Autonomous Network Provisioning for Digital Transformation Era

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Resume of the presenter

Taro Ogawa

Since joining Hitachi, Ltd., he has been mainly engaged in research and development of telecommunications equipment for network carriers.
In addition, he is engaged in the development of carrier switches, carrier transmission devices, PON devices, carrier core devices, and packet transport devices.
He was also involved in research on network virtualization technology (SDN) in the national project.

Contents

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Contents

1. Research Background

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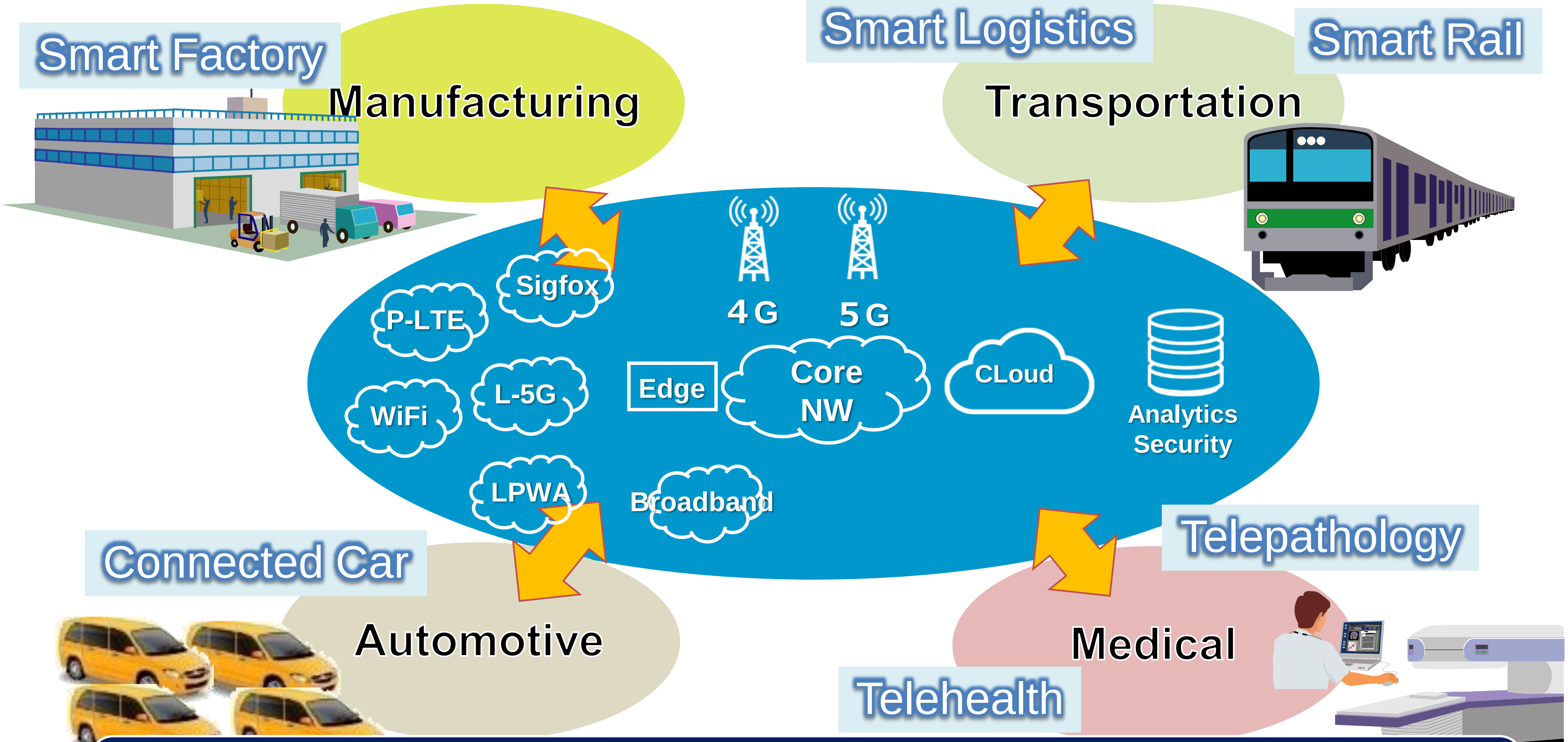
Systems engineering has been becoming significantly complex process.
- Vertical industries: Network requirements are diversifying company by company
- ICT infrastructure: Radical changes are ongoing in architecture and technologies

