NFV/SDN & 5G PROJECTS

- Overview
- (Selected) Projects
- Use cases

OVERVIEW OF SDN/NFV PROJECTS (1/3)

Name	Leader and/or Funding	Main Contribution	Focus Areas						Open Source	State
			VNFs	VNFM /EMS	VIM	NFVO	OSS/ BSS	NFVI		
OPNFV	**Linux Foundation**	An integrated and tested open source platform to accelerate the evolution of NFV.			✓			✓	✓	●
OpenMANO	**Telefonica**	A multi-layer orchestration environment for easy creation of complex network scenarios. Facilitates the SDN and NFV integration with cloud services and implements a graphical user interface (GUI)	✓		✓	✓		✓	✓	●
T-NOVA	**European Union**	A novel framework for deploy and management of VNFs (NFV Marketplace) and extend SDN aspects for efficient allocation of IT resources, network slicing, traffic redirection and QoS provision.	✓						?	●
CloudNFV	**Dell, CIMI Corp**	Implementation of multi-operator federated services to provide open access to services. Creates the required environment to composition, deployment, and management features outside the NFV scope.	✓	✓	✓	✓	✓	✓	✓	?
CloudBand	**Alcatel-Lucent**	A platform which facilitates interoperability between different NFV solutions. Besides, it makes use of industry-standard open APIs (e.g. OpenStack and CloudStack) where the software is independent of hardware- and cloud platform.	✓	✓	✓	✓		✓	✓	?
Cloud4NFV	**Portugal Telecom**	Develop an automated infrastructure management platform for NFV and SDN, including the deployment, configuration, and lifecycle management of VNFs with the costumer site domains.	✓		✓	✓			✓	?
ZOOM	**TM Forum**	An architecture based on components (physical and virtual) dynamically assembled into personalized services. APIs to enable automation, scalability, and agility in the virtual ecosystem.		✓	✓	✓	✓		✓	●

OVERVIEW OF SDN/NFV PROJECTS (2/3)

Name	Leader and/or Funding	Main Contribution	Focus Areas						Open Source	State
			VNFs	VNFM/ EMS	VIM	NFVO	OSS/ BSS	NFVI		
CALICO	**Metaswitch Networks**	Helping drive the migration to NFV through a solution for hyper-scale virtual networking in cloud datacenters by interconnecting VMs, Linux containers and bare-metal systems.	✓						✓	●
MCN	**European Union**	Extend the concept of cloud computing beyond data centers towards the virtualization of the main components of a mobile network using pure IP layer technology in order to design the next-generation wireless network technologies.	✓				✓		✓	●
OpenEPC	**Core Network Dynamics**	Build a complete mobile core network platform, offering advanced IP mobility schemes and deployment in several configurations (including cloud environment).	✓					✓		●
ClickOS	**European Union**	A minimalistic, virtualized operating system to run VNFs.	✓	✓					✓	●
Blue-PLANET	**Nuage Networks/Ciena Corporation**	A network orchestration suite to automate new services (from creation to delivery) that can be deployed across multi-vendor and multi-domain environments.			✓	✓	✓			●
Planet Orchestrate	**Cyan**	A multi-domain and multi-technology application for the Blue Planet platform aimed at service orchestration, automation, SDN control, and multi-vendor management capabilities.		✓		✓				?
ECOMP	**AT&T, Linux Foundation**	Enhanced Control, Orchestration, Management and Policy software platform to rapidly accelerate network and cloud innovation.		✓	✓	✓	✓		✓	●
CORD	**ON.lab**	Central Office Re-architected as a Datacenter			✓	✓		✓	✓	●

OVERVIEW OF SDN/NFV PROJECTS (3/3)

Name	Leader and/or Funding	Main Contribution	Focus Areas						Open Source	State
			VNFs	VNFM/ EMS	VIM	NFVO	OSS/ BSS	NFVI		
UNIFY	**European Union**	Develop an automated, dynamic service creation platform which supports networks based on SDN and NFV technologies.	✓						✓	●
Catalyst	**TM Forum**	The orchestration of VNFs is done in accordance with technical parameters and policies dynamically defined.	✓				✓			●
ESO	**Overture, acquired by ADVA (JAN-16)?**	Providing a management and orchestration solution for the entire life cycle of any VNF both for centralized or distributed NFV infrastructures.	✓	✓*	✓	✓				?
ExperiaSphere	**CIMI Corporation**	An open-source model implementation for universal management and orchestration, founded on the concept of service models.	✓	✓	✓	✓	✓	✓	✓	?
OPN	**Cisco**	Includes a services orchestrator, a VNF Manager, and a SDN controller. It aims to guide networks to become more open, programmable and automated infrastructures.		✓	✓	✓				?
OpenNFV	**HP**	Open-source architecture to provide an open end-to-end NFV and SDN infrastructure, has solutions to each of the functional blocks defined in the ETSI standards.		✓	✓	✓	✓	✓	✓	●
5GEx	**European Union**	Cross-domain orchestration of services over multiple administrations or over multi-domain single administrations allowing end-to-end network and service elements to mix in multi-vendor, heterogeneous technology and resource environments.			✓	✓	✓	✓		●

✓* Only VNFM

OVERVIEW OF SDN/NFV PROJECT APPROACHES

		Cloud-Band	Cloud-NFV	ESO	Experia-Sphere	OpenMA-NO	OPN	Open-NFV	OPNFV	Planet Orchestrate	ZOOM
Management approach	Centralized	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Distributed										
	Policy-based	✓	✓	✓	✓	✓	✓	✓		✓	✓
	Self-managed	✓		✓	✓		✓	✓		✓	✓
Management function (FCAPS)	Fault			✓			✓		✓	✓	✓
	Accounting					✓			✓		
	Performance	✓	✓	✓		✓	✓	✓		✓	✓
	Security	✓								✓	✓
Management scope	Functions			✓		✓	✓		✓		✓
	Services	✓	✓	✓	✓	✓	✓			✓	✓
	Network			✓						✓	✓
Managing related areas	SDN	✓				✓	✓		✓		
	Cloud	✓	✓		✓			✓	✓	✓	✓

Source: Rashid Mijumbi, Joan Serrat, Juan Luis Gorricho, Steven Latre, Marinos Charalambides, Diego Lopez. Management and Orchestration Challenges in Network Function Virtualization, IEEE Communications Magazine, Jan., 2016

OVERVIEW

The 5G Infrastructure Public Private Partnership

	Name	M1 = July 2015																																	
		M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	M15	M16	M17	M18	M19	M20	M21	M22	M23	M24	M25	M26	M27	M28	M29	M30	M31	M32	M33	M34	M35	M36
CSA	EURO 5G	Euro-5G																																			
R&I	5G-NORMA	5G NOvel Radio Multiservice adaptive network Architecture																																			
R&I	5G-Xhaul	Dynamically Reconfigurable Optical-Wireless Backhaul/Fronthaul with Cognitive Control Plane for Small Cells and Cloud-RANs																																			
R&I	5G-CrossHaul	Developing an integrated 5G backhaul and fronthaul transport network																																			
R&I	5G-Ensure					5G Enablers for Network and System Security and Resilience																																	
R&I	CHARISMA	Converged Heterogeneous Advanced 5G Cloud-RAN Architecture for Intelligent and Secure Media Access																																			
R&I	COGNET	Building an Intelligent System of Insights and Action for 5G Network Management																																			
R&I	COHERENT	Coordinated control and spectrum management for 5G heterogeneous radio access networks																																			
R&I	FANTASTIC 5G	Flexible Air iNTerfAce for Scalable service delivery wiThin wIreless Communication networks of the 5th Generation																																			
R&I	Flex5Gware	Flexible and efficient hardware/software platforms for 5G network elements and devices																																			
R&I	METIS II	Mobile and wireless communications Enablers for Twenty-twenty (2020) Information Society-II																																			
R&I	mmMAGIC	Millimetre-Wave Based Mobile Radio Access Network for Fifth Generation Integrated Communications																																			
R&I	SELFNET	SELFNET - FRAMEWORK FOR SELF-ORGANIZED NETWORK MANAGEMENT IN VIRTUALIZED AND SOFTWARE DEFINED NETWORKS																																			
R&I	SESAME	Small cElls coordinAtion for Multi-tenancy and Edge services																																			
R&I	SPEED-5G	quality of Service Provision and capacity Expansion through Extended-DSA for 5G																																			
R&I	SUPERFLUIDITY	Superfluidity: a super-fluid, cloud-native, converged edge system																																			
I	5GEx				5G Exchange																																	
I	SONATA	Service Programing and Orchestration for Virtualized Software Networks																																			
I	VirtuWind	Virtual and programmable industrial network prototype deployed in operational Wind park																																			

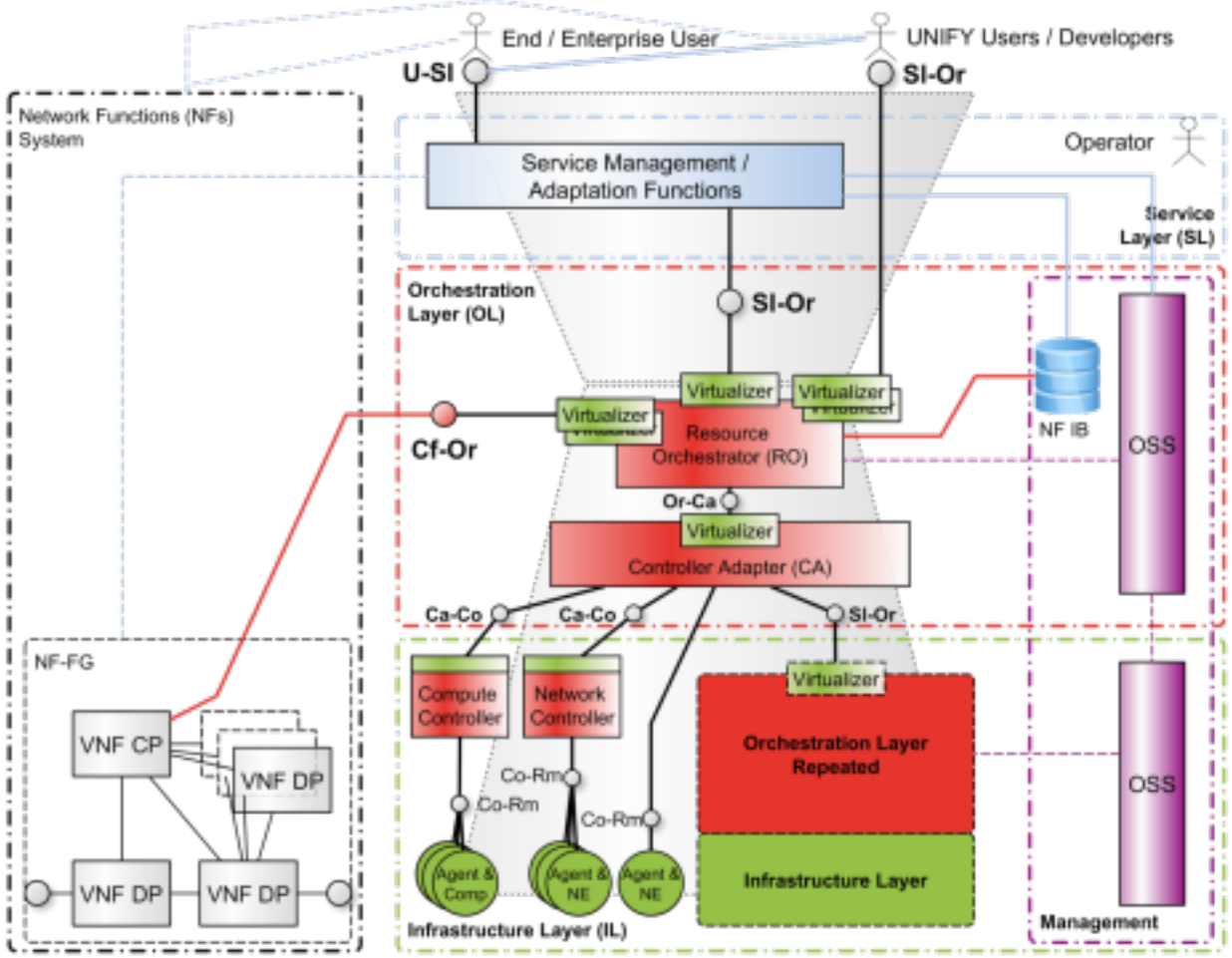
› Source: https://5g-ppp.eu/5g-ppp-phase-1-projects/

UNIFY

- Architecture to unify carrier and cloud services
- Service abstraction model and an associated domain-specific service creation language and programming interfaces to automate and optimize the deployment of service chains
- Advanced management and operation schemes to cope with increased network/service agility and to handle network services end-to-end
- Design and performance of a universal node architecture based on standard x86 components and accelerators for network functions virtualization

UNIFY ARCHITECTURE

unifying cloud
and carrier networks



Source: UNIFY Deliverable 2.2 Final Architecture.pdf

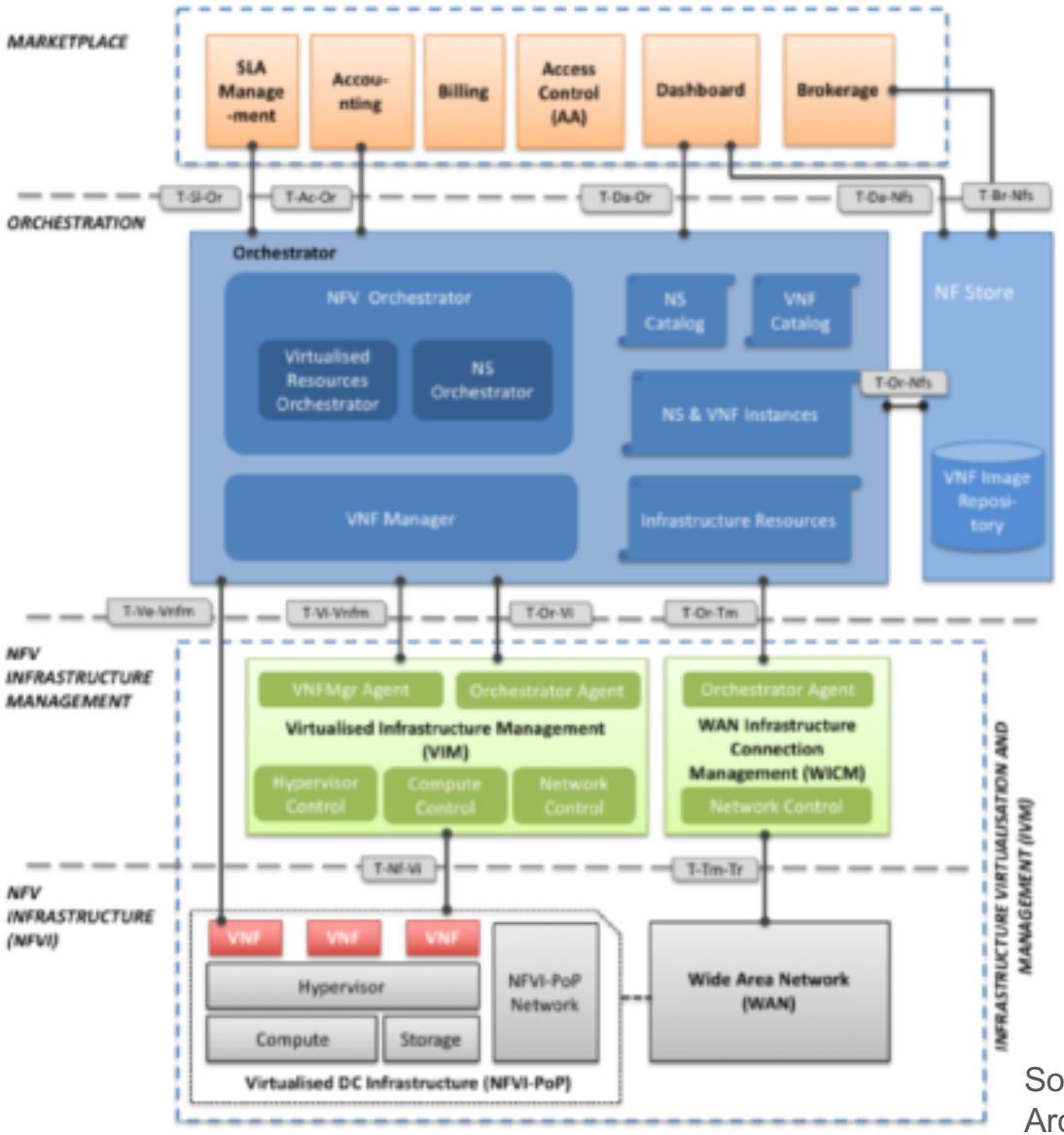
UNIFY

- Approach
  - Service Programming, Orchestration and Optimization: NFs abstractions, description languages, algorithms for automated creation of service chains
  - Service Provider DevOps: agile operations and development aids for dynamic service chains
  - Unified Node Architecture (as an abstracted domain): based on commodity hardware
- Impact
  - Evolve impact of European community in standard organizations (e.g., IETF, ETSI, ONF)
  - Unified service operator resources abstractions

