

## A Method of Network Provisioning on Layer 2 Networks

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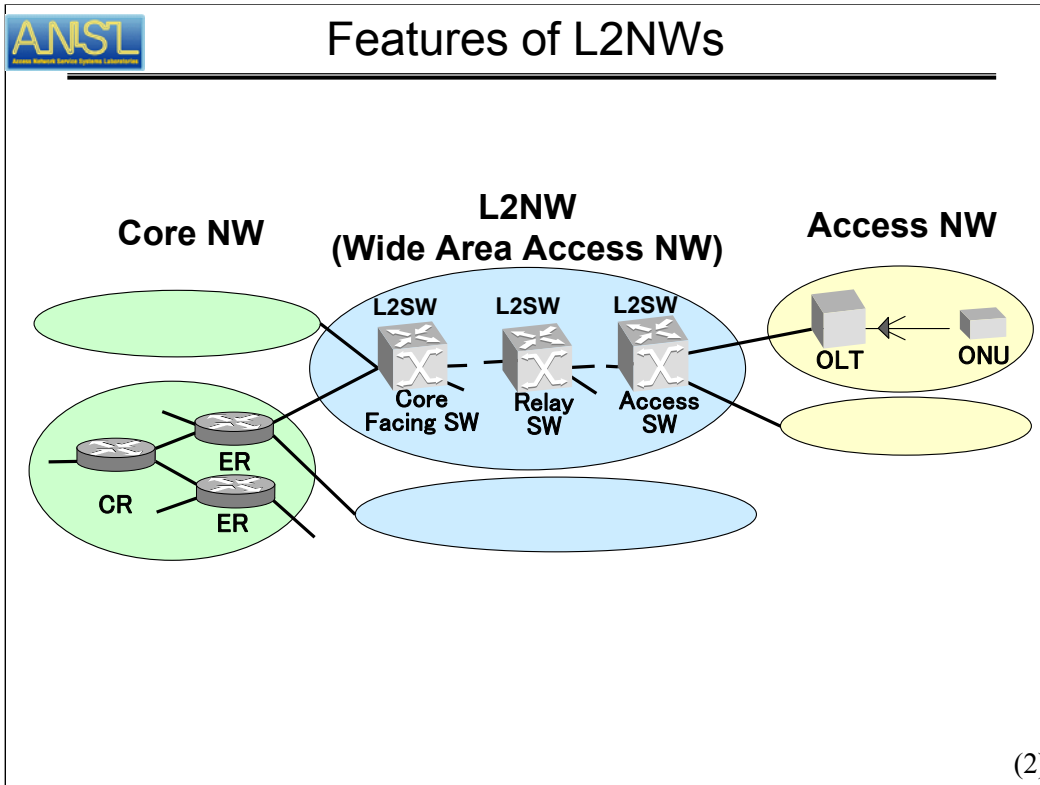
### Abstract

Layer 2 networks (L2NWs) have attracted much attention as an approach for use in broadband communications because the layer 2 switches (L2SWs) that compose L2NWs are more cost-effective than the layer 3 switches used in current layer 3 networks and can convey not only IP but also other protocols [1]. Wide-area Ethernet services (WAESs) are the main application for L2NWs. Japan has business, leased line, and fiber-to-the-home (FTTH) services in WAESs. The market for WAES has been expanding rapidly in recent years [2] and is forecast to keep growing in the future.

When provisioning L2NWs, i.e., configuring networks (NWs) to meet customer requirements, provisioning operators configure VLAN-IDs and quality-of-service (QoS) parameters properly for each customer. As the scale of a L2NW increases, so do the number of L2SWs and configuration items of each L2SW. Even if two switches (SWs) are of the same model, the configuration items for them are different if the topologies of their NWs are different. Furthermore, if the vendors and models of the SWs are different, the connection protocols and configuration command languages needed to configure the SWs are different. Therefore, L2NW configuration becomes more complex when we provide more kinds of services for more customers using more kinds of L2SWs.

