# Software defined control of optical networks


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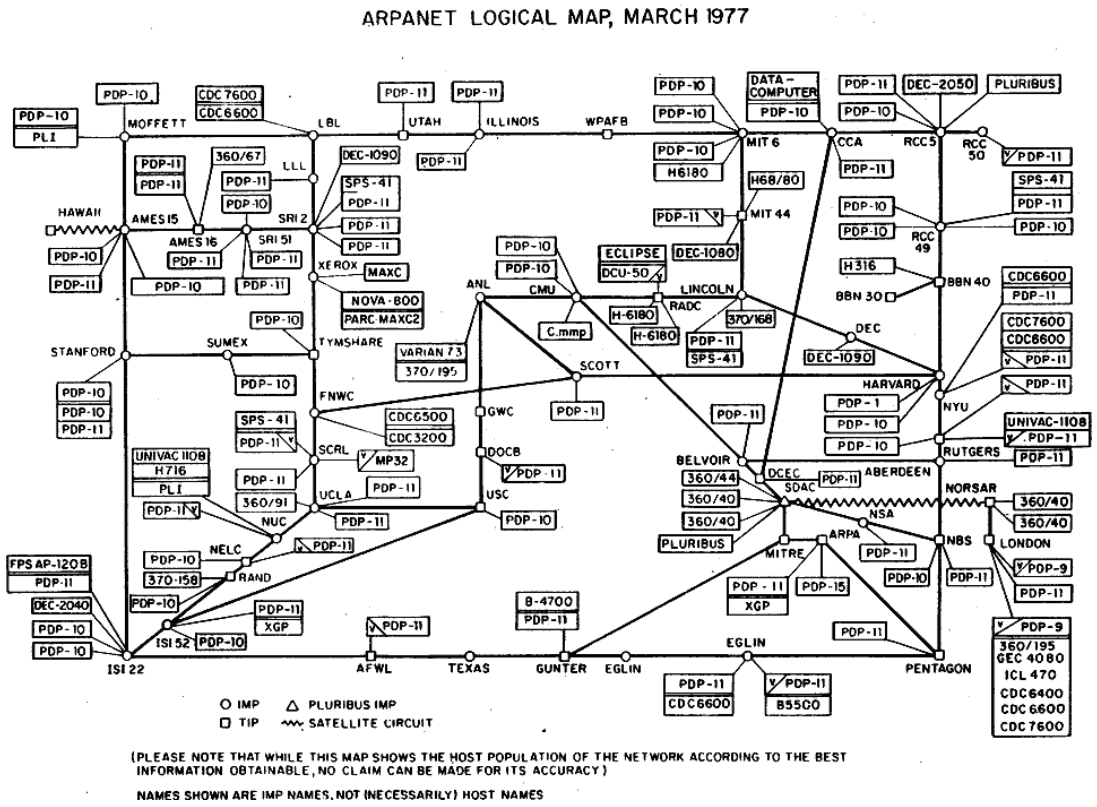
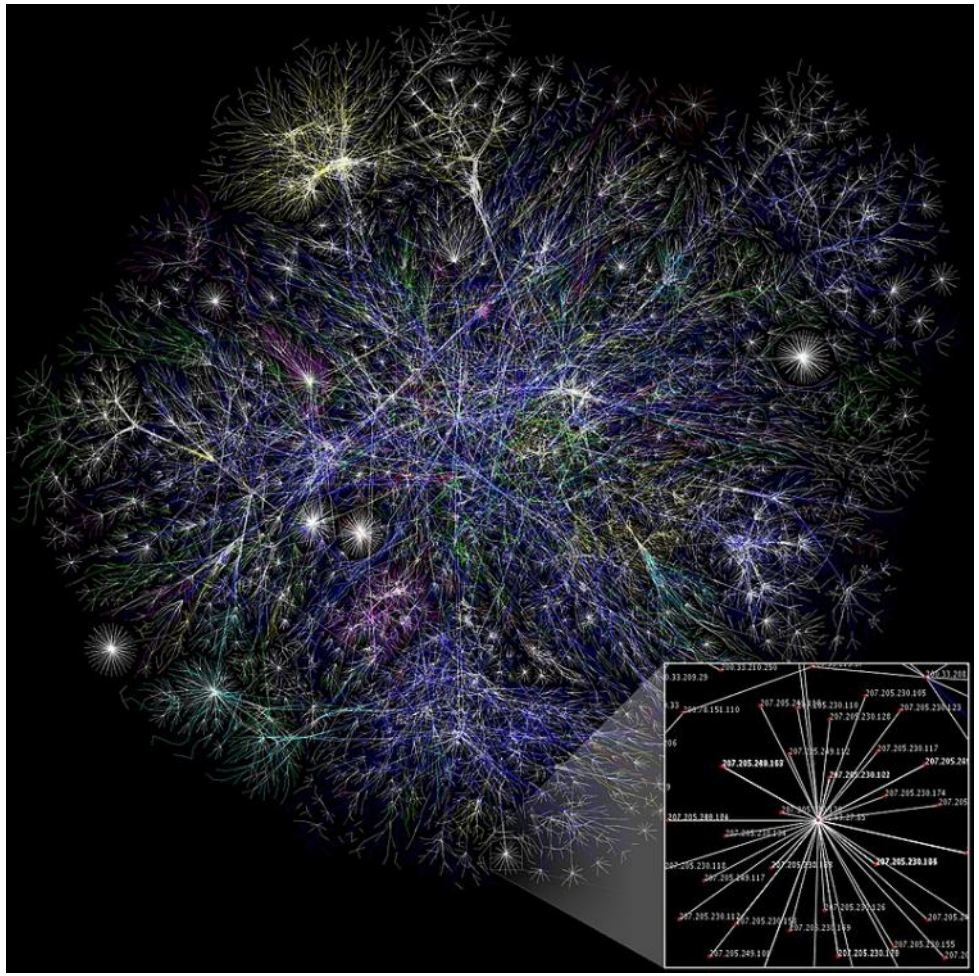
# The Internet: a meme

- How it started

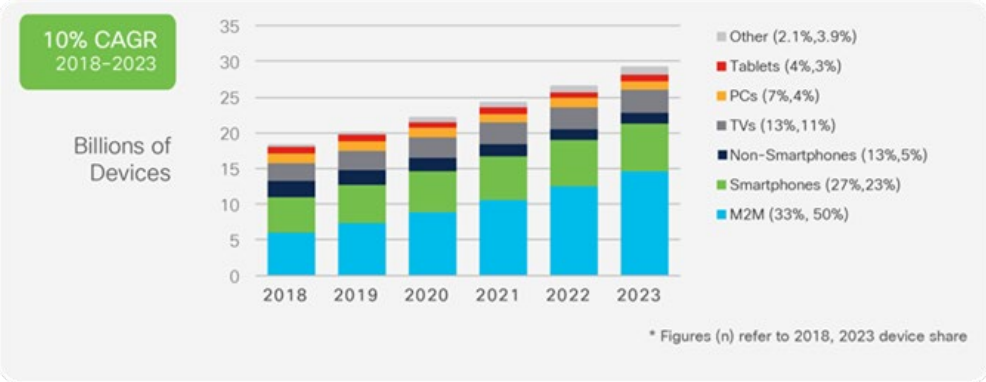



- How it's going



# Why do we need to improve Internet?

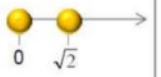
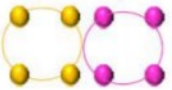
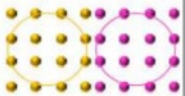
## Support data growth



