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

Cloud Computing

Framework of big-data-driven networking

Recommendation ITU-T Y.3650

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Recommendation ITU-T Y.3650

Framework of big-data-driven networking

Summary

Recommendation ITU-T Y.3650 specifies a framework for big-data-driven networking. The scope of this Recommendation includes the model architecture of big-data-driven networking (bDDN), the high-level capabilities of bDDN and the interface capabilities among different planes and layers.

History

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Recommendation ITU-T Y.3650

Framework of big-data-driven networking

1 Scope

This Recommendation specifies a framework for big-data-driven networking. The scope of this Recommendation includes the model architecture of big-data-driven networking (bDDN), the high-level capabilities of bDDN and the interface capabilities among different planes and layers.

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 X.200] Recommendation ITU-T X.200 (1994) | ISO/IEC 7498-1:1994, *Information technology – Open Systems Interconnection –Basic Reference Model: The basic model*.

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

[ITU-T Y.3600] Recommendation ITU-T Y.3600 (2015), *Big data – Cloud computing based requirements and capabilities*.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 big data [ITU-T Y.3600]: A paradigm for enabling the collection, storage, management, analysis and visualization, potentially under real-time constraints, of extensive datasets with heterogeneous characteristics.

NOTE – Examples of datasets characteristics include high-volume, high-velocity, high-variety, etc.

3.1.2 deep packet inspection (DPI) [ITU-T Y.2770]: Analysis, according to the layered protocol architecture OSI-BRM [ITU-T X.200], of:

- payload and/or packet properties (see list of potential properties in clause 3.2.11 of [ITU-T Y.2770]);
- deeper than protocol layer 2, 3 or 4 (L2/L3/L4) header information, and other packet properties

in order to identify the application unambiguously.

NOTE – The output of the DPI function, along with some extra information such as the flow information, is typically used in subsequent functions such as reporting or actions on the packet.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 application-driven networking (ADN): ADN is a type of future network framework that provides the network programmability for the applications. ADN is application quality of experience (QOE)-centric while a traditional network is network efficiency-centric.

3.2.2 big-data-driven networking (bDDN): 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.

3.2.3 big-data plane: The big-data plane is the main part of bDDN. It is responsible for network big data collection, storage and computation, and has powerful big data computing and analytical ability. It extracts the useful information and intelligence from the network's big data. Then it provides network intelligence for network management, operation, control, optimization and security, etc.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

ADN Application-Driven Networking

bDDN big-Data-Driven Networking

CAPEX Capital Expenditure

DPI Deep Packet Inspection

LB Load Balance

NI Network Infrastructure

OAM Operation, Administration and Maintenance

OPEX Operating Expense

PDU Protocol Data Unit

QoE Quality of Experience

QoS Quality of Service

SDN Software Defined Network

5 Conventions

This Recommendation uses the following conventions:

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

In the body of this Recommendation and its appendices, the words shall, shall not, should and may sometimes appear, in which case they are to be interpreted, respectively as, is required to, is prohibited from, 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 Introduction

As the Internet becomes ubiquitous in its role as a social infrastructure, various Internet applications have emerged, and the complexity of traffic carried over the telecommunication networks continues to increase. We can obtain large amounts of traffic data based on deep packet inspection and operation data from the telecommunication network management or operation entity, and how to use this data to obtain useful information, thus improving the traffic and network management process is the problem that the operators need to consider. Big data technology and machine learning are important technical trends in the industry. The big data technology will be effective in handling traffic and network complexities, and big-data-driven networking will propose to study the applying of big data analytics technologies and machine learning for future networks.

7 Overview of big-data-driven networking

The big data generated by networks themselves implies a great deal of useful information for network management, operation, control, optimization and security, etc. Such valuable and such a tremendous amount of information, unfortunately, cannot be efficiently utilized by traditional network architecture.

Big-data-driven networking (bDDN) solves this problem by make use of big data generated by the network itself. The bDDN separates complex data computing and processing functionalities from the network control plane and management plane, and converges it into a big data plane. This big data plane has powerful big data computing and analytical ability, can perform pervasive and inclusive network data collection and computation, and extract useful information and intelligence from the big data. By applying big data technologies to massive data in the future network, the bDDN provides computational data intelligence support for network management, operation, control, optimization and security, etc. Furthermore, the bDDN would decrease the complexity of the network plane and management plane, which in return, would facilitate smart management, improve user QoE, elastic expansion and easy adaptation to emerging business requirements in the future network.

