Agile^{AFP}: ML-enabled Agile Private/Public 5G/B5G Service and Network Autonomic Federation Platform

Taesang Choi[1], Jeongyoon Kim[2], Sangsik Yoon[3], Moonkook Park[4], Seungyu Ko[5], Ranganai Chaparadza[6]

Abstract — Future Networks in 5G and beyond will continue to expand in scale, complexity and interconnectivity, and will be highly shaped by distributed systems that serve various use cases that go beyond current use cases like mMTC and URLLC. This will be coupled with an increasing demand for autonomy in self-provisioning and self-management, network interoperability, and service federation on a very dynamic flexible way. Requirements on systems-of-systems architectures will become more relevant as multiple autonomous/semi-autonomous systems/networks (AN) adaptively seek to operate and interact with their peers. Federated Distributed Open Platforms (DOPs) as peers for cross-industry sectors end-to-end (E2E) services innovation and delivery agility can meet such requirements. The use of federation and associated mechanisms is a promising technology for interconnecting systems, innovation and service delivery by the federating AN systems; and allowing asset sharing and extending traditional eco-systems and value-chains with further resources and stakeholders. However, such a concept of cross-industry E2E services innovation and delivery agility in the 5G & Beyond Era and the associated ecosystem that would emerge DO NOT EXIST yet. This paper proposes an architecture to enable cross-industry DOP network federation and our proof of concept implementation, Agile^{AFP}.

Keywords: Autonomic/Autonomous Networking (AN); Federations & Governance of ANs; Multi-Layer Autonomics and AI/ML Frameworks; Autonomic Management & Control (AMC); Autonomics Levels; Degrees of Autonomy in ANs

I. INTRODUCTION

Future Networks in 5G and beyond will continue to expand in scale, complexity and interconnectivity, and will be highly shaped by distributed systems that serve various use cases that go beyond current use cases like mMTC and URLLC. This will be coupled with an increasing demand for autonomy in self-provisioning and self-management, network interoperability, and service federation on a very dynamic flexible way. The need for network automation and related standards has continued to grow, mainly because it is becoming very difficult to manage the increasingly complex networks and technologies using traditional manual management of networks. For ICT Network Operators who operate the evolving and future networks such as 5G and beyond networks, there is need for a shift to the way ICT networks are designed and operated. A shift to a new way that brings about OPEX sustainability in operating networks and services and enables operators and enterprises to innovate and deliver services to consumers in a richly agile manner.

Various Enablers for this new vision are required, such as capabilities for automatic discovery of the availability and proximity of various kinds of assets and infrastructures to enable them to innovate and/or deploy services over assets owned by different players that avail them for on-demand usage, capabilities for on-demand dynamic service composition and delivery using various assets owned by players that may even seek to monetize them from across various industries, capabilities for autonomic network(s) and connectivity formation in self-managed manner in response to agile service delivery needs, emergency situations and predicted situations.

This paper proposes an architecture for agile private and public 5G/B5G service/network federation platforms to address the required functionality and its proof of concept implementation, Agile^{AFP}. The remainder of the paper consists of Section II and III which describe the proposed architecture and the proof-of-concept implementation and its evaluation respectively, and then Section IV describes the conclusion with future work.

II. RELATED WORK

There has been huge efforts recently launched in various SDOs/Fora in producing standards for cognitive/autonomic management and control (AMC) of ICT networks and services, artificial intelligence models/algorithms and computational intelligence. Systems at various levels of abstractions within the heterogenous industry sectors, ranging from network elements/functions of ICT infrastructures and associated management and control systems/platforms of the ICT infrastructures that serve consumer devices and services delivered for human consumptions should be designed to incorporate control-loops for autonomics, cognition, AI models/algorithms and computational intelligence at varying degrees of complexity. Such design principles for the various systems shall enable the systems to be intelligent and exhibit

[1]Taesang Choi: ETRI: choits@etri.re.kr
[2]Jeongyoon Kim: ETRI: jykim@etri.re.kr
[3]Sangsik Yoon: ETRI: ssyoong90@etri.re.kr
[4]Moonkook Park MOBIGEN: hipmk@mobigen.com
[6]Seungyu Ko: IN-soft: skgo@in-soft.co.kr
[5]Ranganai Chaparadza: ETSI AFI & IPv6Forum: ran4chap@yahoo.com

the so-called Self-* behavioral attributes/features such as *Auto-*Discovery of Resources, Information, Context-changes or environments; Self-Configuration; Self-Diagnosis; Self-Repair; Self-Optimization; Self-Protection; Self-Defense; Self-Healing; Self-Awareness, Self-Organizing; Self-Adapting attributes; etc.

