An Intent-based Smart Slicing Framework for Vertical Industry in B5G Networks

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Abstract—End-to-end slicing provides more opportunities for telecommunications in vertical industry. It is able to satisfy the different Service Level Agreement of vertical industry. However, a smarter and more flexible slicing management framework is required to support the deep application of vertical industry in beyond 5G networks. The slicing research and standardization of 3GPP and other SDOs has started to focus on smart slicing. A significant target of smart slicing is to satisfy the users' intents and requirements. An intent-based network can recognize the users' intent in real-time and then update the network slicing to guarantee the SLA. In this paper, an intent-based smart slicing framework is proposed to support the applications in vertical industry. It is able to recognize and guarantee the users' intent by closed-loop management.

Keywords—intent-based networks, vertical industry, Beyond 5G, intent translation, intent guarantee, E2E slicing

I. INTRODUCTION

With the rapid development of the new generation of vertical industry featuring a wide variety of smart services and intelligent devices, the major challenges at present include how to effectively allocate network resources to meet the demands of multiple services and to provide high quality of service (QoS) for users.

At present, the application of fifth-generation (5G) network slicing technology to resource allocation in vertical industry scenarios is still at the growing stage. With vertical industries such as the Internet of Vehicles (IoV), the Internet of Things, and the Industrial Internet taking off, the 5G mobile communication technology has been aiming at the interconnectivity of multiple fields. As a new generation of wireless communication technology, 5G takes the demand of machine type communication into consideration on the basis of the traditional human type communication, boasting a ultra-low time delay with 1ms and high connection density of 106/km2 that can better match the requirements of industrial control business. Network slicing turns out to be a promising solution for the diversified service demands of 5G.

Network slicing is one of the significant technologies of 5G, which divides the existing physical network into multiple logical networks that are independent of each other and provides customized services for differentiated businesses. According to the QoS requirements, network slices are assigned appropriate network functions and resources to achieve the same level of security as the virtual wireless private network. As an effective means of resource allocation, 5G network slicing, especially facing demands of network connection in diversified vertical industries, can be tailored to different businesses with different needs, so as to provide better services.

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With the Internet of Things on a tear, the telecommunication demand of vertical industries is also increasing. We mainly investigate into three vertical industries, namely the Internet of Vehicles, Smart Grid and Smart Manufacturing.

The IoV provides safe, efficient and convenient intelligent transportation services through environmental awareness, data computing, decision control and other capabilities. In the case of 5G network, specific indicators related to network in the scenarios of IoV mainly include time delay, reliability, bandwidth, security isolation, etc. When it comes to the typical applications of the IoV such as formation driving, remote driving and high-precision map downloading, the end-to-end delay requirement is significantly increased, the maximum response time should be less than 10ms [1]. For services requiring high bandwidth consumption, for instance the downloading of high-precision map, the bandwidth demand is up to 200M [2]. At the same time, the Internet of Vehicles also has a communication reliability requirement of 99.999% [1-2].

Smart grid industry is expanding at a frenetic pace in recent years. The number of user terminals is roaring thanks to the diversification of power grid services. Current research has been focusing on means to meet the various service needs in smart grid in a cost-effective approach. In addition, the boom of smart grid business has raised challenges for network QoS, demanding larger-scale connection and higher reliability. Specifically, in the smart grid, distributed energy regulation may reach millions of connections [3]. Phasor measurement service require communication reliability of 99.999% [3].

Another industry that will be profoundly transformed by 5G is smart manufacturing. In the 5G era of smart manufacturing, working conditions will be improved, manual labor on production lines will be reduced, and efficiency and product quality of enterprises will be enhanced. In the industrial circle, high reliability and low delay communication system is crucial. Large amount of money has been pouring into equipment renewal, whether it is machine tools, production lines, or mechanical equipment. Shutdown caused by faults in the production process often affects the entire production line, or even puts off the entire product delivery cycle. The intelligent manufacturing industry has a particularly prominent demand for wireless network reliability, to make the robot arm plug-in I/O wireless, the communication reliability has to reach 99.9999% [3].