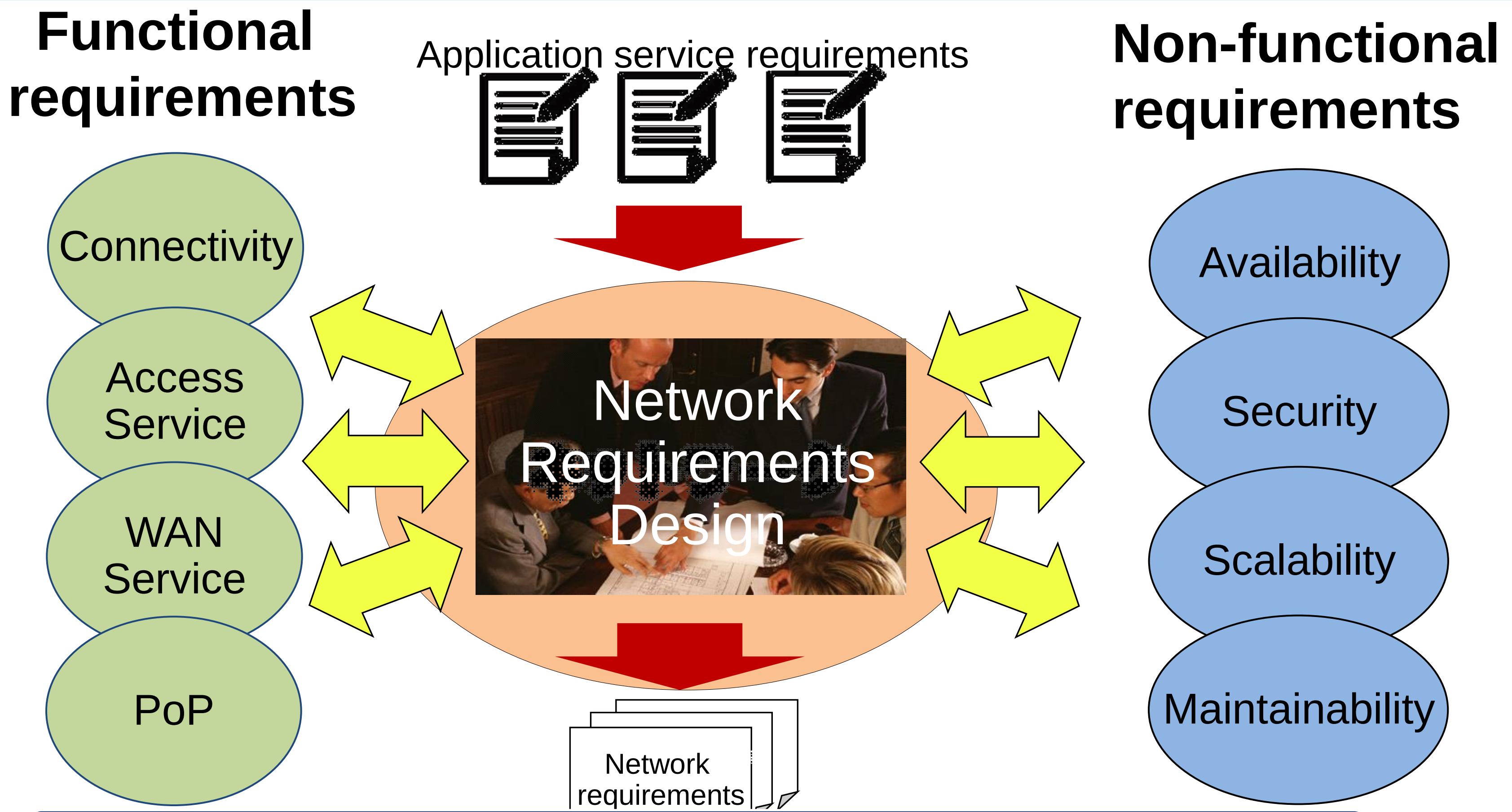


Conventional requirements engineering cannot manage the explosively increasing network configuration patterns.

Contents

2-1. Network Requirements Design

Network requirements design is not just a connectivity design.
- Functional: Bandwidth, PoPs, networking functions, …
- Non-functional: Availability, security, scalability, maintainability, …
- Business operational: BCP, social responsibility, …



