How Close are we towards Autonomic Networking?

KNOM Workshop 2018
SKT Supex hall

2018. 11. 30

Taesang Choi
ETRI

What does "**Autonomic**" mean?

- **Automatic vs Autonomic vs Autonomous**

- **Automatic:** A process that occurs without human intervention, with step-by-step execution of rules. However, it relies on humans defining the sequence of rules, so is not Autonomic in the full sense. For example, a start-up script is automatic but not autonomic. An automatic function may need manual adjustments if the environment changes**.**

- **Autonomic:** Self-managing (self-configuring, self-protecting, self- healing, self-optimizing) however, allowing high-level guidance by a central entity, through Intent.

- **Autonomous:** Self-governing. Intelligent, sentient, self-aware, thinking, feeling, Governing independently. No intervention (human or intent) at all.

- **Intent**: An abstract, high-level policy used to operate the network. Its scope is an autonomic domain, such as an enterprise network. It does not contain configuration or information for a specific node. It may contain information pertaining to a node with a specific role (for example, an edge switch) or a node running a specific function. Intent is typically defined and provided by a central entity.

How can we judge that "**Autonomic Networking**" era is close?

- Market Demands
- Technology Maturity
- Standardization Readiness
- Use Cases
- Challenges

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Market Demands – Telcos

58% Experience issues driven by complaints

Pulled by customer requests

75B Connected devices by 2025

Network complexities beyond human capabilities

System architecture innovation to solve structural problems

OPEX ⇧ > Revenue ⇧

Last decade

Pushed by structural problems

3 *OTT players* **vs** **300+** *Telcos*

Efficiency to maintain 10,000 devices

Source: Hwawei, IETF103 Host Speaker Series

Market Demands – OTTs

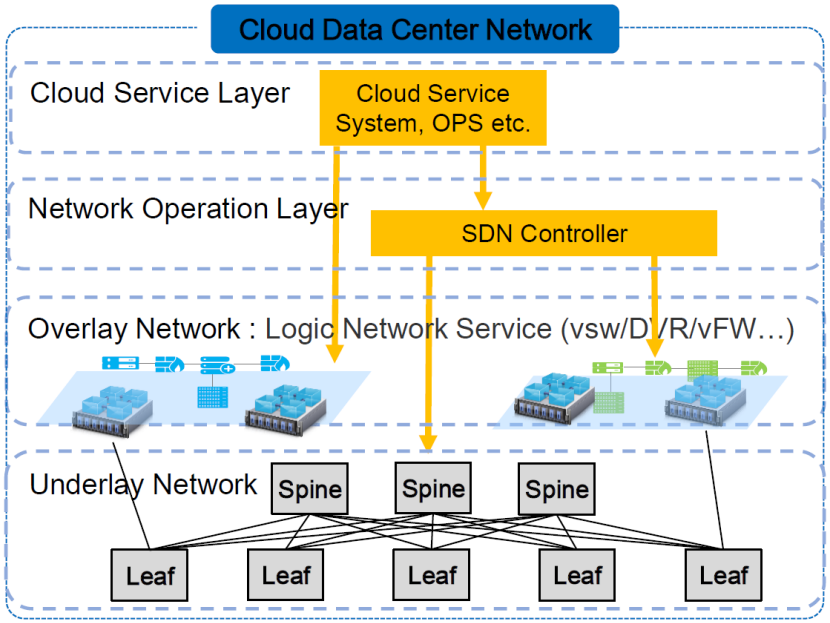
- 20+ network device roles
- more than half dozen vendors, multiple platforms
- 4M lines of configuration files
- up to ~30K configuration changes per month

- more than 8M OIDs collected every 5 minutes
- more than 20K CLI commands issued and scraped every 5 minutes
- many tools, and multiple generations of software

- proprietary CLIs, lots of scripts
- imperative, incremental configuration
- lack of abstractions
- configuration scraping from devices
- SNMP monitoring -- not always “simple” and not often scalable

Market Demands – Gaps between Telcos vs OTTs

~ 3000 devices / person in Hyper-scale DC
~ 4 hours OTT New Service Provisioning
CAPEX 10%↑ Traffic Double Growth



Decoupling of network transport & service in hardware and software individually

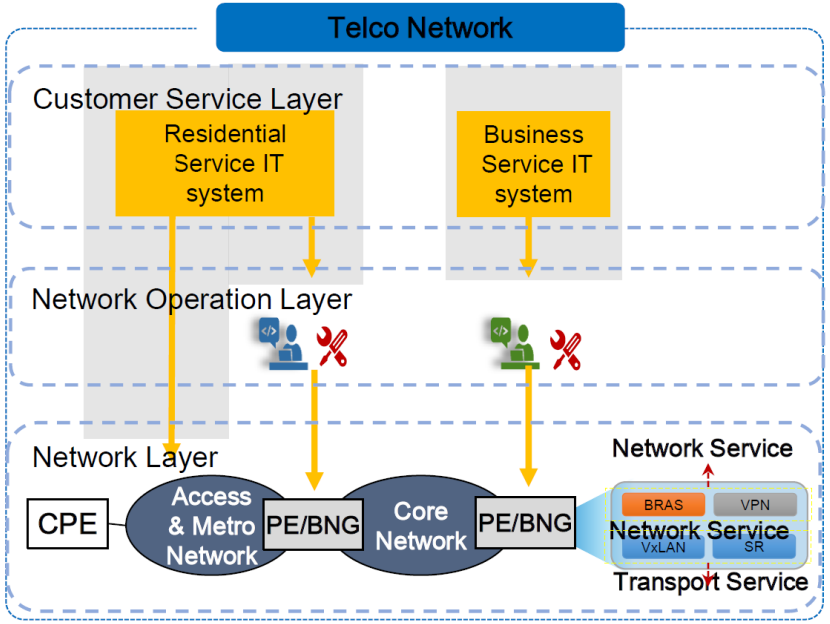
Spine/Leaf Arch, elastic scale out, any to any non-blocking

Simplified protocols, reduce O&M experience requirements

Clear boundary of Network operation and Service system, Automatic service

VS

~ 100 Devices / person in Telco-S network
~ 28 weeks Private Line Service Provisioning
CAPEX 60%↑ Traffic Double Growth



Coupling network transport & service into dedicated HW, difficult to scale up independently

Aggregation network with bandwidth convergence

30+ protocols, high experience requirement

Unclear boundary of network operation and service IT system, Low efficiency by

Source: Hwawei, IETF103 Host Speaker Series

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Technology Maturity

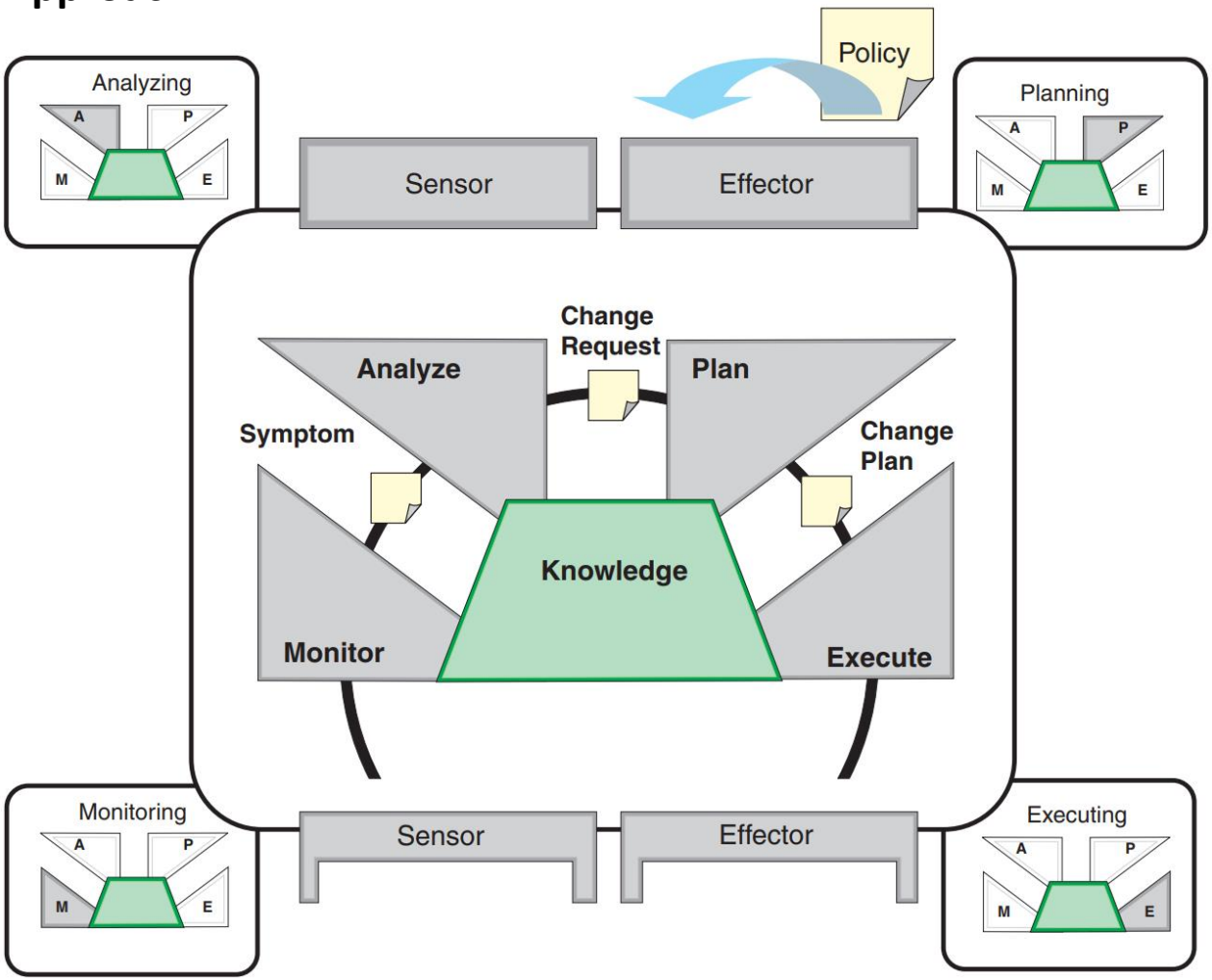
- AN R&D history re-cap.
- Enabling Technology
  - SDN
  - NFV
  - Machine learning
  - Orchestration
  - Network slicing

Quick Recap on Academic Research on AN

- First mentions → *circa* 2005, 2006
  - Several antecedentes → e.g., Artificial Intelligence in NM (90s)
- A lot of momentum → circa 2007-2009
  - 6h Framework Network of Excellence. Deliverable D9.5 Autonomic Management: Challenges and Solutions
- Decrease in interest → circa 2011-2013
  - Other technology gaining momentum? → SDN, NFV...

IBM: Blueprint for Autonomic Computing - 2005

IBM MAPE Approach



ANA: EU FP7 Project – 2006 ~ 2009

Objective

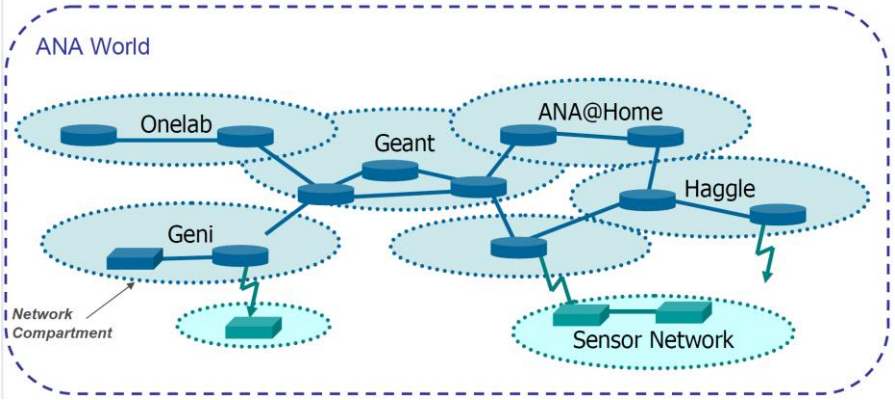
We want to design the
Future Internet Network Architecture
(with an autonomic flavor)

- Develop a novel (meta-) network architecture that enables for flexible, dynamic, and secure autonomic formation and adaptation of network nodes and whole networks
- ANA is disruptive research: no backward compatibility constraints
- Demonstrate feasibility of autonomic networking: two prototype cycles within the project lifetime
- ANA will use experimental facilities and testbeds as an investigative research vehicle

→running code matters

ANA: EU FP7 Project – 2006 ~ 2009

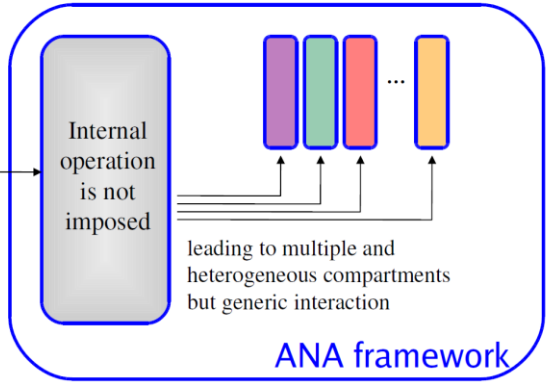
ANA for interconnection of (test)networks - support for multiple network personalities



ANA compartment = wrapper for NWs

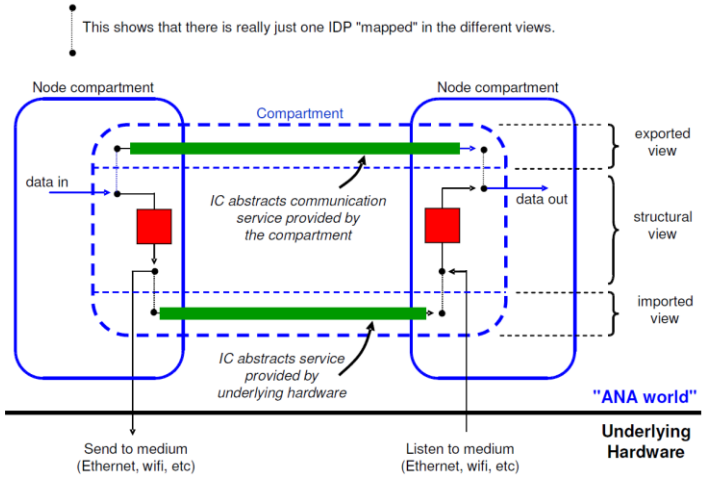
- The ANA framework specifies how networks can interact, not how they organize themselves internally.

