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Recommendation

ITU-T Y.3400 (12/2023)

SERIES Y: Global information infrastructure, Internet protocol aspects, next-generation networks, Internet of Things and smart cities

Future networks

Coordination of networking and computing in IMT-2020 networks and beyond – Requirements

ITU-T Y-SERIES RECOMMENDATIONS

Global information infrastructure, Internet protocol aspects, next-generation networks, Internet of Things and smart cities

GLOBAL INFORMATION INFRASTRUCTURE	Y.100-Y.999
General	Y.100-Y.199
Services, applications and middleware	Y.200-Y.299
Network aspects	Y.300-Y.399
Interfaces and protocols	Y.400-Y.499
Numbering, addressing and naming	Y.500-Y.599
Operation, administration and maintenance	Y.600-Y.699
Security	Y.700-Y.799
Performances	Y.800-Y.899
INTERNET PROTOCOL ASPECTS	Y.1000-Y.1999
General	Y.1000-Y.1099
Services and applications	Y.1100-Y.1199
Architecture, access, network capabilities and resource management	Y.1200-Y.1299
Transport	Y.1300-Y.1399
Interworking	Y.1400-Y.1499
Quality of service and network performance	Y.1500-Y.1599
Signalling	Y.1600-Y.1699
Operation, administration and maintenance	Y.1700-Y.1799
Charging	Y.1800-Y.1899
IPTV over NGN	Y.1900-Y.1999
NEXT GENERATION NETWORKS	Y.2000-Y.2999
Frameworks and functional architecture models	Y.2000-Y.2099
Quality of Service and performance	Y.2100-Y.2199
Service aspects: Service capabilities and service architecture	Y.2200-Y.2249
Service aspects: Interoperability of services and networks in NGN	Y.2250-Y.2299
Enhancements to NGN	Y.2300-Y.2399
Network management	Y.2400-Y.2499
Computing power networks	Y.2500-Y.2599
Packet-based Networks	Y.2600-Y.2699
Security	Y.2700-Y.2799
Generalized mobility	Y.2800-Y.2899
Carrier grade open environment	Y.2900-Y.2999
FUTURE NETWORKS	**Y.3000-Y.3499**
CLOUD COMPUTING	Y.3500-Y.3599
BIG DATA	Y.3600-Y.3799
QUANTUM KEY DISTRIBUTION NETWORKS	Y.3800-Y.3999
INTERNET OF THINGS AND SMART CITIES AND COMMUNITIES	Y.4000-Y.4999
General	Y.4000-Y.4049
Definitions and terminologies	Y.4050-Y.4099
Requirements and use cases	Y.4100-Y.4249
Infrastructure, connectivity and networks	Y.4250-Y.4399
Frameworks, architectures and protocols	Y.4400-Y.4549
Services, applications, computation and data processing	Y.4550-Y.4699
Management, control and performance	Y.4700-Y.4799
Identification and security	Y.4800-Y.4899
Evaluation and assessment	Y.4900-Y.4999

For further details, please refer to the list of ITU-T Recommendations.

Recommendation ITU-T Y.3400

Coordination of networking and computing in IMT-2020 networks and beyond – Requirements

Summary

The emergence of new services presents the need for the support of critical service requirements on computing, networking and storage resources at the same time. Coordination among resources of the same or of different types of resources (computing, networking and storage resource types) is necessary. By applying coordination of utilization, computing control and management, storage, and networking resources for the purposes of provisioning and optimization, satisfaction of requirements of resources users, and the improvement of resources utilization, may be achieved.

Recommendation ITU-T Y.3400 specifies the requirements for coordination of networking and computing in IMT-2020 networks and beyond (CNC).

History *

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Table of Contents

Page

1 Scope ... 1

2 References ... 1

3 Definitions ... 1

3.1 Terms defined elsewhere ... 1

3.2 Terms defined in this Recommendation ... 1

4 Abbreviations and acronyms ... 1

5 Conventions ... 2

6 Introduction ... 2

7 Requirements ... 2

7.1 Measurement of resources ... 2

7.2 Identification and addressing of resources ... 3

7.3 Awareness of resources ... 3

7.4 Joint scheduling of resources ... 4

7.5 Unified management and orchestration of resources ... 4

7.6 Resource transaction ... 5

7.7 Energy saving ... 6

7.8 QoS assurance ... 6

7.9 Fixed, mobile and satellite convergence ... 6

7.10 Intelligence and automation level ... 6

7.11 Security and privacy ... 7

Appendix I – Scenarios of coordination of networking and computing in IMT-2020 networks and beyond ... 8

Bibliography ... 11

Recommendation ITU-T Y.3400

Coordination of networking and computing in IMT-2020 networks and beyond – Requirements

1 Scope

This Recommendation specifies the requirements for coordination of networking and computing in IMT-2020 networks and beyond (CNC).

