Interaction of Satellite Networks in the 5G Ecosystem

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Outline of the presentation

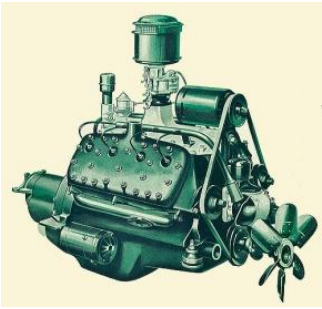
- Introduction to 5G
- Network Slicing
- Experience in the field
- Potential role of satellite in 5G
- Integration of satellites and 5G
- Open challenges
- Satellite-related functionalities as full-fledged slice components

Introduction to 5G

- Extreme flexibility levels to support services and applications with highly heterogeneous requirements in terms of performance, scalability, and deployment scenarios
- “Network of networks,” adoption and combination (as needed by the overlying applications) of different and alternative network stacks and communication technologies
- “Virtualization” paradigm as key crosscutting enabler of 5G, which will pervade the 5G architecture at any layer in order to provide the related resources “as a service”

Virtualization Technological Frameworks

- Network Functions Virtualization (NFV)
- Software Defined Networking (SDN)
- Software Defined Radio (SDR)

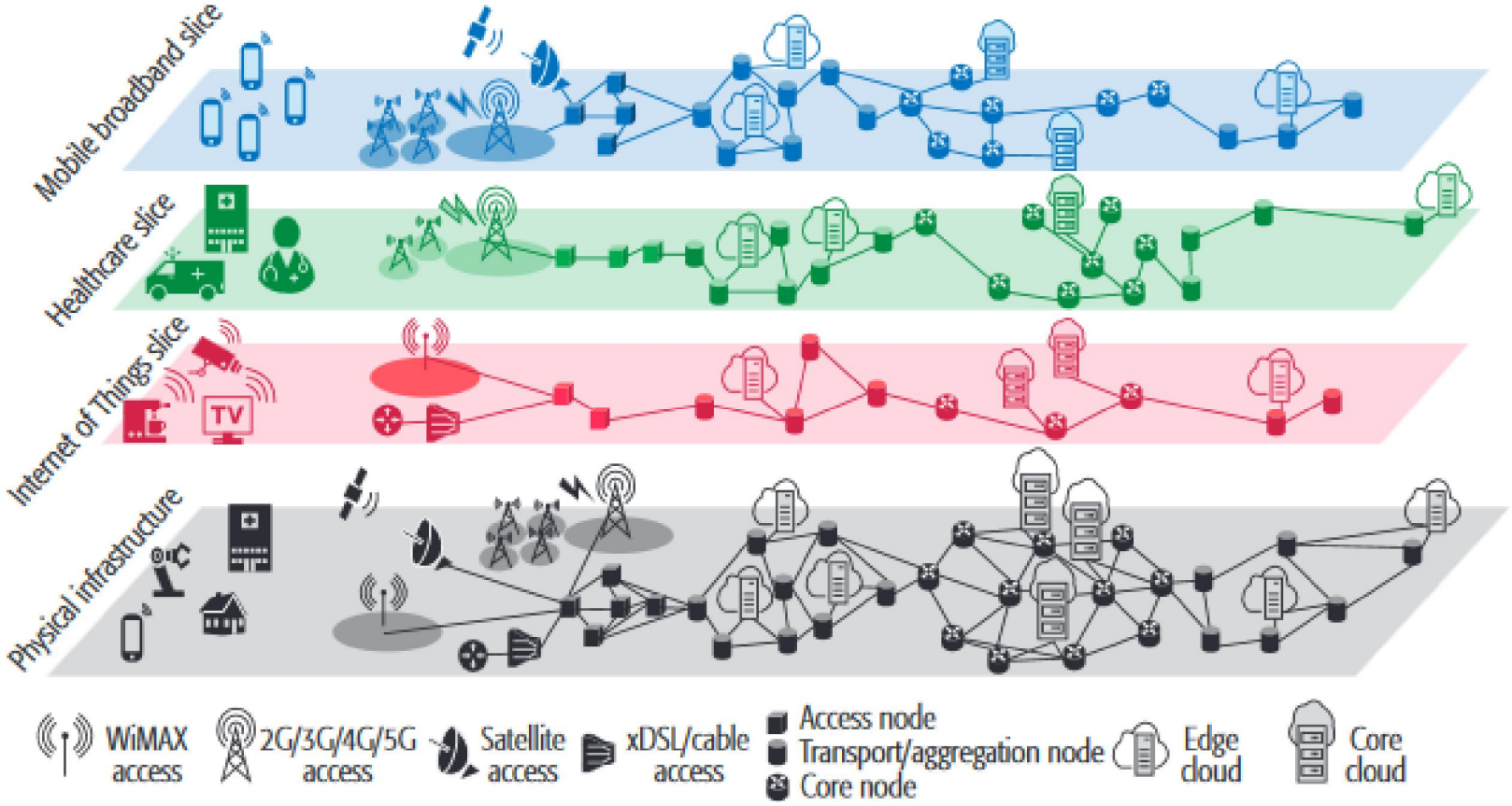


- The aim of NFV is to decouple network functions from dedicated physical devices, making it possible to run such functions on general-purpose servers that could be deployed in network operators' data centers
