DETERMINISTIC6G

6G for dependable communication

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HEXA-X-II Workshop on 6G

DETERMINISTIC6G has received funding from the European Union's Horizon Europe programme under grant agreement No 101096504.

Outline

- Some general reflections on 6G
- DETERMINISTIC6G – dependable time-critical communication

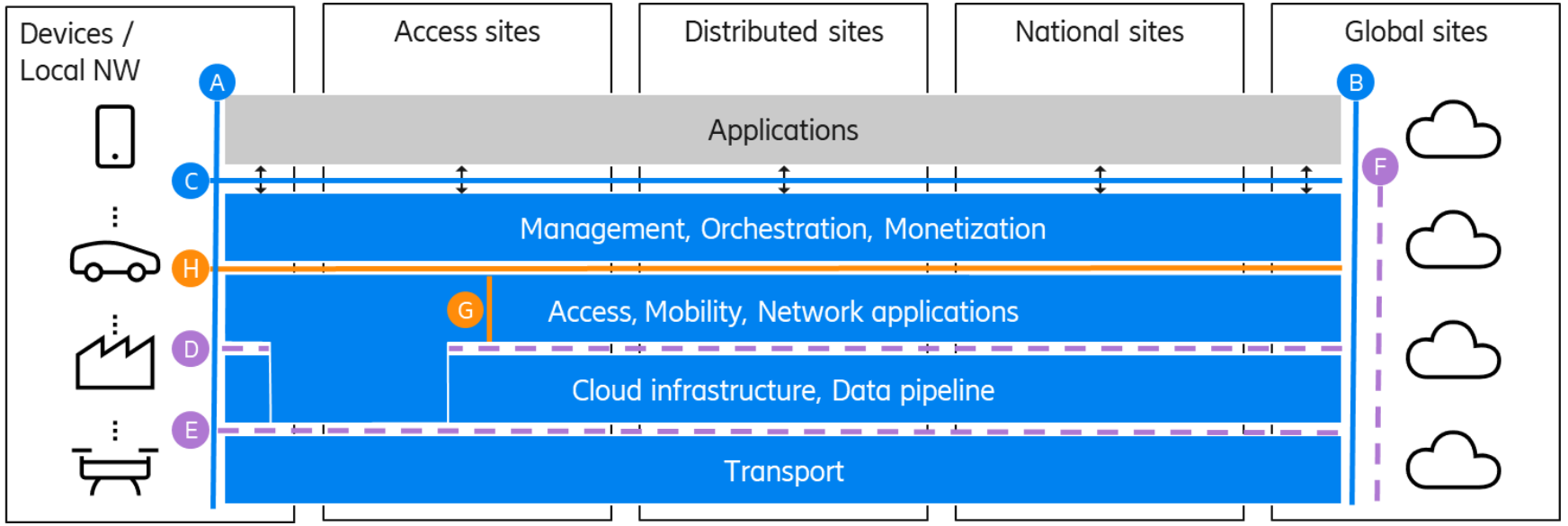
6G architecture trends

- AI-enabled / Data-driven architecture
- Cloudification / virtualization / distributed compute
- Flexible topologies
- Edge-compute and offloading
- 6G automation and & optimization (intent-based)
- Exposure for interaction of network with application domain
- KVIs and sustainability

- Efficient migration to 6G

High level 6G architecture

A – Access interfaces
B – Interconnect /roaming interfaces
C – Service interfaces
D – Cloud platform interfaces
E – Transport interfaces
F – Data sharing, Managed service, CI/CD interfaces
G – Network internal interfaces
H – Multi domain management interfaces



- Ref1: Ericsson, Future Network Architecture, April 4, 2023
- Ref2: 6G network architecture – a proposal for early alignment, Ericsson Technology Review, October 2023

Highlights:

A – new stand-alone 6G radio interface operating in new / existing frequency bands, efficient spectrum co-existence

