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SERIES Y: GLOBAL INFORMATION INFRASTRUCTURE, INTERNET PROTOCOL ASPECTS, NEXT-GENERATION NETWORKS, INTERNET OF THINGS AND SMART CITIES

Big Data

Big data-driven networking – Functional architecture

Recommendation ITU-T Y.3653

ITU-T

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Recommendation ITU-T Y.3653

Big data-driven networking – Functional architecture

Summary

Recommendation ITU-T Y.3653 specifies a functional architecture for big data-driven networking, which includes: an overview of functional architecture, functional architecture for a big-data plane, functional architecture for a network plane and functional architecture for a management plane.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T Y.3653	2021-04-29	13	11.1002/1000/14615

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Big data-driven networking, functional architecture.

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1 Scope

This Recommendation specifies a functional architecture for big data-driven networking. The scope of this Recommendation includes:

- an overview;
- functional architecture for a big-data plane;
- functional architecture for a network plane;
- functional architecture for a management plane;
- other aspects.

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 M.3400] Recommendation ITU-T M.3400 (2000), *TMN management functions*.

[ITU-T Y.2704] Recommendation ITU-T Y.2704 (2007), *Security mechanisms and procedures for NGN*.

[ITU-T Y.2770] Recommendation ITU-T Y.2770 (2012), *Requirements for deep packet inspection in next generation networks*.

[ITU-T Y.2771] Recommendation ITU-T Y.2771 (2014), *Framework for deep packet inspection.*

[ITU-T Y.3650] Recommendation ITU-T Y.3650 (2018), *Framework of big-data-driven networking.*

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following term defined elsewhere:

3.1.1 big-data-driven networking (bDDN) [ITU-T Y.3650]: Big-data-driven networking (bDDN) is a type of future network framework that collects big data from networks and applications, and generates big data intelligence based on the big data; it then provides big data intelligence to facilitate smarter and autonomous network management, operation, control, optimization and security, etc.

3.2 Terms defined in this Recommendation

None.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

bDDN	big Data-Driven Networking
CLI	Command Line Interface
DPI	Deep Packet Inspection
ETL	Extract Transform Load
FCAPS	Faults, Configuration, Accounting, Performance and Security
FTP	File Transfer Protocol
GRPC	Google Remote Procedure Call
HTTP	Hyper-text Transport Protocol
MPP	Massively Parallel Processing
NA-OAM	Network Application layer OAM
NAS	Network Attached Storage
NC-OAM	Network Control layer OAM
NetConf	Network Configuration
NFV	Network Function Virtualization
NI-OAM	Network Infrastructure layer OAM
OAM	Operation, Administration and Maintenance
QoS	Quality of Service
SDN	Software-Defined Network
SLA	Service Level Agreement
SNMP	Simple Network Management Protocol
VNF	Virtualized Network Function
WAN	Wide Area Network
YANG	Yet Another Next Generation

5 Conventions

This Recommendation uses the following conventions:

In the body of this document and its annexes, the words "should", and "may" sometimes appear, in which case they are to be interpreted, respectively, as "is recommended", and "can optionally". The appearance of such phrases or keywords in an appendix or in material explicitly marked as informative are to be interpreted as having no normative intent.

6 Overview of functional architecture for big data-driven networking

Big data-driven networking (bDDN) uses the big data generated by a network itself to improve the capability of network control and management. As is described in [ITU-T Y.3650], the key characteristics of bDDN include:

- introduction of a big-data plane to enable end-to-end network intelligence and artificial intelligence to future networks;

- collection of network big data, and analysis of the network state using these data;
- enablement of autonomous control and management of the network according to the results of the analysis;
- compatibility with a software-defined network (SDN) framework, as well as support for network orchestration and programmability.

NOTE – "End-to-end network intelligence" means intelligent service to all layers of the management plane and all aspects of network plane.

As is shown in Figure 7-1 of [ITU-T Y.3650], the bDDN framework is made up of three planes for:

- big data;
- management;
- the network.