- Possibility to create multiple isolated virtual domains over the same physical infrastructure

Network Slicing

- 5G network platforms are meant to expose "customized" and isolated virtual projections of the mobile network (called network slices) to vertical industries and OTT players, so as to enable them to run their applications and services on top of these network slices
- Isolation concerning: performance, security and privacy, management

Network Slicing - example



From: J. Ordóñez-Lucena et al., “Network Slicing for 5G with SDN/ NFV: Concepts, Architectures, and Challenges,” IEEE Commun. Mag., vol. 55, no. 5, May 2017, pp. 80–87.

UNIGE/CNIT Research Projects

- **MATILDA (CNIT)**
- **MISE – OPENFIBER – WIND TRE (UNIGE)**

EU - MATILDA

- MATILDA - A Holistic, Innovative Framework for Design, Development and Orchestration of 5G-ready Applications and Network Services over Sliced Programmable Infrastructure
- MATILDA aims to devise and realize a radical shift in 5G-ready vertical applications, by providing the tools to foster and speed up the extension/evolution of the “cloud” paradigm to the 5G ecosystem, intrinsically bridging the application and the network service domains

MATILDA

A HOLISTIC, INNOVATIVE FRAMEWORK FOR THE DESIGN, DEVELOPMENT AND ORCHESTRATION OF 5G-READY APPLICATIONS AND NETWORK SERVICES OVER SLICED PROGRAMMABLE INFRASTRUCTURE

