Evaluaion of assurance closed loop PoC for achieving scheduled maintenance in telecommunication carrier networks

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***Abstract*— As an issue for operating and managing virtual network in telecommunication carrier networks, "multi-slice management technology" have been reported, and implementing method of autonomous control loop (closed loop) for virtual network is one of the key topic of it. This article focuses on the reduction of unexpected failures in large scale network, which is one of the major issues in network maintenance and assurance operation. This article proposes a method and an implementation of autonomous control loop (closed loop) that combines Network-AI, NFV orchestrator, virtual network, and cloud technologies. The benefits of the proposed method and the results of the implementation evaluation, including feasibility evaluation result of scheduled maintenance are also explained and reported in this article.**

Keywords*— *NFV, MANO, SDN, orchestrator, autonomous control loop, closed loop, assurance, scheduled maintenance, operating system, SLA

I. Introduction

The technology of network virtualization has been evolving through the research, development and standardization of SDN (Software Defined Networking) and NFV (Network Functions Virtualization), and also the diffusion of SDN/NFV related OSS (Open Source Software). However, in order to get these benefits, it is necessary to appropriately control the virtualized network. NFV ISG (NFV Industry Specification Group) in TMF (Tele Management Forum) and ETSI (European Telecommunications Standards Institute) discusses and standardizes maintenance and operation aspects of virtual network (NFV MANO), and network virtualization technology has been refined with the increase in showcases and deployment in real networks. These changes and progress in network virtualization technology suggests that it may be ready to apply network virtualization technology to telecommunication carrier networks.

A. NFV MANO Architecture

The NFV architecture defined by ETSI consists of VNF (Virtual Network Functions), NFVI (Network Function Virtualization Infrastructure) and NFV MANO (N FV Management and Network Orchestration) [1]. NFV MANO is an orchestration architecture that manages NFV operations. NFV MANO consists of the following 3 functional blocks.

- NFVO (NFV Orchestrator)
- VNFM (VNF Manager(s))
- VIM (Virtual Infrastructure Manager(s))

NFV MANO specifies the interface between each functional block and the interface (Os-Ma) for cooperating with outer OpS/BSS (Operation Support System / Business Support System) of conventional network.

B. Autonomous control loop (closed loop) in network operation

The basic operation flow in network maintenance involves (1) collecting data from the network, (2) analyzing the collected data, and determining the action to be taken (decision making), and (3) executing control procedure depending on the equipment. The operation flow in which the network is optimized by following to this sequence is called the autonomous control loop (closed loop) in this article.

C. Current issues in assurance of telecommunication network

In order to reduce OPEX, it is necessary to accomplish autonomous control loop that is useful in actual maintenance (assurance) operations.

Although systematization is progressing in the assurance operation of telecommunication carrier networks, there still remain operations requiring decision making by human. One example is in the task of recovering from a network device failure. An experienced maintenance operator first notices the alarm from the failing network device and decides whether to take action, and what to do based on their own experience, knowledge and skill. The operator then operates OpS to control the network. In parallel, onsite workers hurry to the site of the fault to repair and replace the faulty network equipment. In telecommunication carrier, network operators monitor network 24 hours a day, 365 days a year so as to be able to take emergency response whenever a failure occurs. In addition, the OPEX required to maintain this kind of operation team at night and on weekends is higher than that of weekday daytime. It is clear that the total cost of maintaining the team is high, but at present it is the cost necessary to provide highly reliable network services.

For virtual network management of communication networks, the authors have reported an issue for managing virtual network; "multi-site management technology" [2]. From this the authors has been focusing and working on autonomous control loop for virtual network. This article proposes a method for implementing autonomous control loop that combines the established Network-AI technology, NFV orchestrator, virtual network, and cloud technologies, and evaluate the benefits of the proposed method and the feasibility of scheduled maintenance.

II. Approach to Reduce OPEX

In order to reduce OPEX, it is effective to reduce the number of sudden failures and to reduce the number of failures at night and weekends, which are expensive. For this purpose, it is ideal that maintenance operations should be automated, and on-site maintenance work should be carried out as a schedules maintenance on daytime, in weekdays. In this paper, the word “scheduled maintenance” is defined as a method of operation that eliminates immediate and sudden response of human operator, and carry out assurance work in daytime on weekdays[3].

