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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 – Machine learning mechanism

Recommendation ITU-T Y.3654

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Recommendation ITU-T Y.3654

Big data driven networking – Machine learning mechanism

Summary

Recommendation ITU-T Y.3654 specifies the mechanisms of machine learning in big data driven networking (bDDN). A set of related aspects of machine learning in bDDN are presented, these aspects include: overview, learning procedure, deployment, interfaces, learning path and control path, security considerations.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T Y.3654	2022-02-13	13	11.1002/1000/14862

Keywords

bDDN, machine learning.

* To access the Recommendation, type the URL http://handle.itu.int/ in the address field of your web browser, followed by the Recommendation's unique ID. For example, http://handle.itu.int/11.1002/1000/11830-en.

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1 Scope

This Recommendation specifies the mechanisms of machine learning in big data driven networking, its scope includes the following aspects:

– Overview

– Learning procedure

– Deployment

– Related interfaces

– Learning and control path

– Security considerations

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.2704] Recommendation ITU-T Y.2704 (2010), *Security mechanisms and procedures for NGN*.

[ITU-T Y.3172] Recommendation ITU-T Y.3172 (2019), *Architectural framework for machine learning in future networks including IMT-2020*.

[ITU-T Y.3180] Recommendation ITU-T Y.3180 (2022), *Mechanism of traffic awareness for application-descriptor-agnostic traffic based on machine learning*.

[ITU-T Y.3531] Recommendation ITU-T Y.3531 (2020), *Cloud computing – Functional requirements for machine learning as a service*.

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

[ITU-T Y.3652] Recommendation ITU-T Y.3652 (2020), *Big data driven networking - requirements*.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 big data [b-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.

3.1.2 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.

3.1.3 machine learning (ML) [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 machine learning sandbox [ITU-T Y.3172]: An environment in which machine learning models can be trained, tested and their effects on the network evaluated.

3.1.5 machine learning model [ITU-T Y.3172]: Model created by applying machine learning techniques to data to learn from.

3.2 Terms defined in this Recommendation

None.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

API	Application Programming Interface
bDDN	Big Data Driven Networking
C	Collector
CPU	Central Processing Unit
FTP	File Transfer Protocol
GPU	Graphic Processing Unit
HTTP	Hyper-Text Transfer Protocol
INF	Interface
L-ML	Local Machine Learning
M	Model
ML	Machine Learning
PP	Pre-Processing
R-ML	Remote Machine Learning
SNMP	Simple Network Management Protocol
SRC	Source

5 Conventions

In the body of this Recommendation, the words shall, should and may sometimes appear, in which case they are to be interpreted, respectively, as is required to, is recommended to, 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 mechanisms of machine learning in big data driven networking

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. In [ITU-T Y.3650], the bDDN framework is made up of three planes – big data plane, management plane and network plane. Additionally, each plane in bDDN has sub-layers.

Machine learning (ML) provides a way to teach a computational system to learn knowledge using data without necessarily being explicitly programmed in order to realize complicated tasks such as characteristic detection or behaviour prediction. ML has become an important technical trend, networks operators are trying to find a way to utilize ML for better network performance. In [ITU-T Y.3531], machine learning is classified as: supervised learning, unsupervised learning, semi-supervised learning and reinforcement learning, according to the characteristics of the learning algorithm. To integrate ML into a network, it should be noted that,

i ML builds a mathematical model based on sample data known as training data, data is the basis of ML,

ii the purpose of incorporating ML into a network is for a better network performance by using the output of ML to control or operate the network.

The framework of bDDN is a good fit for using ML in a network, the big data plane collects various data from the network which can be used for model training, the output of the ML can be used on the network plane and the management plane. As described in [ITU-T Y.3650], ML can be efficient in many cases, such as troubleshooting of network problems, network traffic prediction, traffic optimization adjustment, network security auditing, etc. When ML cooperates with bDDN, it can be applied to everywhere in bDDN, for example in the big data sensing layer of the big data plane, ML can be used for application-descriptor-agnostic traffic awareness [ITU-T Y.3180], in the network control layer of the network plane ML can be used for cellular network traffic scheduling.

7 The learning procedure of machine learning in bDDN

When applying ML in bDDN, the learning procedure is mainly mapping to the big data plane of bDDN which is composed of four layers: network big data sensing, network big data repository, network big data analyser and network intelligence and service. Figure 7-1 shows the general procedure of machine learning in bDDN. (The ellipse in Figure 7-1 maps the procedure to the big data plane of bDDN.)