Each plane is composed of several layers or several aspects. The big-data plane is composed of four layers for its:

- sensing;
- a repository;
- computing and analytics;
- intelligence and service.

The data sensing layer is the basic layer, which, with the help of deep packet inspection (DPI) [ITU-T Y.2770] and [ITU-T Y.2771] and other technologies, collects various data (including that on traffic, network device performance, network management and operations) from the network scientifically. The big-data plane also collects some external circumstance data that may have an impact on networks. Such real time massive and inclusive information from all network dimensions and the external environment is critical to reveal the true face of network circumstances and problems, distinct from current non-intuitive, tiresome trouble shooting and defence against hackers. The collection data is stored in a repository that is based on cloud architecture, and the data storage repository function is deployed in the data storage repository layer. To genuinely solve network problems and decrease network complexity, a data computing and analytics layer is needed, in which various network models and cloud computing capability are applied, although collection data contain all the necessary information. The computing methods, models, capabilities and even the form of results can be either preconfigured or freshly issued by the data intelligence layer. The data intelligence and service layer needs to further process the result into handy information and to give clear instructions (according to the topology, device manufacture, network status, etc.), as well as providing end to end network intelligence to the other two planes in the form of service.

The network plane is composed of three layers for its:

- infrastructure;
- control;
- application.

The network infrastructure layer includes all kinds of network devices performing packet transmission. The network control layer includes network controllers, responsible for policy making and dispatching. The application layer includes different kinds of user application, such as those for network reconstruction, security, quality of service (QoS) and load balance.

The management plane includes three aspects for network:

- operation;
- administration;

• maintenance.

Taking advantage of data analysis and end-to-end network intelligence in the big-data plane, the management plane automates the network, handling smart maintenance, trouble shooting, configuration and optimization. The management plane can further bring about elaborate fine-grain network operation according to user requirements and feedback, which can provide customers with a better network surfing experience.

There are two autonomous circles in the framework for:

• control;

• management.

The autonomous control circle is formed between the big-data and network planes and represents the big data-driven control process, while the autonomous management circle is formed between the big-data and management planes and represents the big data-driven operation, administration and maintenance (OAM) process.

7 Functional architecture of the big-data plane for big data-driven networking

The big-data plane is the core part of the bDDN architecture. It consists of four layers for network big data: sensing; a repository; analysis; and intelligence and service. The overall functional architecture of the big-data plane is shown in Figure 7-1.

