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Cloud Computing

Cloud computing – Functional architecture of big data as a service

Recommendation ITU-T Y.3519

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Cloud computing – Functional architecture of big data as a service

Summary

Recommendation ITU-T Y.3519 describes the functional architecture for big data as a service (BDaaS). The functional architecture is defined on the basis of the analysis of requirements and activities of cloud computing-based big data described in Recommendation ITU-T Y.3600.

Following the methodology of Recommendation ITU-T Y.3502, the BDaaS functional architecture is described from a set of functional components and cross-cutting aspects. The specified functional components consist of sets of functions that are required to perform the BDaaS activities for the roles and sub-roles described in Recommendation ITU-T Y.3600.

History

Edition	Recommendation	Approval	Study Group	Unique ID[*]
1.0	ITU-T Y.3519	2018-12-14	13	11.1002/1000/13816

Keywords

Big data, big data as a service, cloud computing, functional architecture, functional component.

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Table of Contents

Recommendation ITU-T Y.3519

Cloud computing – Functional architecture of big data as a service

1　Scope

This Recommendation provides an overview of the big data as a service (BDaaS) functional architecture and defines the BDaaS functional architecture and cross-cutting aspects by specifying the functional components for the support of BDaaS.

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.3502]　Recommendation ITU-T Y.3502 (2014) | ISO/IEC 17789:2014, *Information technology – Cloud computing – Reference architecture*.

[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　activity [ITU-T Y.3502]: A specified pursuit or set of tasks.

3.1.2　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.

3.1.3　big data as a service (BDaaS) [ITU-T Y.3600]: A cloud service category in which the capabilities provided to the cloud service customer are the ability to collect, store, analyse, visualize and manage data using big data.

3.1.4　cloud computing [b-ITU-T Y.3500]: Paradigm for enabling network access to a scalable and elastic pool of shareable physical or virtual resources with self-service provisioning and administration on-demand.

NOTE – Examples of resources include servers, operating systems, networks, software, applications, and storage equipment.

3.1.5　cloud service [b-ITU-T Y.3500]: One or more capabilities offered via cloud computing invoked using a defined interface.

3.1.6　cloud service customer (CSC) [b-ITU-T Y.3500]: Party which is in a business relationship for the purpose of using cloud services.

3.1.7　cloud service partner (CSN) [b-ITU-T Y.3500]: Party which is engaged in support of, or auxiliary to, activities of either the cloud service provider or the cloud service customer, or both.

3.1.8   cloud service provider (CSP) [b-ITU-T Y.3500]: Party which makes cloud services available.

3.1.9   functional component [ITU-T Y.3502]: A functional building block needed to engage in an activity, backed by an implementation.

3.1.10   metadata [b-ISO/IEC 2382]: Data about data or data elements, possibly including their data descriptions, and data about data ownership, access paths, access rights and data volatility.

3.1.11   party [b-ITU-T Y.3500]: Natural person or legal person, whether or not incorporated, or a group of either.

3.1.12   role [ITU-T Y.3502]: A set of activities that serves a common purpose.

3.1.13   sub-role [ITU-T Y.3502]: A subset of the activities of a given role.

3.2   Terms defined in this Recommendation

None.

4   Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

BDaaS   Big Data as a Service

BDAP   Big Data Application Provider

BDIP   Big Data Infrastructure Provider

BDSU   Big Data Service User

CSC   Cloud Service Customer

CSN   Cloud Service Partner

CSP   Cloud Service Provider

DP   Data Provider

OSS   Operations Support Systems

5   Conventions

This Recommendation follows the conventions regarding the diagrams shown in Figure 5-1 of [ITU-T Y.3502].

6   Overview of BDaaS functional architecture

Big data as a service (BDaaS) is a cloud service category, which provides cloud service customers (CSCs) the ability to collect, store, analyze, visualize and manage data using a big data paradigm. BDaaS services utilize capabilities of the cloud computing infrastructure, platform and applications, which are necessary to build a big data ecosystem.

6.1   Framework of BDaaS functional architecture

BDaaS provides big data services based on a cloud service environment. The BDaaS functional architecture defined in this Recommendation follows the concept of constructing the user view, the functional view and aspects defined in [ITU-T Y.3502]. The user view and functional view are specified as follows:

–   user view: The system context, parties, roles, sub-roles and cloud computing activities;

–   functional view: The functions necessary for the support of cloud computing activities.

The user view and requirements of BDaaS are defined in [ITU-T Y.3600].

This Recommendation defines:

–   functional components required for the functional view based on the requirements in [ITU-T Y.3600];

–   cross-cutting aspects for BDaaS.