Simply put, vertical industry services are characterized by multiple service types and high communication requirements. 5G network slicing technology can be applied to various aspects of vertical industry. For example, the slices of mobile broadband, large connection, low delay and high reliability are enhanced to meet the security, stability and flexibility requirements of vertical industry communication services, to realize differentiated service guarantee, to further improve the independent and controllable ability of enterprises for their own business, and to realize industry private network services.

However, the configuration of network slicing is nothing but complex. For scenarios need to create a new section, network slicing management system slices the SLA (such as network slicing list, PLMN list, maximum number of users, service areas, the end-to-end delay) for each domain (access network, transmission network, core network, etc.) of the SLA decomposition according to the requirements of the tenants. Then comes to the resource configuration of each domain, including bandwidth, delay and so on. For users of vertical industry network slicing, they are faced with more complicated scenarios. In the process of slicing operation, operators are unable to effectively evaluate the service quality of various businesses due to the lack of real-time monitoring experience related. Meanwhile, as the application of 5G network slice in vertical industry is still in its infancy, there is few research on the intelligentization of network slicing.

Based on the above factors and facing the vertical industry scene, an intelligent network slicing method is urgently needed. By evaluating the SLA of the network slicing, the business experience in the slicing can be monitored in real time, so as to accurately perceive the business quality experienced by users and make accurate, dynamic adjustment and error correction of the network.

This paper studies an intent-based intelligent slice to solve the problem that the network slice is not intelligent enough to effectively target specific industry scenario. An intent-based smart slicing framework is proposed to support the applications of vertical industry. The main contributions of the framework include:

1. An intent input and translation module is provided based on nature language processing algorithms to translate the users' intent to the suitable network parameters.

2. An intent instance management module is proposed to management the users' real-time intents. The intent instance is able to create, save, update and delete the records of users' intents.

3. An intent guarantee module is developed to monitor and analysis the network situation and then provide network optimization solutions by closed-loop management. It provide an autonomous network to support the guarantee of users' intents.

The rest of the paper is organized as below. Section II is the related works. Section III proposes a basic intent-based network framework based on ONAP architecture. In section IV, an intent-based smart slicing framework is proposed to support the applications in three main vertical industries and details about the applications are discussed. The research advice for further works is discussed in section V and conclusion is in section VI.

II. Related Works

In recent years, Intent-based Networks (IBN) have attracted lots of attention from academia and industry researchers. This section provides a description of previous works related to IBN. Here, we investigate three aspects: academic research, existing standards, existing open-source development and applications.

A. Academic Research

As a promising paradigm to automate administrative tasks across a network, IBN attracted researchers carried out many related researches. In paper [4], the authors surveyed existing technologies, clarify definitions, and summarize features for Intent Driven Networks. A survey investigating the recent-advances in intent-based technologies while concentrating on aspects related to network management and orchestration is proposed in paper [5]. To help achieve the goal of moving to an intent-based design, the paper [6] proposed an SDN-based network programming framework, the Open Software Defined Framework. In paper [7], the authors proposed a novel prototype that leverages source-based routing and programmable data planes using P4 in order to reduce the overheads of intent-based forwarding. Paper [8] presented the definition and a proof-of-concept implementation of an intent-based northbound interface. An Intent-based network control framework has been designed over the SDN architecture for data dissemination in the vehicular edge computing ecosystem in paper [9]. To avoid suspicious vehicles during message dissemination in IoV, paper [10] proposes the Elliptic Curve Cryptography based Ant Colony Optimization Ad hoc On-demand Distance Vector routing protocol. In paper [11], the authors presented an evaluation of the SDN network operating system Intent northbound interface using a methodology that takes into consideration the interface access method, type of Intent and number of installed Intents. To the best of our knowledge, there has been a relatively unified definition of IBN. The basic architecture and key technologies of IBN are gradually formed, and the research cases have been designed and implemented based on IBN. However, for the aspect of vertical industry and smart slicing, there is still a lack of researches.

