INCLUSION OF ARTIFICIAL INTELLIGENCE IN COMMUNICATION NETWORKS AND SERVICES

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Abstract – AI with learning abilities is a revolutionary technology which the communication industry is exploring, with the aim of introducing it into communication networks and to provide new services, and to improve network efficiency and user experience. At this time there is no total solution or complete framework to do so. One contender in the steps towards a solution is a FINE framework, which can be illustrated by the example of an SDN/NFV collaboratively- deployed network.

Keywords – Artificial intelligence, communication network, network functions virtualization (NFV), software-defined network (SDN)

1. INTRODUCTION

In recent years, with the development and maturation of such technologies as cloud computing, big data and deep learning, the industrialization of artificial intelligence (AI) has been developed accordingly. Since AlphaGo won the Go match against Lee Se-dol in 2016, AI has attracted more and more attention. AI technology has been introduced into a number of areas. As a revolutionary force, AI has been making great progress and realized many achievements in these areas.
Communications is a sector with heavy ICT use, dealing with a variety of consumer demands on individualization requirements, multimedia services and precision management, which has made network security become more and more important. With AI's advantages in learning, understanding, reasoning, and cooperating gradually being discovered, software-defined networks (SDN) and network functions virtualization (NFV) have appeared, technologies of deep packet inspection and service aware networks are almost in maturity, and the intellectualization of communication networks and services are becoming possible. Furthermore, operators have a keen interest in AI which may decrease capital expenditure (CAPEX) and operating expense (OPEX).

2. TRENDS IN COMMUNICATION NETWORKS AND SERVICES

2.1. Characterized requirements

With an increasing number of users and the growing size of the communication network, differences of preferences, habits and the information needs of enterprises and individual users are gradually exposed. The demand for specialized businesses is becoming stronger with customized networks and services now being provided for enterprise users. In the future there will be a special service package for each user, and even a special network. Such complex requirements would be unimaginable without an intellectual tool.

2.2. Multimedia services

With the arrival of the Web 2.0 era, Internet users have become information producers, as well as information consumers, and are producing more and more information in multimedia. User-generated content increases Internet traffic at an unbelievable speed. Under these circumstances, both storage and transmission are a great challenge. The inclusion of AI bolsters our abilities to handle this challenge.

2.3. Precision management

The use of smartphones makes it inevitable that the various dimensions and granularities in today's wireless traffic models should be considered in the networks.

With the development of the technologies of network function virtualization and software-defined networks, the management of the network has become more precise. Virtualization is not only at the level of network elements, but also at the level of components such as the CPU, memory, port, bandwidth, etc.
AI-based technologies allow operators to set up an on-demand networks for special users. Operators can also attain their energy-saving goals, as well as other goals with AI.

2.4. Predictable future

The expansion of business requirements and increasing numbers of users has meant that the gap between the peaks and troughs of network usage is becoming greater. In this case, operators are requested to predict the future status of networks more accurately to satisfy users' demand and improve their experience.

2.5. Intellectualization

Networks are becoming more heterogeneous. Users often use a variety of equipment with different wireless access technologies such as 2G, 3G, 4G, Wi-Fi and Internet of Things (IoT), and the adoption of 5G will reshape telecommunication networks in the near future.
The increase in network equipment and user terminals, the expansion of network size, the increase in the number of users, and the increasing complexity of the network has resulted in the network management becoming more difficult to maintain with an acceptable quality of service (QoS). As well as expanding capacity by introducing more equipment, operators are expected to raise their network performance with smart tools and intelligence technologies. This includes introducing more intelligence into networks and management to meet customer needs, make more profits, reduce operating costs, and improve network performance.

2.6. More attention to security and safety

Security incidents are growing and becoming more severe. These events have resulted in significant commercial consequences, including broken networks, economic losses, etc. AI can be introduced into several network layers to establish strong security protection and behavioral analysis based on machine learning will significantly improve the ability of network detection attacks, automatic analysis of data, and the identification of relationships between isolated behaviors.

3. ADVANTAGES OF AI

AI continues to develop rapidly. In the communications industry, whether it's network operators, equipment manufacturers or solution providers, etc., the industry hopes to take advantage of AI to assist in areas in which they are currently struggling, such as in designing, operating, maintaining and managing communication networks and services. The next few subclauses describe some of the advantages of AI.