Appendix I illustrates some relevant application scenarios for CNC.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T Y.3101] Recommendation ITU-T Y.3101 (2018), *Requirements of the IMT-2020 network.*

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 fixed, mobile and satellite convergence (FMSC) [b-ITU-T Y.3200]: The capabilities that provide services and applications to end users regardless of the fixed, mobile or satellite access technologies being used independently of the users' location.

3.1.2 IMT-2020 [b-ITU-T Y.3100]: Systems, system components, and related technologies that provide far more enhanced capabilities than those described in [b-ITU-R M.1645].

3.1.3 machine learning (ML) [b-ITU-T Y.3172]: Processes that enable computational systems to understand data and gain knowledge from it without necessarily being explicitly programmed.

3.1.4 network function [b-ITU-T Y.3100]: In the context of IMT-2020, a processing function in a network.

3.2 Terms defined in this Recommendation

None.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

AI Artificial Intelligence

AR Augmented Reality

CNC Coordination of Networking and Computing in IMT-2020 networks and beyond

CPU Central Processing Unit

DLT	Distributed Ledger Technology
e-VLBI	Electronic Very Long Baseline Interferometry
FMSC	Fixed, Mobile and Satellite Convergence
IMT-2020	International Mobile Telecommunication 2020
IoV	Internet of Vehicles
ML	Machine Learning
QoS	Quality of Service
VR	Virtual Reality

5 Conventions

In this Recommendation:

The keywords "is required to" indicate a requirement which must be strictly followed and from which no deviation is permitted, if conformance to this Recommendation is to be claimed.

The keywords "is recommended" indicate a requirement which is recommended but which is not absolutely required. Thus, this requirement need not be present to claim conformance.

The keywords "can optionally" indicate an optional requirement which is permissible, without implying any sense of being recommended. This term is not intended to imply that the vendor's implementation must provide the option, and the feature can be optionally enabled by the network operator/service provider. Rather, it means the vendor may optionally provide the feature and still claim conformance with this Recommendation.

6 Introduction

The emergence of new services presents the need for the support of critical service requirements in computing, networking and storage resources at the same time. Coordination among resources of the same or of different types (computing, networking and storage resource types) is necessary.

By applying coordination of utilization, control and management of computing, storage, and networking resources for the purposes of provisioning and optimization, satisfaction of requirements of resources users and improvement of resource utilization may be achieved.

In the context of IMT-2020 networks and beyond, coordination of networking and computing in IMT-2020 networks and beyond (CNC) aims to address new network requirements, including, but not limited to, those imposed by application scenarios requiring extreme low latency, high computing, high mobility, dynamic services and energy savings. Appendix I illustrates some relevant application scenarios of CNC.

7 Requirements

This clause specifies the requirements for the coordination of utilization, control and management of computing, storage, and networking resources in IMT-2020 networks and beyond.

NOTE – CNC functions may be exposed to resource users or resource providers in order to support the utilization, and control and management of resources. For example, the resource characteristics may be exposed to resources users in order to check whether the users' requirements are met.

7.1 Measurement of resources

Computing, storage and networking resources are in general of a heterogeneous nature.

NOTE 1 – Multiple dimensions of computing resources include computing resource type, computing resource characteristics, such as capacity, performance, central processing unit (CPU) frequency and number of CPU cores.

NOTE 2 – Multiple dimensions of storage resources include storage resource type, storage resource characteristics, such as storage capacity, storage access speed, storage operation time cycle and storage reliability.

NOTE 3 – Multiple dimensions of networking resources include networking resource type, and networking resource characteristics, such as bandwidth and delay.

The CNC functions are required to measure the characteristics of the resources in a unified and comprehensive way.