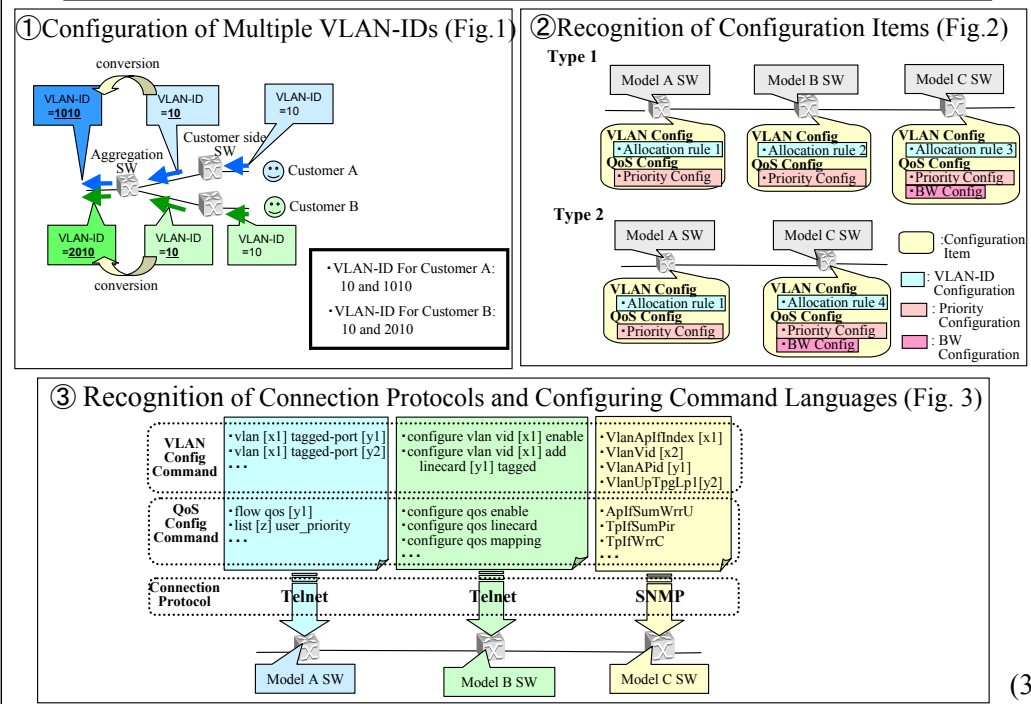
We propose a method of NW provisioning that can automatically configure L2SWs so that the operators can reduce the cost of L2NW provisioning. The method is based on the NW information model, which can manage the information of different NWs together regardless of the kinds of L2NWs included. We show that our method is valid by using a L2NW operation support system (OSS) that uses the method. First, we explain the features of L2NWs. Second, we discuss in detail the problems of L2NW configuration. Third, we explain the method used in the information model. Fourth, we explain the outline and main function of the OSS. Finally, we evaluate the method to see if the OSS improves it.

**Keywords:** Layer 2 networks (L2NWs), layer 2 switches (L2SWs), network provisioning, VLAN-ID, quality-of-service (QoS), operation support system (OSS), automatic configuration



## 1. Features of L2NWs

In general, L2NWs such as wide area access NWs are located between core NWs, which are operated by ISPs and long-distance carriers, and access NWs, which are operated by regional carriers. The access NWs admit customers and transport traffic (data, voice, etc.) to the wide area access NWs using the layer 2 protocol. The wide area access NWs aggregate the access NWs and transport the traffic to the core NWs, also using the layer 2 protocol. The core NWs aggregate the wide area access NWs and transport the traffic between the wide area access NWs using the layer 3 protocol. The access NWs are composed of optical line terminals (OLTs), which are located in the regional carrier's buildings, and optical network units (ONUs), which are in customers' homes if they have FTTH. The wide area access NWs are composed of access SWs connected to the OLTs in the access NWs, core facing SWs connected to edge routers (ERs) in the core NWs, and relay SWs connected to the access, facing, and other relay SWs and in between the access and relay SWs. The core NWs are composed of the ERs connected to the facing SWs in wide area access NWs and core routers (CRs) and the CRs connected to the ERs and other CRs.



## 2. Problems of L2NW Configuration

The problems of L2NW configuration are described in detail below.

### 2.1. Configuration of Multiple VLAN-IDs

An aggregation SW aggregates the SWs closest to customers, or customer side SWs, such as in the L2NW in Fig. 1. In this case, the VLAN-ID configured on the upper port is different from the VLAN-ID configured on the customer side port of the aggregation SW because NW provisioning operators allocate VLAN-IDs on customer side SWs flexibly without considering the VLAN-IDs allocated to other customer SWs. That is, the operators should allocate at least two VLAN-IDs for a customer such that the VLAN-IDs on the upper side ports are not duplicated. For example, in Fig. 1, the VLAN-IDs allocated for customer A are 10 and 1010, and those for customer B are 10 and 2010.