3.1. Abilities of learning

Operators need intelligent decisions to manage complex resources and dynamic traffic. But so far no one single model has the ability to accurately describe the network traffic characteristics. Fortunately, AI has entered into the cognitive age, and deep learning can be used (confirmed by Hinton in 2006 [1]). Through deep learning, the machine system can use the existing training data to process large amounts of data through data mining. AI can also learn the characteristics of data traffic, management, controls and other characteristics automatically and master expert experience of operating, managing and maintaining networks. By these efforts, the accuracy of analysis can be enhanced, and the intelligent management and services of communication networks can be realized.

3.2. Abilities of understanding and reasoning

Due to the dynamics of the network system, the state information of a resource may have changed when it is transmitted to the network management system. Therefore, the network management can only know the local state information without the knowledge about the system internal state. Machine learning happens to have the strength to deal with this kind of fuzzy logic and uncertainty reasoning. In order to make the classification or prediction easier, deep learning constructs a multi-hidden layer model and uses the hierarchical network structure to transform the feature representation of the sample into a new feature space layer by layer. In particular, AI does not need to describe the mathematical model of the system accurately, and therefore has the ability to deal with uncertainty or even 'unknowability.

3.3. Ability of collaborating

Due to the expansion of the network both in scale and size, the structure complexity of communication networks are increasing quickly. Concepts such as distribution and hierarchy are often talked about in the network management.
Management tasks and controls are distributed to the entire network. As a result, we have to deal with issues such as tasks' distribution, communication and collaboration between management nodes. If we introduce the multi-agent collaboration of distributed AI into the network management, we can expect the ability to collaborate between network managers distributed in every layer.

4. POSSIBILITY TO USE AI IN COMMUNICATIONS

From the TDM automatic switch, it has been the pursuit of the communications industry to introduce intelligence into network operations, management and maintenance management. N. Kojic, et al. [2] suggested a neural network algorithm for the optimization of routing in communication networks. SUI Dan and JIN Xian-hua [3] suggested a network congestion control method based on AI. Sandra Sendra et al. [4] introduced AI into a routing protocol using SDN. Sahebu, K.M. [5] suggested an AI approach to planning and managing communication networks. Undoubtedly, they achieved very good results in their research. But under the condition that networks, equipment and systems must be treated as undivided management objects, their research mainly focused on the theoretical analysis and simulation to give a certain kind of solution and this could not be used in real communication networks or services.
However, SDN, NFV, network slicing and other technologies, coupled with integrated network management systems have been able to directly issue orders which can be executed by network equipment, and DPI systems can be deployed on network equipment, and it is possible to realize real-time monitoring of networks and services and intelligent management.

4.1. AI in SDN

Through the separation of control and forwarding, SDN provides network operators with a logical centralized control and flexible programming interfaces which greatly promote the capabilities of network automated management and control; more than was previously possible.

A typical SDN framework [6] is composed of three layers: infrastructure layer, control layer and application layer. The infrastructure layer includes some network elements which can provide network traffic, acting as the object controlled by the SDN controller, as well as a data source of the network resource. The control layer has the SDN controller, which is the core component of the SDN network carrying out important tasks of controlling network traffic. The application layer includes various applications. The southbound interface D-CPI (Data-Controller Plane Interface) is responsible for exchanging data between the SDN controller and the network element. The northbound interface A-CPI (Application-Controller Plane Interface) is responsible for providing the upper-level application with the channel exchange to obtain the underlying network resource information and send data to the lower-level network. SDN provides a good interface with its programmability to introduce AI into the communication networks. This is SDN's biggest advantage. SDN uses the application programming interface to send powerful programming instructions to the network device. With AI, network managers cannot only schedule an automated intelligent business orchestrator, but also program the AI-optimized network strategy and automatically compile them into the task script, then assign them into the network allocation tasks with the application programming interface (API). Network managers can also automatically collect network statistics information to lay a solid foundation for continuous network optimization. If necessary, some new functionalities can also be added intelligently through the SDN application for the network environment.

4.2. AI in NFV

With virtualization technology, network functions virtualization (NFV) [7] can divide network-level functions and applications, such as routing, customer premises equipment (CPE), mobile core, IP multimedia subsystems (IMS), content delivery networks (CDN), switching elements, mobile network nodes, home routing operations, set-top box business, tunnel gateway elements, traffic analysis, service assurance, service level agreement (SLA) monitoring, testing and diagnosis, next generation network (NGN) signal, aggregation and network range functions, application optimization, security policy, etc., into several functional blocks, and run them in software mode respectively. This means that they are no longer limited to the hardware architecture.

