# Construction of SDN Network Management Model Based on Virtual Technology Application

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**Abstract.** This paper designs a virtual SDN network management model constrained by fair and equal network management information access mechanisms by analyzing the problems existing in the universality of existing SDN network management models. Starting with the three-tier structure of the SDN network management system, the main parameters involved in the network management service function, information processing and transmission channel construction in the system were strictly and normatively defined. The design of virtual nodes is regarded as the core element of the network management system, and the information transmission inside it adopts logical operation; The network management service function and the channel for realizing the network management service function are isolated, and the iterative search, analysis and update mechanism is enabled in the network management information transmission channel. By constructing the experimental verification platform and setting the evaluation parameters of the system performance objectives, the scalability and timeliness of the model were evaluated from two aspects: the deployment of network virtual nodes and the dynamic control of network management information channels. The collected experimental core evaluation parameters, the realization time of the network management service function, can show that the dynamic distribution mechanism of network management information can be cross-applied to each virtual node, and the channel update mechanism of network management information can adjust the information processing queue in real-time. The network management system model that has been built realizes the separation of management and control of the network management system and has the characteristics of independent operation, autonomous function, self-matching, rapid deployment and dynamic expansion.

**Keywords:** Network function virtualization · OpenFlow communication protocol · Virtual node of a network · Channel iterative update · Separation of network management and control

## 1 Introduction

Because of the current heterogeneous network environment, building an SDN-based network management model by applying the above research results does not have strong


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universality [1–7]. The main reasons are: the research and application of computer network technology are developing rapidly, new networking technologies are emerging one after another, the research and application of network management technologies supporting it are given priority, and faults in the technical application are inevitable results, which is also a common phenomenon in heterogeneous network systems; The main body of research and development and practical application of network management technology is numerous network technology developers, and developers are used to modelling network management system based on their own rules and products, and there will inevitably be deviations in the implementation of unified modelling standards. Based on this main factor, according to the Network Functions Virtualization (NFV) standard put forward by ETSI Standardization Organization, this paper firstly determines the three-tier structure of network management, namely, user layer, service layer and device layer, and realizes the virtualization of network management functions and resources in the three-tier structure, and then designs the virtual network management node structure. Applying the virtual network dynamic management and control mechanism, introducing the concept of fair and equal network management to control information access, a general SDN network management model is constructed, and its performance is evaluated.

## 2 The Construction of Virtual Network Management Framework

### 2.1 Application Layer Construction

Constructing a decentralized and distributed network management system can realize the high integration of network management information transmission, control and management. Among the three elements of the application layer, the network communication lines can be extended to the Internet system, and the network operation management service and network security management service can be extended to the cloud management platform. Figure 1 shows the component set and information transmission process of the application layer of virtualized network management services.

According to the structure diagram of the application layer and the diagram of information transmission process shown in Fig. 1, to build the application layer of network management service based on OpenFlow communication mechanism, firstly, it is necessary to define the system configuration service (Network Management Services1, Abbreviated as NMS1), system control service (NMS2), system performance detection service (NMS3), information flow collection service (NMS4), information flow control service (NMS5), safety detection service (NMS6), fault alarm service (NMS7), data detection service (NMS8) and data analysis service (NMS9). Then, these nine service types are identified and their attributes are marked, and the service functions of NMS1–NMS9 are identified by P1–P9, and their service function attributes can be defined by themselves according to certain programming rules (not listed here). Then, according to all the element sets of the application layer, all the service functions provided by this set are defined, which is called Virtual Network Function Element Collection, abbreviated as VNFEC. Finally, the specific service contents of all the element sets are defined, The main element sets of will be all service function subsets (define this subset as S), attribute subsets of all service functions (define this subset as F), input parameter subsets between service functions and service function attributes (define this subset as I), output parameter subsets between service functions and service function attributes (define this subset as O), The time subset of network management service function realization (this subset is defined as T), the subset of information exchange channel established between every two network management service functions (this subset is defined as L), and the subset of information exchange channel connection state (that is, the channel can be started) (this subset is defined as Q) are composed of six subsets, of which seven subsets are S, F, I, O, T, L and Q. Figure 3 shows the information exchange process of an application layer network function element set to complete a network management event.