B. Existing Standards

The standardization of IBN is also in full swing. ITU proposed scenarios and requirements of intent-based Network for network evolution and provides specification about auto-scenarios and requirements for intent based network evolution in 476-WP3 [12]. In Intent-based network management and orchestration for network slicing, ITU proposed 750-WP1 to guide the network slice deployment and management based on intent-based network [13]. IETF proposed the concept and overview and definitions of IBN, intent classification, service assurance, interconnection of intents, YANG models for VN/TE performance monitoring telemetry and scaling intent autonomics in [14-19]. For transporting of slice intent, IETF proposed [20] to explore the usage of intent technologies for requesting transport slices. 3GPP proposed TR 28.812 and TS 28.312 [21-22], mainly includes the aspects of technical specification group services and system, management and orchestration, intent driven management services for mobile networks. In IG1253 [23], TMF proposes a framework for intent-based operations implementation in autonomous networks. In IG1253C [24], TMF defines the life cycle of intent objects and the interface to manage the framework in IG1253. IG1234 introduces a method to make real-time decisions through customers' intentions [25]. In IG1161 [26], TMF provides methods and cases of intent-based resource management and service orchestration. ETSI proposed ENI-0013 discusses various design options, in terms of a set of new stand-alone and nested functional blocks, for using intent with

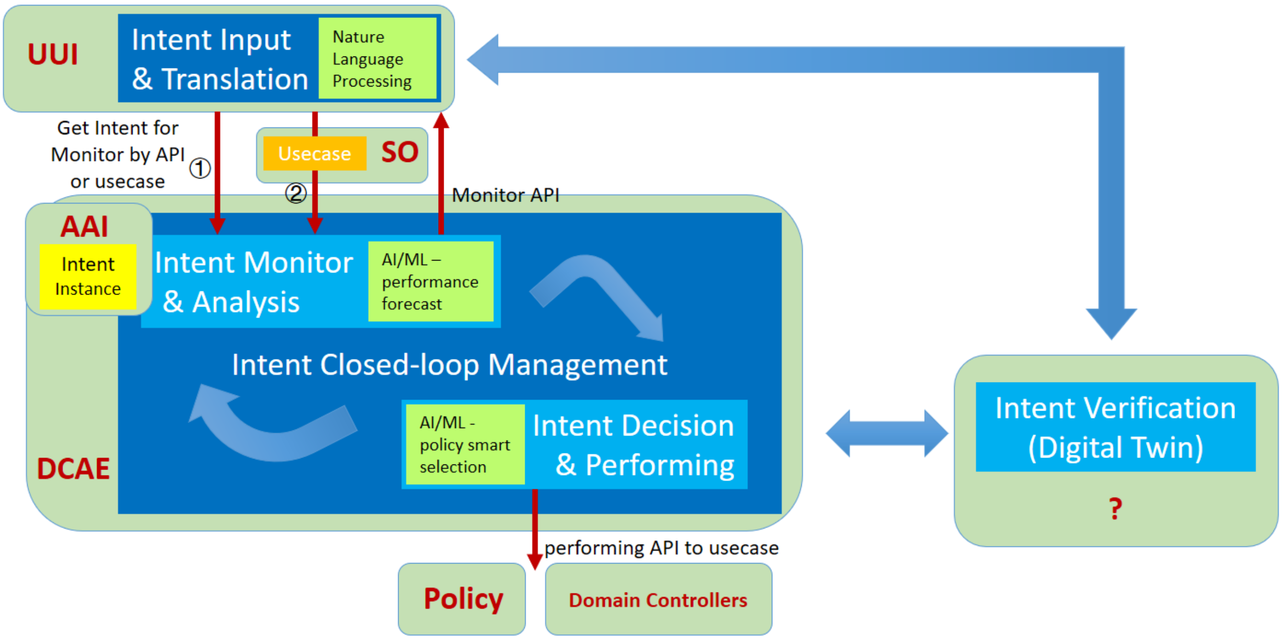

Figure 1. A Basic Framework of Intent-based Network

the experiential networked intelligence system architecture [27]. ETSI also proposed ZSM-005 to have all operational processes and tasks executed automatically by the zero-touch network and service management [28].