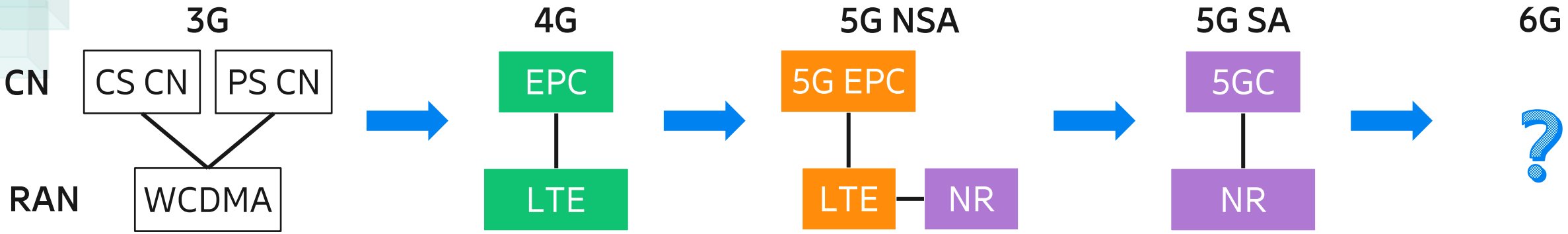
G – support for key multi-vendor interfaces incl. LLS, RAN-CN and RAN-RAN

D – SW/HW separation of RAN/CN apps from compute (GPP, HW acceleration), support for data pipelines and other common platform functions

H – multi-vendor automation and management (LCM, FCAPS, orchestration, optimization) driven by intents and operator deployed Apps, supporting analytics and service exposure

C – service exposure and APIs (e.g. CAMARA) enabling new applications, supporting App-NW interaction for improved performance, added value services and capabilities

Architecture evolution



- CS voice (cont.)
- GPRS evolved
- HSPA (start of MBB)

- MBB
- VoLTE
- mMTC

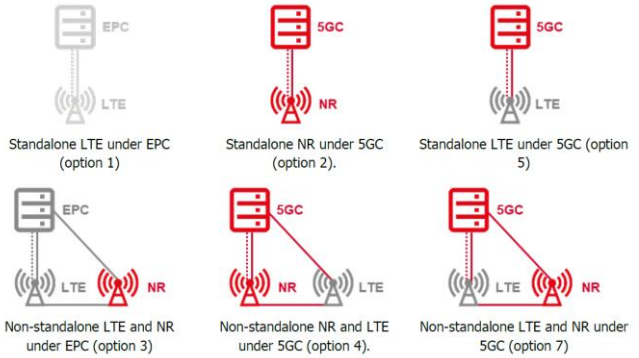
- eMBB
- VoLTE (cont.)
- mMTC (cont.)

- eMBB (cont.)
- VoNR (VoLTE cont.)
- mMTC (cont.)
- Time Sensitive & Reliable Communication
- Network slicing
- Private networks

Migration towards 6G

- For 4G→5G migration multiple connectivity options were introduced
  - Enabling different migration options for fast 5G introduction

- Resulted in significant standardization effort for multiple options
- Fragmented the market
- 5G deployments not living up to the full standard potential
  - Status Jan 2024: [GSA][Ericsson Mobility Report]
    - ~1.6 billion 5G subscribers
    - ~20% of CSP 5G networks are 5G SA
    - ~90% of devices support 5G SA