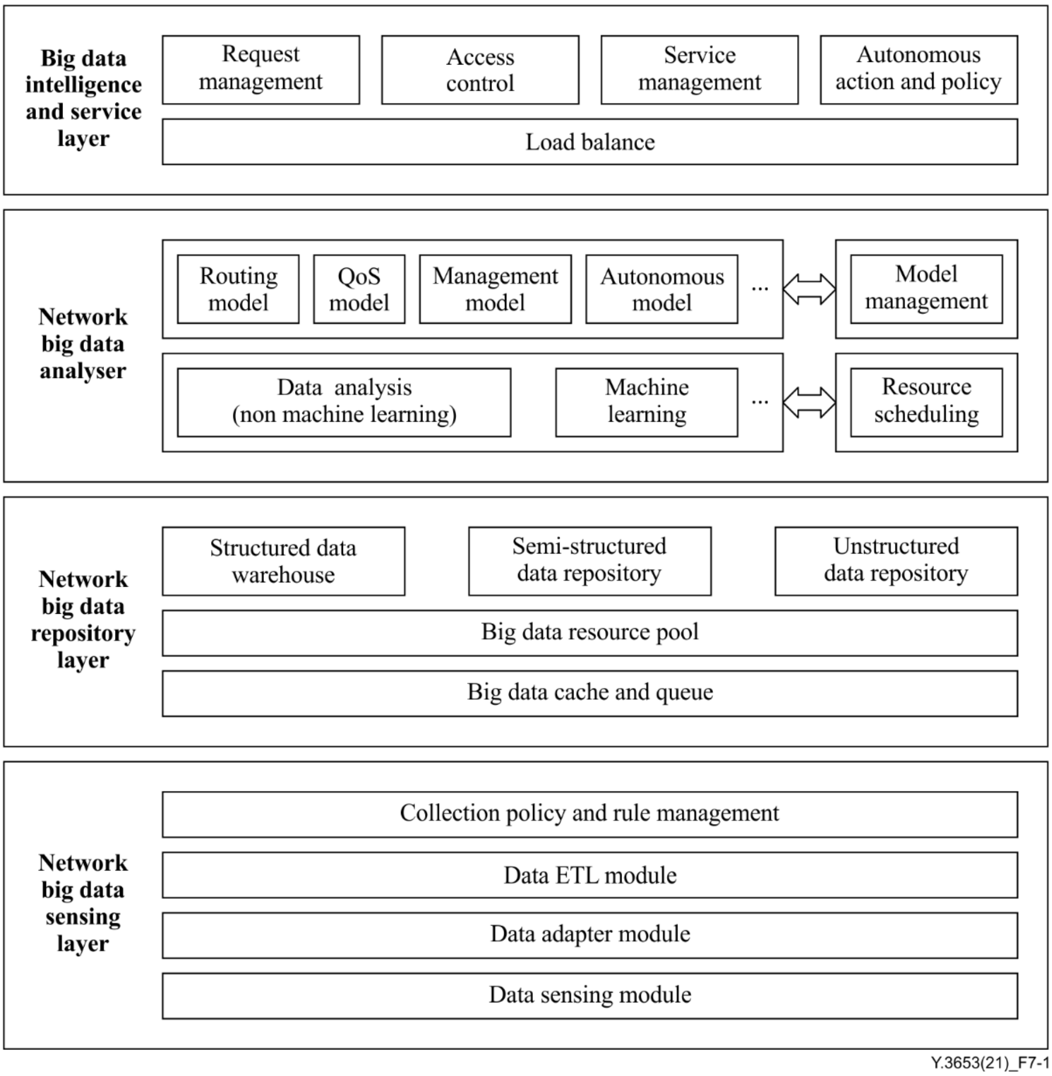


Figure 7-1 – Functional architecture of the big-data plane

7.1 Network big data-sensing layer

The functional architecture of the network big data-sensing layer can be seen in Figure 7-2 and includes four modules for: sensing; an adapter; extract transform load (ETL); and collection policy and rule management.

The data sensing module is responsible for collecting data from the network. There are two sensing modes: active and passive.

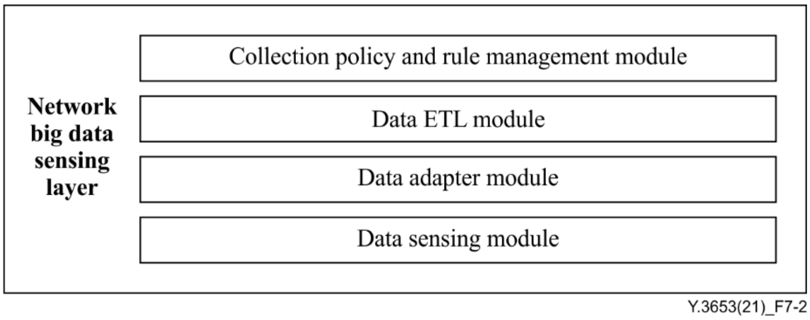
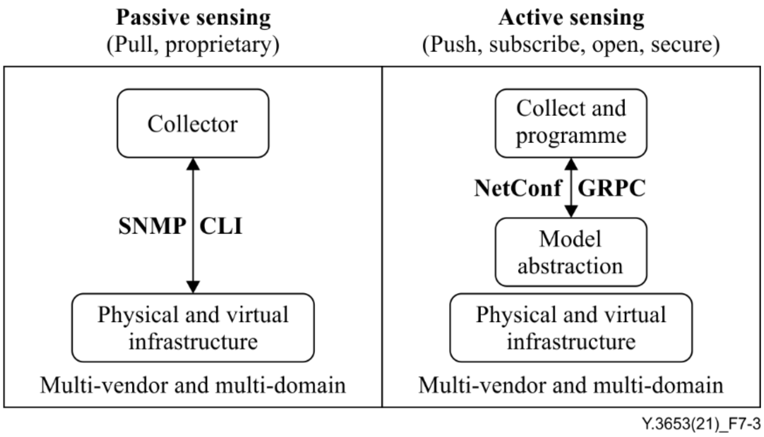