### 2.2. Recognition of Configuration Items

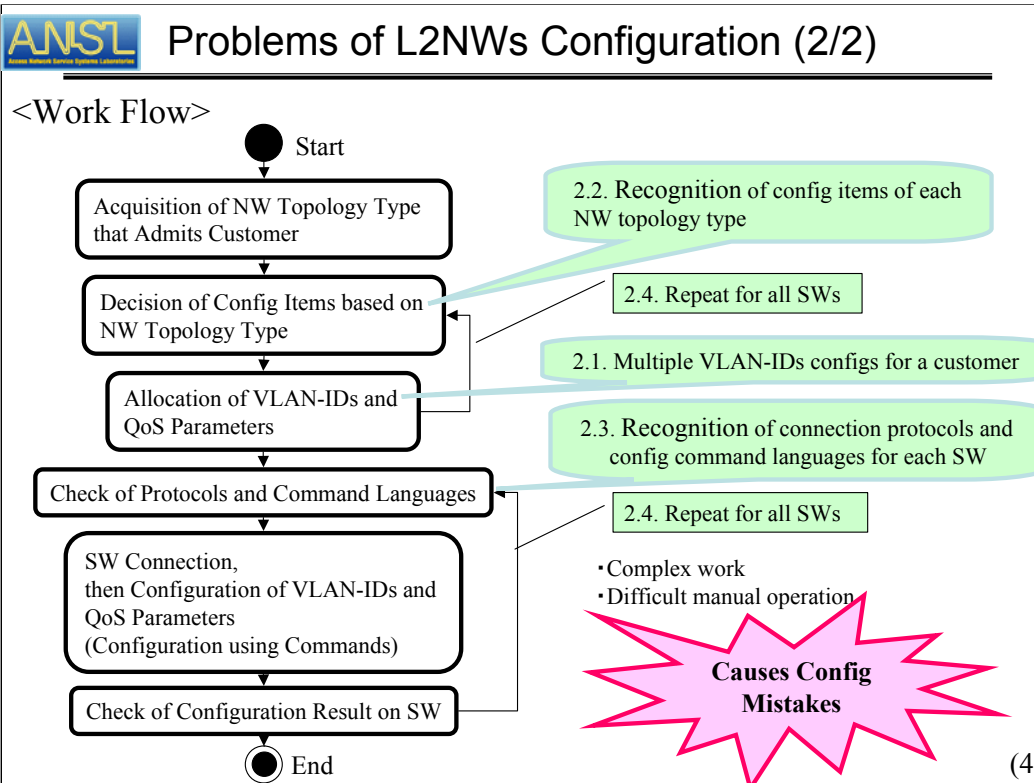
The items that must be configured for each SW are different. Two examples of the items when one service is provided in NW topology types 1 and 2 are shown in Fig. 2. Only the priority type of QoS configuration was used in the model A and B SWs in type 1. Not only the priority but also the bandwidth (BW) configuration was used in the Model C SW.

The VLAN-ID allocation rules are different in each SW (Fig. 1). The upper side port on the customer side SW is allocated the same VLAN-ID allocated on the customer side port. The upper side port on the aggregation SW is allocated a VLAN-ID that is calculated by adding the customer side port number to the VLAN-ID allocated on the customer side port. In the type 2 network in Fig. 2, the allocation rules are different in the model A, B, and C SWs. Furthermore, the allocation rules of the model C SW are different in types 1 and 2.

The different items that must be configured depend on the NW topology, which is characterized by the kind of switches the L2NW is composed of. Therefore, the operators must know the items that must be configured for each SW of each NW topology type.

### 2.3. Recognition of Connection Protocols and Configuration Command Languages

When NW provisioning operators configure SWs, they control each SW by using the control interfaces (IFs) of each SW. The control IFs are different for each vender and model of SW. In Fig. 3, when the operators configure a VLAN-ID as “100” on a SW, they input the command “vlan 100” to a model A SW using telnet, “configure vlan vid 100 enable” to a model B SW using telnet, and “set VlanVid 100” expressed using Object-ID to a model C SW using SNMP. Therefore, the operators must know which connection protocols and configuration command languages each SW uses to configure each SW.