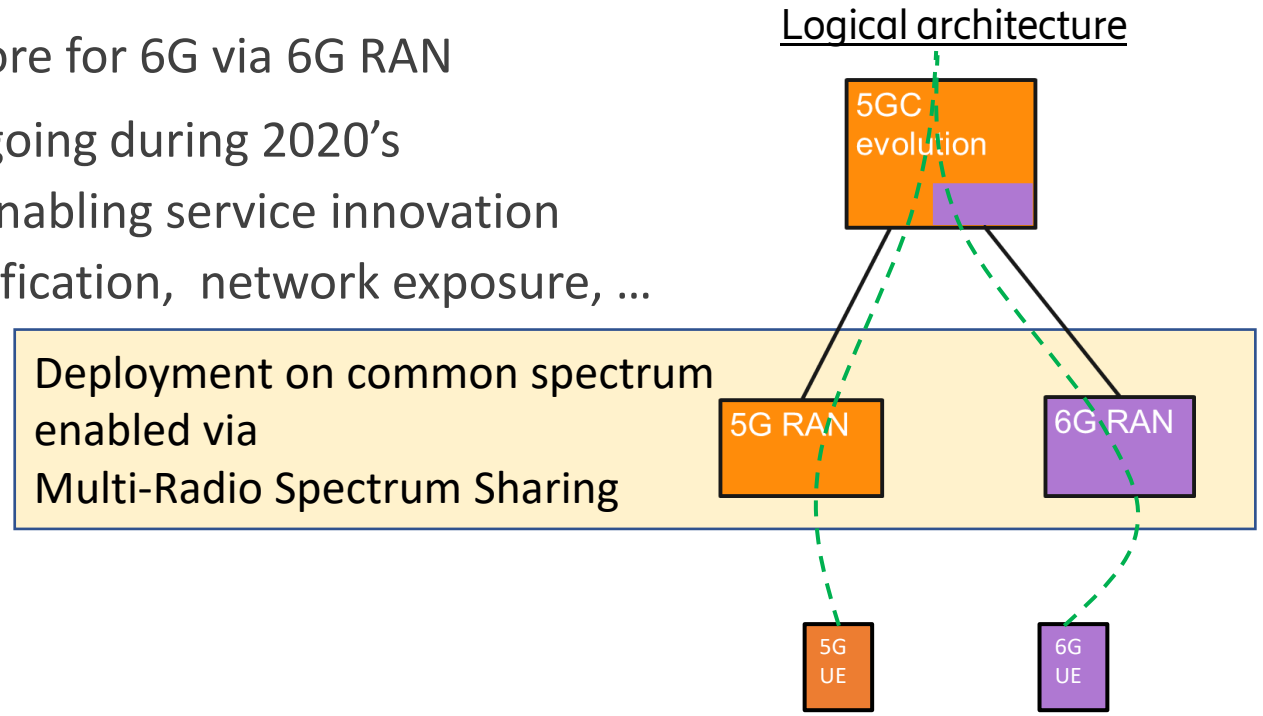
GSMA: Road to 5G: Introduction and Migration April 2018

Connectivity option	Core network	Master RAT	Secondary RAT	3GPP term	3GPP release
Option 1	EPC	LTE	-	LTE	Rel. 8
Option 3	EPC	LTE	NR	EN-DC	Rel. 15, Dec 2017
Option 2	5GC	NR	-	NR	Rel. 15, June 2018
Option 4	5GC	NR	eLTE	NE-DC	Rel. 15, March 2019
Option 5	5GC	eLTE	-	eLTE	Rel. 15, June 2018
Option 7	5GC	eLTE	NR	NGEN-DC	Rel. 15, March 2019

Simplifying 5G ecosystem by reducing architecture options (ericsson.com)

Proposed Network Migration towards 6G

- Standalone 6G preferred
  - Direct connection of 6G UE to core for 6G via 6G RAN
- Investments in 5GC deployment ongoing during 2020's
  - 5GC, flexible network platform enabling service innovation
    - Network slicing, NPN, cloudification, network exposure, …
  - Core for 6G proposed as evolution of 5GC with support for 6G RAN and 6G UEs



Dependable E2E communication with 6G

Project coordination: Ericsson, Technical coordination: KTH, Project start: January 2023, Project duration: 30 months, Contact: coordinator@deterministic6g.eu, deterministic6g.eu

E2E deterministic system architecture

6G challenges and vision

System aspects for deterministic E2E communication

- 6G use cases requiring deterministic communication
- Deterministic service definition (KPI/KVI)
- Security analysis