C. *Existing Open-source Development and Applications*

The industry has also proposed related network architectures of IBN in recent years. The open source ONOS (Open Network Operating System) [29] project provides the control plane for a software-defined network (SDN), managing network components, such as switches and links, and running software programs or modules to provide communication services to end hosts and neighboring networks. ONOS, however, has done only preliminary work on Intent-based Framework.

Different from ONOS, ONAP (Open Network Automation Platform) provides a complete intent-based network architecture. ONAP is a comprehensive platform for orchestration, management, and automation of network and edge computing services for network operators, cloud providers, and enterprises. Real-time, policy-driven orchestration and automation of physical and virtual network functions enables rapid automation of new services and complete lifecycle management critical for 5G and next-generation networks [30].

III. Intent-Based Networks Framework

The basic model of intent-based network is based on the existing components of ONAP. The current functional modules are divided into several parts, namely intent translation in Usecase User Interface, Intent Instance Management in Active & Available Inventory and Closed-loop Management in the Data Collection, Analytics, and Events Subsystem.

A. *Intent Translation in Usecase UI*

UUI provides self-service management GUI and monitor GUI for operators and end-users. This project targets identifying all GUI requirements which operators and end-users need ONAP to support, coordinating GUI parts of each ONAP subsystem, filling the gaps for improving GUI functionalities for various use cases.

The team's work in recent versions have led to the success in the UUI-based intent translation function. As shown in Figure 1, the main functions of this model include intention input and intention translation in UUI, and to achieve these functions a model trained by natural language processing algorithms is required. Intent Translation through Natural Language Processing (NLP) in Usecase User Interface (UUI). The user's input of voice or text is translated into the parameters of the corresponding network slices through the natural language processing algorithm model, and after these parameters are automatically filled, the slices are configured and sent through the end-to-end slicing process.

B. *Intent Instance Management in Active & Available Inventory (AAI)*

Active & Available Inventory (AAI) maintains a live view of services and resources in the network, providing the state and relationships of the service components. At the same time, it maintains the view of the managed systems services and resources, as well as information of the external systems that ONAP will connect to. It also provides real-time views of a managed systems resources, services and relationships with each other. AAI provides a GUI to provide users the ability to find and inspect inventory data. This includes a free-text search, inspection of specific entities and their relationships, and aggregated views of data.

Intent Instance is created to save the users' real-time intent (network parameters) and connected service ID (CCVPN service ID / E2E Slicing customer service intent ID) in AAI. The user's real-time intent is stored in AAI, providing two ways for intention storage. One is to directly send user's intent to AAI and then send it to DCAE, and the other is a use-case-oriented approach, where UUI sends the intent of user to a use case based on SO orchestration management, and then the use case sends user's intent to AAI for storage. DCAE will call the