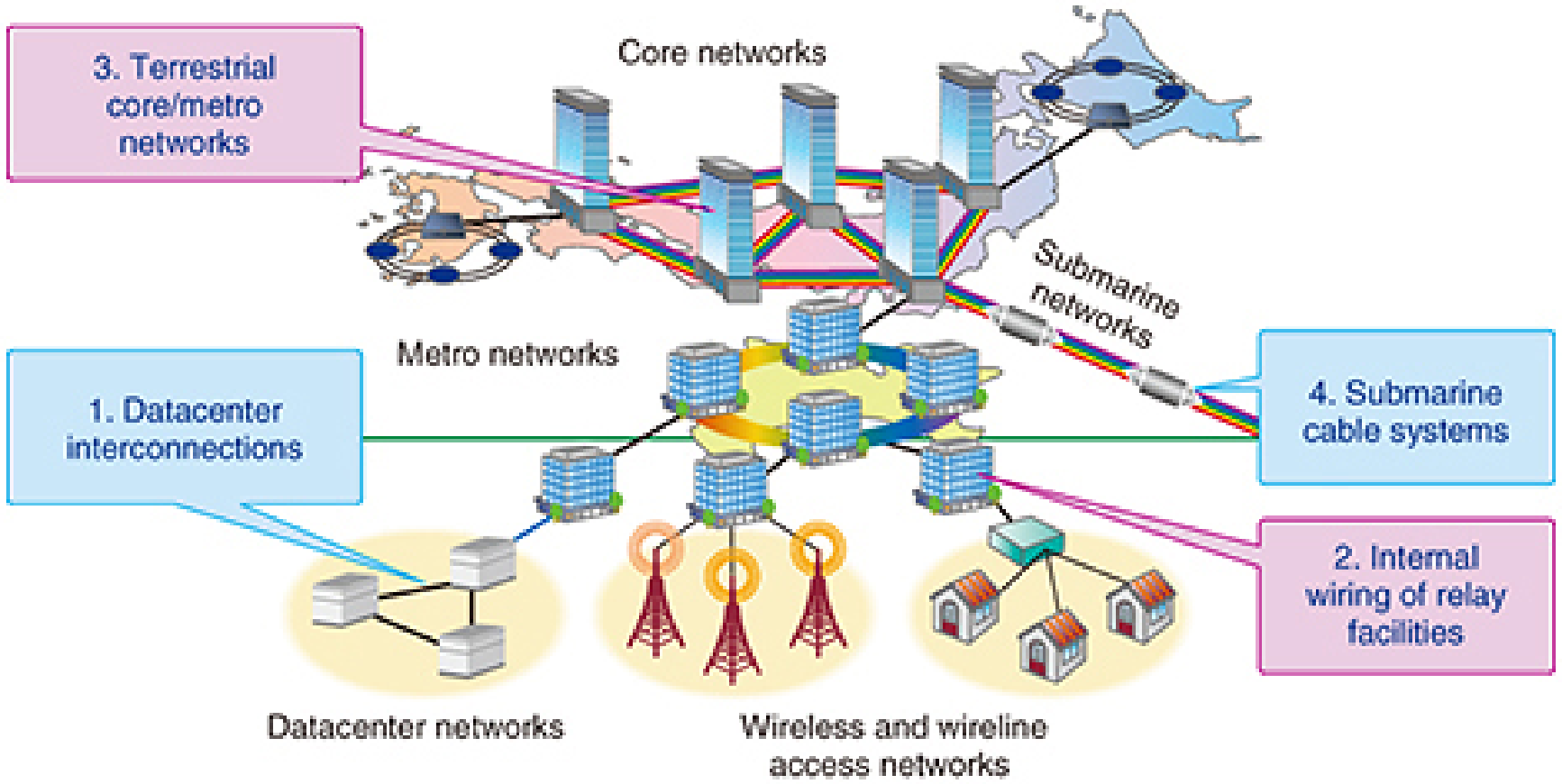

https://www.cisco.com/c/en/us/solutions/executive-perspectives/annual-internet-report/index.html

## Provide data faster

Year: 1980 1990 2000 2010 2020

| Data rate per channel | 2.5 Gb/s | 10 Gb/s | 40 Gb/s | 100 Gb/s | 200G/400G/1T and beyond |
|---|---|---|---|---|---|
| **Modulation format** (typical) | OOK (NRZ)   | OOK (RZ)   | DPSK   DQPSK  | PDM-QPSK   | PDM-16QAM   |
| **System features** (newly added) | Single-span, Single-channel | Multi-span with EDFAs, WDM | DWDM, Raman amplification, and ROADMs | 1:N WSS, CDC-ROADMs | Flexible-grid WDM, M:N WSS |
| **System capacity** (typical) | **2.5 Gb/s** (single channel) | **400 Gb/s** (40 WDM channels) | **1.6 Tb/s** (40 WDM channels) | **8 Tb/s** (80 DWDM channels) | **20 Tb/s** (50 flexible-grid WDM channels) |
| **System reach** (typical) | 100 km (single span) | 1000 km | 1000 km @40G 3000 km @10G | 2000 km @100G | 4000/2500 km @100(200)G |
| **Enabling technologies** | Optical modulation and detection | High-speed modulation, HD-FEC | Differential phase-shift-keying | Coherent detection with ODSP | SD-FEC, PDM-QAM, FTN, Superchannel |

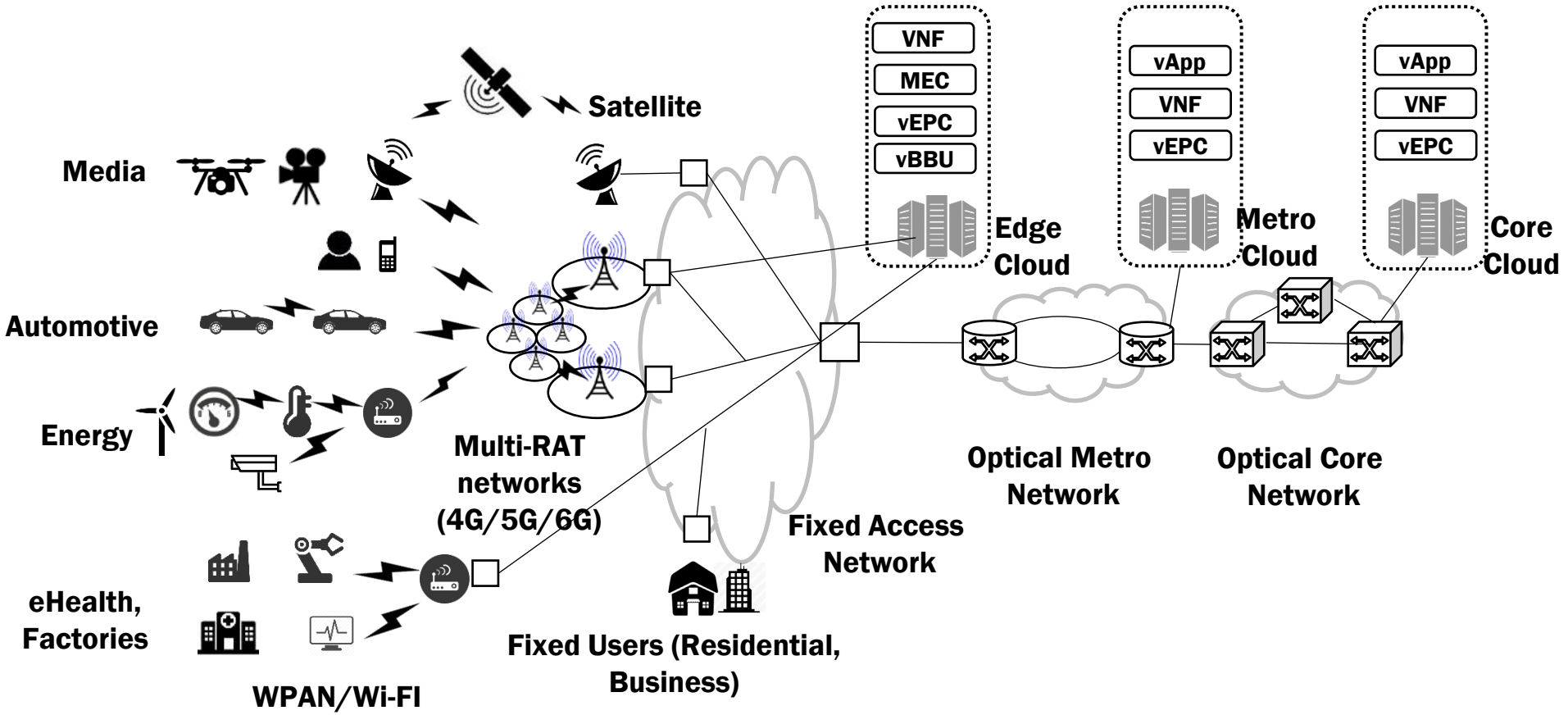
# Optical networks: Flexible, Scalable and Available




https://www.ntt-review.jp/archive/ntttechnical.php?contents=ntr201706fa1.html

# ONS Target scenario

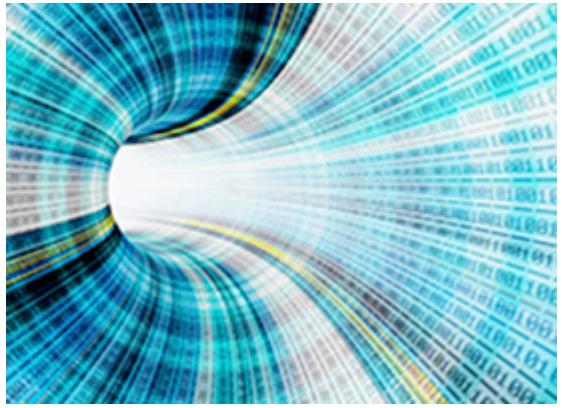
- Future end-to-end transport (packet/optical) networks seamlessly integrated with massive cloud/fog computing and storage services for the **six generation of mobile technology (6G), Internet of Things** (IoT) including **Vehicle-to-everything** (V2X) services.