Deterministic communication technology enablers

- Deterministic 6G wireless transmission design
- Data driven characterization for 6G wireless system
- E2E time synchronization
- Deterministic communication standards (TSN, DetNet) Evolution
- Edge computing solution for deterministic communication
- Situational awareness via digital twins
- Security countermeasures

Validation framework

- System level modelling
- Data driven model evaluation and validation
- System level simulations

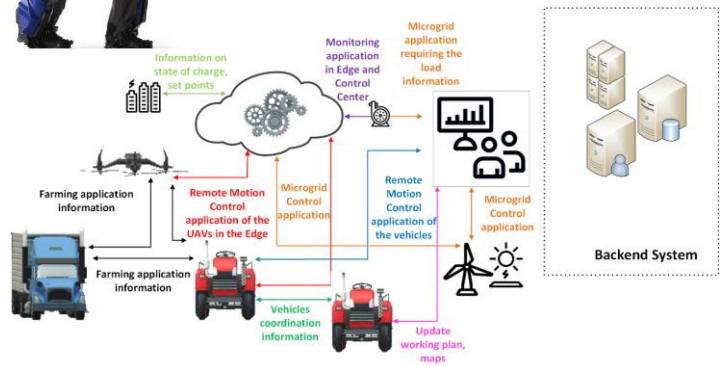
Beyond DETERMINISTIC6G

DETERMINISTIC6G has received funding from the Smart Networks and Services Joint Undertaking (SNS JU) under grant agreement No.101096504. The SNS JU receives support from the European Union's Horizon Europe research and innovation programme

Time-critical Applications

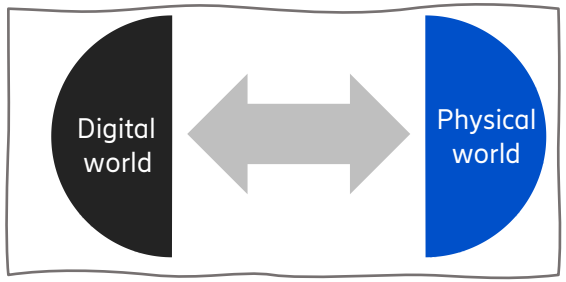
- Increasing number of time-critial applications, in industrial automation, XR, smart grid, etc…
  - Requirements on guaranteed bounded latency (ms-range) with high availability (>99.999%)

- Use cases in DETERMINISTIC6G
  - Occupational exoskeletons
  - Extended Reality (XR)
  - Flexible production (manufacturing)
  - Smart farming

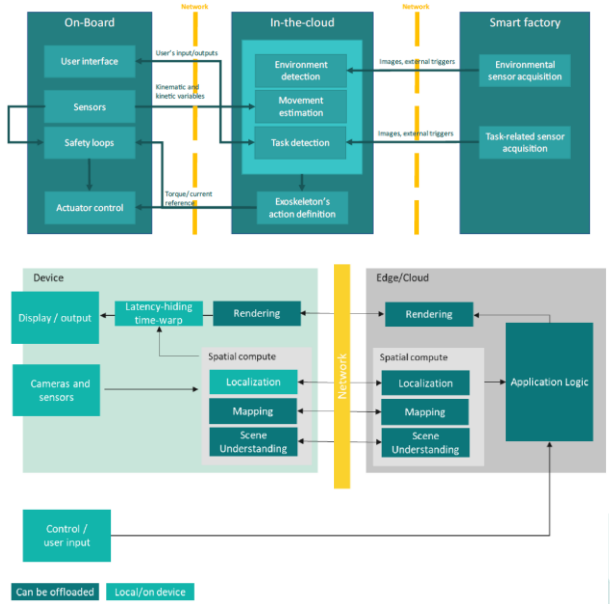


Time-critical Applications

- Time-critial applications:
  - Often part of connecting the physical and digital elements of the cyber-physical world (monitoring an control from a digital twin)



  - Includes compute offloading from physical assets to edge cloud, e.g.
    - Spatial compute in XR
    - ML-friendly, collaboration-friendly control
    - device simplicity (power, footprint, complexity)



Time-critical Applications (cont.)