Requirements on systems-of-systems architectures will become more relevant as multiple autonomous/semi-autonomous systems/networks (AN) adaptively seek to operate and interact with their peers. Federated Distributed Open Platforms (DOPs) as peers for cross-industry sectors end-to-end (E2E) services innovation and delivery agility can meet such requirements. The DOPs should be formed by way of federations of ICT network facilities and assets that are owned by various sectors (including public sector ICT infrastructures, enterprise/private ICT infrastructures, government owned infrastructures, research institutes, and other stakeholders). The use of federation and associated mechanisms is a promising technology for interconnecting systems, innovation and service delivery by the federating AN systems; and allowing asset sharing and extending traditional eco-systems and value-chains with further resources and stakeholders (including new ones that were never involved in the traditional ICT ecosystems but should now be involved in 5G and 6G ecosystems). However, such a concept of cross-industry E2E services innovation and delivery agility in the 5G & Beyond Era and the associated ecosystem that would emerge DO NOT EXIST yet.

III. PROPOSED ARCHITECTURE

This section describes a proposed architecture for agile private and public 5G/B5G service/network federation platforms. Figure 1 highlights functional components for unified management of resources owned by different service/network players (private/public 5G network operators), for control specific service/network domains, for orchestration of OSS/BSS, E2E service/network operations, security and for autonomic service/network control and management.

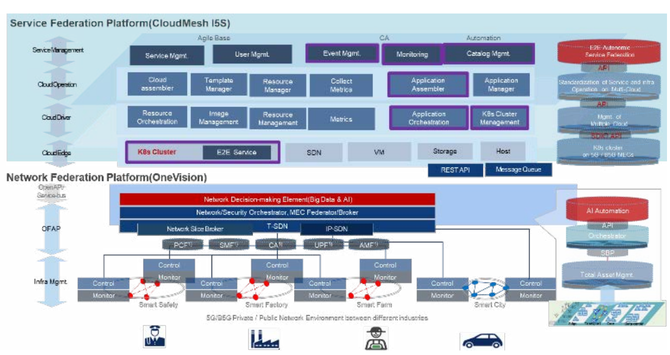

Figure 1. Proposed Agile^{AFP} architecture

II.1. Service Federation Architecture

The service federation platform architecture proposed in this paper consists of three layers as shown in Figure 1: "Cloud Edge Management layer", "Cloud Operation Management layer", and "Service Management layer". Detailed description of each layer is provided below.

- Cloud Edge Management Layer

Cloud edge is a managed cloud infrastructure for operating and managing services. It is the basic management unit for operating and managing federated services, and MEC (Mobile Edge Computing) is cloud edge in 5G. Cloud infrastructure consists of virtual machine, storage, k8s cluster etc. And mobile asset is included in the service target. Cloud Edge manages all of them running in multi-cloud.

In particular, the federated network configured in the network federation platform is registered as a functional component which is controlled by SDN controller. It is provisioned on the cloud edge, and used as a basic unit of network assets to configure services.

And it supports auto discovery of mobile assets connected to this network and provides basic functions for registering, managing and controlling assets

- Cloud Operation Management Layer

Cloud operation management layer is a layer that operates and manages multiple cloud edges and composes the actual service federation. To provide services, it supports functions such as deploying and connecting physical virtual resources and additionally deploying services on them.

The deployment function can be divided into Cloud Orchestrator and Container Orchestrator. Cloud Orchestrator deploys virtual resources, Container Orchestrator deploys applications to configure services to Kubernetes Cluster. By supporting the MSA-structured cloud, it provides an environment for quickly deploying and operating services.