# ONS Research Lines

- **Network control and service management**:
  - *Control and orchestration of disaggregated transport networks*
  - *End-to-end network service orchestration*
  - *Network service sharing for verticals*

- **Optical transmission and subsystems**:
  - *Advanced photonic transceiver solutions*
  - *Programmable optical transmission*
  - *Optical systems and subsystems for network telemetry and performance analysis*

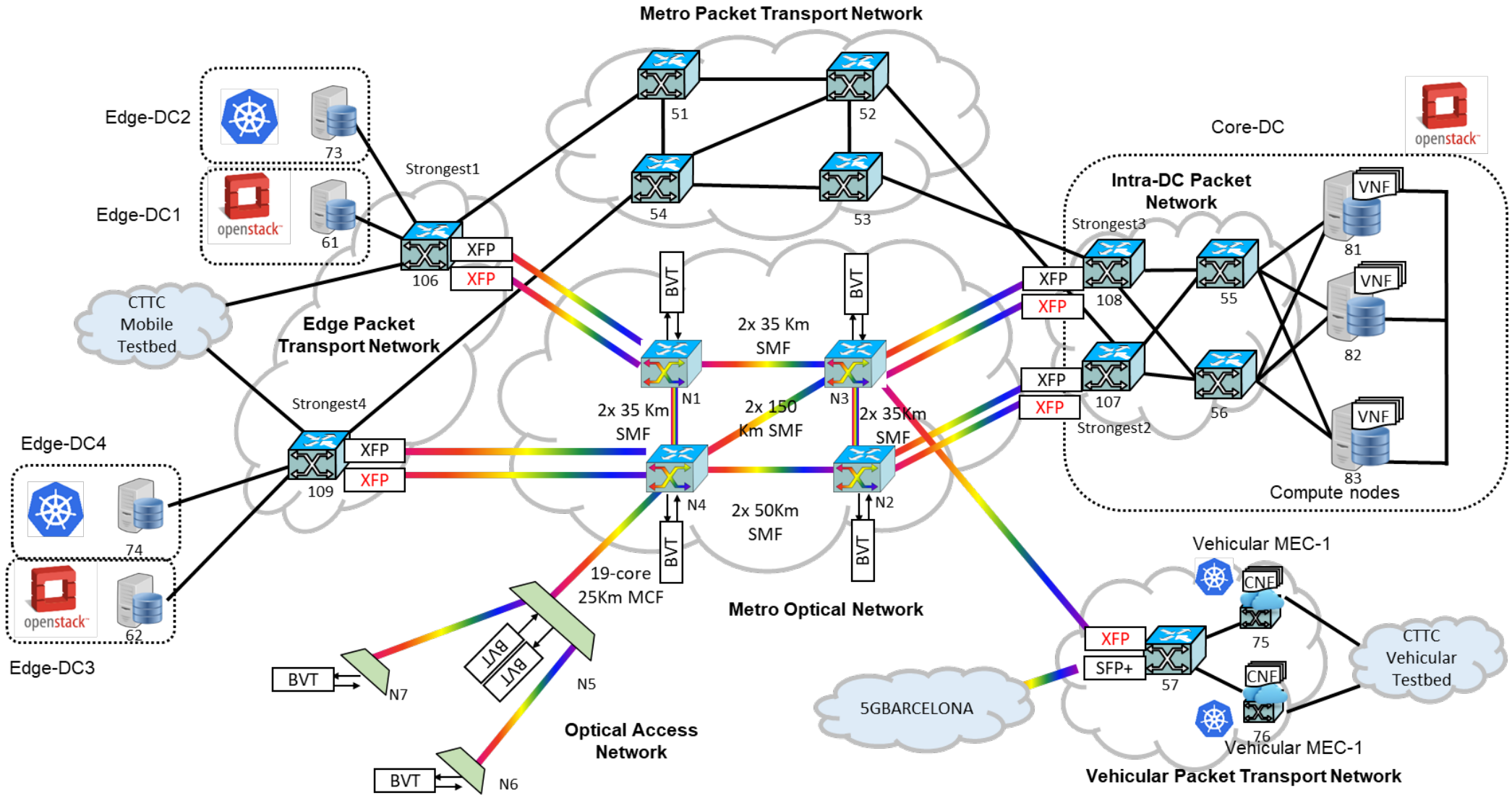


# ONS Experimental activities

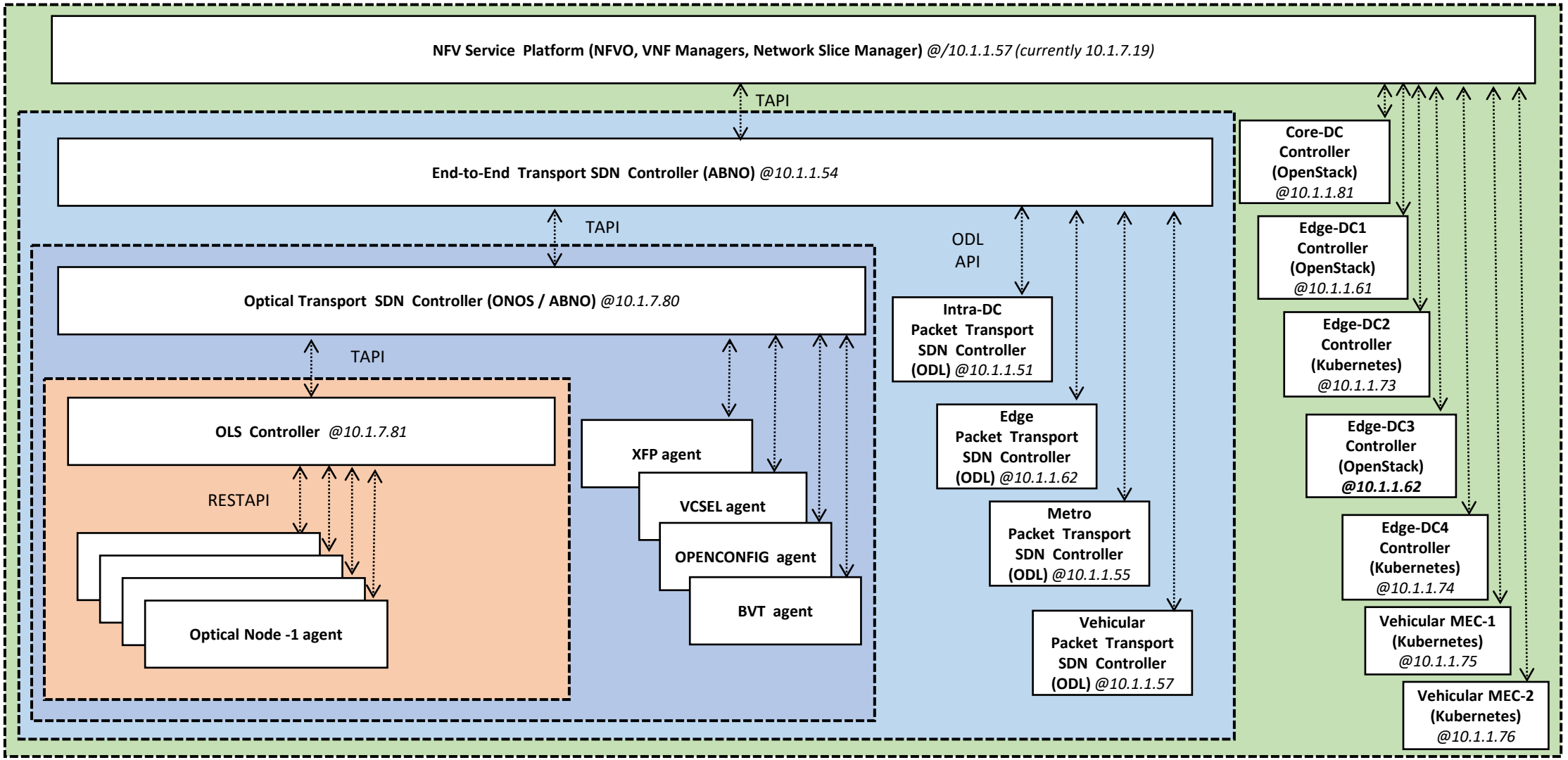
- Demonstration and validation of proof of concepts are performed by means of the ADRENALINE Testbed®, an experimental infrastructure designed and developed by the CTTC ONS Department to conduct cutting-edge research activities in the context of:
  - i) End-to-end SDN/NFV Transport Network and Computing platform for 5G/IoT Services
  - ii) coherent and direct detection Optical OFDM systems for fronthaul and backhaul networks.