Figure 7-2 – Functional architecture of the network big data-sensing layer

Active sensing is a collection mode. It is a new approach for network monitoring, in which data is streamed from network devices continuously using a push method and provides near real-time access to operational statistics. Its characteristics are determined by operational needs and requirements set by telecommunication network operators. Active sensing enables vendor-agnostic network state monitoring on a continuous basis using time series streams, and abstracts data modelling from data transport, like the yet another next generation (YANG) model [b-IETF 6020] or Google remote procedure call (GRPC). Furthermore, one of the key differentiators in moving from passive to active sensing is the use of subscription-based data access, as opposed to request or trap-based desired data selection.

Figure 7-3 illustrates a few key differences between the passive and active sensing modes.



CLI: command line interface

Figure 7-3 – The difference between the push mode and traditional mode

bDDN can precisely define which data it wants to subscribe to using standard YANG [b-IETF 6020] models. It allows network devices to continuously stream real-time configuration and operating state information to subscribers. Structured data is published at a defined cadence, or on-change, based on subscription criteria and data type.

The adapter module is responsible for the management of various acquisition interfaces, including a variety of protocol interfaces, e.g., the simple network management protocol (SNMP), file transfer protocol (FTP) and hyper-text transport protocol (HTTP).

The ETL module is responsible for cleaning and transformation of original data; the ETL extracts the heterogeneous data to temporary middle storage, after cleaning and transformation, the data are finally loaded into a warehouse. These data are the basis of data processing and mining. This part also includes data standardization.

NOTE – YANG is a data modelling language used to model configuration and state data manipulated by the network configuration (NetConf) protocol.

The data collection policy and rule management module includes the management of the collection method, e.g., whether it is active or passive, and the collection object, interval and fields.

The data collection function from the data sensing module can be applied on the management and the network planes in a network, as well as other data sources out of the network.

At each plane, active sensing can be further partitioned into four distinct components, as shown in Figure 7-4.

- Data source component

  This component determines where the original data is acquired. The data source usually just provides raw data that needs further processing. A data source can be considered a probe. A probe can be statically or dynamically installed.

- Data subscription component

  This component determines the protocol and channel for applications to acquire desired data. Data subscription is also responsible for determining the desired data that might not be directly available from data sources. The subscription data can be described by a model. The model can be statically or dynamically installed.

- Data generation component

  The original data needs to be processed, encoded and formatted in network devices to meet application subscription requirements. This may involve in-network computing and processing on either the fast or slow path in network devices.

- Data export component

  This component determines how the available data are delivered to applications.

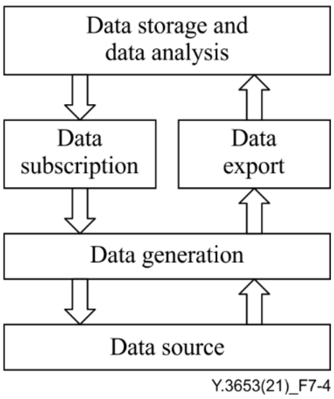


Figure 7-4 – Components of the active sensing module

7.2 Network big-data repository layer

As shown in Figure 7-5, in the big-data repository layer, there is a structured data warehouse, and semi-structured and unstructured data repositories. Structured data can be stored with a traditional relational database or on distributed Nosql technology and massively parallel processing (MPP) technology. Semi-structured and unstructured data can be stored in a distributed file system, network attached storage (NAS) or other Nosql repositories. A big-data resource pool makes all data available.

Some data may be processed in a real time streaming pattern; these data will also be stored in the big data resource pool after processing.