NOTE 4 – Techniques for measurement of the characteristics of the networking resources are already available, for example, concerning network bandwidth and network delay.

NOTE 5 – The bandwidth and latency of networking resources to connect multiple computing resources may affect the overall performance of multiple computing resources.

NOTE 6 – The bandwidth and latency of networking resources to connect multiple storage resources also affect the overall performance of multiple storage resources.

7.2 Identification and addressing of resources

CNC may use resources from multiple resource providers. In order to utilize, as well manage and control these resources, CNC needs to uniquely identify and address them.

– The CNC functions are required to uniquely address resources, including in the case of resources from multiple resource providers.

  NOTE 1 – Techniques for addressing of networking resources are already available, for example, Internet protocol (IP) address and transmission control protocol (TCP) port [b-IETF RFC 793].

– The identification of resources is required to be verifiable.

  NOTE 2 – Unified identification and addressing information is actually used by resource awareness, resource scheduling, and management and transaction.

7.3 Awareness of resources

Resources may be deployed in a distributed fashion, their status may vary over time, and they may belong to different resource providers, resulting in the possible inability to collaboratively schedule and optimize them efficiently. To have an overall and up to date view of the resource status, and further utilize, manage and control these resources jointly, a resource awareness function is required. Considering the introduction of overhead network traffic and CNC processing, the efficiency of the awareness mechanisms also needs consideration.

NOTE 1 – Resource awareness addresses how resource-related information is obtained, while resource measurement (clause 7.1) addresses the generation of resource-related information locally, at the resource level.

– The CNC functions are required to have awareness of resource attributes.

  NOTE 2 – Resource attributes include, but are not limited to, the following:

  a) Resource type;

  b) Resource characteristics;

  c) Resource location;

  d) Resource cluster (if applicable).

– The CNC functions are required to have awareness of total resource information.

  NOTE 3 – Total resources include available resources and used resources.

– The CNC functions are required to have awareness of subscription information on resources.

NOTE 4 – Examples of subscription information include terms of validity.

– The CNC functions are required to have awareness of resource operational status information.

NOTE 5 – Examples of operational status information include, but are not limited, response time.

– The CNC functions are required to have awareness of anomaly usages of resources and their locations.

– The CNC functions are required to have awareness of historic data of resources.

– The CNC functions are recommended to adjust the awareness period (i.e., a fixed period of time over which periodic acquisition of status information is made) according to the expected frequency of resource status changes and/or resource usage.

NOTE 6 – A short awareness period can be set for resources with a high frequency of status changes or resource usage, while a long awareness period can be set for resources with a low frequency of status changes or resource usage. This can reduce the amount of awareness information to be processed by CNC as well as the related network traffic, and improve the efficiency of the awareness mechanisms.

– The CNC functions are recommended to consider the energy efficiency of resources.

– The CNC functions are recommended to be aware of the priority of resource requirements.

NOTE 7 – Resource users may impose different requirements on resources. For example, for an augmented reality (AR)/virtual reality (VR) service or a cloud gaming service, the resources requirements are different. The resource requirements may include multiple parameters, such as latency and security related parameters, and resource users may specify their priority (e.g., the latency related parameter may be the first priority requirement that needs to be met, and the security related parameter the second priority requirement that needs to be met).

NOTE 8 – The integration of distributed ledger technology (DLT) functionalities may benefit the resource awareness among multiple resource providers in the case of lack of trust.

7.4 Joint scheduling of resources

For optimization purposes, the coordination of networking, computing and storage resources is required to ensure the joint optimization of the different resources, including from different resource providers. For example, as concerns the scientific computing applications introduced in Appendix I, the joint scheduling of the three different types of resources may be required in order to reduce the computing time and improve the whole resource utilization.

– The CNC functions are required to support joint scheduling of resources.

NOTE 1 – The joint scheduling of resources may consider information such as topology information, resource operation status information and resource requirements.

– The CNC functions are recommended to enable the support of the generation of joint scheduling policies of resources in a centralized way.

NOTE 2 – The integration of DLT functionalities may benefit joint resource scheduling among multiple resource providers in the case of lack of trust.

7.5 Unified management and orchestration of resources

In order to further improve network management efficiency, the coordination of networking, computing and storage resources benefits from unified management and orchestration of resources.