6.1.1   User view for BDaaS architecture

The user view of BDaaS (See [ITU-T Y.3600]) identifies the system context including roles, sub-roles and activities as well as data and service flows as shown in Figure 6-1.
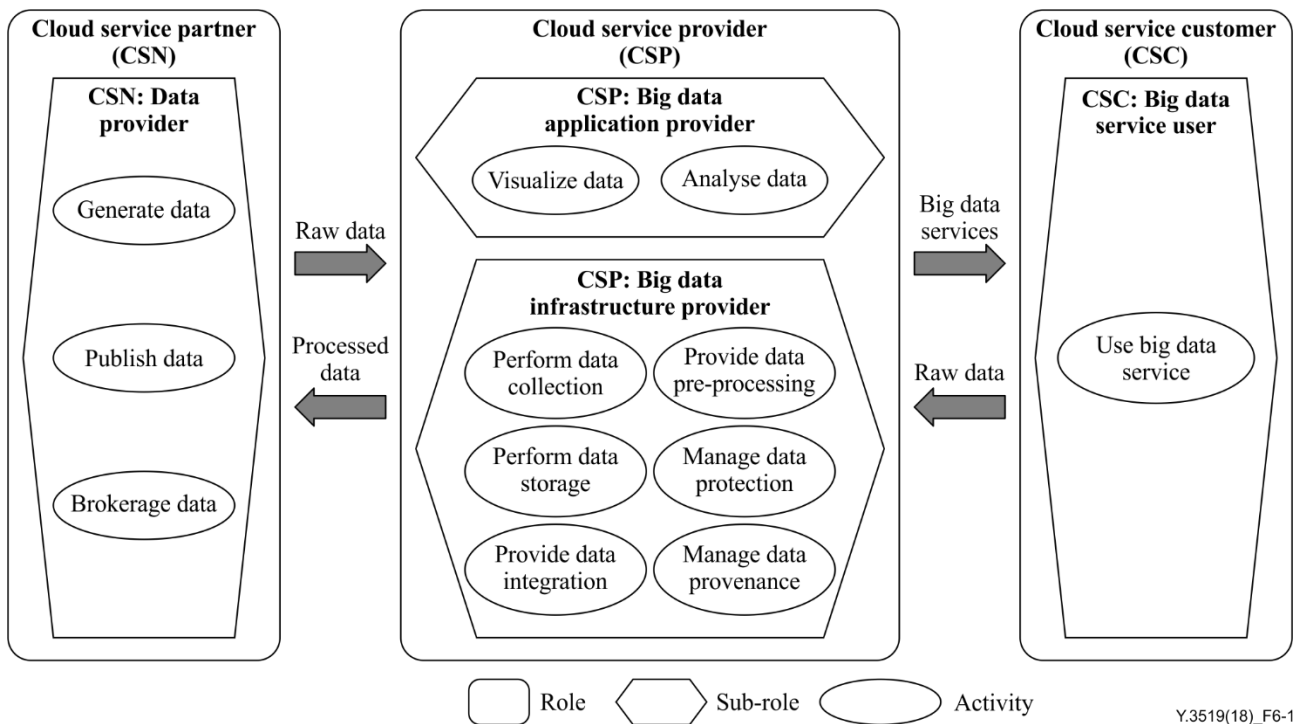
Figure 6-1 – Cloud computing based big data system context

6.1.2   Functional view for BDaaS

The functional architecture of cloud computing in [ITU-T Y.3502] describes functional components in terms of a layering framework where specific types of functions are grouped into each layer and where there are interfaces between the functional components in successive layers.

The functional components for BDaaS represent sets of functions that are necessary to perform the BDaaS activities for various roles and sub-roles.

6.1.3   Cross-cutting aspects for BDaaS

Cross-cutting aspects include both architectural and operational considerations. Cross-cutting aspects for BDaaS apply to multiple elements within the description of the functional architecture or in connection with its operation as an instantiated system. These cross-cutting aspects for BDaaS are shared issues across roles, activities and functional components.

6.2   Relationship between user view and functional view

Figure 6-2 illustrates the relationship between the user view and functional view for BDaaS.
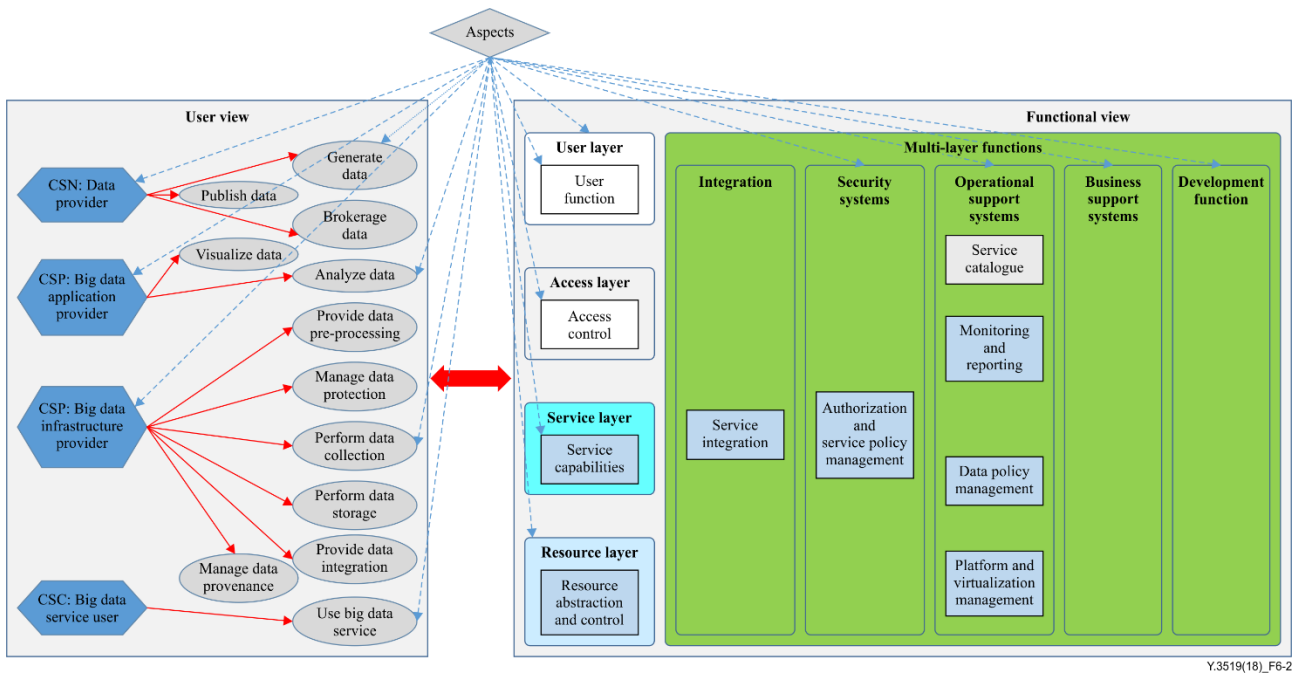
Figure 6-2 – Relationship between user view and functional view

In terms of user view, 4 sub-roles and 12 activities are defined in [ITU-T Y.3600]. These activities in the user view are supported by functional components in the functional view. Clause 7 identifies the functional components needed for support of the activities and of the requirements defined in [ITU-T Y.3600].

NOTE – Appendix I provides the mapping between requirements, activities and functional components.

7 Functional architecture for BDaaS

This clause defines the functional architecture for support of the BDaaS cloud service category. The functional architecture is identified on the basis of the analysis of requirements and capabilities of cloud computing based big data described in [ITU-T Y.3600].