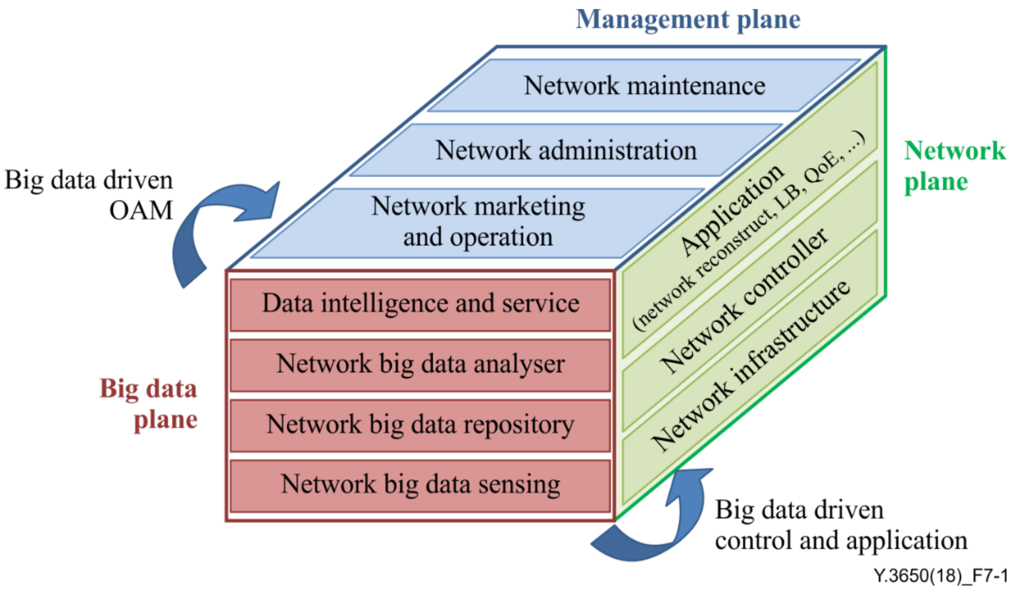

Figure 7-1 – The framework of big-data-driven networking (bDDN)

As shown in Figure 7-1, the bDDN framework is made up of three planes – big data plane, management plane and network plane. The bDDN model differs from existing network models in two major ways:

1) The bDDN framework is tridimensional, unlike the traditional vertical layered model which focuses on a common process of network traffic.

   As time goes by, challenges are brought forward mostly by network measurement and management issues. However, they are not clearly and independently illustrated in the traditional vertical layered model. As a result, solving network problems in the traditional framework becomes increasingly obscure and cumbersome. The bDDN model clarifies the three major facets of future networks, as well as their relationships.

2) The new model introduces the big data plane to support the management plane and network plane.

The big data plane is introduced because we found neither the SDN architecture nor the traditional network framework could handle big data challenges properly.

The SDN centralizes the problems described earlier and transfers problems to the network management and control process. The burden is centralized and must be predigested there. Facing "network inflation" in future networks, the complexity of network management would increase and problems during the control process would burst out. Full intelligence is a must if future network management is to solve problems one by one and to, step by step, diminish complexity.

In a word, bDDN is a type of future network framework that provides big data service and network intelligence to facilitate smarter network management, operation, control, optimization and security, etc. based on the big data generated by the network itself.