– The CNC functions are required to support unified registration, configuration, provision and authentication of resources.

– The CNC functions are required to support the monitoring of resources.

NOTE 1 – Monitoring includes capacity monitoring, fault monitoring and performance monitoring.

– The CNC functions are required to provide alternate resources when monitored resources are not available or not adequate to the resource requirements.

– The CNC functions are required to have autonomous anomaly detection capabilities to realize safety isolation of resources.

– The CNC functions are required to have fault discovery and fault recovery capabilities on resources.

– The CNC functions are recommended to support unified management of the storage of resource information data.

NOTE 2 – Stored resource information data may include operational data, log data and fault data.

– The CNC functions are required to support unified management interfaces for resources independently of their attributes.

NOTE 3 – Management interfaces include resource registration interface, resource configuration, resource provision interface and resource authentication interface.

NOTE 4 – The integration of DLT functionalities may benefit the unified resource management and orchestration among multiple resource providers in the case of lack of trust.

7.6 Resource transaction

Resource transaction aims to realize resource matching of resource supply and resource demand between the resource users and the resource providers [b-BBF TR 466].

NOTE 1 – The aggregation of multiple providers' resources is a relevant aspect to be handled by the resource transaction.

The parties involved in a resource transaction include, but are not limited to, resource users, resource providers and the CNC resource transaction function. The resource transaction policies are used to define the matching rules of resource supply and resource demand. Through the CNC resource transaction function, which executes the resource transaction policies, the resource users and the resource providers agree on the resource trading terms through contracts, including but not limited to, resource transaction amount, resource transaction performance and resource transaction price.

– The CNC functions are required to support unified management of resource transaction information.

NOTE 2 – There is resource transaction information related to resource users and resource providers, including but not limited to, accounting information and multi-party settlement information.

– The CNC functions are required to receive the resource users' requirements of resources and publish resource user's requirements to resource providers, including lower price demand or higher price demand.

– The CNC functions are required to match the resource user's requirements and resource providers' supply and select the optimal resources for resource users.

– The CNC functions are required to support the capability of storage management of transaction data.

NOTE 3 – Resource transaction data includes, but is not limited to, data related to resource transaction contract information, resource transaction ledger information and resource exchange information.

– The CNC functions are recommended to support multiple resource transaction policies, including, but not limited to, policies for performance-based weighted resource transactions, price-based weighted resource transactions, global energy efficiency optimization resource transactions, global volume-based resource transactions.

– The CNC functions are recommended to support the capability of managing resource user's quality of experience.

– The CNC functions are recommended to support the capability of providing resource transaction incentives.

NOTE 4 – The resource transaction incentives are used to encourage the resource providers to provide resources as previously agreed in order to increase the motivation of resource providers and to avoid malpractice. Resource transaction incentives may include monetary and/or non-monetary incentives. An example of non-monetary incentive is reputation of resource providers, which increases when resources are provided as previously agreed.

NOTE 5 – The integration of DLT functionalities may benefit the resource transaction among multiple resource providers in case of lack of trust.

7.7 Energy saving

With the background of low carbon emission and energy saving, there is an urgent need for CNC to consider the related requirements and introduce new capabilities to support these requirements.

– The CNC functions are required to have awareness of energy related information (including, but not limited to, consumption, energy type and energy efficiency) of resources.

– The CNC functions are required to be aware of resource energy requirements, including, but not limited to, energy consumption demand.

– The CNC functions are required to support resource scheduling policies which address resource energy requirements and energy related information.

7.8 QoS assurance

Quality of service (QoS) assurance concerns functionalities or mechanisms that enable service providers to have a degree of confidence that the service meets the quality characteristics or objectives previously defined. In the context of IMT-2020 networks and beyond, coordination of networking and computing implies new requirements on QoS assurance, including the aspects of QoS planning, QoS provisioning, QoS monitoring, and QoS optimization.

The QoS aspects for coordination of networking and computing deal with the QoS assurance, and new QoS assurance-related mechanisms are required.

7.9 Fixed, mobile and satellite convergence

Fixed, mobile and satellite convergence (FMSC) concerns the capabilities that provide services and applications to end users regardless of the fixed, mobile or satellite access technologies being used [b-ITU-T Y.3200].