http://networks.cttc.es/ons/adrenaline/

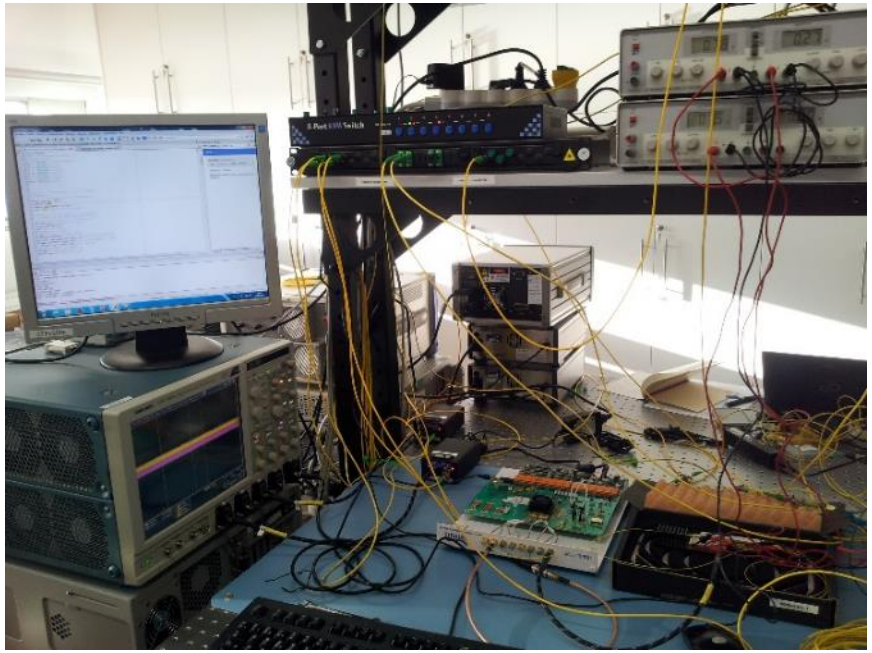
# ADRENALINE's end-to-end transport and cloud infrastructure