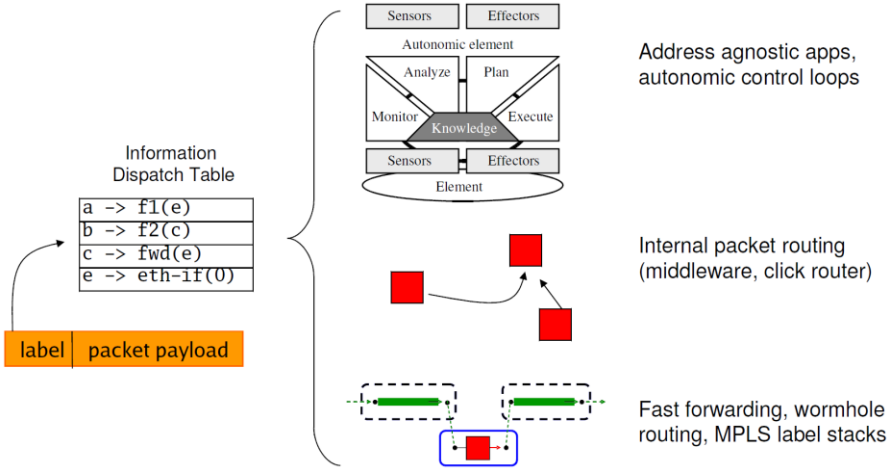
ANA specifies **interfaces** and **interactions** with any network compartment



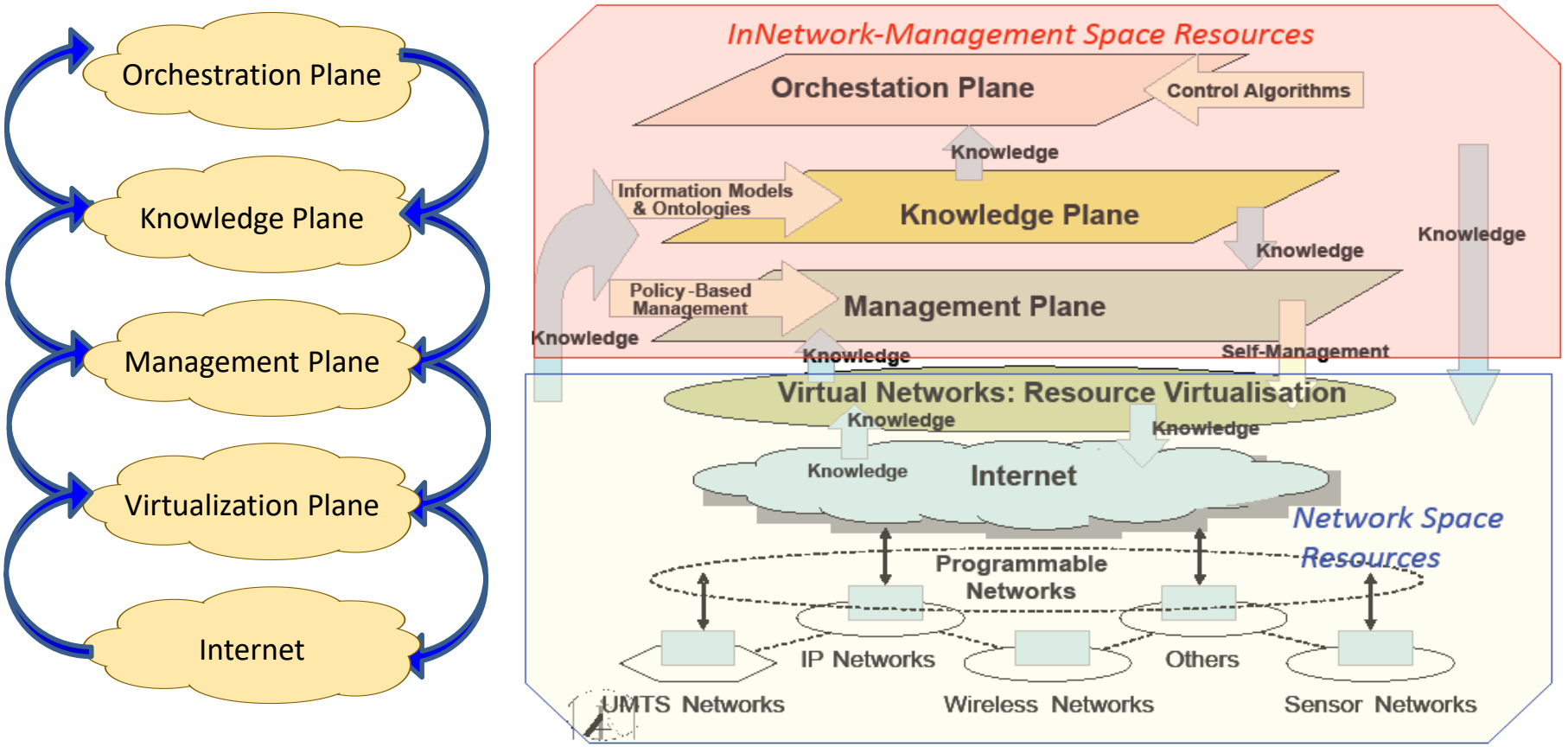
Node and Network compartments

- A node compartment starts/terminates ICs, "runs" the FBs, IDPs,
- A network hosts ICs, offers different views, for different usage.





AutoI: EU FP7 Project – 2008 ~ 2010



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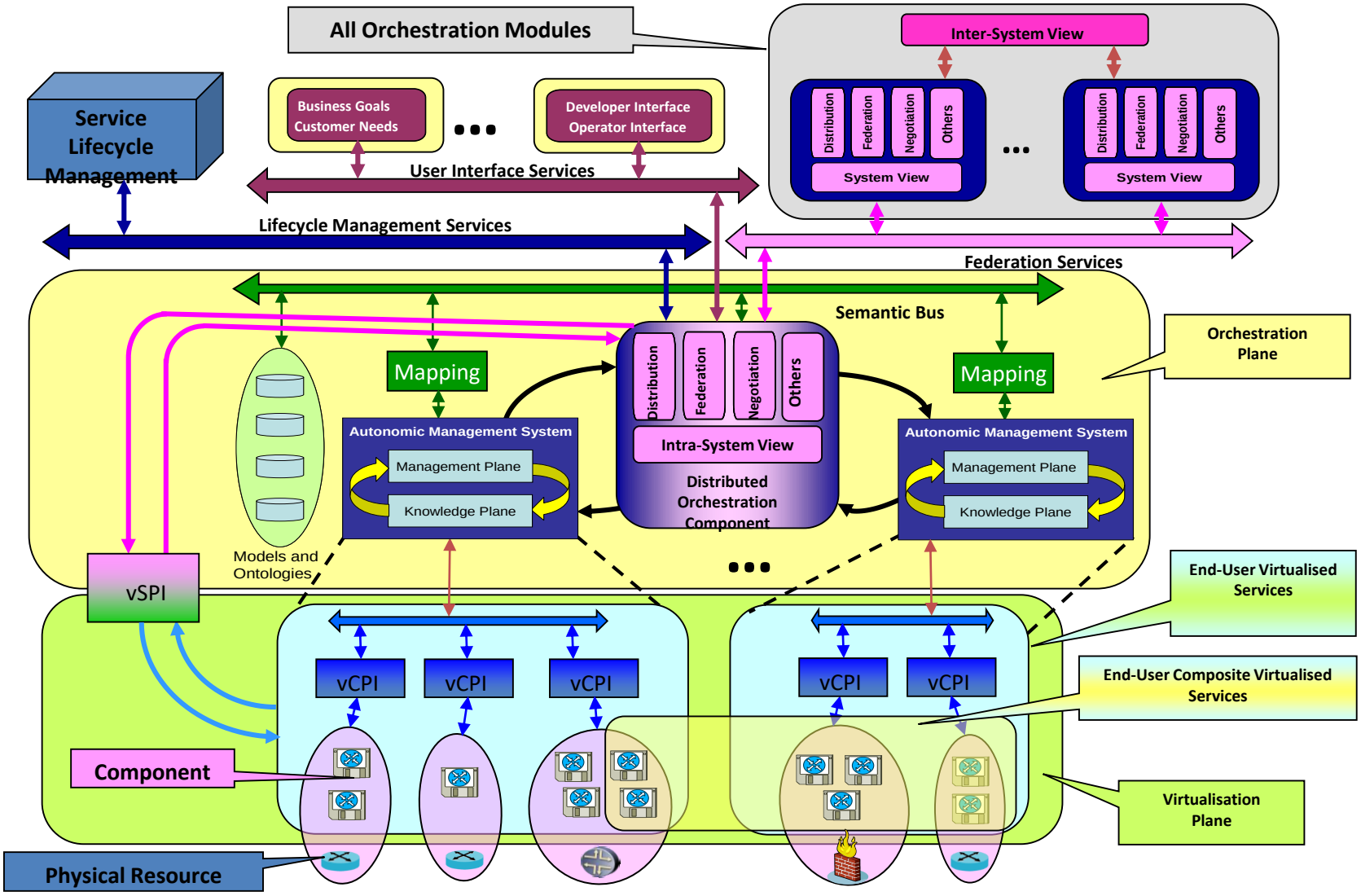
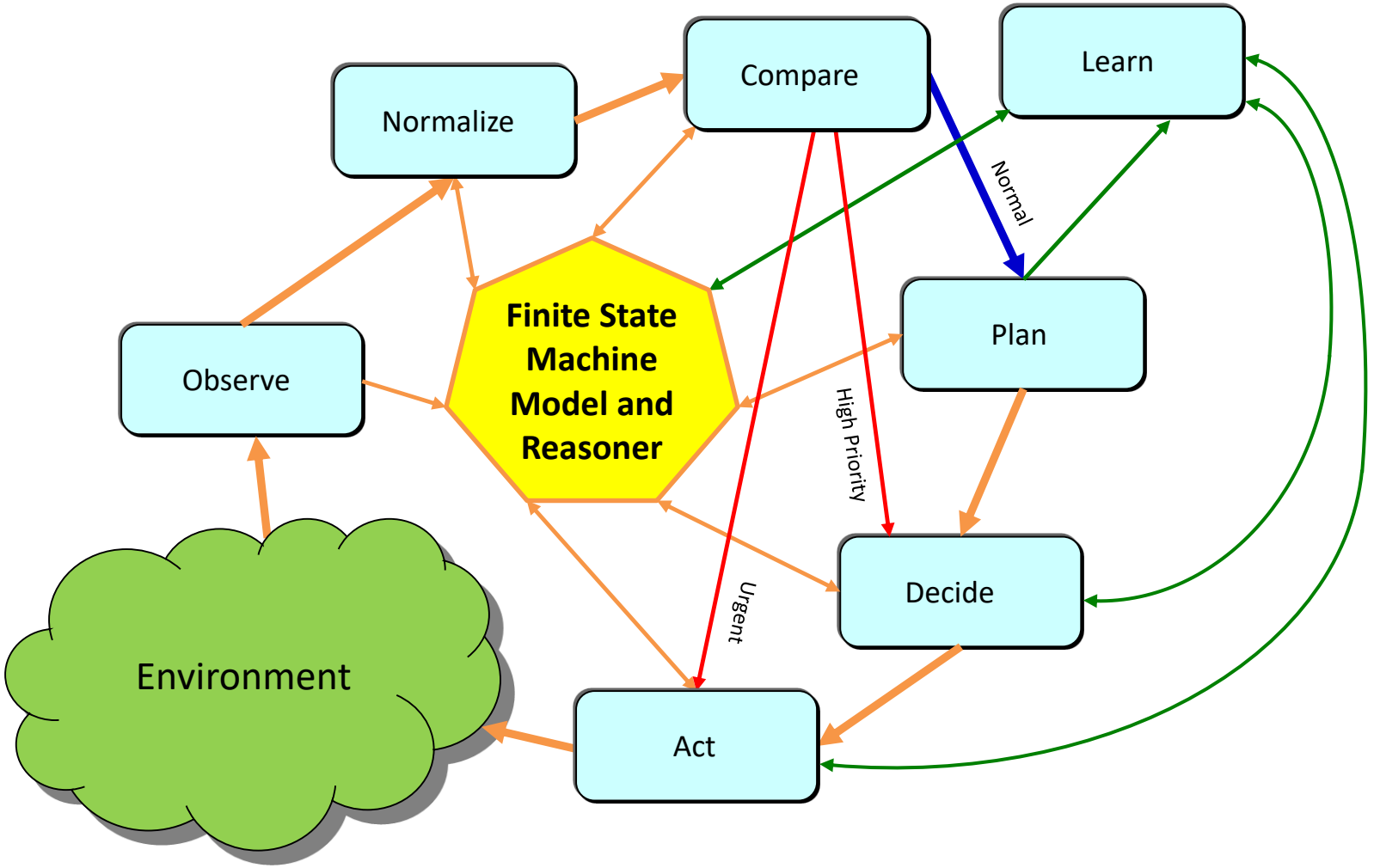


AutoI: EU FP7 Project – 2008 ~ 2010

- The Orchestration Plane governs the behavior of the system in response to changing context and in accordance with applicable business goals and policies. It supervises and integrates all other planes' behavior.
- The Knowledge Plane (KP) consists of models and ontologies to provide increased analysis and inference capabilities. This offers a subset of the functionality provided by **FOCALE**.
- The Management Plane (MP) consists of a set of AMS (Autonomic Management Systems). Each AMS consists of a MP and a KP, as well as interfaces to a dedicated set of models and ontologies and interfaces to one or more Distributed Orchestration Components (DOC). AMSs are federated using the DOC.
- The Virtualization Plane consists of software mechanisms to treat physical resources as a programmable pool of virtual resources that can be organized by the OP into appropriate sets of virtual resources to form components, devices, and networks

AutoI: EU FP7 Project – 2008 ~ 2010

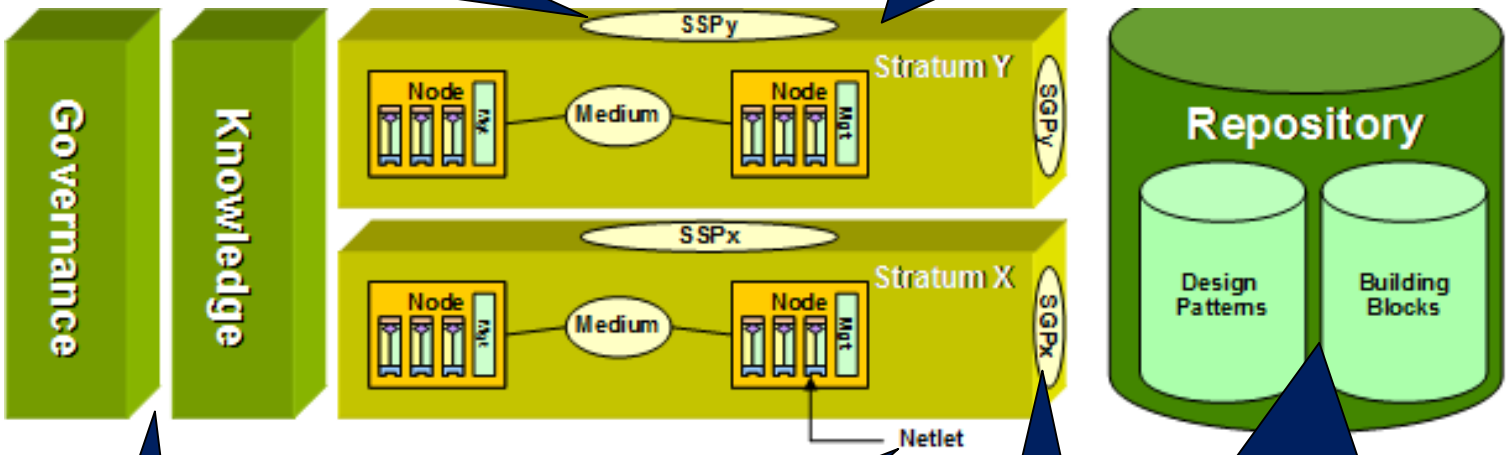
FOCALE Cognition Cycle



4WARD: EU FP7 Project – 2008 ~ 2010

Stratum Service Point provides access to capabilities and functions of a Stratum; contains 1 or more interfaces