According to the cloud computing layering framework [ITU-T Y.3502], the functions in the cloud computing functional architecture are divided into four layers and a division called multi-layer functions, which spans across the four layers.

Following the methodology of [ITU-T Y.3502], the BDaaS functional architecture is described from a set of functional components. The functional components consist of sets of functions that are required to perform BDaaS activities for the roles and sub-roles described in [ITU-T Y.3600].

Figure 7-1 shows the functional architecture for BDaaS. The BDaaS architecture is defined by leveraging cloud computing reference architecture (CCRA) ([ITU-T Y.3502]) with:

– extensions to the existing functional components;
– adding new functional component.
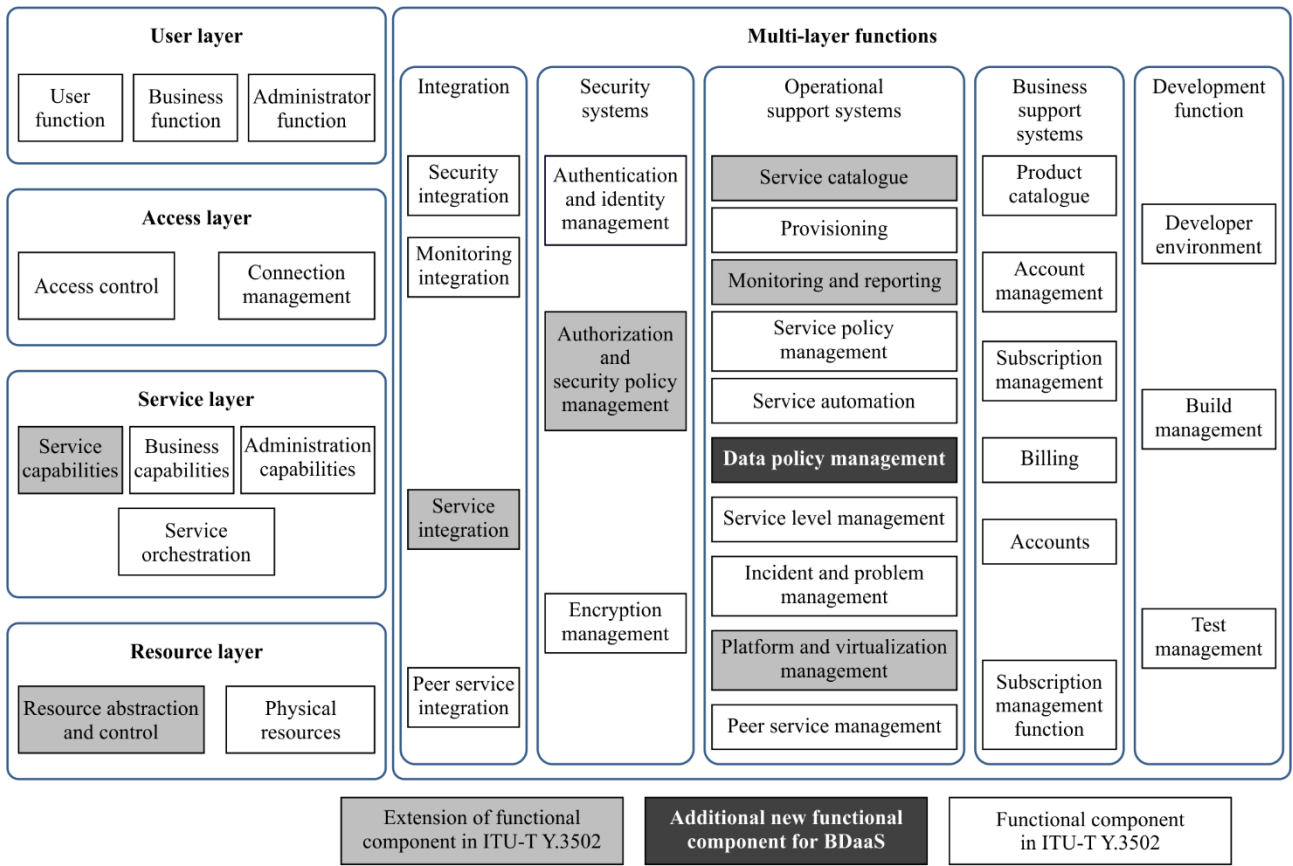
Figure 7-1 – Functional architecture for BDaaS

7.1 Service layer functional components

The service layer functional components for BDaaS (see Figure 7-2) include:

– data collection functional component (see clause 7.1.1);

– data visualization functional component (see clause 7.1.2);

– data pre-processing functional component (see clause 7.1.3);

– data analysis functional component (see clause 7.1.4);

– data storage functional component (see clause 7.1.5).
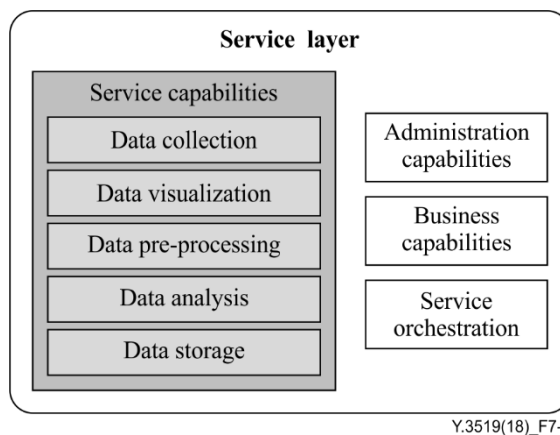
Figure 7-2 – Service capabilities functional components extended for BDaaS

7.1.1 Data collection functional component

The data collection functional component performs data collection based on various data collection configurations. The data collection functional component provides:

– setting up various data collection configurations, such as data amount, traffic volume, collection period, collection method;

> NOTE 1 – Examples of collection methods include crawling, rich site summary collecting, log /sensor collecting.

> NOTE 2 – Rich site summary is used to aggregate syndicated web content, such as online newspapers, blogs, podcasts and video blogs in one location.

> NOTE 3 – Crawling is used to gather data from the world wide web, especially web indexing.

> NOTE 4 – Log collecting is used to collect data from log files generated by web servers.