$$VNFEC = [S; F; I; O; T; L; Q] \quad (1)$$

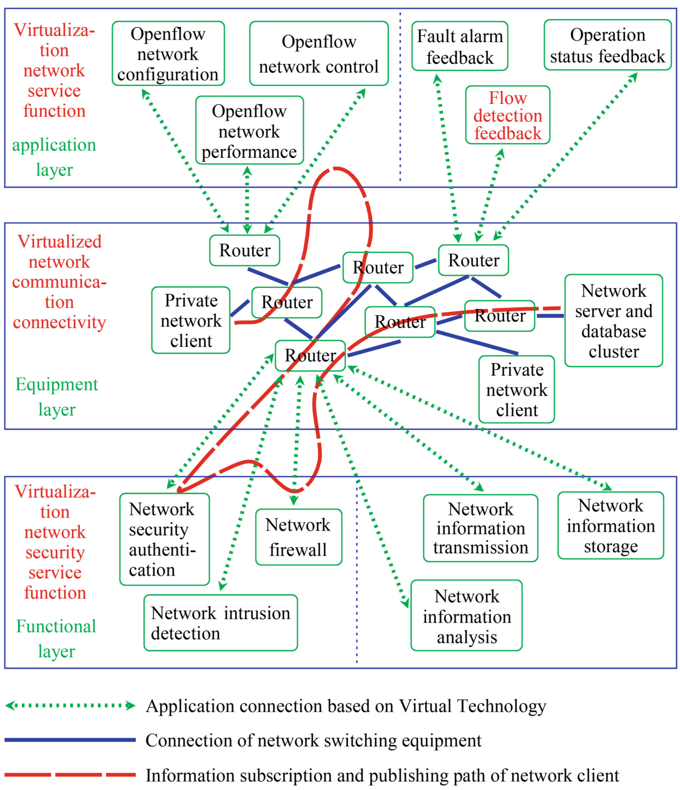


**Fig. 1.** Composition structure diagram of virtualization network management service application layer.

## 2.2 Functional Layer Construction

The functional layer construction of virtualized network management system mainly solves two problems: one is to provide network management service functions, and the other is to provide network management service channels. To construct a functional layer, it is necessary to define three-element sets of service function, service channel and the connection state of channel respectively. The formation of the three-element sets mainly depends on the determination of various parameters.

In Formula 1, the set of service function elements is defined as S, and the network management service function identifier is defined as: $(S \rightarrow S_p \in (S_{p+1} \sim S_{p+n}))$; The period for realizing network management service functions can be defined as T, and the time for completing one or more network management service functions can be defined as: $(T \rightarrow T_p \in (T_{p+1} \sim T_{p+n}))$; the collection of software and hardware resources managed by the network management service function can be defined as $(R \rightarrow R_p \in (R_{p+1} \sim R_{p+n}))$. In the whole $S_p$, $T_p$ and $R_p$, and one-to-one relationship, the processing process is a single channel, and when multiple events occur simultaneously, you can selectively choose the processing process to build the channel according to the need. when multiple events occur, each event is shared in $T_p$, and, due to the one-to-one correspondence for $T_p$, $S_p$ and $R_p$, the $S_p$ identification and $R_p$ resources occupied by each event processing are shared. The benefit of this is to discard the complexity of multi-parameter definition through design running time limit, time interval, time cyCle adopted in many systems, reduce the parameters of the system when programming, and ensure that the hierarchy of the system is clear.

According to the above analysis, the service function set S can be defined by formula (2), where,$S_p$, T and R must be described by vectors.

$$S = [S_p \in (S_{p+1} \sim S_{p+n}); \mathrm{T}(T_p \in (T_{p+1} \sim T_{p+n})); \mathrm{R}(R_p \in (R_{p+1} \sim R_{p+n}))] \tag{2}$$

Formula (3) is the definition of the service channel element set L, among them, $S_{p+i}$ for the output identification after the completion of the previous service function, $S_{p+j}$ is the received input identification for the latter service function, $O(S_{p+i})$ is the corresponding attribute for the output identification, and $I(S_{p+j})$ is the corresponding attribute for the input identification. The attribute here represents the data information processed by the corresponding service function. Formula (4) is the definition of the input and output data information D, where E is the collection of network management events, F is the collection of network service function attributes, and k is the definition rules for the VNFEC set of all service functions of the virtual network management system. The parameters in the above formula are all vector representations.