– The CNC functions are required to provide support to the FMSC functions, including consideration of the FMSC network characteristics [b-ITU-T Y.3200].

7.10 Intelligence and automation level

Future networks including IMT-2020 need to support a huge scale of resource categories and resource amounts, and a rich variety of services, thus presenting a high degree of complexity. For the needs of providing measurement, awareness, scheduling and management of large and heterogeneous resources, and the needs of intelligent processing of large amounts of data, it is necessary to enhance the intelligence and automation level of CNC.

– The CNC functions are required to have the capability of data processing, modelling and analysis to operate and manage resources.

– The CNC functions are required to have the capability of assessment, including risk assessment, of resources.

– The CNC functions are required to have the capability of prediction on fault, performance decrease, resource consumption and energy consumption.
– The CNC functions are required to have the capability of recognition, analysis and treatment of resource users' requirements.
– The CNC functions are required to have the capability of intelligent scheduling, including intelligent scheduling strategy generation, execution, adjustment and switching.
– The CNC functions are required to have the capability of intelligent management operation and maintenance, including intelligent fault management, intelligent configuration management, intelligent accounting management, intelligent performance management and intelligent security management.

NOTE – The integration of artificial intelligence (AI) / machine learning (ML) functionalities may benefit the intelligence and automation level of CNC.

7.11 Security and privacy

– The CNC functions are required to verify the credibility of resource information.

NOTE 1 – The resource information includes, but is not limited to, the source of the resource information and the resource attributes.

NOTE 2 – Possible means to verify the credibility of the resource information include, but are not limited to, authentication and encryption mechanisms.

– The CNC functions are required to authorize the access to the resource information.
– The CNC functions are required to authenticate and authorize the source of resource scheduling policy.
– The CNC functions are required to authenticate the identity of resource users.
– The CNC functions are required to keep the resource usage records of resource users confidential.

NOTE 3 – Possible means to keep confidentiality include, but are not limited, to encryption mechanisms.

NOTE 4 – Resource usage records include, but are not limited to, information on resource usage time, resource usage amount and resource usage location.

– The CNC functions are required to keep the resource status information confidential.

NOTE 5 – Resource status information has to not be disclosed according to the security policies, e.g., to other resource providers.

– The CNC functions are recommended to encrypt the resource information and the scheduling policy to avoid information leakage.

In addition, the security and privacy related requirements specified in [ITU-T Y.3101] are applicable to this Recommendation.

Appendix I

Scenarios of coordination of networking and computing in IMT-2020 networks and beyond

(This appendix does not form an integral part of this Recommendation.)

Scenario 1: Low latency and high computing requirements

The cloud virtual reality (VR) service introduces the concept and technology of cloud computing and cloud rendering into VR business applications. With the help of a high speed and stable network, the network transmits the display output and sound output of the cloud to the user's terminal device after encoding and compression, as shown in Figure I.1.

A cloud VR service has high requirements for computing, networking and storage. Concerning computing, multi-channel parallel computing is required to realize video codec, real-time content generation and content rendering. Concerning networking, the network needs to provide large bandwidth, low delay and very low packet loss rate to ensure that the content generated by the cloud can be reliably distributed to the user side with low delay. Concerning storage, the huge amount of generated content requires a large amount of storage space, and the higher the quality of the video is, the more content is generated, and the more storage space is required. Consequently, according to the service requirements, the measurement of resources, the awareness of these resources and the joint scheduling of these resources are required.