- Requirements for time-critical applications
  - Time-awareness
    - Enabled via 3GPP time-synchronization support in Rel (16/17/18)
  - Typically integrated with end-to-end time-sensitive networking based on
    - Ethernet-based: IEEE 802.1 Time-sensitive networking (TSN)
    - IP-based: IETF Deterministic Networking (DetNet)

Dependable Time-critical Communication

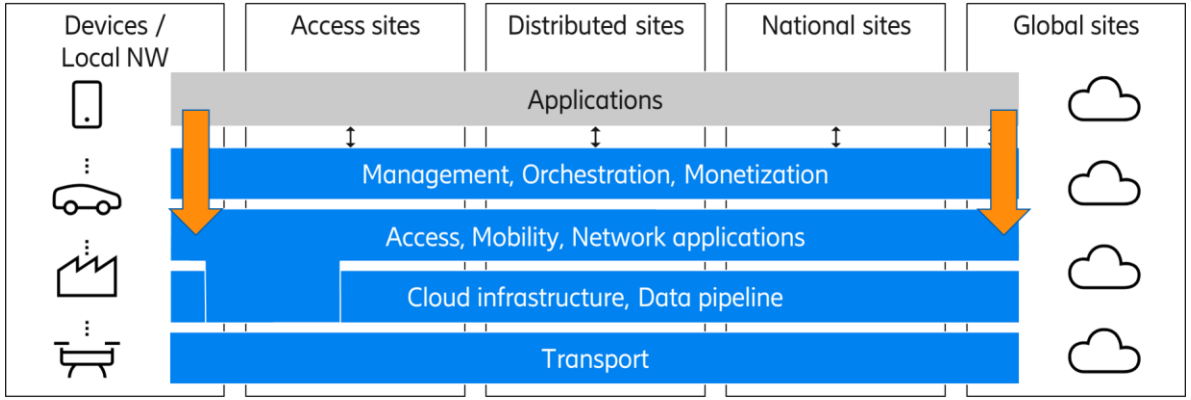
- Dependable communication
  - *Be able to* ***quantitatively ascertain the delivery of required service performance for the communication that are agreed.***

- Comprises several steps
  - Clarity on required and agreed service performance
  - Monitoring and prediction of delivered service performance
  - Automated service assurance
  - Feedback on service delivery to the application domain
  - (enabler for application-communication co-design)

TSN – time-sensitive networking
DetNet – determinisitc networking

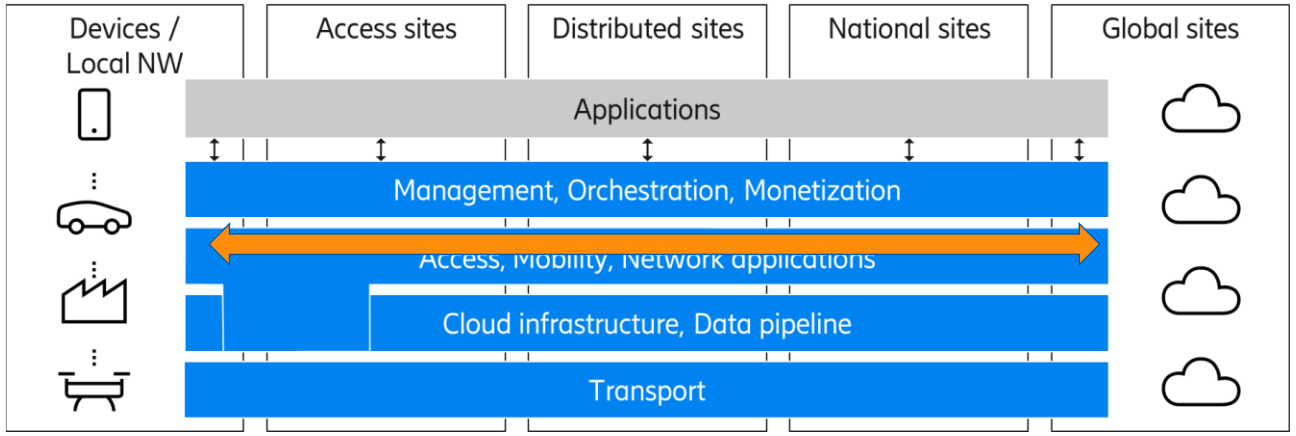
Dependable communication components – (1) service specification

