Orchestration and Management in 5G/B5G - Intent Based Networking Approach

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Orchestration and Management in 5G/B5G - Intent Based Networking Approach

- **Acknowledgement**
  - **This presentation is an overview and analysis of IBN applied in 5G.** It has been compiled and structured, based on information selected from several **public documents** such as: conference proceedings, studies (surveys, tutorials, research papers), standards (Including 3GPP, 5GPPP, IETF, ETSI, GSMA, etc) research projects, etc. (see specific references in the text and the Reference list).
  - **The selection of this material, structure and presentation belong to the author.**
  - A few relevant examples (extracted from some studies) are given, on IBN approach in 5G management and orchestration.
  - **Notes:**
    - Given the extension of the topics, this **presentation is limited to a high-level overview only**, mainly focused on concepts and architectural aspects.

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Orchestration and Management in 5G/B5G - Intent Based Networking Approach

- **Motivation of this talk**
  - **Current state in networks and services**
    - **Increased complexity** (challenges: integration of cloud/edge computing and networking technologies, 5G, 6G, ..AI/ML technologies, big data, large range of services, …)
    - **Driving forces for extension of IT&C technologies :** IoT, smart cities, industry, governance, health systems V2X/IoV/automotive, UAV, safety/ emergency-oriented systems, environment, entertainment, etc.
  - **Orchestration, management, and control (OMC) in networks and services** is highly complex and costly (both for CAPEX and OPEX)
    - **Need for**
      - **automation, adaptability, intelligence, programmability, flexibility, sustainability, security**
    - **Support technologies**
      - **Softwarization/virtualization, Policy Based Management, Cognitive and Autonomic Management, Intent Based Networking (IBN)**
      - **Artificial Intelligence /Machine Learning (Ai/ML)**
      - **Centralized/edge cloud computing technologies**

CONTENTS

1. Introduction

- **Current status in networks and services**

  - **Increased complexity** (challenges: integration of cloud/edge computing and networking technologies, AI/ML, big data, …)
  - **Driving factors:** IoT, smart cities, industry, governance, IoV/automotive, safety/emergency-oriented systems, energy saving, green technologies, entertainment, environment preservation, etc.

  - **Example: 5G/Beyond 5G (B5G) networks and services**
    - High bandwidth, **very large range of services**, large communities of users/terminals (e.g., IoT), mobility, inter-operability with clouds
    - **Logical, separated virtual networks (slices)-** customized for various business demands
    - Programmability through softwarization, virtualization, open sources and open interfaces that allow access for third parties

  - **Orchestration, Management and Control (OMC) for 5G/B5G Multi-x** (**x= tenant, operator, provider, domain**) → **need enhanced concepts, methods and technologies**

1. Introduction

FCAPS classical management functions

- **F- Failure** detection (based on monitoring) and repairing
- **C- Configuration** of the entities (physical, logical)
- **A - Accounting** of resource usage (who, what, when, how much)
- **P- Performance** evaluation (including enforcement and checking Service Level Agreements fulfillment)
- **S - Security** – protection of the system

Orchestration- extension of the traditional management

- **Harmonization of components in complex systems**
- **High level services management and mapping on resources**

Trends in network and service management

- **extension of the classical FCAPS:** more adaptability, dynamicity, flexibility, inter-operability, etc.
- Several management architectures such as: ***SLA-driven, business-driven, autonomous, adaptive, and self-* management***

- **AI/ML techniques offer support to OMC by cognitive methods**

1. Introduction

1.1 Examples of OMC functions

- **they can be significantly enhanced by novel cognitive methods**
- **Configuration Management**
  - mapping high-level service requirements to low-level configurations
  - configuration setup, verifications, changes
- **Fault Management** in cloud and virtualized environments
  - failure prevention (proactive fault prediction and mitigation)
  - multi-tenancy, E2E, multi-domain in cloud/NFV environment → high complexity and dimensions of the fault space in a network
- **Spectrum management in 5G, B5G**
- **Traffic management and control**
  - Classification, prediction, balancing, congestion control
- **Resource management**
  - mapping services requirements to sets of resources
  - admission control, resource reservation and allocation in multi-domain multi-operator and multi-tenant contexts
  - adaptive and automatic (re)allocation of resources to meet dynamic needs (including in sliced systems)

1. Introduction

1.1 Examples of OMC functions (cont'd)

- **Performance Management**
  - performance prediction: datasets with quality measurements
  - adaptive probing in monitoring activities
  - regression, mostly based on time series data – usable for prediction
  - detecting patterns of degradation before the quality drops below an acceptable level
  - elastic resource (re)allocation- to preserve the performance level

- **Network transport - management and control**
  - routing strategies and methods
    - constrained routing (for QoS enabled paths)
    - decentralized/ centralized/mixed routing
    - load balancing and traffic monitoring
    - 3D routing in 6G
    - routing in high mobility context (V2X/IoV)
  - E2E path bandwidth availability prediction and checking

1. Introduction

1.1 Examples of OMC functions (cont'd)

- **QoS and QoE management:**
  - QoS assurance with different levels of guarantees
  - QoE optimization; Session quality information; QoS/QoE mapping
  - QoS prediction
    - under QoS impairment;
    - for media-oriented communications

- **Network and services protection and security: i**ntrusion detection (misuse-based, anomaly-based); anomaly detection; hybrid intrusion detection
- **Mobile networks specific functions**
  - mobility management**,** (horizontal and vertical handover), network-level mobile data analysis; mobility patterns analysis, user localization, mobile networks applications
- **Internet of Things (IoT) –**specific functions
- **Wireless sensor networks-**specific functions

1. Introduction

1.2 Policy Based Network Management (PBNM) concepts

- **PBM** – (developed after 2000) separates the rules that govern the behavior of a system from the system functions; it increases the management flexibility
  - PBM is an **imperative management paradigm**
  - **PBM applied to networks: PBNM**
- **Policy:** a **set of rules** used to manage and control/change/maintain the state of one or more managed objects
  - It is defined at a higher level of abstraction, involving a canonical model of systems and devices to which the policy will be applied
  - **definition of a rule** : ***[if.. then ... actions]*** structure
    - an ***event* occurrence** will trigger a rule if a ***set of conditions*** are valid, then a ***set of actions*** are carried out
    - It specify ***what*** to be done, ***when*** and in ***which circumstances***

- PBNM offers simple **control loops**, allowing autonomic behavior: ***self - **** management properties, (* = ***configuration, healing, optimization, protection****)* *(CHOP)* – In a similar way as in autonomic managed systems

Source: J. Strassner, "Policy-Based Network Management", Elsevier.", 2003.

1. Introduction

1.2 Policy and Policy Based Management (PBNM) concepts (cont'd)

- A **policy agent** on a **controller** (or a device), subsequently "renders" the policy, i.e., translates the canonical model into a *device-specific representation*
- The policy definition is de-coupled from policy instantiation and policy enforcement
- The **policies** can be
  - **pushed (**by a **controller)** onto devices where they will be enforced
    - the controller deploys policies across the network and monitors their proper operation
  - or **pulled**
- The decision on actions is delegated to a **Policy Decision Point (PDP),** which:
  - can reside outside the managed device itself
  - typically, it has a global visibility on the context on which to take policy decisions
  - usually gets the policies from a **Policy Data Base**
- When a network device observes an event, it asks the PDP for a decision
    - then, the device carries out the actions derived from the decision
    - the device "enforces" the policy acting as a **PEP (Policy Enforcement Point)**

1. Introduction

1.3 Cognitive Management concepts

- **Cognitive technologies**
  - enable the implementation of cognitive capabilities to a technical system
  - based on AI, ML, machine reasoning, adaptive data and knowledge management

- **Cognitive computing (CogComp)**
  - essentially - smart decision support systems
  - provide decision-makers with the information needed to make better data-based decisions
  - can handle huge amounts of data and intensive iterative analytics
    - adapt conclusions as new data enters the system
  - employ self-learning AI-type algorithms (e.g., data mining, visual recognition, speech recognition, etc.) to find answers (usable by humans) to solve complex problems
  - learn, reason and interact with humans
  - they can work with symbols and concepts (like humans)

1. Introduction

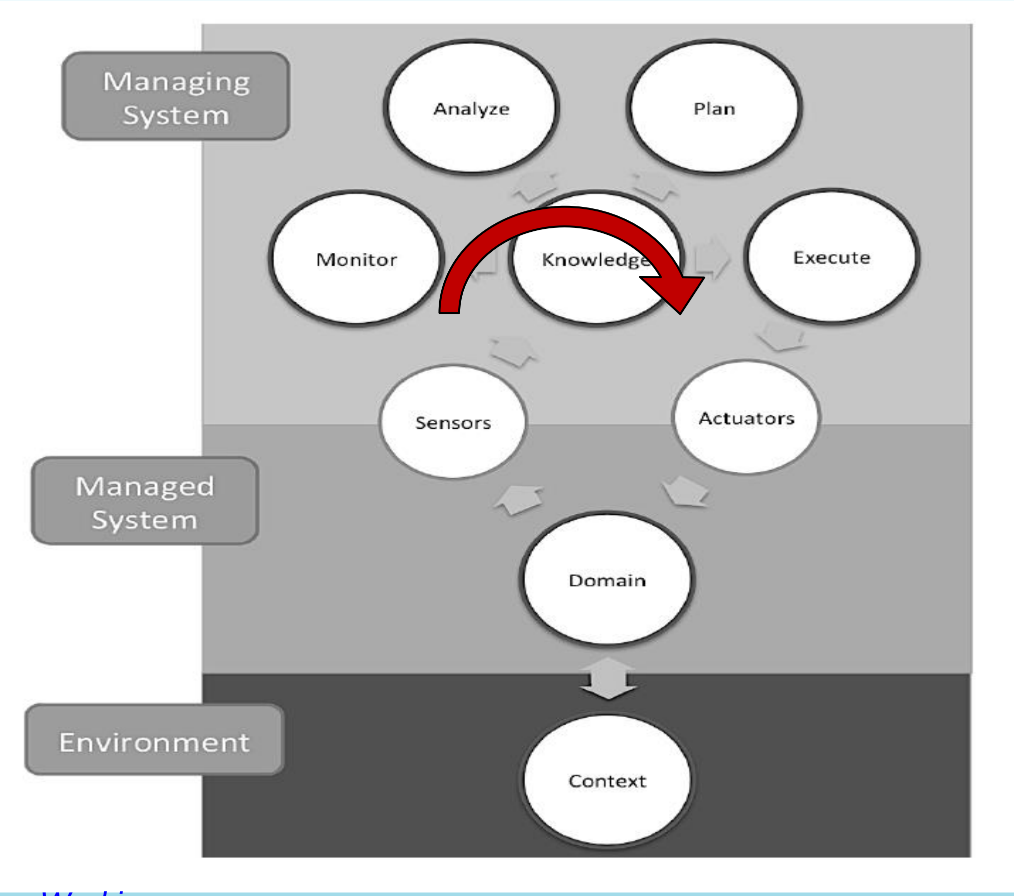
1.3 Cognitive Management concepts (cont'd)

- **Cognitive networks (CogNet) –** in communication and computer networks
  - cognitive processes analyze the current network condition, make decisions based on findings, and then improve from such actions
  - the observations allow: patterns are found - autonomously, in resource usage
    - actions are taken to optimize the usage towards an objective
  - capability to evaluate the actions effect, based on a defined utility function
  - an autonomous system can adapt itself to new situations in the managed environment and changed business objectives
- **Autonomic Network Management (ANM)** - introduce self-governed networks for pursuing business and network goals while maintaining performance
  - define a **control loop**: **Monitor-Analyse-Plan-Execute (MAPE)** over a shared Knowledge
  - recursive architectural model
- **Cognitive Network Management (CogNetMgmt)** - extension of ANM
  - recent trend, using AI and in particular ML, to develop
    - **self-x** (-x= -aware, -configuration, -optimization, -healing and –protecting systems)
- **ANM + ML= Cognitive Network Management (CogNetMgmt)**

1. Introduction

- **1.3 Cognitive Management concepts** (cont'd)
- **Autonomous Network Management (ANM)-** summary

  - **Loop:** The **Monitor-Analyse-Plan-Execute** over a shared Knowledge
  - (**MAPE-K**) is a control theory-based feedback model for self-adaptive systems
  - Full-duplex communication between ***managing systems, managed system*** and the ***environment***
  - **ANM –** hierarchical and recursive approach
  - IETF ANIMA working group



Source: 5GPPP Network Management & Quality of Service Working Group, "Cognitive Network Management for 5G", 2017

1. Introduction

1.3 Cognitive Management concepts (cont'd)

- **Autonomic Network Management** functions
  - **Monitoring**: active/passive, centralized/distributed, granularity-based, timing-based and programmable
  - **Analysis:** many approaches exist –relying, e.g., on probability and Bayesian models for anticipation on knowledge, timing, mechanisms, network-level, user applications
    - **Challenge: to define a concentrated data set** that comprehensively captures information across all anticipation points
    - Recent solutions – **use learning and reasoning** for enhanced
  - **Planning** and **Execution**
    - The network **adaptation plan** – several aspects: knowledge, strategy, purposefulness, degree of adaptation autonomy, stimuli, adaptation rate, temporal/spatial scope, open or closed adaptation and security

    - **Current status**: the adaptation solutions differ broadly (innvarious contexts)
      - there is no unanimity in defining proper planning and execution guideline

1. Introduction

1.3 Cognitive Management concepts (cont'd)

- **Autonomic Network Management** functions (cont'd)
  - **Knowledge base**
    - The network information is shared across the MAPE-K architecture
    - Many approaches exist - to build knowledge on network/topology, including models from learning and reasoning, ontology and DEN-ng models.
  - **Integrated solution-** able to capture knowledge on: ***structure***, ***control*** and ***behavior***
  - **Typically:**
    - In order to drive the decisions of **Self Organizing Network (SON)-type** (e.g., self-planning, self-optimization and self-healing), the knowledge-based framework should :
      - process the input data from multiple sources
      - extract relevant knowledge, **through learning-based classification, prediction and clustering models**

CONTENTS

2. Intent Based Networking (IBN)- concepts and architecture

2.1 IBN general characteristics

- **IBN**
  - Novel technology for **orchestration and automation** of networks
  - **Operators will focus** on **“what” (**i.e. , **desired outcomes),** while **leaving details about “how” those outcomes would be achieved**
  - IBN is adopted by IETF, ITU, … also by some industry entities (e.g., Cisco, Huawei, etc.)
  - IBN **captures business intent and translates it into policies** that can be **automated** and applied consistently across the network
  - IBN can
    - **automatically** convert, deploy, and configure the network resources according to operator intentions
    - **control** and **overcome** abnormal events or failures
    - **continuously monitor** the network resources to get statistics, and adjust network functioning and performance towards desired business outcomes
  - IBN can use a centralized controller (e.g., SDN)

See: A.Clemm et al., Intent-Based Networking - Concepts and Definitions , RFC: 9315 October 2022