T-NOVA

- Network Functions as-a-Service over Virtualized Infrastructures
- New enabling NFV framework for operators
  - Deployment of NFV concepts
  - Offer to customer value-added services
  - Virtual network appliances on-demand as-a-Service
  - Marketplace for VNFs and services
    - Third party NF development and trading
  - NF resource optimization and elasticity

T-NOVA



TNOVA
NETWORK FUNCTIONS AS-A-SERVICE OVER VIRTUALISED INFRASTRUCTURES

Source: TNOVA D2.22 Overall System Architecture and Interfaces

T-NOVA

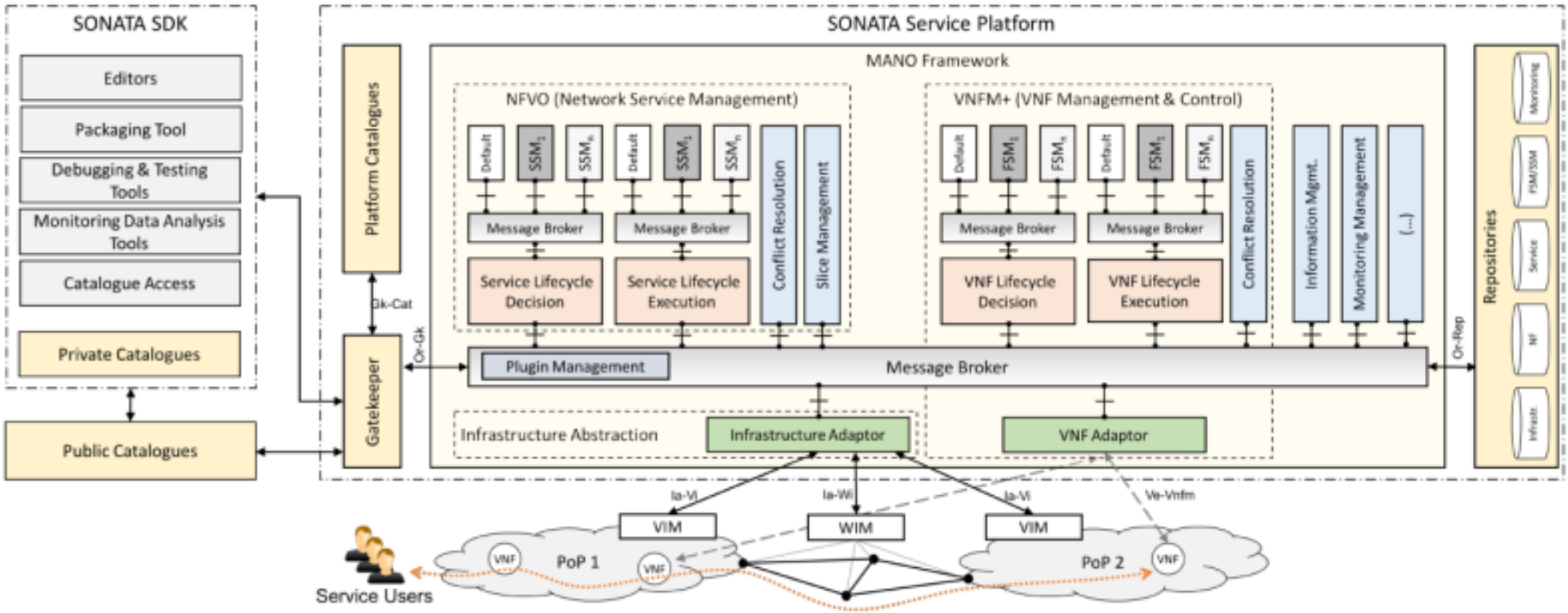
- Approach:
  - Address most of NFV design challenges
  - NFV marketplace (plug-and-play NFs)
  - Brokerage platform for best service bundles selection
- Impact:
  - Boosting competitiveness (NFs in Function Store)
  - Lower operator costs (CAPEX-to-OPEX transformation for more efficient planning)
  - Promote EU standardization (e.g., ETSI)

SONATA

- NFV framework that provides a programming model and development tool chain for virtualized services
  - Network Service SDK
  - Service platform
  - NFV DevOps Workflow

http://www.sonata-nfv.eu/

SONATA ARCHITECTURE



Source: SONATA D2.2 Architecture and Design

SONATA

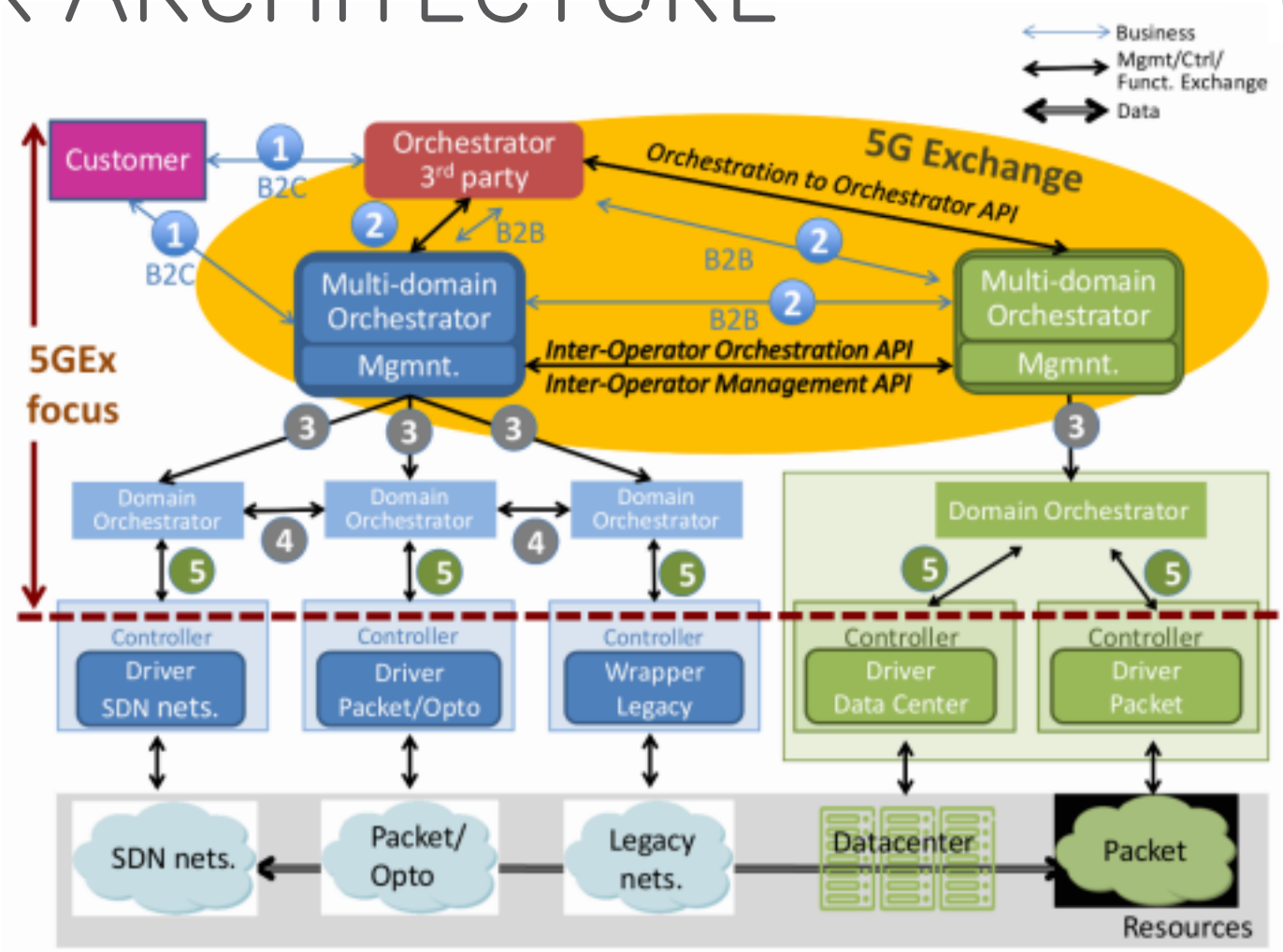
- Approach
  - Modular and Customizable MANO Plug-in Architecture
  - Interoperable and Vendor Agnostic Framework
  - Efficient Network Service Development and NFV DevOps
  - 5G Slicing and Recursion Support
- Impact
  - Reduce time-to-market of networked services
  - Optimize resources and reduce costs of service deployment and operation
  - Accelerate industry adoption of software networks

5GEX

- 5GEx pursues Abstractions and Programmability in Multi-Provider Environments, which are key components for 5G to achieve Service Agility and Service Diversity

- Three dimensions:
  - Intra-operator multi-domain scenarios
  - Multi-operator scenarios
  - Business efficiency

5GEX ARCHITECTURE



Source: http://www.5gex.eu/wp/wp-content/uploads/2015/11/5GEx_eucnc2015.pdf

5GEX

- Approach
  - Achieve a 90-minute services setup
  - Integrate monitoring instances in the developed multi-operator architecture
  - Optimally solve the embedding problem of service requests into multiple operators domains matching SLA requirements
- Impact
  - Proof of innovation multi-domain platform enabling 5G use cases
  - Open source software tools and extensions
  - Standardization and contributions based on concepts and experiments
  - Telecom and IT market to extend 5GEx open solutions

5GEX

- **5GEx: Multi-domain orchestration of software defined infrastructures**

- 5GEx main mission and plans
- Enable business and technical cross-domain service orchestration over multiple administrations,
- Realize composite services by combining cross-domain network, computing and storage resources
- Develop suitable business models for operators to optimally buy, sell, and integrate 5GEx services
- Build and deploy a proof-of-concept system prototype, implementing the “Sandbox Exchange”
- Contribute to relevant standard forums and Open Source communities.

Source: http://www.etsi.org/news-events/events/1025-2016-04-5g-from-myth-to-reality

CORD

Central Office Re-architected as a Datacenter

http://opencord.org

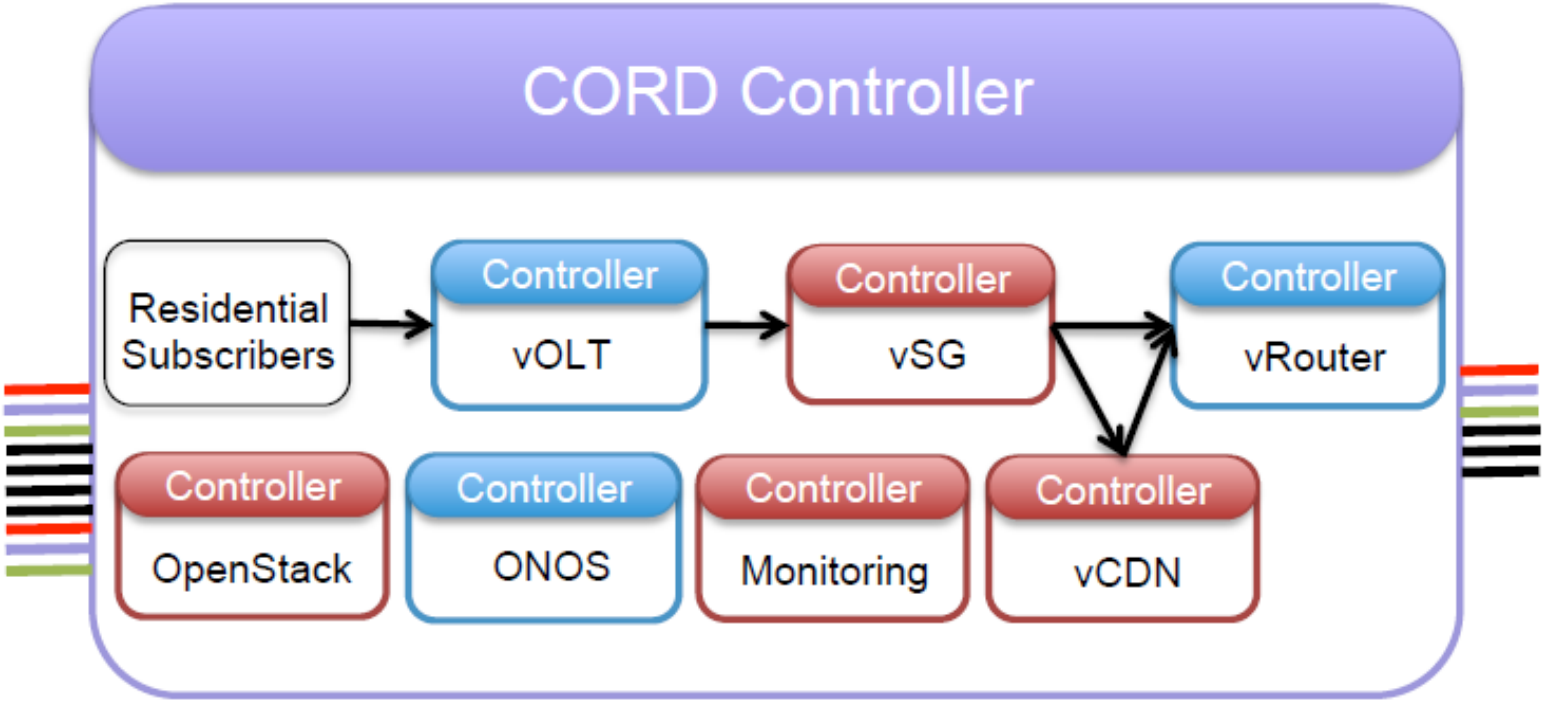
Source Material (extracted from): CORD Summit 2016 - https://wiki.opencord.org/display/CORD/CORD+Summit+--+July+29%2C+2016

CORD

- CORD is a Vision
  - *A common goal the community is working towards*
  - *Start with Business Case -> Reduce to Design Requirements*
- CORD is an Architecture
  - *A collection of abstractions and interfaces*
  - *Start with an Organizing Principle -> Iterate-and-Refine*
- CORD is a Reference Implementation
  - *An integrated system built from concrete components*
  - *Make Technology Choices -> Be More Inclusive with Time*

CORD ARCHITECTURE - SOFTWAR

› Cloud + SDN + NFV = XaaS



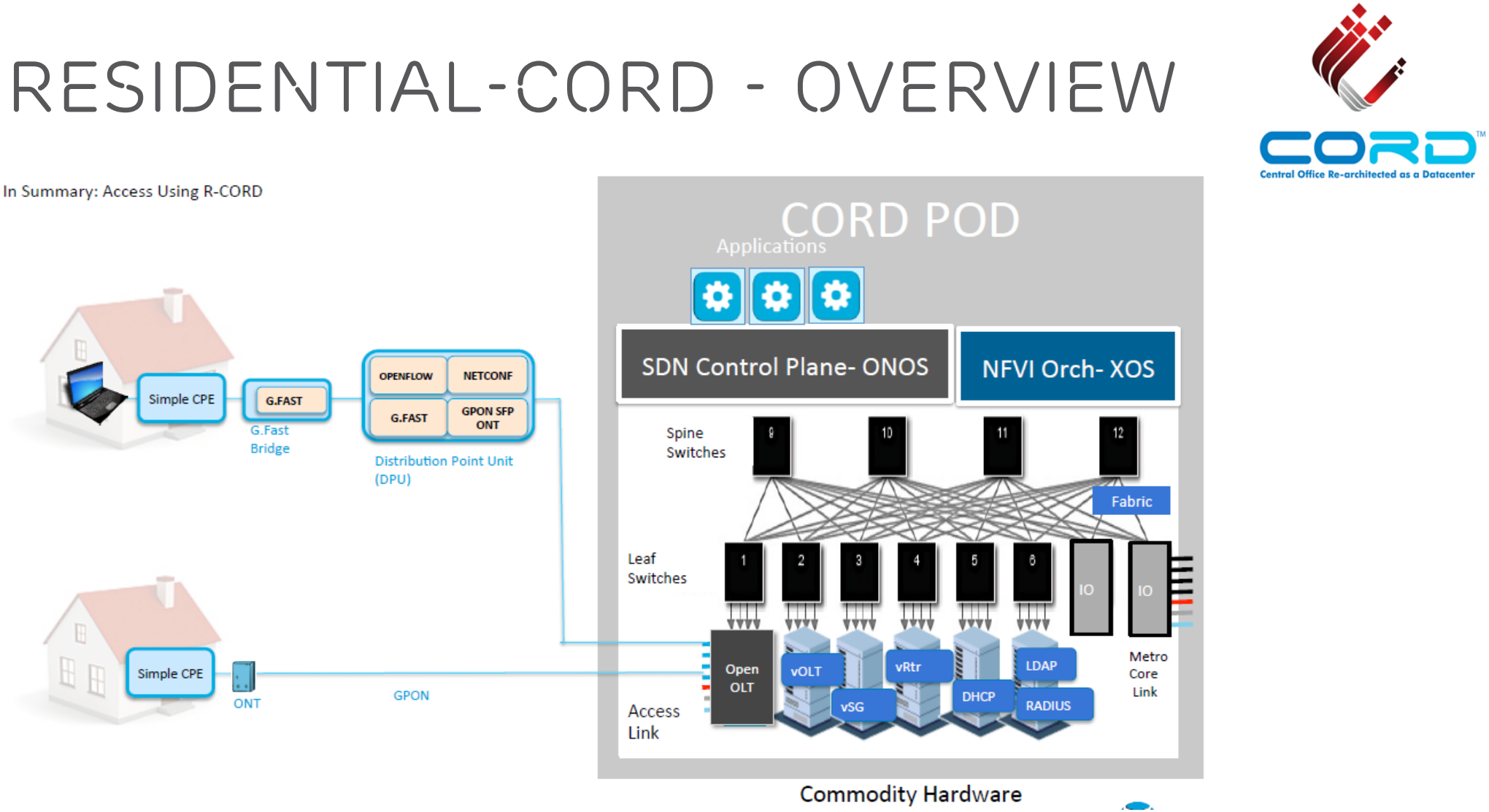
Source (extracted from): CORD Summit 2016 - https://wiki.opencord.org/display/CORD/CORD+Summit+--+July+29%2C+2016