Horizontal strata provide resources and capabilities for communication and information management across networks



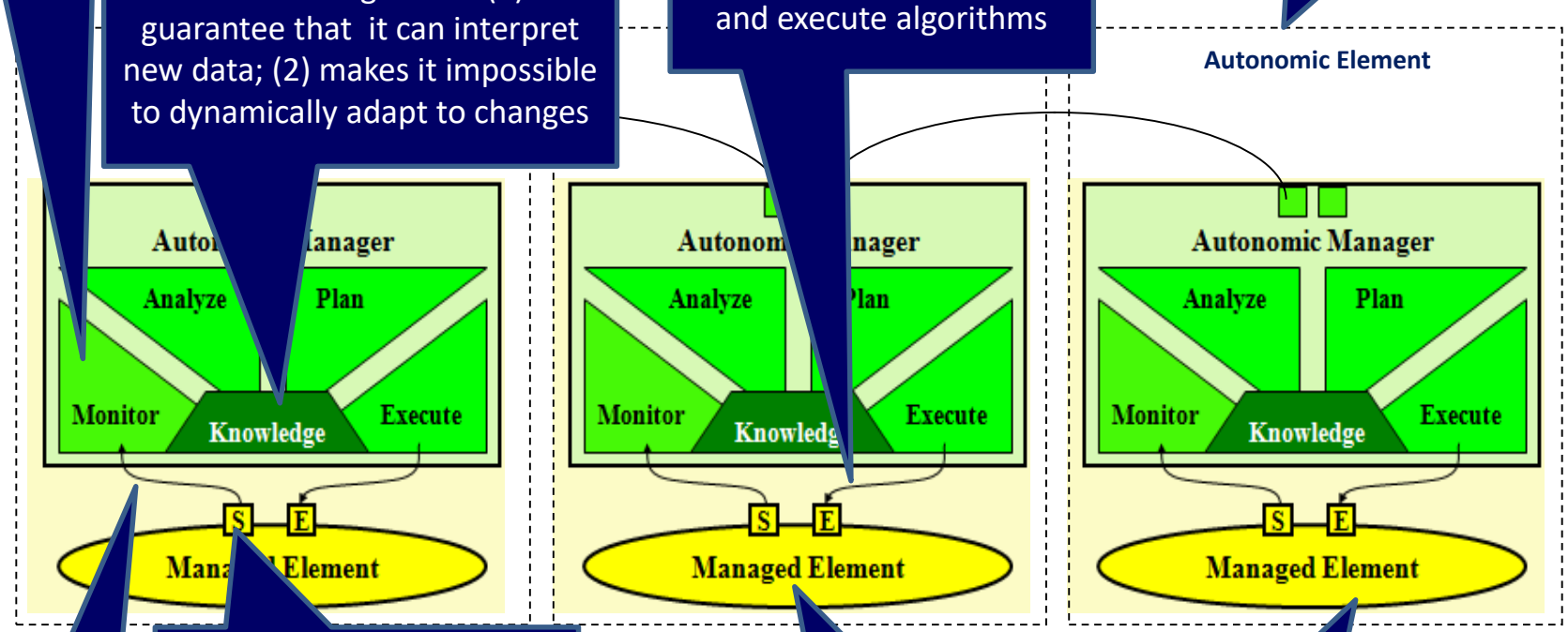
Used to construct new architectures and Netlets

Vertical strata listen to and control other strata

Netlet are components that contain a set of functional blocks that realize a set of protocols for a specific network architecture

Stratum Gateway Point provides access to other strata of the same type

Limitations of IBM MAPE Approach



Too much data received hurts entire system

Static knowledge base: (1) no guarantee that it can interpret new data; (2) makes it impossible to dynamically adapt to changes

Commands limited by pre-defined knowledge, plan, and execute algorithms

Complex non-distributed architecture

Sensors and effectors use pre-defined data formats

Self-Awareness *limited* to what can be instrumented

System cannot dynamically reconfigure itself to support new goals

No support for context-awareness, *emergent functionality, self-organization*

Simple Analysis of the Past Projects

- Knowledge plane & Intelligence
- Network Virtualization
- Flexibility & Programmability
- Mostly Architecturing Work with constrained PoC

- AI & Machine learning Technology
- NFV & SDN based Network Softwarization
- P4 like Programmable Networking

UNIVERSELF: EU FP7 Project – 2010 ~ 2013

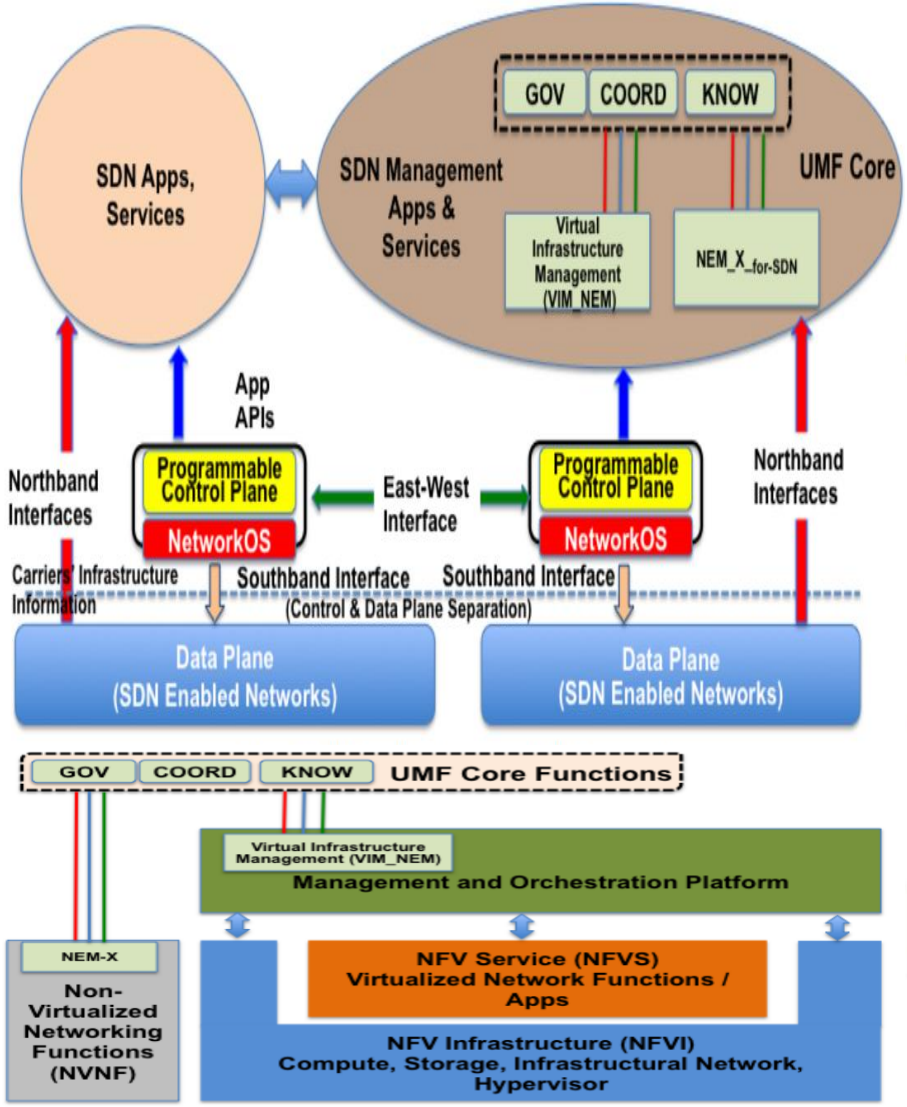
- The **Unified Management Framework (UMF),** which was developed in the UniverSelf project, is an innovative management framework that aims to solve actual network problems and address the growing management complexity of the highly decentralized and dynamic environment of resources and systems in Future Internet.

- The **novel characteristics** are achieved through the smooth and trustworthy embodiment and empowerment of **autonomic principles and techniques** in both services and networks.

- Unified Management Framework (UMF) is a **framework that will help produce the unification, governance, and "plug and play" of autonomic networking solutions within existing and future management ecosystem**s. The objective of the UMF is to facilitate the seamless and trustworthy interworking of autonomic functions (e.g. Network Empowerment Mechanisms - NEMs). As such, UMF aims also the migration from an ecosystem of separate autonomic functions (AFs) towards a coordinated arrangement of AFs.

- UMF as a management framework is based on three main functional blocks namely, **Governance, Coordination and Knowledge** and the interworking with the autonomic management applications – the Network Empowering Mechanisms (NEMs).

UNIVERSELF: EU FP7 Project – 2010 ~ 2013



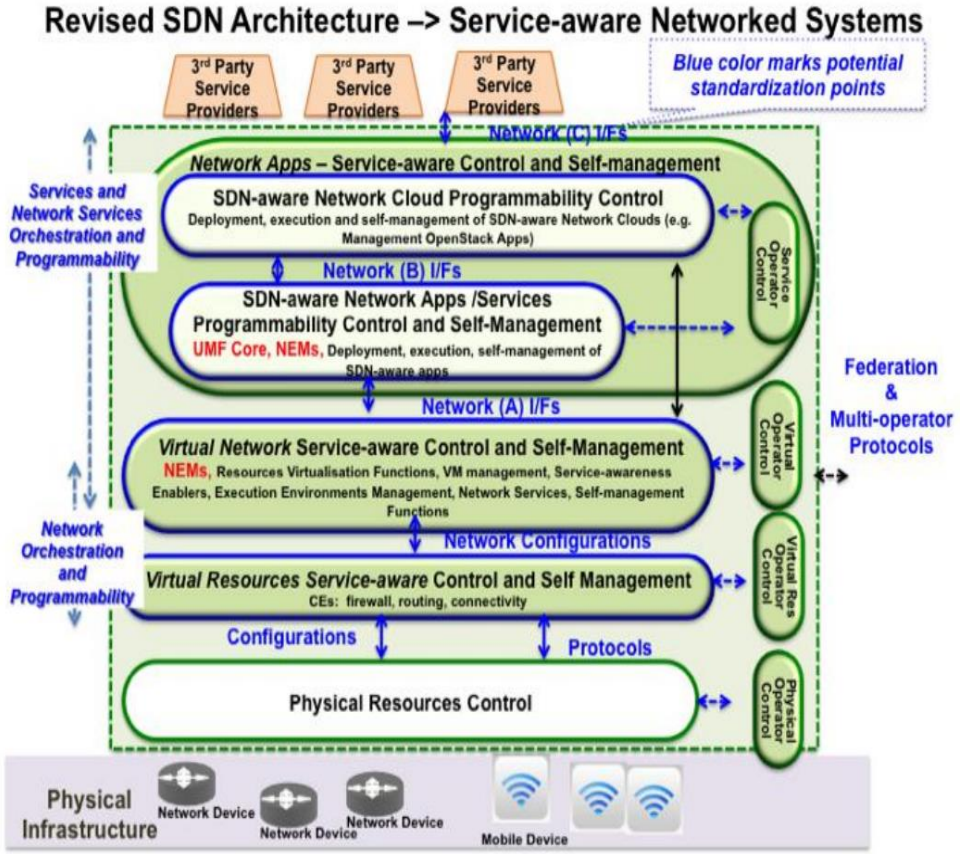
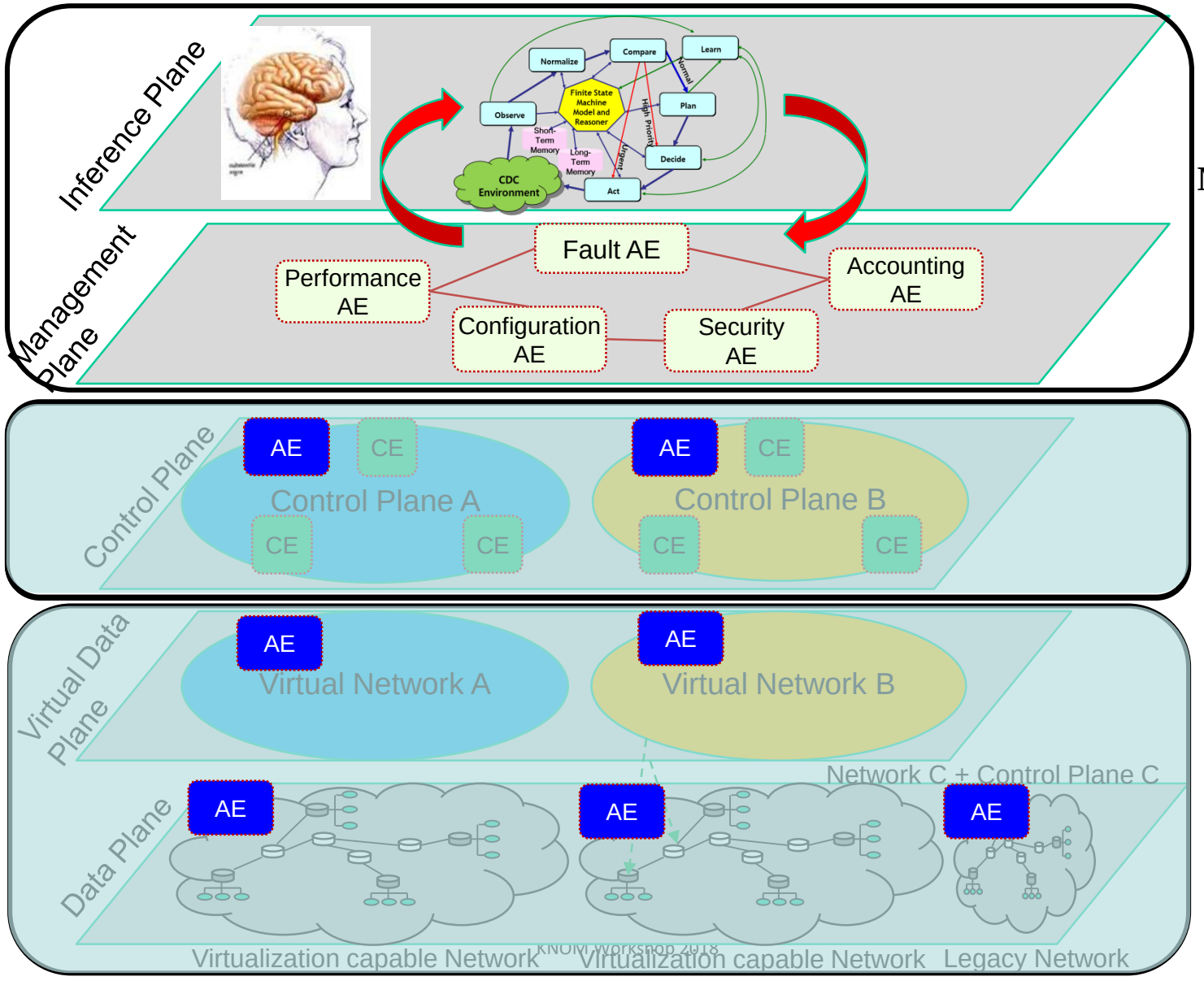