2. Intent Based Networking (IBN)- concepts and architecture

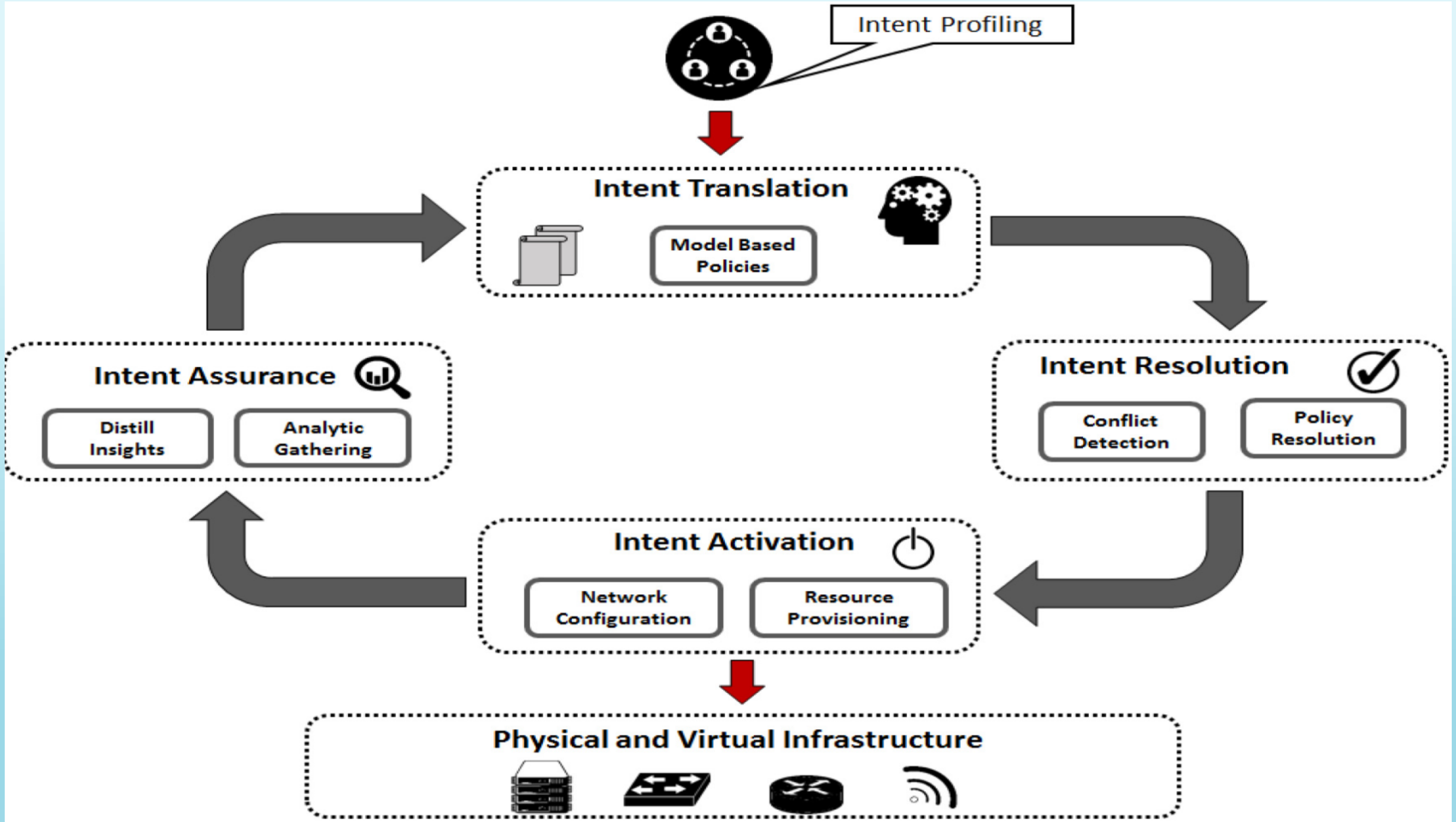
2.1 IBN general characteristics (cont'd)

- Current trends (IETF, etc.): IBN addresses an **E2E management** and not individual devices in isolation: e.g., YANG models for network topology [RFC8345]; service models used by service orchestration systems and controllers [RFC8309])
- An IBN **closed-loop system** includes the conceptual building blocks:
  - **Intent translation**: into policies the network can act on
    - the input and operational guidance are commonly referred to as "intent"
  - **Intent resolution**: conflict detection, policy resolution
  - **Intent activation:** policies installation across the Physical/Virtual (P/V) network infrastructure; network configuration, resource provisioning
  - **Intent assurance**: verify if the desired intent has been applied and the business outcomes are achieved
    - by continuously monitoring the network (distill insights, analytic gathering)
  - IBN can use AI/ML techniques

2. Intent Based Networking (IBN)- concepts and architecture

2.1 IBN general characteristics (cont'd)

- **Interaction loop of the conceptual IBN components**



Source: Aris Leivadeas and Matthias Falknerm, A Survey on Intent-Based Networking IEEE COMMUNICATIONS SURVEYS & TUTORIALS, VOL. 25, NO. 1, FIRST QUARTER 2023

2. Intent Based Networking (IBN)- concepts and architecture

2.1 IBN general characteristics (cont'd)

- **Interaction loop of the conceptual IBN components** (cont'd)
  - **Intent Profiling:** simple declarative requirement, reflecting what the user expects from the network as an outcome
  - Intent can be submitted in a human-friendly way (natural language expressions, drop down menus, etc.)
  - **Intent Translation:** the abstracted intent is translated into a network policy that will be rendered into low-level network configurations to be be pushed and configure network devices
  - **Intent resolution:** solving contradictory or conflicting network configurations that will affect new or already deployed intents
    - The **IBN System (IBNS)** policy resolution module is able to disambiguate conflicting intents by proposing ways to resolve conflicts, and alert the user and/or the network administrators should it be the case

Source: Aris Leivadeas and Matthias Falknerm, A Survey on Intent-Based Networking
IEEE COMMUNICATIONS SURVEYS & TUTORIALS, VOL. 25, NO. 1, FIRST QUARTER 2023

2. Intent Based Networking (IBN)- concepts and architecture

2.1 IBN general characteristics (cont'd)

- **Interaction loop of the conceptual IBN components**(cont'd)
  - **Intent activation:** performs provisioning of the requested service
    - Intents should be customized for users
    - The IBNS deploys each intent in a customized way (the network should be be configured as to be able to answer the intent goals)

  - **Intent assurance:** the intent activation module ensures that the intent will be satisfied during the life cycle of its deployment
    - Problem: the networks are dynamic nature both in time and space
      - an intent assurance component is needed to create the envisioned autonomous behavior
    - The component will assure that the network complies with the intent throughout its lifetime
      - by proactive and reactive measures
      - to achieve the self-configuration and self-healing, or refining the user intent when a gap is detected between the user desires and the actual network behavior

Source: Aris Leivadeas and Matthias Falknerm, A Survey on Intent-Based Networking
IEEE COMMUNICATIONS SURVEYS & TUTORIALS, VOL. 25, NO. 1, FIRST QUARTER 2023

2. Intent Based Networking (IBN)- concepts and architecture

2.1 IBN general characteristics (cont'd)

- The IBN concepts are related to **Autonomic Network Management (ANM)**
  - However, **ANM still require input from an operator** or an outside system to provide operational guidance and information about **goals, purposes**, and **service instances**
  - Networks, even if autonomic, **have no way of automatically knowing**:
    - particular operational goals; which service instances to support

- *Note: in this section the word "user" can also refer to operators and administrators who are OMC responsible*

- IBN implementation: **Intent Based Networking Systems (IBNS)**
  - Implementation variants: a controller or a management system
    - application that runs on a server or a set of servers
    - or, a set of functions distributed across a network
      - they collectively perform their intent-based functionality
  - ***Note : IBNS = IBS notation in IETF documents***

2.2 Some IBN- related – IETF definitions (summary)

- **Intent:** a set of operational goals and outcomes, defined in a declarative manner, without specifying how to achieve or implement them
- **Intent-Based Analytics (IBA):** defined and derived from users' intent
  - it is used to validate the intended state
- **Intent-Based Networking System (IBNS):** a system that supports and executes management functions, guided using intent
- **Service Model:** a model representing a service that is provided by a network to an end user
- **Single Source of Truth (SSoT):** an IBNS functional block that normalizes users' intent and serves as the single source of data for the lower layers
- **Single Version of Truth (SVoT)**
- **User:** In the context of this section, it is an operator and/or administrator responsible for the management and operation of communication services and networking infrastructure (it is different from **end user** of a service).

See: A.Clemm et al., Intent-Based Networking - Concepts and Definitions , RFC: 9315 October 2022

2. Intent Based Networking (IBN)- concepts and architecture

2.3 Intent based management (IBMg)

- The **intent (desired outcome)** should be communicated to the network
  - **Intent** defines goals and outcomes in a *declarative manner,* specifying only **what to accomplish**
- **Important concepts:** operators **do not need to be concerned** with
  - **data abstraction**: i.e., no low-level device configuration concern
  - **functional abstraction** from particular OMC logic: how to achieve a given intent
- **The IBNS automatically figures out a course of actions** (e.g., using an algorithm or applying a set of rules derived from the intent) to achieve the outcome

- **Intent example** (expressed in natural language) :
  - *“a VPN service must have path protection at all times for all paths."*
- **Non-intent example** :
  - *"Configure a given I/F with an IP address."* (this is device configuration)

See: A.Clemm et al., Intent-Based Networking - Concepts and Definitions , RFC: 9315 October 2022

2. Intent Based Networking (IBN)- concepts and architecture

2.3 Intent based management (IBMg) (cont'd)

2.3.1 Specific aspects of Service Models, Policy and Intent

- These are higher-layer of abstraction of a network (not device-specific)

- **Service model:** data model on which **instances of services** are based
  - It has **dependencies on lower-level models** (device and network) to describe the service mapping onto the underlying network and IT infrastructure
  - A **service model instantiation requires orchestration**
    - Note: the logic to orchestrate/manage/provide the service model and its mapping onto underlying resources **is not included in the model itself**
- **Policy:** set of rules, typically modeled around a variation of **events/ conditions/ actions**
  - used to express **control loops** that can be rendered by devices without intervention by the outside system
  - the policies let operators
    - to define **what to do** under what circumstances
    - but **they do not specify** (in an explicit way) **the desired outcome**

2. Intent Based Networking (IBN)- concepts and architecture

2.3 Intent based management (IBMg) (cont'd)

2.3.1 Specific aspects of Service Models, Policy and Intent (cont'd)

- **Intent**: high-level, declarative goal, operating at the level of a network and services it provides, not individual devices
  - It **defines outcomes** and high-level operational goals
    - **It does not**
      - **specify how the outcomes should be achieved,** neither how goals should specifically be satisfied
      - **enumerate specific events, conditions, and actions**
  - The algorithm or rules to apply can be automatically "learned/derived from intent" by the IBNS
- **Subcategories of intent :**
  - **Operational Intent**: defines intent related to operational goals of an operator; it corresponds to the original "intent" term and the concepts
  - **Rule Intent:** a synonym for policy rules regarding what to do when certain events occur
  - **Service intent:** a synonym for customer service model [see RFC 8309]
  - **Flow Intent:** a synonym for a *Service Level Objective* for a given flow

2. Intent Based Networking (IBN)- concepts and architecture

2.3 Intent based management (IBMg) (cont'd)

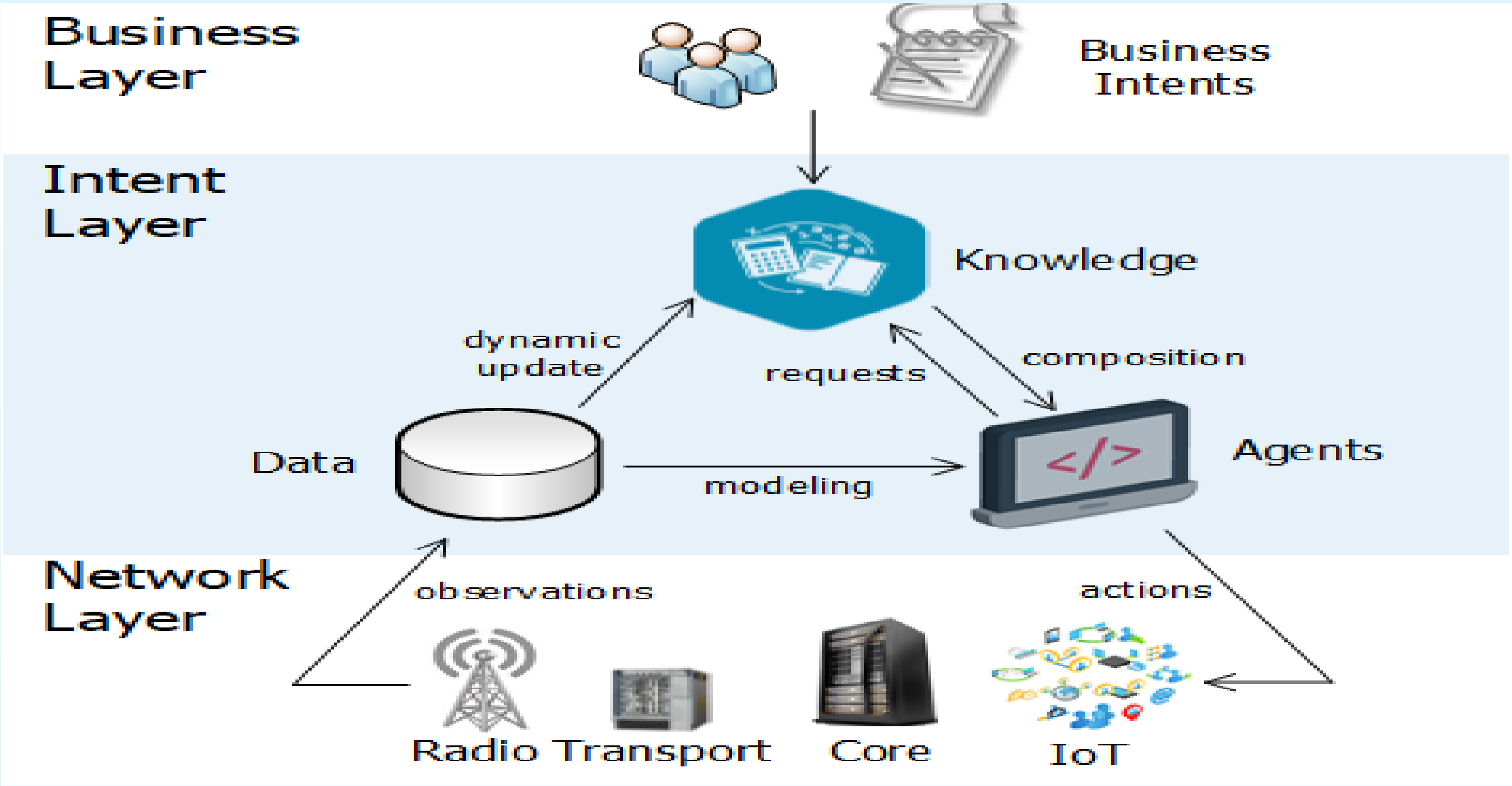
2.3.2 Intent based networking –layered architecture

- **Architectural goals of IBN**
- Problems to be solved:
  - **Composition/decomposition** @scale
  - **Dealing with changes**:
    - Planned change –attempt to achieve desired (future) state while preserving the original intent
    - Unplanned change – impact of the change, difference between intended and operational state (remediation/notification)
  - **Closed loop validation:**
    - continuously validate outcomes against the intent to ensure that the composition is working as intended
    - extract more knowledge by collecting less data through IBA (Intent Based Analytics)

2. Intent Based networking (IBN)- concepts and architecture

2.3 Intent based management (IBMg) (cont'd)

2.3.2 Intent based networking layered architecture (cont'd)



Source: E.Zeydan and Y.Turk "Recent Advances in Intent-Based Networking: A Survey", https://ieeexplore.ieee.org/document/9128422, 2020, Spanish MINECO grant TEC2017-88373-R (5G-REFINE) and Generalitat de Catalunya grant 2017 SGR 1195.