It manages configuration for efficient service distribution through Template Manager. From the infrastructure for configuring the service to the application, you can code and bundle all the contents into a template, and manage the separated information required for deployment as a parameter. This allows the federated services to be deployed on multiple cloud edges simultaneously, and intuitive management is possible.

It provides a function for monitoring deployed InrRA and applications. It also checks asset configuration information and collects and manages metrics.

- Service Management Layer

Service management layer provides governance and life cycle to operate and manage the federated services. It manages the service life cycle in units of templates provided by the cloud operation management layer. Figure 2 shows the cycle structure from "application" to "operation/management" and disposal of services in the life cycle.

Service Management provides a portal to operate and manage services, which is divided into "Admin Portal" and "User Portal".

Users can apply for distribution and use of services, and operate and manage services through “User Portal” and assets in themselves or in the group to which they belong. It also provides a monitoring dashboard to operate and manage the service.

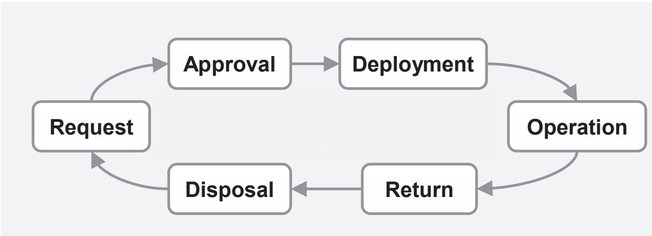

Figure 2. Agile 5G/B5G federated service Life Cycle

Administrators manage infrastructure and assets for the entire service they manage through "Admin Portal".
You can manage the cloud edge's account, register users and groups, and assign permissions
In summary, the service management layer enables a business support functionality for operating and managing 5G/B5G E2E federated services between heterogeneous industries.

II.2. Network Federation Architecture

The network federation platform architecture proposed in this paper consists of three main functional components as shown in Figure 1: "Network Automation", "Network Federation Orchestration", and "SDN controller".

- Network Automation

The network automation functional component provides Autonomic Management & Control (AMC) functions of network belonging to different industry sectors (private and public networks) to enable E2E Service Innovation, Orchestration and Agile Delivery across the industry sectors in an agile manner and enable autonomic network and connectivity formations and orchestrations in response to agile service delivery needs or detected situations and predicted situations. As enablers for autonomic networks federations within and across multiple 5G public network operators and private 5G networks, AMC platform based on ETSI GANA Knowledge Plane(KP) [1] will be implemented and specially, advanced machine learning/deep learning algorithms also implemented/evaluated for GANA KP Decision-making Element(DE).

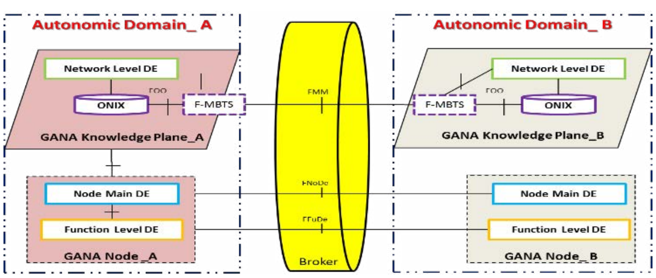

Figure 3. Federation of GANA domains of management and control architectures for inter-domain autonomics

The autonomics properties (e.g. self-configuration, self-diagnosis, self-repair, self-healing, self-protection, self-awareness, etc.) within network nodes/functions themselves are instantiated to drive fast control-loops achievable by low level GANA DE for network nodes/elements and policy-controlled (governed) by higher level autonomics ("slow control loops") achievable by higher level GANA DE for network-wide and logically centralized autonomic management and control of networks and services. Figure 3 illustrates federation of GANA KP-based AMC domains [2].

- Network Federation Orchestration

The network federation orchestration functional component provides orchestration functionalities in response on-demand service delivery need in general for the interest of the E2E network service instantiation and delivery parties, or in response to detected network fault/anomaly/emergent situations and predicted situations. Various orchestration components will be used such as E2E network orchestrator for MEC Cloud & Transport networks, security orchestrator and orchestrator for OSS/BSS systems within/across multiple 5G public/private networks.