8 The reference model of bDDN

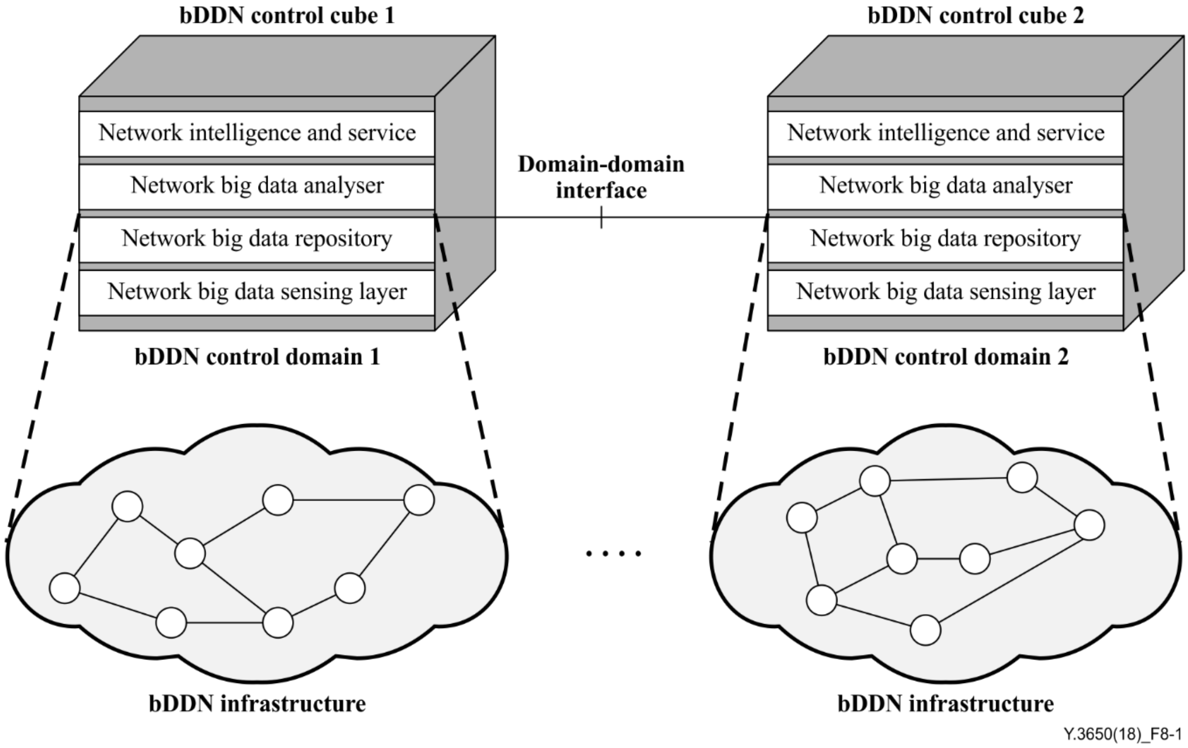

Figure 8-1 – The reference model of bDDN

To express the differing scopes of big data collection and/or administrative/control responsibilities, we introduce the domain notion in bDDN. A bDDN control domain thus represents a collection of entities that are grouped for a bDDN control and data collection purpose. A bDDN control domain is comprised of a collection of network infrastructure components, and components in a bDDN control cube. One component in the network infrastructure can only belong to one domain. The big data plane only collects the data of the component in this domain. The management plane only manages the nodes of the domain, and the control plane is only responsible for the nodes of this domain.

The data exchange between the bDDN control domains is defined by the domain-domain interface (DDI). The DDI is defined in the following clause.

Each domain of bDDN corresponds to a bDDN control cube. It is generally based on the cloud architecture, responsible for big data collection, processing, computing and network control and management. The bDDN control cube constitutes the control centre of the bDDN network.

The bDDN control cube is composed of a data plane, network plane and management plane; the relationship between the three planes is as follows:

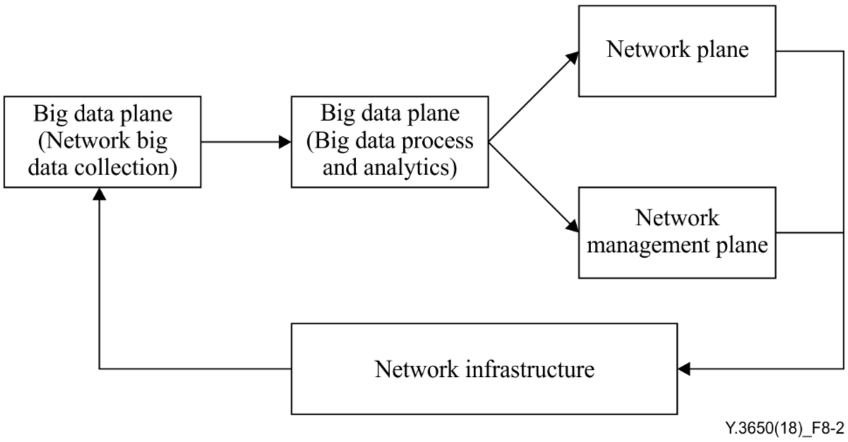

Figure 8-2 –The relationship of three planes

9 The model architecture of big-data-driven networking

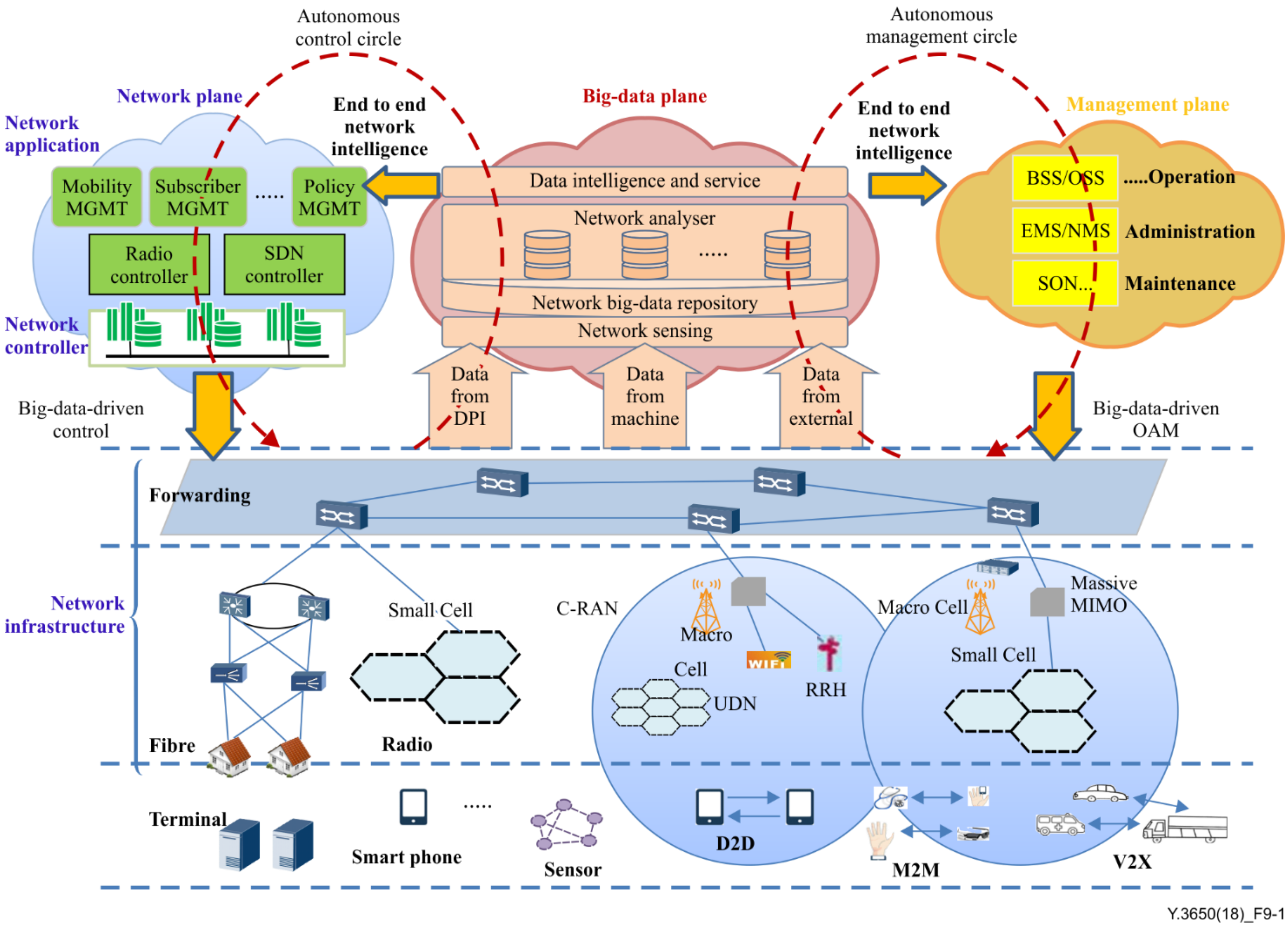

Figure 9-1 – The module architecture of bDDN

Specifically, bDDN is composed of three planes, and each plane is composed of several layers. The big data plane is composed of four layers. The bottom lays the data sensing layer, which, with the help of DPI and other technologies, collects various data (including traffic data, network device performance data, network management data and operation data, etc.) from the network scientifically.

The big data plane also collects some external circumstance data that may have an impact on networks. Such large real-time and inclusive information from all network dimensions and the external environment is critical to help reveal the true face of network circumstances and problems, distinct from current face-covering tiresome troubleshooting and misty defence against hackers. The collection data is stored in a data storage repository which is based on cloud architecture.