Multi-dimensional requirements space optimization

2-2. Autonomous requirements design

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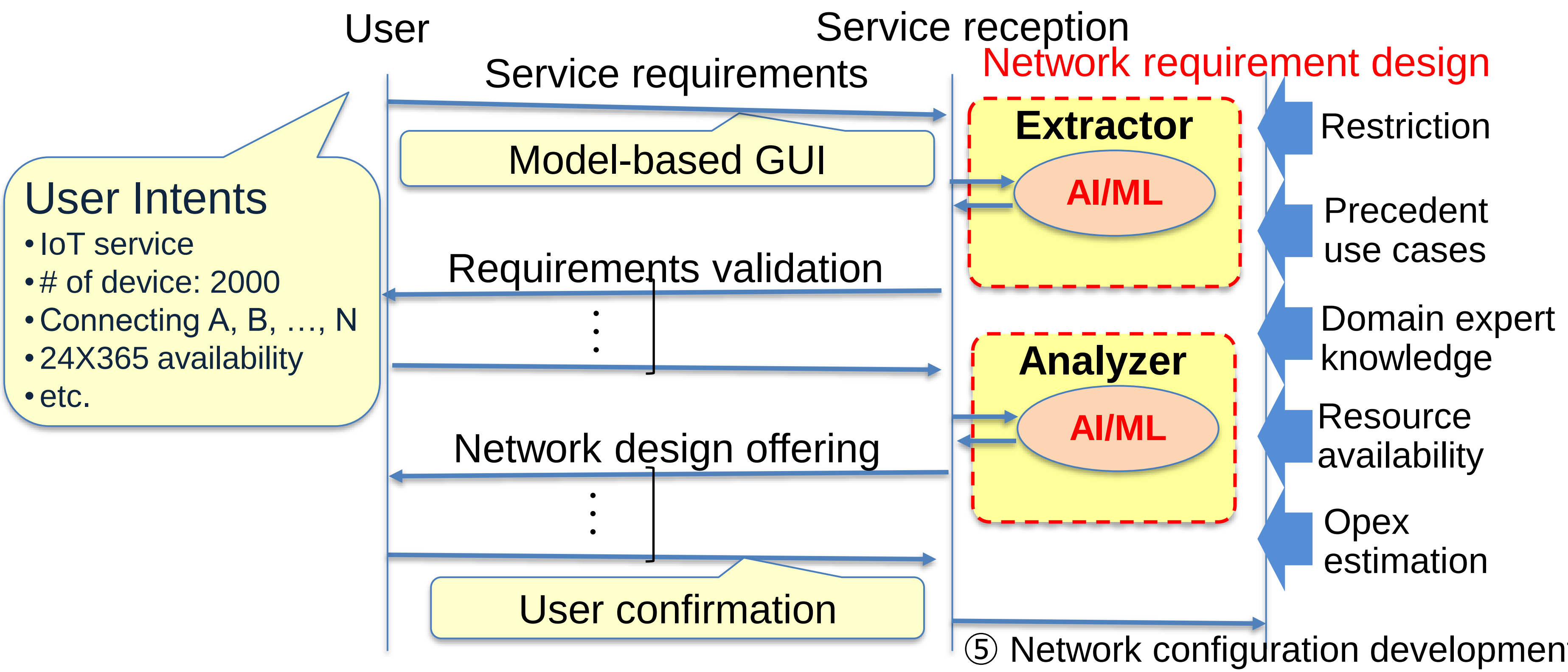
Network requirements design needs domain expert knowledge in each sector.
- Extract the service requirements from ambiguous user "intents"
- Analyse the service requirements with expert knowledge in relevant industry



AI-based network requirements design workflow

- Appropriate ML method for network requirement analysis
- Bootstrapping the system without sufficient data of each domain

Contents

3-1. Model-based user intents entry

Reducing ambiguities for efficient translation of user intents to requirements
- Functional and non-functional requirements
- User requirements validation
- Classification to relevant industry category

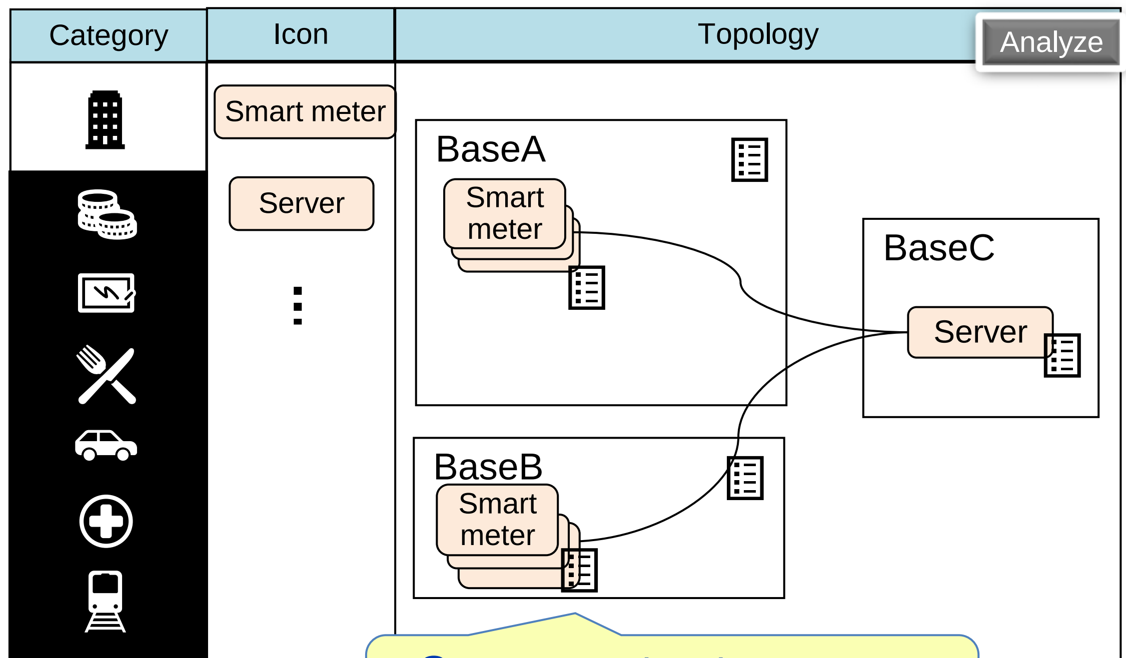
Example use case: Connecting 1,000 smart meters to make power inspection more efficient.