$$L \in (S_{p+i}, S_{p+j}), L_F = O(S_{p+i}) \cap I(S_{p+j}) \tag{3}$$

$$D = [E; F; k; L_F] \tag{4}$$

Only when the service channel is opened can all kinds of service functions play a role in sequence. In formula (1), the channel connection state element set is defined as Q(a dynamic collection). $Q_0$ for the initial channel connection state, $Q_e$ and $Q_{e-1}$ is the channel connection state for the first and previous event, then $Q_e$ can be defined as:

$$Q_e = G * (Q_{e-1}) + H * G(s \times s) \tag{5}$$

In formula (5), G represents a vector matrix consisting of the number of all service channels and the number of all service functions in the designed functional layer; H represents a vector matrix consisting of the number of actually needed service channels (1) and the number of actually needed service functions (s) in the event; the vector $G(s \times s)$ represents the matrix of $s \times s$ dimension.

Whether the service channel is on or off can be defined by $G(i, j)$ definition, which $L(i, j)$ represents the connection state of the previous service function with the subsequent service function, $G(L(i, j))$ describes a certain connection, and the connection state $L(i, j)$ is represented by the vector-matrix, with only two values: either connected or disconnected.

### 2.3 Equipment Layer Construction

In Fig. 1, the devices in the device layer are mainly divided into two categories: network switching devices and network analysis and operation devices. These two types of devices will be virtually applied in the network management system, so they need to be described abstractly. Therefore, these devices first need to be defined by multi-angle configuration parameters like the set elements in the application layer and the functional layer. Then define the resource allocation mechanism for service functions and the resource allocation mechanism for service channels.

The number of functional processes that devices can accept can be defined as C. The entire content of network management resources can be completely defined by formula (6), in which c is the mapping function of t (the time of network management service function realization) and r (the network management resource set), which can be expressed by (c: T → R), and the constituent elements in T and R sets have been defined in the previous functional layer construction. It should be noted that the specific information of these devices, such as the model, function and performance of the devices, should not be defined here.

$$R = [R_p \in (R_{p+1} \sim R_{p+n}); \mathrm{c}(c_p \in (c_{p+1} \sim c_{p+n}))] \tag{6}$$

The resource allocation of service channels also needs to be defined by constructing element sets. Its main components include four-element sets: service function set S, service channel set L, priority of service function operation X and allocation process function Y of network management resources. If the service channel resource allocation set is defined as V, then formula (7) can describe the network resource requirements.

$$V = [S; L; x; y] \tag{7}$$

## 3 Application of Fair Peer-to-Peer Access Mechanism

### 3.1 Design Fair Peer-to-Peer Access Mechanism

The application of peer-to-peer information access mechanisms in network management and control is the basis of a dynamic combination of network management service functions. The key part of fair and peer-to-peer information access mechanism application lies in the virtual network management node in the network management service channel. That is to say, the key to the application of a fair and equal information access mechanism is to design virtual network management nodes, and to realize the interconnection between virtual network service nodes in a fair and equal way is the main goal.

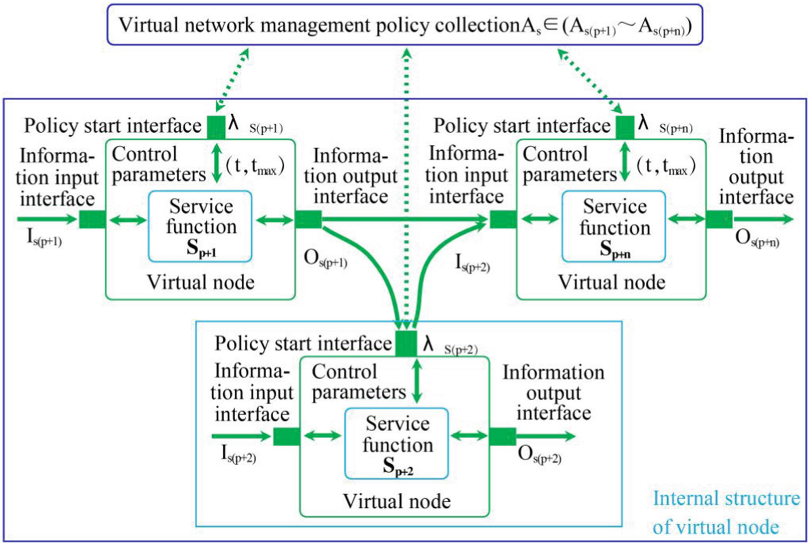


**Fig. 2.** Network management service virtual channel structure diagram.

To design a virtual network management node, firstly, the functional attributes of network management services need to be uniformly encapsulated. The premise that the functional attributes of network management services can be encapsulated is that it is a kind of data information. Under the platform of big data and cloud computing, the best way to uniformly encapsulate information is to express information in the form of granularity, and Granular Computing (GRC) must be carried out before information encapsulation [8].