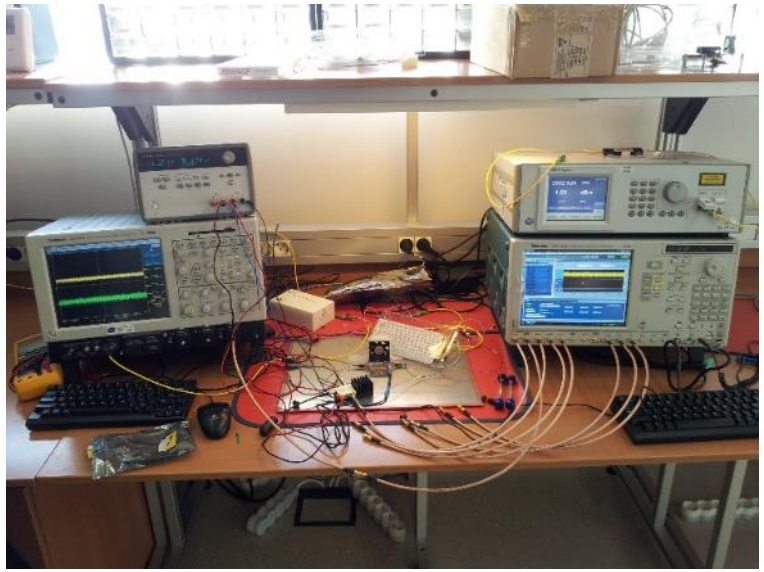


# ADRENALINE's control and orchestration

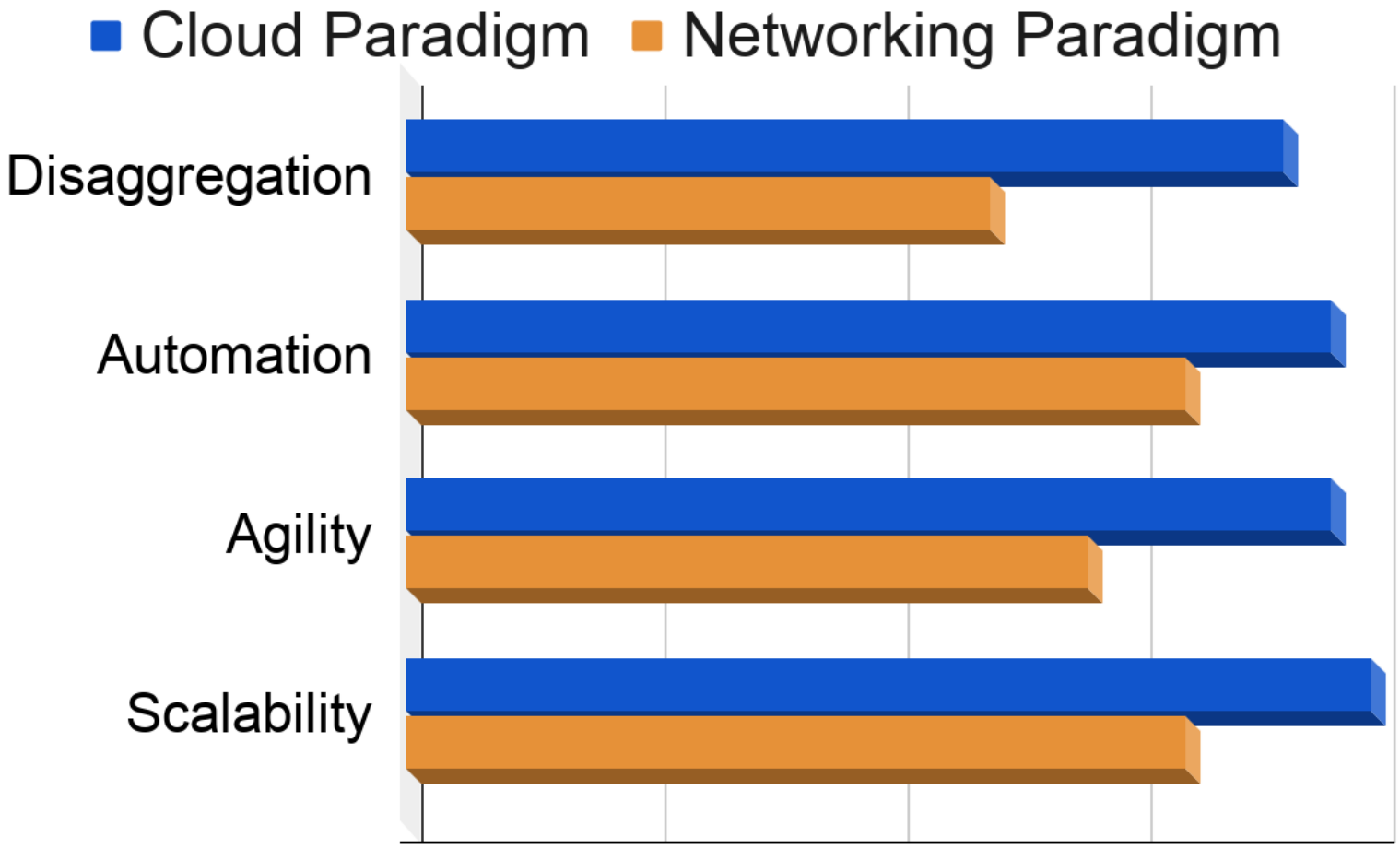


# CTTC ADRENALINE testbed view





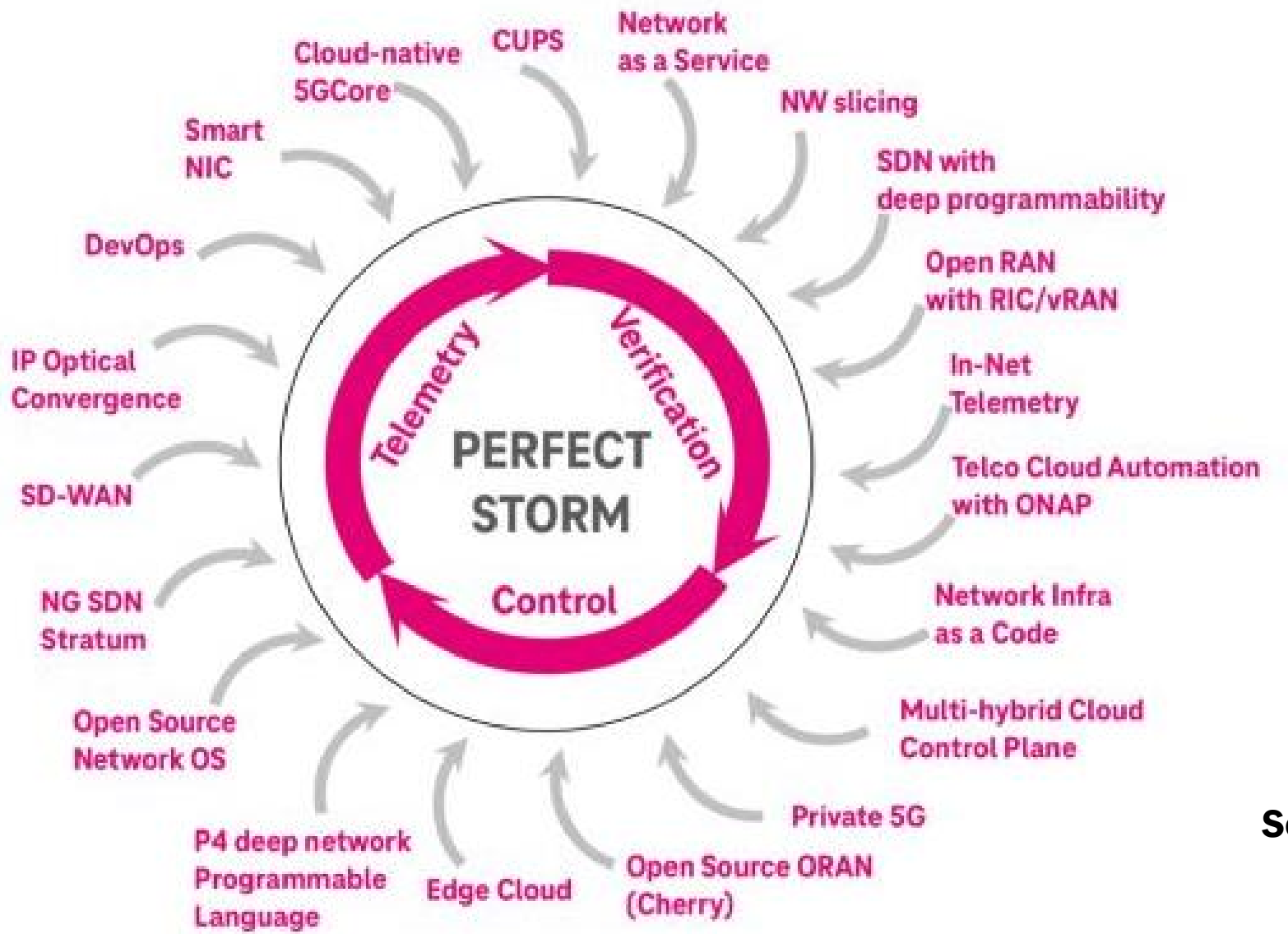
# Motivation




Networking evolution still lags behind (the faster) cloud evolution

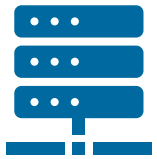
* This figure depicts a relative comparison between important aspects of the Cloud and Network paradigm evolutions

# Networks need automation



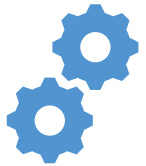

**Source: DT**

# We need a Network Operative System

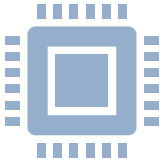


**Use Case Driven for IP and Optical networks**

**Distributed smart connectivity with integrated with (edge) computing and storage resources.**



**Dynamically adaptation based on flows and application requirements**



**Novel interaction between human and digital systems (e.g., In cars, doors, mirrors, appliances, etc.)**

# How should be an SDN Controller?

**Help break vendor lock-in**

**Open-Source Software with Apache License**

**Contributions to other OSS**

# Main Goals

## Today

Status of today's state-of-the-art SDN controllers

- ✗ Mostly monolithic
  - Microservice-based architectures (e.g., µONOS) are planned (not fully-disaggregated yet)
- ✗ Even the best distributed SDN controllers to date may not meet the excessive traffic demands of B5G networks
- ✗ Bridging SDN deployments across multiple transport networks (with multi-access technologies) remains open
- ✗ The connection between a slice and its SLA is still vague
- ✗ Mostly semi-automated deployments

## TeraFlow

TeraFlow bridges the gaps of state-of-the-art SDN controllers

- ✓ Fully-disaggregated cloud-native network OS based on microservices
- ✓ Distributed control plane achieving at least 10x higher flow processing performance
- ✓ Transport-level network slicing for bridging geo-distributed SDN deployments with multi-access technologies
- ✓ Slicing coupled with complex network operator SLAs
- ✓ Fully-automated (zero touch) deployments