①Model input

Service name
Smart sensor data collection service
System critical level
Failure impact (life threatening) ☐Yes ✓ None Service scale (economic loss or number of affected people) ☐Less than 100 million or less than 100,000 ✓ 100 million to 1 billion or 100 to 1 million people ☐Over 1 billion or over 1 million

- **Service name**
- **System critical level**

②Topology input (application-level view)



- **Component category**
- **Logical connectivity**

3-2. Requirements structure extraction

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User inputs transformed into hierarchical structured service requirements

- Break down to functional and non-functional requirements
- Non-functional requirements not rightly grasped by users
- Accumulated domain expert knowledge can be utilized

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Smart sensor data collection service
System critical level
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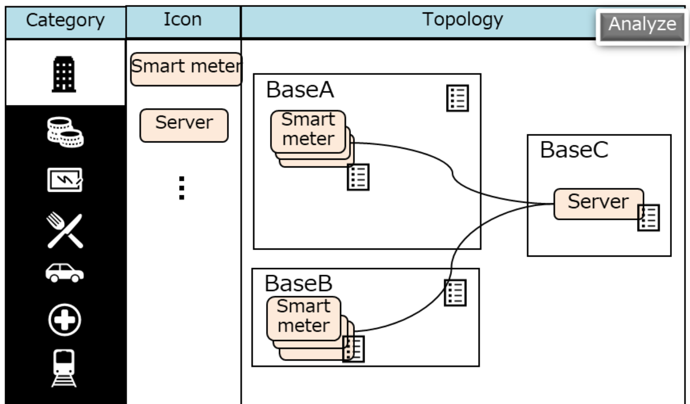

Service requirement input config input example

information	Selection example
Terminal information	
Terminal name	Remote terminal
Terminal address	Chiyoda ward, Tokyo
Number of terminals	100 units
Base information	
Base name	Chiyoda Ward area
Base address	Chiyoda ward, Tokyo

Extraction and classification

#	Requirements	Details	
1	Functional requirements	Connection form	Client-server type
2		Base	Client: Osaka: 500 / Tokyo: 500 Server: Tokyo 1
3		Line Type	WAN : IP-VPN
4		Bandwidth	BaseA/B : ~128Kbps/BaseC : ~1Gbps/WAN : ~100Mbps
6	Non-functional requirements	Bandwidth Guarantee Delay	ApplicationA Bandwidth guarantee:BestEffort/Delay:300ms ApplicationB x x x x
7		Security	With Firewall
8		Reliability	Redundancy: Route Backup: Database only

3-3. Two-step requirements conversion

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Model-based GUI → Functional and non-functional requirements breakdown

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Output parameters by system conversion and service template conversion

Service requirements	Reference source
Base name	Config
Number of units used	Config
Icon	Topology
System model	GUI

<Functional / non-functional requirements>

Base	Parameter 1	Parameter 2	Set value
Function	Base name		Tokyo/Osaka
	Number of units used		500/Base
Calculation	Bandwidth	LAN_A LAN_B LAN_C	~128Kbps ~128Kbps ~1Gbps
		WAN	~100Mbps
	Line type	WAN	IP-VPN
Non-functional	App A	App type	ERP
		Bandwidth guarantee	BE
		Allowable delay time	300ms
	App B	・・・	xxx
	Security		Firewall
	Redundant configuration		Route redundancy

Non-functional template

<Input parameters>

Service requirements	Reference source
Connection Status	Topology

Service template

<Output parameters>

NWType	Base	Parameter 1	Parameter 2	Set value
LAN	Base A	Base name		Tokyo
		Number of units used		500
		Line type		LTE
		Bandwidth		~1Mbps
		App A	App type	ERP
			Bandwidth guarantee	BE
			Allowable delay time	300ms
		App B	・・・	xxx
	Base B	Base name		Osaka
		・・・		Xxx
	・・・			
WAN		Bandwidth		~1Gbps
		Line type		IP-VPN
		Security		Firewall
		Redundant configuration		Route redundancy
Connection form		Connection1		BaseA~C
		Connection2		BaseB~C
		Relay		Concentrator