HIGHLIGHTS

- CORD Provides Cloud Economies and Agility
  - Fully Exploits Micro-Services (Access-as-a-Service)
  - Fully Exploits Disaggregation (vOLT -> vSG ->vRouter)
  - Fully Exploits SDN (overlay, underlay, services)
- CORD Controller
  - Assembles services from building block components
  - Exports a unified interface to a collection of services
    - Operators specify service graph (configuration-time interface)
    - Operators and customers control services (runtime interface)

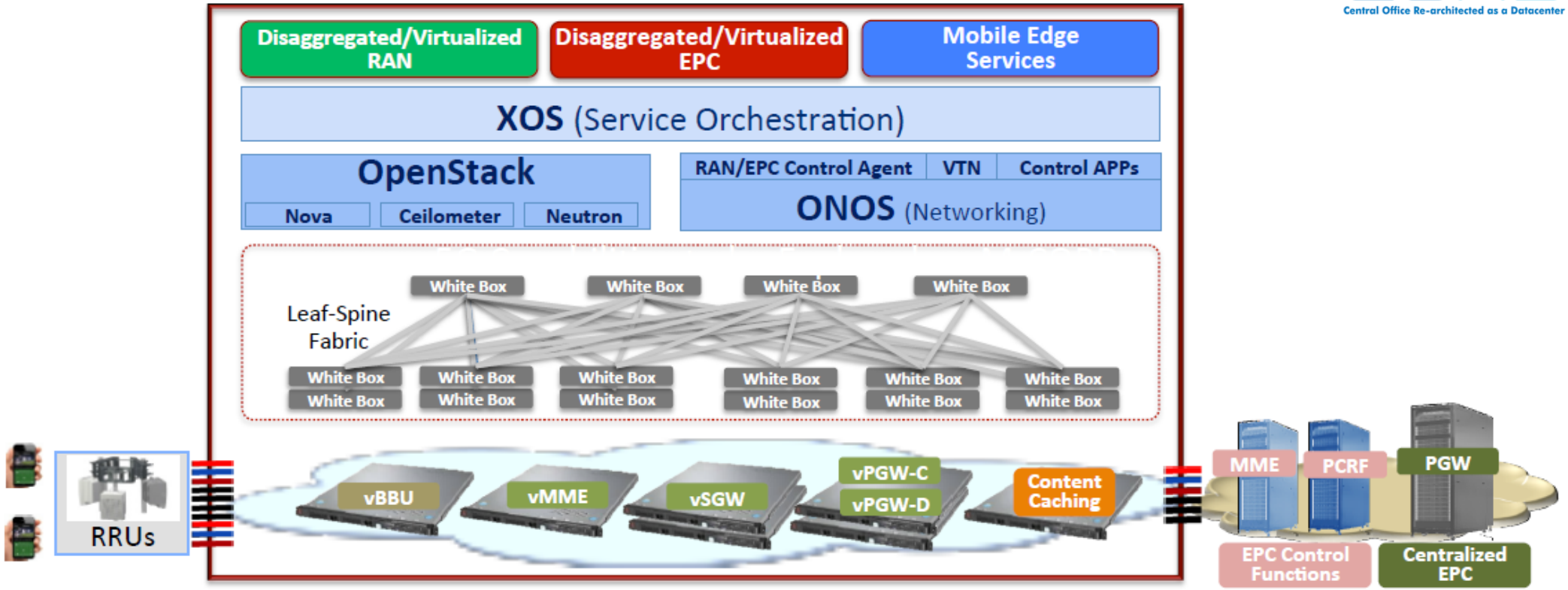
Source (extracted from): CORD Summit 2016 - https://wiki.opencord.org/display/CORD/CORD+Summit+--+July+29%2C+2016

RESIDENTIAL-CORD - OVERVIEW



Source (extracted from): CORD Summit 2016 - https://wiki.opencord.org/display/CORD/CORD+Summit+--+July+29%2C+2016

MOBILE-CORD - OVERVIEW

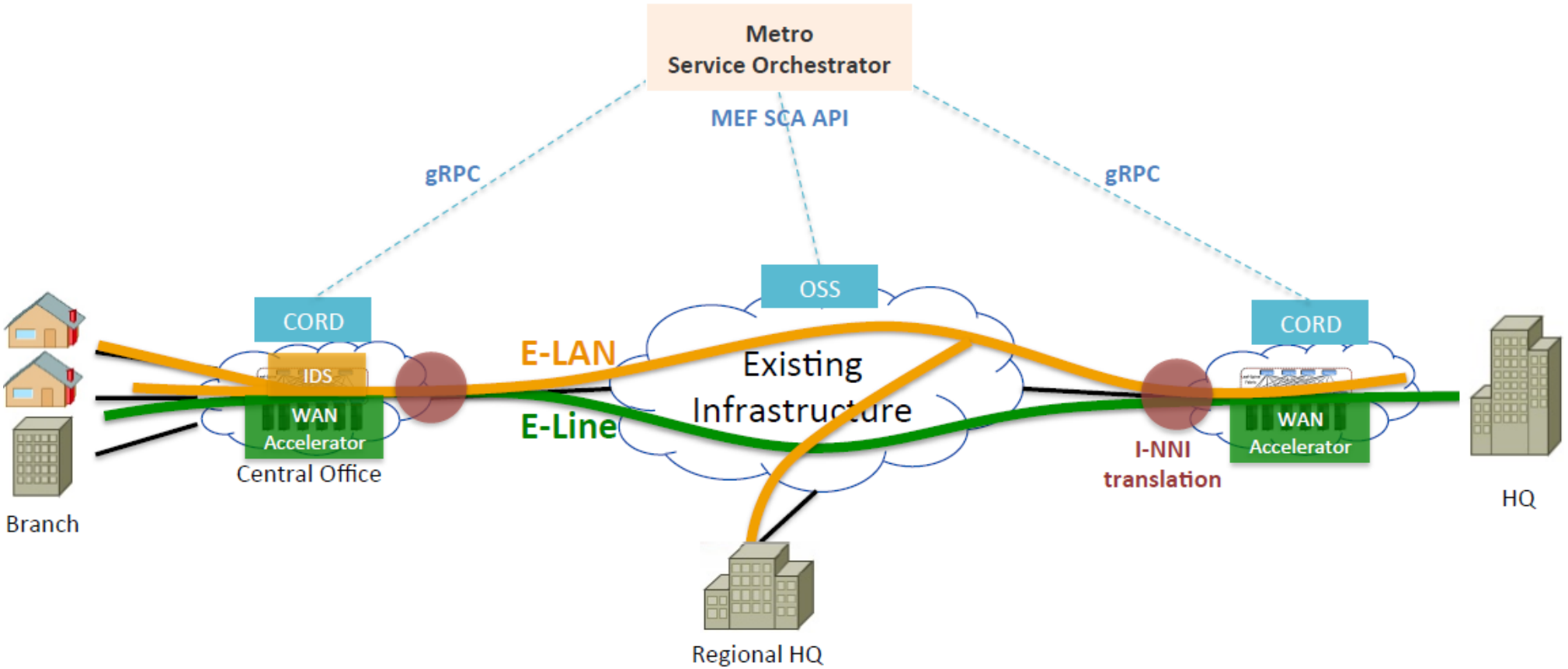


[M-CORD mobile edge]

[Mobile Core]

Source (extracted from): CORD Summit 2016 - https://wiki.opencord.org/display/CORD/CORD+Summit+--+July+29%2C+2016

ENTRERPRISE-CORD - OVERVIEW



Source (extracted from): CORD Summit 2016 - https://wiki.opencord.org/display/CORD/CORD+Summit+--+July+29%2C+2016

ECOMP

Enhanced Control, Orchestration, Management and Policy

[AT&T]

virtualize 75% of our network by 2020.

ECOMP INTRO

- AT&T Domain 2.0 Strategy (SND + NFV + cloud)
  - AT&T Integrated Cloud (AIC)
- Contribute and leveraging open source
  - Cloud Standards (OpenStack, TOSCA, etc...)
- Platform uses micro-services to perform roles
- Does not directly support legacy physical elements

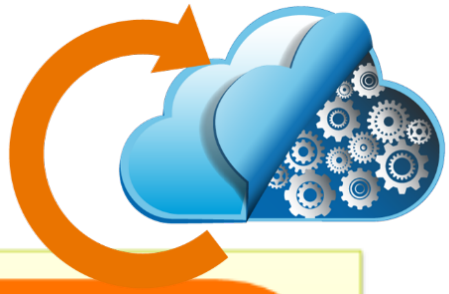
Source (extracted from): http://about.att.com/content/dam/snrdocs/ecomp.pdf

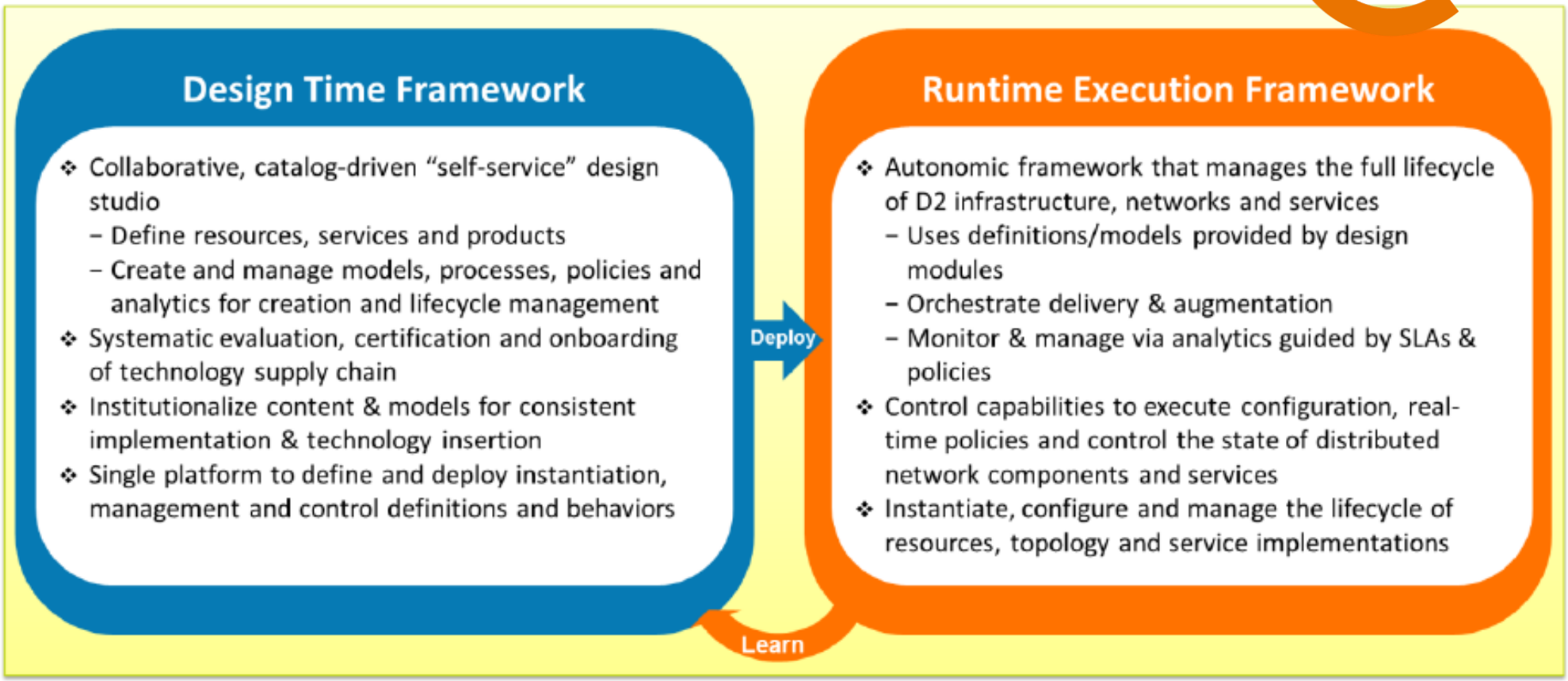
PLATFORM PRINCIPLES

- The architecture will be metadata-driven and policy-driven to ensure flexible ways in which capabilities are used and delivered
- The architecture shall enable sourcing best-in-class components
- Common capabilities are ‘developed’ once and ‘used’ many times
- Core capabilities shall support many AT&T Services
- The architecture shall support elastic scaling as needs grow or shrink