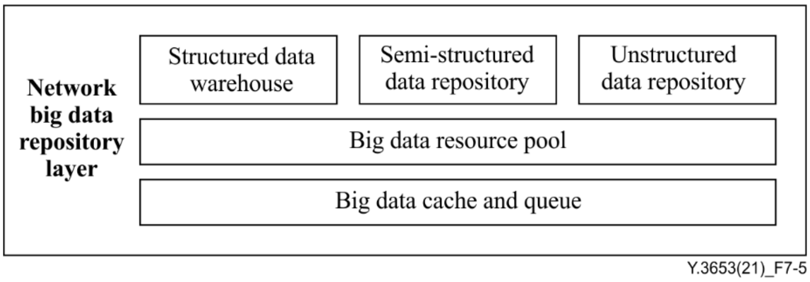


Figure 7-5 – Functional architecture of the network big-data repository layer

7.3 Network big-data processing layer

As shown in Figure 7-6, the network big data analyser layer is composed of two parts for:

- big-data processing;
- management.

The big-data processing part is mainly responsible for big data analysis and machine learning. Each process is based on the model of service. The model is from the requirements of the management and network planes. Also, machine learning technologies can be used in bDDN. The autonomous model is the result of the machine learning function. It means the big-data plane of bDDN can automatically learn and analyse the condition of the network from the big data collected, and formulate action and policy according to the results. The data-processing method can be divided into three aspects:

- on-line analysis;
- data mining;
- machine learning.

Resource scheduling needs to take account of computing, storage and communication resources. For example, a network device with superior performance can support online and off-line computing, while network devices with sufficient storage space and better computing performance can be deployed to support off-line processing of massive amounts of data.

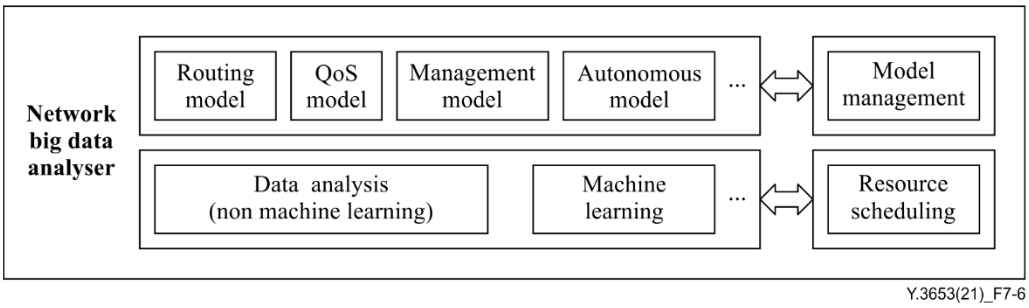


Figure 7-6 – The functional architecture of the network big-data analyser

7.4 Big data intelligence and service

The big data intelligence and service layer mainly deals with requests from the management and network planes. As shown in Figure 7-7, the big-data service layer includes request management and access control. On the other hand, the data service layer is also responsible for the management of service that is sent from the big-data plane to the management and network planes. Due to so many requests and services processed by the big-data plane, there is a requirement for the load balance to schedule resources and request dispatch. The autonomous action and policy function is generated by the autonomous model, which is also an important function of bDDN.