Figure 75: UMF Mapping to NFV

HIMANG: ETRI Project – 2010 ~ 2012



HiMang Management Plane

FI Infra + HiMang AE processes

HIMANG: ETRI Project – 2010 ~ 2012

현재 인터넷의 구조적 한계를 극복하기 위해 안정성, 신뢰성, 확장성, 품질 보장을 위한 미래 인터넷 자율 관리 구조 도출, 관련 원천기술 및 연구 시제품 개발

- **원천연구: HiMang 인지기반 자율 관리 구조/알고리즘 설계 및 적합성 검증**
  - **Data, Control, Management Plane 기능을 분리** 확장성, 신뢰성, 보안성을 고려한 **미래인터넷 최적 관리 분산 구조** 설계 및 적합성 검증
  - 자율관리 실현을 위한 **인지 기반 Self-management** 관리 구조 및 알고리즘 설계
  - 상세 트래픽 모니터링을 통한 **정확한 트래픽 품질 제어, 장애 탐지** 및 관리 구조 설계
- **연구시제품 개발: HiMang 구조 기반 연구시제품 개발**
  - HiMang^{Smart}: 스마트네트워크 구성, 성능 및 장애 관리 시스템
  - HiMang^{Cloud}: 미래형 클라우드 망/서비스 구성, 성능 및 장애 관리 시스템
  - HiMang^{Testbed}: 미래인터넷 테스트 베드 구성, 성능 및 장애관리 시스템

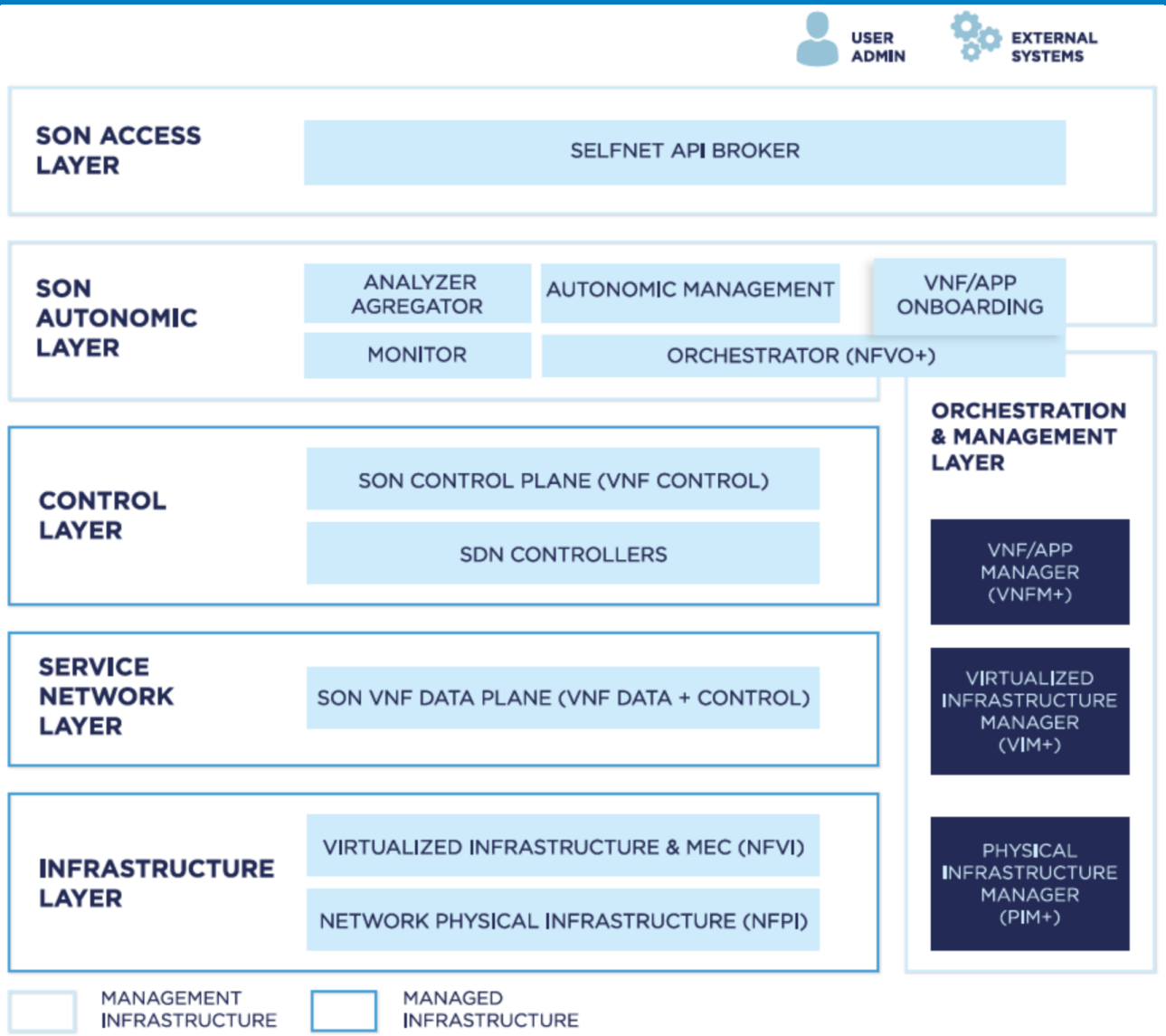
HiMang: Highly Manageable Network and Service Architecture for New Generation

SELFNET: EU Horizon2020 Project – 2015 ~ 2018

- SELFNET is a project focusing on **5G network management**, with the main objective of developing an efficient **self-organizing network management framework for 5G** through the combination of a **virtualized and software defined network** infrastructure with **artificial intelligence** technologies, pursuing an automated network monitoring, an autonomic network maintenance, an automated deployment of network management tools and an automated network service provisioning.

- SELFNET is driven by **use cases** designed to address major network management problems including
  - **Self-protection capabilities against distributed cyber-attacks**,
  - **Self-healing capabilities against network failures, and**
  - **Self-optimization to dynamically improve the performance of the network and the Quality of Experience (QoE) of the users**.

SELFNET: EU Horizon2020 Project – 2015 ~ 2018



How can we judge that "**Autonomic Networking**" era is close?

- Market Demands
- Technology Maturity
- Standardization Readiness
- Use Cases
- Challenges

Standardization/Open Source Activities: Why Now?

- Many aspects of small networks have been self-configuring for years, including unmanaged home and small office networks.
- And numerous existing protocols have a flavour of autonomic properties (e.g., the spanning-tree algorithm needs no manual configuration in order to operate, and some routing protocols require very little configuration).
- Recently, prototypes and initial products of explicitly autonomic protocols have emerged from some of the major networking equipment vendors.
- However, it is clearly necessary to have some basic standards in place if AN is to become relevant to large multivendor networks.

Standardization/Open Source Maturity

- GANA
- IETF
- ITU-T
- FG ML-5G
- 3GPP
- ZSM
- ONAP

Standardization/Open Source Maturity: GANA

ETSI NTECH AFI Working Group focuses mainly on:

1) ***Autonomic Networking*** which includes **Self-Manageability** and properties within **Network Nodes/Functions** and **"in-network"** Self-Management
2) ***Autonomic Management and Control of Networks and Services*** by Autonomics introduced in the **outer (logically centralized) Management and Control Planes** of Network Architectures.

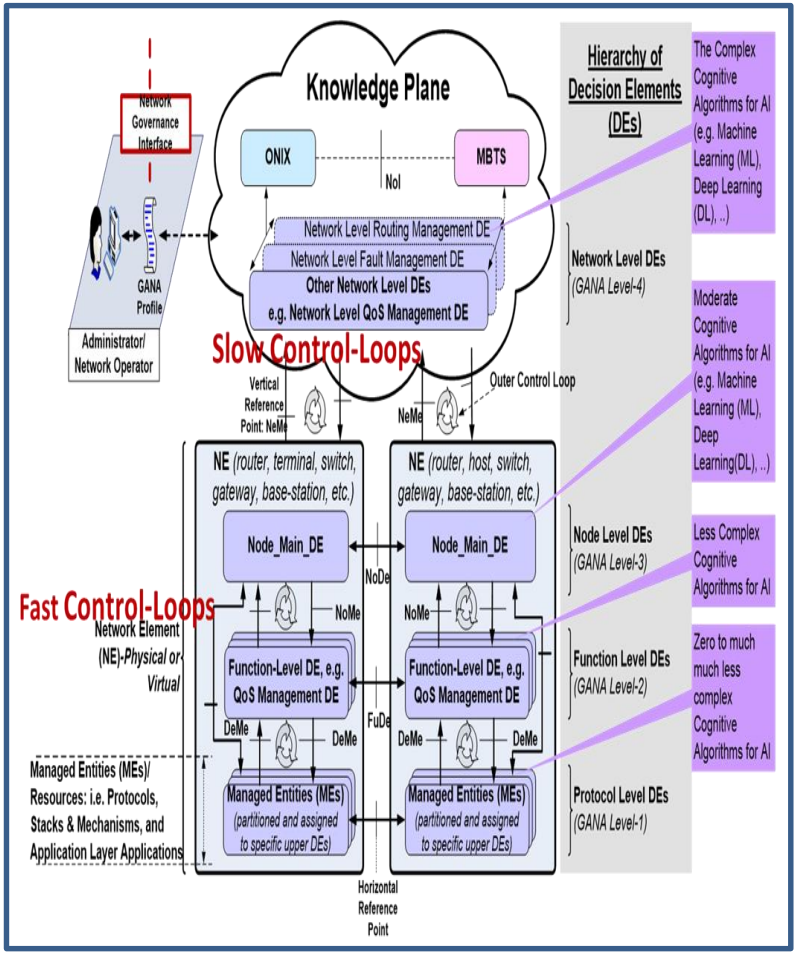
- The ETSI NTECH AFI WG **"GANA" (Generic Architecture Networking Architecture) Reference Model** combines perspectives on these **two aspects**, so as to capture **the holistic picture** with **the goal of prescribing** Autonomic Networking, Self-adaptive networking, Cognitive Networking and Self-Management **Design** and **Operational** principles that enable to achieve OPEX reduction and other benefits "Autonomics" brings to Telecom Service Provider Networks and Enterprise Networks

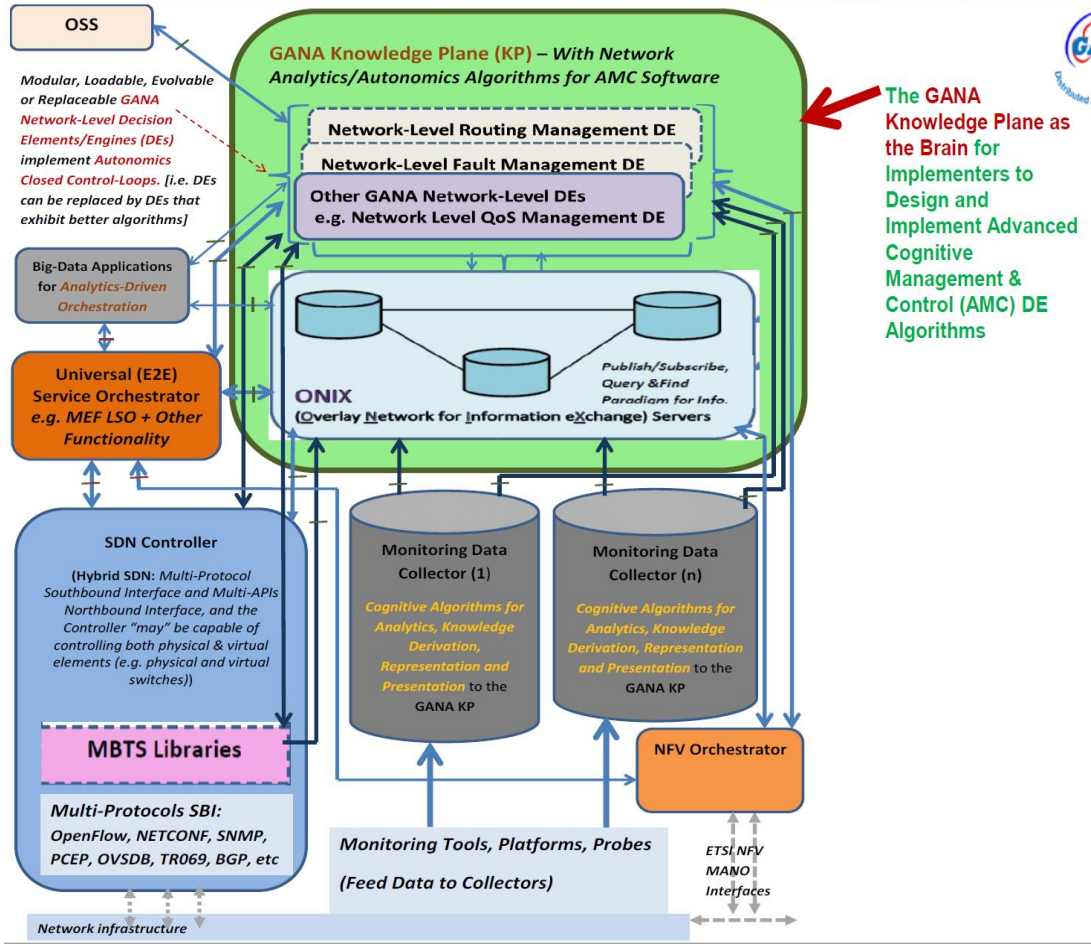
- ETSI NTECH AFI WG performs **GANA instantiations** onto Evolving and Future Network Architectures and their Management & Control Architectures, ***e.g. GANA instantiations onto BBF and 3GPP Architectures***

- Autonomics algorithms in the scope of NTECH AFI WG work are meant to be implemented by the so-called GANA Decision-making-Elements **(DEs)**, and such algorithms include **Cognitive algorithms** for Artificial Intelligence **(AI)**—such as Machine Learning **(ML)** and Deep Learning **(DL)**, etc.