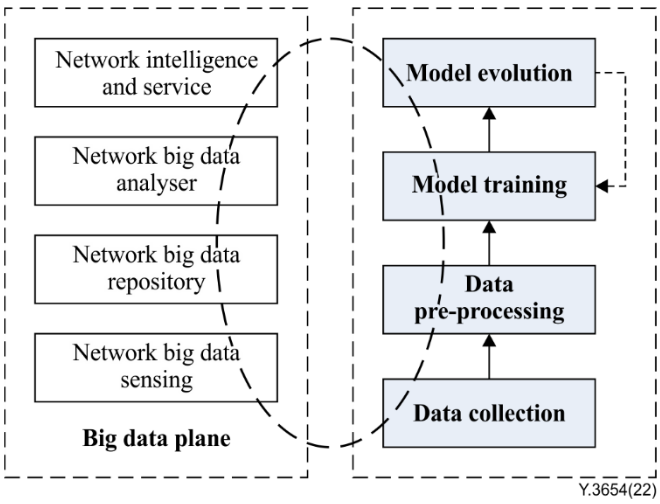

Figure 7-1 – The learning procedure of ML in bDDN

7.1 Data collection

Machine learning in bDDN relies on the data collected from the network, it requires specified data for a given networking problem. In general, data collection can be achieved in two phases – offline and online. Offline data collection allows a large amount of historical data for model training and testing to be gathered. Real-time network data collected in the online phase can be used as feedback to the model, or as input for re-training the model. The data sensing layer of the big data plane in bDDN supports multiple methods and data collection interfaces, such as simple network management protocol (SNMP), file transfer protocol (FTP), hyper-text transfer protocol (HTTP), Restful service, etc. [ITU-T Y.3652], and collects various data from the network including the traffic data, network device performance data, network management data and network operation data. In addition, the big data plane also collects some external circumstance data that may have an impact on networks. The data collected in the big data plane contains lots of information about the true status of the network and is very helpful for network operation, maintenance and optimization.

7.2 Data pre-processing

The ML learns by using large amounts of training data to adjust its internal parameters until it can reliably discriminate similar patterns in data it has not seen before. By its very nature, ML is acutely sensitive to the quality of the data, high quality datasets are essential for developing machine learning models. While the raw data collected in the big data plane of bDDN usually occurs with low quality, so it is necessary to pre-process the data before training. The main pre-processing includes handing null values, data standardization, handling categorical variables, etc. Feature engineering is also a vital part. With feature engineering the performance of a certain ML algorithm may be improved significantly. Feature engineering includes feature selection, feature scaling and feature extraction [ITU-T Y.3531]. Furthermore, data labelling is necessary for supervised learning and semi-supervised learning.

7.3 Model training

There are many models that have been created over the years, while different algorithms are for different tasks. For a certain task, choosing the suitable model will have a significant impact on the effect. Then moving on to the model training, the pre-processed data is divided into two parts, training data and testing data. The model learns specific parameters over the training data, such parameters will minimize the loss or how badly it performs on the training dataset. The big data analyser layer usually has sufficient available computing resources, such as central processing unit (CPU) and graphic processing unit (GPU), which can accelerate ML model training.

7.4 Model evaluation

Once the ML model has been built, it is crucial to gauge the performance of the ML model. The performance metrics can be used to measure the different aspects of the model, such as reliability, robustness, accuracy and complexity. The model tries to perform on the testing dataset using the knowledge gained from the training dataset. The performance of the model can further be improved on the training dataset and the testing dataset using various techniques, or by trying multiple machines learning algorithms and using the one that performs best.

NOTE – The aforementioned procedure is the common procedure of ML in bDDN. In the case of reinforcement learning, the pre-preparation of training dataset and testing dataset, in which the intelligent agent learns by maximizing the reward, is not very necessary.

8 The deployment of machine learning in bDDN

8.1 Overview of deployment of machine learning in bDDN

After the ML model is trained, it shall be deployed in bDDN to solve specified problems. To minimize the impact on the live network, the ML model could be performed in a machine learning sandbox [ITU-T Y.3172] before deploying.

When deploying the ML model in bDDN, the data collected through collector (C) from the source node (SRC) is taken as the input of the trained ML model (M) after optional pre-processing (PP), and the output of the ML model is applied to the target node (SINK). In most use case, the ML is deployed in a remote machine learning system (R-ML) in which the C, PP M node will be implemented in the big data plane, the ML model is deployed in the big data analyser layer, and acts on the SINK through restful application programming interface (API) or other interfaces (INF) powered by the network intelligence and service layer. In R-ML, it takes full advantage of bDDN which integrates the big data capability and computing resources, the underlying network nodes will need no or only need slight modifications.