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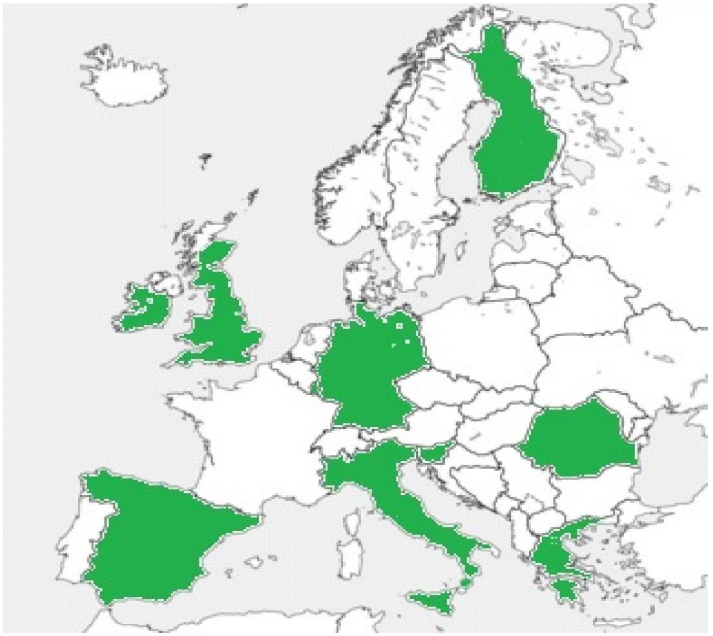
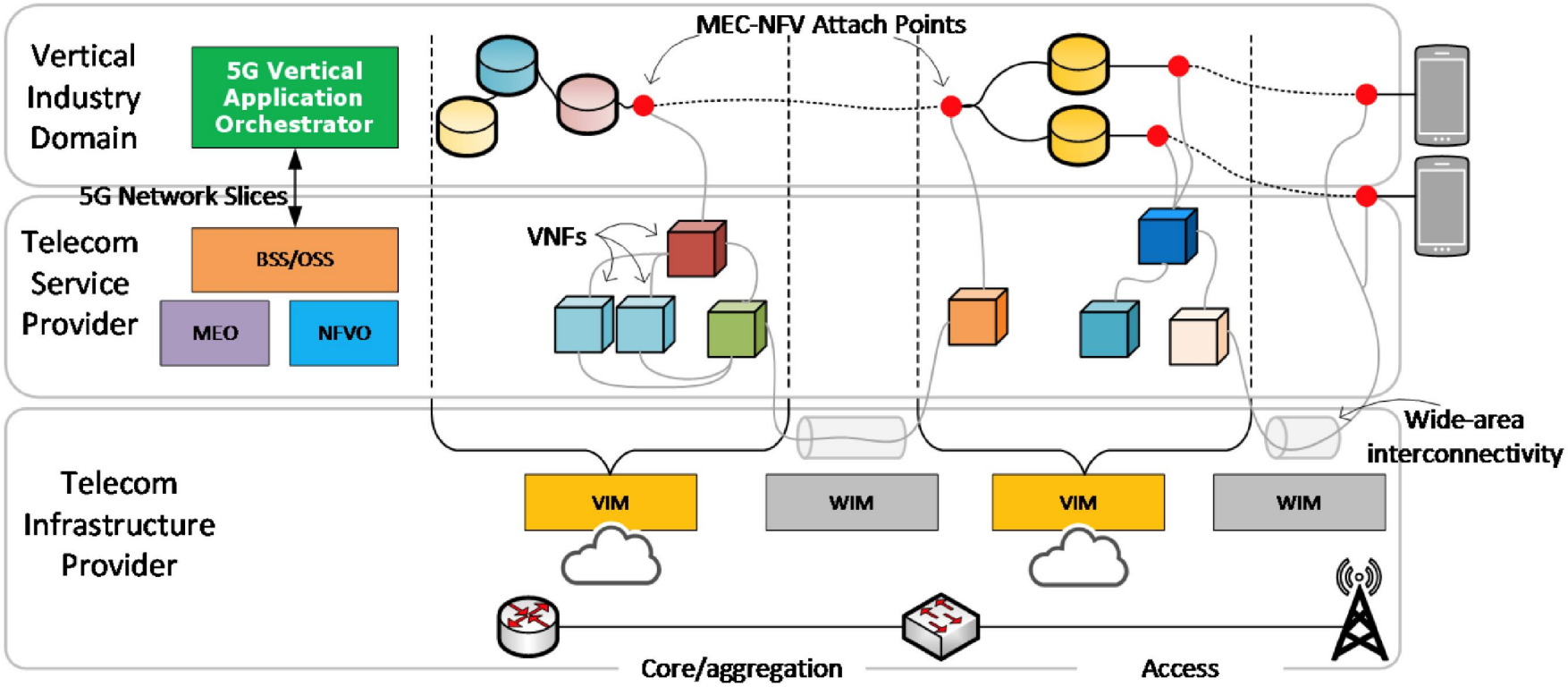