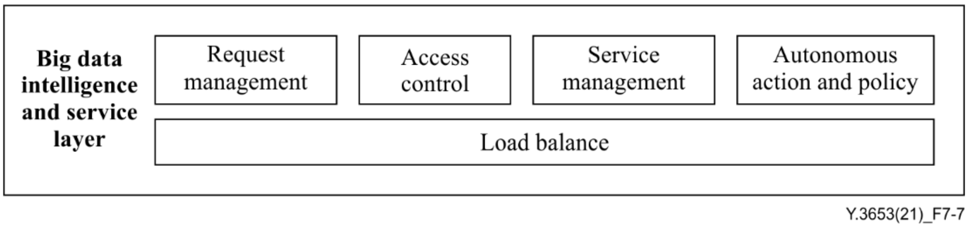
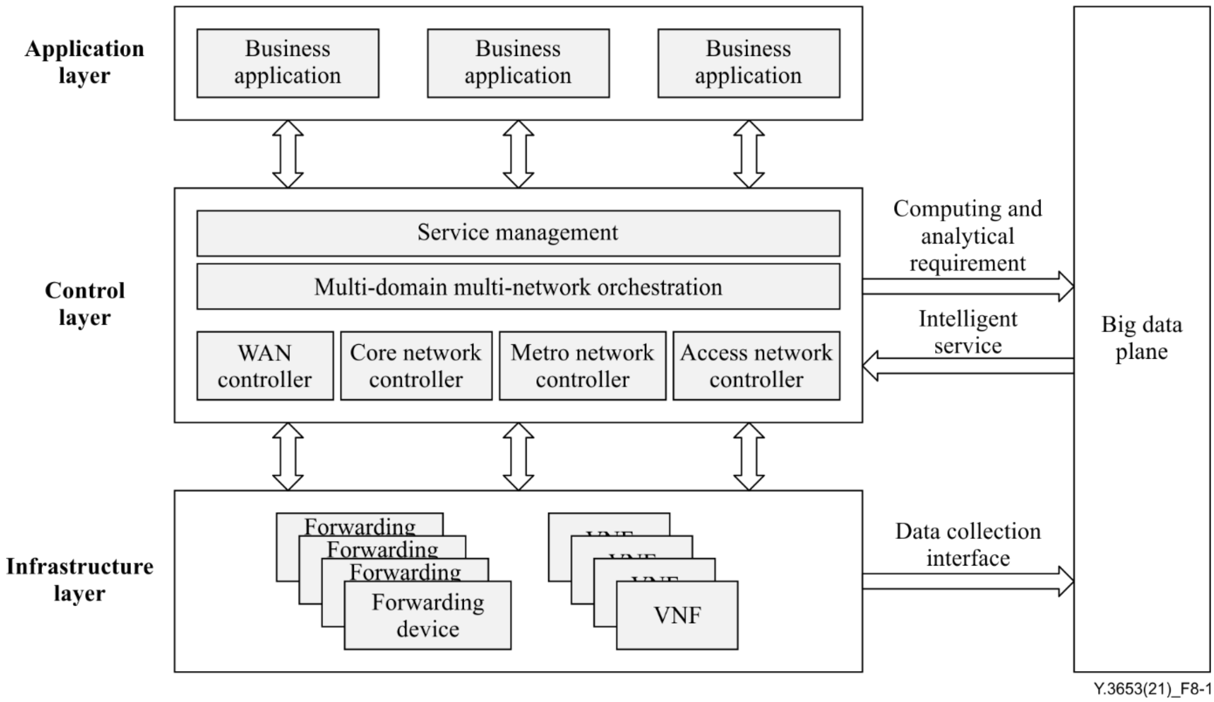


Figure 7-7 – Functional architecture of the big-data service layer

8 Functional architecture of the network plane for big data-driven networking

The network plane of bDDN consists of three layers, infrastructure layer, control layer and application layer. The overall functional architecture of network plane is shown in Figure 8-1.



VNF: Virtualized Network Function; WAN: Wide Area Network

Figure 8-1 – Functional architecture of network plane

8.1 Application layer

Applications specify network services in a programmatic manner in the application layer. These applications interact with the control layer via application-control interfaces, in order for the control layer to automatically customize the behaviour and properties of network resources.

8.2 Control layer

The control layer provides a means to dynamically control the behaviour of network resources (such as data transport and processing), as instructed by the application layer.

Applications specify how network resources should be scheduled and allocated by interacting with the control layer via interfaces. The signalling from the control layer to network resources is then delivered via resource-control interfaces. The configuration or properties exposed to applications are abstracted by means of information and data models. The level of abstraction varies according to the applications and the nature of the services to be delivered.

Service management can transform application requirements into a specific service of cloud and network, transform the service into a network orchestration request and network function virtualization (NFV) service chain orchestration request, and transmit it to the network orchestration layer.

