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

Cloud Computing

SERIES M: TELECOMMUNICATION MANAGEMENT, INCLUDING TMN AND NETWORK MAINTENANCE

Cloud Computing – Telecommunications management network

Overview of end-to-end cloud computing management

Recommendation ITU-T Y.3521/M.3070

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Recommendation ITU-T Y.3521/M.3070

Overview of end-to-end cloud computing management

Summary

Recommendation ITU-T Y.3521/M.3070 presents a conceptual view and the common model of end-to-end (E2E) cloud computing management based on the service management interface (SMI) and cloud computing reference architecture, from the perspective of the telecommunications industry.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T Y.3521/M.3070	2016-03-15	13	11.1002/1000/12714

Keywords

Cloud computing management, end-to-end, model, multi-cloud, service management interface.

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FOREWORD

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1 Scope

This Recommendation provides an overview of end-to-end (E2E) cloud computing management.

This Recommendation covers the following:

− cloud computing management objectives from telecommunication industry's perspective;

− conceptual view and management layering;

− common model for multi-cloud environment management;

− cloud computing management functionalities.

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.1601] Recommendation ITU-T X.1601 (2015), *Security framework for cloud computing*.

[ITU-T Y.3502] Recommendation ITU-T Y.3502 (2014), *Information technology – Cloud computing – Reference architecture*.

[ITU-T Y.3510] Recommendation ITU-T Y.3510 (2016), *Cloud computing infrastructure requirements*.

[ITU-T Y.3511] Recommendation ITU-T Y.3511 (2014), *Framework of inter-cloud computing*.

[ITU-T Y.3512] Recommendation ITU-T Y.3512 (2014), *Cloud computing – Functional requirements of Network as a Service*.

[ITU-T Y.3520] Recommendation ITU-T Y.3520 (2015), *Cloud computing framework for end to end resource management*.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 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.

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

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

NOTE – A business relationship does not necessarily imply financial agreements.

3.1.4 cloud service provider [b-ITU-T Y.3500]: Party which makes cloud services available.

3.1.5 cloud service user [b-ITU-T Y.3500]: Natural person, or entity acting on their behalf, associated with a cloud service customer that uses cloud services.

NOTE – Examples of such entities include devices and applications.

3.1.6 inter-cloud computing [ITU-T Y.3511]: The paradigm for enabling the interworking between two or more cloud service providers.

NOTE – Inter-cloud computing is also referred as inter-cloud.

3.1.7 management system [b-ITU-T M.60]: A system with the capability and authority to exercise control over and/or collect management information from another system.

3.1.8 service level agreement (SLA) [b-ITU-T Y.3500]: Documented agreement between the service provider and customer that identifies services and service targets.

NOTE 1 – A service level agreement can also be established between the service provider and a supplier, an internal group or a customer acting as a supplier.

NOTE 2 – A service level agreement can be included in a contract or another type of documented agreement.

3.2 Terms defined in this Recommendation

This Recommendation defines the following term:

3.2.1 service management interface (SMI): Interface that provides a set of management capabilities exposed by a cloud service through which the cloud service can be managed.

NOTE – For additional details of SMI concepts, see [ITU-T Y.3520] and [b-TMF TR198].

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

BSS Business Support System

CSC Cloud Service Customer

CSP Cloud Service Provider

CSU Cloud Service User

CT Communication Technology

E2E End-to-End

EMS Element Management System

eTOM Enhanced Telecom Operations Map

IaaS Infrastructure as a Service

IT Information Technology

KQI Key Quality Indicator

NaaS Network as a Service

NMS Network Management System

OSS Operational Support System

PaaS Platform as a Service

SaaS Software as a Service

SLA Service Level Agreement

SLO Service Level Objective

SMI Service Management Interface

TMN Telecommunications Management Network

VM Virtual Machine

5 Conventions

None.

6 Introduction

In both telecommunication and cloud computing environments, management refers to the ability of maintaining visibility and control of all the managed resources in delivering a service to the customer and satisfying the negotiated service level agreement (SLA). However, until now, these approaches have been different.

For the management of telecommunication services and networks, telecommunication operators (as well as other stakeholders in the telecommunication industry) have applied the mature telecommunications management network (TMN) principles and enhanced telecom operations map (eTOM) as a standard framework and technologies. This has led to the construction of a set of management systems (e.g., element management system (EMS), network management system (NMS), business support system (BSS) or operational support system (OSS)) to realize the required telecommunication management functions.

With the convergence of information technology (IT) and communications technology (CT) industries, cloud computing is being adopted in telecommunication infrastructures. Telecommunication operators are now delivering various cloud services to their users in addition to applying cloud computing technologies for the optimization of their telecommunication service platforms and telecommunication support systems.

Cloud computing has a different management approach in that it does not expose individual elements of itself to the telecommunications management system. Rather, a cloud computing system incorporates its own sophisticated management functionality, which is able to manage the cloud computing system in a coherent manner. Therefore, cloud computing does not distinguish between management operations carried out on behalf of the customer, and identical management operations carried out on behalf of the network operator. Rather, cloud computing defines the role of cloud service customer (CSC) and sub-role of cloud service user (CSU), both of which can be performed by end-customers and telecommunication operators alike.

This Recommendation addresses the need to bring these two very different approaches together.

It is important to note that the creation and use of many cloud-based virtual resources and services are no longer treated as traditional "management" activities, but by the nature of cloud computing are regularly performed in an on-demand self-service manner by CSCs who do not require "management" credentials for this task. As an analogy, many of these tasks are therefore closer to placing telephone calls than to managing telephony equipment.

Many cloud computing use cases extend across multiple cloud service providers (CSPs) and multiple services. CSPs engaged in such a multiple cloud ecosystem therefore, are required to implement appropriate management capabilities on the inter-cloud interfaces [ITU-T Y.3511] to other CSPs. In such a scenario, a single company may be simultaneously acting as a CSP for its own customers, as a CSC for the services provided by another CSP, and as a CSC of its own CSP services.

In a virtualized environment, a CSP focuses on monitoring E2E network and application performance and needs the ability to dynamically add or remove resources when performance requirements change. Considering the addition of multiple technology domains involved, E2E management must cover both virtualized and physical infrastructures across potentially multiple CSPs.

In a multiple cloud environment, the E2E management means composition of:

a) service and resource management chains across:
   i) layers;
   ii) multiple CSPs.

b) service and resource management chains which may include:
   i) the CSC;
   ii) one or more CSPs providing the cloud service;
   iii) non-cloud-based telecommunications facilities.

See [ITU-T Y.3520] for further information.

Platforms on which the virtual resources are hosted are typically managed within a cloud computing management system, and might not be exposed directly to the telecommunications management system.

Therefore, the introduction of cloud computing brings new aspects to management for telecommunication operators:

- cloud computing roles and sub-roles, see clause 7.2.2 of [ITU-T Y.3502];
- cloud computing multi-layer functions, see clause 7.3.3 of [ITU-T Y.3502], including development environment, test environment, and the cloud computing BSS/OSS functions;
- cloud services, see clause 9.2.3 of [ITU-T Y.3502];
- cloud computing resources, see clause 9.2.4 of [ITU-T Y.3502].

7 Objectives

From the perspective of the telecommunication industry, the following management objectives regarding cloud computing should be considered:

- fulfil the holistic management of cloud computing resources and services together with the existing telecommunications management framework. For the purpose of providing cloud services effectively, both the telecommunication BSS/OSS and the cloud BSS/OSS should collaborate properly to support the holistic management of cloud computing resources and services, together with telecommunication networks;
- fulfil the network management needs of cloud computing. As defined in [ITU-T Y.3510] and [ITU-T Y.3512], network resources (e.g., bandwidth, switching and routing, network addresses) will need to be scalable, and adapt dynamically to the traffic generated. Telecommunication operators will need to provision self-managed and on-demand network capability to meet various requirements from the cloud service, and to apply dynamic control and adapt its configuration (including network bandwidth, protocols, codecs, security mechanisms, etc.) over the telecommunication network on the direct request of cloud services or CSCs;
- realize E2E service quality management. E2E service quality management is vital for telecommunication services which are deployed using cloud computing resources and services. Telecommunication services demand high availability, high security, and excellent service experience (e.g., short response times, high service success rate). Telecommunication operators need to be able to control and manage the cloud computing resources and services for the purpose of ensuring E2E telecommunication service quality and CSC experience.