The typical NFV reference architecture includes three layers of the complete infrastructure layer, the resource management layer, and the business flow orchestrator layer. NFV helps ISV and telecommunication operators to achieve virtual network functions by deploying hypervisor at the infrastructure layer to virtualize infrastructure resources such as commercial general computing, storage and network resources and others. The resource management layer is in charge of the NFV infrastructure's management, configuration and collaboration. The business flow orchestrator layer is a key part of the NFV network function for network operating; it is used to organize and orchestrate the functions of the NFV network. It is also in charge of managing and monitoring the global resources across the data center or the resource pool.
With the virtualization of network functions NFV can realize an on-demand dynamic network configuration separated from the underlying architecture. As key issues have been solved, AI can play its full role in critical network management.

4.3. Network monitor and control

To master the real-time information of the communication network, the network must have the function of initiative uploading. Currently there are many DPI systems. With inspectors, the deep packet inspection (DPI) [8] system can collect the information such as the running state of network equipment, the usage of resources and the quality of services.
With the big data obtained from the DPI system, the AI system can rapidly analyse and find if there are or will be abnormity within the information. For example, if the AI system finds a burst a continuous traffic, it can doubt a distributed denial of service (DDoS) attack in the network and analyse the package characteristics immediately, then orchestrate an inspector collaboration task to drop all packages with the characteristics to avoid the damage. It could write a new record in the security database in case of the appearance of unknown hack attacks or new virus flooding.

5. AN AI-BASED NETWORK FRAMEWORK

On the basis of the above analysis and Xu's work [9] the establishment of an intelligent communication network, called future intelligent network (FINE) can be considered in the near future. The system architecture of FINE is shown in Fig. 1.

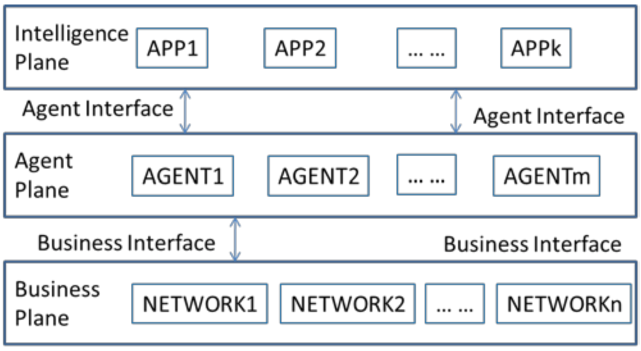

Fig.1. A system architecture of FINE

5.1. Intelligence plane

The intelligence plane, see Fig. 2, is in charge of providing intelligence for the entire FINE, and it acts as the brain of the FINE system. Therefore, FINE is an intelligent network with an AI core. The intelligence plane can be composed of the basic layer, the core layer, the platform layer, the application and terminal layer and the scheme layer.

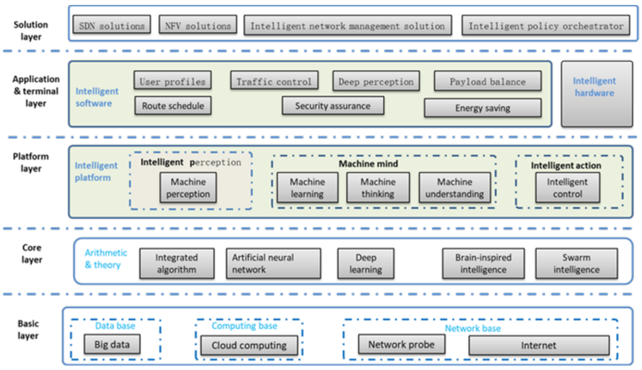

Fig. 2. The intelligence plane

The base layer provides support in data, calculation and the network for the intelligent plane. The data here is big data, not only including static data such as expert knowledge data, network infrastructure data, user profile data and others, but also including dynamic original data collected by the network probes from the business layer, such as status data of various types of equipment, applications and services.
The core layer is the provider of intelligent algorithms in the intelligent plane, such as integrated algorithms, an artificial neural network, depth learning, brain-inspired intelligence and swarm intelligence. It is the kernel of the FINE core.
The platform layer provides intelligent planes for the realization of the intelligent logic of AI ability and behavior, such as intelligent perception, machine mind, intelligent action etc. The intelligent

perception function can make use of theories and algorithms of the core layer, and deal with the big data of the basic layer supported by the computing resources, so as to perceive the development trends of networks and services. The machine mind function includes machine learning, machine thinking, machine understanding, etc. The machine learning consists of machine learning abilities generated by algorithms such as deep learning, brain-inspired intelligence and swarm intelligence. The machine thinking function provides the ability of knowledge mapping and knowledge reasoning. The machine understanding function provides the abilities of understanding based on the existing knowledge and the phenomenon, solving the ambiguity problem in reasoning, etc.