The application of granularity and the definition of data I/O interface are the key strategies for the construction of virtual network management nodes and the connection of virtual network management nodes. Figure 2 shows the virtual channel structure diagram of network management service based on a fair peer-to-peer access mechanism and the internal structure diagram of a single virtual node.

### 3.2 The Internal Structure Design of Virtual Nodes

In the internal structure of the virtual node, the information flow representation and the operation process of input and output all adopt logical operation mode, which is completely different from the coding operation mode commonly used in other software

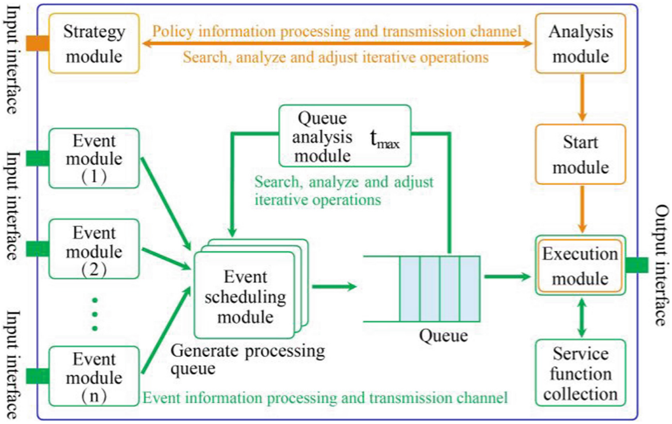


**Fig. 3.** Diagram of the process of dynamic device connection and information processing and transmission by virtual nodes.

system designs. The realization of its network management service function is mainly based on the unified planning operation strategy, which is the key operation organizer of the network management service function operation strategy. Running policies are planned for different service functions, connection modes between virtual nodes, descriptions of input and output information, etc. They are also a set, which can be expressed by using $A_s$, and a collection of running policies for a service feature can be defined as $A_s = [A_{sp} \in (A_{s(p+1)} \sim A_{s(p+n)})]$.

The input and output flow of network management information flow in a virtual node mainly consists composed of four elements, single operation policy $A_{sp}$, the information transmission channel $L_{sp}$, policy execution part and network management service function $S_p$; the control parameters to be defined are mainly $t$ and $t_{\max}$; the main logical operation data information includes operation policy start instruction $\lambda_{sp} \in (\lambda_{s(p+1)} \sim \lambda_{s(p+n)})$, input information $I_{s(p+1)} \sim I_{s(p+n)}$, and output information $O_{s(p+1)} \sim O_{s(p+n)}$, Fig. 3 shows an information operation transmission process of network management virtual nodes, wherein the information transmission channel $I_{s(p+1)} \sim I_{s(p+n)}$ provides processing information to the policy execution part through logical operation, the operation execution process $A_{s(p+1)} \sim A_{s(p+n)}$ defined by the policy execution part and the processed output interface. The policy execution component also needs to complete the data information packaging, the operation and processing rule setting of the service function, the establishment of the connection channel of each virtual node, and the construction of the internal communication mechanism.

### 3.3 Dynamic Control Strategy of Network Management Information Channel

The operation strategy of the whole network management system and the processing and transmission of network management event information not only need to provide the information transmission channel but also need to introduce the management and control mechanism of the channel, which can be realized through the overall deployment of the network management channel. For the deployment of network management channels, first of all, it is necessary to formulate the deployment rules of transmission channels for network management function information and operation strategy information and apply the corresponding scheduling update rules to realize the overall dynamic management and control, so that it can have limited intelligent management. Figure 4 shows the dynamic deployment plan of the whole information transmission channel of the network management system.