2. Intent Based Networking (IBN)- concepts and architecture

2.3 Intent based management (IBMg) (cont'd)

2.3.2 Intent based networking layered architecture (cont'd)

- **Business Layer:** higher-level declarative policy that operates above the level of a network and services
  - provides semantic to consume network services
  - allows high-level guidance by a central entity
  - detects and resolves conflicts between multiple intents
- **Intent Layer**
  - **Knowledge:** allows access to knowledge and executes judgement; performs inference from relations between objects
  - **Agent:** captures the business intent and translates into policies; utilizes ontology-based approach to communicate with users; assures communication interface directly to the network objects
  - **Data:** keeps the state of each intent and relations between network objects; provides models for the observed data; provides algorithms for data modeling
- **Network Layer**: presents abstraction of domain-specific data and control plane technologies; specifies context-aware architecture for enhancing the network intelligence

2. Intent Based Networking (IBN)- concepts and architecture

2.3 Intent based management (IBMg)

2.3.3 IBN Operational principles

- **Single Source of Truth (SSoT)** - the set of **validated intent expressions**
  - SSoT and the records of the operational states enable comparing the intended/ desired state and actual/operational states of the system and determining drift between them
  - SSoT + drift information - provide the basis for corrective actions
  - IBNS
    - can predict states
    - develop strategies to anticipate, plan, and pro-actively act on any diverging trends
- **Single Version (or View) of Truth** is derived from the SSoT
  - It can be used to perform other operations, such as *querrying, polling, or filtering measured and correlated information* in order to create so-called "views"
  - These views can serve the IBNS users to create intents as single sources of truth; the IBNS must follow well-specified and well- documented processes and models

See: A.Clemm et al., Intent-Based Networking - Concepts and Definitions , RFC: 9315 October 2022

2. Intent Based Networking (IBN)- concepts and architecture

2.3 Intent based management (IBMg) (cont'd)

2.3.3 IBN Operational principles (cont'd)

- **One-touch but not one-shot**
  - The user expresses intent (in different forms) and then the system takes over all subsequent operations (one-touch)
    - The I/F user - IBNS could be designed as an interactive and iterative process
    - The intent expressions may initially contain more or less implicit parts and unprecise or unknown parameters and constraints
    - **The IBNS parses, understands and refines the intent expression** to reach a well- formed and valid intent expression, further used by the system for operations
    - An intent refinement process could use a combination of iterative steps

- **Autonomy and Supervision**
  - The **IBNS – autonomous- to conduct its tasks and operations** (no user intervention)
  - It takes its own decisions as to meet the user expectations in terms of (performance, quality) and providing the proper level of supervision

2.3 Intent based management (IBMg) (cont'd)

2.3.3 IBN Operational principles (cont'd)

- **Learning**
  - IBNS can learn, make reasoning, get knowledge representation and management
  - It is different from an imperative-type of system, (e.g., PBM):
    - the user only declares outcome and not how to achieve these goals
  - The AI/ML naturally provide support for IBNS ability for learning

- **Capability exposure**
  - It consists in the need for expressive network capabilities, requirements, and constraints allowing to compose/decompose intents and map the user's expectations to the system capabilities

- **Abstract and outcome-driven (IBN – focused on "what" and not "how")**
  - Users are not concerned with mechanisms to get outcomes
  - They can refer to concepts at a higher level of abstractions, independent, e.g., of vendor-specific renderings

2. Intent Based Networking (IBN)- concepts and architecture

2.3 Intent based management (IBMg) (cont'd)

2.3.4 IBN Functionalities

- **Intent Fulfillment :** functions and I/Fs that
  - allow **users to communicate intent to the network**
  - **perform actions** (e.g., algorithms and functions to learn and optimize)
  - It can include also **traditional functions**
    - orchestration of coordinated configuration operations
    - rendering of higher-level abstractions into lower- level parameters

- **Intent Assurance:** functions and I/Fs that
  - allow users to **validate and monitor** that the network is adhering with intent
  - this **assesses the actions effectiveness**
  - **feedback -** allow training trained or tunning
  - addresses the **"intent drift"**
    - Intent is stateful
      - expected to remain in effect over time (unless explicitly stated otherwise)
    - **Intent drift**: the system originally meets the intent, but over time gradually change its behavior

2. Intent Based Networking (IBN)- concepts and architecture

2.3 Intent based management (IBMg) (cont'd)
2.3.4 IBN Functionalities (cont'd)

- **Intent Fulfilment details**
  - **Intent Ingestion and Interaction with Users**
    - **"Ingesting" intent = obtaining intent through interactions with users.**
    - The specific functions:
      - **recognize intent from interaction with the user**
      - allow users to refine their intent so that it becomes actionable by an IBNS
      - may go beyond those provided by a traditional API
      - may support unconventional human-machine interactions

  - One may have a set of intuitive workflows to guide users through the intent ingestion phase, (assuring that all inputs are gathered and translation have been done)

2. Intent Based Networking (IBN)- concepts and architecture

2.3 Intent based management (IBMg) (cont'd)

2.3.4 IBN Functionalities (cont'd)

- **Intent Fulfilment details** (cont'd)

  - **Intent Translation**
    - The IBNS core functions
      - **translate user intent into courses of action and requests** to take against the network
        - translation is made in information meaningful to network configuration and provisioning systems
    - These functions are bridging the gap
      - between interaction with users and the traditional management and operations side that orchestrate provisioning and configuration across the network
  - **Intent Orchestration-** deals with the **actual configuration and provisioning** steps to be orchestrated across the network and that were determined by the previous intent translation step

See: A.Clemm et al., Intent-Based Networking - Concepts and Definitions , RFC: 9315 October 2022

2. Intent Based Networking (IBN)- concepts and architecture

2.3 Intent based management (IBMg) (cont'd)
2.3.4 IBN Functionalities (cont'd)

- **Intent Assurance- details**
  - Functions to ensure that the **network complies with the desired intent** once it has been fulfilled
  - **Monitoring**
    - It include the usual network monitoring (events, performance measurements) to assess service levels to be delivered
    - Monitored data are inputs for the next set of functions that assess whether the observed behavior is compliant to the intent
  - **Intent Compliance Assessment**
    - Functions to compare the observed network behavior v.s. the intended one
    - This includes assessing the effectiveness of intent fulfilment actions
    - The assessment results can *be fed back to facilitate learning* functions that optimize outcomes
    - Assessing whether intent drift occurs over time

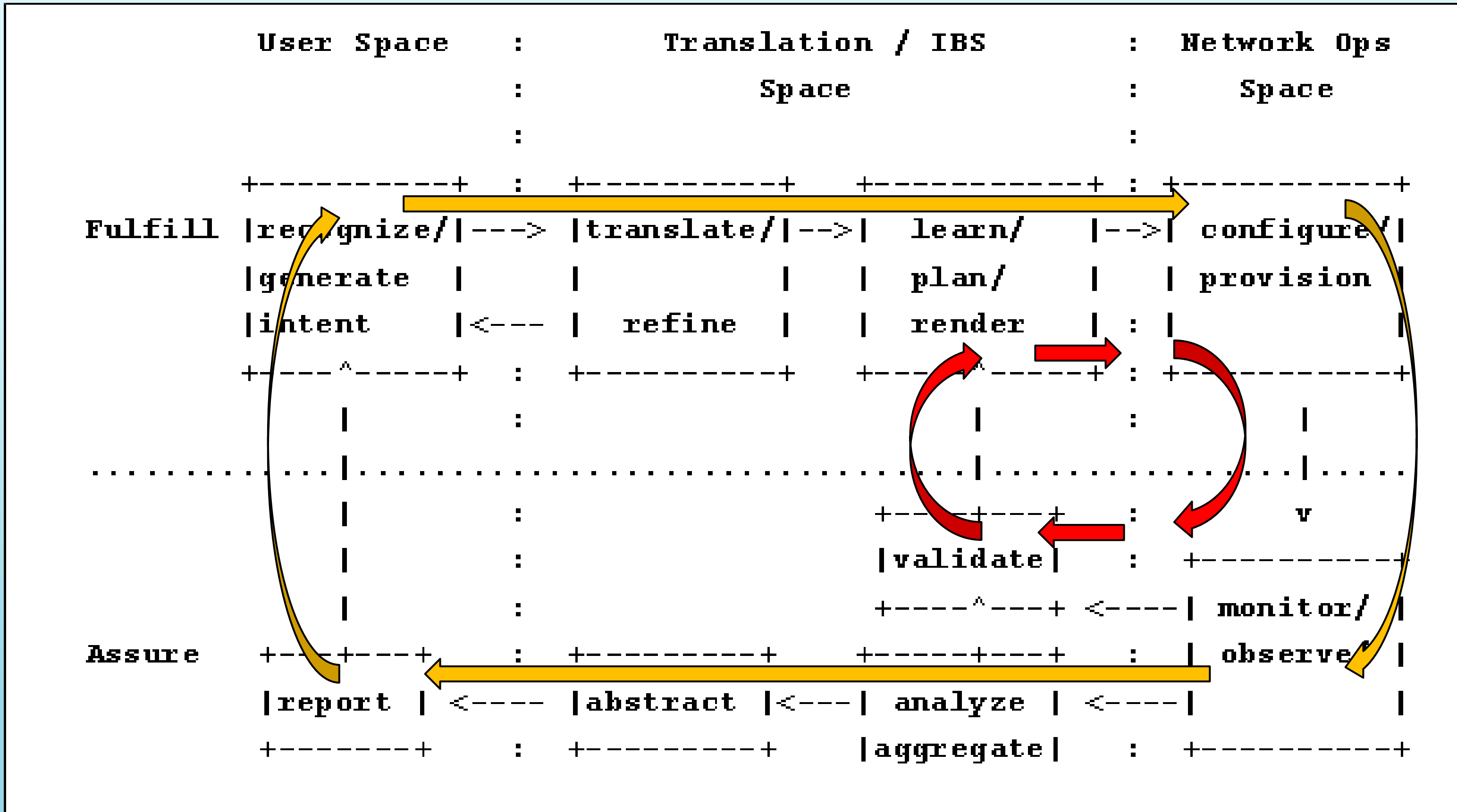
2. Intent Based Networking (IBN)- concepts and architecture

2.3 Intent based management (IBMg) (cont'd)
2.3.4 IBN Functionalities (cont'd)

- **Intent Assurance- details** (cont'd)
  - **Intent Compliance Actions**
    - When intent drift occurs or network behavior is inconsistent with desired intent, these functions are triggering corrective actions to resolve intent drift
    - Or, if necessary, reporting functions will alert operators (provide information and tools to react appropriately)
    - Maybe modifications of the original intent is necessary
  - **Abstraction, Aggregation, Reporting**
    - The Intent Assurance outcome is reported back to allow the users to relate the outcomes to their intent
    - Functions are needed to analyze, aggregate, and abstract the results of the observations accordingly

2. Intent Based Networking (IBN)- concepts and architecture

2.3 Intent based management (IBMg) (cont'd)
2.3.5 Intent Life Cycle- IETF view



Adapted from : A.Clemm et al., Intent-Based Networking - Concepts and Definitions, RFC: 9315 October 2022

2. Intent Based Networking (IBN)- concepts and architecture

2.3 Intent based management (IBMg) (cont'd)

2.3.5 Intent Life Cycle –IETF view (cont'd)

- ***"Inner"* intent control loop-** fully autonomic between IBNS and Network operations
  - The closed-loop involves **automatic analysis and validation of intent** based on observations from the network operations space
  - To make adjustments in the network configuration, the observations are input into the functions that plans the rendering of networking intent
  - The loop
    - addresses and counteracts any intent deviation/drift that may occur
    - allows to assess the effectiveness of actions taken in order to continuously learn and improvement

- ***"Outer"* intent control loop -** is extended to the user space
  - It includes the user taking actions and (possibly) adjusting their intent based on observations and feedback from the IBNS
  - **Intent has a lifecycle**: It comes into being, may undergo refinements, modifications, and changes in time, and retracted later

2. Intent Based Networking (IBN)- concepts and architecture

2.3 Intent based management (IBMg) (cont'd)

2.3.5 Intent Life Cycle – IETF view (tied to interconnection functions)

- **Two** functional planes, (**fulfillment and assurance**); **three** (vertical) spaces

- **User Space -** its functions I/F the network and IBNS with the human user
  - Users can **generate** intent and IBNS recognize that intent
  - Functions **reporting** back the network status and which allow users to assess outcomes and whether their intent was achieved
- **IBNS functions**
  - Translation
    - translate an intent into a course of actions
    - bridge the gap between intent users and the network operations infrastructure
  - Algorithms to plan and optimize actions based on network feedback
  - Analyze and aggregate network observations in order to validate compliance with the intent and to take corrective actions
  - Abstract network observations
- **Network Operations Space:** traditional orchestration, configuration, monitoring, and measurement functions

CONTENTS

1. Introduction
2. Intent Based Networking (IBN)- concepts and architecture
3. IBN approach in 5G/B5G orchestration and management
4. Conclusions

3. IBN approach in 5G/B5G orchestration and management

3.1 5G general aspects

- **Three views/sets-of-requirements for 5G**
  - ***user-centric*** (uninterrupted connectivity and communication services, smooth consumer experience)
  - ***service-provider-centric*** (connected intelligent systems, multi-tenant, multi-domain capabilities, large set of services, monitoring/tracking ***network-operator-centric*** (scalable, energy-efficient, low-cost, efficiently managed, programmable, and secure - communication infrastructure)

- **5G: evolution of mobile *broadband networks* + *new unique network and service capabilities*:**
- **5G –support for a large set of services for fixed and mobile applications**

- **5G Key technological characteristics**
  - Heterogeneous set of integrated air interfaces, various **Radio Access Technologies (RAT)**
    - Seamless handover between heterogeneous RATs
  - Ultra-dense networks with numerous small cells
    - New interference mitigation, backhauling and installation techniques
  - **Driven by SW**
    - unified OS in a number of PoPs, especially at the network edge

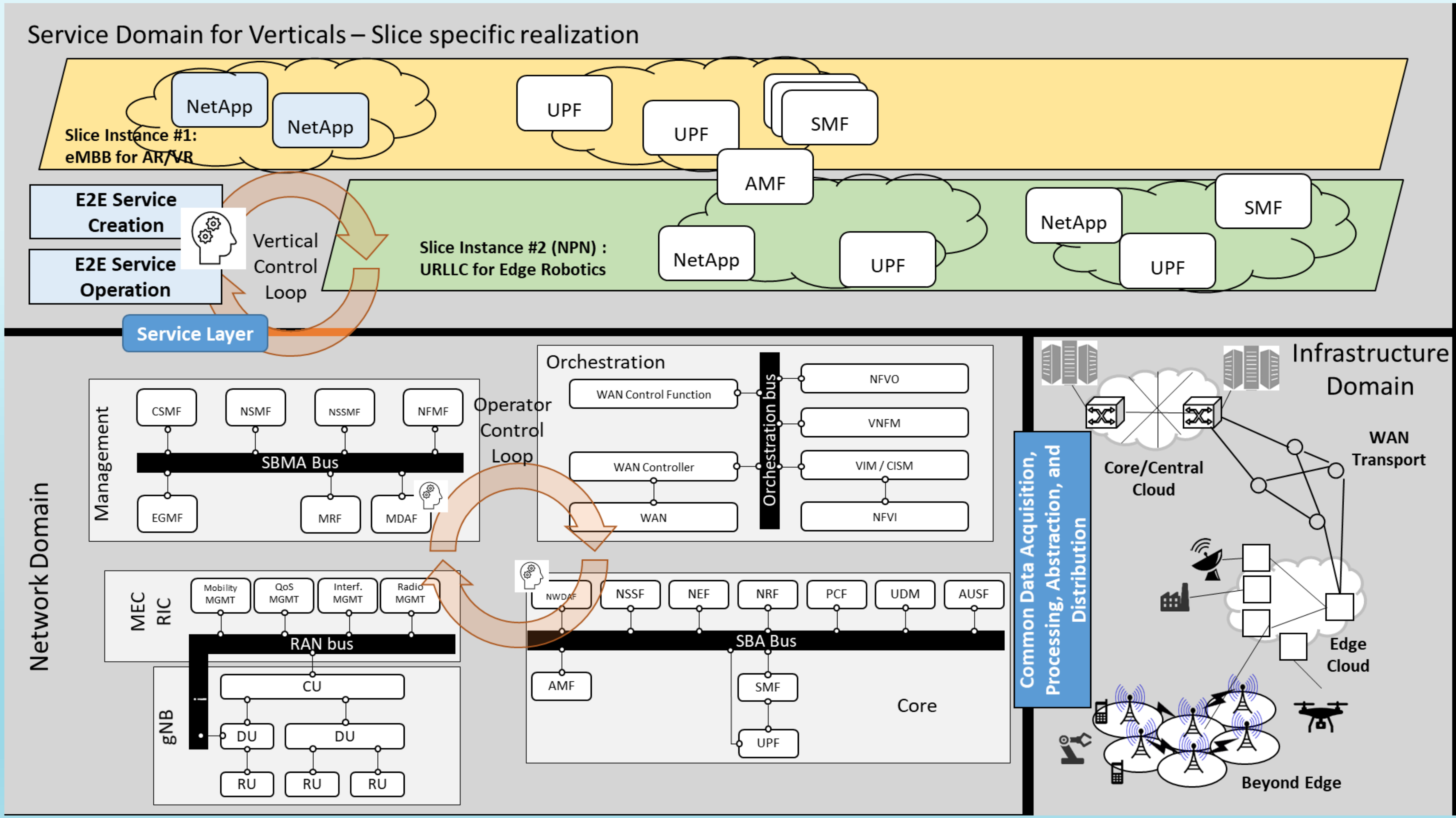
3.IBN approach in 5G/B5G orchestration and management