- SDN Controller

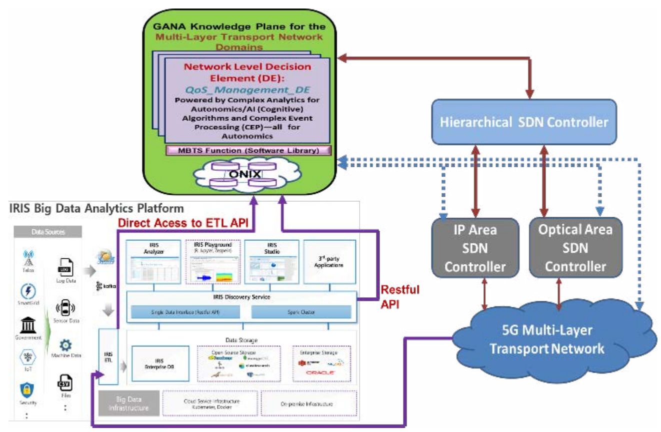

Figure 4. AMC Platform architecture for 5G Transport Network

The SDN Controller functional component provides service programming and policing, traffic engineering and steering for underlying networks. In general, Telecom operator 5G Transport networks consist of multi-layer(IP/Optic), multi-vendor network equipment and multiple SDN controllers for each layer/vendor will be used such as Transport SDN(T-SDN) Controller, IP SDN Controller, Data Center SDN(DC-SDN) Controller. SDN Controllers provide API interfaces for other components such as Orchestrators, AMC platform and GANA MBTS-like library within SDN Controller provides intermediation layer between the GANA KP DEs and the NEs ((Network Elements)—physical or virtual elements of public/private 5G networks)) for translating technology specific and/or vendors' specific raw data onto a common data model for use by GANA KP DEs, based on an accepted and shared information/data model.

Figure 4 illustrates AMC platform for 5G transport network, consists of GANA KP DE & ONIX, Big Data Platform and ETL[3], SDN Controllers.

IV. Proof of Concept Implementation and Evaluation

III.1. Service Federation Platform PoC: CloudMesh^{I5S}

To verify the proposed service federation architecture, we have been developing a proof-of-concept implementation called CloudMeshI5S.

CloudMeshI5S is a solution developed to validate the proposed architecture. Figure 5 depicts the deployment architecture of the agile private and public 5G/B5G service federation platform.

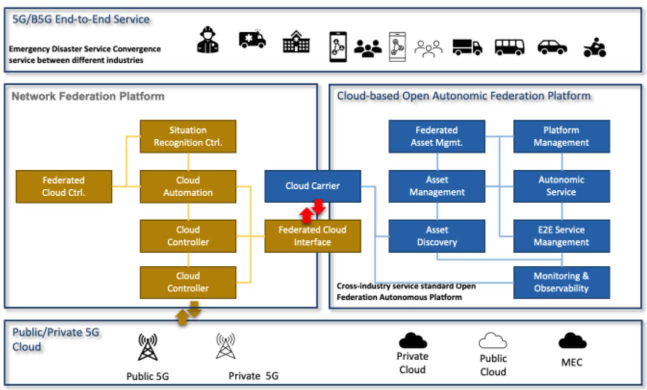

Figure 5. CloudMesh^{I5S} PoC Implementation Architecture

- 5G/B5G E2E Autonomic Network Federation Platform:

It is largely divided into "5G/B5G E2E Autonomic Network Federation Platform" that composes Network Federation and "Cloud-based Open Autonomic Federation Platform" that composes the service federation. This paper mainly focuses on the PoC for service federation.

- Cloud-based Open Autonomic Federation Platform":

It consists of a total of eight functions, and Asset Management is further divided into "Federated Asset Management" and "ICT Asset Management". Table 1 describes the contents of these nine functions.