Source (extracted from): http://about.att.com/content/dam/snrdocs/ecomp.pdf

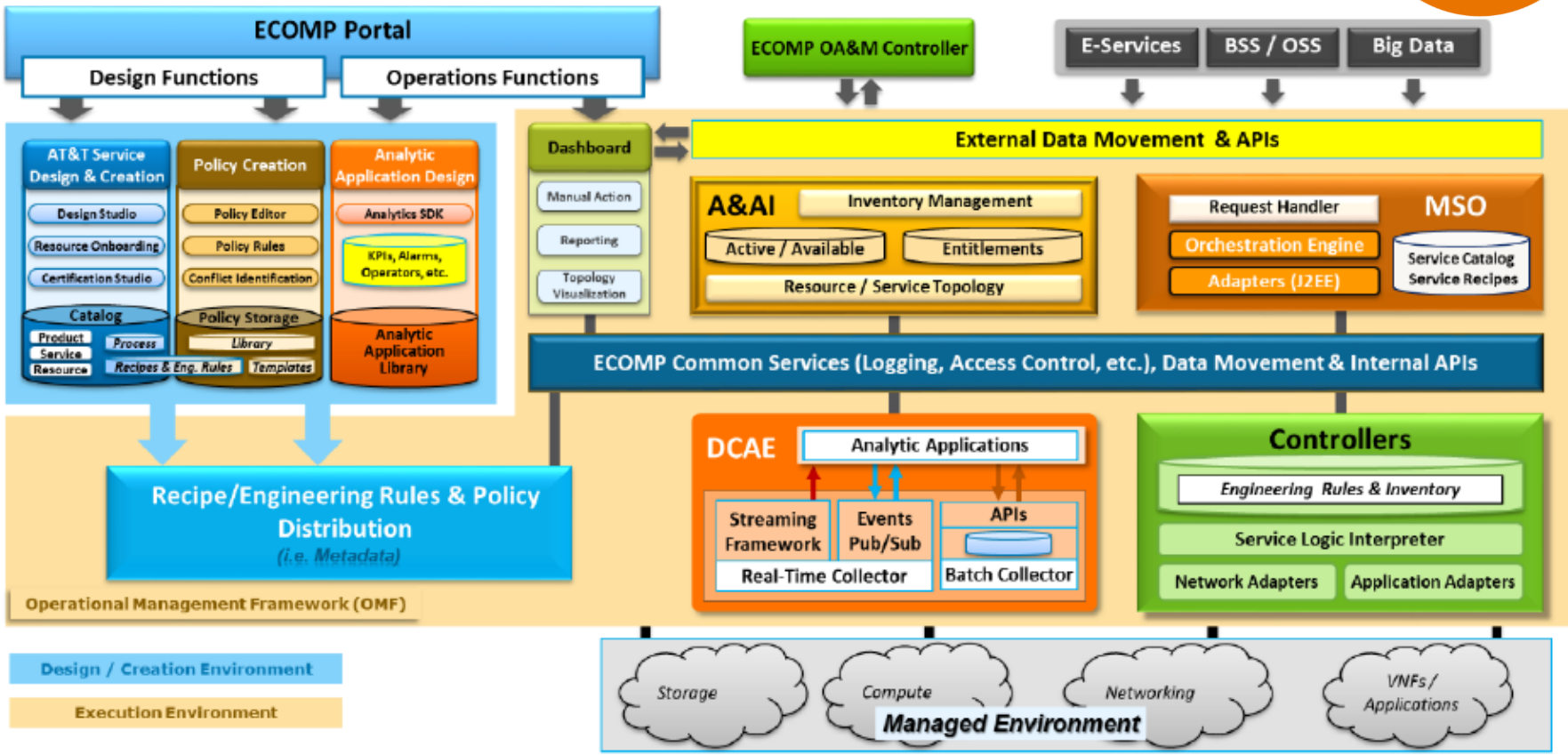
ECOMP PLATFORM





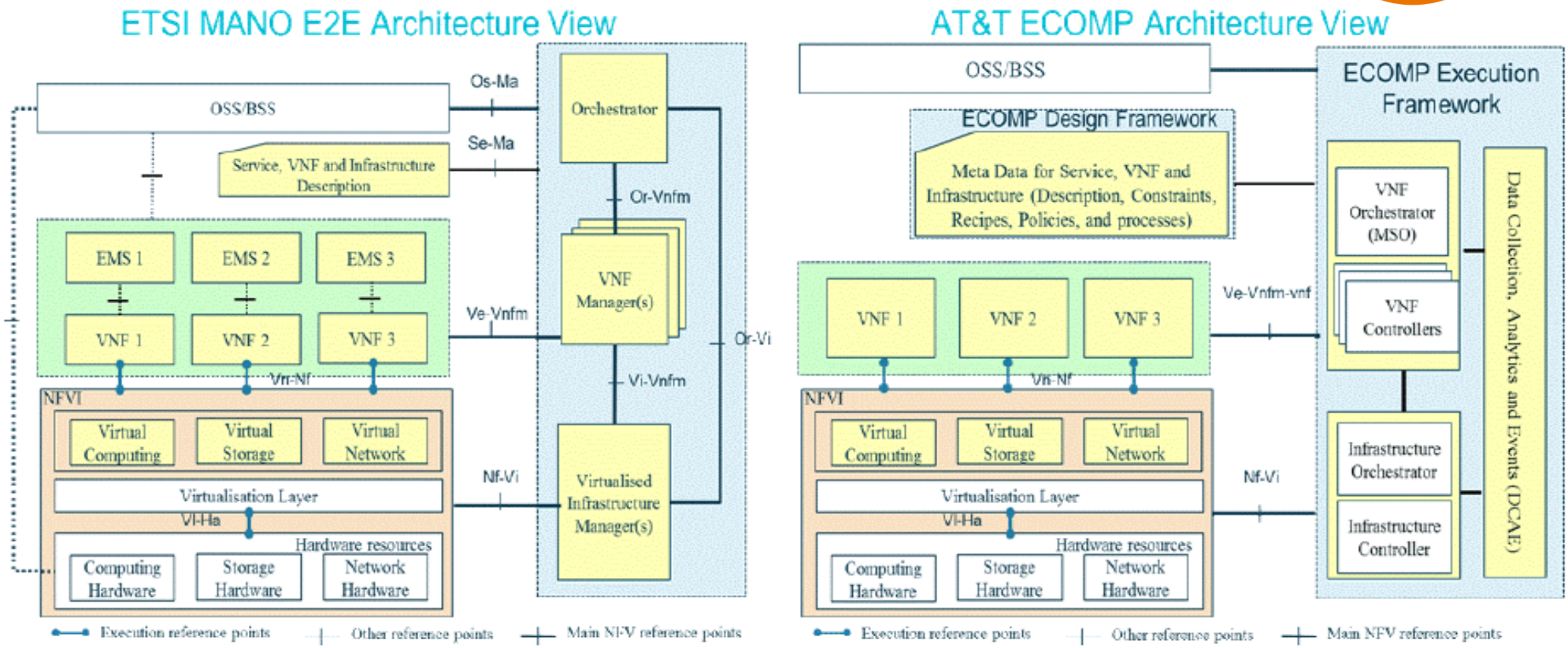
Source (extracted from): http://about.att.com/content/dam/snrdocs/ecomp.pdf

ECOMP PLATFORM COMPONENTS



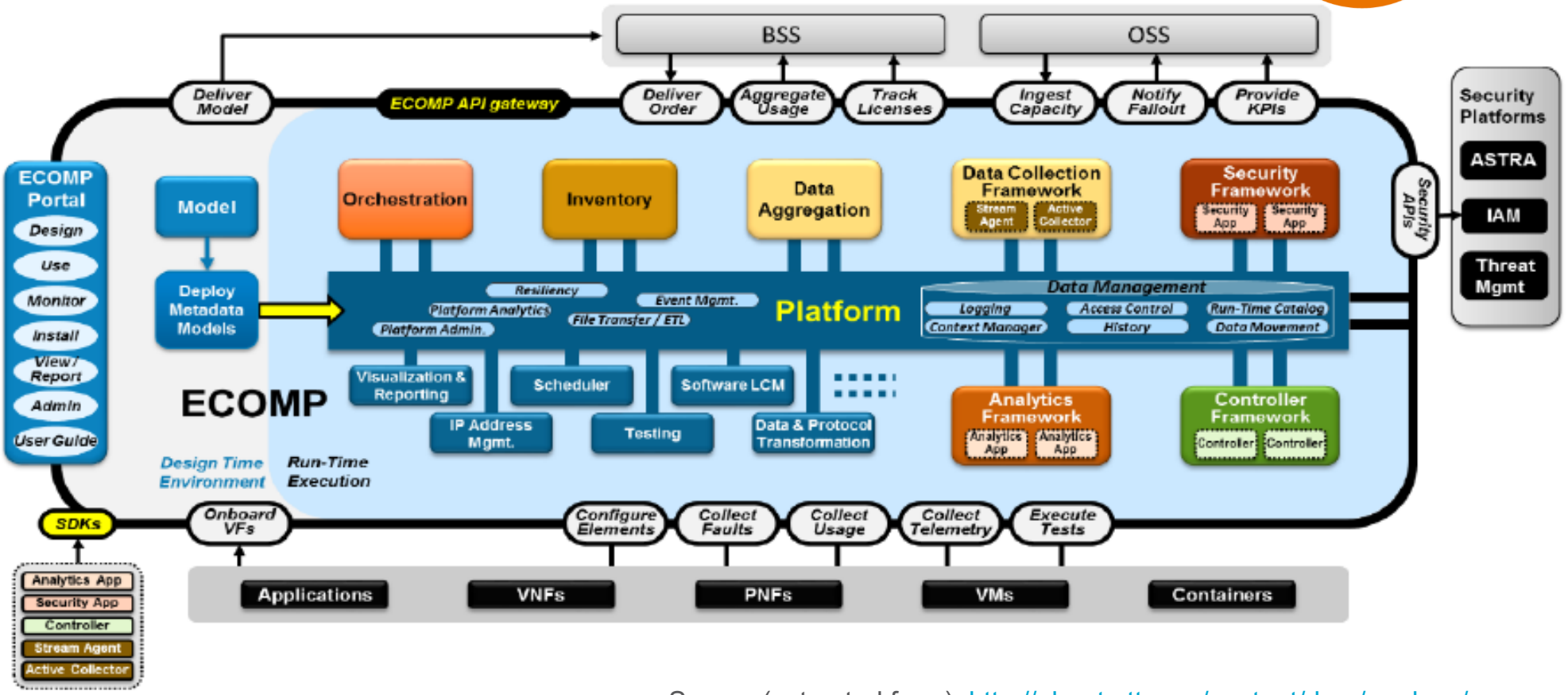
Source (extracted from): http://about.att.com/content/dam/snrdocs/ecomp.pdf

ETSI MANO AND AT&T ECOMP ARCHITECTURES COMPARISON



Source (extracted from): http://about.att.com/content/dam/snrdocs/ecomp.pdf

ECOMP PLATFORM DECOMPOSITION



Source (extracted from): http://about.att.com/content/dam/snrdocs/ecomp.pdf

HIGHLIGHTS

- **ECOMP Platform** assists 74 deployed AT&T Integrated Cloud nodes
- Agile development and holistic architecture
- Designed and built for real-time workloads at carrier scale
- Portal for user's role configuration
- Active and Available Inventory keeps resources updated
- Service Catalog supporting multiple types of data input (e.g., Yang, TOSCA, Heat, Yaml, etc)

FURTHER PROJECTS

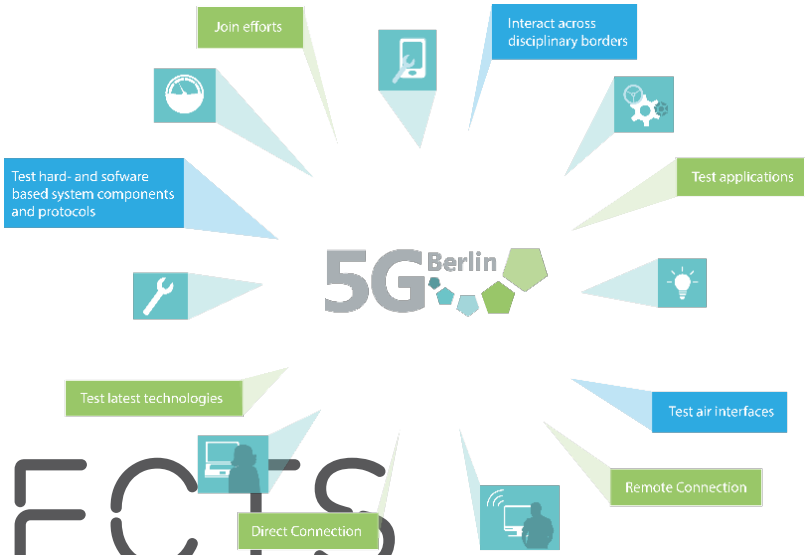


Image source: http://www.5g-berlin.org

(incomplete list of) Related Work

https://5g-ppp.eu/5g-ppp-phase-1-projects/

FURTHER PROJECTS

- **SUPERFLUIDITY : achieving superfluidity in the Internet: the ability to instantiate services on-the-fly, run them anywhere in the network (core, aggregation, edge) and shift them transparently to different locations** http://superfluidity.eu
- Data plane processing architecture: A flexible, open and programmable 5G data plane processing architecture and relevant APIs for network functions' convergence
- Converged 5G platform
- New Algorithms and functions
- Ultra-fast and efficient virtualization
- Hardware adaptation and abstraction
- Control and provisioning framework
- Security framework
- Contribution to standardization

Source: http://superfluidity.eu

FURTHER PROJECTS

- **CogNet : An NFV/SDN based architecture for Autonomic 5G Network Managment using Machine Learning**
  http://www.cognet.5g-ppp.eu/
- Machine learning Smart Engine for traffic patterns analysis and computation of network situational context
- Infrastructure virtualization based on NFV framework
- infrastructure network resource optimization – Prediction of failure and self-healing of network services
- dynamic SLA enforcement in a NFV-SDN based architecture

Source: http://www.etsi.org/news-events/events/1025-2016-04-5g-from-myth-to-reality

FURTHER PROJECTS

- **SELFNET: Self-organized Network Management for 5G through Virtualized andSoftware Defined Networks**
  https://5g-ppp.eu/selfnet/
- A framework for automated network service provisioning and monitoring, capable of automated deployment of network management tools, which maximises advantages of SDN, NFV, Cloud computing, Self-organizing networks, and Artificial intelligence
- Three key network management problem areas to tackle: Self-protection against distributed cyber-attacks; Self-Healing for increased resiliency of 5G networks to network failures; Self-optimization to dynamically improve the performance of the 5G network and the QoE for users.
- Market potential and societal benefits through improved users' quality of experience, more secured and resilient mobile services and applications

Source: http://www.etsi.org/news-events/events/1025-2016-04-5g-from-myth-to-reality

FURTHER PROJECTS

- **5G-Crosshaul: Next generation of fronthaul/backhaul integrated transport network** http://5g-crosshaul.eu/
- Integration of fronthaul and backhaul traffic in a unified packet based network supporting multiple functional splits.Service-oriented unified data plane for backhaul and fronthaul traffic based on a common transport frame.
- Unified SDN-NFV based control plane.
- Flexible, adaptive, cost-efficient and recursive sharing of 5G-Crosshaul infrastructure over multiple operators and service providers.
- System wide optimization of multiple policies, from QoS to energy efficiency.
- Network-aware innovative application development of mobility, multi-tenancy, energy and resource management.
- Build and deploy a proof-of-concept prototype implementing the integrated fronthaul/backhaul transport network in a real life testbed located in 5TONIC at Madrid and Berlin

Source: http://www.etsi.org/news-events/events/1025-2016-04-5g-from-myth-to-reality

FURTHER PROJECTS

- **VirtiWind: Virtual and programmable industrial network prototype deployed in operational wind park**
  http://www.virtuwind.eu/
- VirtuWind mission and studied use cases
- Requirements of different industry use cases
- Realization of industry-grade QoS through SDN & NFV solutions
- Inter-domain QoS and multi operator ecosystem
- Time and Cost savings in network maintenance and service provisioning
- Ensuring security by design in SDN/NFV– based industrial networks
- Field trial and prototyping in the wind park

Source: http://www.etsi.org/news-events/events/1025-2016-04-5g-from-myth-to-reality

FURTHER PROJECTS

- **INSTINCT: Scenarios for integration of satellite components in future networks – Satellite–terrestrial integration opportunities in the 5G environment**
  https://artes.esa.int/projects/instinct

- Some of the key findings of the ESA ARTES study INSTINCT aiming to find the most appropriate solutions for satellite and cloud networks integration.

- The study focused on how Network Functions Virtualization (NFV) and Software Defined Networks (SDN), cornerstone technologies for the 5G networks, are providing the immediate next step for a larger adoption of satellite as backhaul technology.

- Through the practical demonstrator and the evaluation results obtained we believe that the INSTINCT results are highly relevant to the 5G use case definition and architecture discussions.

Source: http://www.etsi.org/news-events/events/1025-2016-04-5g-from-myth-to-reality

SDN/NFV USE CASES IN THE CONTEXT OF 5G

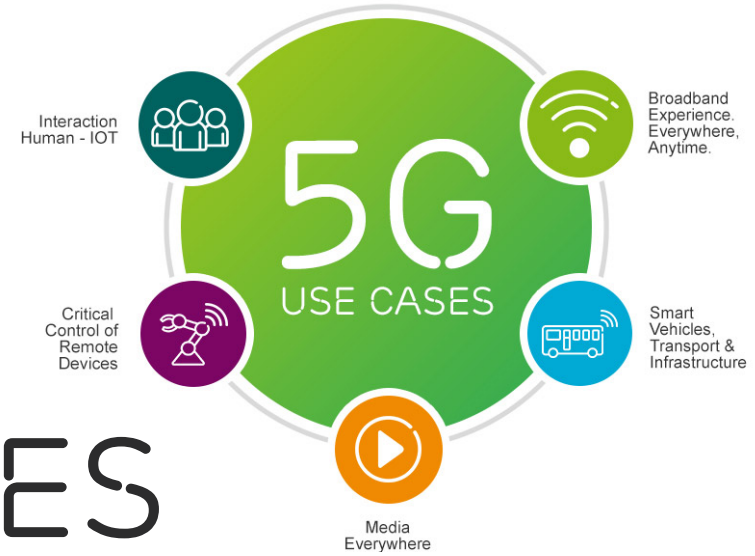


Image Source: Ericsson

PROGRAMMABILITY FOR 5G

High level of flexibility and programmability in individual domains (mobile core, radio access & transport network).
Cross-domain programmability and orchestration.