# TeraFlow SDN Controller

TeraFlow

TeraFlow

ACCESS

RAN

BACKHAUL

EDGE COMPUTING

IP & OPTICAL TRANSPORT

MICROWAVE

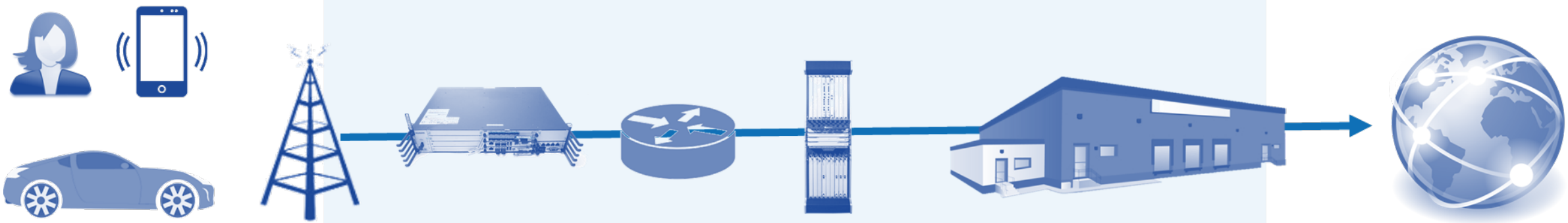
CORE

AI & MACHINE LEARNING

AUTONOMICITY AND NETWORK/COMPUTE INTEGRATION

AI-BASED CYBERSECURITY

TRUSTED MULTI-TENANCY



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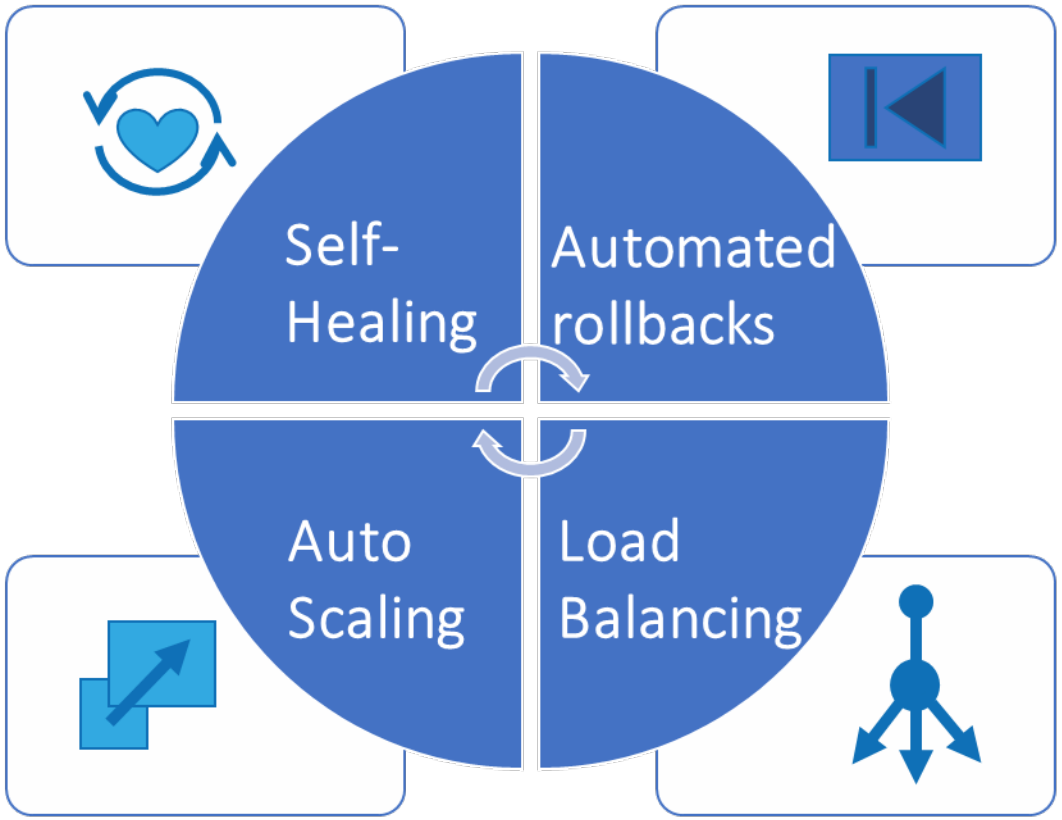
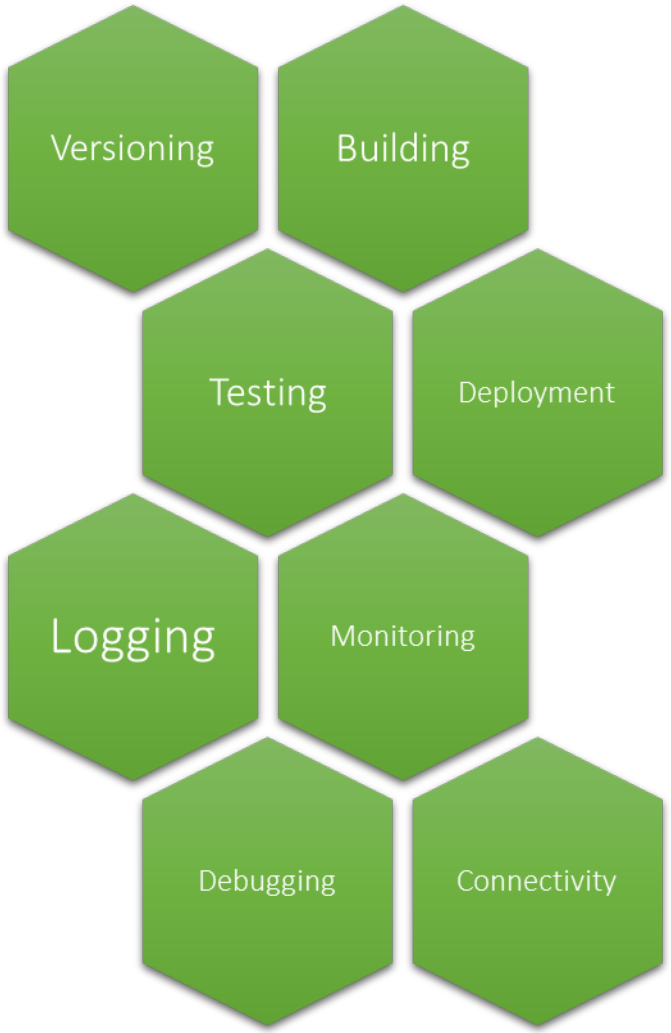
# Cloud-native development benefits and challenges



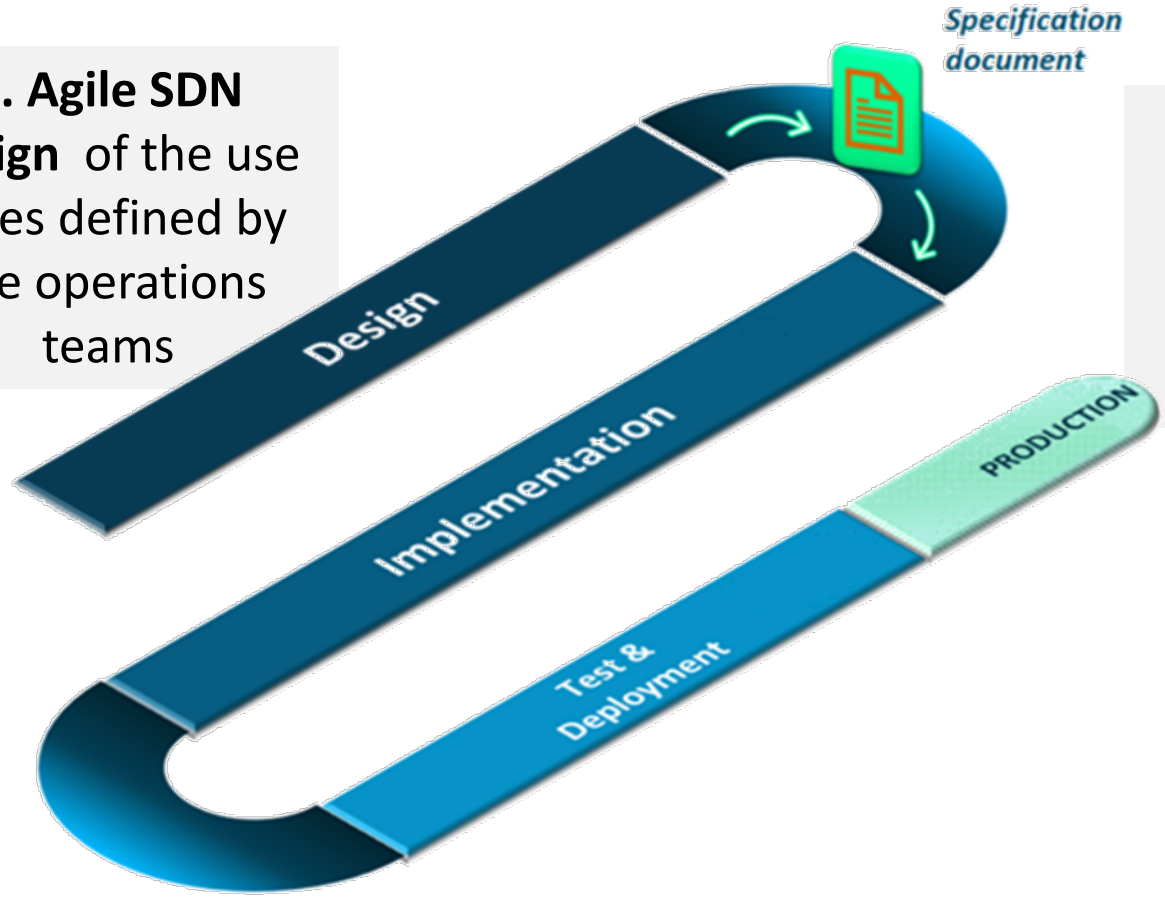




- Mentality Change
- Robust monitoring
- Testing complexity
- Design with failure in mind