Class	System	Description
Asset	Federated Asset Management	Federated ICT/Not Asset, Resource Management
	ICT Asset Management	ICT Asset Management (Regist/Update/Remove)
	Asset Monitoring	List of using assets, monitoring metric of asset
Service	Autonomic Service	Serveice Management, Application of Service Management, Autonomic Service Deployment
	E2E Service Management	Service single console, E2E service dashboard
	Service Observability	Service state, monitoring metric of service and service application, Tracing of transaction
Cloud & Others	User Interface	OAFP Portal. Web based User Interface
	OAFP Management	Platform management
	Cloud Carrier	Cloud Provider, Cloud Broker, and Cloud Audit

Table 1. CloudMesh I5S Functions

III.2. PoC evaluation objectives and methods

We have defined the following evaluation objectives and methods for PoC system functionality verification.

- Evaluation objective 1 :
  - Name: Cloud resource creation success rate for end-to-end service application
  - Evaluation method:
    1) Establish resource requirements for deploying and operating end-to-end service applications.
    2) Resource creation request to deploy and operate end-to-end service application.
    3) Check the normal operation of the requested resources.
    4) Resource creation success rate = number of successful resource creation / number of resource creation requests.

- Evaluation objective 2 :
  - Name: Success rate of deleting cloud resources created for end-to-end service applications
  - Evaluation method:
    1) Confirm that the operation resource of the end-to-end service application is in the running state.
    2) Request to delete operational resources of end-to-end service application.
    3) Check the deletion result of the requested resource.
    4) Resource deletion success rate = number of successful resource deletion / number of resource deletion requests

- Evaluation objective 3 :
  - Name: 5G/B5G ICT Asset search speed for end-to-end service provision
  - Evaluation method :
    1) Create asset by requesting detailed 5G/B5G ICT asset provisioning.
    2) Time record of 5G/B5G ICT Asset creation and running status.
    3) Start exploring running state on cloud-based open federated autonomous platform
    4) Time records that cloud-based open federated autonomous platform recognized ICT Asset.

5) Seek Time = Seek Aware Time - Time of creation and execution
6) Converting 5G/B5G ICT asset search time into seconds.

■ Evaluation objective 4 :
- Name: Failure awareness time for end-to-end service applications
- Evaluation method :
1) Check end-to-end service applications in Running state.
2) Forces end-to-end service in Running state and records time
3) Recognize the end of the forced end-to-end service and check the time that the failure occurred
4) Failure Recognition Time = Time to record failure occurrence - Time to force shutdown.

■ Evaluation objective 5 :
- Name: End-to-end service application provisioning success rate
- Evaluation method :
1) Register an end-to-end service application.
2) Select a registered end-to-end service application to request deployment
3) Check the normal operation of the selected end-to-end service application
4) Provisioning success rate = the number of end-to-end service applications that operate normally / the number of end-to-end service applications requested for deployment.

III.2. Network Federation Platform: OneVision^{NFP}

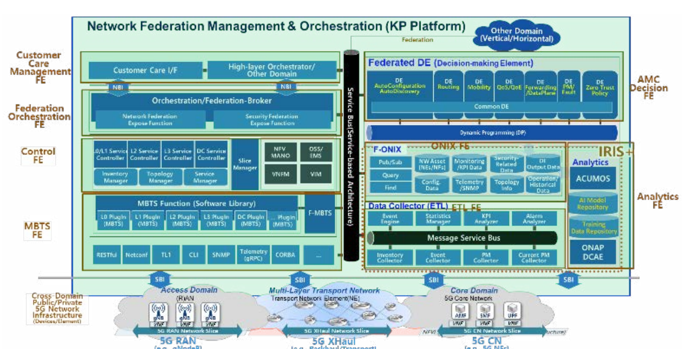

Figure 6. OneVision^{NFP} PoC Implementation Architecture

To verify the proposed network federation architecture, we have been developing a proof-of-concept implementation called OneVision^{NFP}. Figure 6 illustrates a implementation architecture of agile private and public 5G/B5G network federation platform [4]. It consists of GANA KP-based AMC platforms for each network domain (public/private 5G network), E2E network orchestrator & SDN controllers (IP-SDN Controller, T-SDN Controller) for 5G transport network and resource plane components (Fault/Configuration/Performance Management-related data collector, transformer & loader (ETL)). AMC platform consists of IRIS-based big data (ONIX), analytics platform and AI models for high-/low- level DEs.