- Serivce exposure:
  - Specification and Configuration of a time-critical service
    - Traffic characteristics
    - Latency bounds and reliability

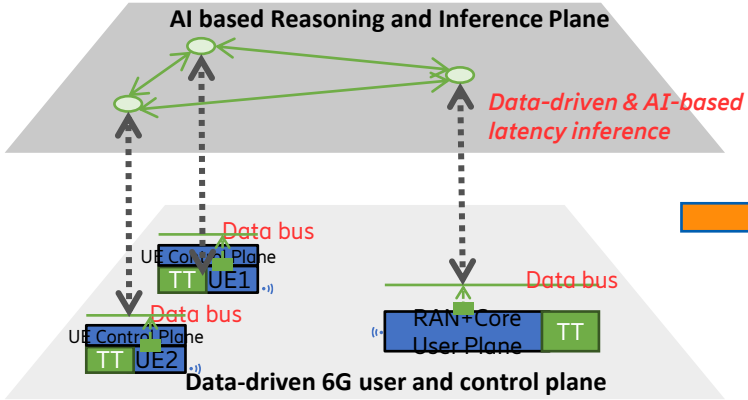


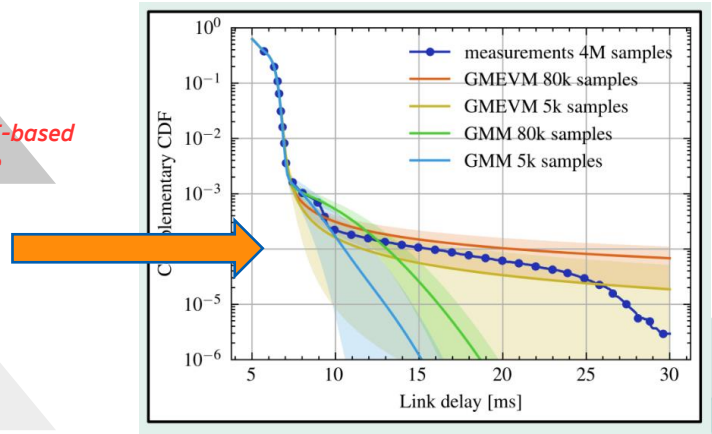
Dependable communication components – (2) Observable service latency performance (and prediction)

- Service performance monitoring
  - Inbuilt observability of (latency) service performance