8 Conceptual view and management layering

This clause defines the conceptual view of cloud computing management based on the cloud computing reference architecture [ITU-T Y.3502], cloud computing management layers and the service management interface (SMI) approach.

8.1 Cloud computing management layering

Figure 8-1 presents a comprehensive view of cloud computing management. It shows the management layers of a cloud computing system:

- customer management;
- product management;
- service management;
- resource management.

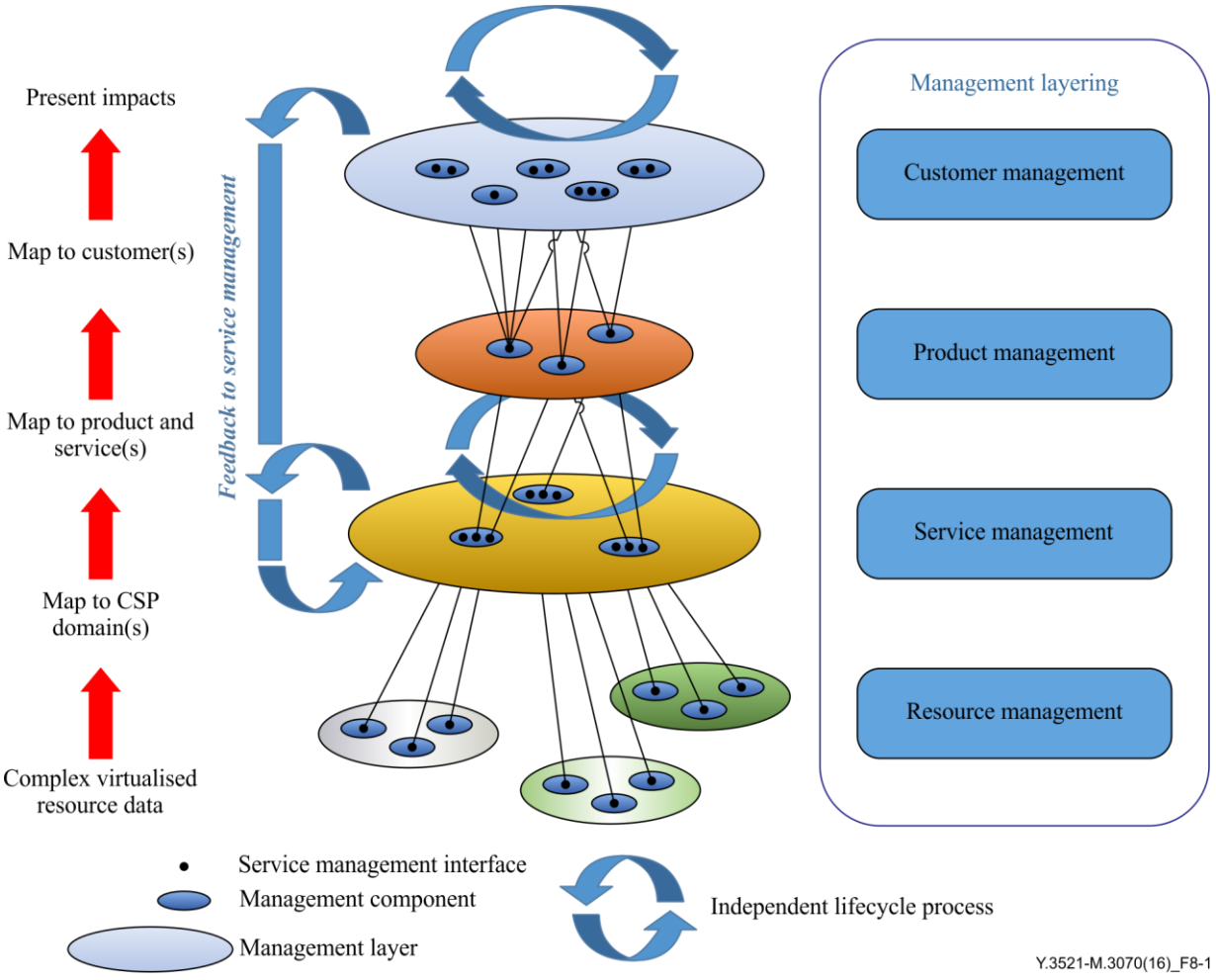

Figure 8-1 – Comprehensive view of cloud computing management

As shown in Figure 8-1, cloud computing management is realized based on SMIs, which correlate layers determined in the reference architecture of cloud computing [ITU-T Y.3502] to offer complete E2E management service chains (see clause 6).

A management layer represents a level of abstraction within the management system, such that higher layers do not need to interact directly with low-level managed elements or components.

A management component as represented here refers to a collection of management functionality that has responsibility for a specific area within a management layer.

The SMIs allow elements, components, and layers to expose management information and telemetry in a consistent matter that can be rolled up into a comprehensive diagnostics and management service.

See Appendix I for a complex scenario example of the use of this concept.

The purposes of the management layers are described below.

8.1.1 Customer management layer

The customer management layer considers the fundamental knowledge of customers' needs and includes all functionalities necessary for the acquisition, enhancement and retention of a relationship with a customer.

For details of the functionalities present in the customer management layer, see clause 10.1.

8.1.2 Product management layer

The product management layer includes the necessary management functions for maintaining the existing product catalogue and providing necessary functions for products sale.

For details of the functionalities present in the product management layer, see clause 10.2.

8.1.3 Service management layer

The service management layer focuses on the knowledge of cloud services and includes all functionalities necessary for the management and operations of cloud services required by or proposed to customers. The focus is on cloud service delivery and management as opposed to the management of the underlying resources.

This layer is accountable for cloud service delivery such as service instance management, and cloud service operation such as service monitoring and problem handling and the assurance of the service quality.

For details of the functionalities present in the service management layer, see clause 10.3.

8.1.4 Resource management layer

The resource management layer is responsible for maintaining knowledge of resources (application, computing and network infrastructures) and for managing all these resources (e.g., networks, IT systems, servers, routers) utilized to deliver and support cloud services required by or proposed to customers.

For details of the functionalities present in the resource management layer, see clause 10.4.

8.2 Service management interface

The SMI-based approach provides a means to allow consistent E2E management of cloud computing services exposed by, and across, different domains of CSPs thus unifying the traditional telecommunication environment and the cloud computing environment.

The SMI capabilities include the following:

- activation of a cloud service, i.e., making a cloud service available for a particular context (deploying a cloud service instance);
- provisioning of a cloud service, i.e., configuring the settings of a cloud service instance;
- status monitoring of a cloud service instance, i.e., querying the history and current status in terms of lifecycle management for a specific cloud service instance;
- usage monitoring of a cloud service instance, i.e., querying for usage metrics from a cloud service instance or listening for usage metrics reports or alarms (e.g., if metrics conditions imply notifications);

– health monitoring of a cloud service instance, i.e., querying for health metrics from a cloud service instance;
– update of a cloud service instance, i.e., modification of the setting or lifecycle management status of a cloud service instance;
– de-activation of a cloud service, i.e., making a cloud service unavailable.

A further description of how the SMI-based model can be used across various cloud computing reference architecture layers can be found in Annex A.

8.3 Relationship with the cloud computing reference architecture

Figure 8-2 illustrates the relationship between the management layers described in clause 8.1 and the BSS and OSS components of the cloud computing reference architecture as defined in [ITU-T Y.3502].