The application and terminal layer provides abilities of modular realization of functions needed by the solution layer. The functions here may include the user portrait, the flow control, the load balancing, the depth perception, the routing, the security, the energy saving, etc. These realizations may be in software or hardware using the abilities of perception, thinking and action provided by the platform layer.

The solution layer is in charge of designing flexible policies and related activities related to satisfy the requirements to operate or manage the network, the network element, the network management system, etc.

5.2. Agent plane

The agent plane consists of a series of agents with characteristics such as autonomy, sociality, responsiveness, initiative, rationality, learning and adaptability, reasoning ability etc. An agent is usually composed of a user interface module, a learning module, a task technology module, an operating system interface module, an execution module, a knowledge base and a central control module. Among them, the central control module is the core of the agent and it controls all other modules. These agents independently play their roles of communicators. It sends the information obtained from network probes to the data module of the intelligence plane, and sends intelligent control instructions from the intelligence plane to the business plane. At the same time, these agents can also communicate with each other and form several linkages for cooperative operation.

The technology of intelligent agents has been deeply researched and widely applied since J. Holland put it forward in 1995 .[10] . Therefore, there are no further details to describe it here.

5.3. Business plane

The business plane, see Fig. 3, mainly includes networks, services, systems intelligently serving the network manager and the end user. It is in charge of executing services orchestrated by the intelligence plane with its components such as the communication network and its operation support system, service support system, etc. Every component in this plane is accompanied by a DPI probe.

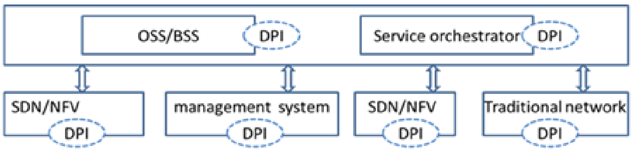

Fig. 3. The business plane

The DPI probe is the sensor and the executor of FINE. Firstly, it perceives the status of its accompanying object. It collects any useful information of its accompanying object, and sends the information to the AI plane through the agent. Secondly, it executes instructions from the intelligence plane and necessary actions reasoned by itself.

Service components include management systems, communication networks, user service systems and infrastructures, etc. Management systems serving the manager could include OSS, BSS, NMS, EMS, etc. Communication networks could include SDNs/NFVs, traditional networks, etc. User service systems include cloud computing, mobile Internet, data communications, 5G, etc. Infrastructures include data centers, equipment, etc.

6. A FINE EXAMPLE

Figure 4 shows an SDN/NFV collaboratively-deployed network. Nodes in this network may be real network elements or virtual ones.

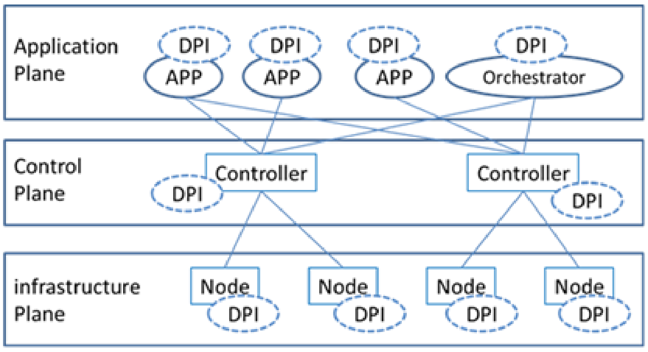

Fig. 4. An SDN/NFV collaboratively-deployed network

To include AI into this network, we can deploy DPIs for every component in it. All the information collected by DPIs will be sent to the big data module in the basic layer of the intelligence plane. The intelligent perception module mines the data to find the characteristics of the changed data. Then the Machine mind module actions a ‘reasoning and understanding’ supported by algorithms at the core layer and the intelligent policy orchestrator module at the solution layer, and gives its judgment. After that, the intelligent control module makes a decision and provides instructions to the control plane through the agent plane. When controllers at the control plane receive instructions sent to them, they carry them out at related nodes.

7. CONCLUSION

In this paper, we highlighted an AI-based network framework, FINE, to give a total solution to introducing AI in communication networks and services. This was then illustrated with an SDN/NFV collaboratively-deployed network.
It has been proven that the FINE framework is feasible to be used in real communication networks and services. Not only that, we can depend on this framework to set up a standard system for AI-based communication networks and services by defining detailed functions of nodes, layers, planes, related interfaces, etc. And finally, questions around privacy and security should be considered.

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