Telecommunication carrier owns large scale network consisting of tens of thousands to hundreds of thousands of network devices, thus device failures occur every day. In a network that network service application and network device are tightly combined, or fixed, immediate response, including on site work, to device failures is necessary because multiple failures may occur even if the network / server is redundant.

In order to achieve scheduled maintenance in telecommunication carrier, the problem is to establish autonomous control loop (closed loop) that automatically ensures and maintains redundancy of network services which do not require operators to respond at all. In the case of virtual network using SDN/N FV technology, redundancy of network service can be ensured and recovered, by transferring VNF to another functioning server in network infrastructure (resource pool), and switching the network to the new VNF. It is not necessary to restore the failed network equipment immediately, and recovery procedure of the failed network equipment can be arranged to be held in next weekday daytime. The idea in this paper is that if the automatic control of VNF (for ensuring redundancy of network services) are accomplished, the scheduled maintenance can be achieved. In virtual network, investment to network infrastructure is necessary to arrange enough resource pool, and this means temporary increase in CAPEX, but continuous OPEX reduction by continuous reduce of maintenance work will finally exceed the increase in CAPEX.

III. Proposing Autonomous Control Loop Method

In this chapter, the authors propose a method for implementing an autonomous control loop for achieving scheduled maintenance.

A. *Features of the proposed method*

The proposed autonomous control loop architecture is shown in Fig. 4. Virtual network operation/orchestration architecture have been published by ETSI NFV MANO, TMF ZOOM (Zero-touch Orchestration, Operations and Management), and ONAP (Open Network Automation Platform), our proposed implementation refer to those architectures, adding new features for implementing autonomous control closed loops while exploiting NFV MANO, which its standardization is advanced. The data flow of the autonomous control loop is divided into 3 fields: "associating and storing network data", "analysis and decision making" and "network service control", and systematization of each field is attempted. Considering the progress of AI (Artificial Intelligence) and its deployment to network, the use of network artificial intelligence is an effective method of automating operations involving decision making of maintenance workers. To integrate network artificial intelligence into autonomous control closed loop, which enables analysis and decision making from a panoramic view of network based on diverse data collection and collected data, this paper proposed to implement "associating and storing network data", and "analysis and decision making" mechanisms outside NFVO. The features of each functional part are described by following.

1) Network data collection and management (associating and storing network data)

The network data collection and management component collects data from network and manages them in association with the resource for each network layer. The data collected from network includes information on alarm, basic information about equipment, resource information such as topology information, bandwidth information and traffic (usage) status, and network quality information such as delay in network, and jitter. Collected network data, VNF catalogue data, and VNF data are systematically managed in association with the physical resources of each network layer.

2) Network aritificial intelligence (analysis and decision making)

The network artificial intelligence component gets input of the collected data, and applies the network artificial intelligence to data analysis and decision making operations previously performed by maintenance workers based on their personal experience and skill. Decision making (calculation) by network artificial intelligence is automatically and objectively evaluated based on the given network topology. Different products of network artificial intelligence are expected to be integrated depending on the type of application, and business area / work to be automated. For example, different network artificial intelligence can be used for early failure detection, VNF optimal location analysis, and so on. Network artificial intelligence also has a function (Service order generator) to convert network artificial intelligence output (calculation results) into NFV MANO formatted control sequence (service order).

3) NFV MANO Extension (network service control)

NFV MANO extension component enables the control of VNF and network, based on network artificial intelligence decision (calculation result), with cooperation of NFV MANO. Even though network and VNF are controlled by