## 2.4. Complex Configuration Work

Network provisioning work on L2NWs mainly includes settings to provision a connection between the two endpoints of a L2NW, to delete the connection, and to modify the connection. The provision connection setting is to configure the NW for providing customer telecommunication service. The delete connection setting is to configure the network for tearing down the provided service. The modify connection setting is to configure the network for modifying the provided service. The figure above shows the general workflow in the provision setting. To configure a L2NW for the setting, provisioning operators must allocate multiple VLAN-IDs and know the configuration items, connection protocols, and configuration command languages. Therefore, as the number and kinds of switches increase, the setting work for manual operation becomes more complex and difficult. Such work takes a long time and causes configuration mistakes.

Many NW-OSSs that have functions to configure NWs already exist and are being used. However, these OSSs cannot solve the problems of L2NW configuration because they cannot

- configure L2NWs depending on various NW topology types, although they can configure a certain NW topology type; in other words, they cannot solve the problem described in 2.2.
- allocate multiple VLAN-IDs to a customer, although they can allocate a single VLAN-ID to a customer; in other words, they cannot solve the problem described in 2.1.
- configure unspecified SW models, although they can configure specified SW models; in other words, they cannot solve the problem described in 2.3.

Therefore, we need a new NW-OSS that solves the problems.

### Requirements for NW Provisioning

- Automatic decision for configuration items based on NW topology type
- Concealment of connection protocols and command languages
- Flexibility for variety of SW models and NW topology types

### Our Approach to Meet Requirements

- Information model
- Automatic decisions made using NW operation policy
- Automatic conversion of protocols and commands

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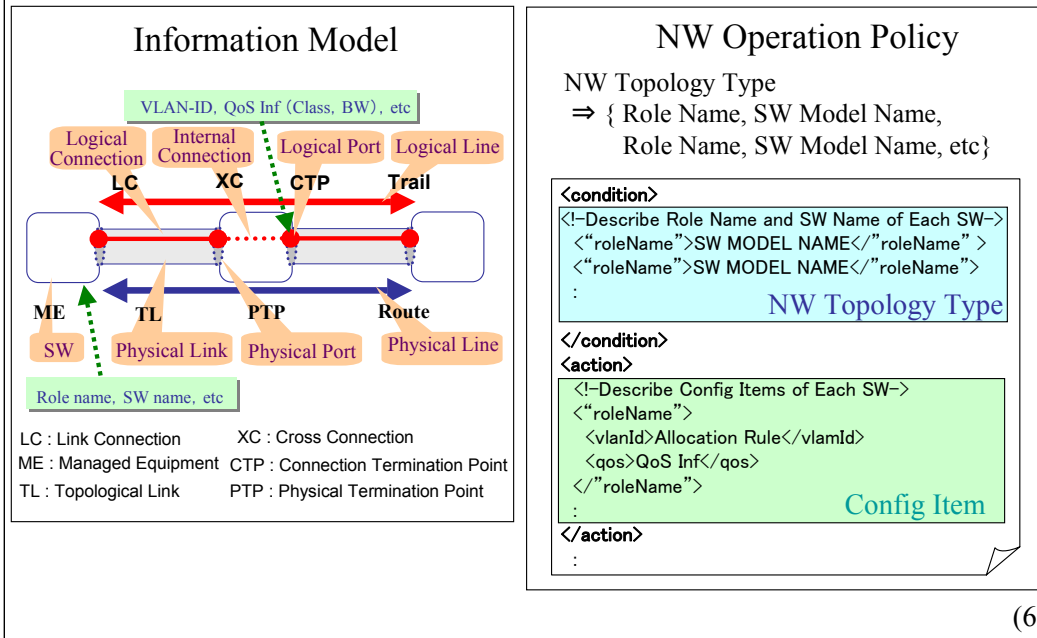
### 3. Our Provisioning Method

To solve the problems of L2NW configuration, we need a provisioning method that rapidly and accurately provides telecommunication service for customers and is independent of the models of SWs and types of NW topologies used. This provisioning method requires the following:

- (1) The method must automate the decision for the items of each SW that must be configured based on the NW topology type. This should reduce the configuration time and mistakes made by operators.
- (2) The connection protocols and the configuration command languages must be concealed. This should reduce the time needed, mistakes made, and complexity of the setting work.
- (3) The method must be flexible to accommodate the various SW models and NW topology types. Various models of SWs and types of NW topologies must be developed before beginning the telecommunication service because the model and type of switch needed depend on the demand and forecast income of service areas. Therefore, the method must be able to deal with various models and types.