For the cases that require a real-time control, the R-ML will not fit well, and the ML shall be deployed in a local machine learning system (L-ML) in which the ML will be deployed as near to the target node as possible to minimize the time delay. In L-ML the underlying network nodes may need be updated for computing and storage resources to deploy the ML.

Figure 8-1 shows the R-ML and L-ML deployment in bDDN.

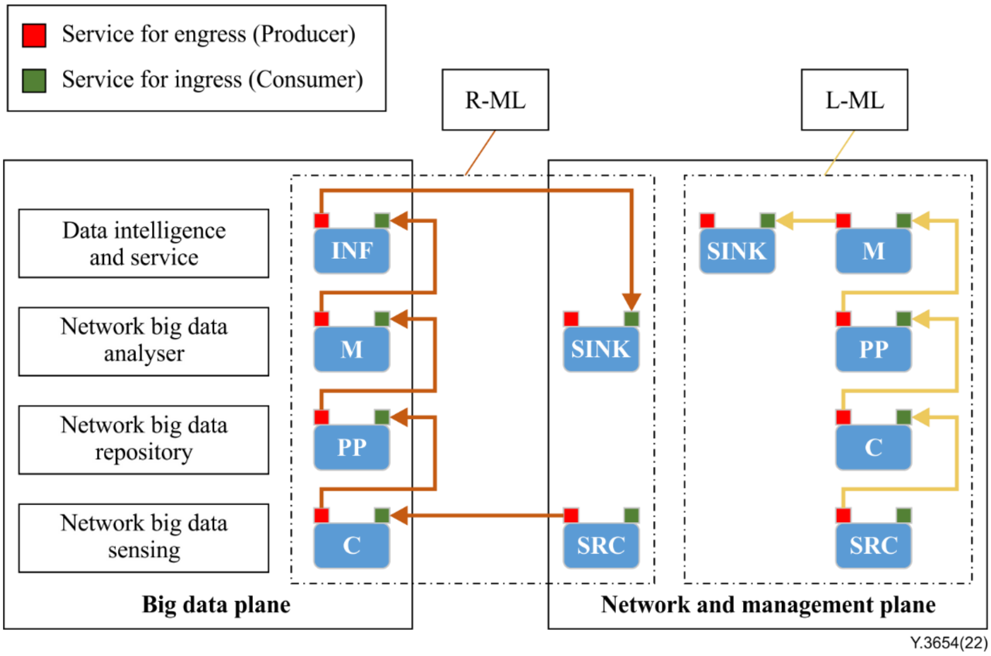

Figure 8-1 – R-ML and L-ML deployment in bDDN

According to the location of the data source and the target node in bDDN, the deployment of ML in bDDN can be classified into four types presented in clauses 8.2 to 8.5.

8.2 Deploying machine learning in network plane

Generally, machine learning functions can be realized in the network control layer or application layer of the network plane. Controller in the control layer is usually extensible and a lot of high-level functions including machine learning can be realized in the controller. In the meantime, application components in the application layer can also be designed to support machine learning functions. For example, the ML can be used for radio resource management [b-ITU-T Y-Sup.55].

Figure 8-2 describes such an approach. In Figure 8-2 the dash line between SRC and SINK node means there may be other ML functions between SRC and SINK node.

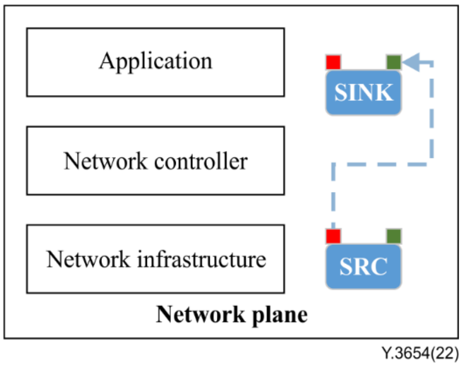

Figure 8-2 – Deploying machine learning in network plane of bDDN

8.3 Deploying machine learning in big data plane

Generally, the ML model is training in the big data plane, and it can also be deployed in the big data plane. For example, it can be used in the network big data sensing layer for application-descriptor-agnostic traffic awareness [ITU-T Y.3180] and for traffic classification, and it can be used to estimate the data volume so that the big data repository can be expanded in time.