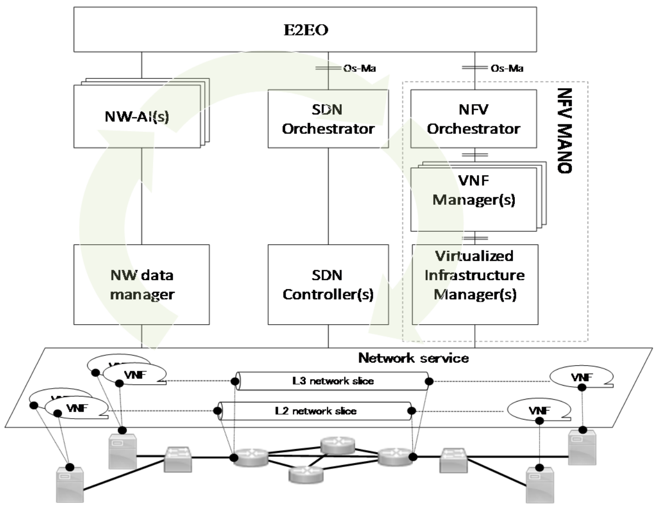

Fig.4. autonomous control closed loop realization method

independent mechanism in NFV MANO, for providing network service, network (C/U plane) VNF should be controlled together. To provide cooperative “network control” and "VNF control," in order to provide network service, this paper proposes to place E2EO above SDNO and NFVO. E2EO controls network and VNF by cooperating SDNO and NFVO, based on VNF catalogue information and service order (control sequence) received from network artificial intelligence via Se-Ma interface defined in NFV MANO. After completing controlling network service, E2EO gives feedback of network service control sequence executed to the network data collection and management component, via Os-Ma interface defined in NFV MANO.

IV. Implementation

In this chapter, the implementation of proposed method is explained, and the implementation issues and other issues that are found during implementation are described.

A. Exploitng OSS and other available technologies

In implementing the proposed autonomous control closed loop shown in Fig. 4, exploiting OSS is the basic method chosen. However, only a part of the proposed architecture is applicable to available OSS, so additional implementation was done as shown in (Table 1).

B. Implementation challenges for fulfilling IFA standard

IFA requires that the VNF catalogue called NSD (Network Service Descriptor) which describes the configuration requirements of network services to be ready in advance at the time of constructing network service. The NSD contains the configuration requirements for the VNF, VL (Virtual Link), the connection port information for the physical network device and other information necessary to construct network service. It is also possible to define a set of information (NsDf: Network Service Deployment Flavour) that defines the NF (Network Function) itself and its deployment conditions which consists network service and belongs to NSD. By selecting appropriate NsDf, it is possible to generate or modify network service depending on the situation. Initially, network artificial intelligence was responsible to choose NsDf to enable automatic network service generation, but it was not successful since all possible configuration pattern (flavour) needs to be defined beforehand in NSD, making it difficult to choose NsDf depending on the calculation result of network artificial intelligence. This issue was solved by limiting PoC use case and network topology, so that defining flavours can be possible, since the flavour chosen by the network artificial intelligence can be estimated from possible results of calculation. Automatic generation of network service, even though it is a temporary implementation, was achieved as a result.

Table 1 Implementation status

Function	Implementation	Remarks
NFV MANO		
NFVO	In-house	Compliant with IFA specifications
VNFM	In-house	Compliant with IFA specifications
VIM	OSS	OpenStack(Ocata)
NFV MANO Extension		
E2EO	In-house	Compliant with IFA specifications
SDNO	In-house	Compliant with IFA specifications
SDN controller	OSS	MSF controller
NW-AI		
NW-AI	In-house	Optimal arrangement AI
Service order generator	In-house	
NW data manager		
Data collector	In-house	
Data manager	In-house	NW data manager

Generating NFV MANO format service order was also an issue. In proposed architecture, the service order generation component generates NFV MANO format service order using the calculation result of the network artificial intelligence. However, the IFA standard lacks some input attributes that are necessary for generating service order. For example, although "address" attribute is specified in the network service generation order, there are no regulation for VLAN ID, IP address, DNS server name, etc., which are assumed to be specified in "address". The automatic generation of the NFV MANO format service order was implemented by inferring IFA non-specified items from IFA specification in a similar manner.

V. Evaluation

In this chapter, the PoC (demonstration experiment) of the proposed method and the results of feasibility evaluation of scheduled maintenance are described.

A. PoC

The flow of the autonomous control closed loop that starts when a network service failure is detected is shown below. It is assumed that the network service before the failure occurred has already been generated.

1) Emulate physical server failure (update network data collection and management component), and invoke network artificial intelligence

2) The network artificial intelligence obtains and analyzes the topology information from the network data collection and management component, and passes the VNF placement calculation result to the service order generation component

3) The service order generation componet converts and generates NFV MANO format service order, and requests E2EO for network service control

4) E2EO resolves the NFV MANO format service order and requests various controls to NFVO and SDNO

5) The VNFs are placed as in the calculation results of network artificial intelligence and the network service is restored

In this PoC, the procedure number 1 is operated by hand, and check whether procedure 2 to 5 are carried out automatically.