– gathering data based on established configurations of data collection. The collected data is stored in an appropriate storage according to the data type.

7.1.2 Data visualization functional component

The data visualization functional component makes data more intuitive and easier to understand for big data service users (e.g., CSC: big data service user (BDSU)) by using various data visualization tools. It also supports multiple user interactive reporting tools.

This functional component provides:

– presenting data with multiple styles such as statistical graphics, forms, diagrams, charts and reports;

– reporting tools that can be configured by CSC:BDSU.

7.1.3 Data pre-processing functional component

The data pre-processing functional component is responsible for preparing data for further processing such as data analysis. This functional component provides support for data cleaning, data integration, data transformation, data discretization and data extraction to improve data analysis efficiency.

This functional component provides:

– cleaning data which includes processing smoothing noise data, and identifying and removing outliers to improve data quality;

> NOTE – Outlier refers to abnormal data in a dataset. If it is not trimmed out, data quality may be damaged.

– combining and integrating data from multiple sources to remove duplicated and redundant data;

– transforming the data collected in different formats and types;

– converting continuous data into discrete interval data;

– extracting the representative features from a large number of data features for data analysis.

7.1.4 Data analysis functional component

The data analysis functional component is responsible for extracting useful information or valuable insights from big data. This functional component provides support for multiple data analysis methods. This functional component also supports customization of specific analysis methods.

This functional component provides:

– registration of data analysis methods which are used for data analysis. Typical Data analysis methods are classification analysis, clustering analysis, association analysis, regression analysis, customized analysis, etc.;

NOTE 1 – Classification analysis: This supports decision tree, support vector machine, neural networks and other algorithms, to identify to which set of categories data belongs.

NOTE 2 – Clustering analysis: This supports k – means, k – center point, overlapping clustering, fuzzy clustering, etc., to classify data into different classes or clusters according to their similarity.

NOTE 3 – Association analysis: This supports some specific algorithms to find associations between stored data. Examples of association algorithms include Apriori algorithm and Frequent Pattern Growth algorithm. Apriori algorithm and Frequent Pattern Growth algorithm are two classical association analysis algorithms which can mine the associations through the frequency of data appearing together in the dataset.

NOTE 4 – Regression analysis: This supports linear regression and logistic regression and other algorithms, for estimating the relationships among data.

NOTE 5 – Customization of analysis supports the customization of detail data analysis methods according to a customer's specific requirements.

–   setting up procedures which enable the analysis using registered analysis methods in the analysis function registry;

–   executing analysis process according to the procedures.

7.1.5   Data storage functional component

The data storage functional component is responsible for storing data. This functional component also provides different types of storage for different data types and different database types while storing data.

This functional component provides:

–   provisioning storage considering the various types of data storage, database, and different types of data such as structured data, unstructured data, and semi-structured data;

NOTE 1 – Data storage types include block storage, file storage and object storage.

NOTE 2 – Databases include Relation database, No SQL database.

NOTE 3 – Unstructured data can include mass data, such as log files, video, audio data, email, Web pages, data generated on social-media sites. Semi-structured data can include data stored in XML, HTML and other format documents. Structured data can include record data persistent in databases (see [ITU-T Y.3600]).

–   allocating the appropriate storage when a storage usage request is initiated;

–   releasing storage when the storage usage is terminated;

NOTE 4 – The data storage functional component interworks with the data collection functional component (see clause 7.1.1) to identify the characteristics of the data such as data type, data volume and so on.

–   storing data on various storage systems. It supports storage mirroring and provides data fragmentation to distribute and store data on distributed storage systems. This provides the ability to update data;

NOTE 5 – Distributed storage system stores data on multiple independent storages. It adopts the scalable system structure, and uses multiple storage servers which are used to share the storage load.

NOTE 6 – Storage mirroring is the replication of logical storage volumes onto separate physical disks.

–   data indexing, stored together with data, to improve the speed of data retrieval operations.

7.2   Resource layer functional components

The resource abstraction and control functional component, in the resource layer functional components, is extended for BDaaS (see Figure 7-3) with the following functional components:

–   distributed processing functional component (see clause 7.2.1).

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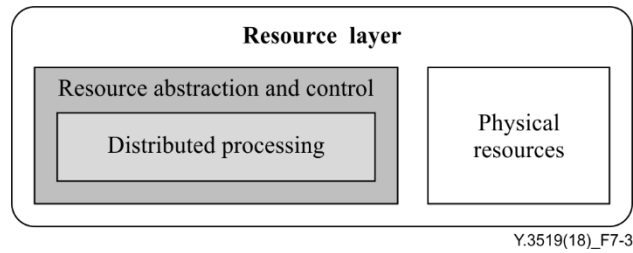
Figure 7-3 – Resource abstraction and control functional component extended for BDaaS

7.2.1 Distributed processing functional component

The distributed processing functional component is responsible for processing data by the distributed cluster resources. This functional component provides distributed computing, as well as storage options for intermediate or final processing results to satisfy the requirements of different data types and scenarios.

This functional component supports:

–   processing data by the distributed cluster resources with each node containing pieces of whole datasets and processing that data locally in parallel, and write the intermediate or final processing results to file system or memory cache;

   NOTE – Cluster resources refer to the physical or virtual servers of the distributed processing cluster.

–   processing data by the distributed cluster resources with nodes organizing into logical topology where data flows through.

7.3 Multi-layer functional components

7.3.1 Integration functional components

The service integration functional component, in the integration functional components, is extended for BDaaS (see Figure 7-4) with the following functional components:

–   third-party service integration functional component (see clause 7.3.1.1).

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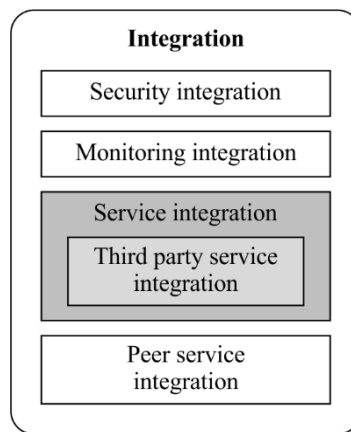
Figure 7-4 – Service integration functional component extended for BDaaS

7.3.1.1 Third-party service integration functional component

The third-party service integration functional component supports the development of service implementation tools which assist in modifying and adapting the service from a set of third-party services.