The service management function requires a unified cloud and network collaborative orchestration. Service management is oriented to applications and user requirements, and can realize the unified end-to-end resource orchestration of network and cloud.

The multi-domain and multi-network orchestration function provides automatic control of network resources and coordination of requests from the application layer for network resources based on the policy provided by the application layer.

The multi-domain and multi-network orchestration function provides control for network resources that are from physical and virtual network elements.

The big-data plane provides an intelligent service interface to the control layer. The big-data plane generates the corresponding policy, resources, and forwarding rules according to requirements and the collected data (including the status of network device and network routing). Additionally, the big-data plane sends the results to the network plane.

The multi-domain and multi-network orchestrator then send these policies to each controller and then to the network devices and hardware resources under the controller.

8.3 Infrastructure layer

The infrastructure layer is where the network elements perform the transport and the processing of data packets according to the decisions made by the control layer.

The infrastructure layer provides a data collection interface to the big-data plane, the collected objects include various hardware equipment and software resources.

The data collected include that for the device state, traffic and device log.

9 Functional architecture of management plane of big data-driven networking

The management plane provides autonomous and smart OAM functionalities for the network plane according to the big data intelligence service from the big-data plane. The big-data plane is responsible for collecting and analysing the data from the network and management planes. The management plane interacts with the layers of the network plane using the i_{NM} interface defined in [ITU-T Y.3650]. The management plane is also responsible for the management of dynamically deployed services and coordinated (orchestrated) reconfiguration of network infrastructure resources. The management plane includes basic functionalities to handle faults, configuration, accounting, performance and security (FCAPS) as described in [ITU-T M.3400]. Examples of such functionalities are equipment inventory, fault isolation, performance optimization, and initial configuration of the network infrastructure layer, network control layer and network application layer.

As shown in Figure 9-1, management plane functions include network infrastructure layer OAM (NI-OAM), network control layer OAM (NC-OAM), and network application layer OAM (NA-OAM) functional components. Figure 9-1 simply shows the relationships among functional components.

The management plane can delegate some operations, specifically those which require intensive exchange of data with the network controller to be performed directly by the SDN-controller (e.g., so-called autonomous management operations).

The network plane of bDDN may adopt virtualization technology (NFV) to encapsulate network functions. Therefore, in the bDDN management plane, unified management and organization of the network can be realized within the NFV framework.

The bDDN network management based on NFV abstracts network functions, service channels, global resources and views from the perspective of network services, realizes virtual organization of computing, storage and network resources through bDDN network resource management technology, supports the elastic expansion of network services, and provides multi-layer network view services and network services through resource and service topology generation technology. The dynamic association of services, through network service composition technology, establishes the arrangement and adaptation of network functions and service channels, and forms a service function chain to meet the needs of network tenants.

Fault management and performance management in bDDN should also be designed and implemented based on NFV architecture. Fault management includes that of physical equipment and virtual units. Performance management also includes the performance of physical devices, links and virtual units.