3.1 5G general aspects (cont'd)

- **5G Key technological characteristics** (cont'd)
  - **Supporting/cooperating technologies for 5G**
    - Software Defined Networking (SDN)
    - Network Functions Virtualization (NFV)
    - Cloud/Mobile Edge Computing (MEC) /Fog Computing (FC)
    - Artificial Intelligence/Machine Learning (AI/ML)
  - **Powerful orchestration, management and control (OMC)**, based on
    - **cognitive features, AI/ML**
    - advanced **automation** of operation through proper algorithms
    - Data Analytics and Big Data techniques
  - **Network softwarization:**
    - **Programmability**, virtual /physical network functions (NFV/PNF)
    - **Network slices – logical, parallel networks on demand, customized for network services and applications**
    - **Architectural planes**: Data/user, control, management
  - **Separation** of concerns between
    - control/ management/ softwarization/ services
    - logical / physical resources functions (connectivity, computing, storage) v.s. network capabilities
  - **On demand composition** of NFs and network capabilities

3. IBN approach in 5G/B5G orchestration and management

3.2 5G Slicing –overall architecture- 5GPPP vision *(see abbreviation list)*



Source: 5GPPP Architecture Working Group , View on 5G Architecture, Version 4.0, October 2021

3. IBN approach in 5G/B5G orchestration and management

3.2 5G Slicing –overall architecture- 5GPPP vision *(abbreviation list)*

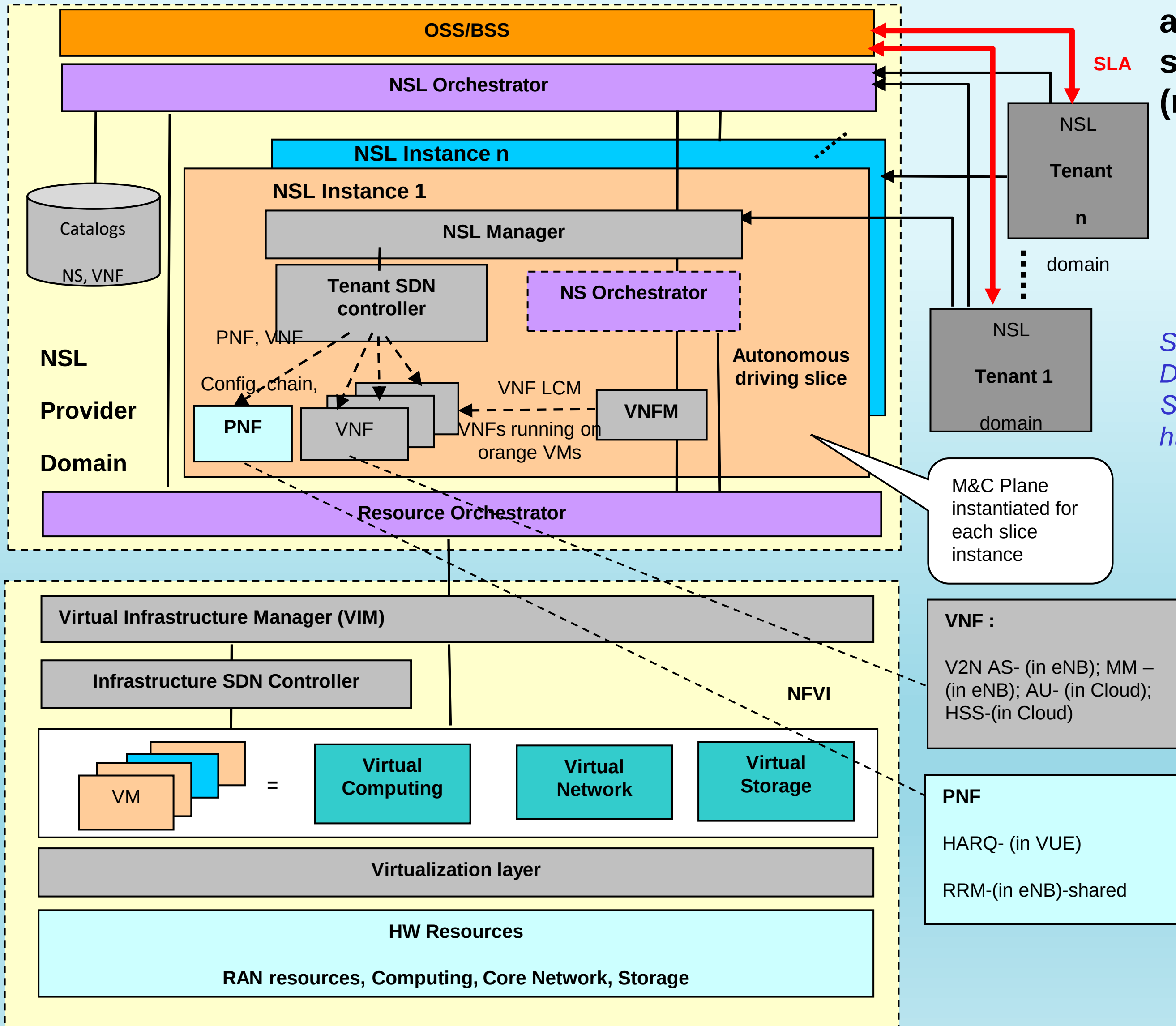
AF	Application Function
AUSF	Authentication Server Function
AMF	Access and Mobility Management Function
CHF	Charging Function
CISM	Container Infrastructure Service Management
CSMF	Communication Service Management Function
CU	Centralized Unit
DN	Data Network
DU	Distributed Unit
E2E	End-to-End
EGMF	Exposure Governance Management Function
eMBB	Enhanced Mobile Broadband
EMS	Element Management System
mMTC	Massive machine type communication
MANO	Management and Orchestration
MCC	Mobile Cloud Computing
MDAF	Management Data Analytics Function
MEC	Multi-access (Mobile) Edge Computing
MGMT	Management
MRF	Multi-Radio Function
NetApp	Network Application
NF	Network Function
NFV	Network Function Virtualization

NFVI	Network Function Virtualization Infrastructure
NFVO	NFV Orchestrator
NSMF	Network Slice Management Function
NSI	Network Slice Instance
NSSMF	Network Sub Slice Management Function
NFMF	Netwrk Function Management Function
NSSF	Network Slice Selection Function
NWDAF	Network Data Analytics Function
PCF	Policy Control Function
RAN	Radio Access Network
RIC	RAN Itelligent Control
RU	Radio Unit
SBA	Service Based Architecture
SMF	Session Management Function
UCMF	UE radio Capability Management Function
UDSF	Unstructured Data Storage Function
UDM	Unified Data Management
UDR	Unified Data Repository
UE	User Equipment
UPF	User Plane Function
URLLC	Ultra-Reliable Low Latency Cellular Networks
VIM	Virtual Infrastructure Manager
WAN	Wide Area Network

Source: 5GPPP Architecture Working Group , View on 5G Architecture, Version 4.0, October 2021

3. IBN approach in 5G/B5G orchestration and management

3.3 Example of a 5G functional layered architecture



High level functional architecture – for V2X slicing- single domain (run-time view)

Source:Solid B5G-Project D2.4 - Deliverable "Final System Architecture" V1.0 https://solid-b5g.upb.ro/

3. IBN approach in 5G/B5G orchestration and management

3.3 Example of a 5G functional layered architecture (cont'd)

- **High level functional architecture – for V2X slicing- single domain (run-time view)** (cont'd)
- **Notations**
- **General (5G slicing, NFV)**
- SDN Software Defined Networking; SLA – Service Level Agreement; MANO- Management and Orchestration; NS – Network Service; NSO- Network Service Orchestrator; NSL - Network Slice; NSLO - Network Slice Orchestrator; RO- Resource Orchestrator; VNF – Virtualized Network Function; PNF- Physical Network Function; VNFM – VNF Manager; LCM – Life Cycle Management; VIM – Virtual Infrastructure Manager; IC- Infrastructure SDN Controller

- **V2X –dedicated entities**
- AS- Application Server; AU- Authentication and Authorization Management; MM Mobility Management ; V2N – Vehicle to Network; RRM – Radio Resource Management; HARQ- Hybrid Automatic Repeat Request

Source:Solid B5G-Project D2.4 - Deliverable "Final System Architecture" V1.0, https://solid-b5g.upb.ro/

3. IBN approach in 5G/B5G orchestration and management

3.4 Example of IBN management automation in 5G core networks

3.4.1 Functional architecture **(proposal –IETF-2022)**

```
   +------------+
   |  IBN User  |
   +------------+
          ^
          | Consumer-Facing Interface
          v
+-------------------+     Registration     +-----------------------+
|   IBN Controller   |<--------------------->|  Vendor's Mgmt System |
+-------------------+      Interface       +-----------------------+
          ^      ^
          |      |
          |      |   Analytics Interface   +-----------------------+
          |      +------------------------>|  IBN Analyzer (NWDAF) |
          |                                +-----------------------+
          | NSF-Facing Interface              ^       ^       ^
          |                                   |       |       |
          |                                   |       |       |
          |    +------------------------------+       |       |
          |    |              +-----------------------+       |
          |    |              |   Monitoring Interface        |
          v    v              v                               v
   +---------------+  +---------------+        +---------------+
   |     NSF-1     |--|     NSF-2     |........|     NSF-n     |
   |(Policy Control|  | (Application  |        |  (IoT Device) |
   | Function, PCF)|  |  Function, AF)|        |               |
   +---------------+  +---------------+        +---------------+
```

Source: J. Jeong, Ed., P. Lingga, J. Kim, Y. Kim, IBN Management Automation in 5G Core Networks draft-jeong-nmrg-ibn-network-management-automation-00, October 2022

3. IBN approach in 5G/B5G orchestration and management

3.4 Example of an IBN management automation in 5G core networks (cont'd)
3.4.1 Functional architecture (cont'd)

- **Functional components**
  - **IBN User**
    - delivers a high-level network policy to IBN Controller
    - an **intent** expressed in a natural language is **translated into a high-level network policy** through a Natural Language Processing (called NLP) technique (e.g., [USENIX-ATC-Lumi]).
  - **IBN Controller**
    - controls and manages the other system components
    - **translates** the **high-level network policy** into a **low-level network policy**
    - **selects** appropriate **Network Service Functions (NSFs)** to execute the network rules of the low- level network policy
  - **Vendor's Management System (VMS)**
    - from IBN point of view: the VMS provides an image of a virtualized NSF for a network service to the IBN framework
    - registers the capability and access information of an NSF with IBN Controller

3. IBN approach in 5G/B5G orchestration and management

3.4 Example of an IBN management automation in 5G core networks (cont'd)
3.4.1 Functional architecture (cont'd)

- **Functional components** (cont'd)
  - **Network Service Function (NSF)**- it can be
    - Virtual Network Function (VNF)
    - Physical Network Function (PNF)
    - Container Network Function (CNF)/Cloud-native Network Function,
      - for specific network services, e.g., network slicing, data aggregation of IoT, V2X communications, etc.
  - **IBN Analyzer**
    - collects monitoring data from NSFs
    - analyzes data for checking the NSFs activity and performance, based on ML techniques (e.gt., DRL)
    - It can be a Network Data Analytics Function (NWDAF) in 5G networks, (defined in [TS-23.288][TS-29.520])
    - in case of a network problem (e.g., traffic congestion) it delivers a report of the augmentation or generation of network rules to IBN Controller
    - it is a key IBN component for the IBN [RFC 9315] – having to collect monitoring data from NSFs and analyzing them

3. IBN approach in 5G/B5G orchestration and management

3.4 Example of an IBN management automation in 5G core networks (cont'd)

3.4.1 Functional architecture (cont'd)

- **Interfaces**
  - **Consumer-Facing Interface:** between consumer and IBN controller
    - delivery of a high-level network policy
  - **NSF-Facing Interface:** between IBN Controller and NSFs -delivery of a low-level network policy
  - **Registration Interface**: VMS –IBN
    - registration of an NSF's capability and access information with the IBN Controller
    - or the query of an NSF for a required low-level network policy
  - **Monitoring Interface:** NSF - IBN Analyzer
    - collect monitoring data from an NSF to check the activity and performance of a NSF for a possible network problem
  - **Analytics Interface:** IBN Analyzer –IBN
    - delivery of an analytics report of the augmentation or generation of network rules to IBN Controller
    - IBN Controller apply the report for network rules to its network policy management

3. IBN approach in 5G/B5G orchestration and management

3.4 Example of an IBN management automation in 5G core networks (cont'd)

3.4.2 Network Policy Translation

- The IBN Controller has a network policy translator
  - [a high-level network policy → low-level network policy]
- **Notes**
  - for automatic NPT services, the IBN framework has to automatically bridge a high-level *YANG data model* and a *low-level YANG data model*
  - a high-level YANG data model is for the IBN Consumer-Facing I/F
  - a low-level YANG data model is for the IBN NSF-Facing I/F
  - the mapper also generates a set of production rules of the grammar for the construction of an XML file of low-level network policy rules

```
High-level YANG Data Module   Low-level YANG Data Model
                        |                   |
                        V                   V
          +---------+----------------------------+---------+
          |   Automatic Policy Data Model Mapper    |
          +-----------------------+------------------------+
                                  |
         Mapping Model (Data Model Mapping Table)
                                  |
                                  V
          +------------------------------------------------+
          |                 NSF Database                   |
          +------------------------------------------------+
```

Source: J. Jeong, Ed., P. Lingga, J. Kim, Y. Kim, IBN Management Automation in 5G Core Networks draft-jeong-nmrg-ibn-network-management-automation-00, October 2022