This functional component supports:

–   integrating multiple big data services;

– integrating third-party services with operational systems, as well as reporting tools or systems;

– integrating, adjusting and optimizing user-defined algorithms.

7.3.2   Security systems functional components

The authorization and security policy management functional component, in the security systems functional components, is extended for BDaaS (see Figure 7-5) with the following functional components:

− security and privacy management functional component (see clause 7.3.2.1).

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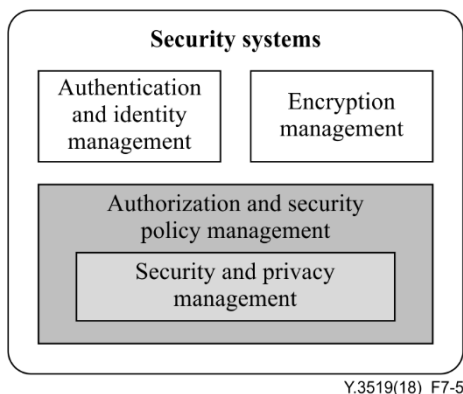
Figure 7-5 – Authorization and security policy management functional component extended for BDaaS

7.3.2.1   Security and privacy management functional component

The security and privacy management functional component is responsible for managing data provenance, personal information in data and user access authority. This functional component aims to avoid data being collected, stored by or disclosed to those who are not appropriate.

This functional component provides:

− the capability to manage identification and authorization so that only authenticated and authorized users shall access the data;

− methods to protect the privacy of confidential data and sensitive data. For example, this function supports data desensitization to protect the sensitive data.

NOTE 1 – Confidential data refers to provide for protection of data from unauthorized disclosure. (see [b-ITU-T X.509]).

NOTE 2 – Sensitive data refers to personally identifiable information or other sensitive information which is collected, stored, used, and finally destroyed or deleted.

7.3.3   Operational support systems functional components

The operational support system functional components are extended for BDaaS (see Figure 7-6) with the following functional components:

− data life-cycle monitoring functional component (see clause 7.3.3.1);

− data policy management functional component (see clause 7.3.3.2);

− data catalogue functional component (see clause 7.3.3.3);

− resource orchestration functional component for Big data (7.3.3.4).
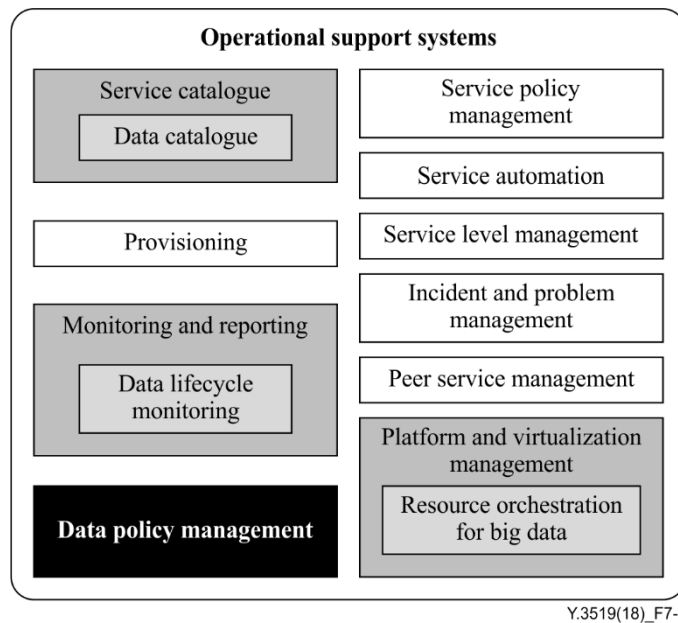
**Figure 7-6 – Operational support systems functional components
extended for BDaaS**

7.3.3.1 Data life-cycle monitoring functional component

The data life-cycle is a sequence of steps from the initial creation or capture of the data to the final archive and/or deletion at the end of its useful life. The data life-cycle monitoring functional component is responsible for monitoring data availability, preservation and usage frequency during the entire data life-cycle from creating, storing, using, sharing, archiving, and destroying data.

This functional component is responsible for:

– monitoring data availability-related information such as expiration date, sensitivity level and sharing right of data;

– monitoring data preservation-related information (e.g., created time) and operation (e.g., data creation and data deletion). The monitoring results guide the data archive, deletion and recovery based on data preservation policy. For example, if archived data have expired, it needs to be deleted;

– checking the frequency of data usage. According to the different frequency of data usage, data processing and data management schemes are adjusted in the process of data life-cycle. For example, in the data storage process, data that are accessed more frequently will be stored on faster, but more expensive storage media, while less critical data will be stored on cheaper, but slower media.

7.3.3.2 Data policy management functional component

The data policy management functional component is responsible for creating, modifying and deleting data policies, such as data provenance sharing policy, data license policy and data preservation policy. The BDaaS service provider applies data policies to the processes of data collection, data processing, data storage, etc.

This functional component provides:

– the ability to create data policies, such as the creation of data sharing policy, data license policy and data price policy according to various usage requirements. For example, for the transmission of sensitive data, an encrypted transmission policy is created;

NOTE 1 – Data sharing policy is used to determine whether the data source can be shared or not according to the security level of the data.

NOTE 2 – Data license policy is used to set up application conditions, period of validity and authentication method for different licenses.

NOTE 3 – Data price policy is used to set reasonable prices according to data volume, data sources and other conditions. In some cases, data prices should be set by negotiating with data users.

– the ability to check and delete useless policies. For example, if a data policy is updated, obsolete ones need to be deleted;

– the ability to apply data policies to the process of data collection, data processing, data preservation, data storage, etc.

NOTE 4 – Data preservation policy is used to protect and prolong the existence and authenticity of data and its metadata.

7.3.3.3   Data catalogue functional component

The data catalogue functional component is mainly responsible for registering data catalogue, and it also supports searching data by browsing data catalogue. This functional component is a sub-function of the service catalogue functional component defined in [ITU-T Y.3502].