Modularity

- Well-defined control modules & interfaces
- Recursive stacking

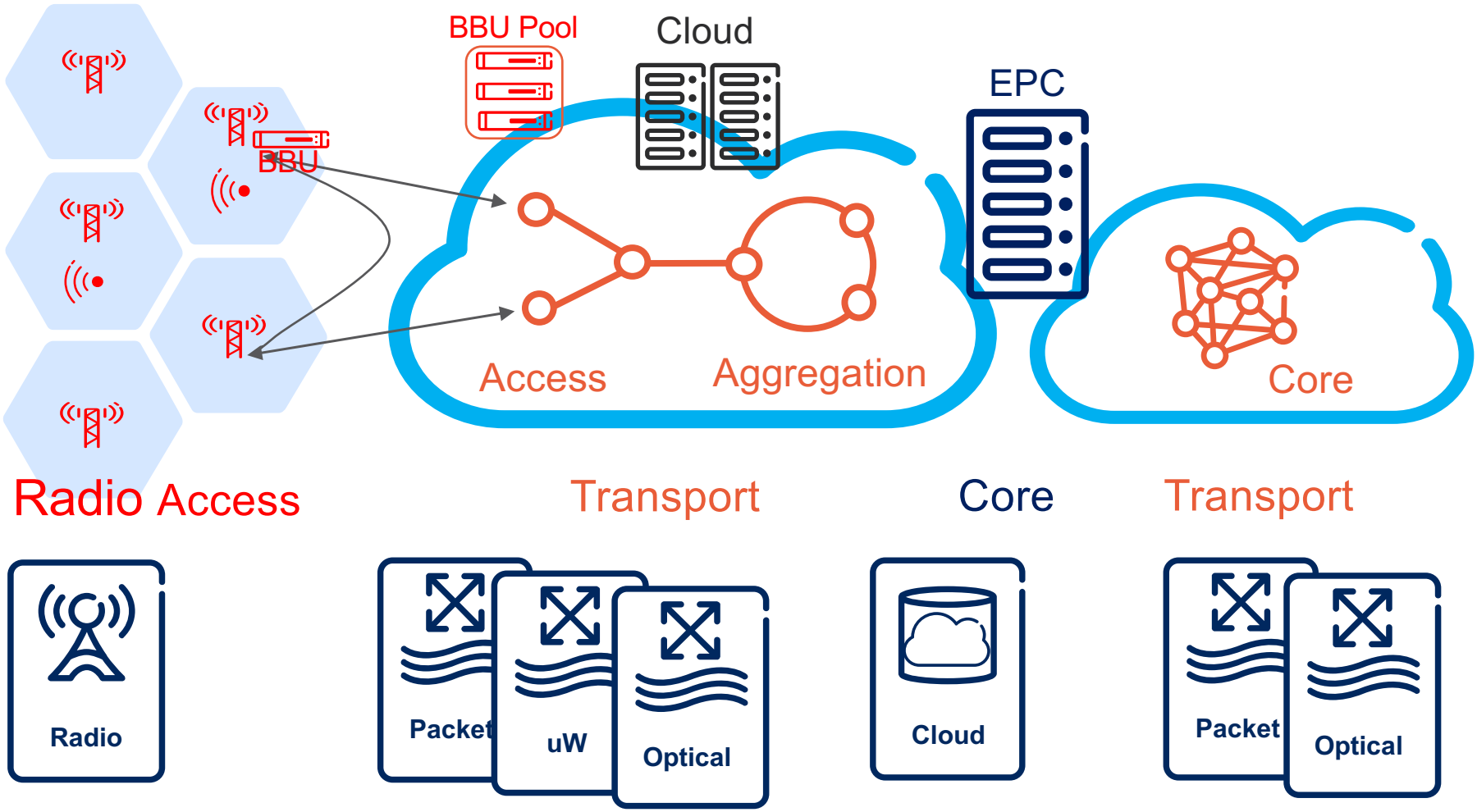
Virtualization

- Grouping resources into slices
- Performance & security isolation

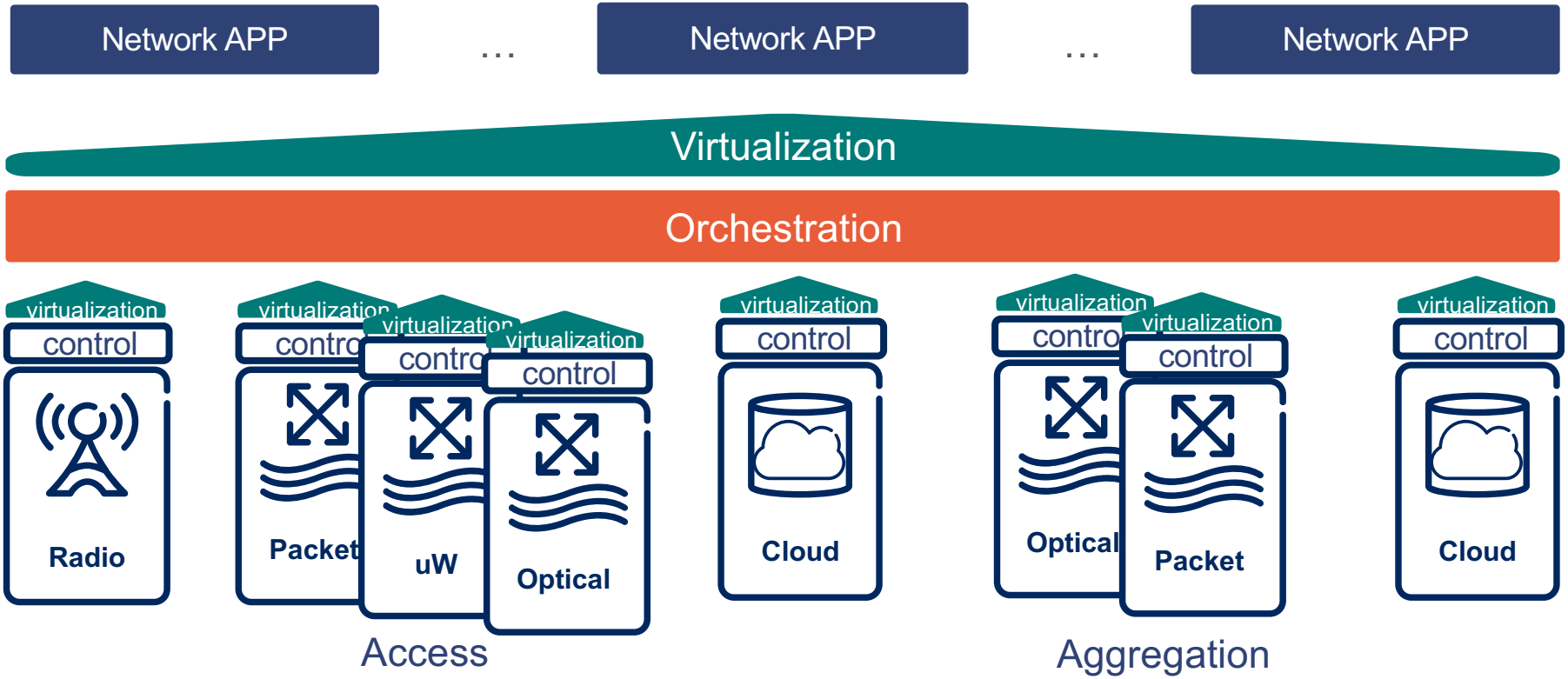
Scalability

- Hiding domain internal details
- Choosing right abstraction

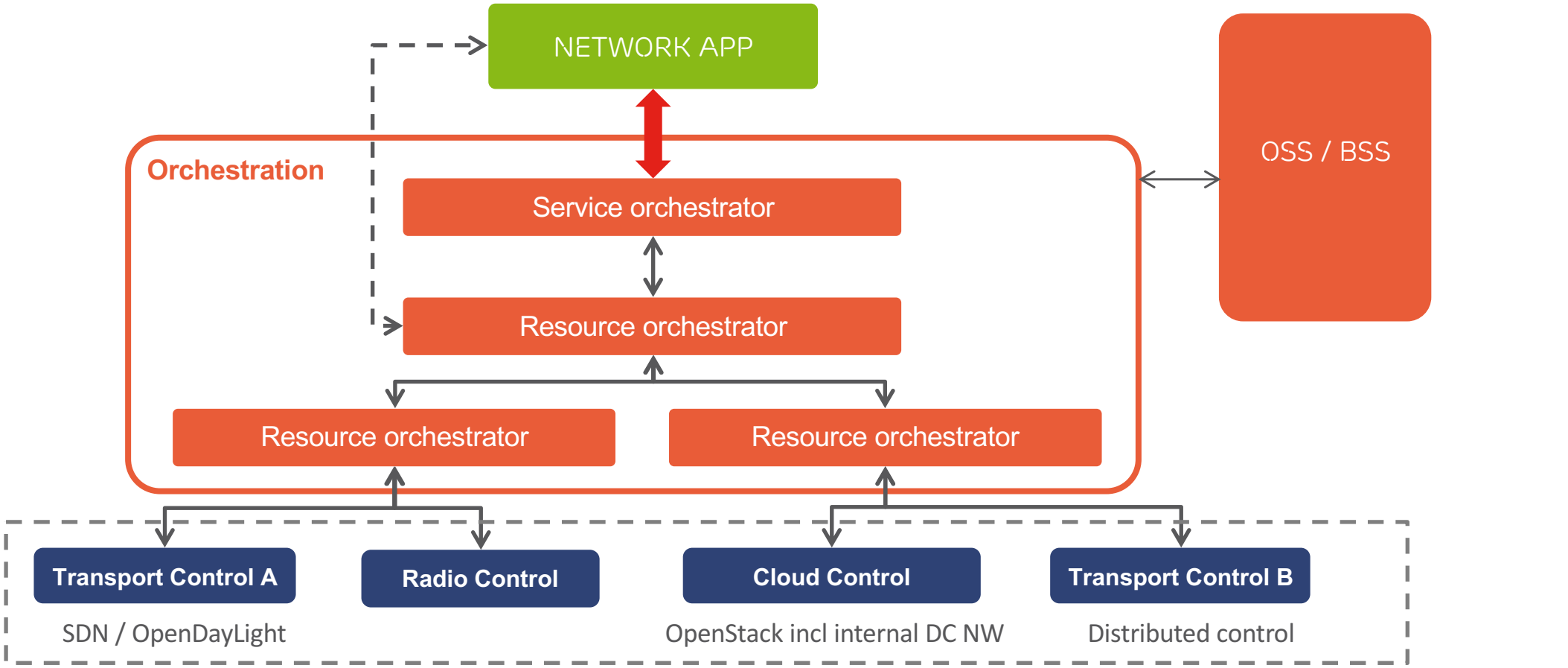
NETWORK ARCHITECTURE



END-TO-END ORCHESTRATION

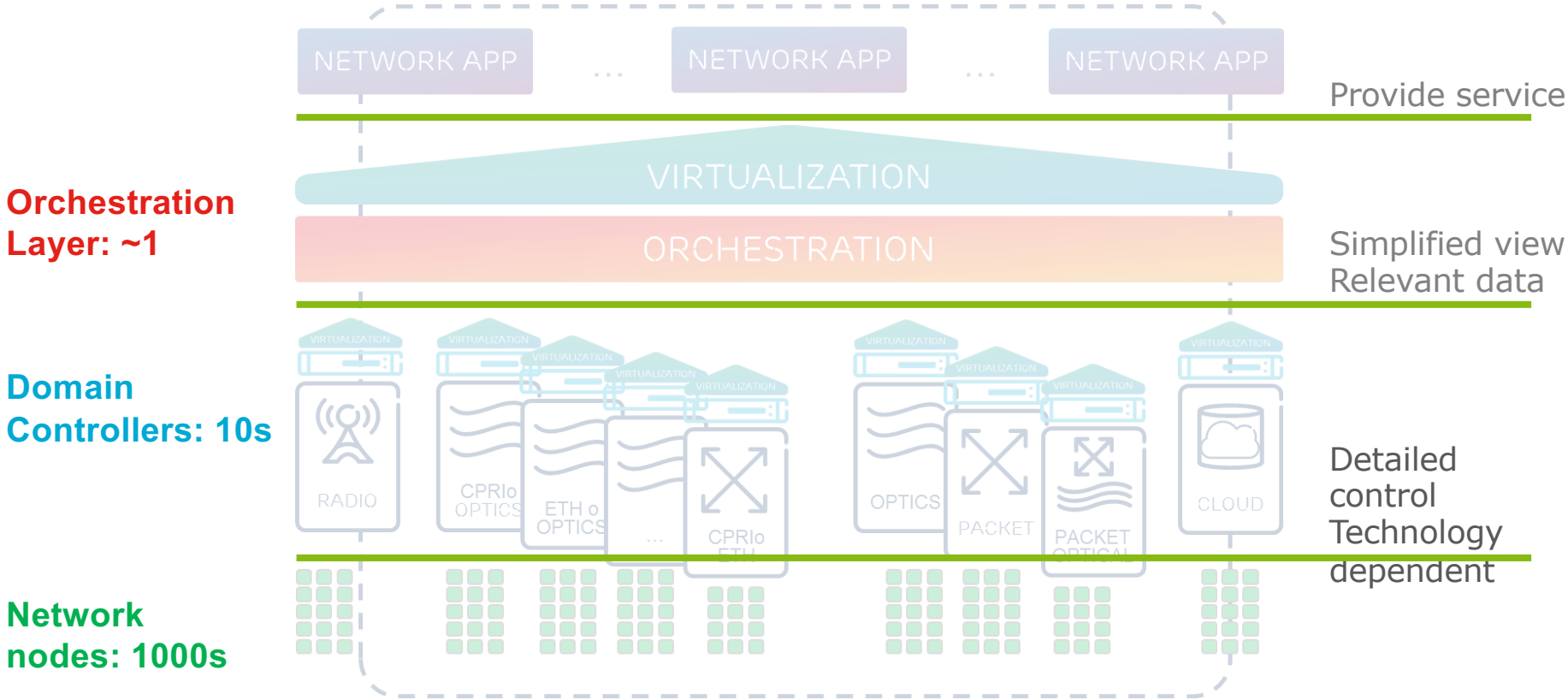


ORCHESTRATION ARCHITECTURE

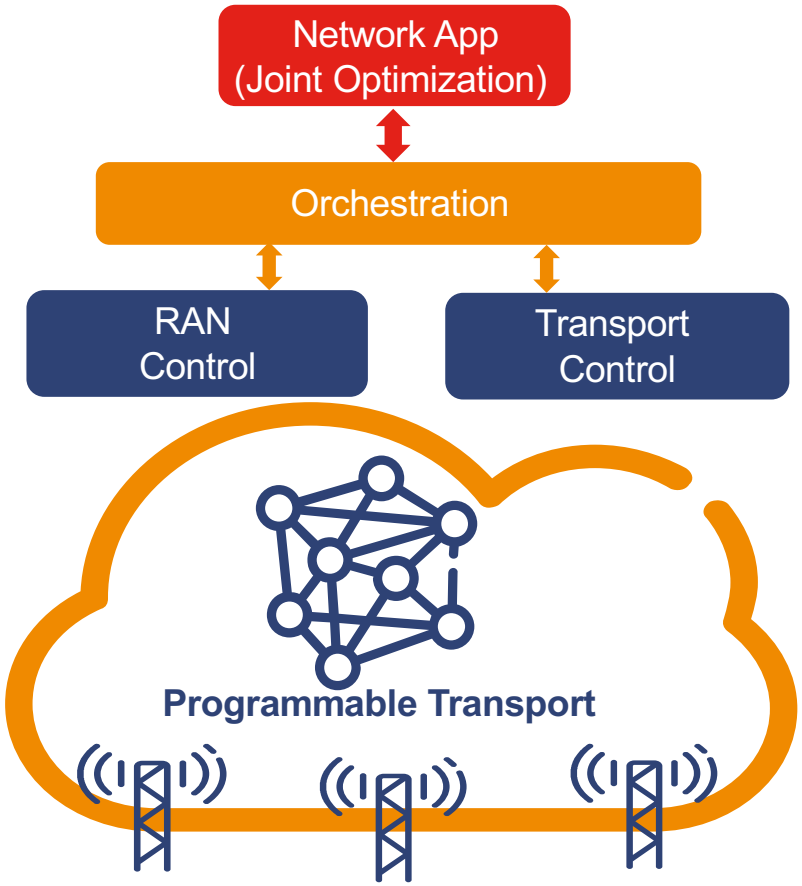


MANAGING COMPLEXITY

Expose just enough information to make optimal resource orchestration.