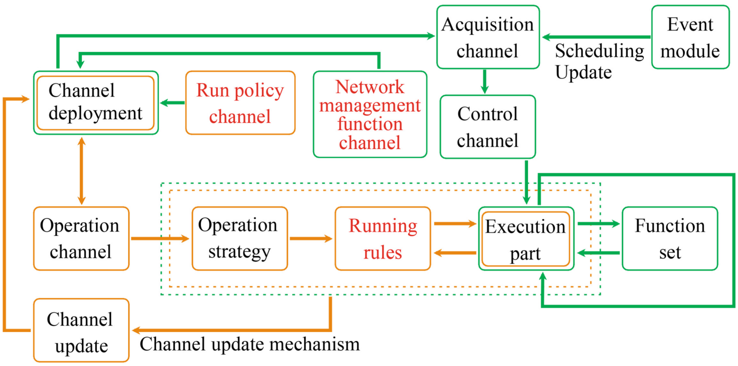


**Fig. 4.** Dynamic deployment planning strategy of the whole channel of information transmission in a network management system.

The management and control of the network management event information transmission channel mainly depend on the realization of the network management event processing scheduling update mechanism shown in Fig. 5, and its dynamic performance is mainly reflected in the t(max) judgment conditions of the queue task analysis module. The management and control of the operation policy information transmission channel mainly depend on the operation policy set and the policy execution component shown in Fig. 6. By formulating the operation policy rules, the dynamic update instructions of the operation policy channel are analyzed and calculated, and the construction of the policy channel update set is completed, thus realizing the redeployment of the entire network management channel. This is also the key to the dynamic deployment of network management information transmission channels. Here, the information transmission channels of the whole network management system can be defined in detail, in which the network management event transmission channel can be defined as $L_{sp} \in (L_{s(p+1)} \sim L_{s(p+n)})]$, the running policy channel set can be defined as $L_{ap} \in (L_{a(p+1)} \sim L_{a(p+n)})]$ when the two channels are dynamically updated, their range of values adjusts dynamically.

# 4 System Performance Verification

## 4.1 System Scalability Verification

The system scalability experiment mainly verifies the deployment mechanism of network virtual nodes. On the premise that 200 network management service events happen at the same time, the experiment sets these 200 network management service events as five parallel processing sets (five parallel processing sets match five network management servers and five virtual nodes at most; Each set handles 40 combined network management service events, aiming at the simultaneous parallel processing capability of the system and the combined capability of network management function services), and configures multiple network management data information processing servers (actually, the network management information processing nodes corresponding to multiple virtual nodes are the combination of virtual nodes and network management processing nodes; The purpose is to provide the information processing and operation ability suitable for large-scale network system management, essentially providing multiple CPUs).

The experimental results show that the number of virtual nodes and corresponding servers is small, and the time from the occurrence of network management events to the start of network management event processing is the longest. Because the network management service events are divided into many single events, the advantages of fully opening the processing queue are not fully reflected, and it takes the longest time from the start of network management event processing to the completion of network management event processing. With the increasing number of virtual nodes and the corresponding servers, the corresponding network management events are dynamically distributed to the corresponding processing units, and the factors of uncertain time consumption for different network management functions are counted, realization in case of change of network management event handling and scheduling mode and the dynamic distribution mechanism is cross-applied to different virtual nodes. Therefore, the time from the occurrence of network management events to the start of network management event processing and the completion of network management event processing shows a steady downward trend. The network management system model designed in this paper fully embodies the centralized management of network management functions and the distributed control of network management information transmission channels. The mechanism of combining and publishing network management events can be successfully realized. The virtualized network management information processing units are closely connected, the dynamic association increases or decreases the deployment of network management information processing units is flexible, and the expansion performance of the whole system is superior.

### 4.2 System Timeliness Verification

The system timeliness experiment is mainly aimed at verifying the dynamic control mechanism of the network management information channel. The experiment is also based on the premise that 200 network management service events occur at the same time, and five parallel processing sets are set, and multiple network management data information processing servers are configured to record the running time of the network management system and the realization time of network management service functions.

The experimental results show that, under the condition that the policy channel update mechanism is not enabled, because five virtual nodes and five network management servers are started to operate, the experimental results are the same as those in the timeliness verification experiment. In the role of the policy channel update mechanism, more network management events will be added to the information processing queue in time, and it will have the ability to deal with some network management emergencies.