Figure 8-3 illustrates the approach to deploy ML in the big data plane.

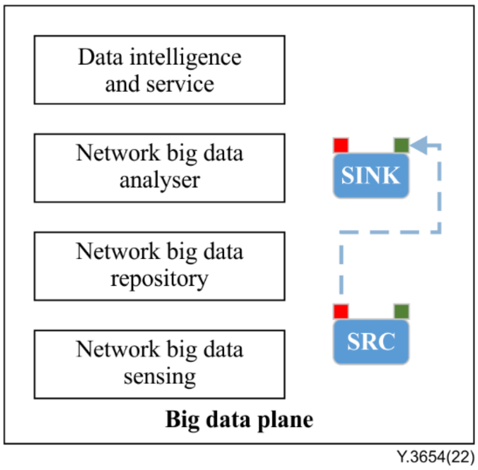

Figure 8-3 – Deploying machine learning in big-data plane of bDDN

8.4 Deploying machine learning in management plane

The ML model can also be deployed in the management plane. Under such circumstances, it is proper to realize machine learning functions in the network marketing and operation layer. The ML can be used for automatic network maintenance.

Figure 8-4 illustrates the approach to deploy ML in the management plane.

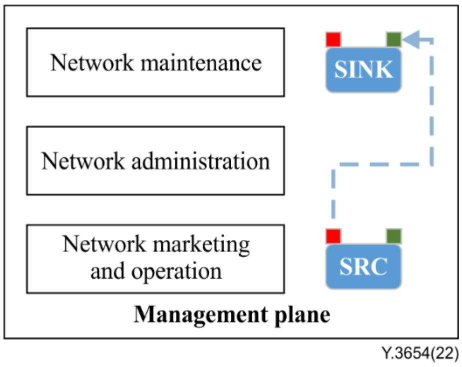

Figure 8-4 – Deploying machine learning in management plane of bDDN

8.5 Hybrid deploying machine learning

In other cases, the ML model is not deployed in a single plane. The SRC node and the SINK node are in different planes. ML can be used for power management by estimating the usage of the network according to the user data collected from the network plane, and the corresponding network devices can be turned off to save energy.

Figure 8-5 illustrates the approach to deploy ML by cooperating different components.