This functional component provides:

– registering a data catalogue to cloud service partner (CSP) for searching the appropriate data. Data catalogue provides data access methods, data use policy, etc.;

– data searching capability that allows browsing of data catalogue and searching data with keywords, application domain, specific data fields, etc.

7.3.3.4   Resource orchestration functional component for big data

BDaaS services are provisioned and maintained over underlying resources which belong to the cloud computing infrastructure, including processing resources, storage resources and network resources. The resource orchestration functional component for big data is responsible for binding, load balancing and scheduling resources provided by service providers (e.g., CSP: big data infrastructure provider (BDIP)) and requested by CSC: BDSU.

This functional component provides:

– resource binding that supports allocating resources related to data processing, data storage and data analysis;

– resource load balancing that enables automated resource movement as workload requirements change;

– resource scheduling that allocates resources to tasks required by big data services, and schedules the start- and end-time of each task according to resource availability.

8   Cross-cutting aspects for BDaaS

Cross-cutting aspects can be shared and can impact multiple roles, cloud computing activities and functional components, as described in [ITU-T Y.3502]. This clause defines cross-cutting aspects for BDaaS.

8.1   Data redundancy

Data redundancy refers to the repeated occurrence of the same data in the system. For example, in a relational database, data redundancy mainly refers to the repeated storage of the same data in the relational database, including repetition of tables, attributes, tuples, and attribute values. Necessary data redundancy can improve the anti-interference ability of data, thus preventing data loss and errors. For example, redundantly encoding data by adding several bits based on the length of the original binary code, to prevent key data loss and errors.

However, data redundancy should be minimized to improve storage space utilization, but in some cases, data redundancy should also be increased appropriately. Data compression and de-duplication are two key technologies to reduce data redundancy.

CSP: big data application provider (BDAP) and CSP: BDIP support reducing unnecessary redundant data and increase useful data redundancy appropriately.

8.2 Performance

Referring to [ITU-T Y.3502], this Recommendation identifies additional performance metrics and indicators relating to the operation of a big data service, such as:

– realtime performance metrics, such as automatic fault tolerance and database extensibility;

– elastic calculation performance indicators, such as connections per second and packets per second;

– storage performance indicators, such as bandwidth and input/output preferences per second;

– data disaster tolerance performance indicators including recovery point indicator.

9 Security considerations

Security aspects for consideration within the cloud computing environment, especially for BDaaS, are addressed by security challenges for CSPs, as described in [b-ITU-T X.1601]. In particular, [b-ITU T X.1601] analyses security threats and challenges, and describes security capabilities that could mitigate these threats and meet the security challenges.

[b-ITU-T X.1631] provides guidelines supporting the implementation of information security controls for CSCs and CSPs. Many of the guidelines guide the CSPs to assist the CSCs in implementing the controls, and guide the CSCs to implement such controls. Selection of appropriate information security controls, and the application of the implementation guidance provided, will depend on a risk assessment as well as any legal, contractual, regulatory or other cloud-sector specific information security requirements.

It is also recommended that the guidelines for CSC data security described in [b-ITU-T X.1641] are considered. It provides generic security guidelines for the CSC data in cloud computing, analyses the CSC data security life-cycle and proposes security requirements at each stage of the data life-cycle.

Appendix I

Mapping between requirements, activities and functional components

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

This appendix (see Table I.1) describes the mapping between BDaaS functional requirements, activities (described in [ITU-T Y.3600]) and functional components in this Recommendation. The related layers with [ITU-T Y.3502] are also shown in Table I.1.

Table I.1 – Mapping between requirements, activities and functional components

Requirements in [ITU-T Y.3600]	Activities in [ITU-T Y.3600]	Functional components in this Recommendation	Related layers with [ITU-T Y.3502]
<Clause 8.1 requirement (4)> It is recommended for CSN: data provider (DP) to provide a brokerage service to CSP:BDIP for searching accessible data.	Brokerage data (7.1.1.3)	Data collection functional component (7.1.1)	Service layer
<Clause 8.1 requirement (1)> It is required for the CSP:BDIP to support collecting data from multiple CSN: DPs in parallel.	Perform data collection (7.1.3.1)	Data collection functional component (7.1.1)	Service layer
<Clause 8.1 requirement (3)> It is recommended that the CSP:BDIP supports collecting data from different CSN: DPs with different modes.	Perform data collection (7.1.3.1)	Data collection functional component (7.1.1)	Service layer
<Clause 8.1 requirement (6)> Data collection can optionally be performed by the CSP:BDIP in realtime.	Perform data collection (7.1.3.1)	Data collection functional component (7.1.1)	Service layer
<Clause 8.6 requirement (1)> It is required for the CSP:BDIP to manage metadata information such as creating, controlling, attributing, defining and updating.	Publish data (7.1.1.2)	Data catalogue functional component (7.3.3.3)	Operations support systems (OSS)
<Clause 8.1 requirement (2)> It is recommended for the CSN: DP to expose data to the CSP:BDAP by publishing metadata.	Publish data (7.1.1.2)	Data catalogue functional component (7.3.3.3)	OSS
<Clause 8.3 requirement (5)> It is recommended for the CSN: DP to expose APIs for data delivery.	Perform data storage (7.1.3.2)	Data catalogue functional component (7.3.3.3)	OSS
<Clause 8.1 requirement (4)> It is recommended for the CSN: DP to provide a brokerage service to the CSP:BDIP for searching accessible data.	Brokerage data (7.1.1.3)	Data collection functional component (7.1.1)	Service layer
<Clause 8.1 requirement (5)> It is recommended that the CSP:BDIP integrates data delivered by the CSC and data publicly available.	Brokerage data (7.1.1.3)	Data collection functional component (7.1.1)	Service layer