- Moreover, NTECH AFI WG via PoCs is addressing **OPEX challenges** faced by **Network and Service Providers** by measuring the benefit of Autonomics/Self-Management for Networks and Services

Standardization/Open Source Maturity: GANA





Standardization/Open Source Maturity: IETF

IETF/IRTF efforts (past and ongoing)

- 3 Autonomics for Network Management meetings @ NMRG
  - Gap analysis, definitions, network configuration, bootstrapping trust, P2P detection of SLA violations, Lessons learned, Real world experiences
- Outcomes of the NMRG work
  - UCAN BoF (IETF 90) → ANIMA WG
  - RFC 7575, RFC 7576
- Related efforts
  - SUPA, HOMENET, SDNRG, NFVRG, NMLRG (proposed), IDN (BoF?)

Standardization/Open Source Maturity: IETF

ANIMA WG

- First charter
  - Development of protocol specifications (or extensions)
    - Discovery and Negotiation for autonomic nodes → GRASP
    - Bootstrapping a trust infrastructure → BRSKI
    - Separated Autonomic Control Plane → ACP
  - Limited initial set of work items → avoid "boiling the ocean"
  - Unchartered work encouraged as individual submissions or **NMRG submissions**
- “Nov 2018 - recharter to refocus scope, or close”

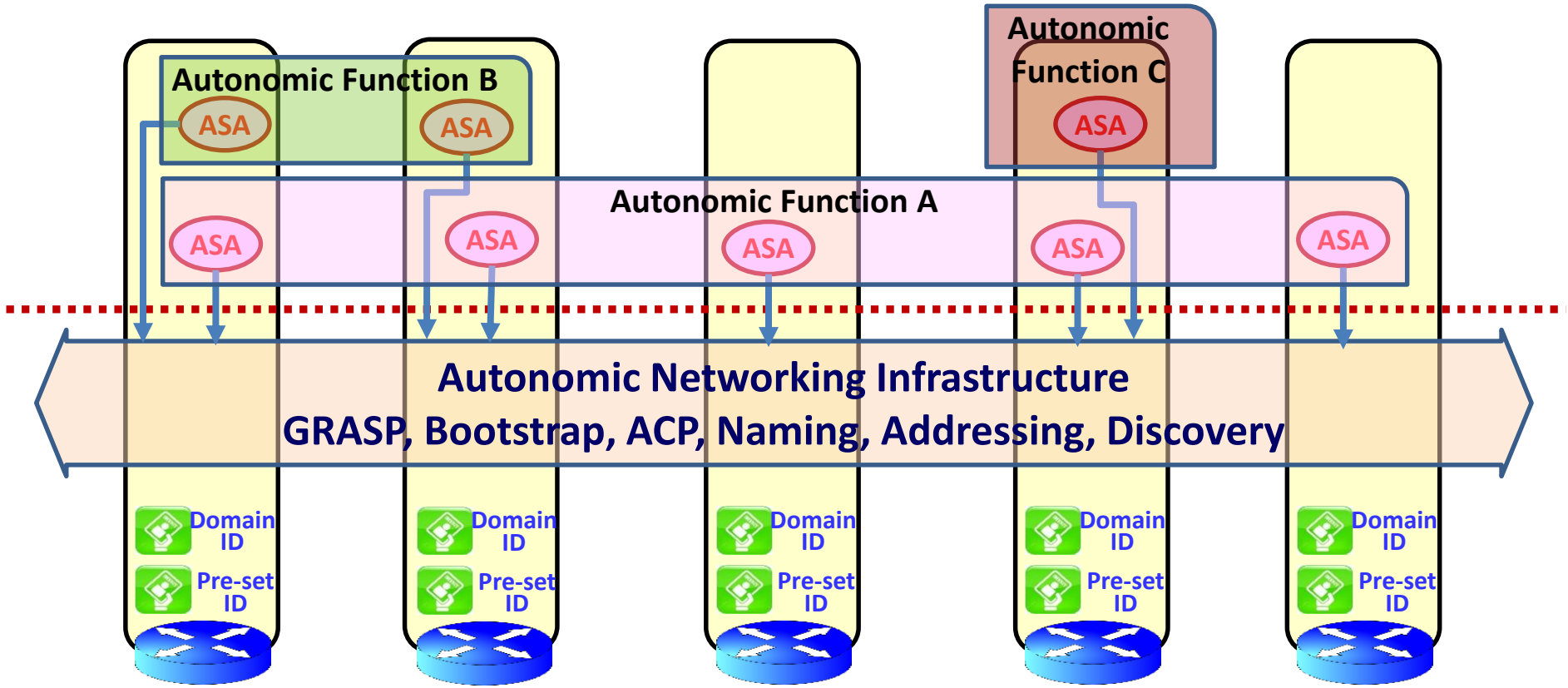
Standardization/Open Source Maturity: IETF

ANIMA Design Goals

- Self-Management
  - Self-configuration, Self-healing, Self-optimizing, Self-protection
- Coexistence with Traditional Management
  - node-specific network management > autonomic Intent > autonomic default behavior
- Secure by Default
  - Asserts membership using a domain identity
  - a certificate issued by a domain certification authority
  - domain identity is used for nodes
    - to learn about their neighboring nodes,
    - to determine the boundaries of the domain, and
    - to cryptographically secure interactions within the domain
  - Nodes from different domains can also mutually verify their identity and secure interactions as long as they have a mutually respected trust anchor

Standardization/Open Source Maturity: IETF

ANIMA Reference Model



Standardization/Open Source Maturity: IETF

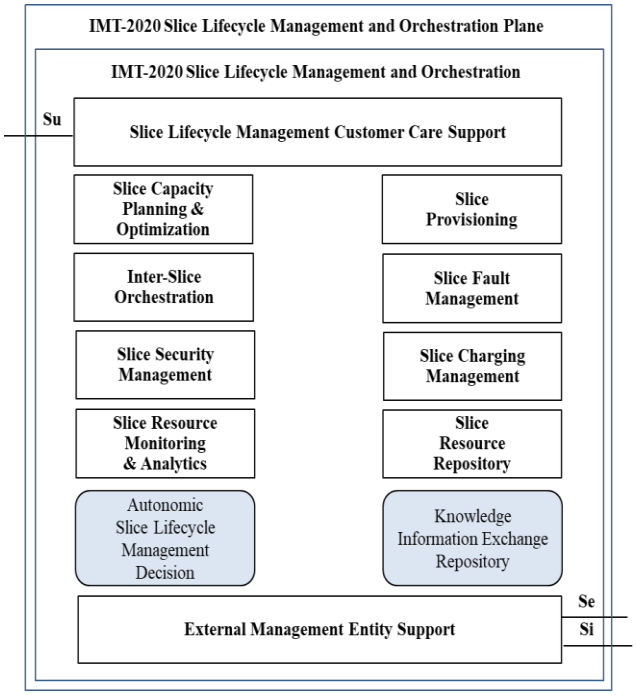
Outlook for AN @ NMRG

- Is there a need/interest/energy for **Autonomics 3.0**?
- If yes, 4 proposed efforts:
  - Intent-Based Networking
    - I-D: [draft-clemm-nmrg-dist-intent-01]
  - AI/ML for Network Management
    - I-D: [draft-kim-nmrg-rl-03]
  - Integration with network automation approaches
    - ETSI Zero Touch Network and Service Management
  - “Eat your own dog food” approach → revisit RFC 7575/7576
    - What is out of ANIMA scope in a long term (after recharter)?

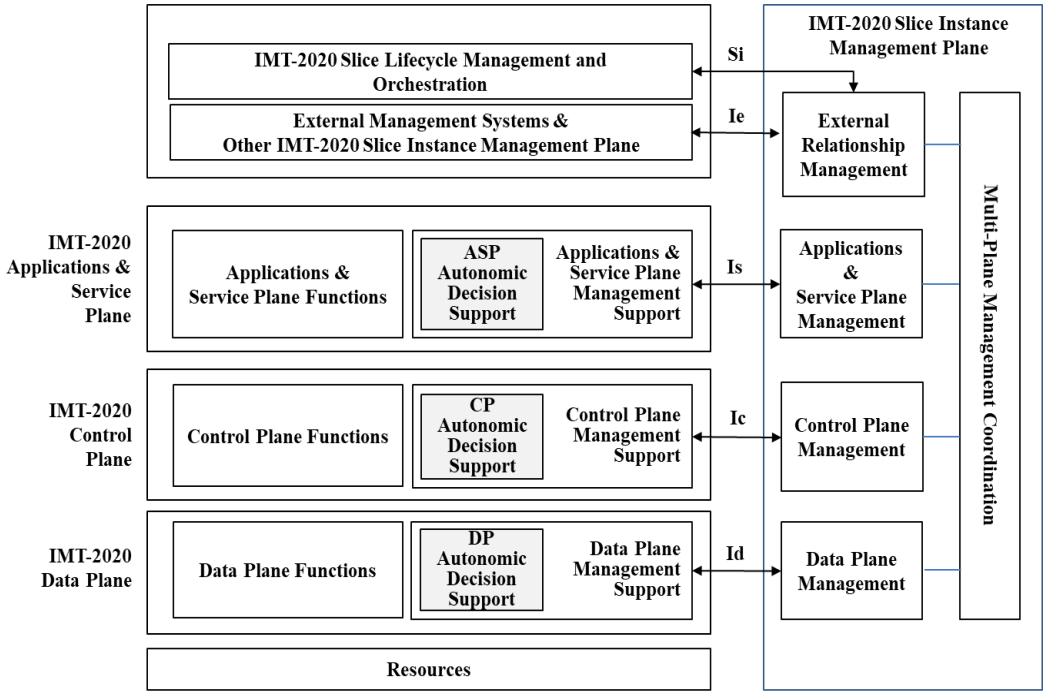
Standardization/Open Source Maturity: ITU-T

Y.3324 (formerly Y.amc): Requirements and Architectural Framework for Auto Manageable Networks and Services

This Recommendation specifies high-level and functional requirements and architecture of Autonomic Management and Control (AMC) for IMT-2020 networks. It also specifies interworking reference points between AMC and IMT-2020 management and orchestration architecture, and legacy NMS/OSS. In Appendix I, it describes a use case to realize the AMC architecture through ETSI GANA reference model.



High-level AMC Architecture for IMT-2020 Network Slice Lifecycle Management



High-level AMC Architecture for IMT-2020 Network Slice Instance Management

Standardization/Open Source Maturity: FG-ML5G

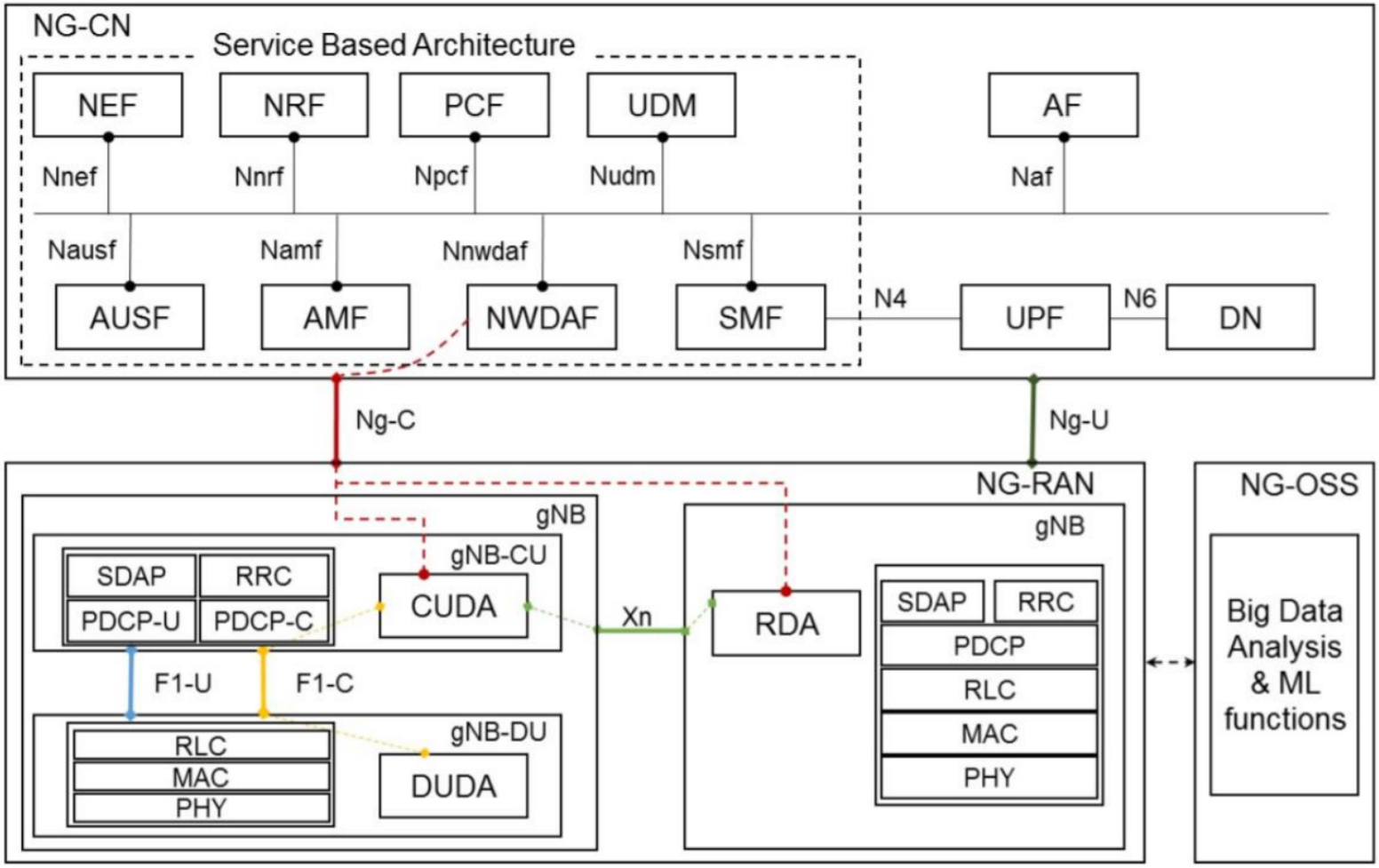


Figure 2 The Reference of Wireless Big Data and AI enabled Architecture.

Standardization/Open Source Maturity: FG-ML5G

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Focus Group on Machine Learning for Future Networks including 5G

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- Focus Group on Machine Learning for Future Networks including 5G
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- Focus Group on Digital Currency including Digital Fiat Currency
- Focus Group on Data Processing and Management

FG-ML5G

The ITU-T Focus Group on Machine Learning for Future Networks including 5G was established by ITU-T Study Group 13 at its meeting in Geneva, 6-17 November 2017. The Focus Group will draft technical reports and specifications for machine learning (ML) for future networks, including interfaces, network architectures, protocols, algorithms and data formats.

Terms of Reference:

- Overall ToR of FG ML5G
- WG1 "Use cases, services and requirements"
- WG2 "Data formats & ML technologies"
- WG3 "ML-aware network architecture"

Participation in FG-ML5G is free of charge and open to all. To receive updates and announcements related to this group, please subscribe to the FG-ML5G mailing list (see the "FG-ML5G Mailing lists" tab on the right of this page).