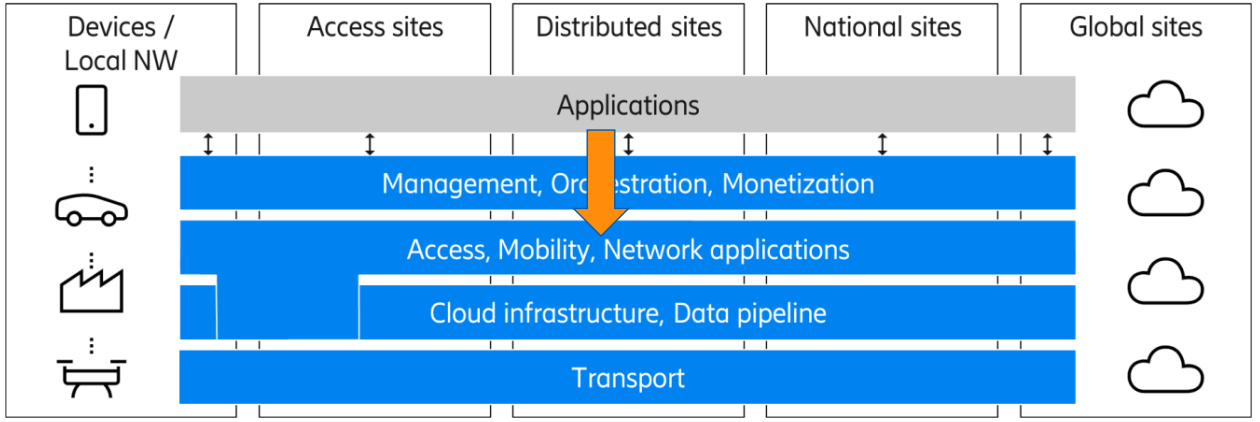
- And enabling performance prediction based on performance observations and ML-based prediction





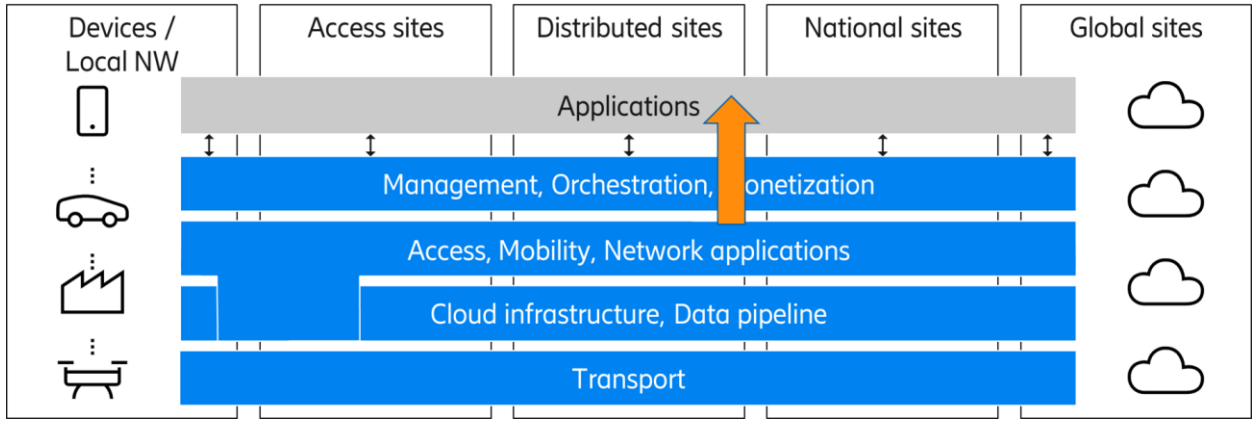
Dependable communication components – (3) automated service assurance

- Serivce assurance:
  - Assurance of service delivery according to the service specification
  - Automation for service assurance e.g. based on intent-based management



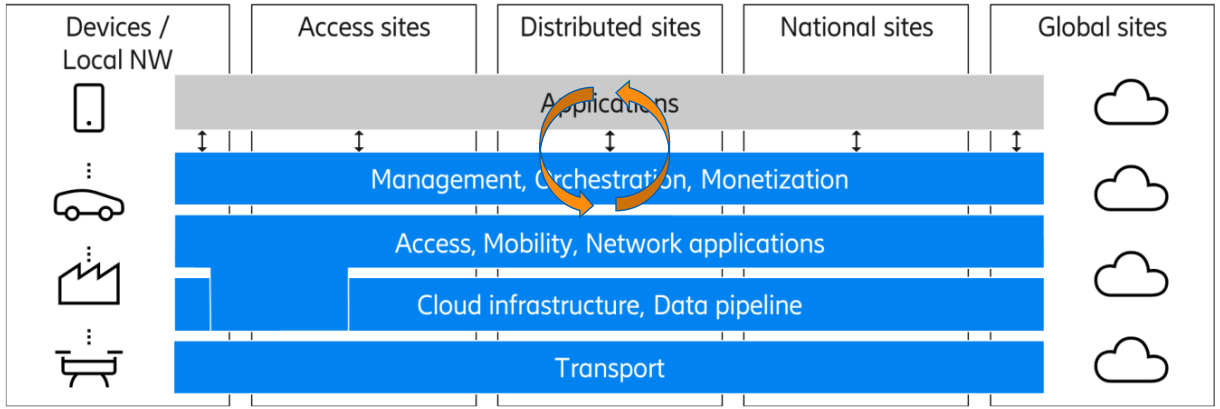
Dependable communication components – (3) reporting on service delivery