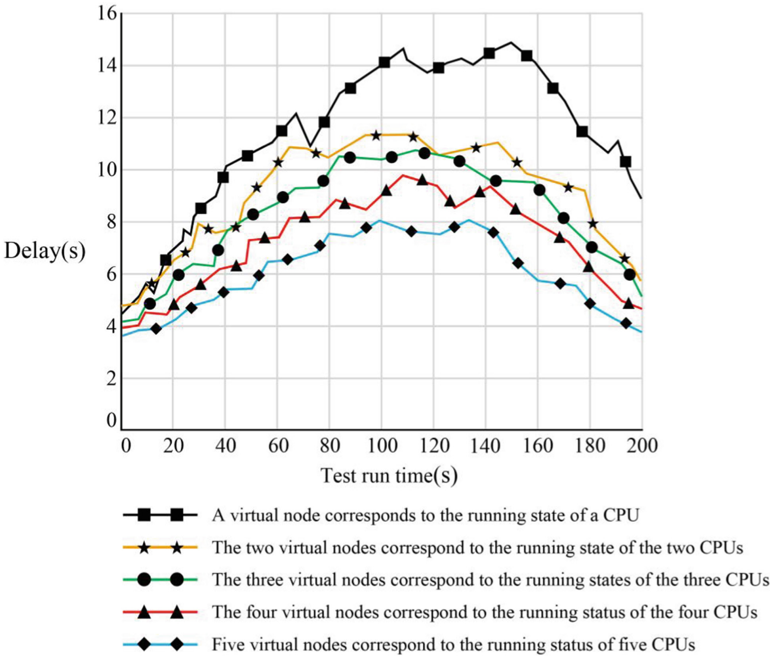


**Fig. 5.** Diagram of time-consuming change state of network management service function realization under the condition of virtual node setting change.

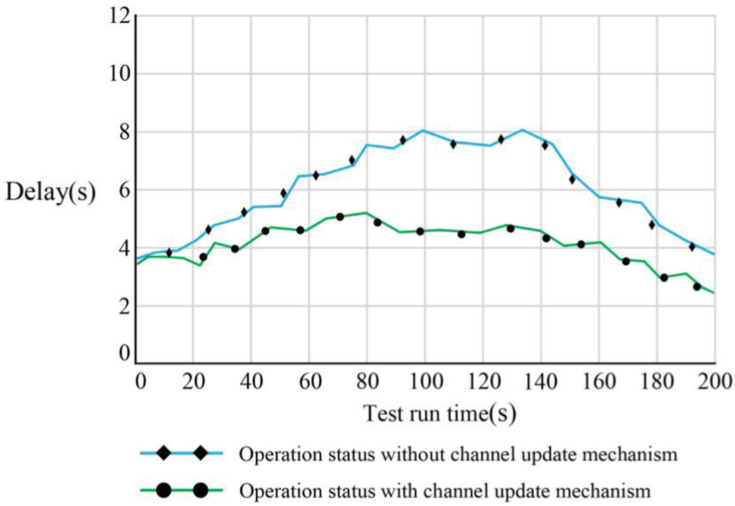


**Fig. 6.** Diagram of time-consuming change state of network management service function.

## 5 Conclusion

According to NFV standard, taking the internal structure design of virtual nodes as a breakthrough, this paper constructs a universal virtual SDN network management model by introducing logical operations to control information transmission, classify and dynamically control network management information channels. The main achievements of the research work include:

(1) The network management functions and resources of the network management system are virtualized; All network management functions are centralized management, and network management information transmission channels are distributed applications.
(2) The network management service channel based on a fair peer-to-peer access mechanism, which encapsulates network management data information in a container virtual way, can flexibly handle multiple network management service functions.
(3) The number of processing functions and processing time of virtual network management nodes are relatively fixed, which can better analyze the network state information and network operation state in real-time; Extensible interfaces for managing network service functions, service channels and resources can realize the construction of flexible network management system.
(4) The virtual network management node adopts logical operation to construct the input and output channels of internal information, which simplifies the structural complexity of the mathematical model and improves the running efficiency of the system.
(5) The independent, dynamic, and combined construction of the two information transmission channels of operation strategy and network management events is also the key to the construction of a virtual network management system.

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