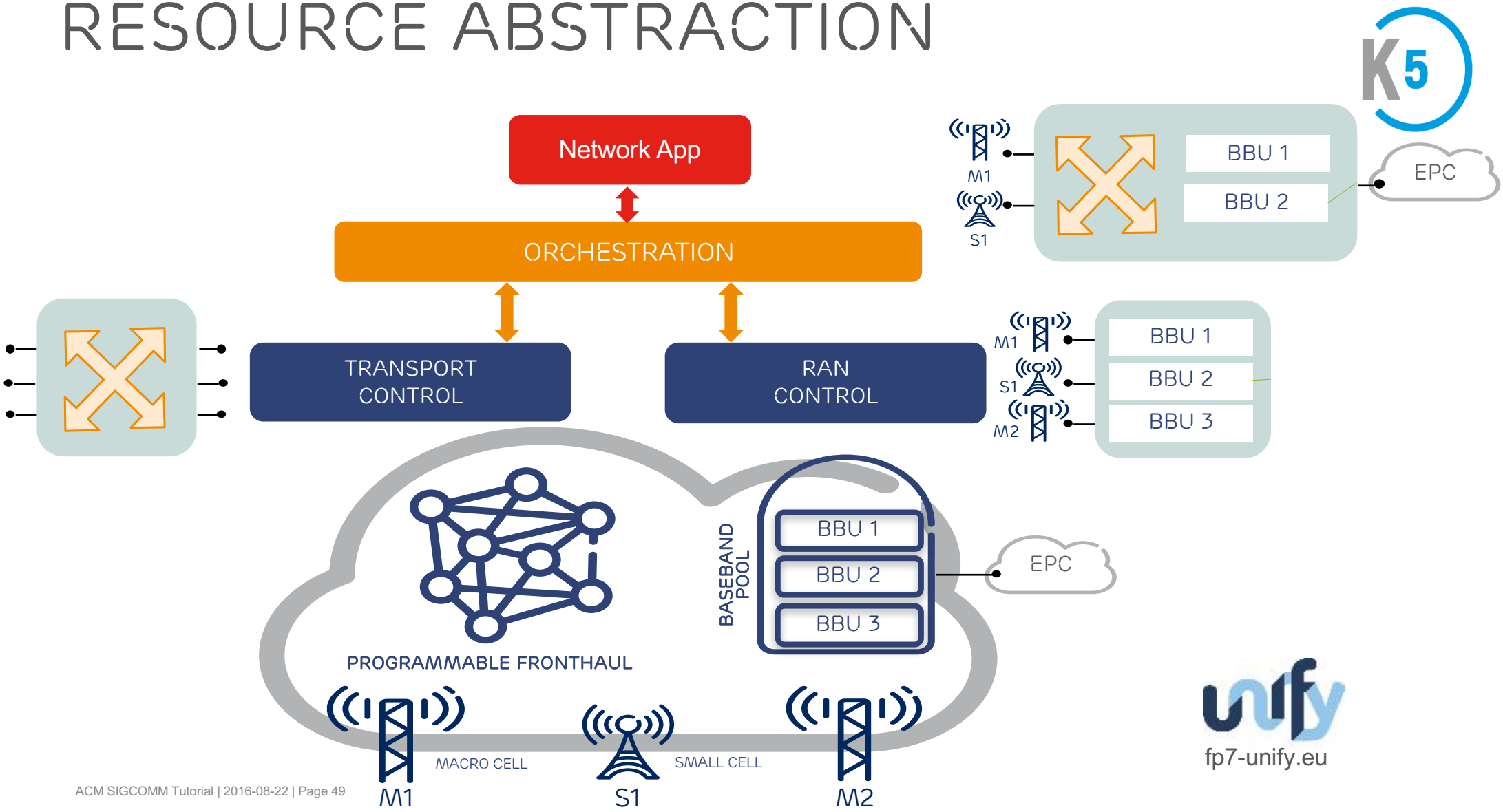
RAN-TRANSPORT ORCHESTRATION



Joint Optimization of RAN and Transport

- Elastic Mobile Broadband Service
- Joint RAN-Transport Slicing (Multi-operator)
- Joint Load-balancing
- Energy saving
- Dynamic clustering
- Pooling
- Shared fronthaul
- Resilience

RESOURCE ABSTRACTION



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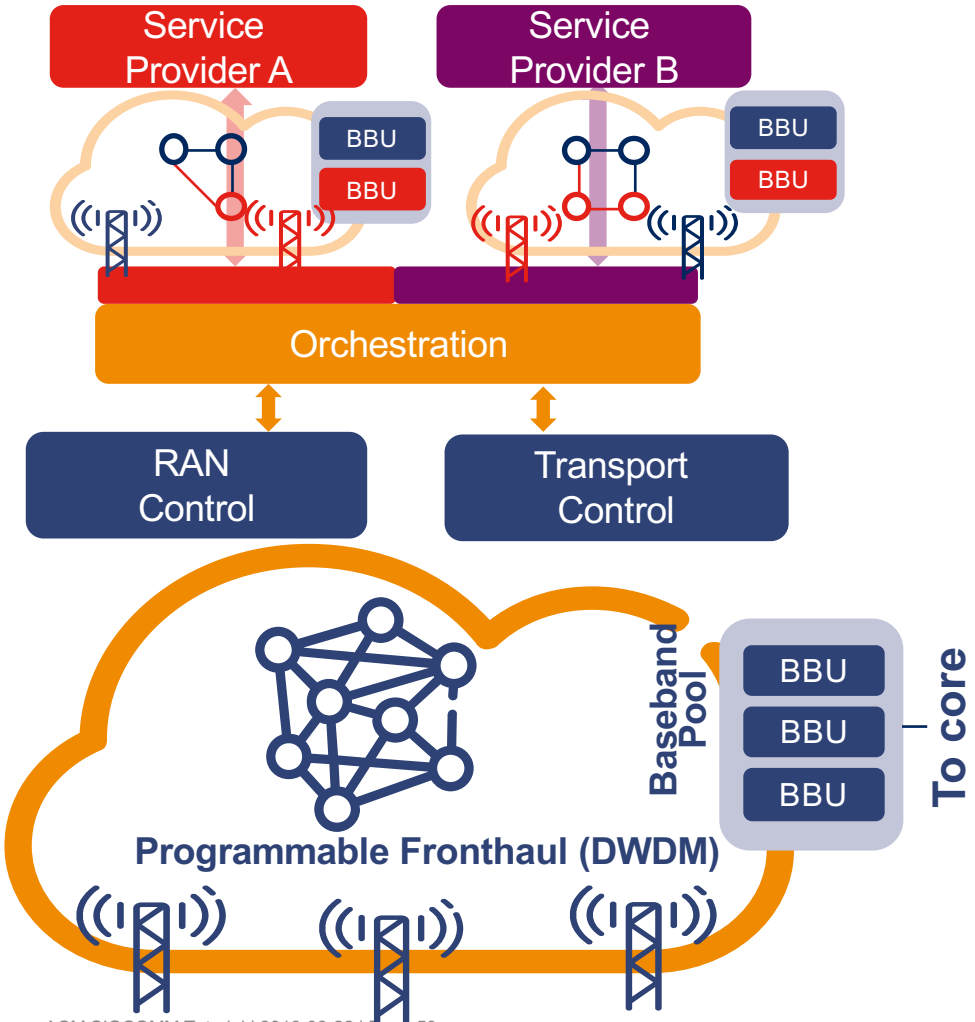
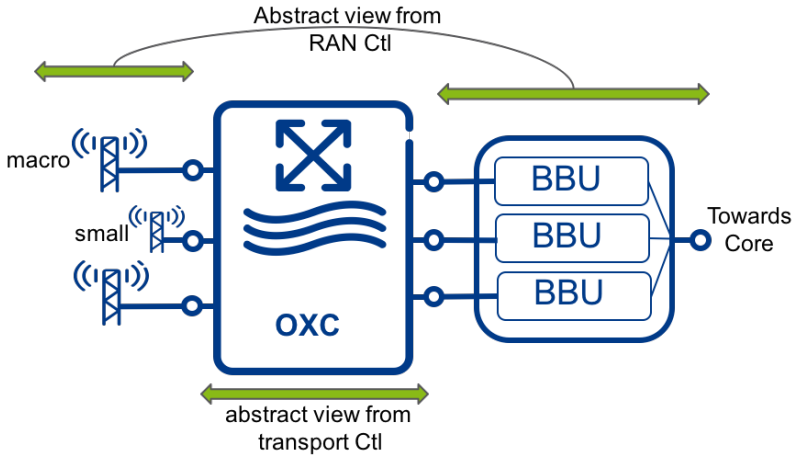
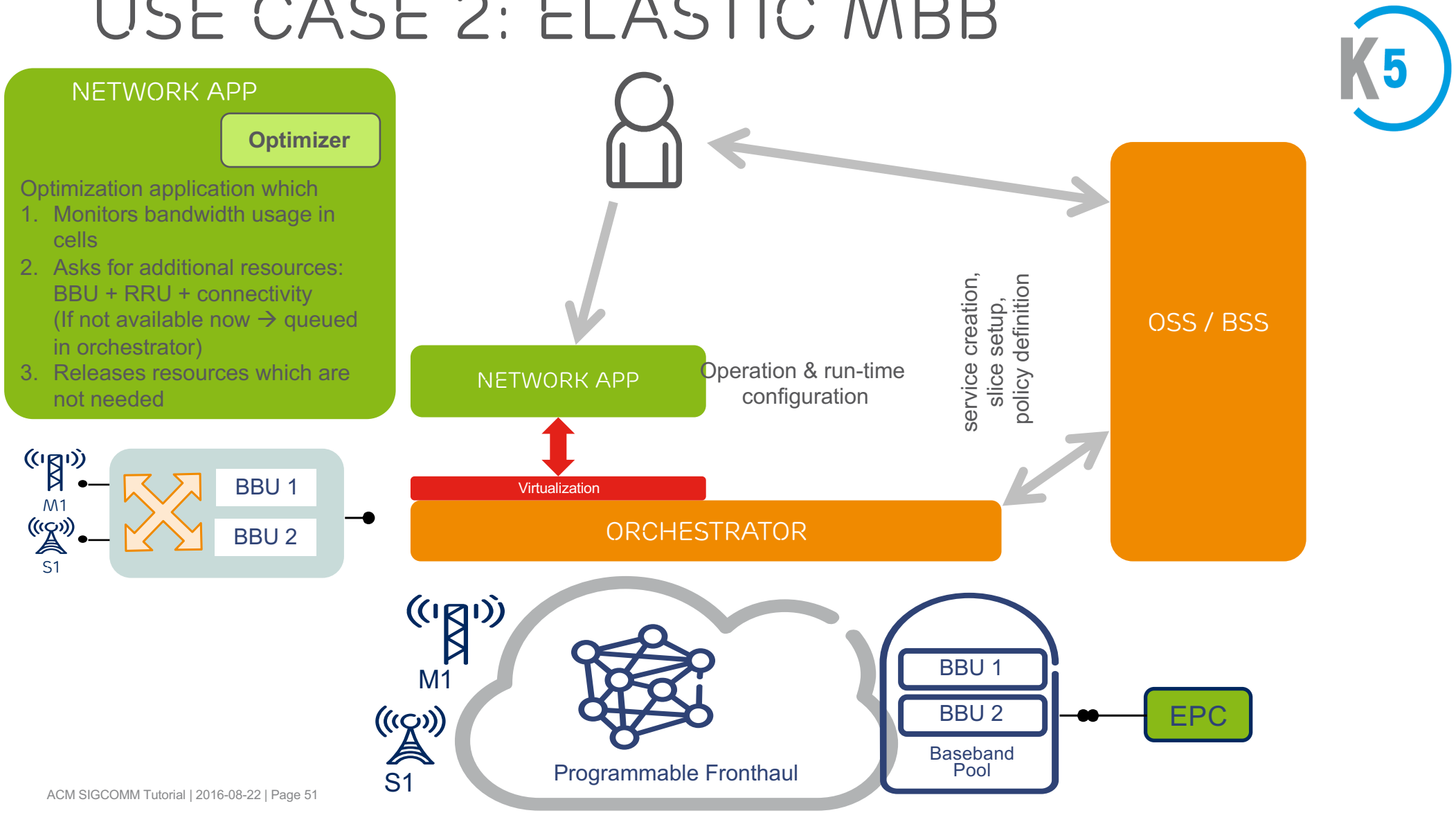
USE-CASE 1:RAN-TRANSPORT SLICING

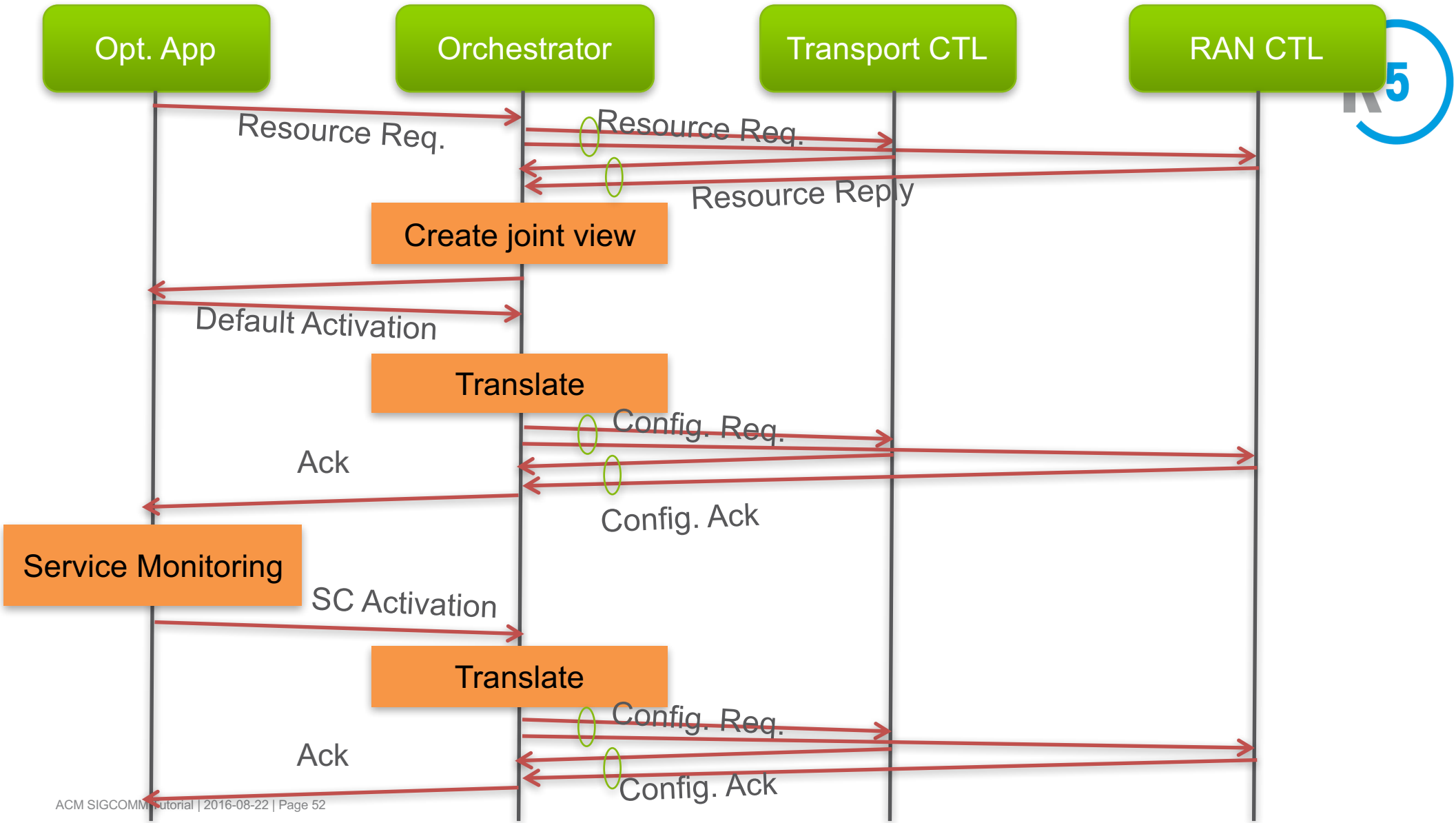


- Multi-operator C-RAN featuring shared BBU pooling and shared fronthaul
  - Efficient utilization of infrastructure
- Each operator can run its own joint optimization of RAN and Transport:
  - Efficient resource utilization & Energy efficiency

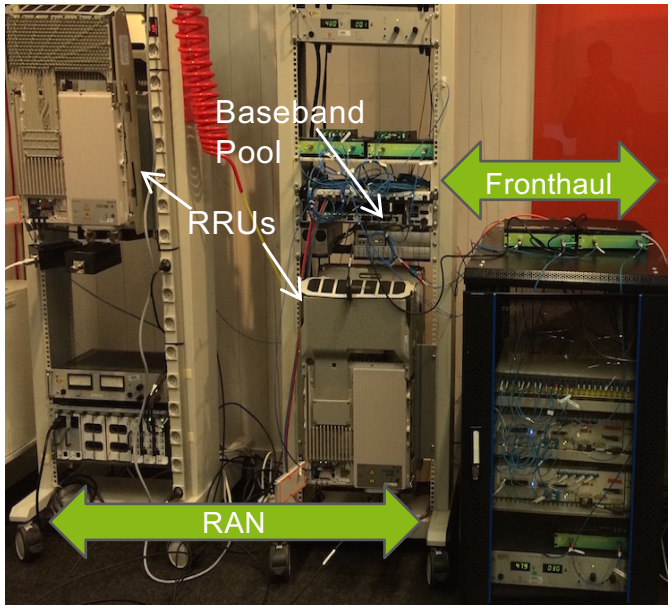


USE CASE 2: ELASTIC MBB




Opt. App
Orchestrator
Transport CTL
RAN CTL
R5
Resource Req.
Resource Req.
Resource Reply
Create joint view
Default Activation
Translate
Config. Req.
Ack
Config. Ack
Service Monitoring
SC Activation
Translate
Config. Req.
Ack
Config. Ack