5G PPP PUBLIC-PRIVATE PARTNERSHIP

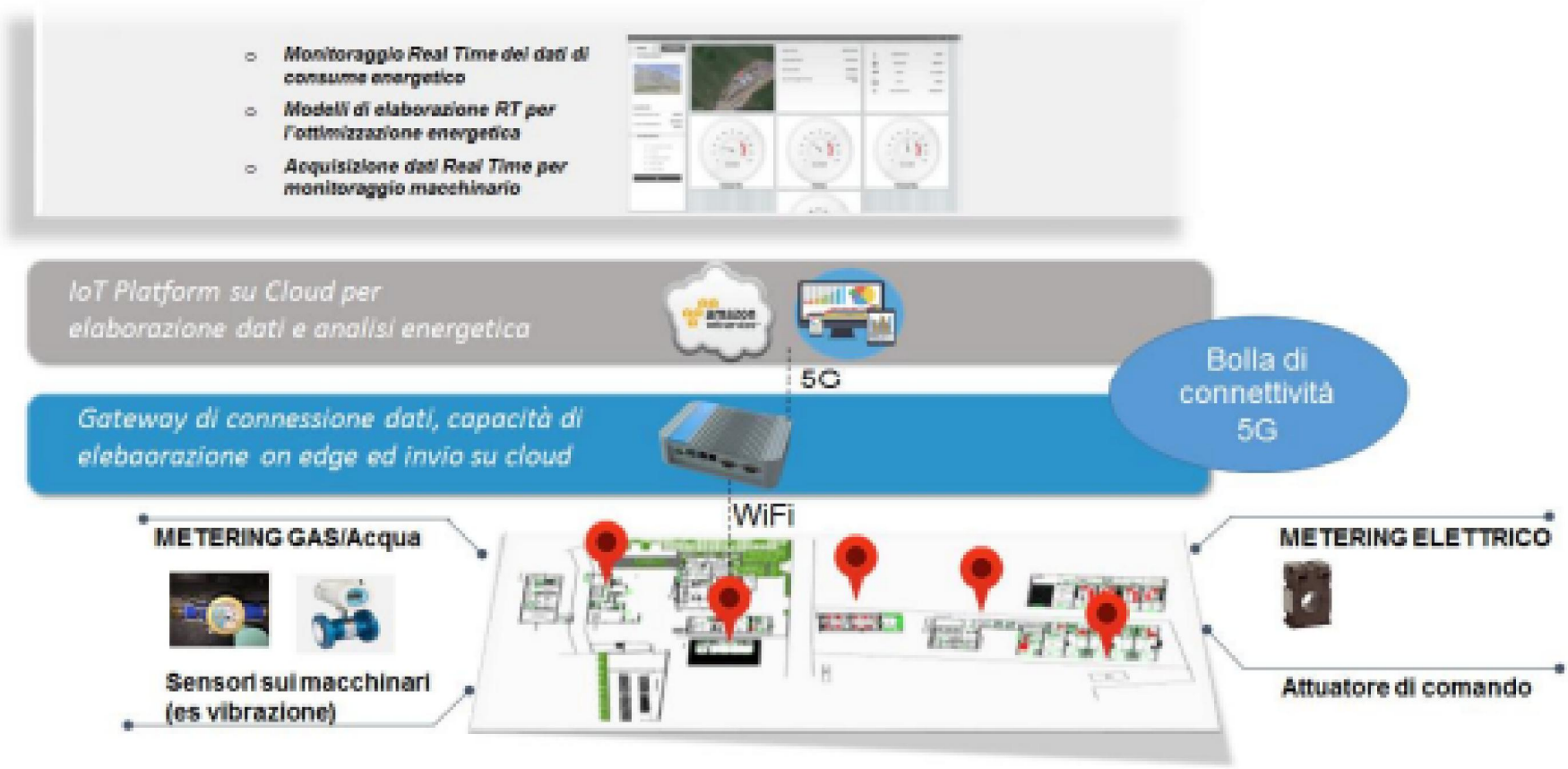
Application-Aware Network Slices



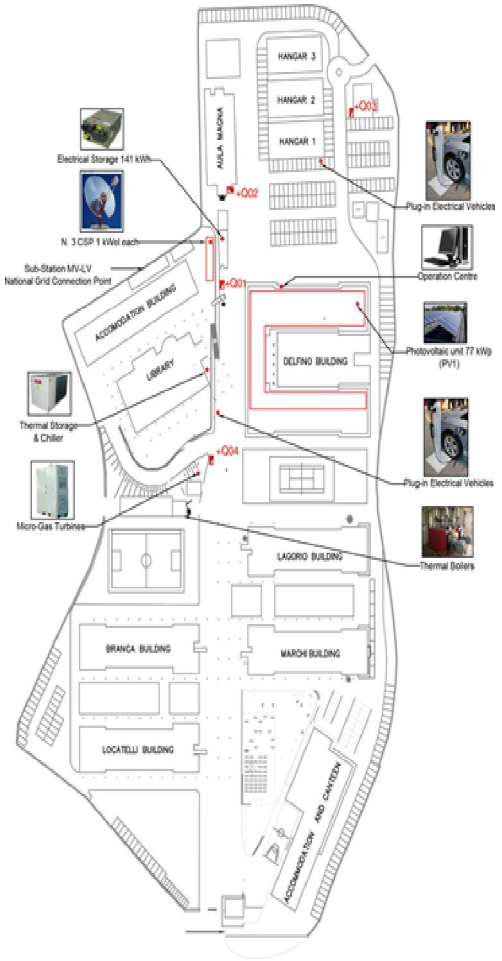
MISE – OPENFIBER – WIND TRE

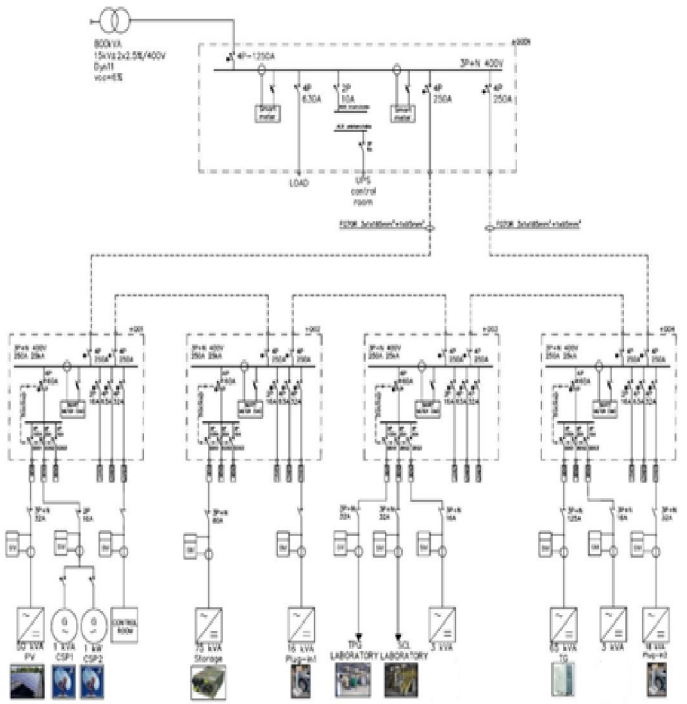
- *Avviso Pubblico per l'acquisizione di proposte progettuali per la realizzazione di sperimentazioni pre-commerciali 5G nella porzione di spettro 3.6-3.8 GHz*
- Autorizzazione MiSE ad OF e Wind Tre per la realizzazione di una sperimentazione pre-commerciale 5G nell'Area 2 – Prato e L'Aquila attraverso l'utilizzo dei diritti d'uso delle frequenze da 3.7 GHz a 3.8 GHz
- **Contratto di ricerca con DITEN – Università di Genova "Analisi dei futuri scenari applicativi 5G e del livello di sicurezza dei protocolli di comunicazione"**