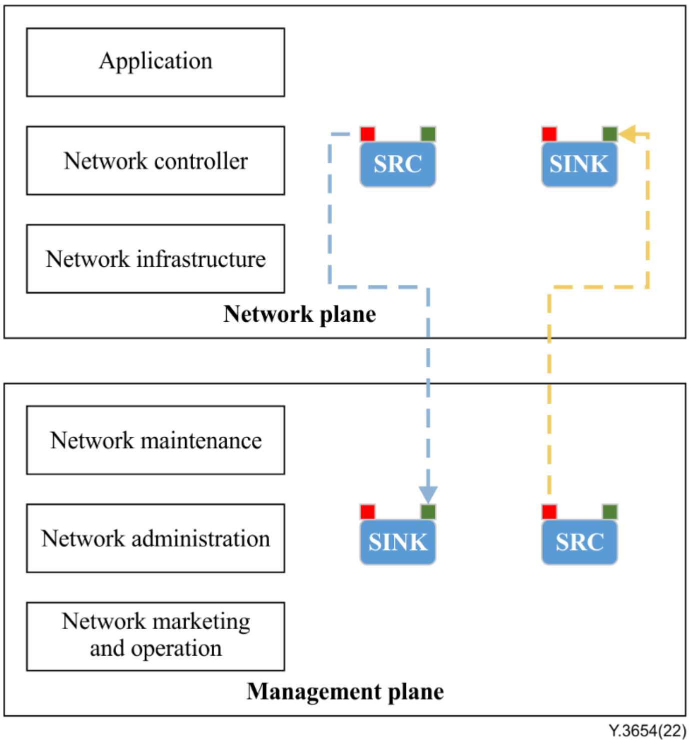

Figure 8-5 – Hybrid deploying machine learning in bDDN

9 The interfaces related to machine learning in bDDN

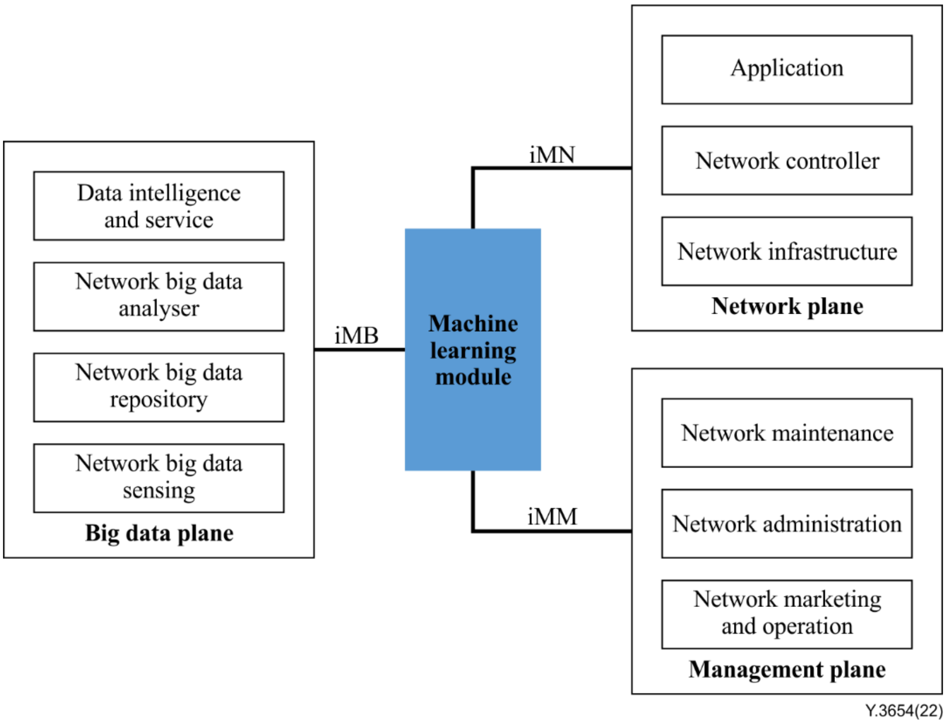

Figure 9-1 – Interfaces related to ML in bDDN

Figure 9-1 shows the interfaces related to ML in bDDN. In the bDDN framework, the learning procedure of ML refers to the big data sensing layer, the big data repositor layer and the big data analyser layer of the big data plane. The deployment of ML in bDDN refers to all three planes. The machine learning module interacts with big data plane via interface iMB, interacts with network plane via interface iMN, and interacts with management plane via interface iMM.

NOTE – the machine learning module is a logical module that contains the functions related to the learning procedure and deployment of ML in bDDN.

- iMB: the interface between the machine learning module and big data plane of bDDN. In the learning procedure the big data plane collects, or pre-prepossess the training and testing datasets, and provides the computing resources for model training and model evaluation via iMB. In the deployment of ML, firstly the output of machine learning can be applied to the big data plane (deploying machine learning in big data plane) via iMB. Secondly in R-ML deployment, the network intelligence and service layer delivers the output of ML to the target nodes in the network plane and the management plane via iMB.
- iMN: the interface between machine learning module and network plane of bDDN. In L-ML deployment the network plane provides the pre-processed source data via iMN, and the output of ML applied to the network plane via iMN. In R-ML deployment the output of the machine learning module is applied to the network plane through iBN, the interface between the big data plane and network plane [ITU-T Y.3650].
- iMM: the interface between machine learning module and manage plane of bDDN. In L-ML deployment the management plane provides the pre-processed source data via iMM, and the output of ML applied to the management plane via iMM. In R-ML deployment the output of the machine learning module is applied to the network plane through the iBM, the interface between big data plane and management plane [ITU-T Y.3650].

10 The learning and control path based on machine learning in bDDN

The learning path

The learning path is to learn the machine learning model from the big data generated in bDDN. The learning path starts from the big data sensing layer and goes through the big data plane. It refers to the data collection, data pre-processing, model training and model evolution steps in clause 7.

The control path

When the machine learning model is ready, it can be deployed to bDDN for control to achieve a better network performance. As described in clause 8, the ML model can be deployed in all the three planes of bDDN.

In general, the learning path and control path is looped, the model, as the output of the learning path is the input of the control path and is deployed to the network in the control path. In addition, the control effect can react to the learning path to update the model, which can keep the model adaptive to the complex network environment.

11 Security considerations

When applying machine learning for big data driven networking, security best practices should be adopted such as authentication, authorization and access control as described in [ITU-T Y.2704]. The big data used for machine learning applying to big data driven networking should be protected in order to avoid leaking and being destroyed.

Bibliography

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

[b-ITU-T Y-Sup.55] ITU-T Supplement 55 to Y.3170-series (2019), *Machine learning in future networks including IMT-2020: use cases*.

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