carlos III de Madrid UC3M, Spain
  - Innovation Management: Deutsche Telekom, Germany
- Main innovative areas
  - Cloud enabled protocol stack
  - Inter-slice control & mgmt.
  - Experiment driven optimization
  - Security & Resilience
  - Resource-elasticity
- Two testbeds
  - Touristic city, Venice, Italy
  - Sea port, Hamburg, Germany