System conversion

Contents

3-4. Requirements analysis as classifier

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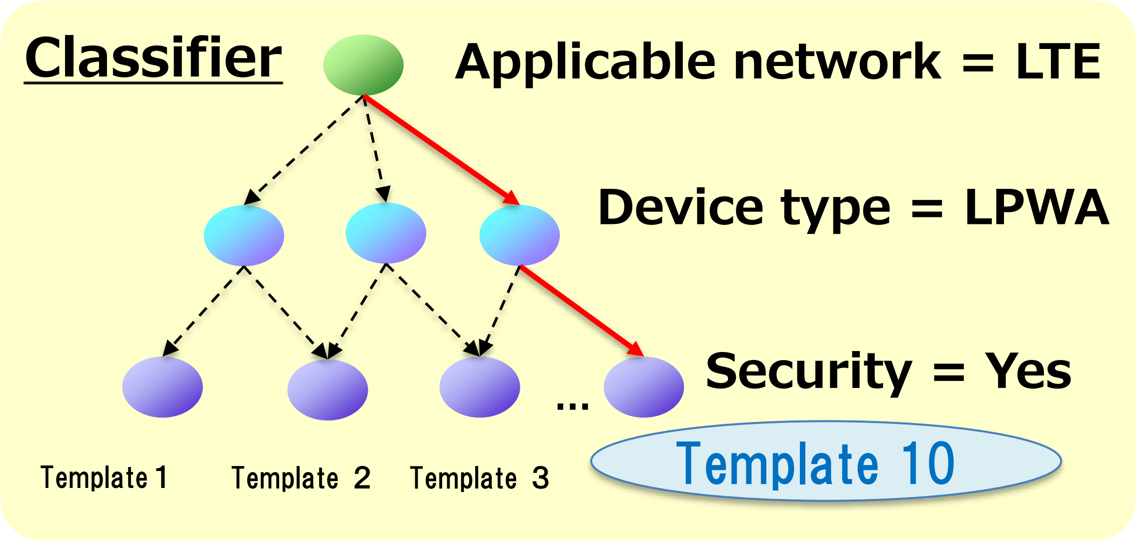
Selection of a set of network requirements close to the matter in question
- Feature variables: Network requirements
- Target variables: Service template



Decision tree for network template selection

- Classifier evaluation for prediction performance
- Data preparation strategy

3-5. ML method comparison

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Decision tree classifier for network requirements analysis
- Computational complexity and prediction accuracy

AI (classifier) method comparison

Function	Functional requirements	Method	Computational complexity	Accuracy
Service requirements	【Input】 • NW functional requirements (Industry, base, bandwidth, etc.) • NW non-functional requirements (Reliability, security, etc.) • Device information (Device type, number, connection configuration, etc.) 【Output】 • Service template	COS Degree of similarity	low ○	low ×
		SVM (※)	high ×	medium to high △
		Random Forest	medium △	medium to high △
		Stacking	somewhat large △	high ○

(※) Support Vector Machine

- Random Forest as a basic classifier
- Ensemble learning (stacking) for more accurate classification

3-6. Analyser architecture

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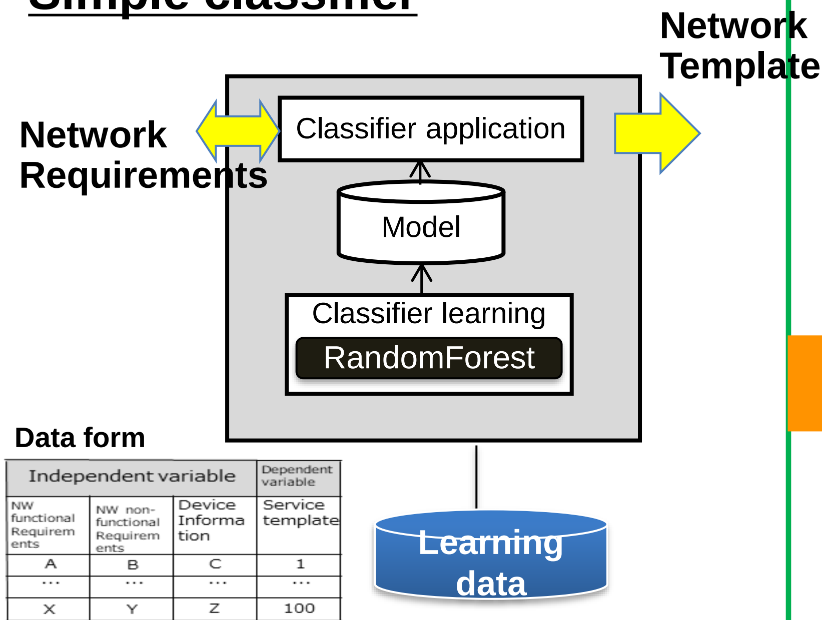
Network requirements analyser architecture