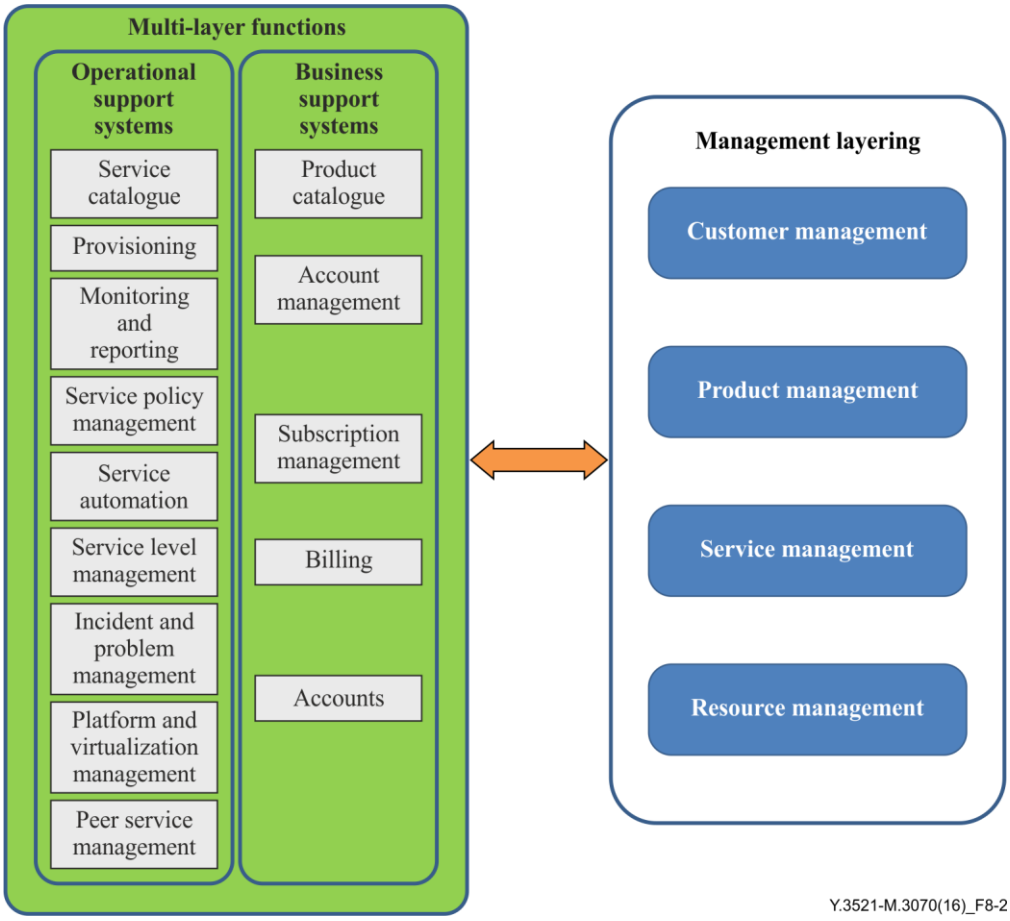

Figure 8-2 – Relationship of BSS/OSS components and the management layering

The cloud computing management layers support the management requirements of cloud computing to provision, operate and administer cloud computing resources and services, and consists of: customer management, product management, service management and resource management.

The OSS functional components encompass the set of operational related management capabilities that are required in order to manage and control the cloud services offered to customers (see clause 9.2.5.3 of [ITU-T Y.3502]). The BSS functional components encompass the set of business-related management capabilities dealing with customers and supporting processes (see clause 9.2.5.4 of [ITU-T Y.3502]).

Figure 8-3 shows how the OSS and BSS components of the cloud computing reference architecture are further split according to the different management layers based on the conceptual view of cloud computing management provided in clause 8.

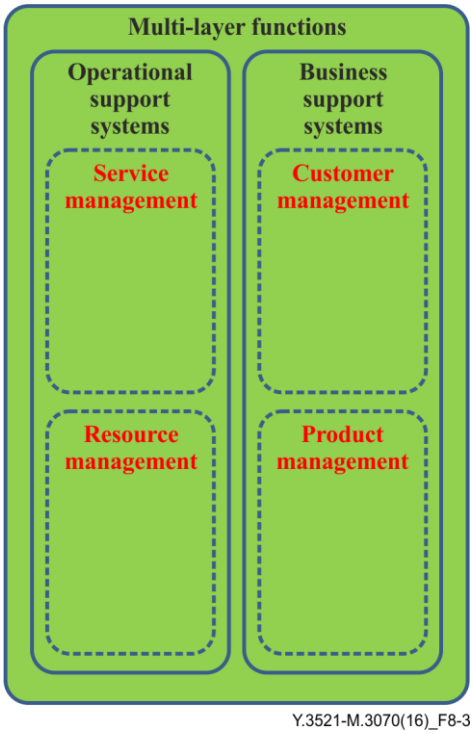

Figure 8-3 – Split of OSS/BSS components according to management layers

9 Common model for E2E cloud computing management

This clause describes a common management model, based on SMIs, for all layers of the cloud computing reference architecture. This allows management of E2E cloud computing applications and solutions in a multi-cloud computing environment, independently from the choice of technology, run-time, programming language or tools made to develop the solutions. This common management model also shows the concept of E2E cloud integrated telecommunications management.

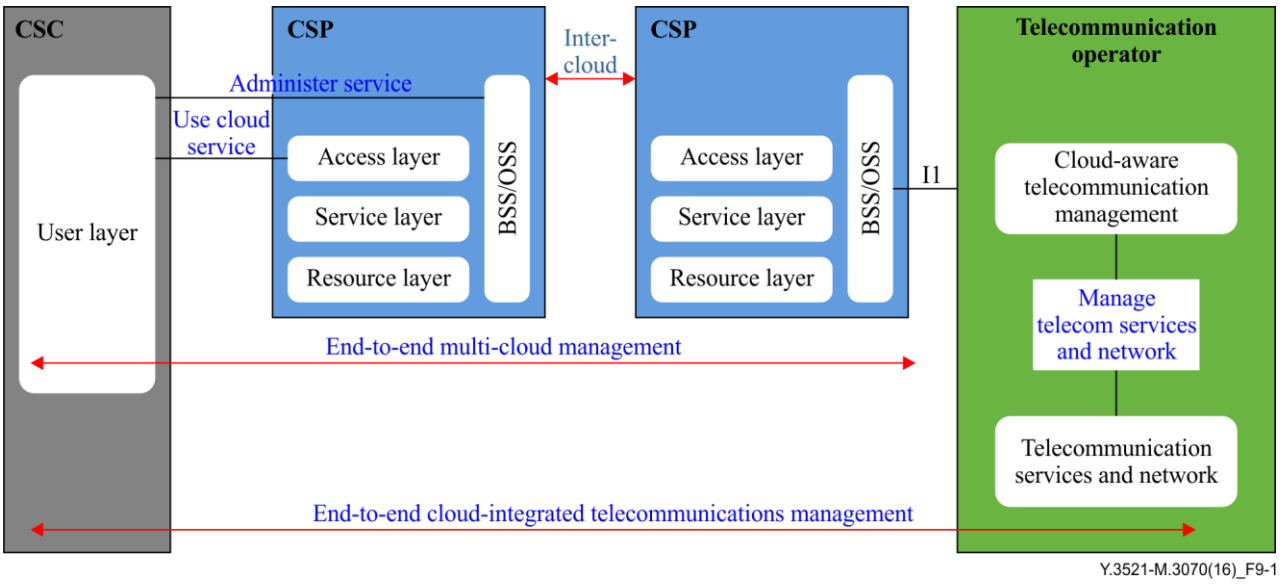

Figure 9-1 – Common model for E2E cloud computing management

Figure 9-1 is based on service and resource management chains including the CSC, one or more CSPs, and a telecommunication operator. The squared boxes with a black outline represent different parties involved in the common model for E2E cloud computing management.

The term "inter-cloud" is used in accordance with [ITU-T Y.3511] and covers the integration of cloud services from two or more CSPs.

The term "multi-cloud", as used in this Recommendation, includes holistic E2E management of one or more cloud service providers providing a given cloud service (see [ITU-T Y.3502], [ITU-T Y.3520], [ITU-T X.1601]).

The term "cloud-aware" is used here to describe the requirement of telecommunication management that are able to manage cloud-based facilities. This ability could be realized through the use of management interface "I1" which provides necessary information from the CSP's BSS/OSS to the cloud-aware telecommunication management system. The management interface "I1" can correspond to a set of SMIs as described in this Recommendation.

Note that the telecommunication operator may also act as a cloud service provider, see Figure 9-2.