3. IBN approach in 5G/B5G orchestration and management

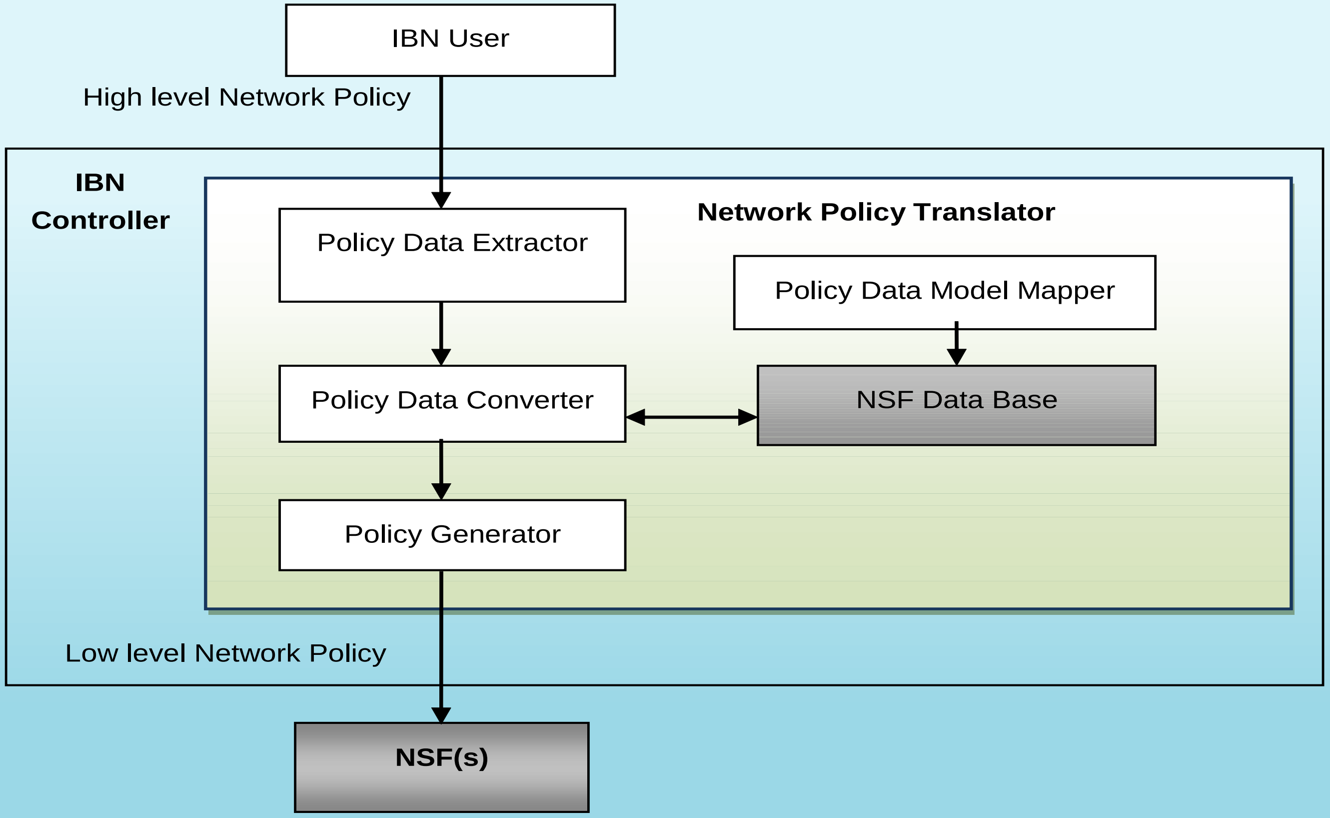
3.4 Example of an IBN management automation in 5G core networks (cont'd)
3.4.2 Network Policy Translation (cont'd)

- **The translator components** : Policy Data Model Mapper; Policy Data Extractor; Policy Data Converter; Policy Generator

  - **Policy Data Extractor** extracts the values of the attributes related to a network policy from a high-level network policy (HLNP) that was delivered by an IBN User via the Consumer-Facing I/F
  - **Policy Data Model Mapper** maps the attributes and their values of a HLNPto values of a low-level network policy (LLNP)
    - The HLNP values may be stated in a human language and will be converted to an appropriate values for a LLNP.(e.g., users -> 192.0.4.0/24)
  - **Policy Data Converter** converts the HLNP values attributes into the values of the corresponding LLNP attributes
  - **Policy Generator** generates the corresponding LLNP that is delivered by the IBN Controller to an appropriate NSF through NSF-Facing I/F

3. IBN approach in 5G/B5G orchestration and management

3.4 Example of an IBN management automation in 5G core networks (cont'd)
3.4.2 Network Policy Translation (cont'd)



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3. IBN approach in 5G/B5G orchestration and management

3.4 Example of an IBN management automation in 5G core networks (cont'd)

3.4.3 Network Audit System

- **It is required** in IBN framework
  - **Reason:** he IBN framework might be attacked (insider attack or a supply chain); IBN system trusts in NSFs provided by VMS and assumes that NSFs would work correctly
  - The audit system can facilitate the non-repudiation of configuration commands and monitoring data generated in the IBN framework.

- **Network Audit System Objectives**
  - To check the existence of a network policy, a management system, and its procedures
  - To identify and understand the existing vulnerabilities and risks of either an insider attack or a supply chain attack
  - To review existing network controls on operational and administrative issues
  - To provide recommendations and corrective actions to IBN Controller for further network and security improvement

Source: J. Jeong, Ed., P. Lingga, J. Kim, Y. Kim, IBN Management Automation in 5G Core Networks draft-jeong-nmrg-ibn-network-management-automation-00, October 2022

3. IBN approach in 5G/B5G orchestration and management

3.4.3 Network Audit System (NAS) (cont'd)

```
+-----------------------------+                   +----------------+
|           IBN User          |                   |  Vendor's Mgmt |
|                             +------------+      |     System     |
+--------------+--------------+            |      +--------+-------+
               | Consumer-Facing Interface |               |
               |                           |  Remote       |
   High-level Security Policy              |  Attestation  |
               |                           |  Interface    |
               |                           |               |
               V                           |               V
+--------------+--------------+            |     +---------+--------+
|                             |            V     |      Network     |
|        IBN Controller       +------------+---->|       Audit      |
|                             |            ^     |      System      |
+--------------+--------------+            |     +---------+--------+
               |  NSF-Facing Interface     |               ^
               |                           |  Remote       |
   Low-level Security Policy               |  Attestation  |
               |                           |  Interface    |
               V                           |               |
+--------------+--------------+            |      +--------+-------+
|            NSF(s)           +------------+      |  IBN Analyzer  |
|                             +------------------>|                |
+-----------------------------+    Monitoring     +----------------+
                                   Interface
```

The IBN components report their activities to Network Audit System (NAS) as transactions through Remote Attestation I/F
The NAS can analyze the reported activities to detect malicious activities.

To determine a minimum set of controls required to reduce the risks, the NAS periodically analyzes the activities, evaluates possible risks, and take actions to such risks.

Source: J. Jeong, Ed., P. Lingga, J. Kim, Y. Kim, IBN Management Automation in 5G Core Networks draft-jeong-nmrg-ibn-network-management-automation-00, October 2022

3. IBN approach in 5G/B5G orchestration and management

3.4 Example of an IBN management automation in 5G core networks (cont'd)

Example: IoT Device Data Aggregation Policy Enforcement

```
IBN             IBN             Vendor's           Cloud              NSF1
User         Controller       Mgmt System    (or Edge Server)(IoT Device)
 |-High-level--->|                 |                 |                 |
 | Policy Request|                 |                 |                 |
 |          Translation:           |                 |                 |
 |        Data Extraction &        |                 |                 |
 |        Data Conversion          |                 |                 |
 |*** Case 1: NSFs available: Go to Policy Generation ***              |
 |*** Case 2: NSFs unavailable (START) ***           |                 |
 |               |-NSF Query------>|                 |                 |
 |               | Request         |-NSF Initiation->|                 |
 |               |                 | Request         |                 |
 |               |                 |                 |-NSF Initiation->|
 |               |                 |                 | Request         |
 |               |                 |                 |                NSF
                                                         Init
 |               |                 |                 |<-NSF Initiation-|
 |               |                 |<-NSF Initiation-|  Response       |
 |               |<-NSF Query------|  Response       |                 |
 |               |  Response       |                 |                 |
 |               |                 |                 |                 |
 |*** Case 2: NSFs unavailable (END) ***             |                 |
 |          Translation:           |                 |                 |
 |       Policy Generation         |                 |                 |
 |               |                 |                 |                 |
 |               |--Low-level Policy Request-------------------------->|
 |               |                 |                 |                NSF
                                                       Config
 |               |<-Low-level Policy Response--------------------------|
```

Source: J. Jeong, Ed., P. Lingga, J. Kim, Y. Kim, IBN Management Automation in 5G Core Networks draft-jeong-nmrg-ibn-network-management-automation-00, October 2022

3. IBN approach in 5G/B5G orchestration and management

3.5 A General model for IBN and service management for 5G

Source: K.Mehmood, K.Kralevska, D.Palma, Intent-driven autonomous network and service management in future cellular networks: A structured literature review, Computer Networks 220 (2023) 109477, https://www.sciencedirect.com/science/article/pii/S1389128622005114

- **It proposes a four layers-general architecture**
  - **Application Layer**
  - **Intent Layer**
  - **Network management and orchestration Layer**
  - **Infrastructure and Resources**

3.5.1 Application Layer

- Includes various **vertical use cases** and their **consumers**
- The consumers get exposure of network infrastructure and services through the Intent North Bound I/Fs (NBIs) and SLAs for infrastructure and service availability awareness
- Intent processing aids in understanding
  - the scope of different domains
  - e2e services expectations
- The **intents representation** may be: **machine and human-readable form** using ontology-based, **vocabulary restricted** or based on **NLP methods**

3. IBN approach in 5G/B5G orchestration and management

3.5 A General model for IBN and service management for 5G

3.5.1 Application Layer (cont'd)

- **Intent description models**
  - constrained model with a layered approach and using three basic primitives construct, transfer, regulate, for different phases in user-defined intents
  - provide pre-defined intent objects by following the Open Network Operating System ONOS intent framework

- **Natural Language Processing (NLP)** provides a user-friendly and high-level abstracted view of the intents
  - a dialogue framework can interact with the user and constructs an intent model using an abstraction language
  - key performance goals are extracted and forwarded towards the intent layer for translation using e.g., Recurrent Neural Network (RNN)

  - Constrained Natural Language (CNL) restricts the broad domain of NLP into more machine-readable scope (avoid extensive processing, improves the scalability and adaptability to requirement of intents)

3. IBN approach in 5G/B5G orchestration and management

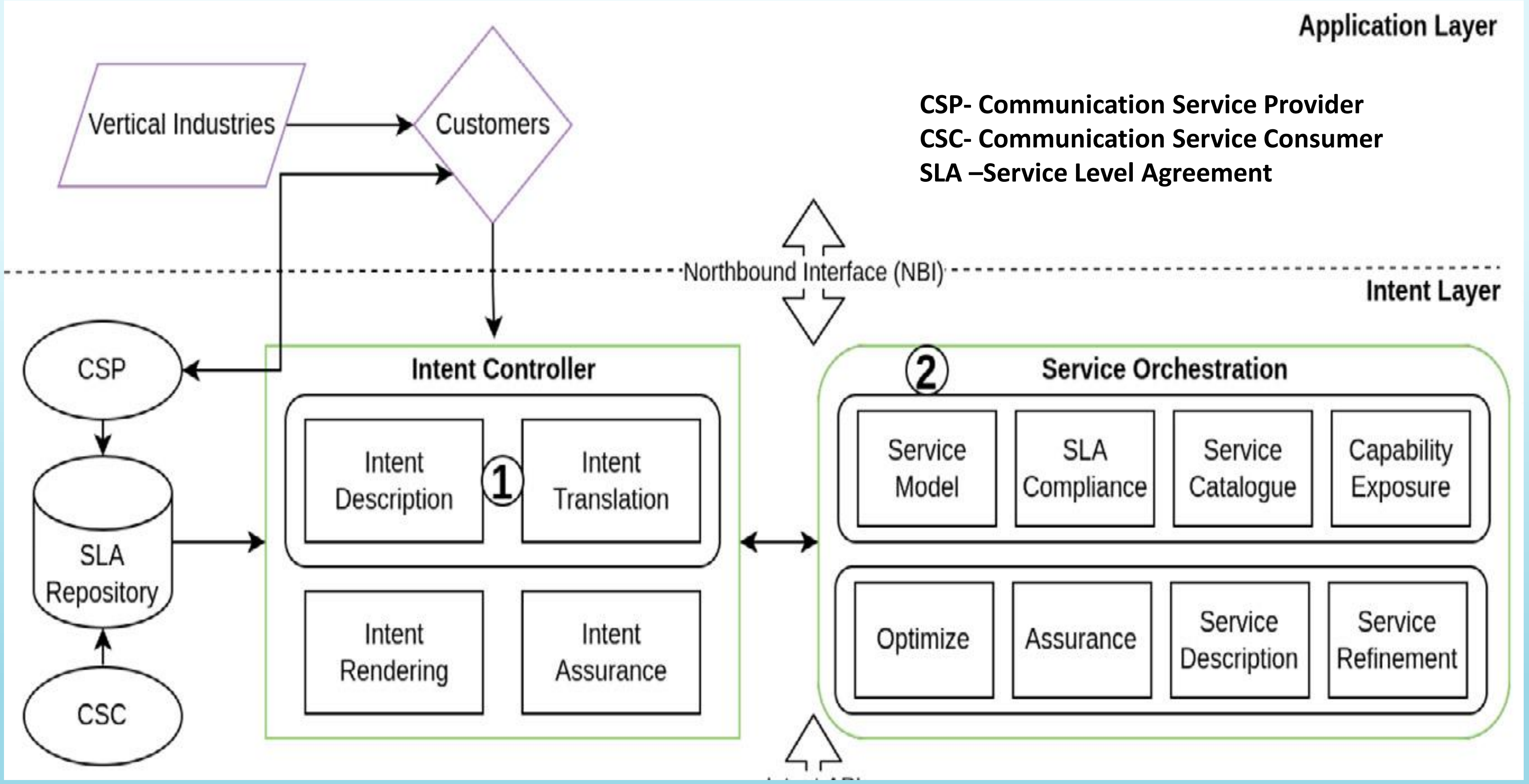
3.5 A General model for IBN and service management for 5G

3.5.1 Application Layer (cont'd)

- **Other approaches**
  - describe the intents using a **restricted vocabulary** model and any vagueness in descriptions is processed using rule-based parsing and matching model
    - The user definitions are saved and utilized in the intent refinement process for subsequent requests
  - consider label namespaces to maintain relationships and interactions between different network entities eventually aiding intent composition and translation
- **Summary of Application Layer features**
  - Intent modeling and NBI
    - Description of user intents using ontology, various NLP, and vocabulary methods.
    - Customer and business-oriented design of intent representation.
    - Benefits in terms of scalability and processing intensity for human/ machine-readable forms.
  - Compatibility and Capability exposure
    - Conformance of user intents with the underlying network and intent infrastructure
    - Exposure of network capability to users in order to provide required information for intent modeling

3. IBN approach in 5G/B5G orchestration and management

3.5 A General model for IBN and service management for 5G



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3. IBN approach in 5G/B5G orchestration and management

3.5.2 A General model for IBN and service management for 5G
3.5.2 Intent Layer

- **Main functional components**
  - (1) **Intent Controller**
    - Description, Translation, Rendering, Assuring
  - (2) **Service Orchestration**
    - Service-directly related: Model, Description, Catalogue, Refinement
    - SLS compliance, Optimization, Assurance, Capability exposure