Reference Scenario

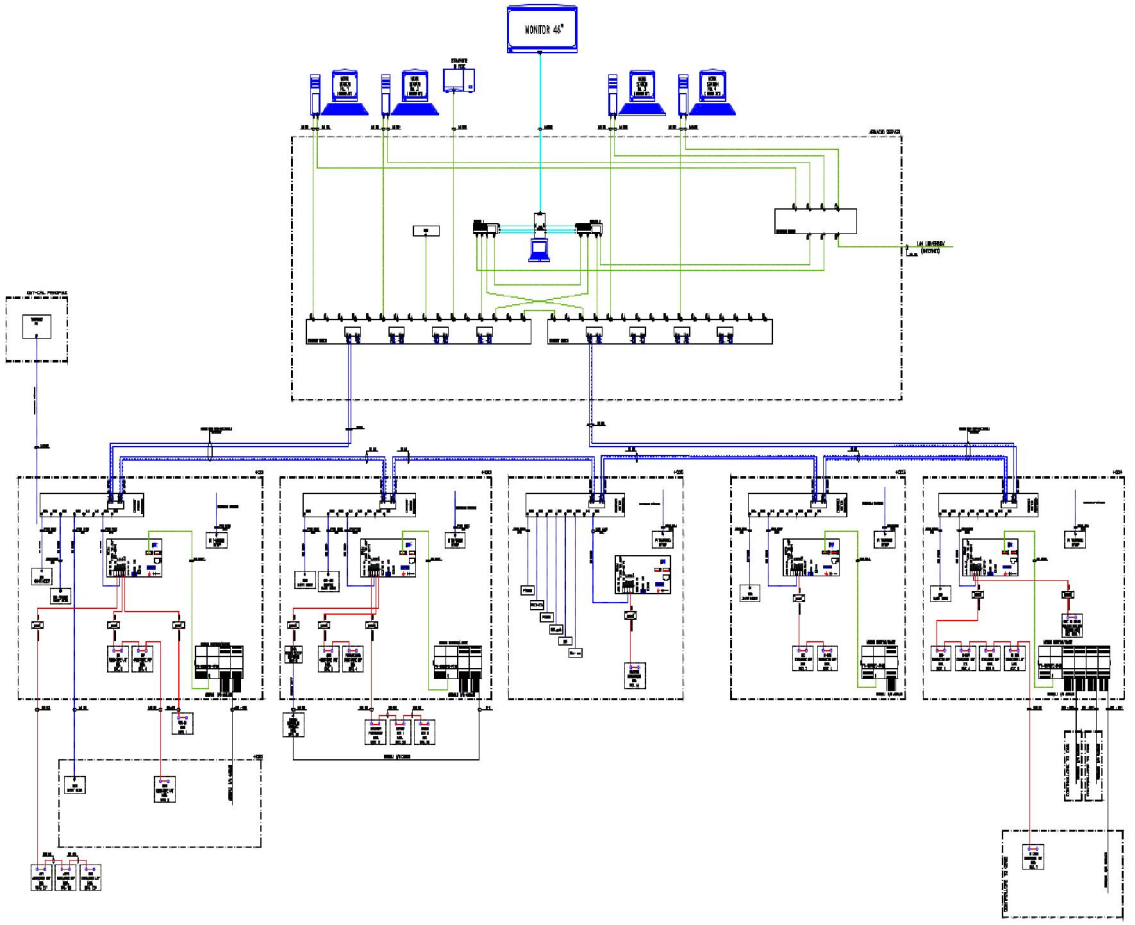


Savona Campus Microgrid





Savona Microgrid Network Scheme



Past research experience

- Satellite, space and heterogeneous telecommunications (since 1998)
  - TCP and transport levels on satellite routes
  - Algorithmic solutions and architectures
  - Control strategies for the dynamic assignment of bandwidth in satellite communications and heterogeneous networks
- Quality of Service over Heterogeneous Networks (2007)
- **SDN**
- **Delay and Disruption Tolerant Networks**
- **Nanosatellites**
- **Extension of satellite networks to the 5G domain, based on SDN and NFV paradigms**

Potential role of satellites

- Thanks to their intrinsic ubiquity and broadcasting capabilities, satellite networks can play multiple roles in 5G and can act as
  - a main single backhaul segment for rural areas, aircraft, vessels, and trains
  - additional backhaul means to opportunistically provide additional connectivity/bandwidth resources, also improving service continuity
  - unicast/multicast/broadcast geographical distribution of video, audio, and application software binaries to a large number of terminals simultaneously

- Physical network functions (PNFs) when considered in their current deployment
- Including their virtualized operational components as manageable entities in the 5G architectural framework