PROOF OF CONCEPT



Software Components

Python-based Orchestrator
- Creates unified view of RAN and Fronthaul
- Maps high-level service requests to RAN and Fronthaul resources

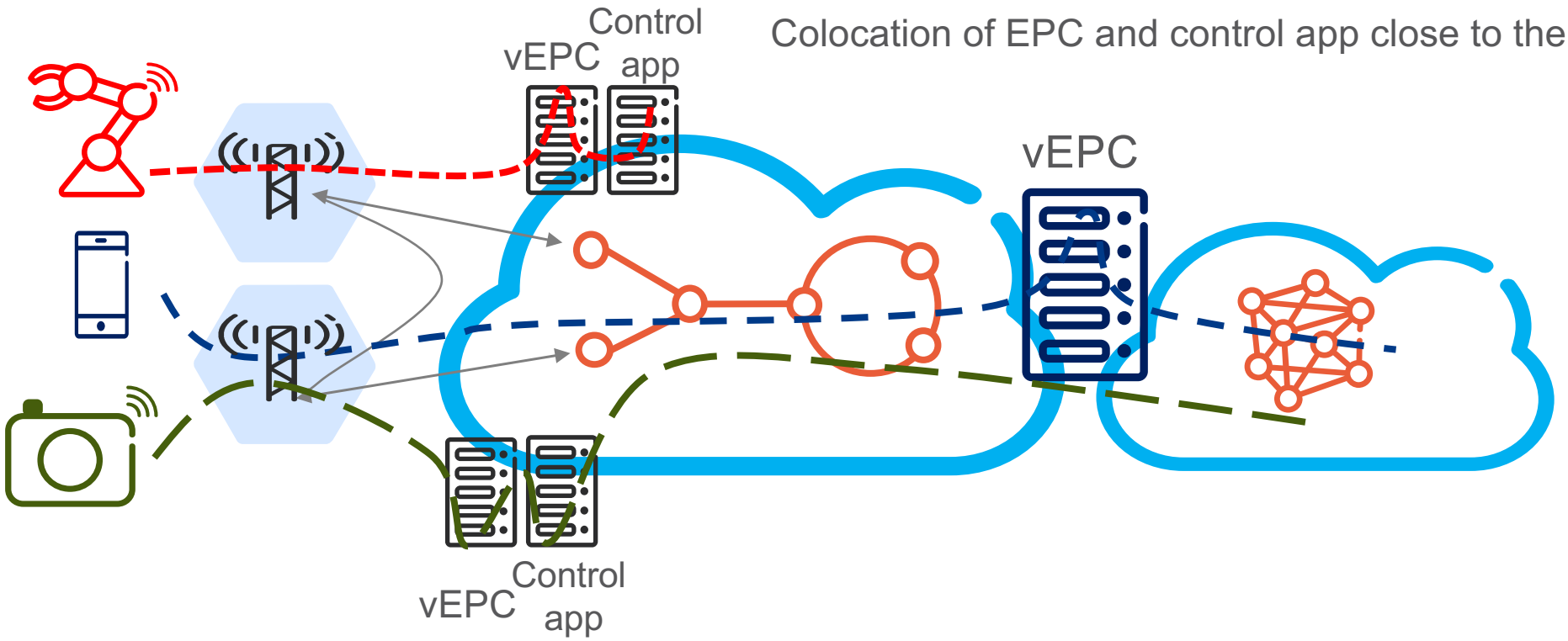
CLI-based RAN controller
- Activation &configuration of RAN
- Assignment of BBU resources
- Live monitoring of RAN demand

Customized OpenDaylight
- Support for circuit switching
- Optical layer abstraction
- Optical PCE

Elastic MBB in a realistic-size scenario leads to more than 30% pooling gain in terms of both radio (baseband processors) and fronthaul (optical wavelengths and transceivers) resources.

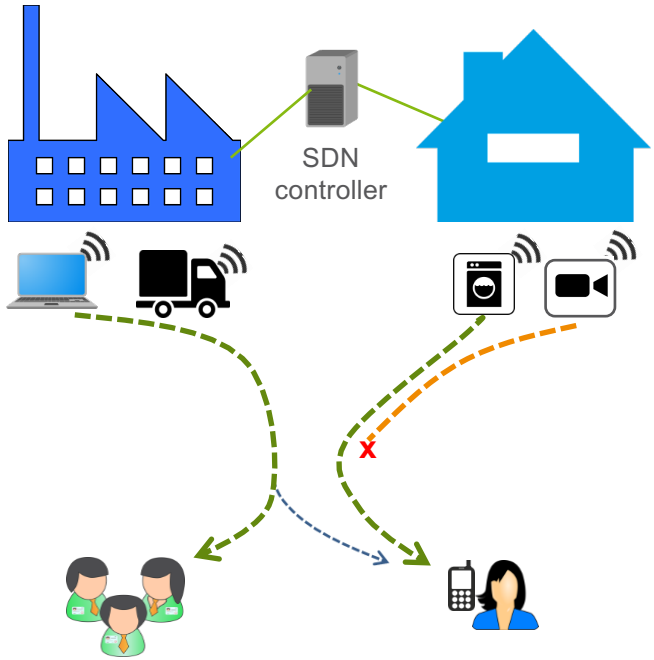
source: Multi-domain orchestration across RAN and Transport for 5G, Sigcomm 2016

FLEXIBLE PLACEMENT OF VNFS + FLEXIBLE TRAFFIC STEERING



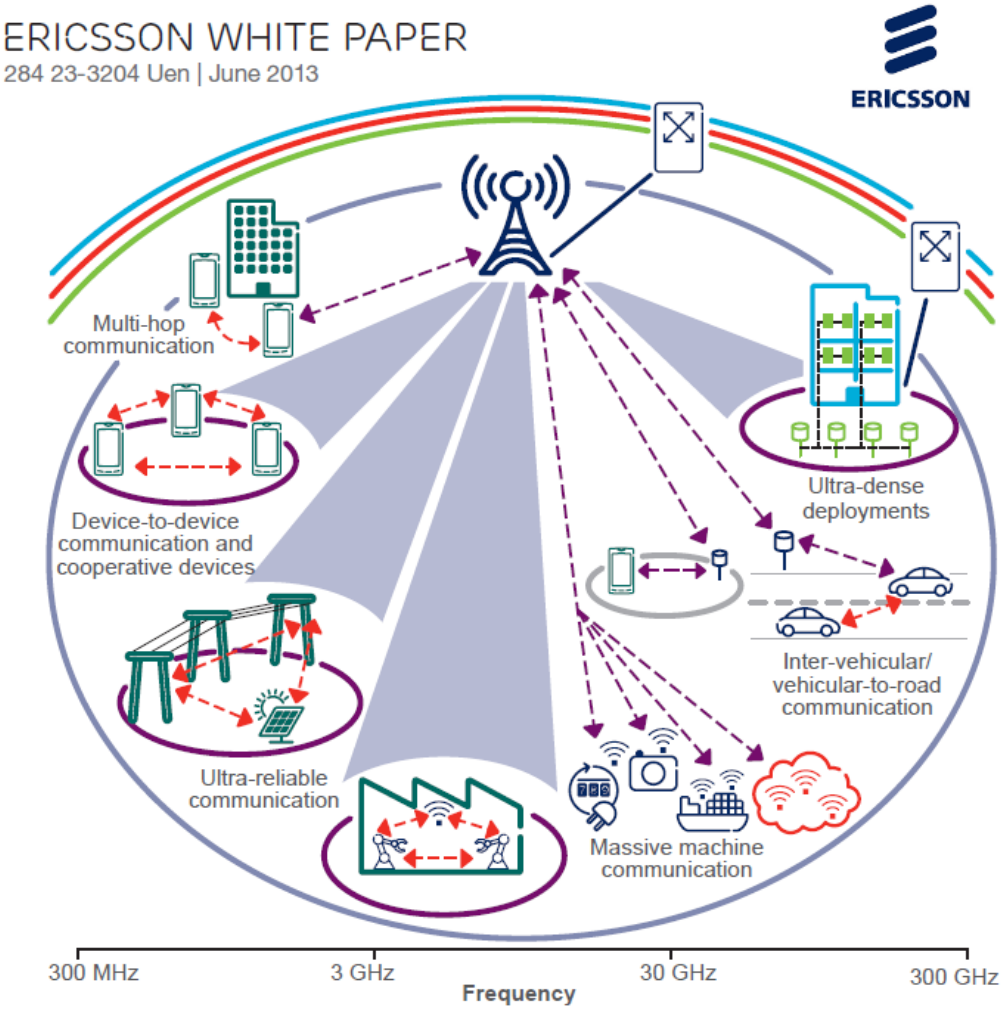
SDN FOR WIRELESS NETWORKING

- Bringing programmability to wireless networks
  - User-centric networking: personalization of services
  - Agility
  - Privacy
  - Efficient resource utilization



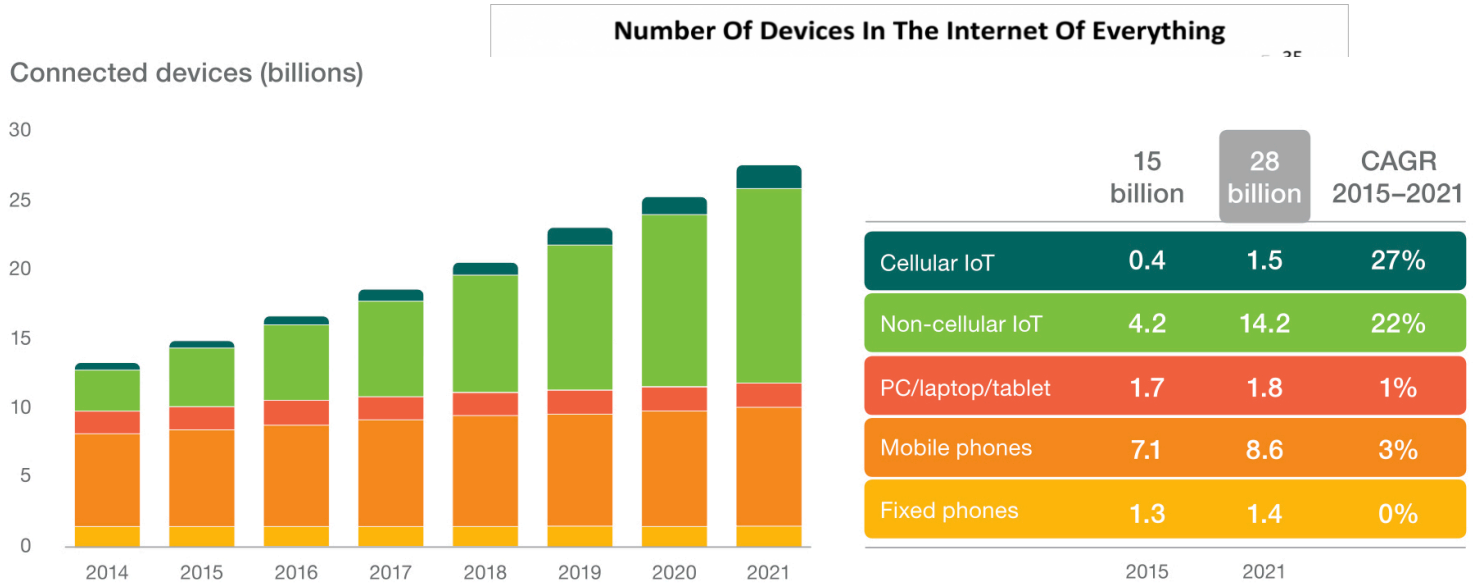
LIMITATIONS OF SDN FOR WIRELESS

- Current SDN architectures
  - Logically centralized control plane may be a bottleneck
    - Scalability
    - Administrative autonomy
    - Network heterogeneity
      - Connectivity disruptions



SCALABILITY AND HETEROGENEITY

- Dense deployments
- Mobile devices
- Heterogeneity



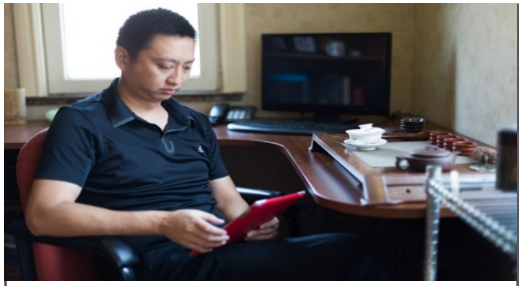
Integrating massive devices (and data) to the network and providing new services is crucial

EMERGING APPLICATIONS (E.G., IOT) ARE "FRAGMENTED"

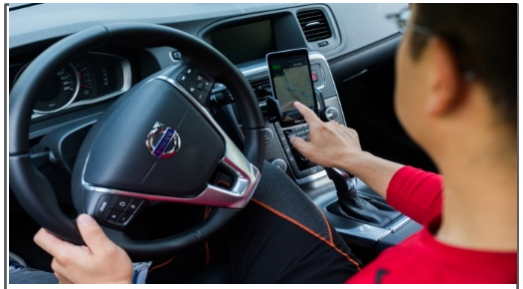
Home Automation

Personal Health Care

Fragmentation does not match SDN unified control



Consumer Electronics



Smart Roads

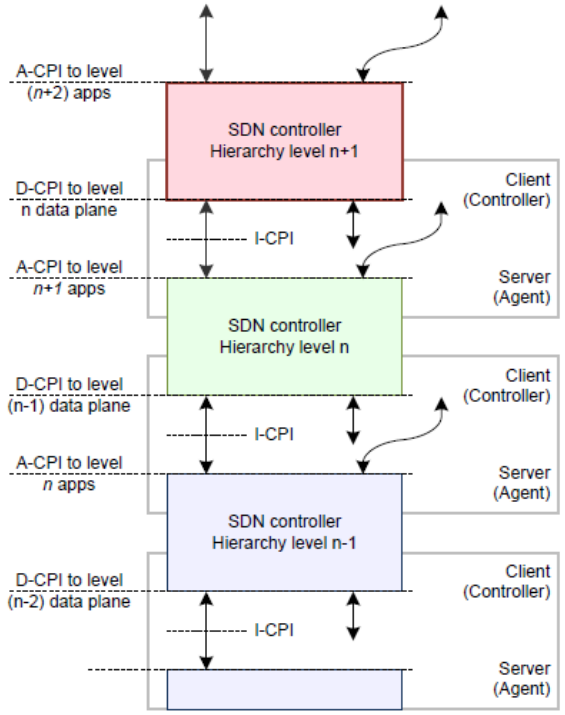
DECENTRALIZING SDN'S CONTROL PLANE

DECENTRALIZING SDN'S CONTROL PLANE

- Control hierarchy
- Control delegation

BENEFITS OF CONTROL HIERARCHY

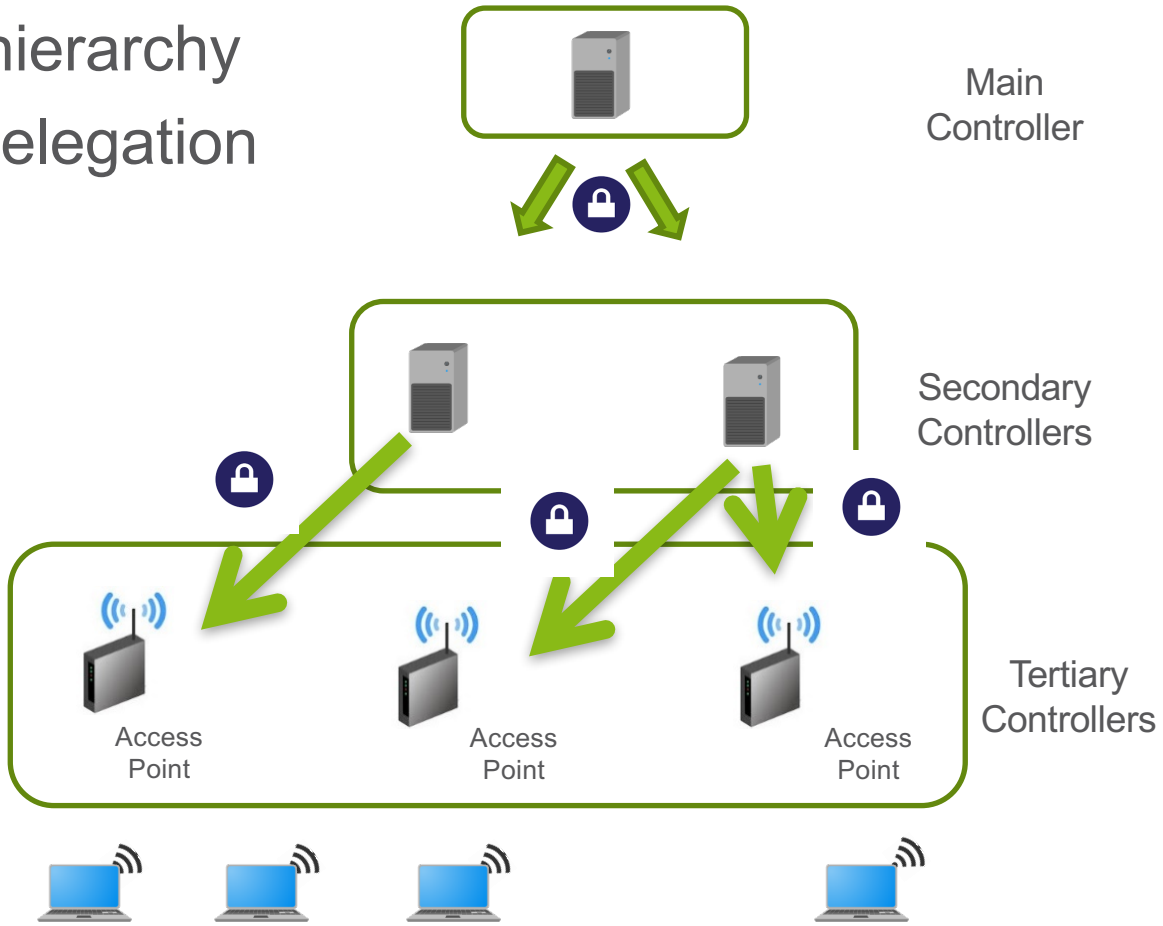
- Scalability and modularity
  - Higher levels have greater abstraction and broader scope
  - Lower levels can adjust quickly: agility (e.g., connectivity disruptions)
- Administration autonomy
- Security and privacy
  - Each level in a different trusted domain