Though the data contains all the necessary information, to genuinely solve network problems and decrease network complexity, a data computing and analytics layer is needed, where assorted network models and cloud computing ability is applied. The computing methods, models, abilities and even the form of results can be either preconfigured or freshly issued by the data intelligence layer. In spite of these analytical results, service is needed to make the answers more satisfactory. No matter how intelligent, the raw result is still quite neutral and takes on a primitive form of metadata. The data intelligence and service layer need to further process the result into handy information and clear instructions (according to the topology, device manufacture, network status and so forth) and provide end-to-end network intelligence to the other two planes in the form of a service.

The network plane is composed of three layers. They are "network infrastructure layer", "network controller layer" and "network application layer". The network infrastructure layer includes all kinds of network devices performing packet transmission. The network controller layer includes network controllers, responsible for policy making and dispatching. The application layer includes different kinds of user applications, such as network reconstruct, security, QoS, load balance, etc.

The management plane is also composed of three layers: "network operation", "network administration" and "network maintenance". Taking advantage of data analysis and end-to-end network intelligence in the big data plane, the management plane realizes a series of network automations, including smart maintenance, troubleshooting, configuration and optimization. It 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: autonomous control circle and autonomous management circle. The autonomous control circle is formed between the big data plane and network plane, while the autonomous management plane is between the big data plane and management plane.

The bDDN model possesses the following features:

1) Introducing big data plane to enable end-to-end network intelligence

   With the help of virtualization and an ever-increasing handling capacity, the computing and storage ability is practically unlimited. Most importantly, the design of computing and storage in bDDN is supposed to be planned together with other network infrastructures. Under the architecture of bDDN, all network elements can become not only visible but also operable. Such end-to-end visibility is critical in reshaping network intelligence by inventing dynamic models in real-time fashion. Network parameters would also be mapped live to network operation, with network resources dynamically allocated.

2) Introducing machine learning to future network architecture

   With the development of a network, it is necessary to introduce big data technology and machine learning to achieve autonomous management and adjustment of the network through the collection of large amounts of data on the network state. The areas of machine learning which are easier to be used in the network field may include: troubleshooting of network problems, network traffic prediction, traffic optimization adjustment, network security auditing, etc., to implement network perception and cognition.

3) Big-data-driven autonomous network management

   The biggest advantage of bDDN is that, such simple network infrastructure plus highly sophisticated data computing and analysis can result in big-data-driven autonomous network operation, administration and maintenance (OAM) – data-driven network operation, administration and maintenance.

Under the framework of bDDN, data from all network ingredients at various levels and different ramifications could be stored and analysed to produce an overall optimized solution for fault detection and troubleshooting, which can cut down operating expense (OPEX) and capital expenditure (CAPEX). More intelligent self-maintaining scripts and algorithms would be invented for resource allocation and network operation to free engineers from cumbersome manual processes.

Moreover, with inclusive information, data-driven OAM will have a marvellous sense of popular application trend, which may reveal business opportunities, as well as potential security pitfalls, which may conceal business catastrophes.

4) Big-data-driven autonomous network control

The big data plane can provide efficient methods for optimized network control compared to other methods when the network behaviour is complex, dependent on many parameters, and changes frequently over time. In fact, the big data plane allows the following and understanding of network behaviour so that control parameters can be autonomously updated during network operation for achieving optimal performance in any given network condition.

In principle, using real-time performance measurement tools, the big data plane can infer an association rule between performance, network status, and network control parameters, thus learning the set of parameters that probabilistically maximize network performance.

5) Application-driven network

In a network plane, it is required that the network can be programmed by the application flexibly. Dynamic programmability is one of the key technologies which enables the application to program the network infrastructure (NI) flexibly; this is the concept of application-driven networking (ADN). See Appendix I for the concept of close-loop bDDN-ADN-NI.

6) Accelerating network architecture evolving

By replacing the network state complexity with big data computing complexity, the burden of network OAM can be greatly alleviated. In other words, as the network architecture is free from burden, it can evolve again, in the direction of becoming more and more flexible, extensible and scalable to match the increasingly challenging application requirements.

10 The high-level capabilities of big-data-driven networking

According to the framework of big-data-driven networking, the bDDN framework is made up of three planes – big data plane, network plane and management plane. The high-level capabilities of big-data-driven networking are categorized into three parts:

– high-level capabilities of big data plane;
– high-level capabilities of network plane;
– high-level capabilities of management plane.