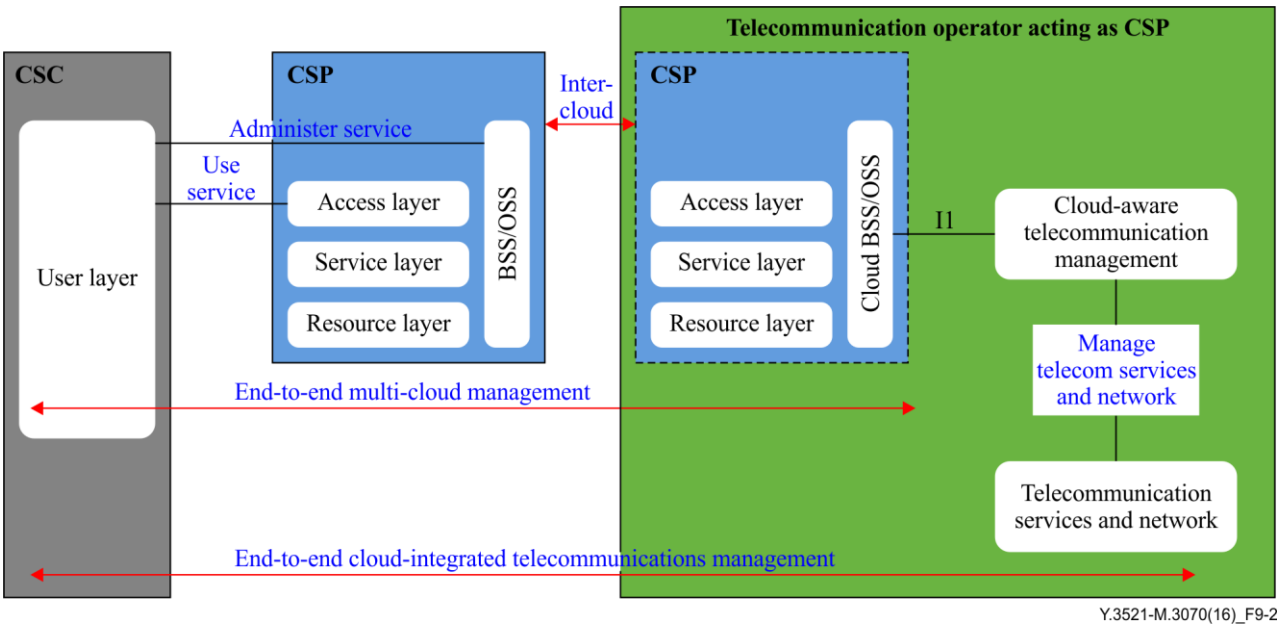

Figure 9-2 – Common model for E2E cloud computing management, with telecommunication operator acting as a CSP

In this case, the "I1" interface resides within the telecommunication operator.

The common model for E2E cloud computing management does not imply any particular arrangement of inter-cloud connectivity. For example, the telecommunication operator acting as a CSP could be acting as an intermediary CSP between the CSC and other cloud services, or in any other inter-cloud role described in [ITU-T Y.3511]. The management architecture is unaffected by this.

10 Cloud computing management functionalities

This clause identifies functionalities for cloud computing management. The high-level organization of cloud computing management functionalities presented in Figure 10-1 is based on the management layering described in clause 8.1 covering customer management, product management, service management, and resource management.

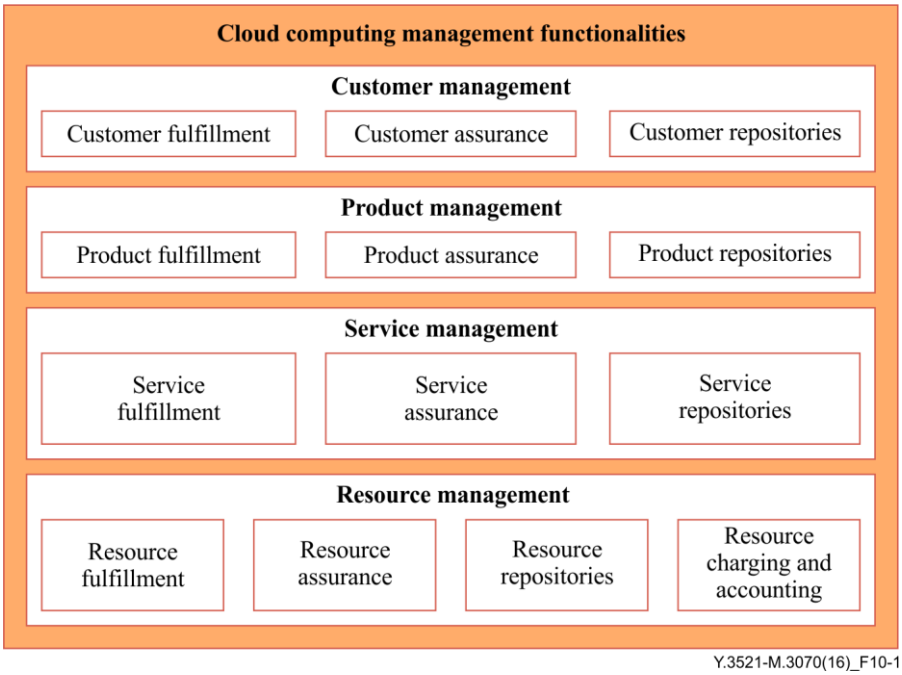

Figure 10-1 – The high-level organization of cloud computing management functionalities

10.1 Functionalities for cloud customer management

This clause identifies cloud customer management functionalities including customer fulfilment, customer assurance and customer repositories functionalities. The detailed functionalities for cloud customer management are presented in Figure 10-2.

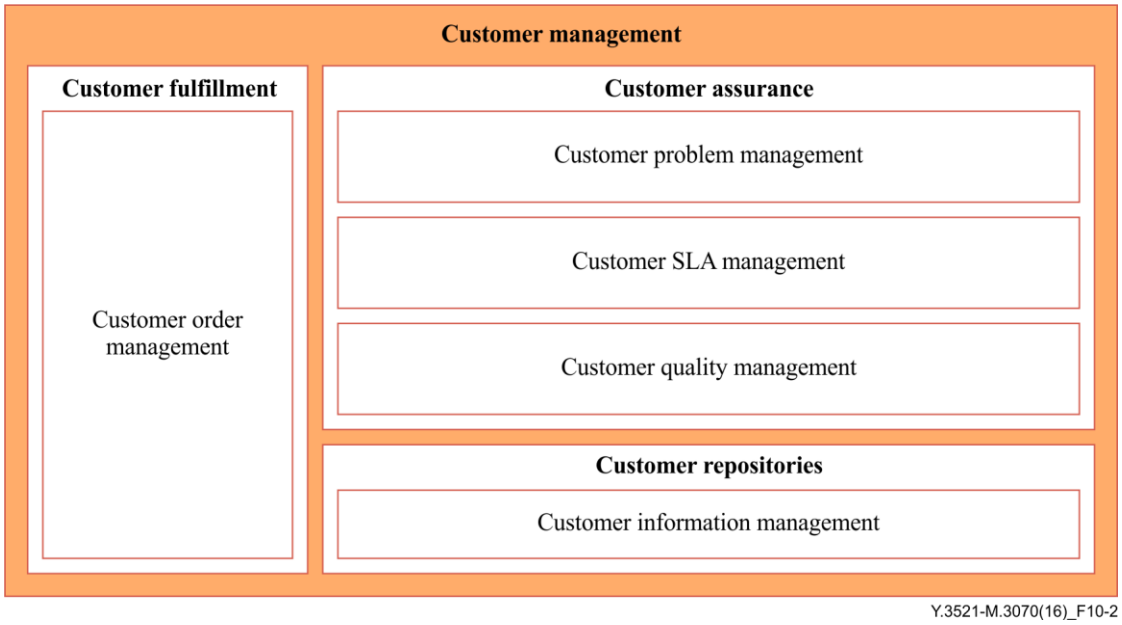

Figure 10-2 – Functionalities related to cloud customer management

10.1.1 Customer fulfilment functionalities

This covers a set of functionalities for the fulfilment management of cloud service customers. These functionalities include customer order management**.**

10.1.1.1 Customer order management

Customer order management is responsible for the E2E lifecycle management of a customer request for products. This includes customer order establishment (step guiding, data collection and validation), customer order publication as well as customer order orchestration and overall customer order lifecycle management.