We propose the following approach to meet the requirements.

- (1) Define the information model  
The information model manages the information of different NWs together without depending on the models of SWs and the types of NW topologies.
- (2) Automatic decisions using the NW operation policy.  
The NW operation policy describes the configuration settings for each NW topology type and is used to automatically determine the configuration items for each SW.
- (3) Automatic conversion of connection protocols and configuration command languages.  
This conceals the protocols and command languages from the operators by using common IFs, equipment profiles, and command templates we define.



### 3.1. Information model

We defined an information model that abstracts a NW's attributes to accommodate various L2NWs by referring to the MTNM model [3].

Managed equipment (ME) objects represent SWs, topological links (TLs) represent physical links between switches, physical termination point (PTP) objects represent physical ports on switches, and route objects represent physical end-to-end lines. Each ME object has a role name, model name, etc. Each route object is composed of multiple TL objects. Cross connection (XC), link connection (LC), connection termination point (CTP), and trail objects represent logical information of NWs. When operators configure L2NWs for customers, these objects are created, deleted, and changed for each customer. XC objects express interconnection in the ME objects. The LC objects represent the logical information of TL objects, CTP objects represent the logical information of PTP objects, and trail objects represent the logical information route objects. A CTP object has a VLAN-ID and a QoS parameter including the QoS classes and the bandwidth values of each class.

This information model can express various SWs and NW topologies because it does not depend on the models of SWs and the types of NW topologies. We propose a provisioning method based the information model.

### 3.2. Network Operation Policy

We propose automatically determining configuration items for each SW using a NW operation policy where "conditions" are NW topology types and "actions" are configuration items because the configuration items on one NW depend on the NW's topology type. Furthermore, we define a NW topology as a pair of a SW model name and a role name that ME objects in the information model have because the configuration items depend on both the model name and the role that the SW plays in the NW. The action describes configuration items for each SW. We defined each configuration item to consist of the VLAN-IDs and QoS parameter configurations of each SW. The VLAN-ID configuration describes allocation rules, and the QoS parameter configuration describes QoS information including QoS classes and the bandwidth of each QoS class.

When a customer wants to subscribe to a telecommunication service, automatic decisions are made as follows. First, get a route object exclusively for the customer. Second, get ME objects from the route object, and get the role names and model names from each ME object. Third, search for a condition in the policy in a set of these names. Fourth, get an action as a configuration item on each SW from the condition.

## Common IF

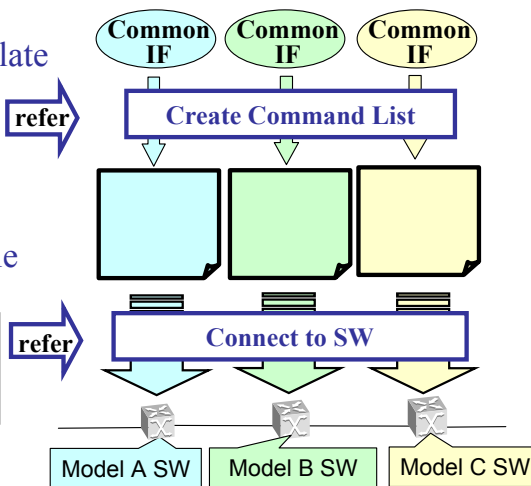
Setting Type	IF Name	Parameter
Provision Connection	createCrossConnect	ME-ID, PTP-ID, VLAN-ID, QoSInf, PTP-ID, VLAN-ID, QoSInf
Delete Connection	deleteCrossConnect	
Modify Connection	modifyCrossConnect	