10.1 High-level capabilities of big data plane

10.1.1 Network big data sensing layer capabilities

1) Capability of DPI-based network sensing

A network sensing layer is required to collect comprehensive data from different layers of the network plane and management plane. Since collecting and storing all network traffic data is not feasible in practice, comprehensive network data collection does not mean to collect all network traffic data. Big-data-driven networking needs to make use of DPI technology to collect interested network traffic and applications for the analyser.

2) Capability of big data collection

A large amount of data is hidden in the network, including traffic data; alarm data, invalidation data and log files from network devices and cloud infrastructures; signalling data, configuration data and routing data from transaction systems; environmental data from external resources, and so on. The bDDN is supposed to collect all the information that is related to network business and status, while at the same time fulfilling the mission of storage, classification and analysation.

10.1.2 Network big data repository capabilities

1) Capability of network big data storage

The network contains a variety of a large amount of data; bDDN needs to provide all kinds of large data storage capabilities, including a mass-structured data storage capability and an unstructured data storage capability.

2) Capability of big data interchanging and sharing

Different network management realms are supposed to be capable of big data sharing and exchanging, so that big data resources can be utilized by different realms or network services.

10.1.3 Network big data analyser layer capabilities

1) Capability of correlation analysis

A big-data-driven network analyser conforms to the traditional big data paradigm: comprehensive data outweighs sampled data, correlation rather than causality. It is difficult for a network designer or operator to find and compute the network causality. The correlations learned from network plane data and management plane data can be utilised to effectively improve network resource allocation, reduce CAPEX and OPEX, and maximize revenue.

2) Capability of big data real-time computing and analysing

Considering the huge amount and fast changing characteristics of network data, bDDN is required to provide real-time analysing ability. bDDN would perform comprehensive data fusing and analysing over the collected information, correlate various influencing factors and network status, and find out the causality and logistics behind them by using big data technologies.

3) Capability of machine learning and deep learning

The network big data analyser layer is the core component of the big data plane. It will take the machine learning and deep learning on the huge data collected by big data sensing layer, to achieve network perception and cognition, including network autonomous optimization, autonomous adjustment, intelligent fault location and a series of network intelligence goals.

4) Capability of network QoS anomaly detection and root cause tracking

Different applications have different QoS parameter requirements, for example, delay/latency, jitter, round trip time, etc. **N**etwork QoS anomaly means network QoS parameters anomaly. To meet the complex QoS/QoE requirements of different applications/services, the networks are required to detect the network QoS anomaly and track the root cause of the anomaly. The bDDN should have the capability to automatically monitor the network QoS anomalies and track the root causes of the anomalies. The problems of network performance anomalies are network data, such as, network traffic data, syslog data and management data, etc. The QoS anomaly network data is from network anomaly events, such as, network attacks, protocol bugs and link up/down, etc. Based on the analysis of multilayer dependence and spatial-temporal dependence of network data and network events, bDDN can reversely track the root causes of network anomalies. The bDDN is able to clarify the positive correlations and reverse tracking mechanisms of network 'anomaly events – anomaly data – network anomalies'.

10.1.4 Data intelligence and service layer capabilities

1) Capability of big data visualization

The network data visualization is a visual representation of the insights gained from the network data analyser. A network data visualization capability may reveal the hidden potential value of comprehensive network data. Network data visualization exhibits the correlations and implications of raw network plane and management plane data with images, tables, graphs, charts, diagrams and maps etc., so that network operators can see and understand the connections in a real network.

2) Capability of end-to-end network intelligence provision

Based on the management and analyzation of assorted network data, end-to-end network intelligence can be provided to network management, QoS, security, maintenance and operation; this makes all these aspects more smart and proactive through big data technologies. Data intelligent services can be provided both on the management plane and network plane.

10.2 High-level capabilities of network plane

10.2.1 Application layer capabilities

The bDDN network application layer is where applications specify network services in a programmatic manner. The network application layer interacts with the network control layer via application-control interfaces. The network application layer needs to interact with the big data plane.

In the network application layer, it is required that the network can be programmed by the application flexibly. Dynamic programmability is one of the key technologies to enable the application to program the network flexibly.

10.2.2 Network controller layer capabilities

The bDDN network controller layer provides a means to control the behaviour of the network resources layer. Instructed by the bDDN network application layer, the bDDN controller layer interacts and instructs the bDDN resource layer to transport and process network traffic. The network controller layer needs to interact with the big data plane.

The controller in bDDN needs to communicate with the big data plane, the calculation of policy, forwarding rule and so on is computed by the big data plane, and then dispatched to the infrastructure layer by the controller. This work in the SDN is completed by the controller with a simple calculation.