Table I.1 – Mapping between requirements, activities and functional components

Requirements in [ITU-T Y.3600]	Activities in [ITU-T Y.3600]	Functional components in this Recommendation	Related layers with [ITU-T Y.3502]
<Clause 8.5 requirement (2)> It is recommended that the CSP:BDAP supports different tools or plug-ins with multiple styles of data visualization.	Visualize data (7.1.2.1)	Data visualization functional component (7.1.2)	Service layer
<Clause 8.5 requirement (3)> It is recommended that the CSP:BDAP supports customization of the reporting tools.	Visualize data (7.1.2.1)	Data visualization functional component (7.1.2)	Service layer
<Clause 8.5 requirement (4)> It is recommended that the CSP:BDAP supports integration of reporting tools with the CSC reporting systems.	Visualize data (7.1.2.1)	Data visualization functional component (7.1.2)	Service layer
<Clause 8.5 requirement (5)> It is recommended that the CSP:BDAP supports integration of reporting tools with the CSC operational systems.	Visualize data (7.1.2.1)	Data visualization functional component (7.1.2)	Service layer
<Clause 8.2 requirement (1)> It is required for the CSP:BDIP to support data aggregation.	Provide data integration (7.1.3.4)	Data pre-processing functional component (7.1.3)	Service layer
<Clause 8.2 requirement (2)> It is recommended that the CSP:BDIP provides the dedicated resources for pre-processing.	Provide data pre-processing (7.1.3.3)	Data pre-processing functional component (7.1.3)	Service layer
<Clause 8.2 requirement (3)> It is recommended that the CSP:BDIP supports unification of data collected in different formats.	Provide data pre-processing (7.1.3.3)	Data pre-processing functional component (7.1.3)	Service layer
<Clause 8.2 requirement (4)> It is recommended for the CSP:BDIP to support extraction of data from unstructured data or semi-structured data into structured data.	Provide data pre-processing (7.1.3.3)	Data pre-processing functional component (7.1.3)	Service layer
<Clause 8.1 requirement (2)> It is recommended for the CSN: DP to expose data to the CSP:BDAP by publishing metadata.	Publish data (7.1.1.2)	Data catalogue functional component (7.3.3.3)	Service layer
<Clause 8.3 requirement (5)> It is recommended for the CSN: DP to expose APIs for data delivery.	Perform data storage (7.1.3.2)	Data storage functional component (7.1.5)	Service layer
<Clause 8.4 requirement (1)> It is required for the CSP:BDAP to support analysis of various data types and formats.	Analyze data (7.1.2.2)	Data analysis functional component (7.1.4)	Service layer

Table I.1 – Mapping between requirements, activities and functional components

Requirements in [ITU-T Y.3600]	Activities in [ITU-T Y.3600]	Functional components in this Recommendation	Related layers with [ITU-T Y.3502]
<Clause 8.4 requirement (2)> It is required for the CSP:BDAP to support batch processing.	Analyze data (7.1.2.2)	Data analysis functional component (7.1.4)	Service layer
<Clause 8.4 requirement (3)> It is required for the CSP:BDAP to support association analysis.	Analyze data (7.1.2.2)	Data analysis functional component (7.1.4)	Service layer
<Clause 8.4 requirement (4)> It is required for the CSP:BDAP to support different data analysis algorithms.	Analyze data (7.1.2.2)	Data analysis functional component (7.1.4)	Service layer
<Clause 8.4 requirement (5)> It is recommended that the CSP:BDAP supports customization of analytical applications.	Analyze data (7.1.2.2)	Data analysis functional component (7.1.4)	Service layer
<Clause 8.4 requirement (6)> It is recommended for the CSP:BDAP to support user defined algorithms.	Analyze data (7.1.2.2)	Data analysis functional component (7.1.4)	Service layer
<Clause 8.4 requirement (7)> It is recommended for the CSP:BDAP to support data processing in distributed computing environments.	Analyze data (7.1.2.2)	Data analysis functional component (7.1.4)	Service layer
<Clause 8.4 requirement (9)> It is recommended that the CSP:BDAP supports data classification in parallel.	Analyze data (7.1.2.2)	Data analysis functional component (7.1.4)	Service layer
<Clause 8.4 requirement (10)> It is recommended that the CSP:BDAP provides different analytical applications.	Analyze data (7.1.2.2)	Data analysis functional component (7.1.4)	Service layer
<Clause 8.4 requirement (11)> It is recommended that the CSP:BDAP supports customization of analytical applications.	Analyze data (7.1.2.2)	Data analysis functional component (7.1.4)	Service layer
<Clause 8.4 requirement (12)> It is recommended for the CSP:BDAP to support real-time analysis of streaming data.	Analyze data (7.1.2.2)	Data analysis functional component (7.1.4)	Service layer
<Clause 8.4 requirement (13)> It is recommended for the CSP:BDAP to support user behavior analysis.	Analyze data (7.1.2.2)	Data analysis functional component (7.1.4)	Service layer
<Clause 8.4 requirement (14)> The CSP:BDAP can optionally perform analysis of different data types and formats in realtime.	Analyze data (7.1.2.2)	Data analysis functional component (7.1.4)	Service layer

