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Purpose: Proposal

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Keywords: robotics, cloud computing, robotics as a service, RaaS

Abstract: This document contains the draft Recommendation ITU-T Y.RaaS-reqts: "Cloud computing - Functional requirements of robotics as a service". This document includes the results of discussion on the Q17/13 meeting which was held via virtual in 29 November -10 December 2021.

The following table shows discussion results for contributions.

No.	Source	Contribution title and Proposals	Agreements
C1384	ETRI	Y.RaaS-reqts: Update of overview of robotics service with general procedure for robot application development	Accepted with modifications.
C1385	ETRI	Y.RaaS-reqts: Update of use case for developing and testing RaaS application	Accepted with modifications.
C1386-R1	ETRI	Y.RaaS-reqts: New use case for extension of robotics application with modules in service catalogue	Accepted with modifications.

During this meeting, it is agreed as follows:

- Add new descriptions for overview of robotics service and general robotics task life cycle based on the C1384 with modifications;
- Modify the use case of 'I.4 Developing and testing robotics applications for navigation task' based on the C1385 with editor's note about the related roles;
- Add new use case of extension of robotics application based on the C1386 with editor's note about the terminology and related roles.
- Update the analysis and considerations for robot developing methodology in C1384 on the living list of Y.RaaS-reqts.

It is recommended that future contributions cover following topics but not limited to:

- **Clarifications of roles and activities for the robotics service catalogue and robotics IDE;**
- Definitions for the robotics service with analysis of service scenarios and use cases;
- Relationships, roles and activities for RaaS system context in clause 7.

Draft Recommendation ITU-T Y.RaaS-reqts

Cloud computing – Functional requirements for Robotics as a Service

AAP Summary

[To be provided before Consent]

Summary

This Recommendation provides cloud computing requirements for Robotics as a Service, which addresses requirements from use cases. Robotics as a Service (RaaS) is a cloud service category aimed at supporting the development of robotics applications and services in a cloud computing environment. On the perspective of cloud computing service provisioning, this Recommendation defines the requirements for RaaS to identify functionalities such as augmented intelligence sharing, integrated robotic control, automated machine learning, data pre-processing, etc. Also, this draft Recommendation aligned with the cloud computing reference architecture of ITU-T Y.3502.

Keywords

RaaS; robotics as a service; cloud computing.

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Cloud computing – Functional requirements for Robotics as a Service

1 Scope

This Recommendation provides the overview and functional requirements for robotics as a service (RaaS) in the cloud environment. This Recommendation addresses the following subjects:

- Concept and overview of robotics service;
- System context of robotics as a service;
- Functional requirements for robotics as a service;
- Use cases of robotics as a service.

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.

[ITU-T Y.3500] Recommendation ITU-T Y.3500 (2014), *Information technology – Cloud computing – Overview and vocabulary*.

[ITU-T Y.3501] Recommendation ITU-T Y.3501 (2013), *Cloud computing framework and high-level requirements.*

[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 (2013), *Cloud computing infrastructure requirements*.

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

[ITU-T Y.3531] Recommendation ITU-T Y.3531 (2015), *Cloud computing - Functional requirements for machine learning as a service.*

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

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

1.1.2 cloud computing [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.

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

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

1.1.5 cloud service partner [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.

1.1.6 cloud service provider [ITU-T Y.3500]: party which makes cloud services available.

1.1.7 robot [b-ISO/DIS 8373]: programmed actuated mechanism with a degree of autonomy to perform locomotion, manipulation or positioning.

NOTE - A robot includes the control system

[Editor's Note on 2021-03-04] JTC 1/SC 42 requested to use their definition from ISO/IEC CD2 22989.

3.1.33 robot

automation system with actuators that performs intended tasks (3.1.7) in the physical world, by means of sensing its environment and a software control system

Note 1 to entry: A robot includes the control system and interface of a control system.

Note 2 to entry: The classification of robot into industrial robot or service robot is done according to its intended application.

Note 3 to entry: In order to properly perform its tasks (3.1.7), a robot makes use of different kinds of sensors to confirm its current state and perceive the elements composing the environment in which it operates.

[SOURCE: ISO 18646-2:2019, 3.1, modified - Note 3 to entry has been added]

In the meeting of March 2021, it was agreed not to fix this issue until the approval of ISO/DIS 8373 and ISO/IEC CD2 22989 because both documents are not the stage of IS.