Customer order management functionalities include the following:

1) customer order establishment. This functionality is responsible for the acquisition of a customer order for products;
2) customer order distribution. This functionality decomposes the customer order into product order requests (e.g., bundle decomposition);
3) customer order publication. This functionality issues valid and complete customer orders, and stores the order into an appropriate inventory;
4) customer order tracking and management. This provides the functionality necessary to track and manage the distributed requests decomposed by customer order distribution;
5) customer order orchestration. This functionality provides workflow and orchestration capability across customer order management;
6) customer order lifecycle management. This provides the functionality necessary to track and manage a customer order from establishment to cancellation.

10.1.2 Customer assurance functionalities

This covers a set of functionalities for the assurance management of cloud customers. These functionalities include customer problem management, customer SLA management and customer quality management.

10.1.2.1 Customer problem management

This set of functionalities is responsible for managing problems reported by customers, resolving these problems to the customer's satisfaction, and providing meaningful status on the issues, as needed, to the customer. These functionalities include customer problem reception and validation, customer problem lifecycle management, customer problem diagnostics, customer problem resolution and customer problem reporting.

10.1.2.2 Customer SLA management

Customer SLA management includes the required functionalities to assure that cloud SLAs made between CSCs and CSPs are met. This includes processing measurements made elsewhere and checking the measurements and taking appropriate actions when the specified agreements are not met. These functionalities include customer SLA issue reception, customer SLA analysis, and customer SLA reporting.

10.1.2.3 Customer quality management

Customer quality management enables CSPs to leverage customer insight gained from CSC transactions, interactions and activities with the CSP to treat the CSC in a personalized manner and provide a unique customer experience. These functionalities include customer profiling (e.g., customer profile inquiries, customer behaviour tracking, prediction), customer experience monitoring, customer satisfaction validation and customer operational decision making.

10.1.3 Customer repositories functionalities

This set includes functionalities for customer information management.

10.1.3.1 Customer information management

Customer information management ensures the management of a consistent, accurate and complete CSP view of customers. This includes functionalities for customer subscription management, customer profile management (e.g., managing customer preferences and customer details) and customer interaction collection and storage.

10.2 Functionalities for cloud product management

This clause identifies cloud product management functionalities including product fulfilment, product assurance and product repository functionalities. The detailed functionalities for cloud product management are presented in Figure 10-3.

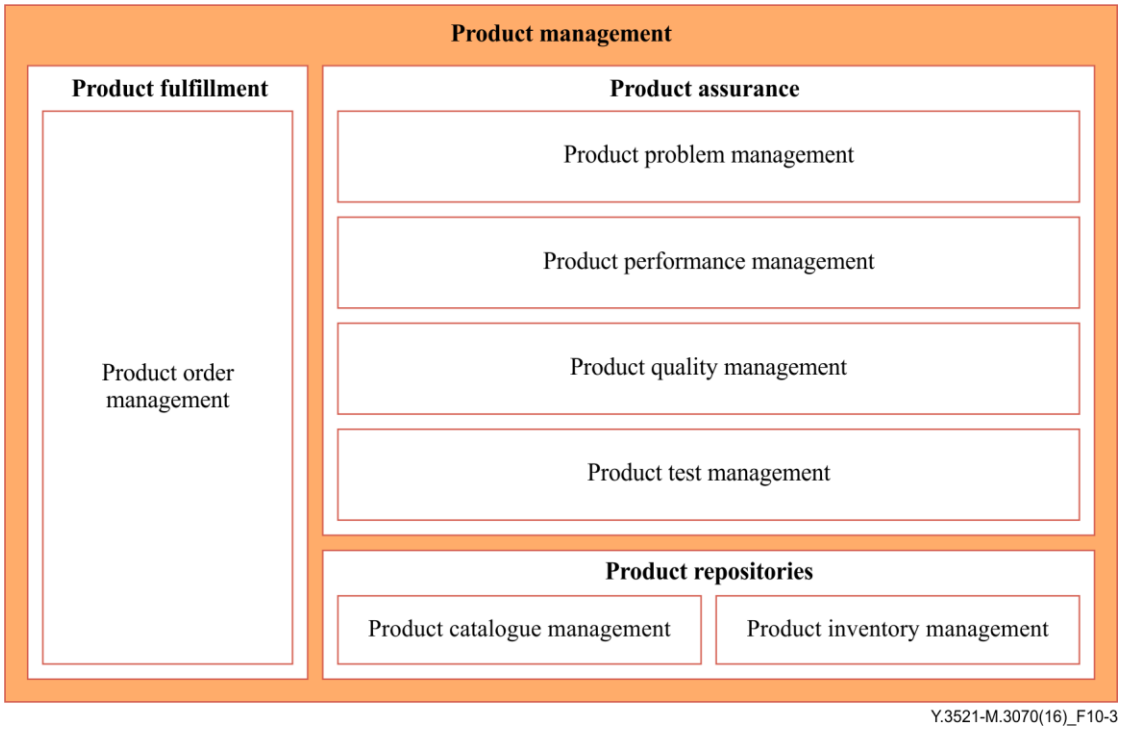

Figure 10-3 – Functionalities related to cloud product management

10.2.1 Product fulfilment functionalities

This covers a set of functionalities for the fulfilment management of cloud products. These functionalities include product order management.

10.2.1.1 Product order management

Product order management is responsible for the E2E lifecycle management of a product orders.

Product order management functionalities include the following:

1) product order establishment. This functionality is responsible for the acquisition of a product order request;
2) product order distribution. This functionality decomposes the product order into service order requests and then distributes each service order request to appropriate service order management functionalities;
3) product order publication. This functionality issues valid and complete product orders, and stores the order into an appropriate inventory;
4) product order tracking and management. This provides the functionality necessary to track and manage the distributed requests decomposed by product order distribution;

5) product order orchestration. This functionality provides workflow and orchestration capability across product order management.

10.2.2 Product assurance functionalities

This covers a set of functionalities for the assurance management of cloud products.

10.2.2.1 Product problem management

This set of functionalities is responsible for handling product-affecting CSC problems as well as CSP services problems. These functionalities analyse and resolve product problems in an efficient manner, tracking these problems and reporting them.

10.2.2.2 Product performance management

Product performance management includes the activities and tools that gather and analyse data regarding the efficiency of the product strategy, propositions and products based upon their performance in the marketplace.

This set of functionalities is responsible for monitoring, analysing and reporting on product performance. This includes the following functionalities:

1) performance monitoring. This functionality collects and monitors product performance data based upon parameters;
2) performance analysis. This functionality is responsible for the analysis and evaluation of products' performance (analysing data received from product performance monitoring). Examples of performance analysis include tracking the performance of a product based on its performance in the marketplace with regard to campaigns or product capacity analysis;
3) performance reporting. This functionality creates product performance reports (such as product revenue reporting or cost reporting) on a periodic basis or on-demand.

10.2.2.3 Product quality management

This set of functionalities is responsible for monitoring and managing the quality of products. They allow collect and compare quality related measurements against established products.

This includes the following functionalities:

1) product quality modelling. This functionality establishes what will be monitored and how it will be monitored in terms of product quality;
2) product quality monitoring. This functionality collects and monitors product quality as determined by the established product quality model;
3) product quality analysing. This functionality analyses and evaluates the quality of products being offered by the CSP;
4) product quality reporting. This functionality generates various reports on product quality and makes them available on a periodic basis or on-demand.

10.2.2.4 Product test management

This set of functionalities allows a CSP to test the quality of products. These functionalities collect and compare quality and performance related indicators. The results can be optionally available to interested parties.

10.2.3 Product repositories functionalities

This set includes functionalities for product catalogue management and product inventory management. The role of particular functionalities is described hereafter.

10.2.3.1 Product catalogue management

This set of functionalities allows the CSP to list and manage available products and their associated characteristics such as: product offering characteristics, product offering effective duration, product offering description.