# Use case oriented methodology

**1. Improve in small steps**
**Value based** design of next use case **with operations teams**

**2. Agile SDN design** of the use cases defined by the operations teams

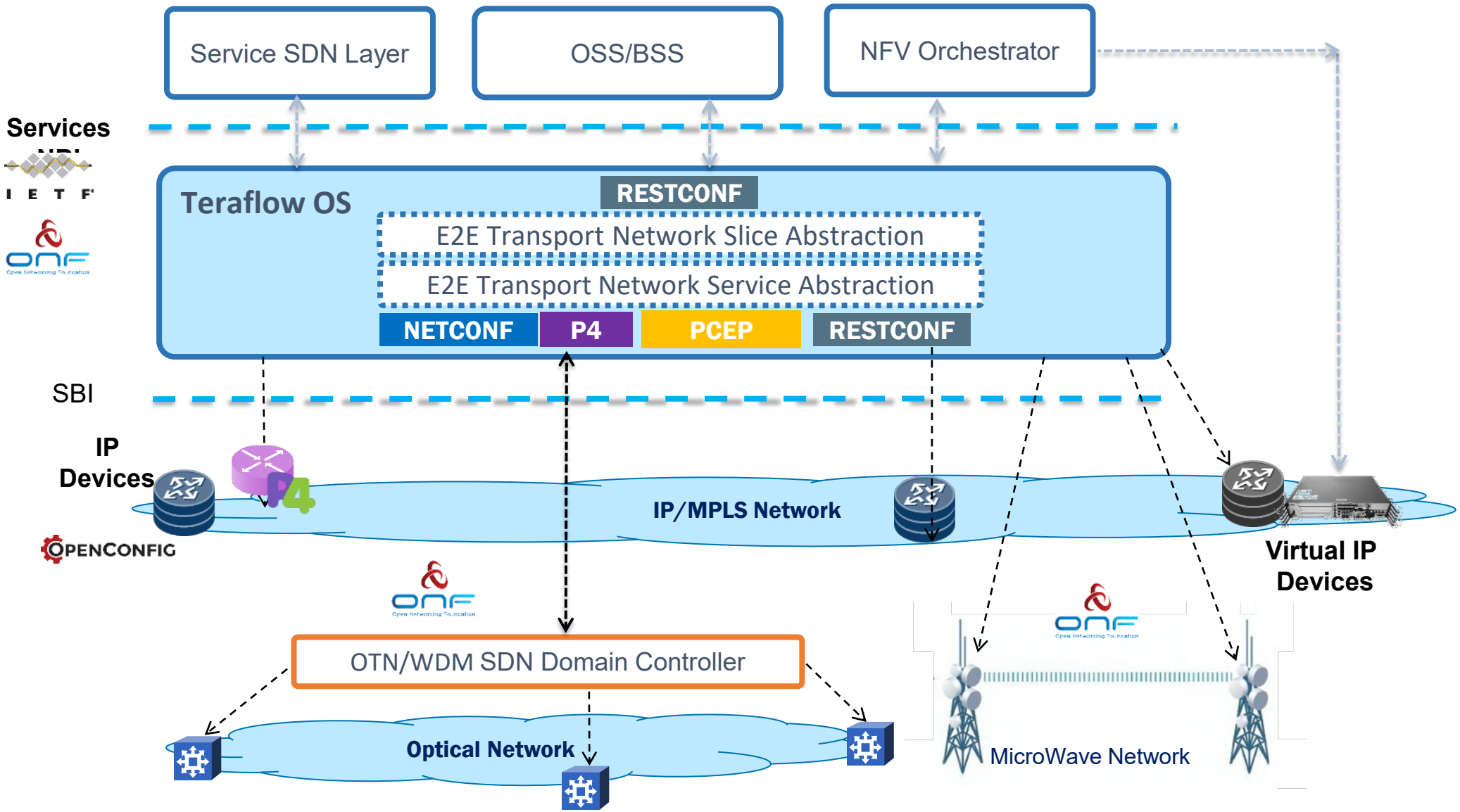



**3. Open Knowledge. Technical specification** based on standard modelling of the use cases

**4. Implementation** as part of vendor product roadmap

**5. Get quick benefits**
Deploy agreed case and make **immediate use** of it

# B5G Network Scenario



# Use Cases – Network Operations Detailed

**1 Topology**

***Service Mapping*** Topology

***Single Layer Topology***

***Multi-Layer*** Topology

***Multi-Domain*** Topology

**2 Inventory**

***Service Catalog***

***Logical Inventory*** Collection

***Hardware Inventory*** Collection

***Host tracking***

**3 Service Lifecycle**

***End-to-End*** Service Provision

***Constrained*** service's provisioning

Service ***Deletion, modification***

***SLA modification***

***IP routing based on IP src/dst***

***Integration with NFV MANO***

**4 Traffic Engineering**

***Automatic Restauration***

Constrains based ***LSP Optimization***

***Protected*** services

Dynamic ***LSP Inventory***

***Optical Impairment*** validation

***Flow QoS specification***

**5 Performance**

***Perfomance*** counters collection

***Telemetry*** Collection

**6 Fault Management**

Multi Dimensional ***Root cause Analysis***

Events collection and ***inteligent grouping***

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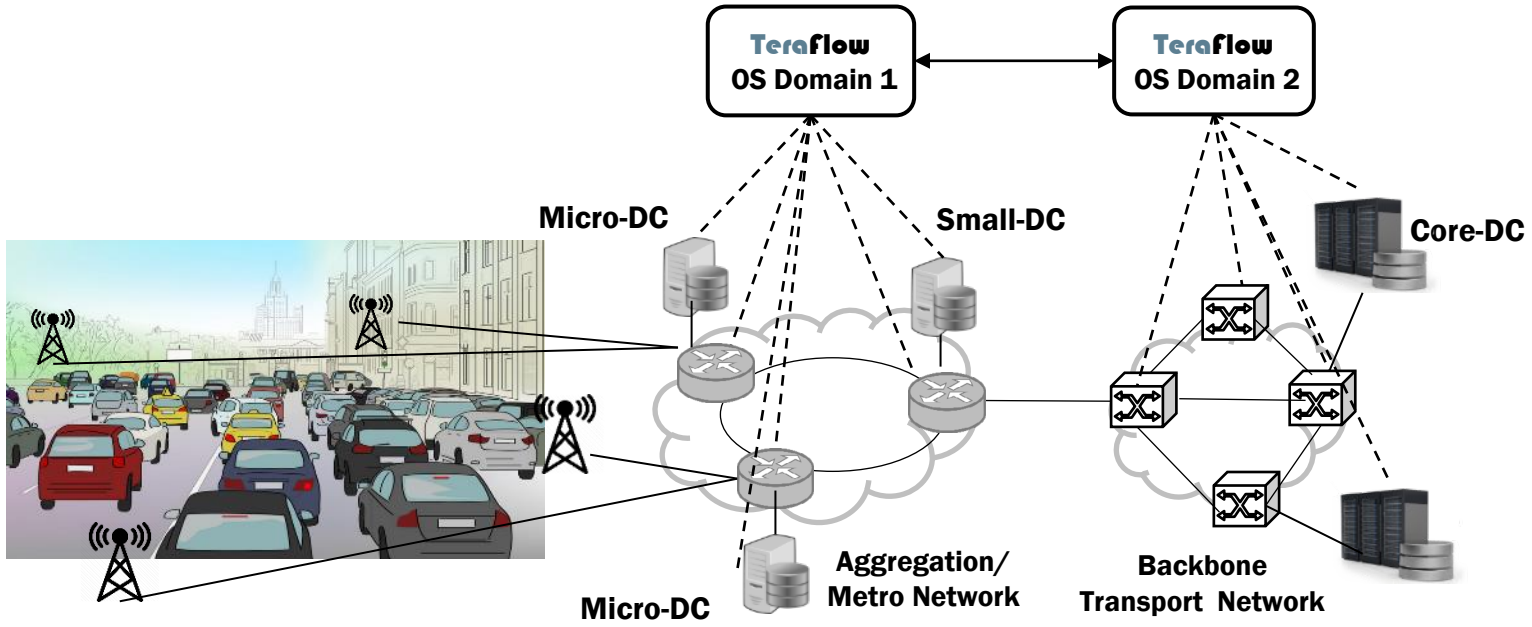
# Automotive Scenario