On the other hand, the policy computation in bDDN is based on the large collected data sets, including some external data; this is not in the SDN. In addition, bDDN also uses machine learning to optimize the computation model. Therefore, policies and rules through bDDN computation are more optimized than those provided by the SDN controller. The bDDN can make better use of network resources, and provide a better network service for users.

10.2.3 Network infrastructure layer capabilities

The bDDN network resource layer is where the network elements perform the transport and the processing of data packets according to the decisions made by the SDN control layer. The network infrastructure layer needs to interact with the big data plane.

10.3 High-level capabilities of management plane

10.3.1 Capabilities of network operation layer

Based on the big data from the network, operators can deeply analyse the real-time status of the network, accurately predict the future status of the network, and effectively configure the network to support better services.

10.3.2 Capabilities of network administration aspect

By analysing the network big data in real time, bDDN can get instant knowledge of network status, existing problems and undergoing risks. Through coordinating with the controllers of the network plane and management plane, bDDN can fulfil autonomous network control and management. Accordingly, operational expenditure and capital expenditure would be both cut down.

10.3.3 Capabilities of network maintenance aspect

Rather than frequent intervention whenever a problem occurs, to circumvent observable latency, optimization must be done beforehand. The pattern would transform from "observe, catch, diagnose, bailout" to "overall circumstance awareness, trend prediction, pre-emptive resolution". The more data collected, the more advanced big data analysis becomes, and the more experience network intelligence evolved, the more network problems can be predicted and the less intrinsic delay inserted between detection and settlement.

10.3.4 Capabilities of network restructuring and optimization aspect

Based on the big data from the network and subsequent analyzation and processing, the network optimization and restructuring can be achieved. It is notable that the action of network optimization and restructuring can be performed by either network operators or the network itself.

11 The interface capabilities of big-data-driven networking

11.1 The interfaces among planes of big-data-driven networking

11.1.1 The interfaces between big data plane and network plane

Figure 11-1 depicts the interfaces between the big data plane and network plane. The big data plane gets network traffic data from the network plane via the *iBN* interface. After data collection and analysis, the big data plane provides a knowledge insight service to the network plane also via the *iBN* interface.

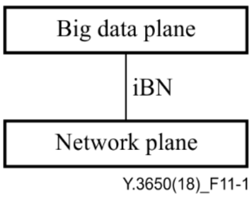

Figure 11-1 – The interfaces between the big data plane and the network plane

11.1.2 The interfaces between big data plane and management plane

Figure 11-2 depicts the interfaces between the big data plane and management plane. The big data plane gets management data from the management plane via the *iBM* interface. After data collection and analysis, the big data plane provides a knowledge insight service to the management plane also via the *iBM* interface.

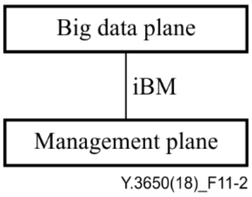

Figure 11-2 – The interfaces between the big data plane and the management plane

11.1.3 The interfaces between management plane and network plane

Figure 11-3 depicts the interfaces between the management plane and the network plane. The network plane provides the management information for the management plane via the *iNM* interface. The management plane manages the network resource in the network plane also via the *iNM* interface.

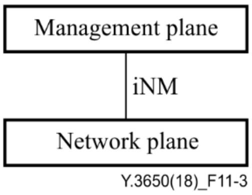

Figure 11-3 – The interfaces between the management plane and the network plane

11.2 The interfaces among layers of big-data-driven networking

Within the big data plane, the interface between the network sensing layer and network big data repository layer is represented by *iSD*, and the interface between the network analyser layer and data intelligence and service layer is represented by *iAI*. The interfaces between the other two layers are outside the scope of this Recommendation.

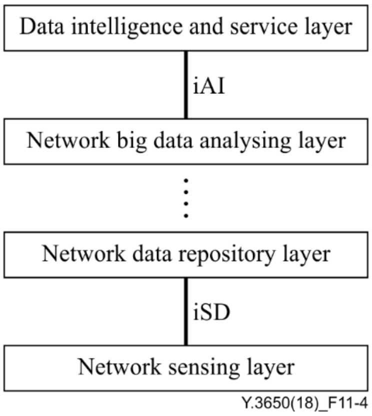

Figure 11-4 – The interfaces among layers of big data plane

Within the network plane, the interface between the network infrastructure layer and network controlling layer is represented by *iIC*, and the interface between the network controlling layer and network application layer is represented by *iCA*.