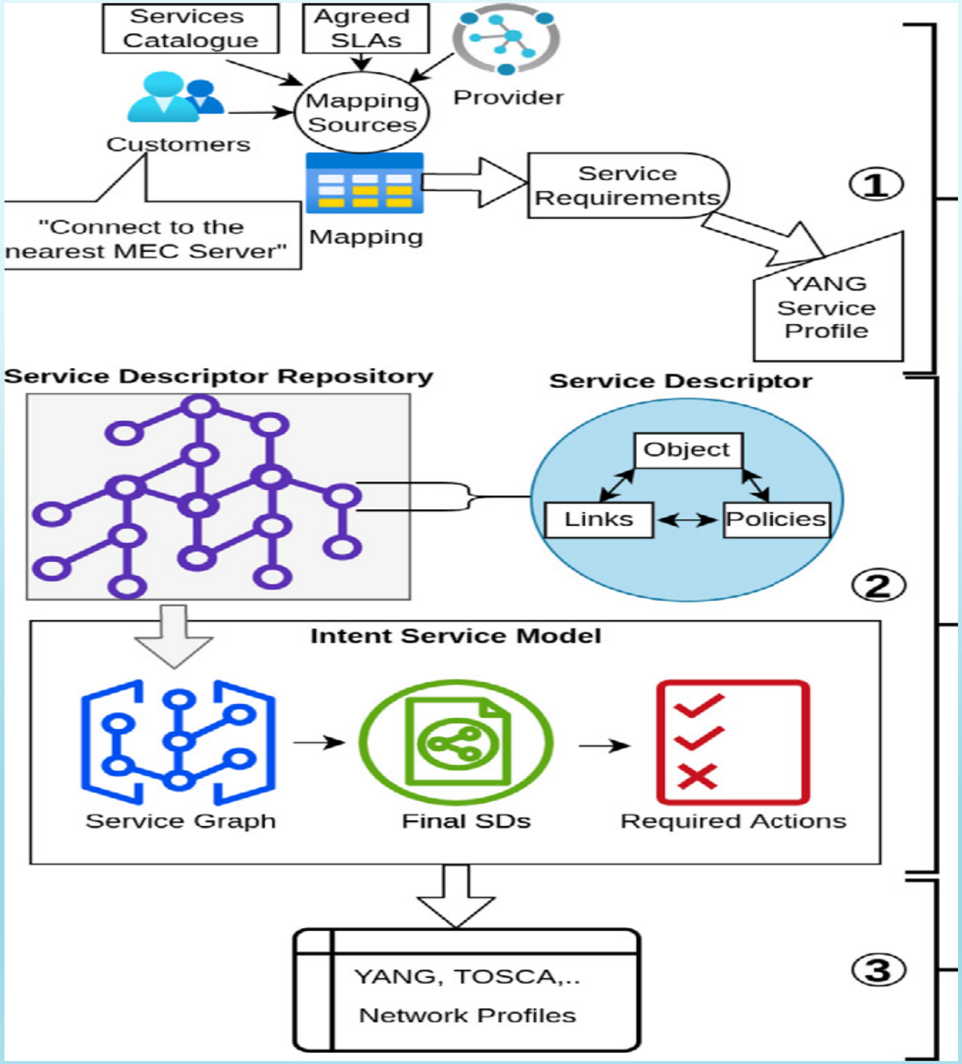
- The service subscribers are intent sources
- They follow a declarative NBI model for the intent design providing the required I/F towards the Intent Controller and the Orchestrator
- NBI - independent from the specific implementations of the service provider and subscriber input
- Example of language for intent description: NEMO
  - https://wiki.onosproject.org/display/ONOS/NEMO+Language

3. IBN approach in 5G/B5G orchestration and management

3.5 A General model for IBN and service management for 5G

3.5.2 Intent Layer (cont'd)

- **Intent layer interactions**
  - **(1) Intent Controller**
  - **(2) Service Orchestrator**



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3. IBN approach in 5G/B5G orchestration and management

3.5 A General model for IBN and service management for 5G

3.5.2 Intent Layer (cont'd)

- **NEMO language**
  - **domain specific language (DSL)** based on **abstraction of network models** and conclusion of operation patterns.
  - provides NBI fashion in the form of language
  - enables network users/applications to **describe their demands for network resources**, services and logical operations in an **intuitive way**
  - the NEMO language description can be explained and executed by a language engine

  - **Main NEMO features:**
    - **User/application centric abstraction**: applications or users can use NEMO directly to describe their requirements for the network without taking care of the implementation
    - **All the parameters without user concern will be concealed by the NBI**
    - Consistent NBI model and pattern:
      - existing NBIs are customized on use cases (e.g., virtual network, QoS, traffic engineering, service chaining)
      - NEMO with consistent model and pattern is promising as easier to use and to extend for future proof applications

3. IBN approach in 5G/B5G orchestration and management

3.5 A General model for IBN and service management for 5G

3.5.2 Intent Layer (cont'd)

- **NEMO language** (cont'd)
  - **Main NEMO features** (cont'd)
    - human-friendly, easily understood by network developers
    - flexibility for northbound application developer
    - platform independent: the application or user can describe network demands in a generic way, so that any platform or system can get the identical knowledge and consequently execute to the same result
    - low-level and device/vendor specific configurations and dependencies can be avoided
    - any technology related network solution can be concealed

  - **Two patterns are available for intent expression**: the **Object+Operation** and the **Object+Result.**

    - **Object-** includes: Customer Facing Node (CFN), Connection, and Service Flow.
    - **Operation,** describes the expected behavior. It can be generally formalized with "on condition, do action, with the constraint".
    - **Result-** describes the expected state. One can use the clause "expect to achieve the state" or "avoid the state".

3. IBN approach in 5G/B5G orchestration and management

3.5 A General model for IBN and service management for 5G
3.5.2 Intent Layer (cont'd)

- **Intent Controller**
  - translates and cross-references the user intents with the service and operator catalogues with SLAs, service and network specifications
  - **human readable consumer information is converted into machine readable** form for the network and service provisioning

  - **Mappings** are
    - established between consumers and Network Providers (NPs), to help the translation of the intents in the form of lookup tables and catalogues
    - dynamically updated if changes occur in the state of the consumer or NP capabilities
  - The intent perspective is utilized for service and network orchestration by the network controllers(SDN, NFV)
    - It is domain specific and has limited phrases to represent user intents

3.5 A General model for IBN and service management for 5G

3.5.2 Intent Layer (cont'd)

- **Intent Controller** (cont'd)

  - A few examples of models proposed (exposure of network resources and functions to aid in the intent translation process):
    - **multi-layered approach -** to classify different types of traffic and improve data dissemination through the V2X environment
      - ONOS intent controller is used plus AI-based optimization engine
    - **user behavior driven model -** for intent translation into distinct well-defined network policies.
      - a NBI abstraction layer based on NLP for intent definition with keywords embedded for intent interpretation and mapping onto low-level configuration policies
    - **utilization of a human-readable query language** for user intent expression and web ontology and resource description framework to aid the processing of user intents for a VNF chaining application

ONOS, Open network operating system, 2021https://opennetworking.org/onos/

3. IBN approach in 5G/B5G orchestration and management

3.5 A General model for IBN and service management for 5G

3.5.2 Intent Layer (cont'd)

- **Intent Controller** (cont'd)
  - **Intent rendering** - creation of a service model through the generation of service objects and service descriptions to be forwarded to the configuration controller for deployment
  - **Intent assurance**
    - monitors the status of intent compliance as per deployed configurations
    - assists in initiating reconfiguration on a service and network level

  - The Intent Controller provides context to the **network orchestration and management** for deploying the required services from the user intents
    - Implementation: intent APIs between the intent and network layers
  - The network represents intents in a **machine readable form**
    - **Yet Another Next Generation (YANG)** - possible modeling language
  - The validation and assurance of the intent allow modifying the behavior of user intents
    - feedback received from the intent monitor module- is used for this action

3. IBN approach in 5G/B5G orchestration and management

3.5 A General model for IBN and service management for 5G

3.5.2 Intent Layer (cont'd)

- **Service orchestration**
  - **Service models**

  - IBN management uses Intent APIs to provide service models across different domains, network controllers in an E2E manner
  - NFV and SDN technologies can reduce the service deployment complexity
  - Service agnostic components usage, to compose services can reduce the complexity of service design and increase portability towards service orchestration

  - The intent controller issues service requests to Orchestrator
  - A service model is generated using different **Service Descriptors (SD)**
  - SD includes - service specification object, links to other SDs and polices (functions, conditions, relationship to other SDs)
  - The SD state evolution – modeled by **Finite-State-Machine (FSM)** - with design, reserve, provision and active state values

3. IBN approach in 5G/B5G orchestration and management

3.5 A General model for IBN and service management for 5G

3.5.2 Intent Layer (cont'd)

- **Service orchestration** (cont'd)
  - **Service models** (cont'd)
  - Different proposals exist for Network SD models applicable in IBN orchestration of network in an SDN environment
  - A **layered service-oriented model** can distinguish business and orchestration scopes
  - **Topology and Orchestration Specification for Cloud Applications (TOSCA)** and **YANG** models are used for service description and automation of service lifecycle
  - The ETSI NSD are extended to provide the necessary information exchange between the intent and network controllers for service orchestration
  - Research is in development on OpenFlow based SDN with promising results in terms of response times for the service requests
  - In 5G/B5G systems, service chaining can be performed using NFV, VIM and MANO through intent-based abstracted service requests

Source: P. Lipton, C. Lauwers, M. Rutkowski, C. Noshpitz, C. Curescu, Tosca simple profile in yaml version 1.3, 2020, https://docs.oasisopenorg/tosca/TOSCA-Simple-Profile-YAML/v1.3/os/TOSCA-Simple-Profile-YAML-v1.3-os.html

3. IBN approach in 5G/B5G orchestration and management

3.5 A General model for IBN and service management for 5G

3.5.2 Intent Layer (cont'd)

- **Service orchestration** (cont'd)
- **Service models** (cont'd)
  - **Example 1:** a platform agnostic is investigated for service design with implementation for OSM and M-CORD orchestration frameworks.
    - Service orchestration and VNF modeling are performed using an IBN manager and policy configurators for different platforms
    - Users design the intent contracts using a GUI and the intent manager interprets and deploys them using a vocabulary store with historic intent contract data.

Source (1) : A. Rafiq, A. Mehmood, T. Ahmed Khan, K. Abbas, M. Afaq, W.-C. Song, Intent based end-to-end network service orchestration system for multi-platforms, Sustainability 12 (2020).

  - **Example 2: TOSCA** and **Network Slicing Template (NST)** models are used for M-CORD and **Open Source MANO (OSM)** orchestrators for deployment of intents

Source (2): GSMA, Ng.116 generic network slice template v2.0, 2019, Available at https://www.gsma.com/newsroom/wp-content/uploads//NG.116-v2.0.pdf

3. IBN approach in 5G/B5G orchestration and management

3.5 A General model for IBN and service management for 5G
3.5.2 Intent Layer (cont'd)

- **Service orchestration** (cont'd)
- **Service assurance and optimization**
  - **Updating** the service model - is performed in service orchestration
    - when changes in the network and resources are reported by the monitoring module in the network management and orchestration layer
    - The closed loop feedback from the monitoring module is critical in providing dynamic service lifecycle for user intents
  - **Optimization** - the service model is optimized according to the updated states and a new **service graph** can be generated if required
  - Service state changes - can be caused by the user based events
    - e.g., intent refinement through a dialogue to clarify any conflicts between different intents or lack of feasibility of the requested intent.

3. IBN approach in 5G/B5G orchestration and management

3.4 A General model for IBN and service management for 5G

3.4.2 Intent Layer (cont'd)

- **Service orchestration** (cont'd); **Service assurance and optimization** (cont'd)
- **Example 1:**
  - **Generative Adversarial Network (GAN)** based resource management framework is proposed for IBN with network slicing for different services in 5G network
    - **OSM network orchestrator** coupled with a **FlexRAN controller** manage the slices configured through high level intents from the users
    - GAN can predict future states of the network resources and allow refinement of user intents and network orchestration

Source (1): K. Abbas, M. Afaq, T. Khan, A. Mehmood, W. Song, Ibnslicing: Intent-based network slicing framework for 5 g networks using deep learning, in: 2020 21st Asia-Pacific Network Operations and Management Symposium, APNOMS, 2020, pp. 19–24.

- **Example 2:**
  - A **GAN based Service Graph (SG)** generation is proposed to aid (DRL) based optimal SG selection process based on user intents.
  - A VNF graph is generated and improved by GAN whereas the DRL engine provides its input with the optimal policy for deploying the graphs without any conflicts.
  - A multi-domain orchestration scenario is also provided for deploying the optimized configuration policies

Source (2):T.A. Khan, K. Abbas, A. Muhammad, A. Rafiq, W.-C. Song, Gan and drl based intent translation and deep fake configuration generation for optimization, in: 2020 International Conference on Information and Communication Technology Convergence, ICTC, 2020, pp. 347–352, http://dx.doi.org/10.1109/ICTC49870. 2020.9289564.

3. IBN approach in 5G/B5G orchestration and management

3.5 A General model for IBN and service management for 5G

3.5.2 Intent Layer (cont'd)

- **Intent APIs**
  - They are vertical interfaces between the Intent Layer and Network Management and Orchestration Layer
  - They allow the intent providers to understand, correlate and interpret the required services and network nodes, in order to accomplish the intent
  - Different possible variants depend on the network infrastructure, data description languages and service models
  - The exposure of network infrastructure to the intent controller and service orchestrator can use different data models (e.g., YANG TOSCA)
  - The intent controller and service orchestrator ensure the conformance with the relevant domain specific models for the creation of service descriptors and NFs

3. IBN approach in 5G/B5G orchestration and management

3.5 A General model for IBN and service management for 5G

3.5.2 Intent Layer (cont'd)

- **Summary of functionalities**
  - **Intent processing**
    - Translation, processing and context generation for intents and exposure to network capabilities
    - Service Level Agreement (SLA) and information from service and network providers is available for the contextual evaluation
  - **Automation and Refinement**
    - Changes in the intent context and low-level resources status updating →
    - Dynamic behavior to support and process sudden environment changes
    - Conflict resolution for different intents in case of contended resources and demands.
  - **Service Model and Orchestration**
    - Service modeling based on service graphs and data modeling languages along with Life Cycle Management (LCM)
    - Low-level configurations generation for the domain specific network orchestration
    - Exposure of low-level resource level information to enable required configuration templates