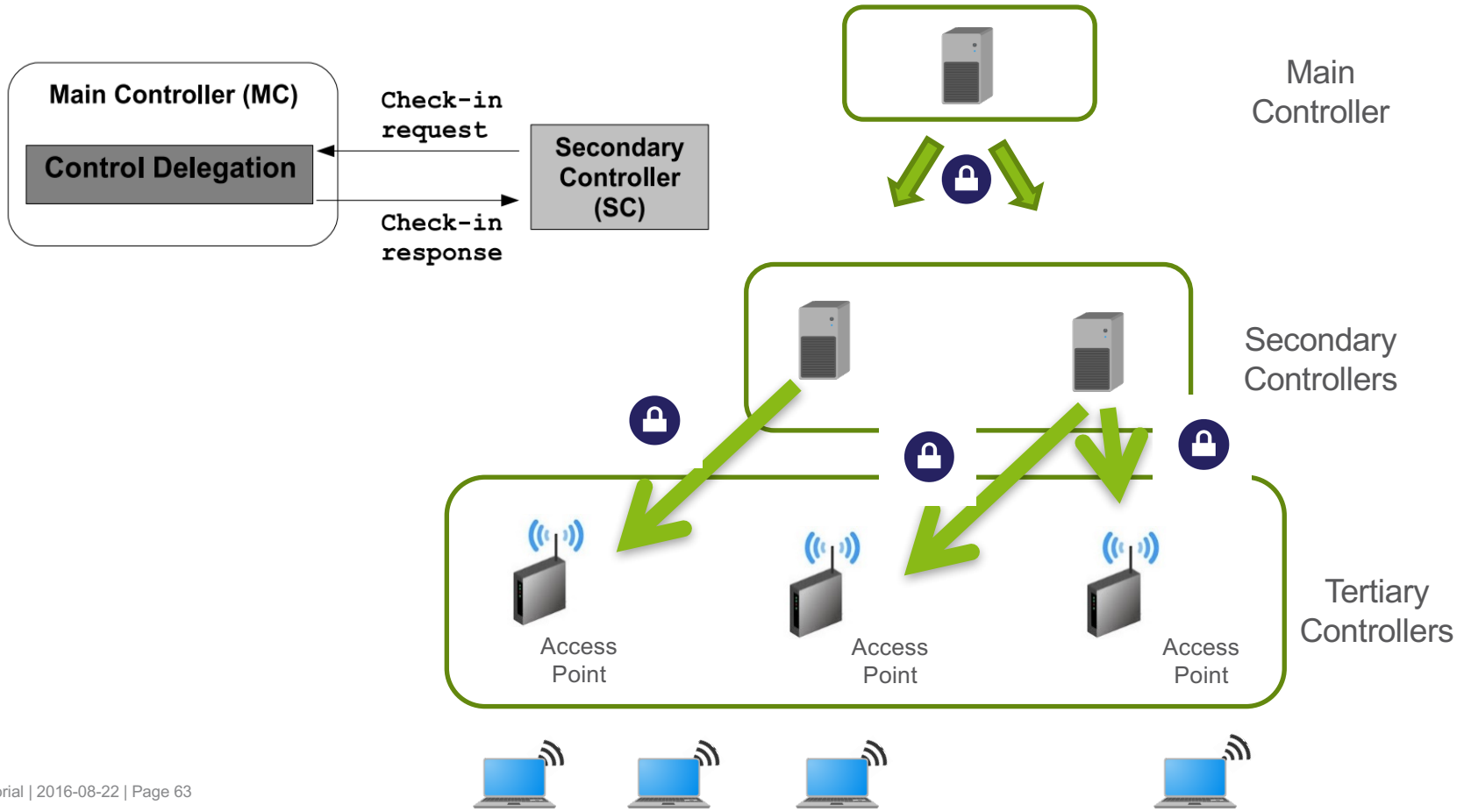
Source: ONF SDN Architecture, June 2014

CONTROL DELEGATION

- Follows hierarchy
- Secure delegation

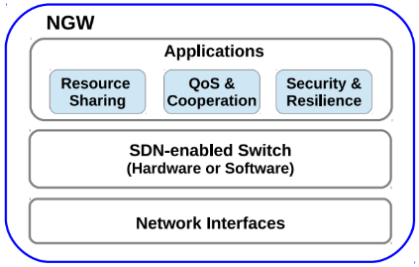


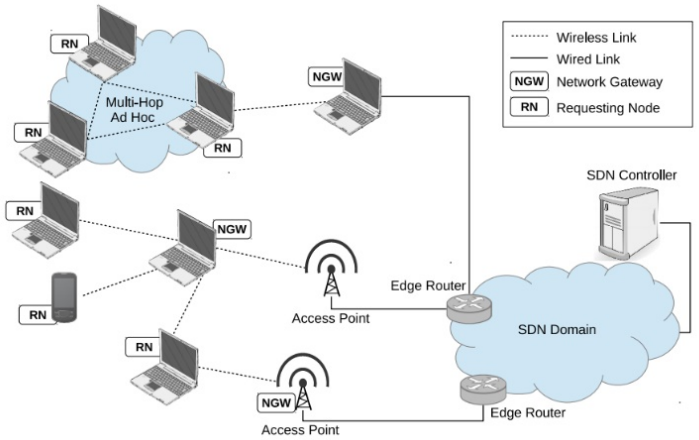
CONTROL DELEGATION



USE CASE: CAPACITY SHARING

- User provides Internet connectivity
  - Shares capacity
  - Incentives
- Becomes a Network Gateway (NGW)
  - NGW is SDN-enabled
  - Resource sharing
  - Service personalization

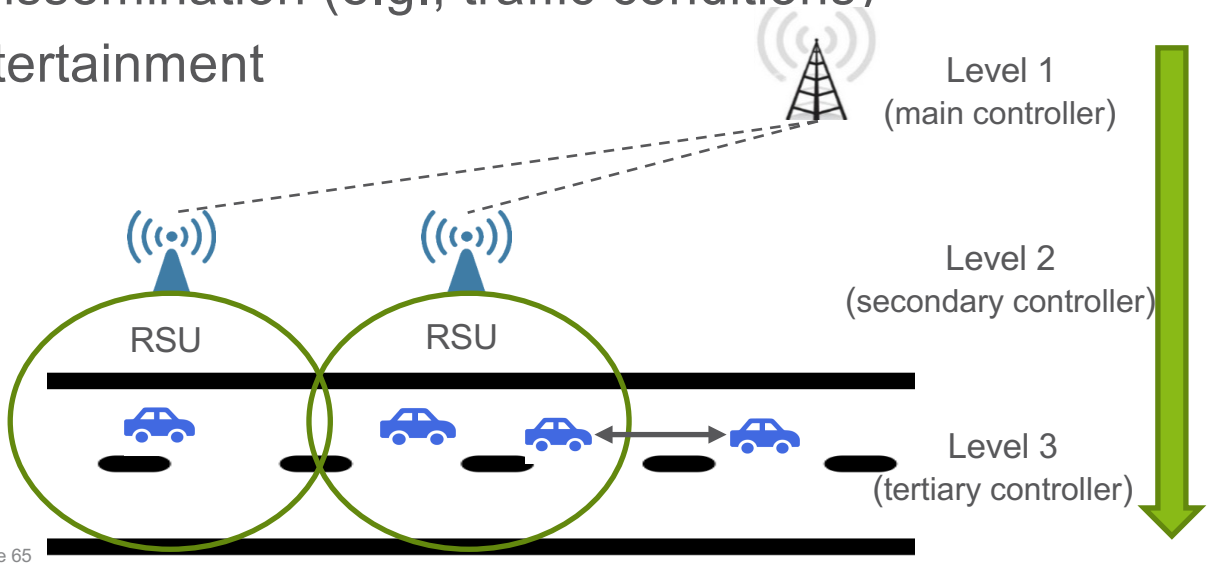




- Mobile NGW can break switch-controller communication
- Solution:
  - Delegation of control
  - NGW also a local controller

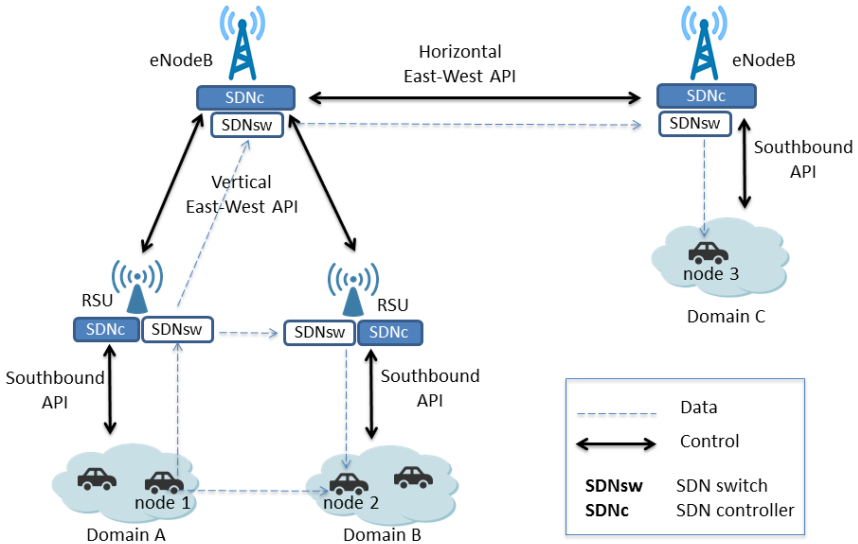
USE CASE: SOFWARE-DEFINED ITS

- "Vertical" *east-west* interfaces
- Applications
  - Autonomous driving
  - Message dissemination (e.g., traffic conditions)
  - Vehicle entertainment



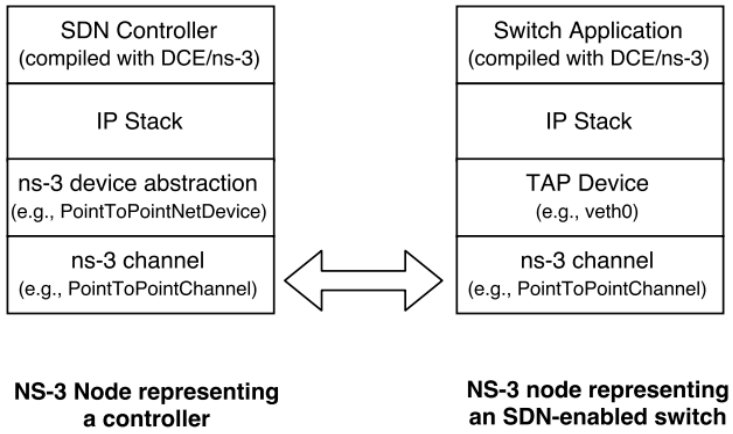
SOFWARE-DEFINED ITS ARCHITECTURE

- Communication
  - Vehicle-to-vehicle
  - Vehicle-to-infrastructure
- Resilient control plane
  - Fault tolerance
  - Connectivity disruption tolerance



SIMULATION PLATFORM

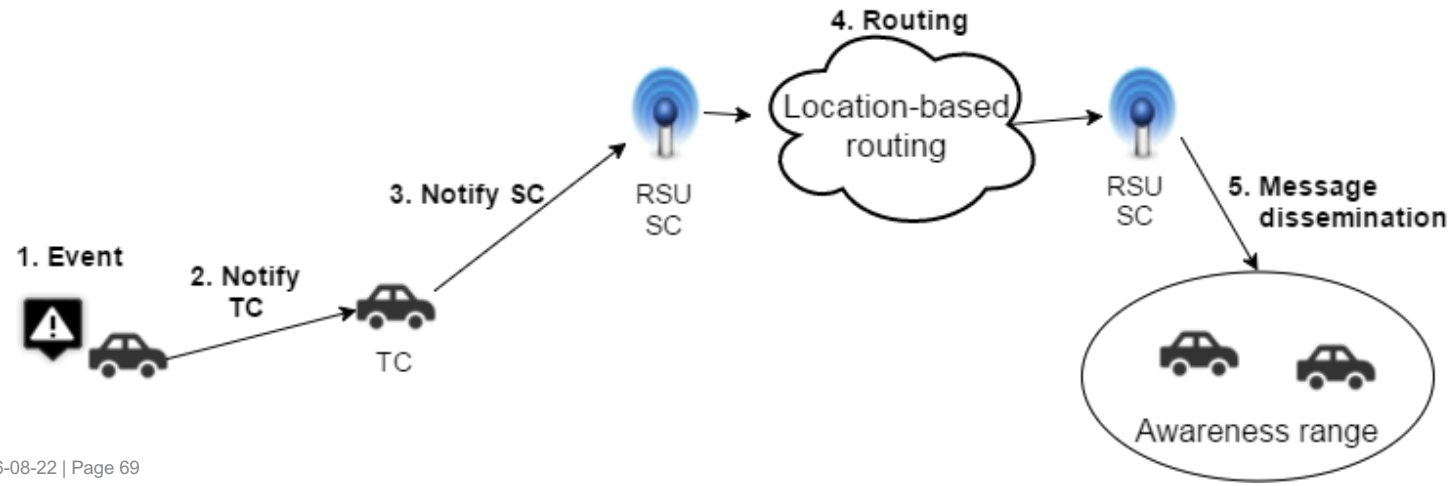
› NS-3 augmented with SDNs
  – Execution of controllers and switches within ns-3
  – Multiple instances of the same protocol implementation running within ns-3



BACKUP SLIDES

SOFTWARE-DEFINED MEASUREMENTS FOR ITS

- SD-measurements for message dissemination
  - SDN-enabled cars send messages upon event detection
  - OpenFlow extended via experimenter messages
- Events become flows
  - dynamic configuration of events (agility)
  - avoid polling



	NFV architectural layers		NFV MANO framework				Traditional management systems	
	NFVI	VNFs	VIM	VNFM	NFVO	Data repositories	OSS/BSS	EM
CloudBand	Nuage, RedHat, CloudBand	VNF Modelling (TOSCA)	CloudBand node	CloudBand Management System	CloudBand Management System	✓		
CloudNFV	Active eesource	Active Contract	Infrastructure manager	OSS/BSS	✓	Active Contract	✓	OSS/BSS
ESO		✓	Ensemble network controller (ENC)	ESO	ESO	Database		
Experia-Sphere	Resource somain	TOSCA, USDL	Infrastructure manager	State-action service life cycle management	State-action service life cycle management	Derived operations	State-action service life cycle management	Derived operations
OpenMANO	✓	✓	Openvim		OpenMANO			
OPN			SDN Overly Controller	✓	Services orchestrator			
OpenNFV	✓		HP Helion Open-Stack Carrier Grade	✓	HP NFV director	HP NFV director	✓	
OPNFV	✓		✓					
Planet Orchestrate				✓	✓			
ZOOM			✓	✓	✓	Shared catalog	Order, SLA, and billing management systems	

Source: Rashid Mijumbi, Joan Serrat, Juan Luis Gorricho, Steven Latre, Marinos Charalambides, Diego Lopez. Management and Orchestration Challenges in Network Function Virtualization, IEEE Communications Magazine, Jan., 2016