We completed implantation of data collector (ETL-FE) for 5G transport network so far and are developing all other functional components. We group functional components into two groups: distributed open network platform which includes customer care management functional entity (FE), federation orchestration FE, control FE, MBTS FE, ONIX FE, and ETL FE and AMC platform which includes AMC decision FE and Analytics FE.

A. Distributed Open Network Federation Platform

Federated DOP platform provides network federation of a mix of clouds, public and private 5G networks and end devices, as assets and infrastructures that enable agile service composition and delivery across multiple industries and as foundation for autonomic ICT networks and assets federations. It also provides capabilities for enabling a truly connected societies in terms of resilience and survivability in the event of physical catastrophes like earthquakes, infrastructure damages, etc. and enabling autonomic security management & control for cross-industry service innovations, orchestration and delivery agility[5][6].

B. AMC Platform

Based on the ETSI GANA reference model, Knowledge Planes(KP)-based AMC platform provides autonomic management/control functions public/private 5G networks to enable E2E service innovation, orchestration and agile delivery across the industry sectors in response to agile service delivery needs or detected situations and predicted situations for public/private 5G network operator and across multiple.

For evaluation, we have defined the following evaluation objectives and methods for PoC system functionality verification: 5G/B5G network asset discovery speed, E2E network fault detection timing, E2E network provisioning success rate, autonomic management AI algorithm processing rate, and resource monitoring performance, etc. We also defined specific evaluation methods like service federation functionality evaluation. Since the development of our PoC system is underway, the evaluation will be performed in near future that we can share the results in the camera-ready version.

III.3. Use Case: Private & Public ITS Network/Service Federation

Figure 7 illustrates the PoC use case, private and public Intelligent Transportation System (ITS) service federation.

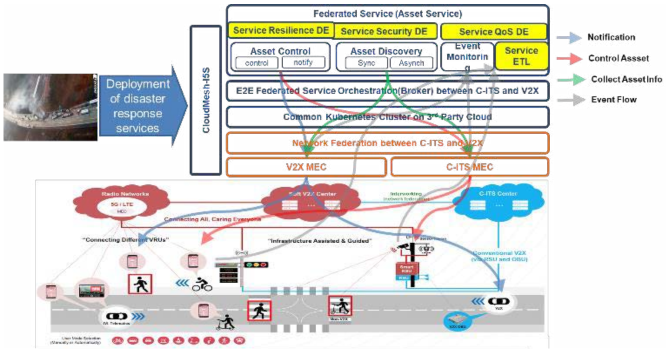

Figure 7. Use Case Scenario

Typically, public ITS is operated and managed by the government transportation agency and private ITS can be operated by any communication service operators based on C-VTX technology. The two ITS services collects and manage different ITS environment and information. For example, public ITS will monitor the transportation system road and traffic related information collected by cameras and sensor in the roadside. On the other hand, private ITS will collect information associated with pedestrian or vehicles through their mobile devices. Therefore sharing the information collected by both ITSs through service and network federation can provide synergy effects. Our use case assumes that both private and public ITS services are deployed over private or public 5G networks. Our agile service/network federation platforms can manage and orchestrate both networks and services entire lifecycle with agile autonomic intelligence from planning and provisioning of the federated service, monitoring the quality of service and any potential anomalies until terminating the service.

IV. Conclusion and Future Work

This paper introduced an architecture for agile private and public 5G/B5G service/network federation platforms. It will be a generic architectural framework blueprint for cross-industry service innovations and delivery agility that defines components that should be available in ICT infrastructures and their associated management and control systems belonging to different industry sectors (private and public networks) to enable E2E service innovation, orchestration and on-demand delivery across the industry sectors in an agile manner, and enable autonomic network and connectivity formations and orchestrations in response to agile service delivery needs or detected situations and predicted situations. We are currently implementing the core enablers and integrating the enablers based on the ITS use case. The feasibility verification based on the evaluation objectives and methods defined will be followed and the preliminary results can be shared in a camera-ready version. Successful service federation requires global standards, we will actively participate standardization efforts.

Acknowledgment

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