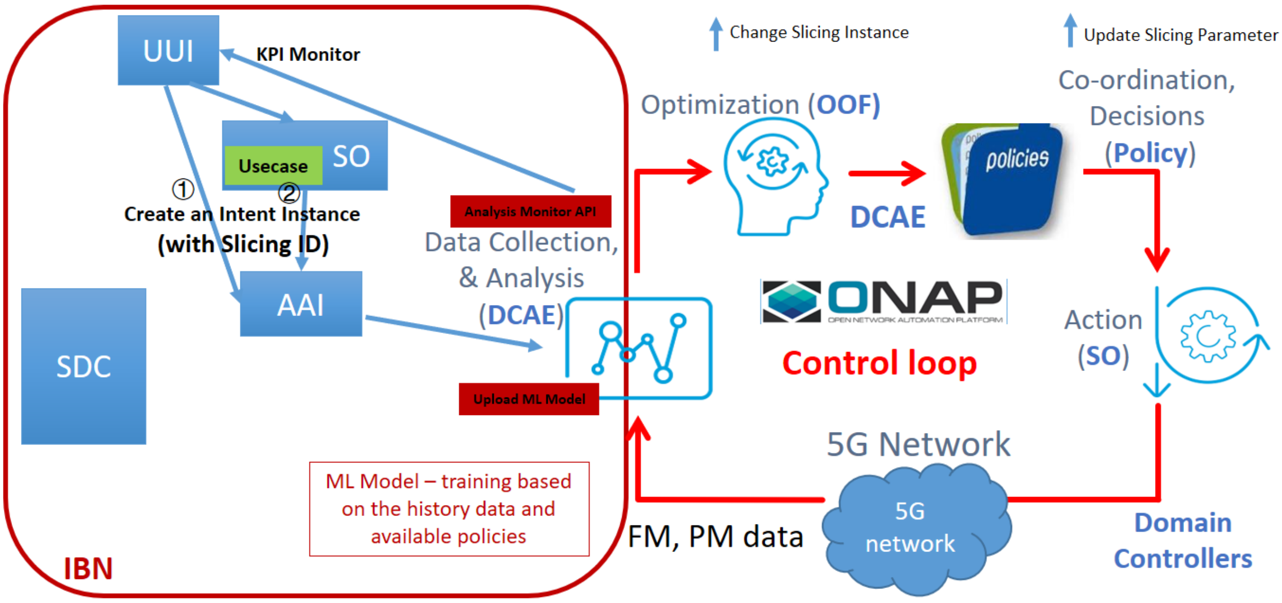

Figure 2. An Intent-based Smart Slicing Framework for Vertical Industry

intent instance later in AAI through the interface, which consists of three parts.

C. *Closed-loop Management in the Data Collection, Analytics, and Events (DCAE) Subsystem*

The Data Collection, Analytics, and Events (DCAE) subsystem, in conjunction with other ONAP components, gathers performance, usage, and configuration data from the managed environment. This data is then fed to various analytic applications, and if anomalies or significant events are detected, the results trigger appropriate actions, such as publishing to other ONAP components such as Policy, MSO, or Controllers. The primary functions of the DCAE subsystem are to collect, ingest, transform and store data as necessary for analysis as well as providing a framework for development of analytics. These functions enable closed-loop responses by various ONAP components to events or other conditions in the network.

Based on the user's intention, the function of closed-loop intention management is implemented in DCAE, which mainly includes intention monitoring and intention analysis. artificial intelligence (AI) algorithms are used to achieve the process of intent decision and intention performing respectively. The closed-loop management enables DCAE to receive the user's intent while monitoring the underlying network data. First, the user provides his user intent in UUI, then the user's intent is stored in AAI through two ways, one is through the use case in SO, and the other is directly through UUI, followed by the user intent instance bound to the service ID, so that DCAE can query the user intent stored in AAI. At the same time, DCAE can also feedback the network status to users through UUI, so that users can easily perceive the change of network status and the prediction of subsequent potential changes in a timely manner, meanwhile users can update their intent for DCAE to monitor.

D. *Further Works*

For future releases, online model training will be a key area of focus. Acumos AI is a joint platform for managing AI and machine learning (ML) applications and sharing AI models, which allows users to export instant-launched AI applications as containers to run in a public cloud or private environment. Online training of AI through this platform might be conducted for future development.

Intent verification is another focus in next releases, Digital Twin is considered a powerful tool to achieve verification of all the new service creation of the use cases, translation result verification and intent closed-loop management and verification. Feasible solutions include adding a new component on the input side, or accessing a third-party platform.