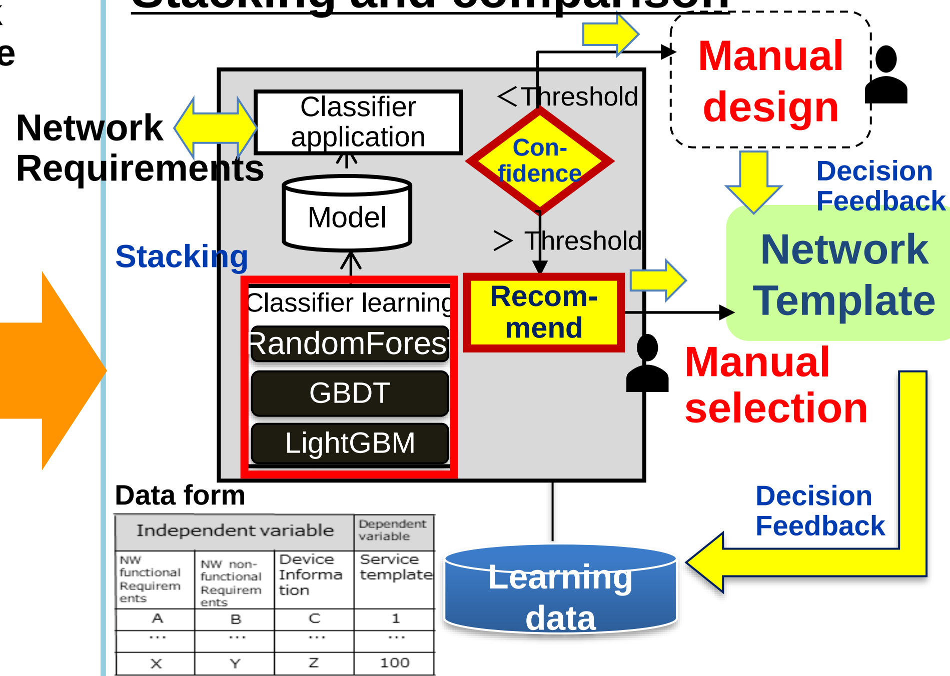
- Stacking of RandomForest, GBDT, LightGBM
- Each classifier predicts with its "confidence“
- Human intervention based on the confidence comparison

Simple classifier



- One-size fits all classifier not suitable for diversified network requirements from various industries

Stacking and comparison



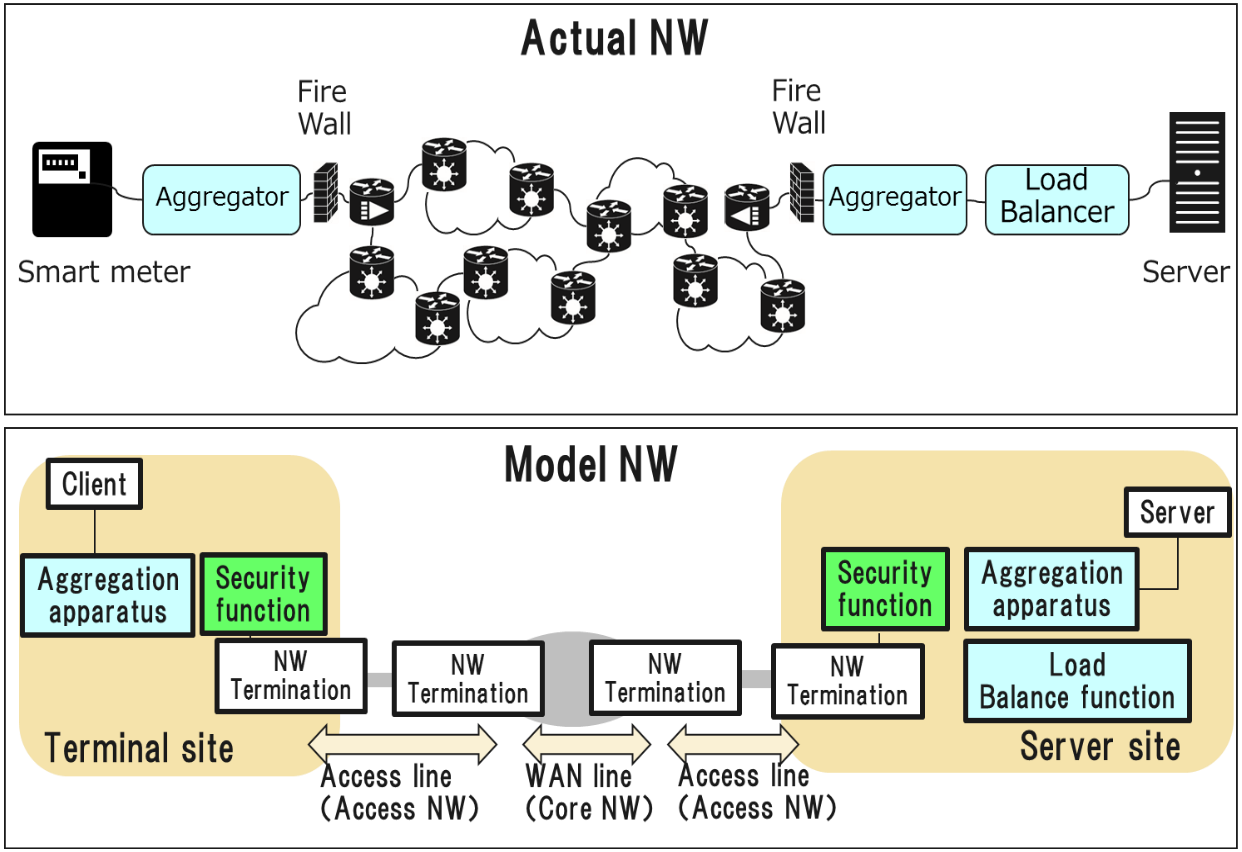
- Select an appropriate classifier with case-by-case basis
- Human intervention based on each classifier’s confidence
- Decision feedback can improve the prediction performance