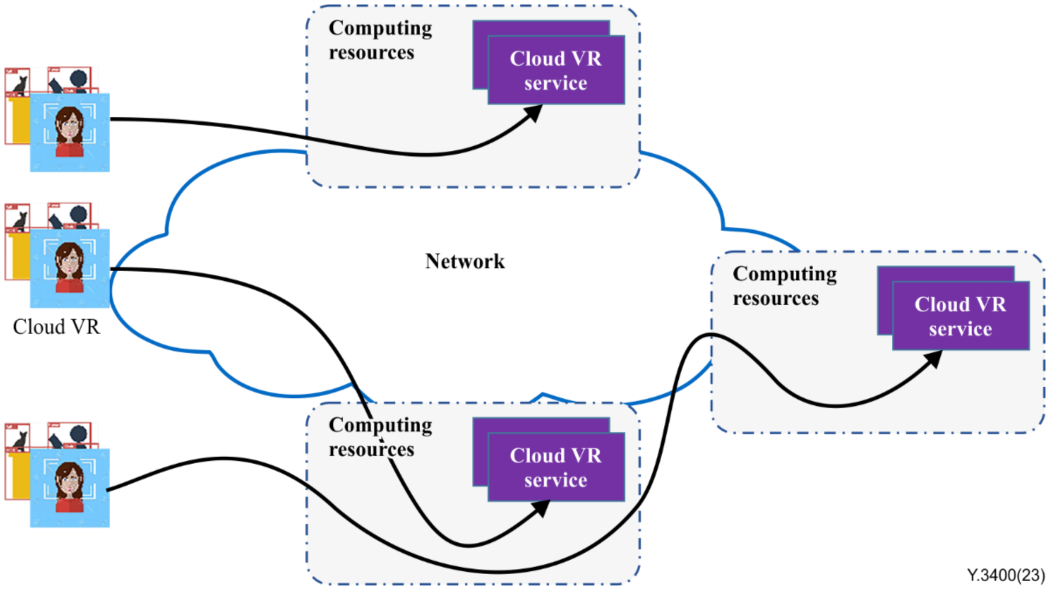

Figure I.1 – Cloud VR

Scenario 2: Service consistency

In an Internet of vehicles (IoV) scenario, services are divided into auxiliary driving services and onboard entertainment services, as shown in Figure I.2. Concerning the auxiliary driving services, they could obtain overall traffic information around the vehicle position through edge computing nodes and then process the data uniformly. There are differences between the services requirements of auxiliary driving services and entertainment services. Concerning latency, computing requirements and also the status of computing resources, CNC related capabilities should be aware of the classification of services and dispatch auxiliary driving service requests to nearby and idle computing resources (e.g., edge cloud 1 and edge cloud 2). On the other hand, the CNC related capabilities should schedule the onboard entertainment service related requests to remote edge clouds (e.g., edge cloud 3) while leaving the priority of the vehicle resource usage to the auxiliary driving services. Consequently, the measurement of resources, the awareness of resources and the joint scheduling of resources are required.

Furthermore, to improve network management efficiency, the unified management and orchestration of resources is required, and when the resources are from multiple resource providers, the identification and addressing of resources is required to manage and control these resources.

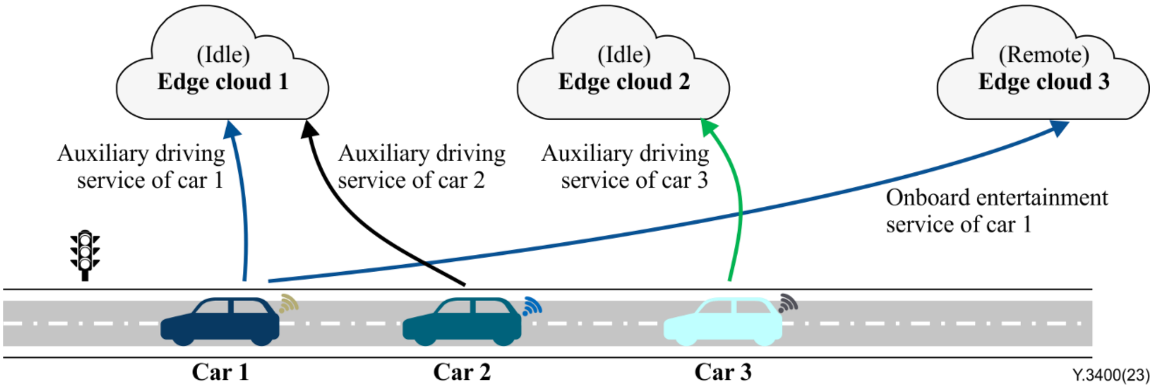

Figure I.2 – Connected vehicles

Scenario 3: Large-scale scientific data applications

Large-scale scientific experiments and observations produce vast amounts of data. Many scientific devices collect and transmit data to a remote processing centre for real-time analysis during observation. For example, during an electronic very long baseline interferometry (e-VLBI) observation, data is continuously collected by multiple radio telescopes distributed at different locations. A delay in one node's flow will result in the delay of the analysis result.