***Example of Use Cases for this scenario***

***Service Mapping*** Topology

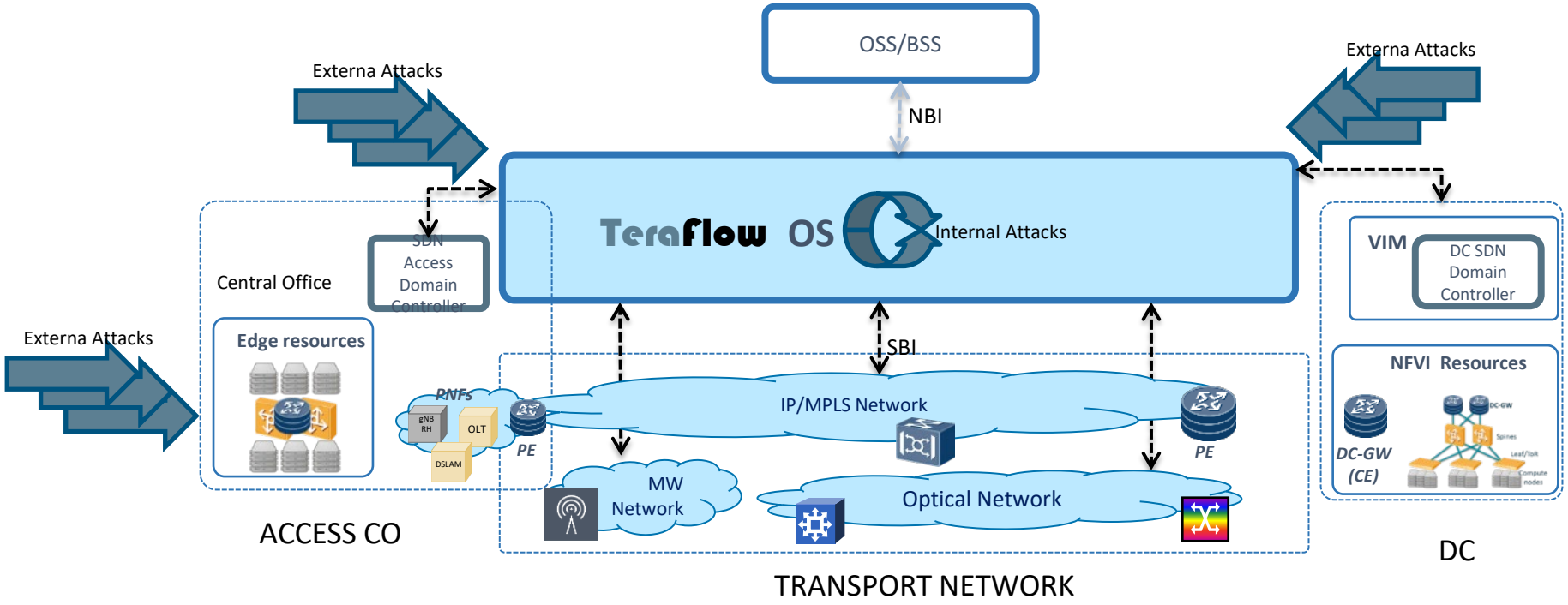
***End-to-End*** Service Provision

***Telemetry*** Collection

***These use cases are common with Beyond 5G Scenario***

***But there may be new ones…***

# Cybersecurity



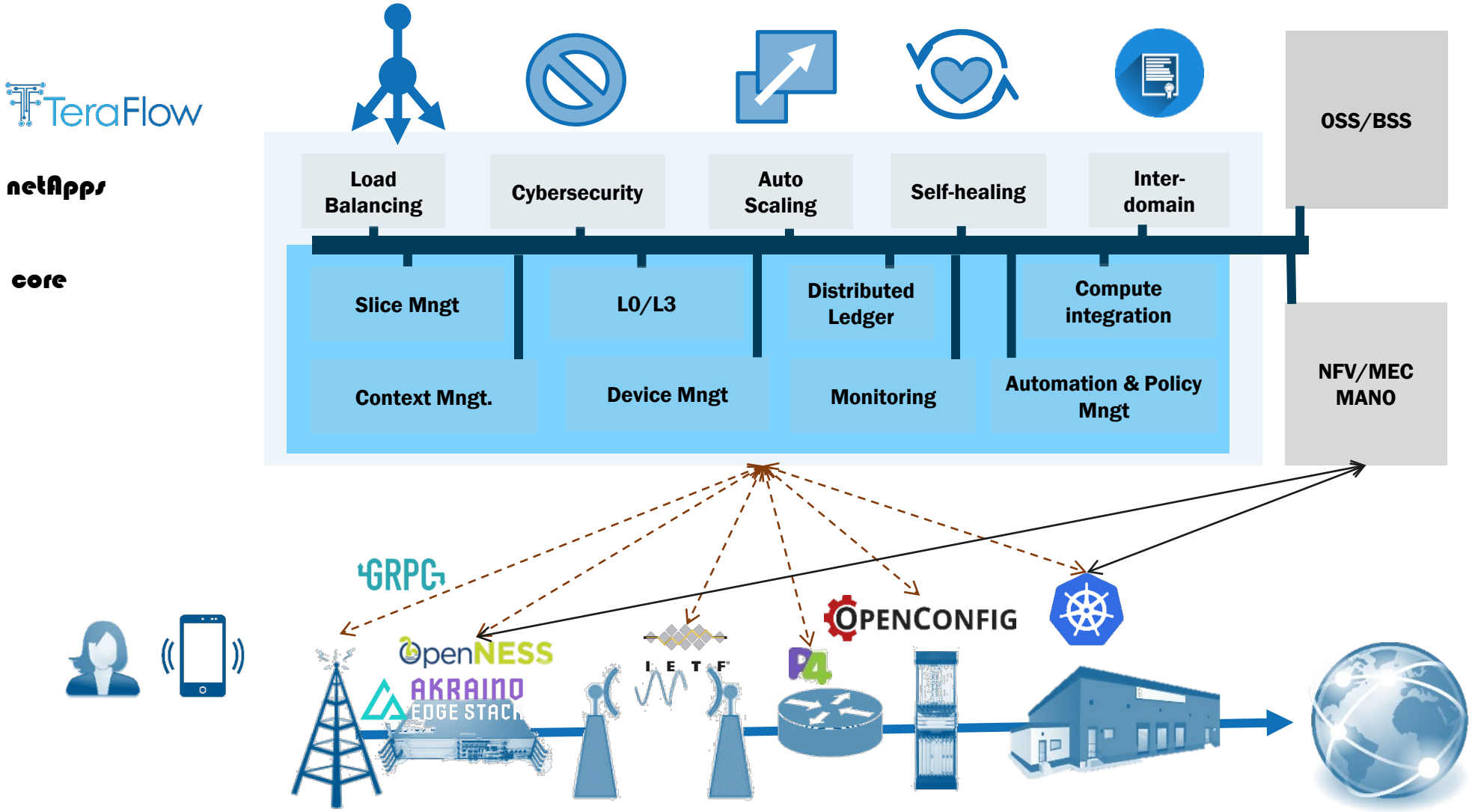

*Categories of use cases*

**Cyberthreat analysis and protection**

**Distributed ledger and smart contracts**

**Interworking across beyond 5G networks**

# TeraFlow architectyre



# Cyberthreat analysis and protection

Cybersecurity solution for protecting TeraFlow infrastructure against attacks at optical/packet layers

Objectives:

- A hybrid central and Edge ML architecture to favor scalability and decrease latency problems
- Machine Learning (ML) to detect attacks at the optical, network, and transport layers
- Protection against sophisticated attacks targeting ML components
- Reduce ML complexity using AutoML techniques

# Distributed ledger and smart contracts

Trustworthy, privacy-aware, and resilient platform for storing, querying, and processing data about network resources and services (e.g., slice requests, device and service configurations, ...)

- Other TeraFlow OS components will use the DL component for critical and sensitive data related to network resources and network management tasks

# Interworking across beyond 5G networks

**Compute integration component:** mechanisms, interfaces, and workflows for lifecycle management (i.e., instantiate, update, release) of compute resources at edge and core cloud locations

i) retrieving information from the compute MANO entities

ii) triggering the placement algorithm to select edge/cloud location and resources fulfilling the service needs

iii) handling the (de-)allocation/update (scaling) of the compute/storage resources interacting with the MANO solution (e.g., OSM)

**Inter-domain component:** data model, protocol, and workflow for communication among TeraFlow OS instances

i) managing the inter-domain links (e.g., allocation of network resources)

ii) gathering abstracted view of remote domains

iii) supporting networking functionalities for requesting/releasing/updating connectivity services to remote domains specifying network service requirements (e.g., maximum tolerated latency, minimum bandwidth, reliability)

# More info


www.teraflow-h2020.eu

@TeraFlow_h2020

www.linkedin.com/company/teraflow-h2020

# Key take-aways

- How are networks organized?
- Why is it necessary to invest in R+D?
- What is an SDN controller?
- Consider CTTC as a follow-up for your studies! We regularly open positions for research assistants, PhD studies, and post-docs.

http://www.cttc.es/career-category/job-openings/

# Thank you! Questions?

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