Contents

3-7. Network modeling

Network model to formulate network template with three categories

- Connectivity: Access, WAN
- Middle box: Aggregator, road balancer, etc.
- Security: Firewall, etc.



Derived from industry use-cases

Modeling

ML-based analyser output as a network template

3-8. Network template

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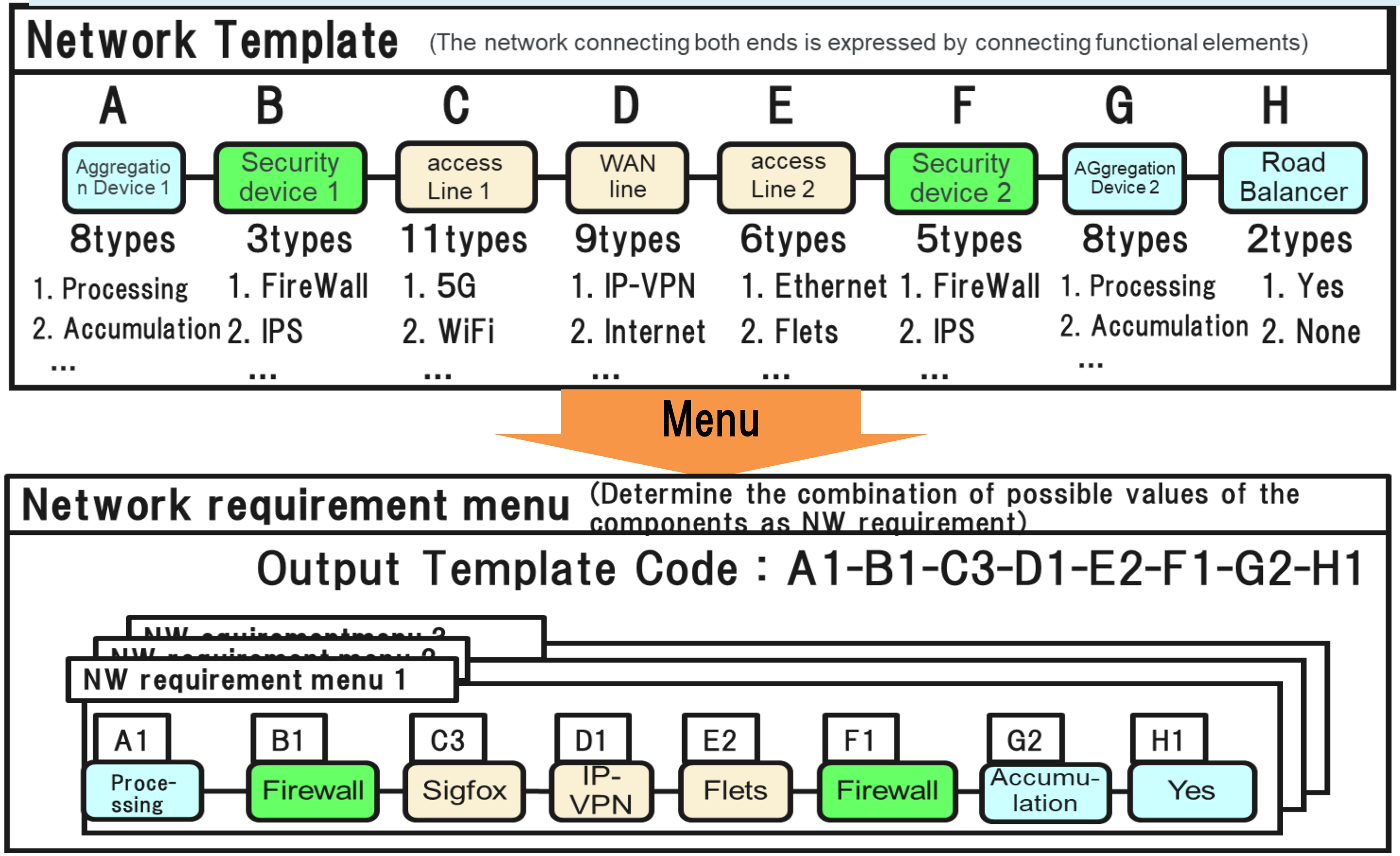
Network template defines a configuration of multiple technology domains.
- Each technology domain has multiple choices
- Network requirements composed of feasible functions and their specifications