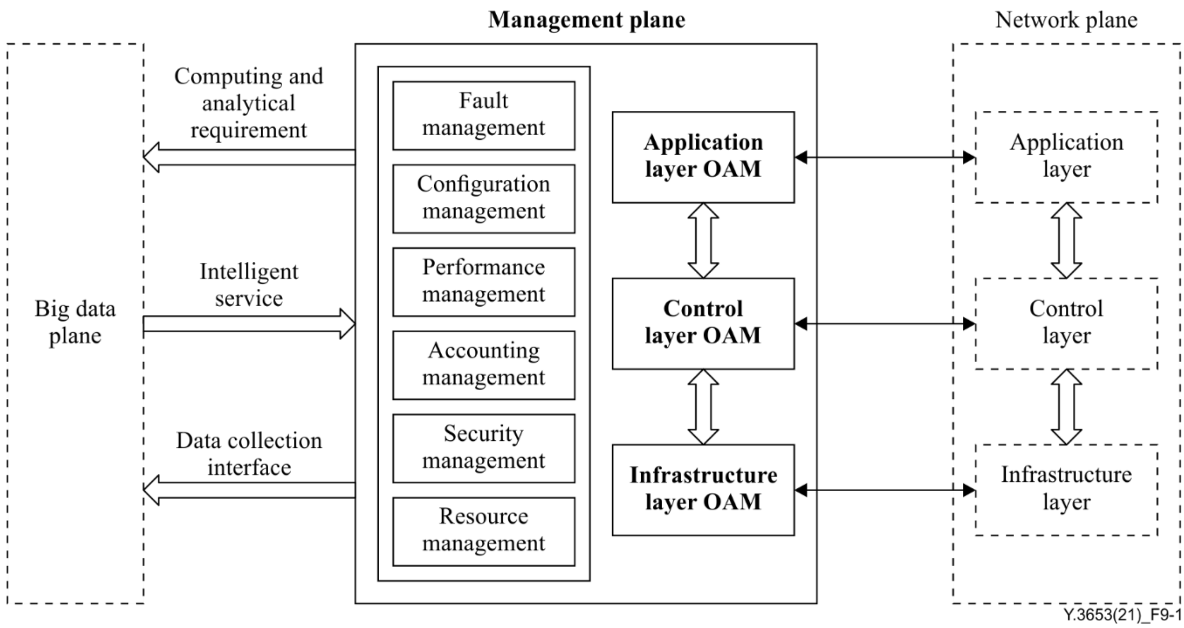


Figure 9-1 – Functional architecture of management plane

9.1 Network infrastructure layer management functional component

The NI-OAM functional component is responsible for the management of physical or virtual resources in the network infrastructure layer. The NI-OAM functional component provides capabilities for discovering and activation of virtual and physical resources to make them ready for operation. The NI-OAM functional component includes support for FCAPS and network infrastructure layer resource orchestration (e.g., coordinated resource reconfiguration). The NI-OAM functional component keeps track of the overall state of allocated and available resources in the network infrastructure layer.

The NI-OAM functional component is also responsible for managing and setting relationships between virtual and physical resources, performance correlation between virtual and physical resources, and faults by considering the relationship between virtual and physical resources, and finally isolation and control of any anomaly concerning network infrastructure resources, as well as authentication and authorization of network resources.

By providing the overall resource status information monitored as an input to the NI-OAM functional component, energy efficient resource management capability and other management capabilities can be realized by turning off unused resources or other methods.

9.2 Network control layer management functional component

The NC-OAM functional component includes management of resources used to deploy network control layer functions (hardware, software platforms, links between control plane and any other plane) in order to ensure high availability and scalability of the network control layer, it is necessary to manage performance, faults and security and control traffic generated between network control layer entities and the network infrastructure layer or network application layer entities.

The component can activate network control layer entities or their components, monitor performance of network control layer entities in terms of network reliability, utilization of network resource, detection of network status, root cause analysis and trace, and correction of faults of the network control layer.

The component can also provide detection, isolation and control of network control layer-related traffic and authentication and authorization management functionality.

The NC-OAM functional component provides policy management that can include business, technical, security, privacy and certification policies, which apply to control layer services and their usage by applications.

9.3 Network application layer management functional component

The NA-OAM functional component provides FCAPS management functionality for network application layer resources. It is also involved in cross-layer orchestration initiated by the network application layer.

The NA-OAM functional component provides network application lifecycle management, such as creation, activation, modification and deletion of network applications. It also provides performance monitoring of network applications to meet service level agreement (SLA) requirements.

The NA-OAM functional component provides fault detection, isolation and recovery functions for the network application.

The NA-OAM functional component also provides authentication, identity management and security management of third party network applications.

10 Security considerations

When using big data-driven networking, security best practices should be adopted, such as authentication, authorization and access control, as described in [ITU-T Y.2704].

In the meantime, operations related to network resources should be subject to multiple reliability guarantees in order to avoid incorrect operation of network resources that results in deterioration of network performance.

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