Parent group: ITU-T Study Group 13

Meetings and Related Event | Focus Group News | Focus Group Videos

4th meeting of FG-ML5G

Tokyo, Japan, 27-29 November 2018

Seminar on "Business innovation and value creation utilizing IoT/AI" ,

26 November 2018 (28 September)

- Meeting announcement (27 August)
- Registration (27 August)
- Practical information (27 August)
- Remote participation
- Draft agenda
- Meeting documents

A TIES or Guest account is required to access FG documents and subscribe to the FG-ML5G mailing lists.

Standardization/Open Source Maturity: FG-ML5G

ITU Workshop on "Machine Learning for 5G and beyond"
San Jose, United States, 7 August 2018

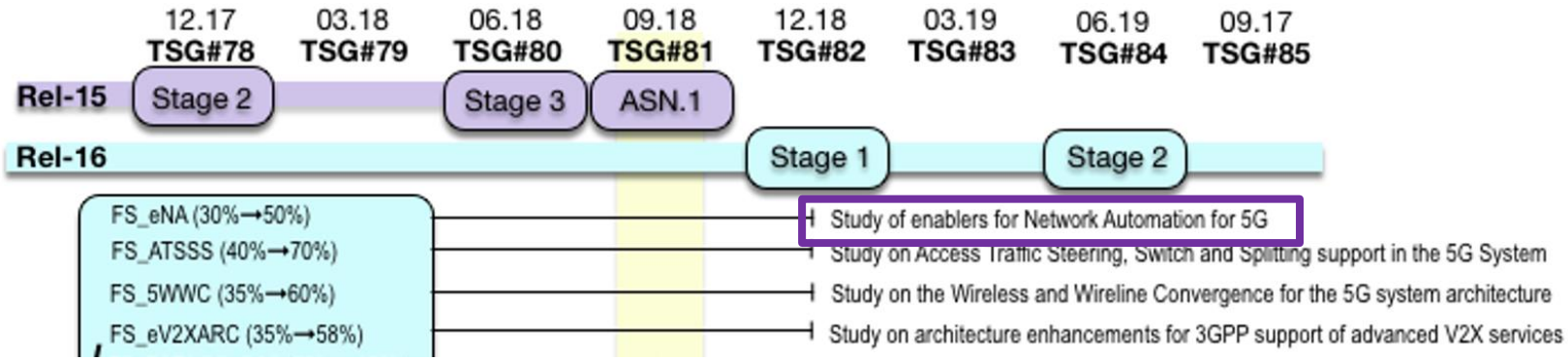
Contact: tsbevents@itu.int

The workshop includes the following sessions, presenting invited expert speakers from the academia and the industry:

07:30	**Registration**
09:00 - 09:15	**Welcome** • **Chaesub Lee**, Director, ITU Telecommunication Standardization Bureau [Biography] • **Bahareh Sadeghi**, Intel [Biography] • **Slawomir Stanczak**, Chairman, ITU Focus Group on Machine Learning for Future Networks including 5G [Biography]
09:15 - 10:10	**Session 1 (part 1): Research advances in ML for wireless networks** **Moderator: Slawomir Stanczak**, Chairman, ITU Focus Group on Machine Learning for Future Networks including 5G [Biography] • **Andreas Molisch**, University of Southern California: *"Machine learning for wireless propagation channels"* [Biography I Abstract I Presentation] • **Geoffrey Li,** Georgia Institute of Technology: *"Deep Learning in Physical Layer Communications"* [Biography I Abstract I Presentation]
10:10 - 10:40	**Coffee Break**
10:40 - 12:00	**Session 1 (part 2): Research advances in ML for wireless networks** **Moderator: Slawomir Stanczak**, Chairman, ITU Focus Group on Machine Learning for Future Networks including 5G [Biography] • **Kwang-cheng Chen**, University of South Florida: *"Machine Learning Enables Mobile Networks – Anticipatory Mobility Management for Ultra-Low Latency Mobile Networking"* [Biography I Abstract I Presentation] • **Sachin Katti**, Stanford University Presented by: **Sandeep Chinchali**, PhD Candidate, Stanford University [Abstract I Presentation]: *"Data-Driven Control of Cellular Networks"* • **Renato Cavalcante**, Fraunhofer Heinrich Hertz Institute & Technical University Berlin: *"Machine learning tools for highly dynamic wireless environments"* [Biography I Abstract]
12:00 - 13:30	**Lunch Break**
13:30 - 14:30	**Session 2: ML solutions for industry applications** Moderator: **Mostafa Essa**, Vodafone [Biography] • **Hujun Yin**, Intel: *"Emerging Network Forms – 5G, AI and Immersive Media"* [Biography I Abstract I Presentation] • **Phil Raymond**, Philips: *"Trends, requirements and challenges in enabling the Continuum of Connected Care"* [Biography I Abstract I Presentation]

Standardization/Open Source Maturity: 3GPP

SA WG2 Summary



SA WG 5 Summary

SP-180823	**New WID on Intent driven management service for mobile network**
SP-180826	**New SID Study on management aspects of communication services**
SP-180827	**New Study on Self-Organizing Networks (SON) for 5G**

Standardization/Open Source Maturity: ZSM

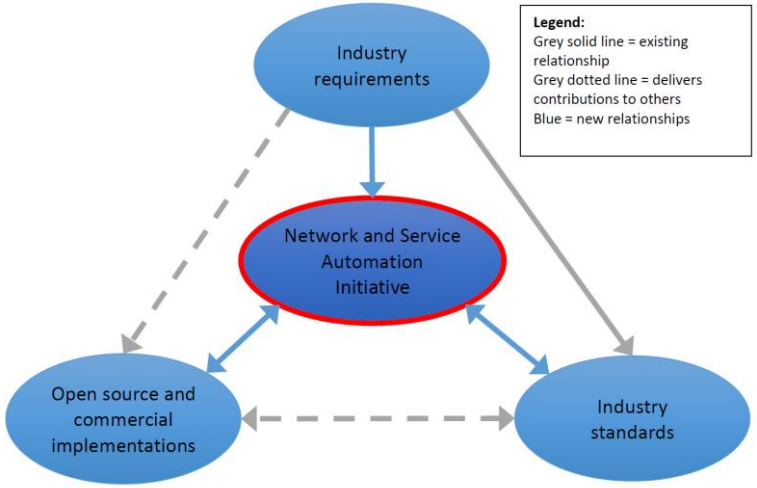
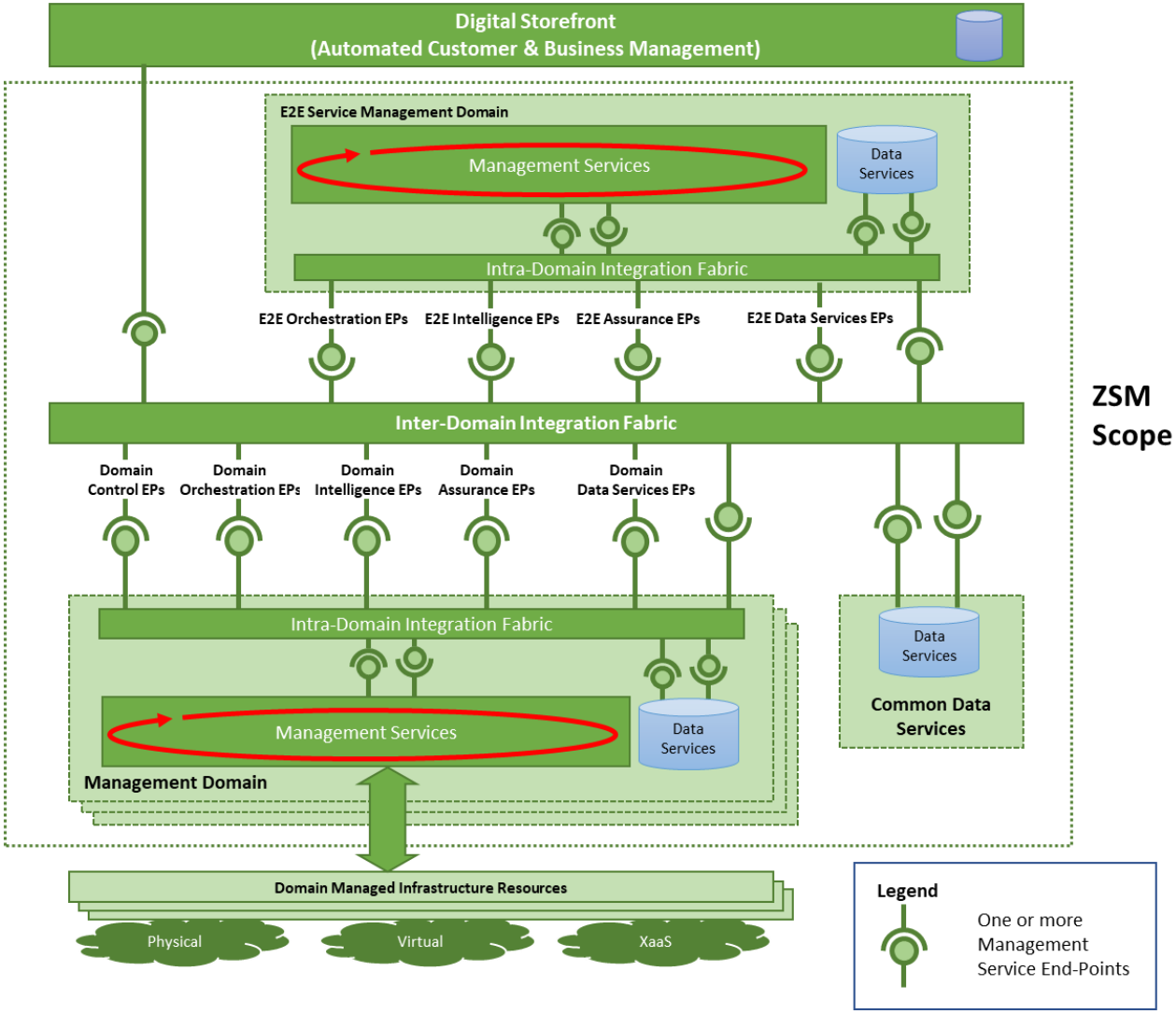


Figure 1: Network & service management automation initiative and its role in the end-to-end operation ecosystem.