10.2.3.2 Product inventory management

This set of functionalities allows the CSP to maintain information about already deployed and provided cloud products. It may also store and manage service relationships: the mapping to other services and/or service components.

10.3 Functionalities for cloud service management

This clause identifies cloud service management functionalities including service fulfilment, service assurance and service repository functionalities. The detailed functionalities for service management are presented in Figure 10-4.

NOTE – "Service order management" corresponds to the process of taking, organizing, tracking and satisfying CSC requests for cloud services provided by a CSP.

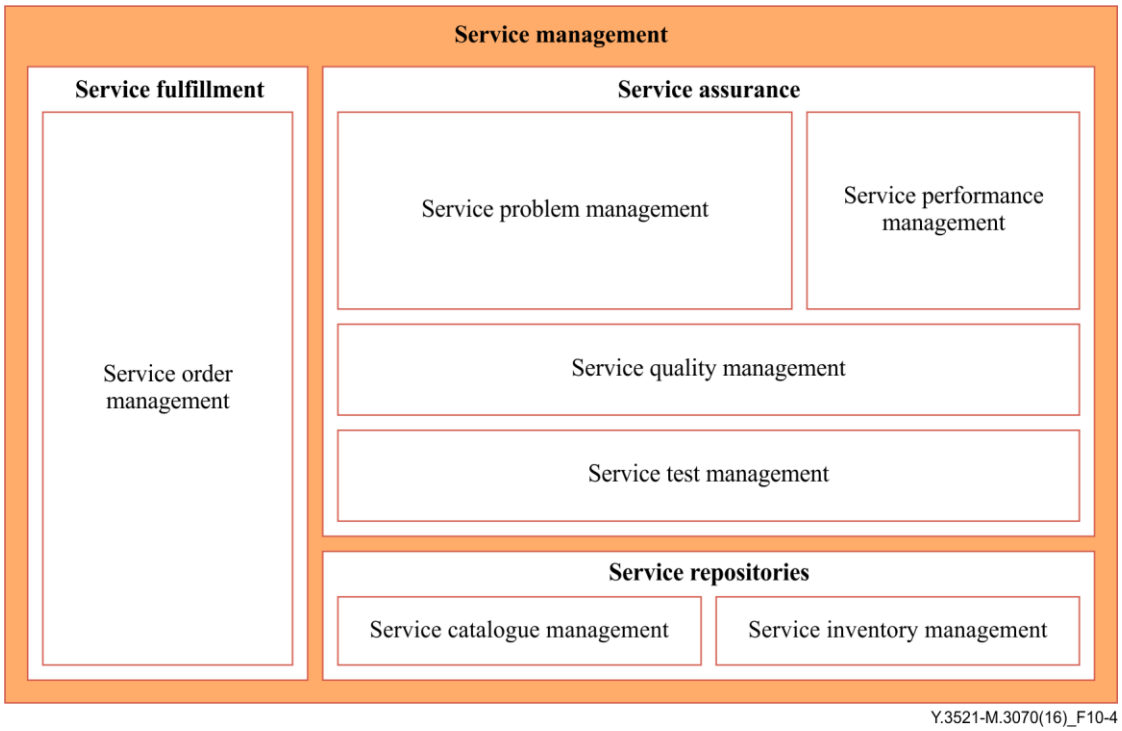

Figure 10-4 – Functionalities related to cloud service management

10.3.1 Service fulfilment functionalities

This covers a set of functionalities for the fulfilment of cloud services. These functionalities include service order management**.**

10.3.1.1 Service order management

Service order management provides a set of functionalities for the management of cloud services considering CSC requirements (e.g., cloud SLA). This set includes the following functionalities:

1) service order orchestration and distribution. This functionality provides for orchestration across service order management. It decomposes a cloud service order into resource order requests, and then distributes each request to provision the service order. It also provides the functionality necessary to track and manage these distributed requests, e.g., tracks the various

resource orders until completed, sequences resource order provisioning if required, provides status on the overall service order;

2) service assign. This functionality determines the availability of facilities required to support a service;

3) service order tracking and lifecycle management. This functionality issues valid and complete service orders, and stores the service order into an appropriate repository;

4) service order establishment. This functionality establishes a complete and valid service order. It validates the cloud service order request according to the service catalogue and installed base, and to provisioning rules. It also validates that the cloud service specified on the service order is available and feasible from the CSP platform/infrastructure point of view;

5) service activation. This functionality is responsible for the activation of a cloud service based on the specific service configuration.

10.3.2 Service assurance functionalities

This covers a set of functionalities for the assurance management of cloud services. These functionalities include service problem management, service performance management, service quality management and service test management.

10.3.2.1 Service problem management

This set of functionalities is responsible for receiving service affecting CSC problems as well as CSP infrastructure faults. These functionalities analyse and resolve service problems in an efficient manner, tracking these problems and reporting them. This includes:

1) service problem reception. This functionality receives problems that are perceived to be service affecting;

2) service problem monitoring. This functionality monitors the operational status of cloud services;

3) service problem analysis. This functionality diagnoses service problems. It correlates CSC problems with resource faults, and prioritize service problems appropriately;

4) service problem correction and resolution This functionality resolves the service problem back to a normal operational state as efficiently as possible;

5) service problem tracking and management. This functionality assures that service problems are assigned, coordinated, and restored efficiently, escalating as needed;

6) service problem reporting. This functionality reports the status of service problems. This includes operational reports, management reports, reports against various metrics, as well as information needed by other related management and operations functionalities.

10.3.2.2 Service performance management

This set of functionalities is responsible for monitoring, analysing and reporting on the E2E service performance. This includes the following functionalities:

1) performance monitoring. This functionality collects and monitors service performance parameters;

2) performance analysing. This functionality is responsible for the analysis and evaluation of services' performance (analysing data received from service performance monitoring, determining the causes of changes, providing operations for adapting the performance);

3) performance reporting. This functionality creates service performance reports on a periodic basis or on-demand.

10.3.2.3 Service quality management

This set of functionalities is responsible for monitoring and managing the E2E quality of services. They allow, collect and compare quality related measurements against established services. The results can be optionally available to interested parties. This includes the following functionalities:

1) service quality modelling. This functionality establishes what will be monitored and how it will be monitored in terms of service quality. This includes the definition of the service quality model and its dependencies as establishment of key quality indicators (KQIs) and service level objectives (SLOs), accepting input from CSC contracts or service definitions, establishment of data sources for monitoring;
2) service quality monitoring. This functionality collects and monitors service quality as determined by the established service quality model;
3) service quality analysing. This functionality analyses and evaluates the quality of services being delivered by the CSP;
4) service quality reporting. This functionality generates various reports on service quality and makes them available on a periodic basis or on-demand.

10.3.2.4 Service test management

This set of functionalities allows a CSP to test the quality of services. They allow collect and compare quality and performance related indicators. The results can be optionally available to interested parties. This includes the following functionalities:

1) service test strategy and policy management. This functionality manages the rules that define the strategies for conducting various service tests;
2) service test lifecycle management. This functionality manages the E2E lifecycle of a service test;
3) service test command and control. This functionality provides access, commands, and controls the service testing environment;
4) service test services. This functionality provides the means to access the testing capabilities.

10.3.3 Service repositories functionalities

This set includes functionalities for service catalogue management and service inventory management.

The role of particular functionalities is described below.

10.3.3.1 Service catalogue management

This set of functionalities allows the CSP to list and manage available services.

10.3.3.2 Service inventory management

This set of functionalities allows the CSP to maintain information about already deployed and provided cloud services. It may also store and manage service relationships: the mapping to other services and/or service components as well as the mapping to resources used to implement a particular service.

10.4 Functionalities for cloud computing resource management

This clause identifies functionalities related to resource management for the support of cloud services. These include resource fulfilment, resource assurance, resource charging and accounting and resource repositories functionalities. These functionalities related to resource management are presented in Figure 10-5.

NOTE – "Resource order management" corresponds to the process of taking, organizing, tracking and satisfying resource requests for the support of cloud services provided by a CSP.