- Serivce delivery report:
  - Maintain service delivery status and feedback to applications



Dependable communication components – (4) reporting on service delivery

- Enabler for nework-aware applications
  - Example communication-control (-compute) codesign

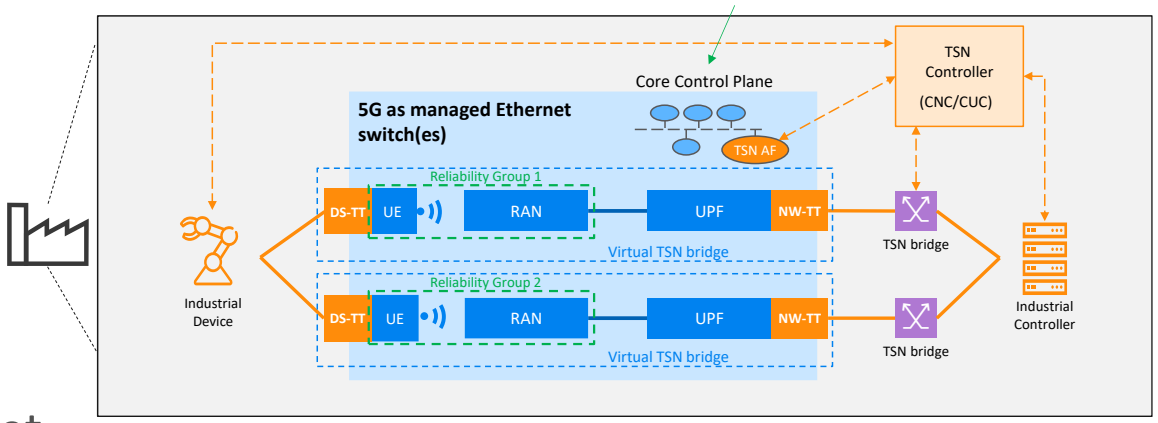


Integration with end-to-end deterministic communication

- End-to-end deterministic communication (DetCom)
  - Ethernet-based: IEEE 802.1 Time-sensitive networking (TSN)
  - IP-based: IETF Deterministic Networking (DetNet)
  - Possibly configured via some application middleware (e.g. OPC UA FX)

- 6G should enable optimized dependable end-to-end communication with 6G for time-critical applications
  - Optimized interworking with TSN and DetNet building on 5G support for TSN&DetNet

CPS – cyber-physical system
TSC – time-sensitive communication
TT – TSC translator
DLI – data-driven latency inference



TR – TSN translator
CNC – centralized network configuration (TSN)
CUC – centralized user configuration (TSN)

More insights

- https://deterministic6g.eu/
  - D1.1 DETERMINISTIC6G use cases and architecture principles
  - D2.1 First report on 6G centric enabler
  - D2.2 First Report on the time synchronization for E2E time awareness
  - D3.1 Report on 6G convergence enablers towards deterministic communication standards
  - D3.2 Report on the Security solutions
  - D4.1 DETERMINISTIC6G DetCom simulator framework release 1
  - D6.3 First Intermediate Project Report

DETERMINISTIC6G Grant Agreement No. 101096504

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