## Command Template

```
config
vlan #ID#
save
```

## Equipment Profile

```
<protocol>telnet
<login>admin
<password>admin
```



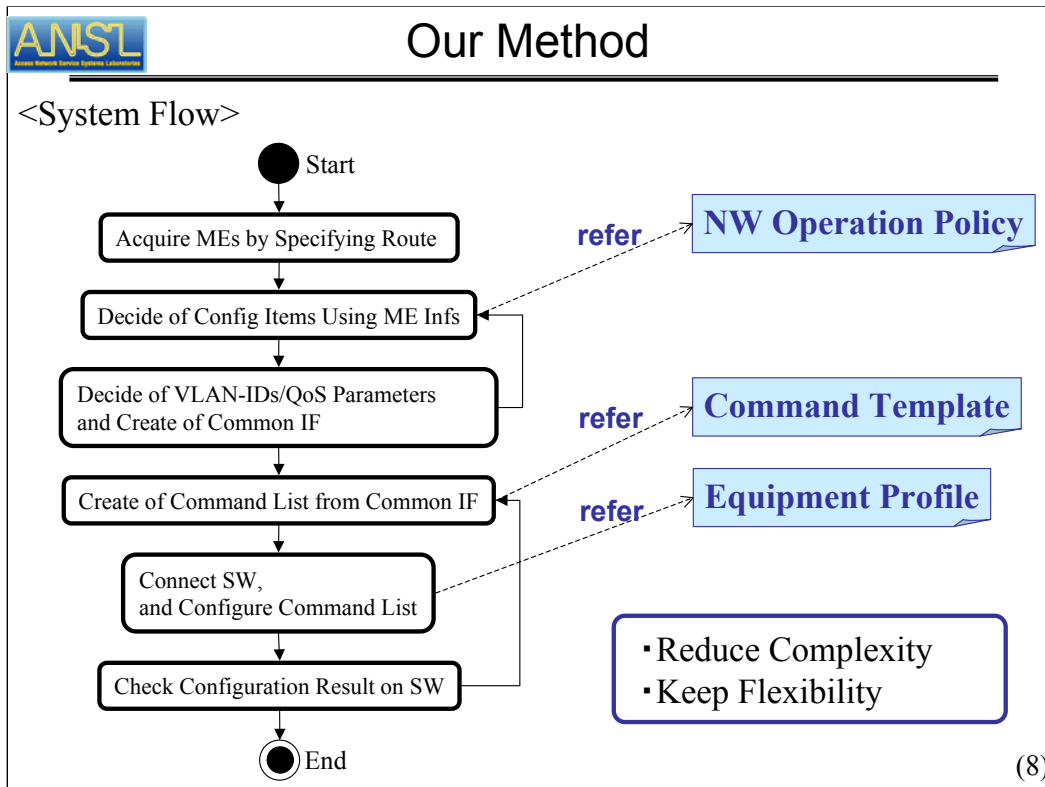
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### 3.3. Automatic Conversion of Protocols and Commands

Because formal configuration information that will be converted is needed to automatically convert to protocols and commands, we define a common IF as the information. Its parameters are based on the information model for each setting type on L2NW provisioning, which includes provisioning, deleting, and modifying connection settings. We propose automatically converting from the common IF to the protocol and command of each SW.

For the conversion, we use command templates and equipment profiles. The command templates are described using the common IF and SW command list, which is a set of commands the operator should use to configure a SW. Parameters needed for SW configuration such as VLAN-IDs, bandwidth values, etc. are expressed as variables in the command list. The equipment profiles are described for each SW protocol type, such as telnet and SNMP, login name, login password, and control port number, which are needed to connect to the SW.

Protocols and commands are automatically converted as follows. First, common IFs are created for each SW for customer requirements. Second, an IF name and a ME object with an ME-ID are gotten from the common IF. Third, a command template is gotten for a SW from the IF name and the ME-ID. Fourth, a command list is created with inserted PTP-IDs, which can be gotten from the ME-ID, VLAN-ID, and QoS parameter using the command template. Fifth, an equipment profile is gotten from the ME-ID. Sixth, a connection is made to the SW using the equipment profile. Finally, the command list is configured to the SW using the connection.



### 3.4. Flow of Our Method

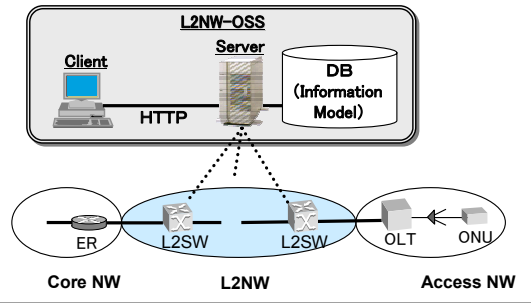
The figure above shows the system flow of our method. Provisioning operators input customer information to the OSS, including customer requirements, and the OSS can find route objects. During this time, the procedure is as shown in the flow.