Standardization/Open Source Maturity: ZSM

ZSM Framework Reference Architecture

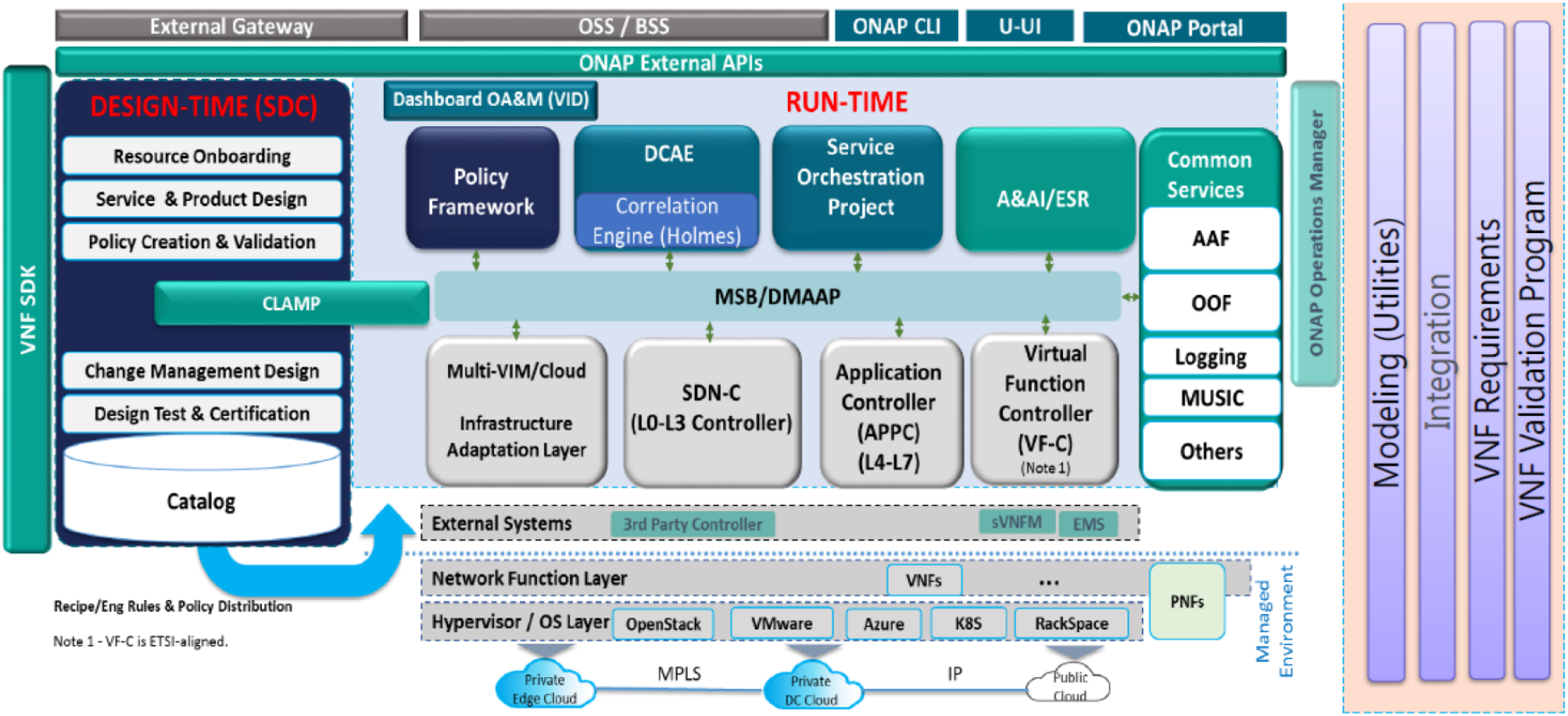


Standardization/Open Source Maturity: ONAP

ONAP Beijing Release Architecture

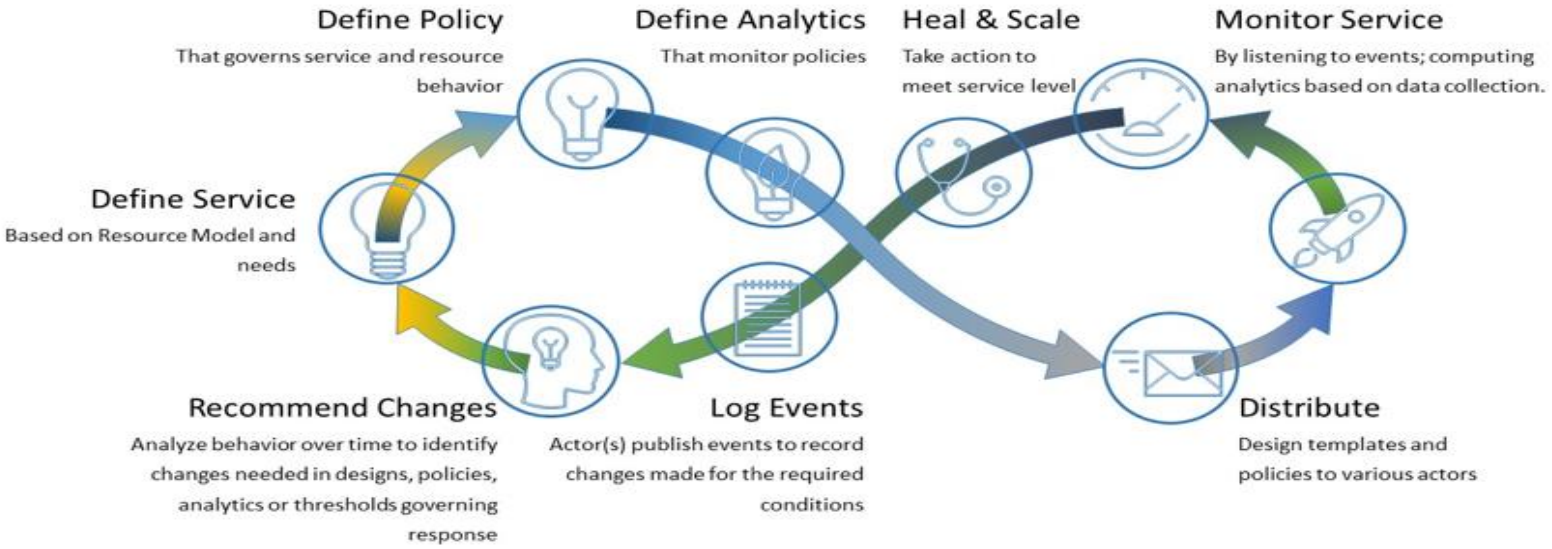
Open Network Automation Platform

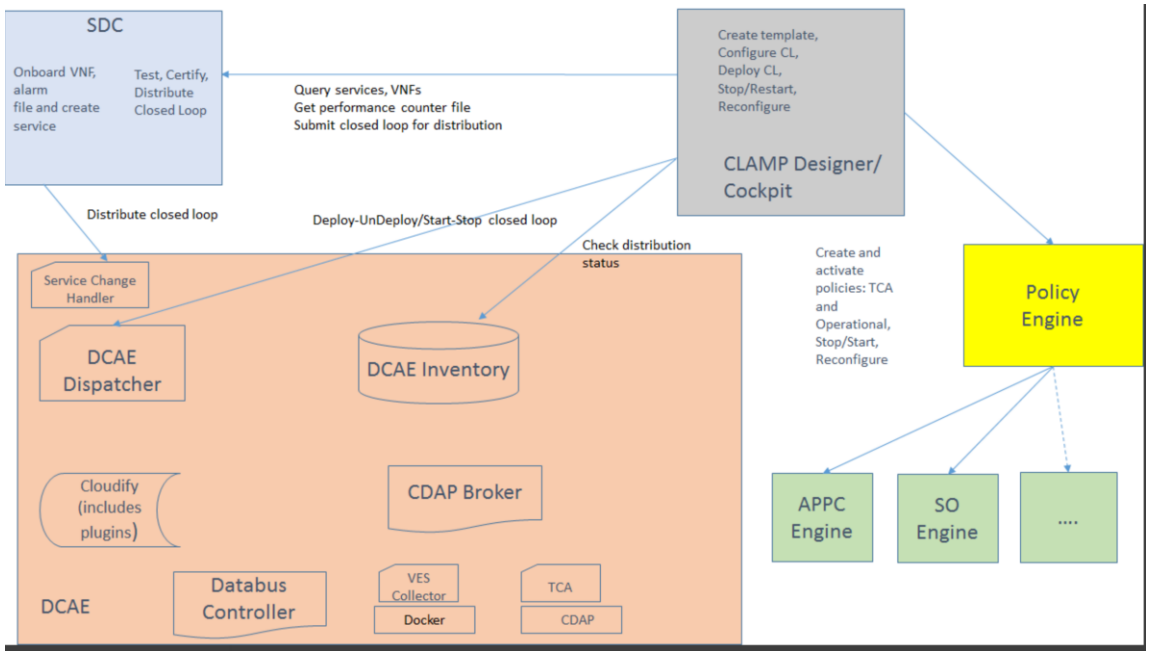
Open source networking projects are transforming how service providers and enterprises develop, deploy, and scale their networks and next-generation services. The Open Network Automation Platform (ONAP) project orchestrates and manages physical and virtual network services to bring agility, higher customer satisfaction and lower costs.



ONAP CLAMP

Closed Loop Automation Management Project



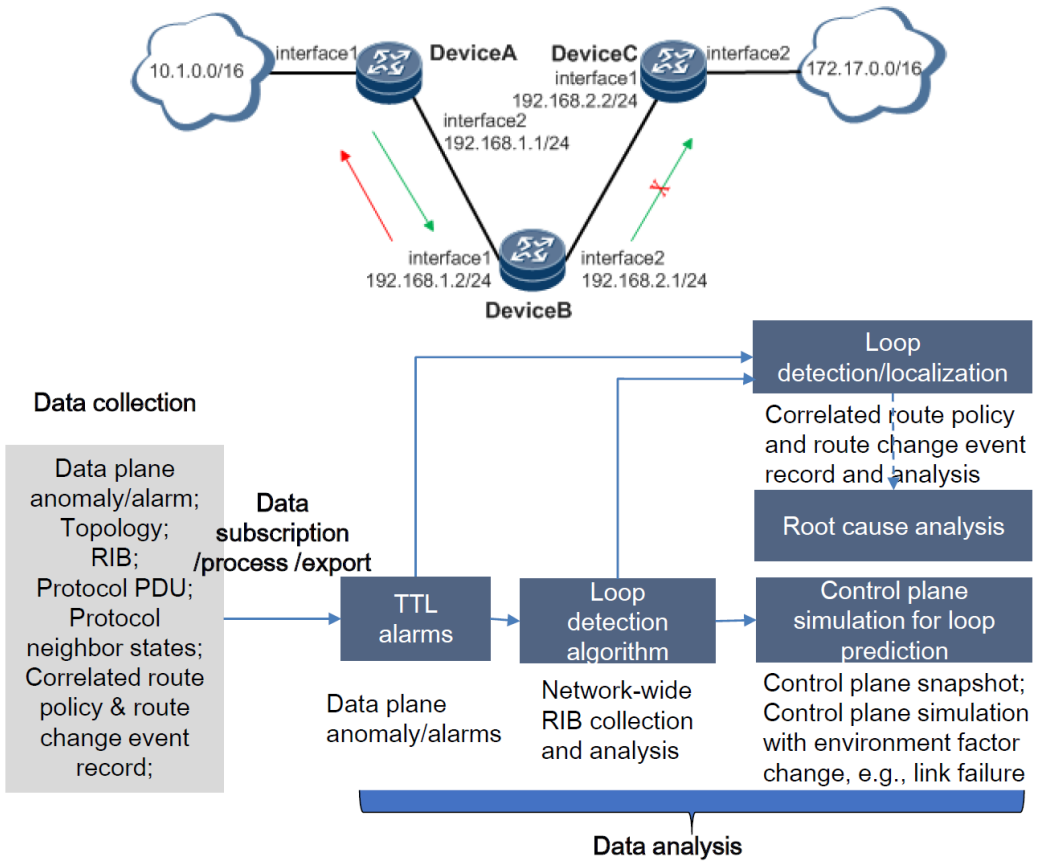


How can we judge that "**Autonomic Networking**" era is close?

- Market Demands
- Technology Maturity
- Standardization Readiness
- Use Cases
- Challenges

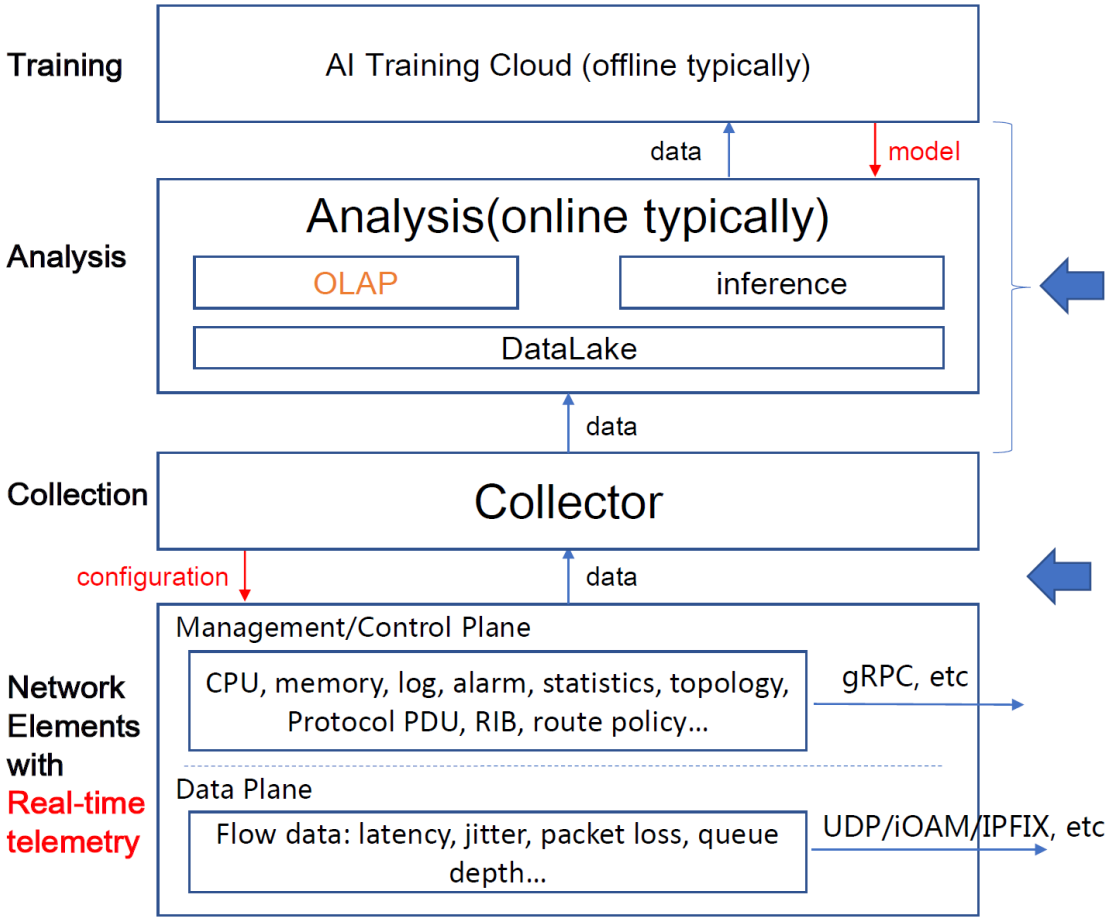
Huawei Use Case: Routing loop detection, Localization, Root cause analysis and predition

- Troubleshooting use cases
  - Routing table error, e.g., route loop
  - Route loop types
    1. Loop currently exists, and reflected at the data plane
    2. Loop currently exists, but not yet reflected at the data plane (i.e., no data flow is currently traversing the path)
    3. Loop currently does not exist, with environment change (e.g., link failure), the loop appears
- Gap and Motivation
  - Traditional device-by-device CLI check is both time and labor consuming
  - Having difficulty correlating the route loop with root cause
  - Not capable of predicting route loop
- Objective
  - Detecting and locating issues in seconds/minutes
  - Accurate root cause analysis to module /configuration /policy
  - Control plane simulation for loop prediction



Source: Hwawei, IETF103 Host Speaker Series

Huawei Use Case: Routing loop detection, Localization, Root cause analysis and predition



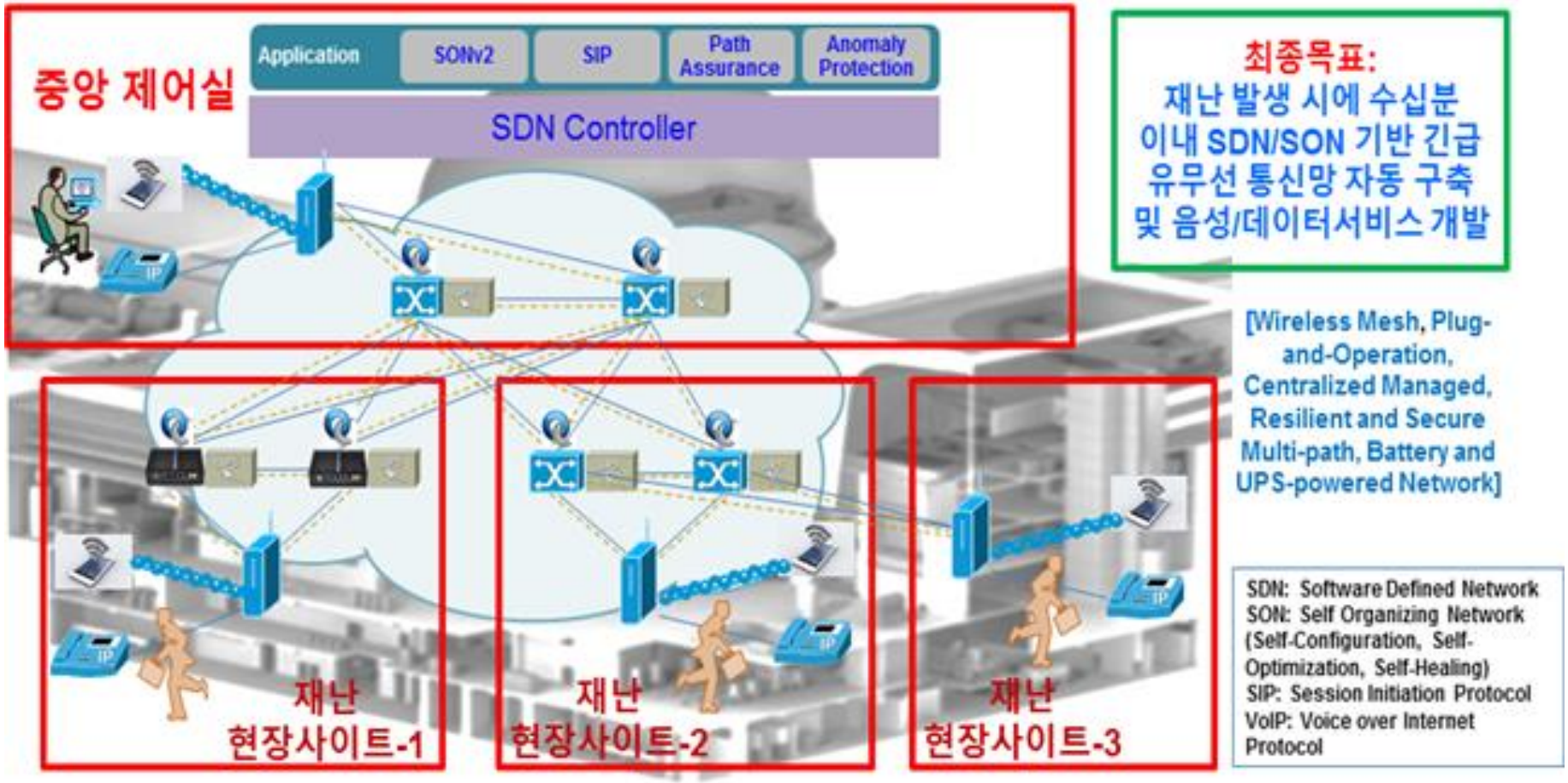
The interface among Training, Analysis and Collection components are service interfaces. Service models can be standardized but in many case not required because it's internal to software system.