Possible candidates for each technology domain

Determining configurable set

Network requirements expressed as a configurable set

3-9. ML performance evaluation

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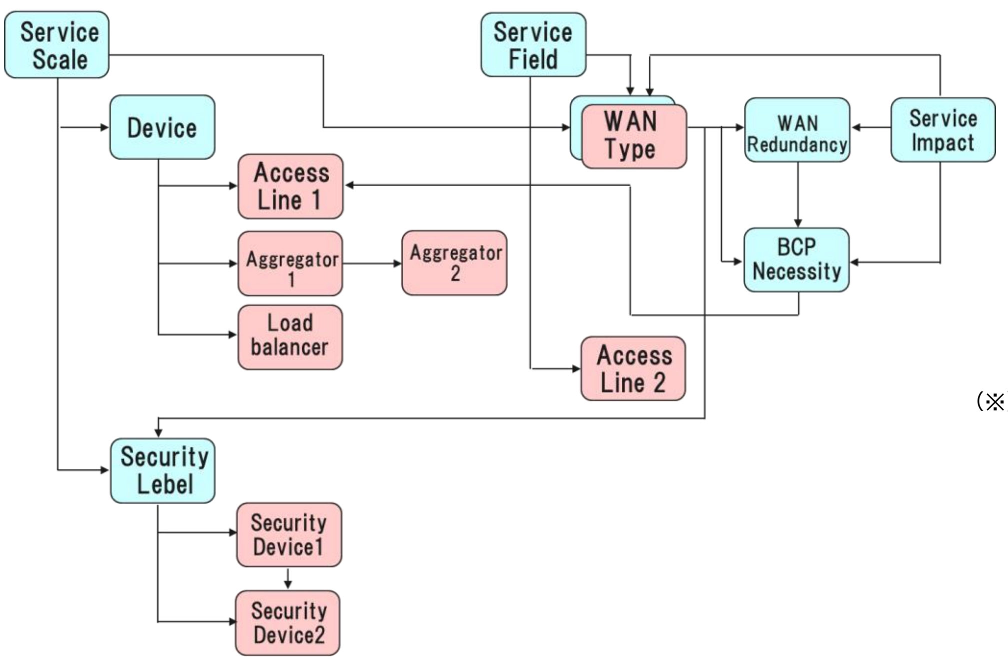
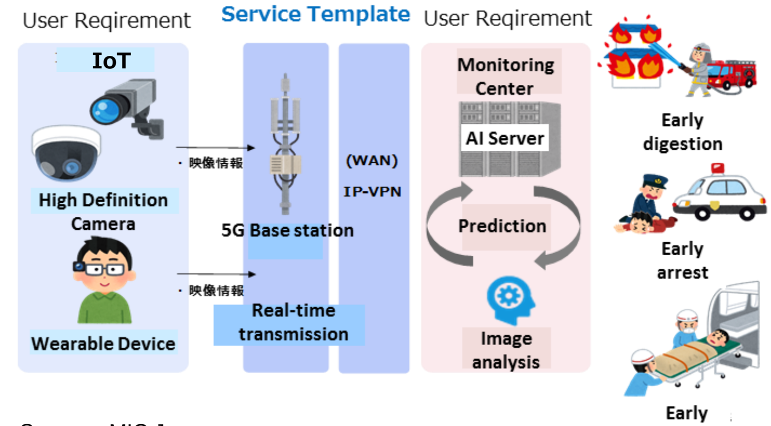
Data preparation for performance evaluation

- 52 use-cases are modelled as base data set
- Classified into industry categories
- Data augmentation with the consideration of feature correlation



Correlation between the feature parameters



(※) Source：MIC Japan
http://www.soumu.go.jp/main_sosiki/joho_tsusin/top/local_support/ict/index.html

Use-case examples

ML performance

Target Industry Category	Accuracy		
	Random Forest	GBDT	LightGBM
Smart city	0.837	0.876	0.855
Construction	0.799	0.858	0.828
Commerce	0.846	0.923	0.928
Manufacturing	0.835	0.877	0.869
Transportation	0.795	0.845	0.831

Accuracy of 80% has been achieved for various industry cases

Contents

Summary

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1） We have developed a requirements analysis system that can handle the explosive growth of network configuration patterns in the future.

→ Extract the service requirements from ambiguous user “intents”
→ Analyse the service requirements with expert knowledge in relevant industry

2） This system uses an Ensemble learning (stacking) for more accurate classification

→ Accuracy of 80% has been achieved for various industry cases

3） AI technology was applied for the first time to formulate network requirements, and basic technology could be established.

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