Deep integration between satellites and 5G

- A number of actions should be undertaken to bring state-of-the-art satellite technologies closer to the virtualization paradigm used within the 5G architecture
  - Physical Layer Aspects
  - Networking viewpoint: Virtualization and Multi-tenancy
    - Satellite capabilities should be exposed “as a service” to multiple concurring tenants
    - Potential impact of architectural frameworks based on NFV, SDN, and SDR might be more than relevant

Open Challenges

- Despite the research efforts performed to fill the gap between current satellite communication networks and their envisioned network virtualization evolution, there are still some open challenges

Open Challenges

- How to distribute the different layer functionalities that compose the SDN architecture, that is, in which nodes to locate the three SDN planes
- Implementation of the communication protocol between the data and control planes
- Handover procedure to tackle network topology changes
- Checking the impact of satellite mobility on virtualization

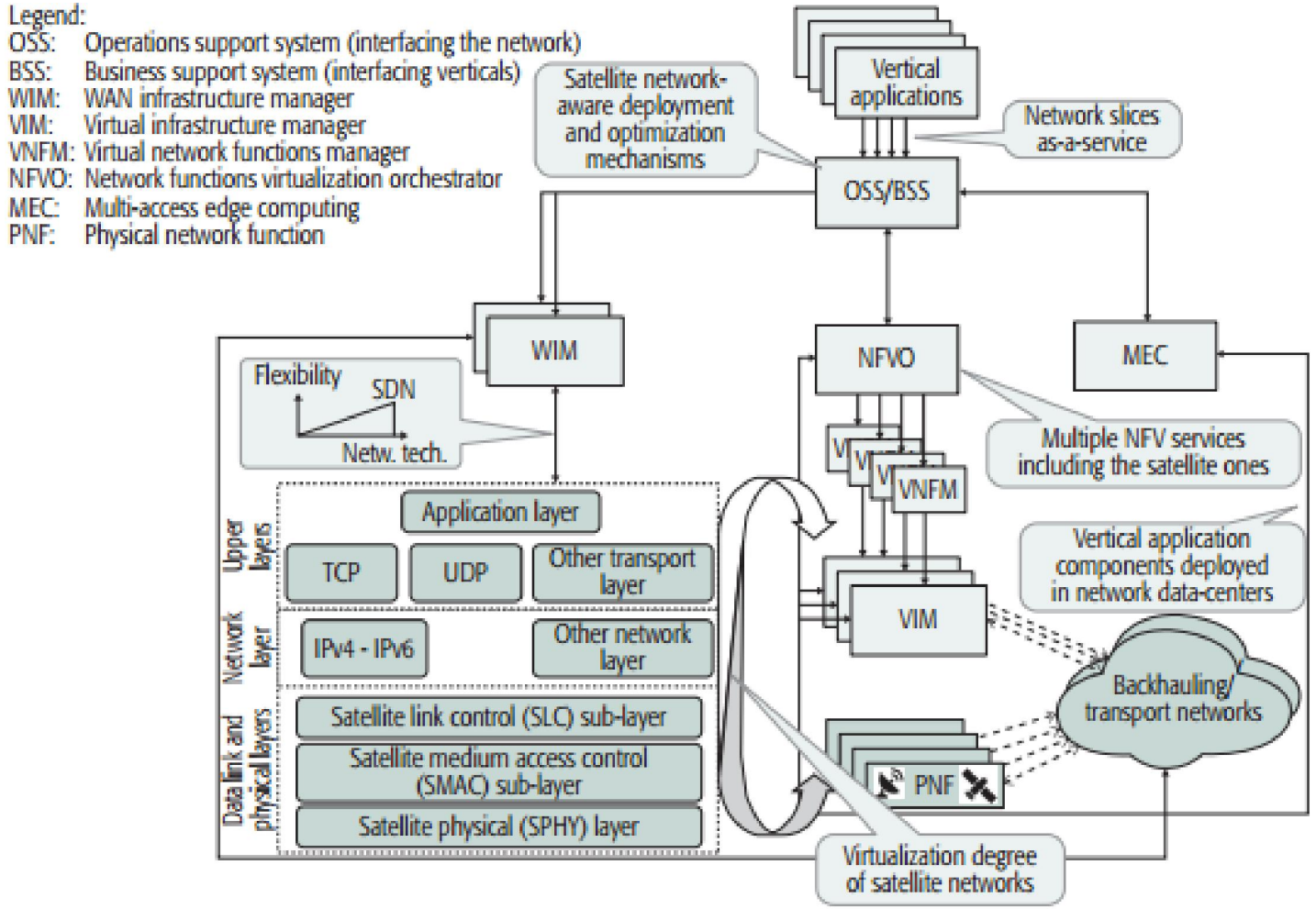
Open Challenges

- Gateway diversity
  - Transparent for OTT players using slices dynamically managed by the network control plane in an agile and flexible fashion. For example, slice internal elements might be reconfigured to route traffic toward the new gateways
- Real-time monitoring and resource constraints, not limited to the widely investigated GEO and LEO scenarios (e.g. nanosatellites)
  - To cope with the dynamic satellite features, slice provision and adaptation should be performed along with real-time monitoring of performance parameters and resource availability

Satellite-related functionalities as full-fledged slice components

- Current satellite networking elements can be seen as PNFs, providing long-haul connectivity
- To be integrated and orchestrated as slice components by an NFV orchestrator, upon requests coming from the OSS to satisfy the requirements of vertical applications, the functionalities of SGWs and satellite terminals (STs) need to be virtualized except for the ODU, which remains a PNF

Satellite-related functionalities as full-fledged slice components



Satellite-related functionalities as full-fledged slice components

- To provide the necessary quality, the satellite network may need to perform specific actions,
  - transport layer (e.g., PEP, TCP optimization)
  - network layer (e.g., IP DiffServ/IntServ, IP routing)
  - data link and MAC and physical layer (e.g., MAC using successive interference cancellation [SIC], adaptive coding and modulation)