Table I.1 – Mapping between requirements, activities and functional components

Requirements in [ITU-T Y.3600]	Activities in [ITU-T Y.3600]	Functional components in this Recommendation	Related layers with [ITU-T Y.3502]
<Clause 8.6 requirement (2)> It is required for the CSP:BDIP to track a data history which contains source of data and data processing method.	Analyze data (7.1.2.2)	Data analysis functional component (7.1.4)	Service layer
<Clause 8.3 requirement (1)> It is required for the CSP:BDIP to support different data types with sufficient storage space, elastic storage capacity, and efficient control methods.	Perform data storage (7.1.3.2)	Data storage functional component (7.1.5)	Service layer
<Clause 8.3 requirement (2)> It is required for the CSP:BDIP to support storage for different data formats and data models.	Perform data storage (7.1.3.2)	Data storage functional component (7.1.5)	Service layer
<Clause 8.3 requirement (4)> It is recommended that the CSP:BDIP provides different types of databases.	Perform data storage (7.1.3.2)	Data storage functional component (7.1.5)	Service layer
<Clause 8.4 requirement (8)> It is recommended for the CSP:BDAP to support data indexing.	Perform data storage (7.1.3.2)	Data storage functional component (7.1.5)	Service layer
<Clause 8.4 requirement (7)> It is recommended for the CSP:BDAP to support data processing in distributed computing environments.	Manage data provenance (7.1.3.6)	Data storage functional component (7.1.5)	Service layer
<Clause 8.5 requirement (6)> It is recommended that the CSP:BDAP supports composed services which could combine two or more big data services to the CSC: BDSU.	Use big data service (7.1.4.1)	Third-party service integration functional component (7.3.1.1)	Integration
<Clause 8.4 requirement (6)> It is recommended for the CSP:BDAP to support user defined algorithms.	Analyze data (7.1.2.2)	Data analysis functional component (7.1.4)	Service layer
<Clause 8.7 requirement (2)> It is required for the CSP:BDIP to support data protection.	Manage data protection (7.1.3.5)	Security and privacy management functional component (7.3.2.1)	Security systems
<Clause 8.7 requirement (5)> It is recommended that the CSP:BDIP supports redundancy mechanism and transaction logging.	Use big data service (7.1.4.1)	Cross-cutting aspect (8.1)	Multiple layers for cross-cutting aspect
<Clause 8.7 requirement (1)> It is required for the CSP:BDIP to protect data collection, data storage, data transmission, and data processing with security mechanisms.	Manage data protection (7.1.3.5)	Security and privacy management functional component (7.3.2.1)	Security systems

Table I.1 – Mapping between requirements, activities and functional components

Requirements in [ITU-T Y.3600]	Activities in [ITU-T Y.3600]	Functional components in this Recommendation	Related layers with [ITU-T Y.3502]
<Clause 8.3 requirement (6)> It is recommended that the CSP:BDIP fulfils storage and database performance demands.	Perform data storage (7.1.3.2)	Cross-cutting aspect (8.2)	Multiple layers for cross-cutting aspect
<Clause 8.6 requirement (3)> It is required for the CSP:BDAP to support distributed cluster monitoring tools to monitor the health and status of computing clusters.	–	Distributed processing functional component (7.2.1)	Resource layer
<Clause 8.6 requirement (5)> It is recommended for the CSP:BDIP to support network resource monitoring.	–	Distributed processing functional component (7.2.1)	Resource layer
<Clause 8.3 requirement (3)> It is required that the CSP:BDIP provides flexible licensing policy for the database.	Use big data service (7.1.4.1)	Data policy management functional component (7.3.3.2)	OSS
<Clause 8.3 requirement (7)> It is recommended that the CSP:BDIP supports data retention policy covering data retention period before its destruction after termination of a contract, to protect the big data service customer from losing private data through an accidental lapse of the contract.	Manage data protection (7.1.3.5)	Data policy management functional component (7.3.3.2)	OSS
<Clause 8.7 requirement (4)> It is recommended that the CSP supports implementing the CSC's data protection and security policies over data and analytical results.	Manage data protection (7.1.3.5)	Data policy management functional component (7.3.3.2)	OSS
<Clause 8.7 requirement (3)> It is required that the CSP deletes CSC related data and analytical results according to the lifetime defined by the CSC or on the CSC's demand.	Manage data protection (7.1.3.5)	Data policy management functional component (7.3.3.2)	OSS
<Clause 8.6 requirement (6)> It is recommended for the CSP:BDIP to support management of data life-cycle operations.	–	Data life-cycle monitoring functional component (7.3.3.1)	OSS
<Clause 8.6 requirement (4)> It is required for the CSP:BDIP to support data preservation policy management rules.	–	Data life-cycle monitoring functional component (7.3.3.1)	OSS

Table I.1 – Mapping between requirements, activities and functional components

Requirements in [ITU-T Y.3600]	Activities in [ITU-T Y.3600]	Functional components in this Recommendation	Related layers with [ITU-T Y.3502]
<Clause 8.1 requirement (4)> It is recommended for the CSN: DP to provide a brokerage service to the CSP:BDIP for searching accessible data.	Brokerage data (7.1.1.3)	Data collection functional component (7.1.1)	Service layer
<Clause 8.3 requirement (1)> It is required for the CSP:BDIP to support different data types with sufficient storage space, elastic storage capacity, and efficient control methods.	Perform data storage (7.1.3.2)	Resource orchestration functional component for big data (7.3.3.4)	OSS
<Clause 8.3 requirement (6)> It is recommended that the CSP:BDIP fulfils storage and database performance demands.	Perform data storage (7.1.3.2)	Data storage functional component (7.1.5)	Service layer
<Clause 8.3 requirement (3)> It is required that the CSP:BDIP provides flexible licensing policy for the databases.	Perform data storage (7.1.3.2)	Data policy management functional component (7.3.3.2)	OSS
<Clause 8.4 requirement (5)> It is required that the CSP:BDAP provides a flexible licensing policy for the analytical applications.	Analyze data (7.1.2.2)	Data policy management functional component (7.3.3.2)	OSS
<Clause 8.5 requirement (1)> It is required that the CSP:BDAP provides a flexible licensing policy for the reporting tool.	Publish data (7.1.1.2)	Data policy management functional component (7.3.3.2)	OSS

NOTE – In Table I.1, "−" means "There is no specific activity related to the requirements in [ITU-T Y.3600]".

Bibliography

[b-ITU-T X.509]	Recommendation ITU-T X.509 (2016), *Information technology – Open Systems Interconnection – The Directory: Public-key and attribute certificate frameworks*.
[b-ITU-T X.1601]	Recommendation ITU-T X.1601 (2015), *Security framework for cloud computing*.
[b-ITU-T X.1631]	Recommendation ITU-T X.1631 (2015)	ISO/IEC 27017:2015, *Information technology – Security techniques – Code of practice for information security controls based on ISO/IEC 27002 for cloud services*.
[b-ITU-T X.1641]	Recommendation ITU-T X.1641 (2016), *Guidelines for cloud service customer data security*.
[b-ITU-T Y.3500]	Recommendation ITU-T Y.3500 (2014)	ISO/IEC 17788:2014, *Information technology – Cloud computing – Overview and vocabulary*.
[b-ISO/IEC 2382]	ISO/IEC 2382:2015, *Information technology – Vocabulary*.

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