B. Result and evaluation

The evaluation is done by comparing the business area that can be automated using the proposed architecture, and that is shown in Table 2.

In this use case (autonomous recovery of network service by auto healing and replacing VNF), the autonomous control closed loop successfully automated as expected. However, the network artificial intelligence used in this PoC outputs

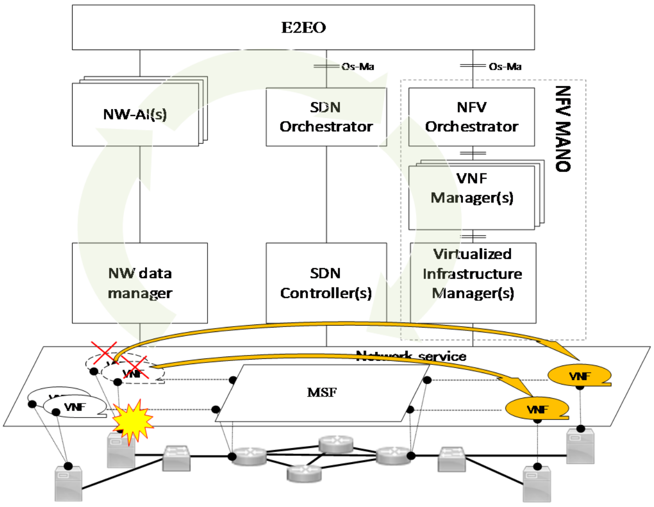

Fig.5. Demonstration experiment procedure flow

optimized VNF placement, and in order to achieve the optimal VNF configuration in a given network topology, it requires human interpretation of the control procedure.

In this PoC, auto healing of VNF was done by deleting the existing network service and constructing a new network service, as the way to achieve the optimal VNF configuration. Applying to actual network maintenance, it is necessary to minimize the effect of control procedure during recovery and optimization procedure. This may require change in service order. In addition, when the network artificial intelligence calculates the optimum arrangement of VNF and optimized network topology, it requires the optimization strategy (i.e. server load equalizing, maximizing performance, etc.) and somebody has to decide and supply those depending on network situation. When, who, and how to make decision and supply the strategy remains as an issue.

Next, network service control was also automated from the generation of a service order to the completion of control execution. In some cases, however, the network service could not continue unless the data held in the old VNF had been transferred to the new VNF, after the network service is reconstructed. In this implementation, VNF data transfer was

Table 2 Scope of automation

Operation item	Automation	As Is
NW data collect & management		
NW data collection	○	○
Topology management	○	○
Logical correspondence	○	-
NW resource management	○	manual
NW usage management	○	manual
Failure detection	▲	▲
Analysis & making decision		
Optimum arrangement of VNF	○	manual
(Suggestion of coping procedure)	（manual）	(manual)
NW service control		
Service order generation	○	-
NW control execution	○	manual
VNF catalogue selection	▲	-
VNF data migration	manual	-
Health check of service provision	manual	manual

not included, but in such a case, additional features are required. In addition, confirming the availability of VNF control is a part of the implementation of network service control, though the process running status inside VNF and checking whether the network service is being provided normally, are excluded from the scope of automation in this article and requires further study.

More issues arise considering autonomous control closed loop. In this PoC, the starting point of the autonomous control closed loop was simulated, making assumption that the network failure could always be detected and the suspected location of the failure could always be identified. However, it is not always possible in real network, since detecting alarm does not mean identifying malfunctioning part in the network. In virtual network, it is necessary to automatically detect and respond to service level agreement (Service Level Agreement) violations, along with physical device failure and VNF failure.

VI. CONCLUSION

This article proposed a method for implementing an autonomous control closed loop using network artificial intelligence and ETSI MANO, and conducted experiments (PoC) to evaluate the proposed method and the feasibility of the scheduled maintenance. In addition, in the feasibility evaluation of scheduled maintenance, the closed loop was compared with conventional work flow and identified tasks that are important for deploying autonomous control closed loop to actual network and for achieving scheduled maintenance.

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