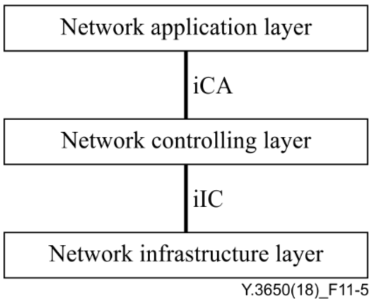

Figure 11-5 – The interfaces among layers of network plane

Within the management plane, no interfaces need defining because there is not the necessary data exchanging between several aspects within the management plane.

11.3 The interfaces between the bDDN control domains

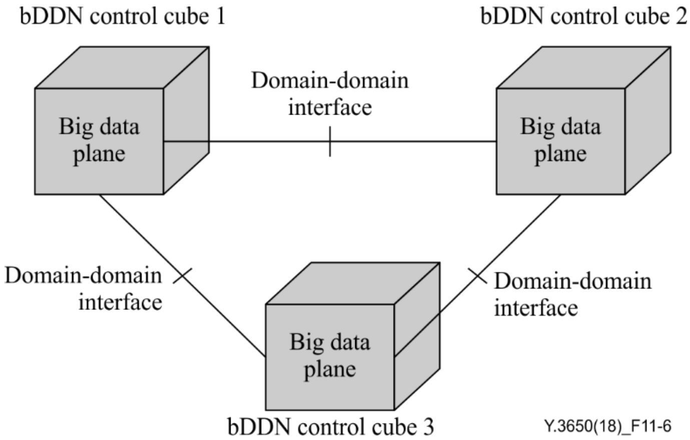

Figure 11-6 – The DDI interfaces

The reference model of bDDN is shown in Figure 8-1. It is recommended that big-data-driven networking has a domain-domain interface which defines the interface between the different bDDN control domains.

In carrier-grade networks, there are many carriers and vendors, and each vendor may have their own bDDN control cube. The bDDN control cubes in different domains need to communicate and negotiate with each other. So, we need a clear definition of the interface between bDDN control domains.

The DDI interface will exchange the data and signalling with other domains. The big data plane in different domains need to communicate with each other. The control cube communication network can be in-band by using embedded communication channels. Also, the control cube communication network can be out-of-band by using additional communication channels.

12 Security considerations

When using big-data-driven networking security best practices should be adopted such as authentication, authorization and access control.

Appendix I

The concept of close-loop bDDN-ADN-NI

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

As the Internet becomes ubiquitous in its role as a social infrastructure, various Internet applications have emerged, and the complexity of traffic carried over the telecommunication networks continues to increase. One of the reason for a low quality of experience and low network efficiency lies in diverse and uncertain Internet applications being transported by a unique and rigid IP network. The diversity of service models requires that the network models dynamically match the service models on demand. Firstly, it requires the network and application to be aware of the status of each other. For the awareness problem, deep packet inspection is one of the key technologies which can enable the network to be aware of the application status. While the big data capability is one of the key technologies which can enable the application to be aware of the network status. This is the concept of big-data-driven networking. Secondly, it is required that the network can be programmed by the application flexibly. Dynamic programmability is one of the key technologies that enables the application to program the network flexibly; this is the concept of application-driven networking (ADN).

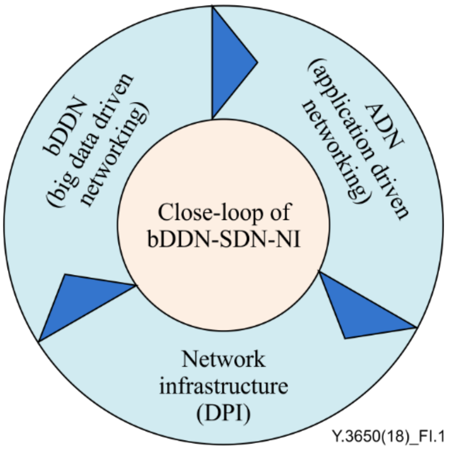

Figure I.1 – The concept of close-loop bDDN-ADN-NI

The concept of close-loop big-data-driven networking (bDDN) is illustrated as Figure I.1. We can obtain large amounts of traffic data based on deep packet inspection and operation data from the telecommunication network management or operation entity. Based on big data capabilities we can use the knowledge discovered by big data analysis to service the applications (e.g., network management, resource) to program the network to improve network and traffic efficiency.

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