Given the telescopes' minimal local storage resources, the continuous data gathered must be transferred in real-time to remote storage nodes, otherwise data will be lost. Thus, the transfer link of scientific data requires a high quality guarantee, such as low packet loss rate, low latency and low jitter, which means that the network needs to identify the scientific traffic and choose an optimal network path to meet the service requirements. Table I.1 presents requirement related information about various large-scale scientific data applications.

Table I.1 – Requirements of large-scale scientific data applications

Large-scale scientific data applications	Network requirement	Storage requirement	Computing requirement
High repetition frequency X-ray free electron laser device	10 Gbit/s	100 Petabytes (PB)	1-10 Petaflops (PF)
Shanghai Light Source Phase II	1 Gbit/s	500 PB	20-40 PF
BES (Beijing Spectrometer) III	100 Gbit/s	15 PB	10 PF
Major marine science and technology infrastructure	Quantum encrypted communication	0.5 Exabytes (EB)	100 PF

As shown in Figure I.3, different astronomical telescopes have individual configurations, such as decentralized global deployment and ground satellite communications. When using e-VLBI observation for locating spacecraft, the analysis results are needed in real-time. Therefore, the data should be synchronously transferred to the remote processing centre and the remote processing centre needs to be able to finish the calculation synchronously. Consequently, it is important to consider the coordination of storage resources and networking resources. For such scenarios, only considering the network status or the remote processing centre status or the storage resource status cannot ensure the end-to-end service experience. For coordination of networking and computing, it is necessary to consider the networking resources status, as well as the storage resources status and the computing resources status to complete the scientific data processing. Consequently, the measurement of resources and the awareness of resources are required.

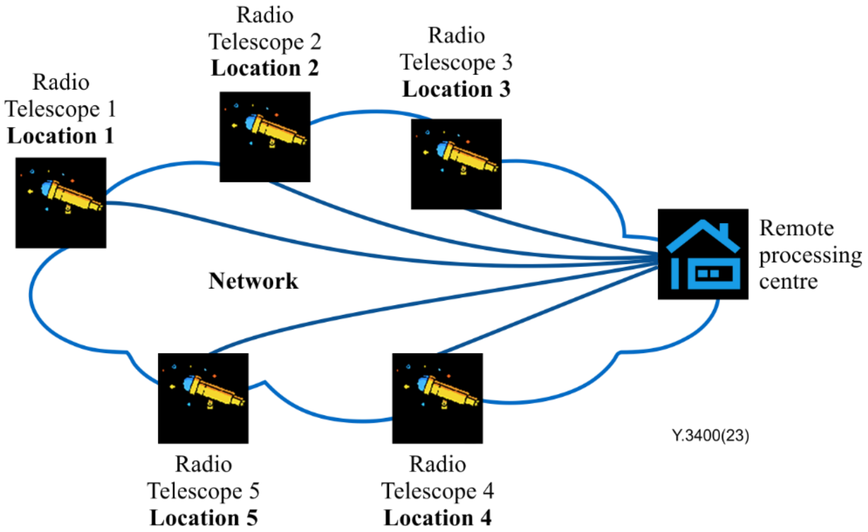

Figure I.3 – Astronomical telescopes observation

Bibliography

[b-ITU-T Y.3100]	Recommendation ITU-T Y.3100 (2017), *Terms and definitions for IMT-2020 network*.
[b-ITU-T Y.3102]	Recommendation ITU-T Y.3102 (2018), *Framework of the IMT-2020 network*.
[b-ITU-T Y.3172]	Recommendation ITU-T Y.3172 (2019), *Architectural framework for machine learning in future networks including IMT-2020*.
[b-ITU-T Y.3200]	Recommendation ITU-T Y.3200 (2022), *Fixed, mobile and satellite convergence – Requirements for IMT-2020 networks and beyond.*
[b-ITU-R M.1645]	Recommendation ITU-R M.1645 (2003), *Framework and overall objectives of the future development of IMT-2000 and systems beyond IMT-2000*.
[b-BBF TR 466]	Broadband Forum: TR 466 (2021), *Metro Compute Networking: Use Cases and High Level Requirements*.
[b-IETF RFC 793]	IETF RFC 793 (1981), *Transmission Control Protocol*.

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