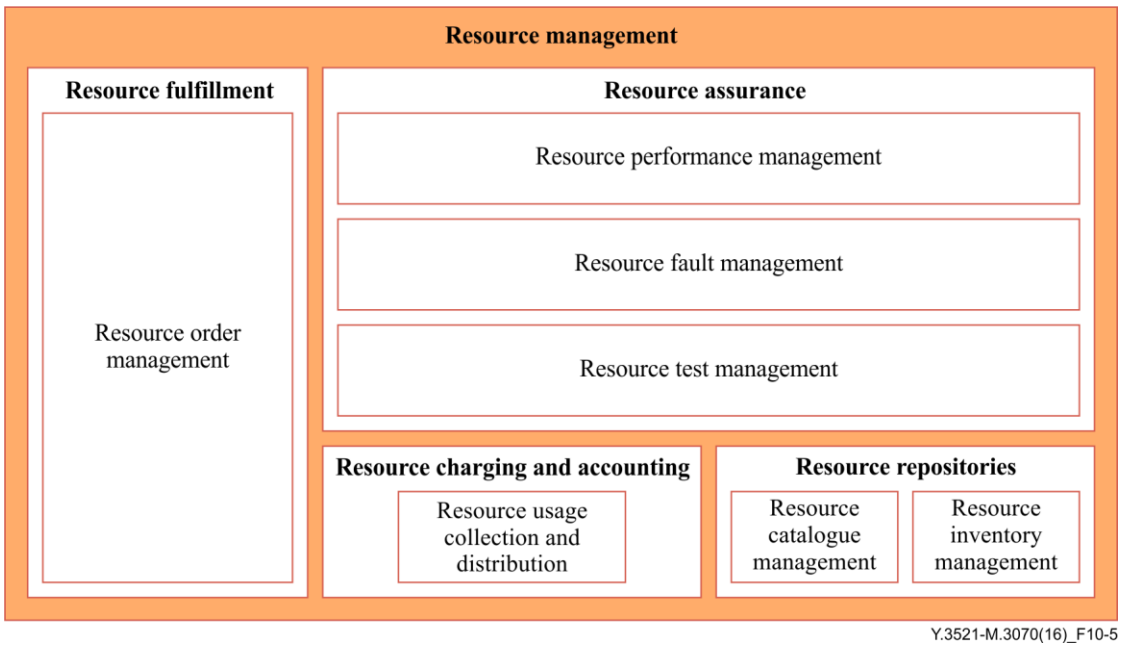

Figure 10-5 – Functionalities related to cloud computing resource management

10.4.1 Resource fulfilment functionalities

This covers a set of functionalities for the fulfilment management of resources for the support of cloud services. This functionality includes resource order management.

10.4.1.1 Resource order management

This set of functionalities manages the E2E lifecycle of a resource order request. This includes validating resource availability as well as the resource order request.

NOTE – Resource order management functionality will typically communicate with service order management and resource layer functionalities. Notifications can be issued to the service order management functionalities during the resource order orchestration process (especially upon completion). Such notification can trigger other steps in the service order management functionalities (e.g., resource order completion).

Resource order management functionalities include:

1) resource order orchestration and distribution. This functionality provides workflow and orchestration capability across resource order management. This functionality has the ability to distribute the resource order. It also provides functionality to track and manage the overall resource order as well as to track the overall order;
2) resource order validation. This functionality validates the resource order request based on contract, catalogue, and provisioning rules;
3) resource order tracking and lifecycle management. This functionality issues valid and complete resource orders, and stores the order into an appropriate repository;
4) resource assign. This functionality addresses resource configurations which are needed to support a service order.

10.4.2 Resource assurance functionalities

This set of functionalities covers the assurance management of resources in support of cloud services. These functionalities include resource performance management, resource fault management and resource test management. The role of particular functionalities is described below.

10.4.2.1 Resource performance management

This set of functionalities monitors, analyses, and reports on the performance of the CSP resources. This includes the following functionalities:

1) resource performance monitoring. This functionality supports data collection and performance monitoring of the CSP resources;
2) resource performance analysing. This functionality analyses the performance of the various CSP resources;
3) resource performance management reporting. This functionality generates reports about the performance of the CSP resources.

10.4.2.2 Resource fault management

This set of functionalities is responsible for the management of faults associated with the resources of CSP.

This includes the following functionalities:

1) resource fault monitoring. This functionality collects and monitors the operational status of the resource layer;
2) resource fault analysis. This functionality relates and analyses the various fault events in the resource layer;
3) resource fault correction and restoration. This functionality is responsible for repairing or replacement of faulty resources;
4) resource fault reporting. This functionality provides reports about the various faults within the resource layer.

10.4.2.3 Resource test management

This set of functionalities is focused on ensuring that the various resources are working properly.

This includes the following functionalities:

1) resource test strategy and policy management. This functionality manages the rules that define the strategies for conducting various resource tests;
2) resource test lifecycle management. This functionality manages the E2E lifecycle of a test of a resource;
3) resource test command and control. This functionality provides access, commands, and controls the resource testing environment;
4) resource test services. This functionality provides the means to access the testing capabilities.

10.4.3 Resource charging and accounting functionalities

This set of functionalities covers resource usage management of the services. This includes resource usage collection and distribution.

10.4.3.1 Resource usage collection and distribution

This set of functionalities is used to channel usage events from the resources to various processes such as billing, legal compliance, and service assurance. Usage event records are collected, processed, edited, correlated, enriched, formatted and distributed to upstream functionalities.

10.4.4 Resource repositories functionalities

This covers a set of functionalities for the resource repositories of the services. These functionalities include resource catalogue management and resource inventory management.

10.4.4.1 Resource catalogue management

This set of functionalities determines repositories of resource listing within the CSP and include the ability to design, create, augment and map new entities and supporting data.

10.4.4.2 Resource inventory management

This set of functionalities manages information of all CSP resources available for the implementation of services and products.

11 Security considerations

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

Annex A

Use of SMI-based model across various cloud architecture layers

(This annex forms an integral part of this Recommendation.)

This annex describes SMI-based models that can be used across various cloud computing architecture layers.

The following figure provides an example of mapping the E2E SMI concept onto the cloud computing reference architecture [ITU-T Y.3502].

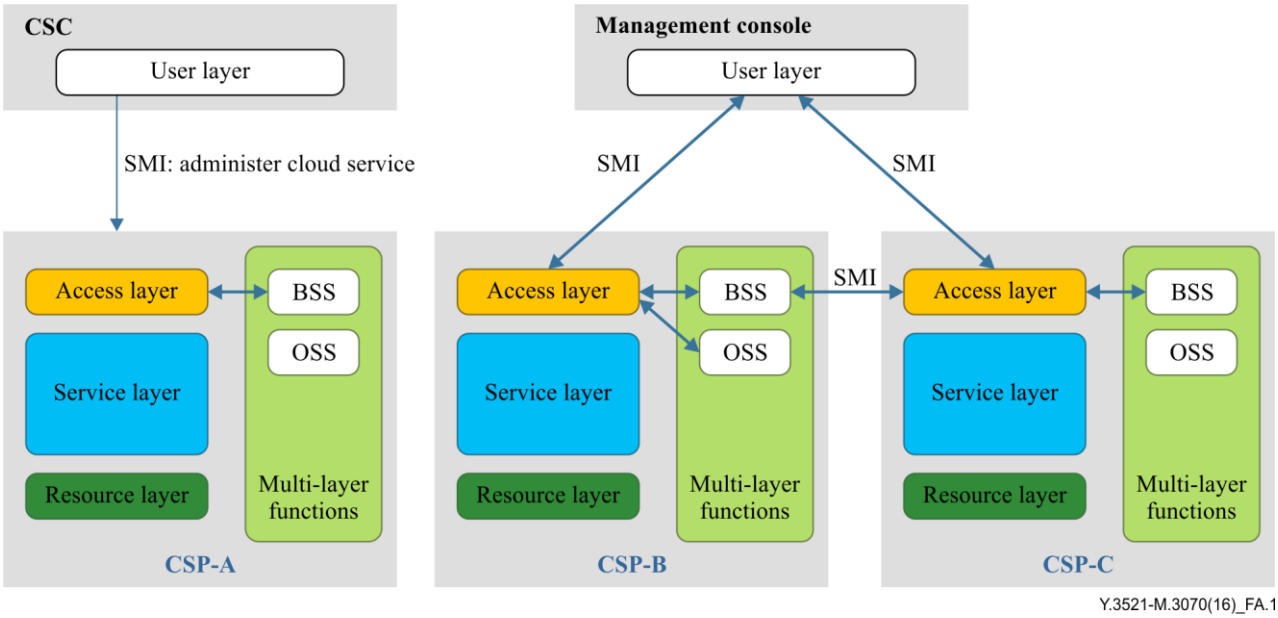

Figure A.1 – Example mapping of SMI to cloud computing reference architecture

In Figure A.1, a number of example SMIs are identified.