- These operations may be performed in a VIM by one or more data centers, not necessarily located near the satellite Earth station, connected to each other by the WIM

Proposed UNIGE/CNIT Research Projects

- A5GILITY (over threshold but not funded)
- SatNEx (under evaluation)

A5GILITY

- 5G NETWORK FOR END TO END EXPLOITATION
- ICT-17-2018 “5G End to End Facility” - Research and Innovation action (RIA)
- Focus on Mission-Critical Communications
  - Focus on communications for mission-critical systems
  - Typical use cases for mission-critical communications (MCC) include public safety and emergency services, eHealth/mHealth applications, and any type of public infrastructure such as electric grids and transportation

A5GILITY

- Inclusion of satellite links as integral part of the infrastructure
- Main partners
  - Airbus Defence and Space
  - Eutelsat
  - Newtec
  - Ericsson
  - DITEN, University of Genoa

SatNex IV

- ESA - CoO2 Part 2, Work Item 4 on "**Innovative Networking Solutions for SatCom in 5G and beyond**"
  - CNIT, National Laboratory of "Smart, Sustainable and Secure Internet Technologies and Infrastructures" at the University of Genoa (CNIT-GE)
  - Siena Research Unit (CNIT–SI)
  - University of Rome Tor Vergata, Department of Electronics Engineering (UNIROMA2)
  - National Research Council of Italy – Institute of Information Science and Technologies (CNR-ISTI)

SatNex IV

- Scenarios
  - Smart Farm, Smart Cities, Smart Industries, Autonomous Driving
- Solutions
  - Mobile Edge Computing (MEC) concept exploitation, operative creation of Network Slices involving Satellite portions
  - SDN planes and orchestrators positioning
  - Satellite Gateway diversity
  - SDN signalling
  - Network performance enhancement – load balancing and high availability
  - Resilience of the end-to-end communication
  - Orchestrator architecture and related information exchange procedures
  - Handover procedures
  - Satellite channel conditions estimation techniques to support the handover process
  - Traffic filtering across multipath and background data traffic
  - Transparent multipath support

Conclusions

- 5G enviroment
  - Smart cities, industries, farms
- Satellite communications intrinsic ubiquity and broadcasting capabilities
- Mission critical
  - public safety and emergency services, eHealth/mHealth applications, and any type of public infrastructure such as electric grids and transportation
- Satellite-related functionalities as full-fledged slice components

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