Because the configuration items are automatically determined using the NW operation policy, the operators do not need to know the configuration items of each SW, and they only input a few items of customer information to the OSS. Because the connection protocols and configuration command languages are automatically converted by using a common IF, equipment profiles, and command templates, the fact that the SWs are different types is concealed from the operators. Therefore, the complexity of L2NW configuration is reduced.

Because the policy, profiles, and templates are external files of the OSS, changing these files does not require changing the source codes and database schemas of the OSS. When a new NW topology type appears, the operator only adds a description to the policy without adding new source codes and schemas in the OSS. When a new SW model appears, the operator only creates a profile and a template without adding them. Furthermore, because the NW information needed by the system flow is based on the information model, the system flow need not be changed when a new NW topology type and SW model appear. Therefore, the method should have the flexibility to handle new NW topology types and SW models.

# Verification of Our Method

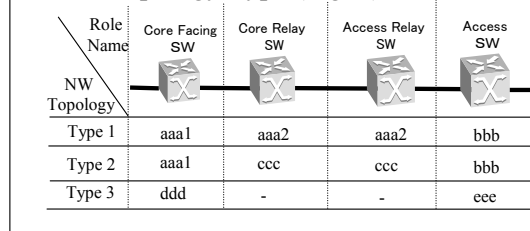
Outline of OSS (Fig. 4)



SW Model (Fig. 5)

	Vender	SW Model Name	Protocol
1	A	aaa1	Telnet
2	A	aaa2	Telnet
3	B	bbb	SNMP
4	C	ccc	Telnet
5	D	ddd	Telnet
6	E	eee	Telnet

L2NW Topology Type (Fig. 6)



(9)

## 4. Verification of Our Method

To check the effects of using our method, we developed a L2NW-OSS that uses the method.

### 4.1. Outline of L2NW-OSS and L2NWs

An outline of the OSS is shown in Fig. 4. The OSS is composed of a client terminal and a server. The server connects to a database that has NW information based on the information model we defined. The server has a NW operation policy, equipment profiles, and command templates as external files. To configure L2NWs, provisioning operators access the server via the client terminal.

We used the six types of SWs shown in Fig. 5 and constructed the three types of NW topologies shown in Fig. 6. We assumed that NW topology types 1 and 2 are express NWs used in metropolitan areas and that type 3 is used in smaller cities. Because the relay SWs in type 1 are different from those in type 2, their configuration items are also different. We assumed that types 1 and 3 are existing NW topologies and that type 2 is a new type composed of new SW models. We prepared NW operation policies, command templates, and equipment profiles for the SWs and L2NWs.

## View of Provision Connection Setting Function

Provision Connection Setting

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Access User ID

ER VLAN-ID

**Bandwidth**

Default Values

EF: 1 Mbps

AF4: 1 Mbps

Change Values

EF:  Mbps

AF4:  Mbps

OLT No.

IF Port No.

ONU No.

: Mandatory Parameter       : Optional Parameter

(10)

## 4.2. Main Functions of the OSS

The OSS has the following four main functions.

### (1) Provision connection setting function

This is used when a customer wants to subscribe to the telecommunication service. By inputting parameters to the client terminal including the access user ID, the VLAN-ID configured on the ER, and the OLT/IF Port/ONU number given to the customer, the VLAN-ID and QoS configurations are automatically set on each SW to provision a connection by the server. This function is shown in the figure above.

### (2) Delete connection setting function

This is used when a customer wants to unsubscribe from the service. By inputting the access user ID to the terminal, the VLAN-ID and QoS configurations are automatically set on each SW to tear down the connection by the server.

### (3) Modify connection setting function

This is used when a customer wants to change the content of the service. We defined the content as the bandwidth values of each QoS class. By inputting parameters to the terminal including the access user ID and the bandwidth values, the QoS configuration is automatically set on each switch to modify the connection setting by the server.