To define what the network element should submit, in what format, encoding, protocols, the domain of standardization, especially the capability of network elements.

- ✓ **Data Subscription:** YANG push
- ✓ **Data Process:** Smart filter, soft/hard DNP (dynamic network probe), Sketch, Marking Trigger
- ✓ **Data Export:** BMP, iOAM, IPFIX, UDP, Netconf, gRPC…

Source: Hwawei, IETF103 Host Speaker Series

ETRI Use Case: AN for Neuclear Reactor Emergency Failure



How can we judge that "**Autonomic Networking**" era is close?

- Market Demands
- Technology Maturity
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- Challenges

AN Challeges

Key design challenges for network transport layer

① **Decoupled from service**

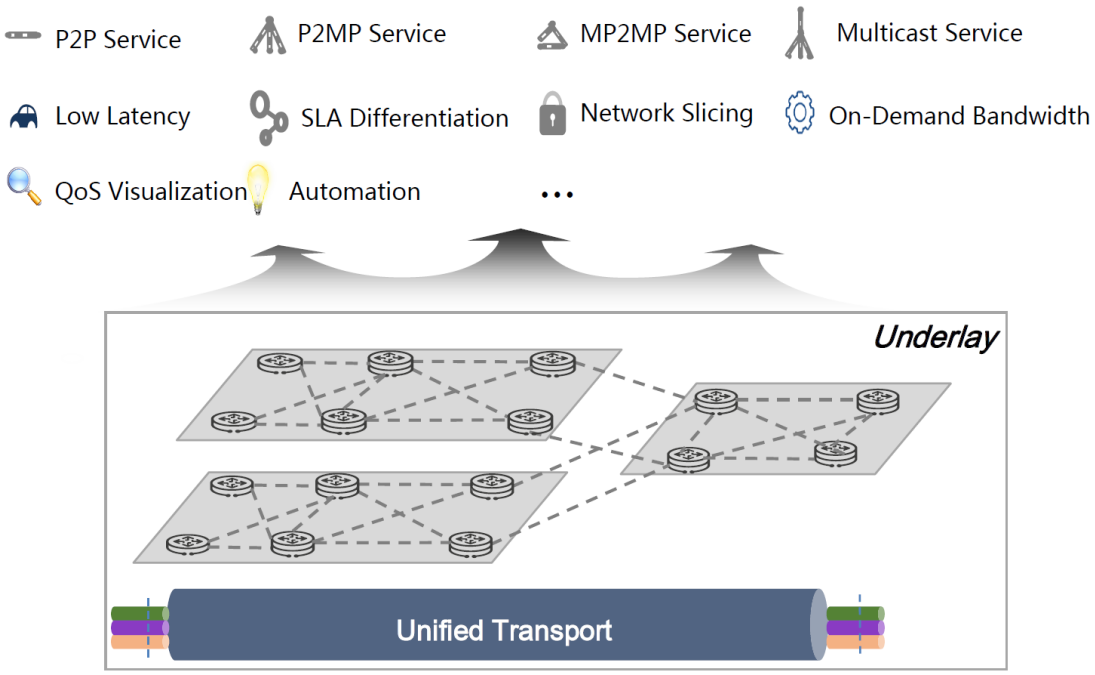
② **Simplified protocols system** to make it easy for O&M, and more robust network

③ **High utilization** by routing with service SLA as input

④ **High Availability,** to recover underlay path quickly at failure, without awareness by overlay, lower the protection requirement of overlay

⑤ **Automatic O&M**, based on machine analysis ans inference, lower the bar for O&M personnel requirement

⑥ **Open programmability**, provide P2P & P2MP service to overlay, with open SLA capability etc



How to guarantee the capacity growth and resource utilization with reasonable cost?

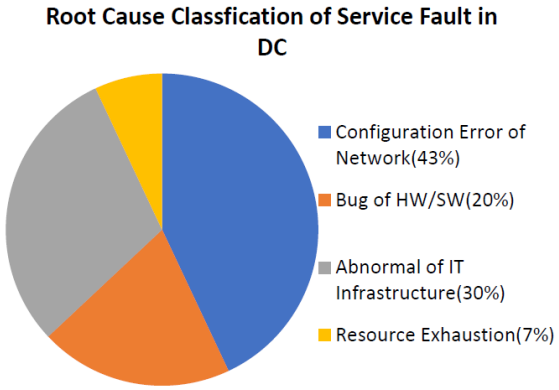
How to visibility and guarantee SLA of service?

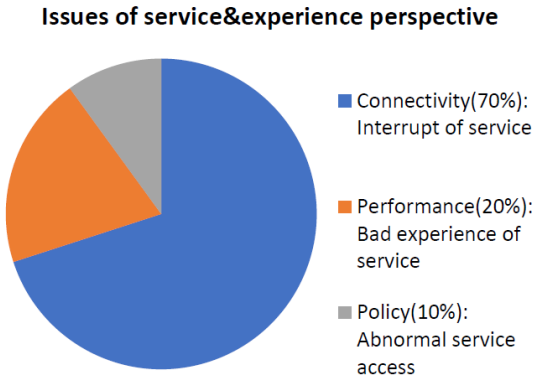
How to achieve always-on underlay?

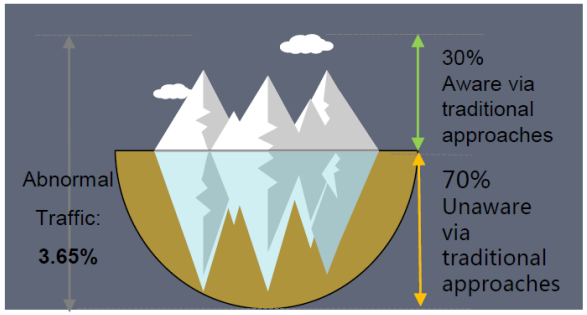
Source: Hwawei, IETF103 Host Speaker Series

AN Challeges

Challenge for analytics and intelligence of autonomous network





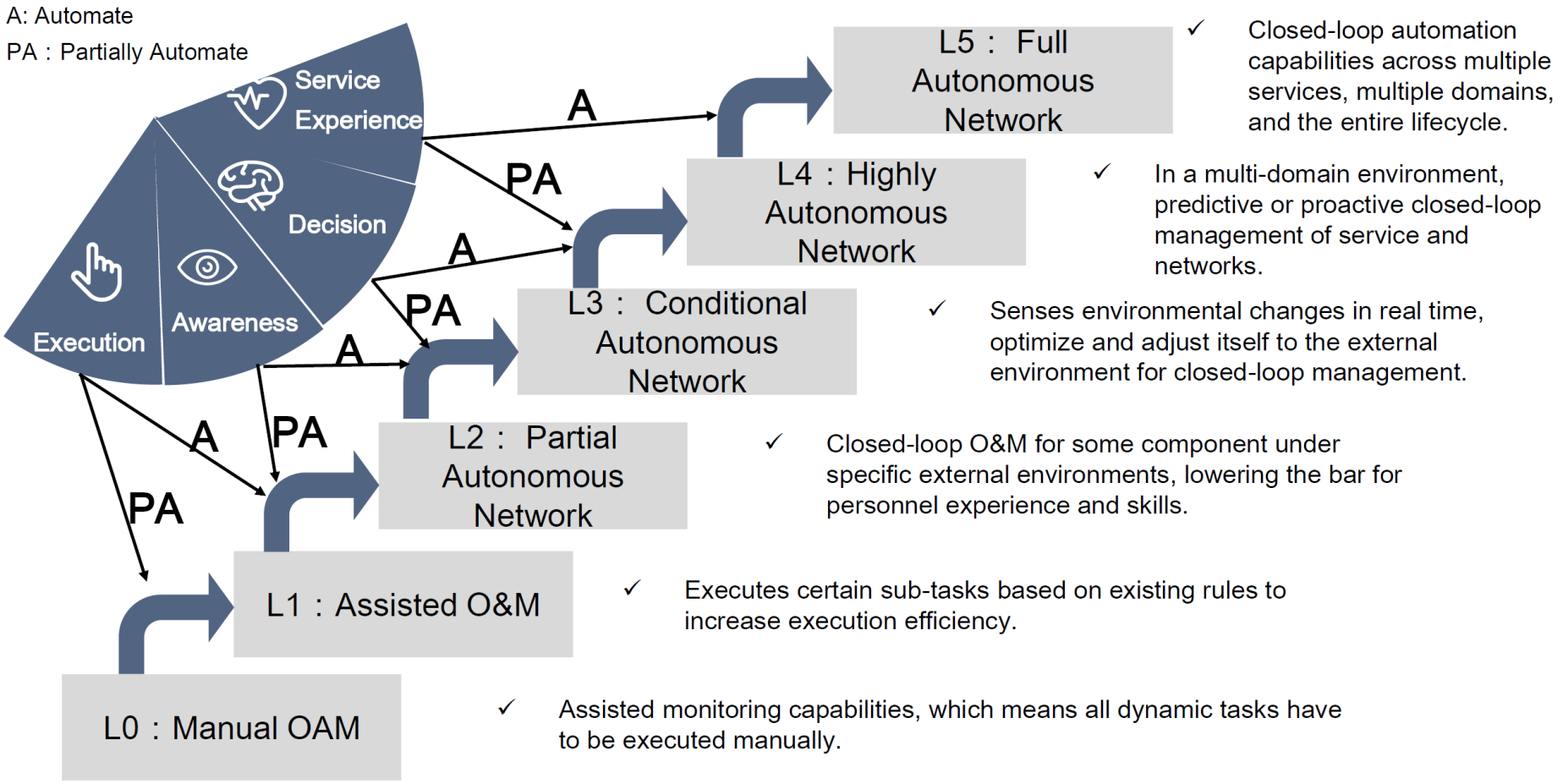


- **Lack of data** for fault cause analysis
  - Not coverage completely from chipset, device, network, IT infrastructure, flow and applications
  - Low sampling frequency, min -> ms;
  - Lack of historic data, **>90%** does not support fault playback
- **Unaware of abnormal** application and network **status**, majority faults are detected **passively**
- Lack of capability to **correlate** the issues between network and applications
- Capability to **predictive** resource exhaustion(<7%), bugs of HW/SW(<20%), configuration error(<43%)

- Data from some real typical medium **DC(5300+ VM, 65 subnet)**
- Average number of flow:96, 545, 774/day , among them 3, 543, 230(3.67%) are abnormal

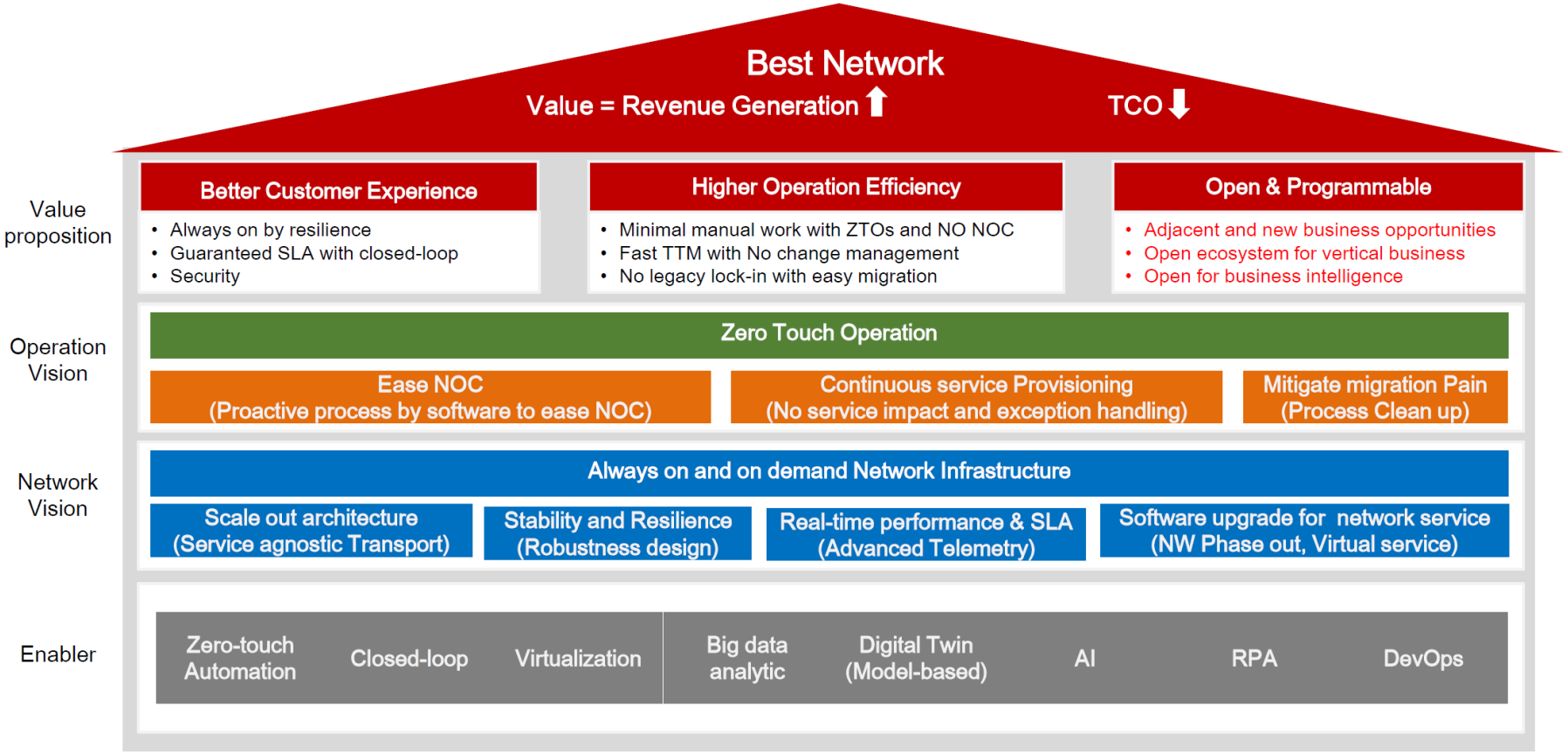
Source: Hwawei, IETF103 Host Speaker Series

AN Challenges



Source: Hwawei, IETF103 Host Speaker Series

Vision and Goal of Autonomic Networking



Source: Hwawei, IETF103 Host Speaker Series

Thank You
Q & A

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