3. IBN approach in 5G/B5G orchestration and management

3.5 A General model for IBN and service management for 5G

3.5.3 Orchestration and Network Management Layer

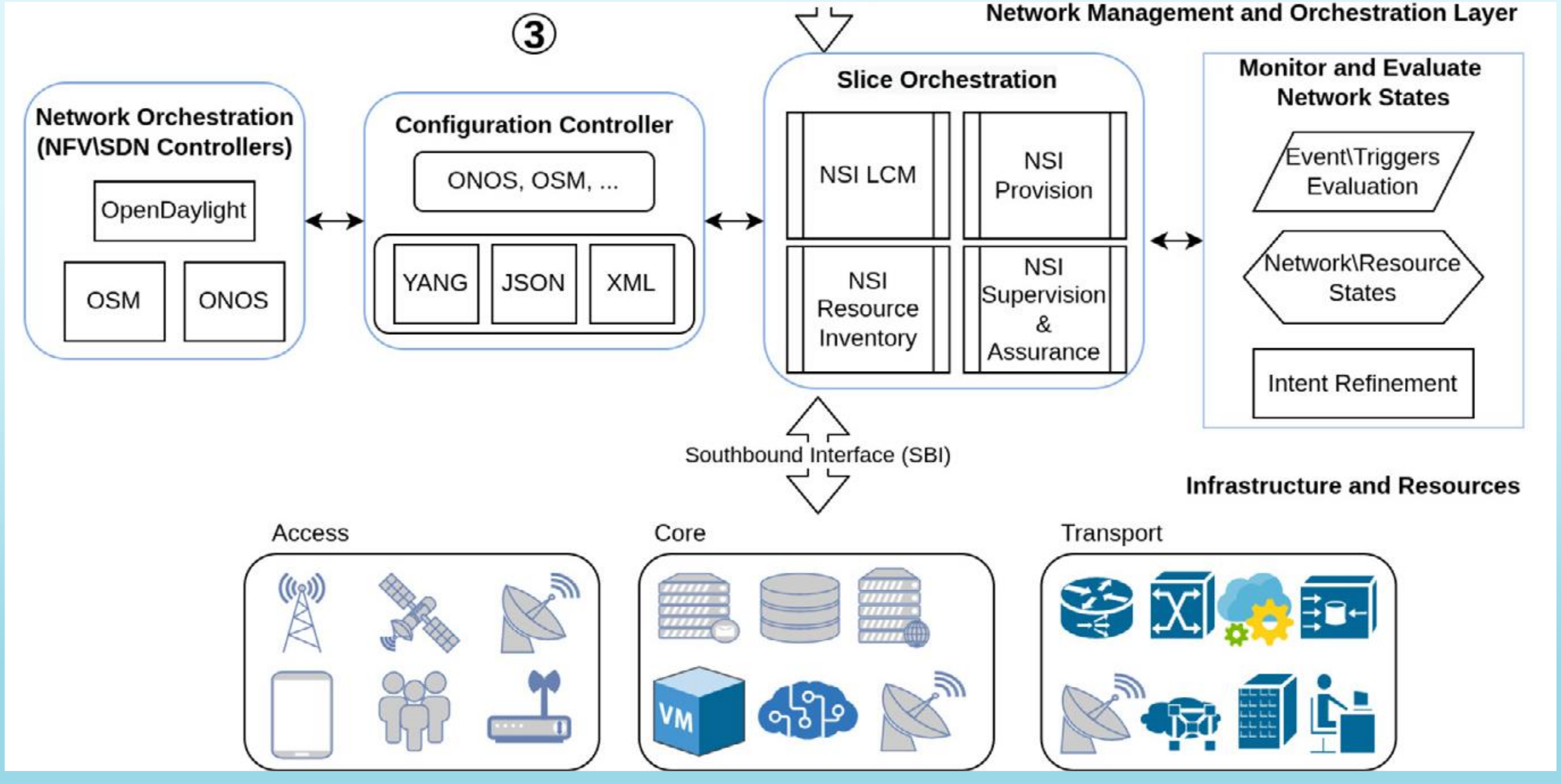
- **Functional modules**
  - **Network orchestration (NO)**
  - **Configuration controller (CC)**
  - **Slice orchestration (SO)**
  - **Monitor and evaluator of network states (MEN**)

- The NO can be based on different domain controllers and orchestrators (e.g., NFV MANO, SDN, slicing controllers) interfaced to the higher layer intent controller (via intent APIs)

- The network layer gets the description of service orchestration and device level service models and integrates them using various orchestration and deployment support
- The configuration controller receives the service requirements (e.g., in the form of TOSCA orchestration models) for generating models based on
    - YANG,
    - Extensible Markup Language (XML) or
    - Yaml Ain't Markup Language (YAML)
  - for different network devices with exposure to the resource state through OpenAPI

3. IBN approach in 5G/B5G orchestration and management

3.5 A General model for IBN and service management for 5G
3.5.3 Orchestration and Network Management Layer



Source: K.Mehmood, K.Kralevska, D.Palma, Intent-driven autonomous network and service management in future cellular networks: A structured literature review, Computer Networks 220 (2023) 109477, https://www.sciencedirect.com/science/article/pii/S1389128622005114

3. IBN approach in 5G/B5G orchestration and management

3.5 A General model for IBN and service management for 5G
3.5.3 Orchestration and Network Management Layer (cont'd)

- The **configuration controller** performs network and intent reconfigurations, based on monitoring and evaluation module information
- Several **network orchestrators** (ODL, ONOS, OSM) can be utilized to create network slices, VNF graphs or Service Functions Chains (SFCs), i.e., to generate configurations for different user intents

- **Example 1:** Slicing the core network and RAN domains through IBN for 5G networks
  - Multi-platform orchestration
    - Open Source MANO (OSM) for core network
    - FlexRAN for the RAN
  - The intent interpretation is propagated to the configuration generator for the appropriate controllers
  - Active monitoring module is implemented through Generative Adversarial Network (GAN)

Source (1): K. Abbas, M. Afaq, T. Ahmed Khan, A. Rafiq, W.-C. Song, Slicing the core network and radio access network domains through intent-based networking for 5 g networks, Electronics 9 (2020).

3. IBN approach in 5G/B5G orchestration and management

3.5 A General model for IBN and service management for 5G
3.5.3 Orchestration and Network Management Layer (cont'd)

- **Summary of functionalities**
- **Network Orchestration**
  - Intent rendering takes place with the allocation and LCM of different network functions.
  - Different domain specific orchestrators can be utilized (OSM, ONOS, OpenDaylight).
- **Intent Adaptation**
  - Monitoring allowing automation and dynamic orchestration of services via intents
  - Exposure of resource layer through resource description models to enable trigger conditions.
- **Intent Deployment and Configuration**
  - Deployment of user intents using domain-specific controllers
  - Resource level information for mapping the VNF and SFC to the appropriate nodes

3. IBN approach in 5G/B5G orchestration and management

3.5 A General model for IBN and service management for 5G
3.5.4 Network Infrastructure and resources

- Resources :Compute, storage and communication
- Provide building blocks for the software-based network and service orchestration
- **SBI interface**
  - resource information is shared through the SBI to enable resource
  - status monitoring and events management through the network orchestrators and controllers
  - provides the exposure to the monitoring module responsible for the closed loop feedback management for the intent layer
- The resources are distributed
  - amongst the access, core and transport parts
  - between different domains in the case of multi-domain slices or in a multi-provider context
- The resource description is important in view of the diversity of domain controllers and orchestrators.
- NVF and SDN can contribute to enhancement of resource description and control

3. IBN approach in 5G/B5G orchestration and management

3.6 Examples of OMC useful technologies for Intent Based Networking in 5G

- **TOSCA -Topology and Orchestration Specification for Cloud Applications (OASIS)**

  P. Lipton, C. Lauwers, M. Rutkowski, C. Noshpitz, C. Curescu, Tosca simple profile in yaml version 1.3, 2020, https://docs.oasisopen.org/tosca/TOSCA-Simple-Profile-YAML/v1.3/os/TOSCA-Simple-Profile-YAML-v1.3-os.html

- **Main features**
  - Declarative & imperative, human-readable & domain agnostic; Service, resource, & inter-dependency modeling; Validation & fine-grained modeling of services; Can be represented in XML, YAML or YANG
- **Role in IBN lifecycle**
  - Service orchestration & LCM; YANG model instantiation for service components
  - Service assurance through adaptable configuration management
- **Required improvements for IBN lifecycle**
  - **Service model**
    - Multi-level graph model (graph, tree-based)
    - Inheritance for service descriptors (complex service design from basic templates)
    - Portability & re-useability of basic service descriptors
  - **Service orchestration**
    - Language semantics definable internally
    - Dependency models based on policies; Dynamic service graph creation

3. IBN approach in 5G/B5G orchestration and management

- **3.6 Examples of OMC useful technologies for Intent Based Networking in 5G**
- **YANG -Yet Another Next Generation (IETF)**
  - *T. Zhou, S. Liu, Y. Xia, S. Jiang, Yang data models for intent-based network model, 2015, https://datatracker.ietf.org/doc/html/draftzhou-netmod-intent-nemo-00*
- **Main Features**
  - Machine-readable & domain agnostic; Device-level configurations & instantiation
- **Role in IBN lifecycle**
  - Representation of service requests as dependencies for intents
  - Service deployment & configurations as per service graph
- **Required improvements for IBN lifecycle**
  - **Service model**
    - Coupling between services and service components
    - Structured naming convention
    - Automated deployment & upgrades
  - **Service orchestration**
    - Deployment state model for service descriptors
    - Dependency analysis of services in runtime
    - Automated modification of deployed services

3. IBN approach in 5G/B5G orchestration and management

- **3.6 Examples of OMC useful technologies for Intent Based Networking in 5G**
- **HOT -Heat Orchestration Template (Openstack)**
  - *OpenStack, Heat orchestration template (hot) specification, 2016, https://docs.openstack.org/heat/rocky/template_guide/hot_spec.html#hot-spec*
- **Main Features**
  - Declarative, human-readable
  - Service LCM, description &orchestration
  - Static and limited support for adaptability & new models
- **Role in IBN lifecycle**
  - Service orchestration & LCM
  - Not suitable for complex services & scenarios
- **Required improvements for IBN lifecycle**
  - **Service model**
    - No dependence on underlying protocol stack
    - Utilization of dynamic service blueprints for service design
  - **Service orchestration**
    - Dynamic LCM of services
    - Resource models & exposure

3. IBN approach in 5G/B5G orchestration and management

- **3.6 Examples of OMC useful technologies for Intent Based Networking in 5G**
- **SDN-based Open Network Operating System (ONOS)**
  - *Y. Han, J. Li, D. Hoang, J.-H. Yoo, J.W.-K. Hong, An intent-based network virtualization platform for sdn, in: 2016 12th International Conference on Network and Service Management (CNSM), IEEE, 2016, pp. 353–358, https://wiki.onosproject.org/display/ONOS/ONOS+%3A+An+Overview*
  - **ONOS - multi-module project** whose modules are managed as OSGi bundles. Goals:
    - Code Modularity : one can introduce new functionalities as self-contained units
    - Configurability : one can load /unload various features, at startup or at runtime
    - Separation of Concern : clear boundaries between
    - Protocol agnosticism : It, and its applications, are not bound to specific protocol libraries or implementations
  - ONOS includes an **Intent Framework component** providing an overall runtime environment and framework
  - The Intent Framework
    - acts as an integral part of IBNs connection
    - treats intent as policy-based directives, allowing applications to broadcast their network needs externally based on policy and management.
  - When an application declares that it need something (e.g., extra bandwidth or a primary channel), the controller performs the necessary configuration changes on the appropriate device

3. IBN approach in 5G/B5G orchestration and management

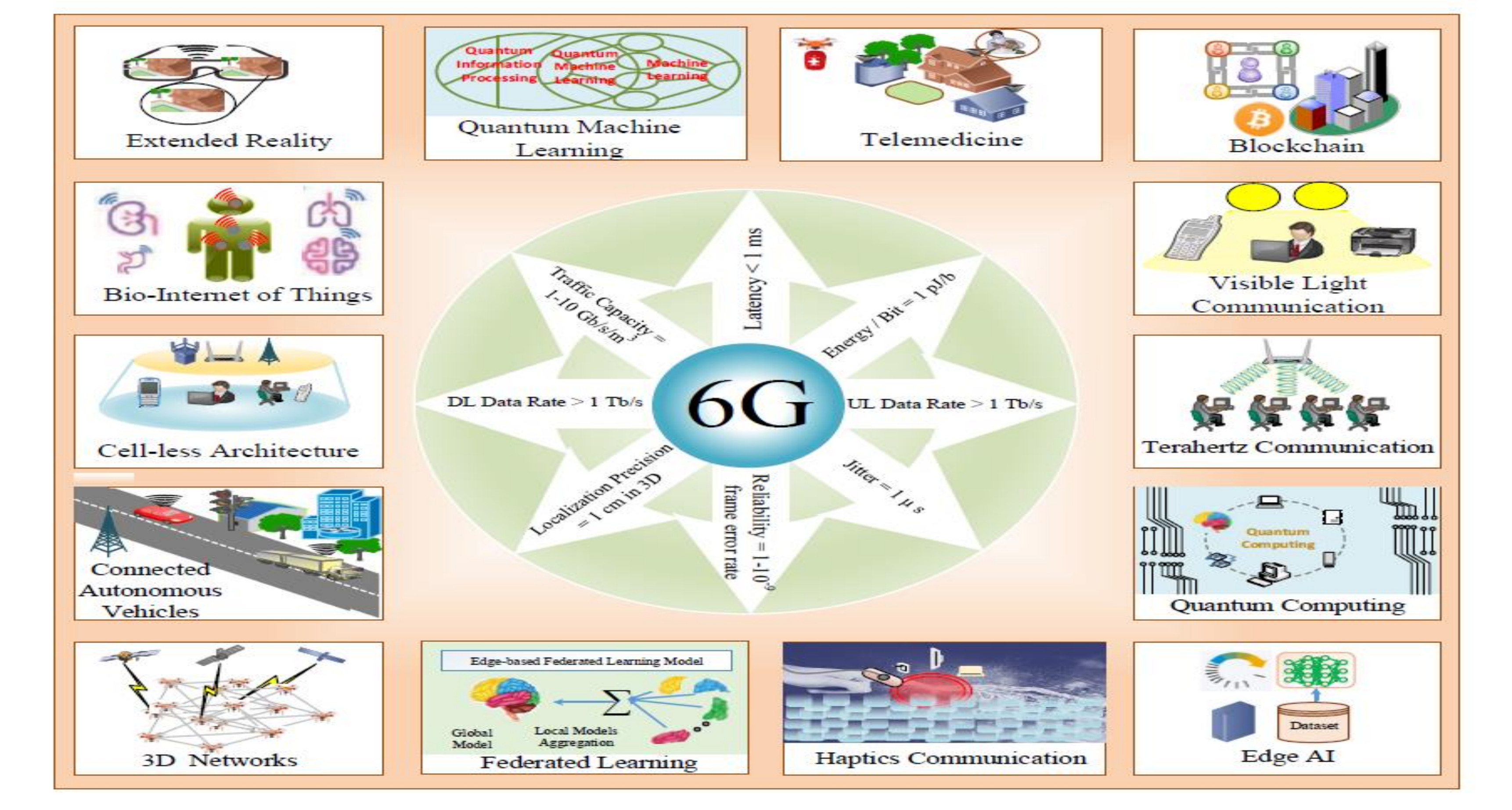
3.7 Intent Based Networking in 6G

3.7.1 6G General overview

- **Key requirements:**
  - capacity, UL/DL data rate
  - localization precision, reliability
  - latency, jitter, energy per bit
- **Several enabling technologies**
  - Machine learning (quantum), federated learning
  - Computing (quantum)
  - 3D networking
  - Edge Artificial Intelligence
  - Cell-less architecture
  - Blockchain
  - Haptic communication
  - Terahertz communication
- **Use cases – examples**
  - Connected autonomous vehicles
  - Telemedicine
  - Extended reality
  - Internet of Things

3. IBN approach in 5G/B5G orchestration and management

3.7 Intent Based Networking in 6G
3.7.1 6G General overview (cont'd)



Source: L.U. Khan, et al., "6G Wireless Systems: A Vision,Architectural Elements, and Future Directions", 10.1109/ACCESS.2020.3015289, IEEE Access, 2020, https://www.researchgate.net/publication/343565534