### (4) Retrieve connection function

This is used when the operators need to check the configuration items of a customer. By inputting the access user ID to the terminal, SWs given to the customer, and VLAN-IDs, the QoS parameters of each SW are shown on the terminal.

• Configuration Time (Fig. 7)

NW Topology	Avr. Manual Operation (m)	Avr. L2NW-OSS (m)
Type 1	15	1
Type 2	10	0.5
Type 3	5	0.3

• Accuracy (Fig. 8)

```

Configuration Result (SW Model Name: eee)
vlan 100 tagged-port 0/1
vlan 100 tagged-port 1/1

flow qos 0/1 out
list 1005 user_priority 5 vlan 100 action priority 6 max_rate 2000

list 1007 user_priority 7 vlan 100 action priority 8 max_rate 1000
    
```

• Complexity (Fig. 9)

NW Topology	Manual Operation	L2NW-OSS
	(Number of Commands / Parameters)	(Number of Commands / Parameters)
Type 1	60/52	1/7
Type 2	36/44	
Type 3	34/17	

(11)

## 5. Experimental Results

We operated a L2NW-OSS and checked the effects of our method. Here are the results.

### 5.1. Configuration Time

The time it took to provision connection settings on NW topology types 1, 2, and 3 by operating on manual and using L2NW-OSS is shown in Fig. 7. We found that by automating the determination of the configuration items, conversion of connection protocols, and configuration of command languages, the OSS reduced the time needed to configure L2NWs. In particular, in type 2, the time was reduced to 1/20 of that needed for manual operation. A similar cost reduction may be possible in actual network provisioning work because we think that the conditions we assumed are similar to actual conditions.

### 5.2. Accuracy

Using a NW of topology type 3, we set a provision connection with the following input parameters: VLAN-ID on ER = 100, bandwidth of QoS class EF = 1 Mbps, and the bandwidth of QoS class AF4 = 2 Mbps. We found that the OSS configured the VLAN-ID to 100 on port numbers 0/1 and 1/1, to 1000 bps on priority 8, and to 2000 bps on priority 6 for an access SW of type eee, as shown in Fig. 8. The configuration result of the access SW after the provision connection setting was set by the OSS is shown in Fig. 8. We can see that the OSS can accurately configure SWs. Furthermore, the same is true of other SWs and setting types.

### 5.3. Complexity

The number of commands and parameters for provisioning connection settings on network topology types 1, 2, and 3 using manual operation and our L2NW-OSS are shown in Fig. 9. We found that by automating the configuration, the complexity of the work the operator must do to configure a L2NW is reduced because for the configuration, the operators input only five parameters to the OSS, and they do not need to know configuration items, connection protocols, and configuration command languages for each SW and NW topology type. A similar cost reduction may be possible in actual network provisioning work because we think that the conditions assumed are similar to actual conditions.

- Flexibility

(1) When new SW type appears,

- Operators only create profile and template.
- However, if original configuration parameter to configure new SW is needed, then new source codes must be added.

(2) When new NW topology type appears,

- Operators only add description to NW operation policy.
- However, if config items of new NW topology type are different from existing config items, then new source codes must be added.

### Summary

- We proposed provisioning method not depend on models of SWs and types of NW topologies in various L2NWs.
- L2NW-OSS using our method enables providing rapid and accurate telecommunication services and easy L2NW configuration.

(12)

#### 5.4. Flexibility

When the new type 2 topology is developed, because in access SWs of type 2 the configuration items are the same as the settings of access SWs of type 1, we do not need to add new source codes and schemas or change the system flow to configure the access SWs of type 2. In the other SWs of type 2, we also do not need to add new schemas or make changes. However, we need to add new source codes in the SWs because the configuration items of the other SWs differ from the configuration items of existing SWs in type 1 and 3 NWs. Also, an original configuration parameter is needed to configure model ccc SWs. Therefore, we found that our method has flexibility in the schemas and system flow. To give the method more flexibility in the source codes, we will continue developing ways to add source codes easily by using the software component concept [5].

#### 6. Summary

We proposed a provisioning method that does not depend on variety models of SWs and variety types of NW topologies to configure L2NWs rapidly and accurately to provide telecommunication services for customers.

The L2NW-OSS using our method can provide rapid and accurate telecommunication services and easy L2NW configuration because operators do not need to know configuration items, connection protocols, and command languages for each SW model and NW topology type.

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