IV. INTENT-BASED SMART SLICING FRAMEWORK FOR VERTICAL INDUSTRY

In vertical industries, intent-based networking methods enable wireless networks to convert captured user business intents into wireless network configuration, operation, and maintenance policies. At the same time according to the real-time collection of network data constantly learn and adapt to the time-varying wireless network environment, which can greatly improve the flexibility and intelligence of vertical industry wireless network operation. Vertical Industry is one of the greatest potential 5G markets, too. It contains the following scenarios: a) One centralized operator ONAP only manages multiple vertical industry networks established by operators, and b) One centralized operator ONAP manages both vertical industry networks and traditional mobile networks (e.g. slicing).

The support of ONAP for vertical industry includes enhancing A&AI Schema for vertical industry tenant, including basic tenant profile as well as providing centralized user interface in UUI for different vertical industry tenants.

As shown in Figure 2, an overview of an existing closed-loop structure for end-to-end slicing is provided. To begin with, the 5G network sends FM and PM data to the DCAE subsystem to monitor the network state, and when the network state cannot meet the user's demand it can trigger the modification of the network policy configuration to achieve the modification of the slice instance, or POLICY to achieve the modification of the slice parameters. The modification request is executed through SO, and then the 5G network is controlled in the domain controller to make some modifications to the network state.

The purpose in detail is to be able to receive the user intent information we provide while DCAE monitors the underlying network data. First, the user provides his user intent in the UUI, and then the user intent is stored in the AAI component through two ways, one is through the use case in the SO, and the other is directly through UUI, and then the user intent instance is bound to the service id, so that DCAE can query the user intent stored in AAI.

As a result, the DCAE subsystem can monitor and analyze the underlying network data while also incorporating user intent for monitoring and analysis, and then achieve closed-loop control of the network based on the existing end-to-end slicing of the closed loop. At the same time, DCAE can also feedback the network status to users through UUI, so that users can easily perceive the change of network status and the prediction of subsequent potential changes in a timely manner, and users can update their intent at the same time, and DCAE can monitor the update of user intent.

The above framework and diagram is suitable for the three main applications of vertical industry below.

A. *Scene 1: Internet of Vehicles*

Internet of Vehicles requires ultra-reliable and low latency communications in a wide area. The network services both IoV and other requirements at the same time. Therefore, it may not able to satisfy all the requirements especial when the network is congestion. In order to solve this issue, the network should recognize the number and intent of IoV nodes, and then provide high priority service for IoV by updating the number of IoV slices in time.

B. *Scene 2: Smart Grid*

There are multiple types of inspections in smart grid. The suitable slicing is also different for varied intent requirements. Therefore, intent-based network is able to be applied to update the type and performance of slicing dynamically for the operation and maintenance of smart grid.

C. *Scene 3: Smart Manufacturing*

The requirements of network slicing is also varied in smart manufacturing. The required parameters are different in each slicing. Therefore, IBN is easy to select the suitable slicing instance or configuration, further supporting the requirements of smart manufacturing.

V. Research Advice

A. *Standardizations and Open-source Developments*

Currently, most of the SDOs, including 3GPP, are working on the research standardization of intent-based networks. In the future, the standardization of IBN will keep evolving to make the network more autonomous.

Open-source development is another type of international cooperation. It also plays a crucial role in the research of IBN. ONAP is a significant open-source platform in network operation area. It will keep evolving of the research and development of IBN in ONAP.

B. *Technical Gaps in Current Researches*

There are still two technical gaps in the smart networks including IBN.

1) Online AI training: Most of the current AI models are trained offline. Online AI training is a major step towards autonomous networks. Online AI training will also improve the ability of intent translation, analysis and decision for IBN.

2) Intent verification by digital twin: Digital twin is able to improve the accuracy of autonomous networks. There is no doubt that it will be used for intent verification in IBN when it is full-blown.

VI. Conclusion

In this paper, an intent-based smart slicing framework is proposed to support vertical industry applications in B5G networks. This framework is based on the architecture and key projects of ONAP. The intent input and translation module is developed in Usecase UI to translation users' intents. Intent instance is defined in AAI to manage the users' real-time intents. The intent guarantee is serviced based on the closed-loop monitoring and analysis of ONAP. This framework is developed based on an open-source platform and suitable for further standardizations and applications.

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