Firstly, an enterprise CSC's management interface into a cloud service, documented in [ITU-T Y.3502] as "administer cloud service", is implemented as an SMI. The interface is routed via the access layer for connectivity and access control purposes.

Secondly, as shown in [ITU-T Y.3520] to support inter-cloud scenarios [ITU-T Y.3511], it is possible for one CSP to act as the CSC of another, and as such it can employ the same type of SMI as in the first case. This is illustrated above in the SMIs between the BSS of CSP-B (acting as a CSU) and the access layer of CSP-C. This can then be cascaded through additional CSPs if desirable.

Thirdly, an operator's management console may employ multiple SMIs to different services and providers. In reference architecture terms, such a console is also acting as a CSC, although a very specialised one.

Thus the same SMI concept [ITU-T Y.3520] is being used in every case.

Appendix I

Illustration on E2E cloud computing management in practice

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

I.1 Introduction

This appendix provides an illustration of how a cloud computing management system can function in practice, following the conceptual view and common model described in clauses 8 and 9.

I.2 Vertical vs horizontal management

This Recommendation describes both vertical relationships within a BSS/OSS, as shown in Figure 8-1, as well as horizontal relationships between CSPs within each managed layer, as shown in clause 9.

Both vertical and horizontal interfaces are implemented as SMIs, however those vertical interfaces between management layers within a single CSP's system are likely to be implementation-specific.

I.3 Orchestrated management actions

For realising E2E cloud computing management, orchestration is required at multiple levels. In each case, this comprises the creation or management of multiple managed objects as a means to implement a higher layer construct. While orchestration can occur directly in the service layer (for example, the creation of a virtual machine (VM) within an infrastructure as a service (IaaS) service may automatically cause the creation of associated storage objects required to support the VM), this can also occur at higher layers of the management system. The following example (see clause I.5) is an illustration of such a case.

I.4 Monitoring and diagnostics

SMI interfaces can also be used for monitoring and diagnostics within a single cloud computing system and this can then be extended into a multi-cloud scenario (as described in [ITU-T Y.3520]). This allows for aggregated performance measurement, reporting, fault detection, and root cause analysis across multiple cloud services.

I.5 Example of E2E cloud computing management

For this example, consider the creation of a video streaming service, designed to deliver training content to a number of enterprise customers.

A cloud service provider is offering a product "video streaming platform" to its customers. This product provides:

1) a storage platform (library) for holding video content, including content management, cataloguing, metadata management;
2) a video-ingestion service, where content in various video formats can be uploaded for transcoding before being placed in the library;
3) a subscription management system, including digital rights management, subscription, payment, authorization, and billing;
4) service usage monitoring, including statistics, trends, and user behaviour;
5) managed network connectivity, both for uploading content to the cloud, and for efficient streaming of the content through a content delivery network and thus to end users.

The enterprise wishing to buy this bundle of services needs only to place a single product order, which will include various choices for capacity, throughput, etc.

Figure I.1 illustrates E2E cloud computing management in practice.

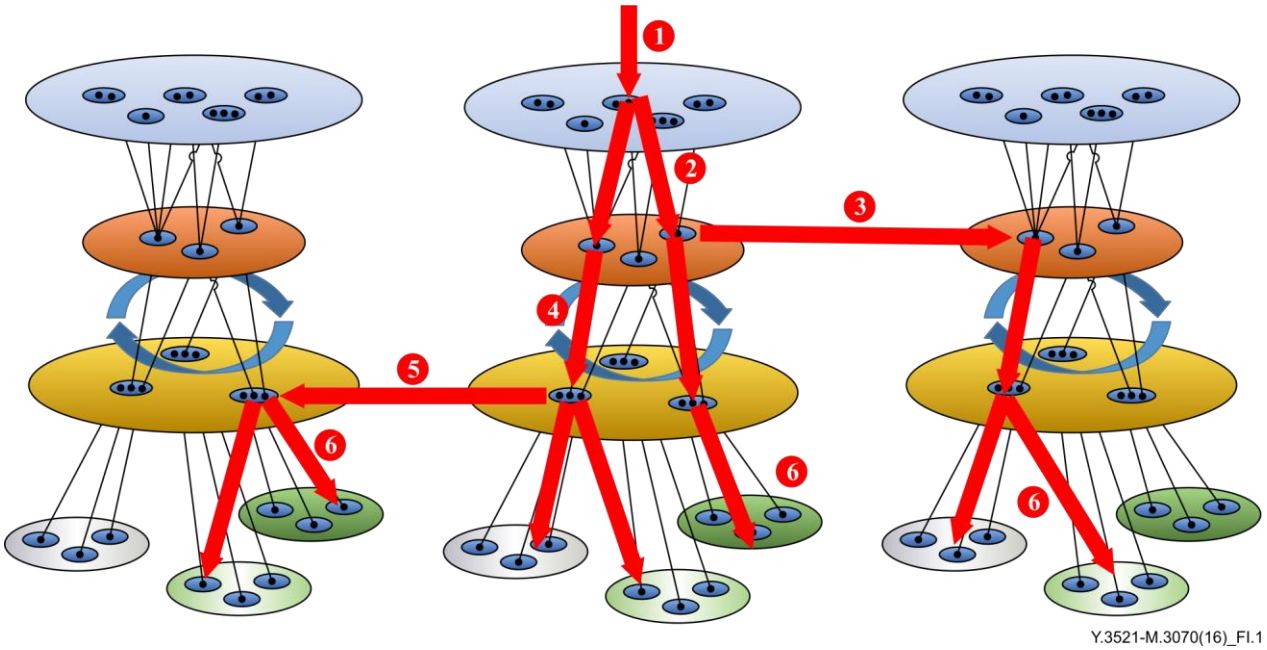

Figure I.1 – Example of E2E cloud computing management in practice

NOTE – This figure is based on the comprehensive view of cloud computing management. See clause 8.

The stages shown in Figure I.1 are as follows:

1) the CSC places the order for the entire package;

2) customer management assesses the validity of the order, determines the appropriate SLA to apply to the overall package, and invokes the individual product objects in the product management layer. There are two of these, a network product and a cloud service product;

3) the network product management creates a network as a service (NaaS) within the CSP service layer, identifying endpoint and network characteristics needed for the overall service. It also requests the creation of a NaaS service from another CSP which includes wide-area telecommunications connectivity. This is done by making SMI-based requests to instantiate the NaaS service at the other CSP. The internal and external NaaS instances are then interconnected with agreed endpoints and SLAs suitable to meet the overall objective;

4) the video cloud product orchestrates a set of cloud services including video processing, storage, content management, a software as a service (SaaS) for the billing and subscription, etc;

5) because the video processing service does not have the capability to directly handle some of the video formats the customer has requested, the video processing service requests this capability as a specialist platform as a service (PaaS) from a third CSP. The PaaS is provided with the code necessary to work with the content platform;

6) each of the invoked services is responsible for creating and managing the underlying cloud computing resources, including compute, storage, and networking. Each of them is also responsible for monitoring the functions of those resources, and reporting usage, performance, faults and SLA breaches up to their "parent" management layer for aggregation and analysis.

In this way, a very large and complex cloud-based solution is requested, instantiated, and managed as a whole, both for business and operational purposes. Within each CSP, the logic of orchestration is a key point of differentiation, but the individual management interfaces follow the general SMI approach, making for a relatively straightforward management architecture.

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