3. IBN approach in 5G/B5G orchestration and management

3.7 Intent Based Networking in 6G
3.7.2 General architectural concepts

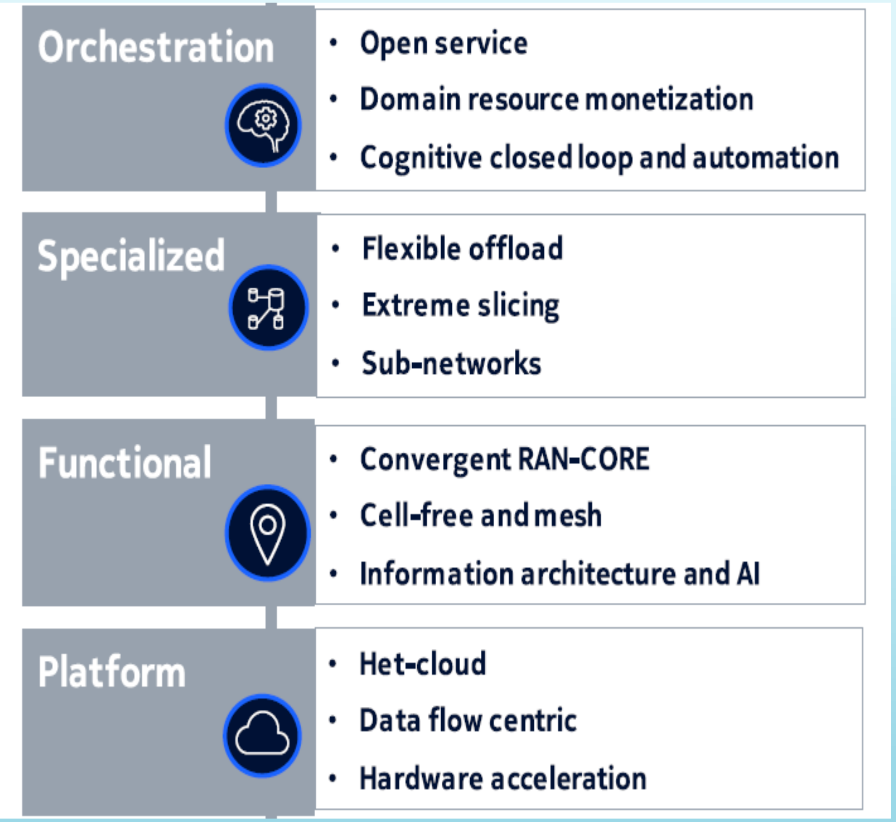
6G Architectural framework – building blocks example
Four major interworking components,
to provide an open and distributed reference framework

Platform infrastructure :
"het-cloud", open, scalable and agnostic run-time environment
data flow centricity, hardware acceleration

Functions (functional architecture)
RAN- CORE convergence
cell free and mesh connectivity
information architecture and AI

Specialized networks and architectural enablers for
flexible off-load, extreme slicing, sub-networks

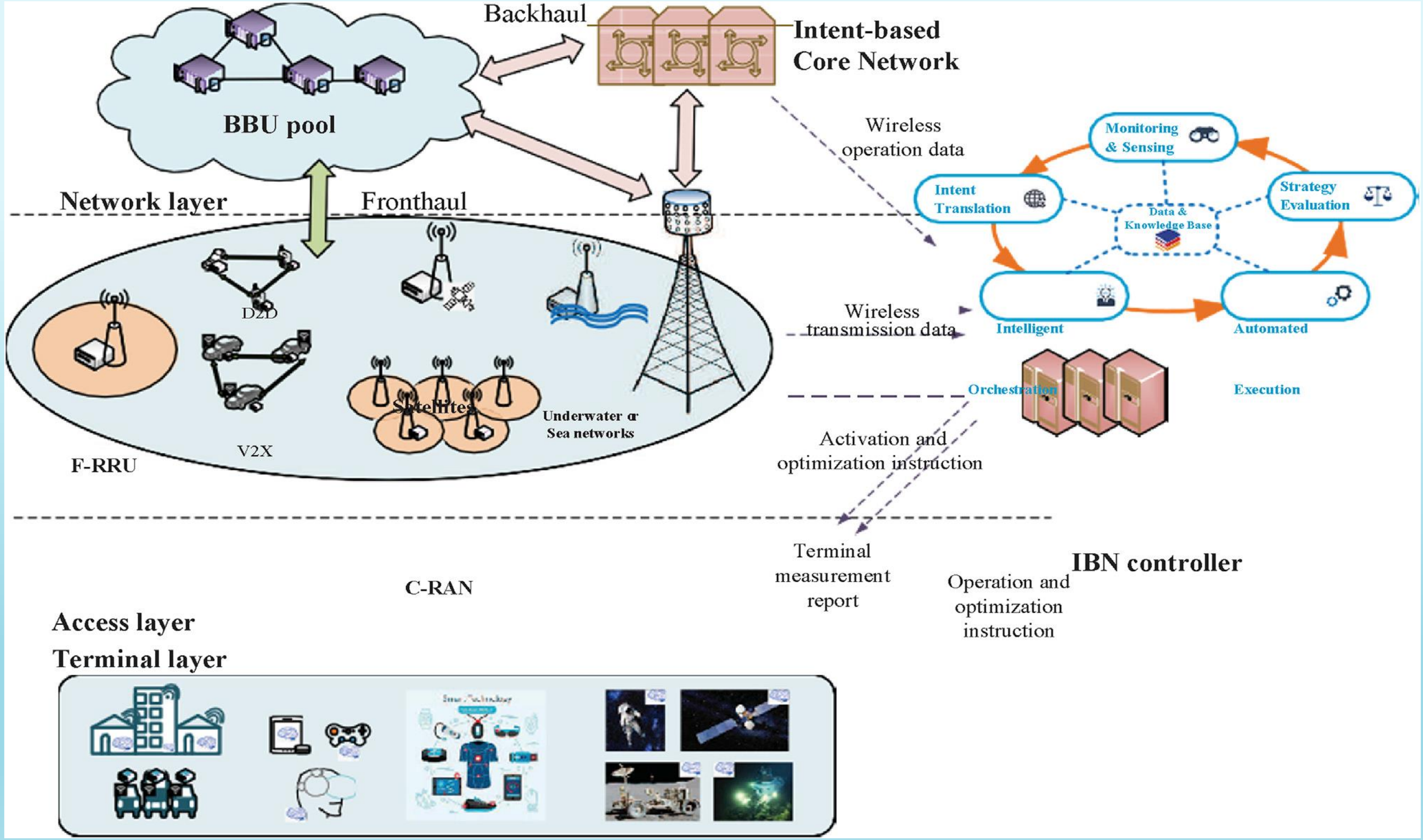
Orchestration component
assures open service enabling and ecosystem
cognitive closed loop and automation



Source: V.Ziegler et al., "6G Architecture to Connect the Worlds", IEEE Access, Sept 2020, https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=9200631

3.7 Intent Based Networking in 6G

3.7.3 An example of intent-based 6G network architecture



Source: Y. Wei, M. Peng, Y. Liu, IBN for 6 g: Insights and challenges, Digit. Commun. Netw. 6 (2020) 270–280.

3. IBN approach in 5G/B5G orchestration and management

3.7 Intent Based Networking in 6G

3.7.3 An example of intent-based 6G network architecture (cont'd)

- The **IBN controller** could
  - perform functions (fully or partially) of wireless intent processing cycle: intent translation, conflict resolution, network layout optimization, strategy optimization, network configuration and activation
  - complete the acquisition of wireless transmission data, and terminal measurement report of the AN (network layer and access layer).
  - be located: in a centralized cloud, a base station controller, or a macro station with network management capabilities
- Distributed data collection and processing and network resource optimization can be carried out in the
  - base station (**Fog-Remote Radio Unit, F-RRU**)
  - terminal equipment (**Fog-User Equipment, F-UE**)
- Edge computing and management allow efficient operation of network management

Source: Y. Wei, M. Peng, Y. Liu, IBN for 6 g: Insights and challenges, Digit. Commun. Netw. 6 (2020) 270–280.

3. IBN approach in 5G/B5G orchestration and management

3.7 Intent Based Networking in 6G (cont'd)

- The IBNs for 6G have evolved from the wireless access network and intent network, toward functions of real-time measurement data collection, network edge computing power and the support of AI/ML algorithms.
- IBNs can adapt to different network configuration methods and PHY layer technology to meet the networking needs of 6G, such as massive connection, ultra-low delay, and super-large bandwidth.
- Based on real-time collected data, IBNs using big data and AI/ML technology can
  - identify network faults in advance
  - proceed to fault remediation
  - carry out active strategy optimization.
- The combination of IBNs/6G/THz, visible light or space-air-ground-sea integrated communication and AI-based networks, can be a key factor in network automation and intelligence.

Source: Y. Wei, M. Peng, Y. Liu, IBN for 6 g: Insights and challenges, Digit. Commun. Netw. 6 (2020) 270–280.

3. IBN approach in 5G/B5G orchestration and management

3.8 Artificial Intelligence/ Machine learning in IBN

- The IBNs initial design: based on the traditional 5G architecture and not taking into account the AI/ML
- The majority of studies of IBNs only focused on the core network; intent-driven wireless networks need further exploration.
- Some studies used AI/ML in systems having traditional IBNs architecture.
  - Example: applying the SDN core network have shown positive features, including business self-sensing network, self-configuring network operations, and performance self-optimization of network
- At present, the combination of AI/ML and wireless communication is mainly focused only on the optimization of 5G system architecture,
- AI/ML will be an important part in 6G; it improves the network intelligence and reduces operation and maintenance costs.

- The AI/ML-enabled IBNs should be
  - powerful to deal with problems and serve for different high-QoS diverse application scenarios
  - able to translate users' operational performance and other requirements into the wireless network configuration, operation and maintenance policies, and realize E2E self-configuration of RANs

Source: Y. Wei, M. Peng, Y. Liu, IBN for 6 g: Insights and challenges, Digit. Commun. Netw. 6 (2020) 270–280.

3. IBN approach in 5G/B5G orchestration and management

3.8 Artificial Intelligence/ Machine learning in IBN (cont'd)

- AI can contribute to collecting network measurement data, and predictive analysis and intelligent optimization, big data processing, etc. , to preserve the network performance
- **Problems to be solved** if introduction of AI/ML based IBN into the 6G architecture:
  - data collection, model training, algorithm selection, evolution of the current network architecture
  - **Data collection (AI/ML data)**
  - It is necessary
    - to specify the types of data to be obtained
    - to specify the ways to obtain data for the realization of each function of the IBNs.
    - an energy-efficient interference control scheme for the ultra-dense small cell systems
  - **Model training** (AI computing power)
  - It is necessary to deploy
    - an AI/ML model training equipment that supports computing and storing at the appropriate protocol layer in combination with network architecture
    - allocate network computing resources and trained models reasonably
  - **Algorithm selection**
  - It is necessary an appropriate AI algorithm with high operation efficiency and high operation accuracy, according to the functional requirements and the operational capability supported by the network

3. IBN approach in 5G/B5G orchestration and management

3.8 Artificial Intelligence/ Machine learning in IBN (cont'd)

- **Autonomous behavior** in network management and service orchestration via IBN can be enhanced via AI/ML.
- **Potential problems** that require dynamic mapping mechanisms with AI/ML: intent description model, mapping intents to service requests, LCM of intents and services, etc.

- NLP helps in understanding the intent structure and context through **traditional Sequence-to-Sequence** (seq2seq) learning models like **Recurrent Neural Networks (RNN), Long-Short-Term Memory (LSTM), Gated Recurrent Unit (GRU))** [1] , **Bidirectional Encoder Representations from Transformers (BERT)** [2]

- The novel approach of **Machine learning as a service MLaaS** [3] provides the required learning in different aspects of network operations and management as - on demand feature.

- *[1] M.I. Jordan, Serial order: A parallel distributed processing approach, Adv.Psychol. 121 (1997) 471–495*
- *[2] . J. Devlin, M.-W. Chang, K. Lee, K. Toutanova, Bert: Pre-training of deep bidirectional transformers for language understanding, in: NAACL-HLT, 2019.*
- *[3] R. Philipp, A. Mladenow, C. Strauss, A. Volz, Machine learning as a service: Challenges in research and applications, in: Proc. of the 22nd Int'l Conf. on Information Integration and Web-Based Applications &Services, IiWAS '20, Association for Computing Machinery, New York, NY, USA, 2020, pp. 396–406, http://dx.doi.org/10.1145/3428757.3429152.*

3.8 Artificial Intelligence/ Machine learning in IBN (cont'd)

- Convolutional Neural Network (CNN) can contribute to the context and declarative parameter retrieval leading to the service extraction, by iteratively considering the service domain and environment, SLAs and supported services.

- Learning as a core functional block has also been included in the ETSI proposed **Zero touch network & Service Management (ZSM)**, ENI model frameworks for autonomous networks of future with differing levels of automation.

- Focused studies related to the learning based problems in IBN model are still to be developed.

CONTENTS

4. Conclusions

- The **Intent Based Networking (IBN)** approach and platforms offer automation of orchestration and management of the 5G/B5G networks and services in single or multi-domain environment.
- The user has to define only its higher-level service requirements (intent) using different tools (including natural language), without dealing with the realization of them.
- IBN system translates the intent into policy configurations through domain policy configurators and forwards them to underlying orchestrators to automatically activate resources over the infrastructure.
- Intent controllers can be used to responsible for handling the core, transport and and RAN parts of the network.
- An IBN system can perform the 5G/B5G network and services orchestration and management in single or multi-domain environment and E2E in a flexible way.

4. Conclusions

- The IBN System eliminates the requirement of professional-level expertise for provisioning of the network service.

- **Artificial Intelligence/Machine learning (ML)** algorithms offer support for intent update engines, making IBN an intelligent platform that can update the run-time resources on demand.
  - The AI/ML updating machine forecasts and predicts the network resources state on runtime, which helps the intent manger in its decision.

- **Open research issues**
  - Further development of data modeling langiages and cooperation in IBN
  - Intent description interpretation and service mapping
  - Deeper ML/AI integration in intent management lifecycle
  - Better compatibility with SDN, NFV, Cloud/edge computing
  - IBN framework in multi-domain, multi-operator, E2E contexts
  - IBN framework security and protection

- Thank you !
- Questions?

Orchestration and Management in 5G/B5G - Intent Based Networking Approach

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Orchestration and Management in 5G/B5G - Intent Based Networking Approach

- **List of Acronyms**

5G CN	Core Network
5G-AN	5G Access Network
5GS	5G System
AF	Application Function
AI	Artificial Intelligence
CC	Cloud Computing
CP	Control Plane
CRAN	Cloud based Radio Access Network
D2D	Device to Device communication
DL	Deep Learning
DN	Data Network
DNN	Deep Neural Network
DP	Data Plane (User Plane UP)
DT	Decision Tree
IoT	Internet of Things
IBN	Intent Based Networking
IBNS	IBN System
M&C	Management and Control
ML	Machine Learning
NaaS	Network as a Service
NAI	Network Access Identifier

Orchestration and Management in 5G/B5G - Intent Based Networking Approach

- **List of Acronyms**

NF	Network Function
NFV	Network Function Virtualization
NN	Neural Networks
NSL	Network Slice
NSLI	Network Slice Instance
NS	Network Service
NSLID	Network Slice Instance Identifier
NSSAI	Network Slice Selection Assistance Information
NSSF	Network Slice Selection Function
ONF	Open Networking Foundation
PaaS	Platform as a Service
PCF	Policy Control Function
QoE	Quality of Experience
RAN	Radio Access Network
RL	Reinforcement Learning
SaaS	Software as a Service
SD	Slice Differentiator
SDN	Software Defined Networking
SLA	Service Level Agreement
SM	Service Management
SMF	Session Management Function
SML	Supervised Machine Learning
S-NSSAI	Single Network Slice Selection Assistance Information
SST	Slice/Service Type
SVM	Support Vector Machine
UML	Unsupervised Machine Learning
UPF	User Plane Function
VLAN	Virtual Local Area Network
VM	Virtual Machine