1.1.8 robotics [b-ISO/DIS 8373]: science and practice of designing, manufacturing, and applying robots.

[Editor's Note on 2021-03-04] JTC 1/SC 42 requested to use their definition from ISO/IEC CD2 22989.

3.1.34 robotics

science and practice of designing, manufacturing, and applying robots

[SOURCE: ISO 8373:2012, 2.16]

In the meeting of March 2021, it was agreed not to fix this issue until the approval of ISO/DIS 8373 and ISO/IEC CD2 22989 because both documents are not the stage of IS.

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

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

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 robotics as a service (RaaS): A cloud service category in which the capabilities provided to the cloud service customer is the provision and use of robotics services.

[Editor's Note on 2021-03-04] It is need to define the definition of "robotics service" including example as a Note.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations:

CSB	Cloud Service Brokerage
CSC	Cloud Service Customer
CSN	Cloud Service Partner
CSP	Cloud Service Provider
RaaS	Robotics as a Service

5 Conventions

The following conventions are used in this Recommendation:

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

– The keywords "is prohibited from" indicate a requirement which must be strictly followed and from which no deviation is permitted, if conformance to this Recommendation is to be claimed.

– The keywords "is recommended" indicate a requirement which is recommended but which is not absolutely required. Thus, this requirement need not be present to claim conformance.

– The keywords "is not recommended" indicate a requirement which is not recommended but which is not specifically prohibited. Thus, conformance with this Recommendation can still be claimed even if this requirement is present.

– The keywords "can optionally" indicate an optional requirement which is permissible, without implying any sense of being recommended. This term is not intended to imply that the vendor's implementation must provide the option and the feature can be optionally enabled by the network operator/service provider. Rather, it means the vendor may optionally provide the feature and still claim conformance with this Recommendation.

– The keyword "functions" is defined as a collection of functionalities.

– The keyword "functional block" is defined as a group of functionalities that have not been further subdivided at the level of detail described in this Recommendation.

6 Overview of robotics service

6.1 Introduction to robotics service

The goal of robotics is to design the machine with intelligence to help or assist human. Robotics is a converged engineering field in which various technical areas are applied. The typical technical areas related with robotics involve computer science, information engineering, mechanical engineering, electronic engineering, bioengineering, nanotechnology, and human factors.

Therefore, robotics engineers carefully consider the technical capabilities or restrictions developed from recent research in related fields while they design, construct, manufacture, operate, and use robots. One example of technical convergence for robotics is to apply machine learning techniques from computer science area. The robotics engineers can apply or utilize the machine learning techniques such as deep learning for building their robot intelligence. The ability of robot vision can evolve with machine learning model which is trained by visual information of big data.

Robotics service is providing development environments for designing, manufacturing, and integrating the hardware equipment and applications of robots. Robot operating system (ROS) is an example of robotics service for developing robots. ROS is a type of platform to help designing, testing and operating robot applications with providing a set of software libraries and tools. ROS serves frameworks and testing environment for building, developing, and operating robot APIs. Also, it can provide services for hardware interface for sensor data, control, actuator and others.

6.2 General aspects for developing robotics service

6.2.1 The general approach to develop robotics service

Development of robot is an integrated technology that combines vary of complexed technologies including hardware design, system control, machine learning, and further. The development of each technology may need expertise in various fields which studied separated domain of research. The modular-based development has many advantages such as:

- Faster time for developing
- Reduced costs with re-usability
- Safety benefits with standardizations
- Higher collaboration
- Improved manageability

NOTE 1 – The cloud-computing can support the advantages of modular-based robotics with the composed services and resources.

NOTE 2 – The safety requirements for modules are applied by standards. For, example ISO 13482, ISO 10218-1, ISO 10218-2, ISO TS 15066 shall be applied and ensures the module safety.

[Editor's Note on 2021-12-06] It is need to develop the safety issues for robotics service in ITU-T through the review of ISO standards.

In the robotics, ~~design~~the modules provide the configurations of the hardware and software aspects with the information including the types of module, their manufacturer, and the connectors or interfaces. The modular framework shall design and define the robotics service in the virtualized environment for simulating the robot behaviours. The module-based framework may support the reusability, interoperability, and composability of the modules with well-defined operating systems, communication protocols, interfaces with supporting data types. Those of aspects are shared and exchanged with the profiles including the values of module properties. The module properties shall be defined for proper executions.

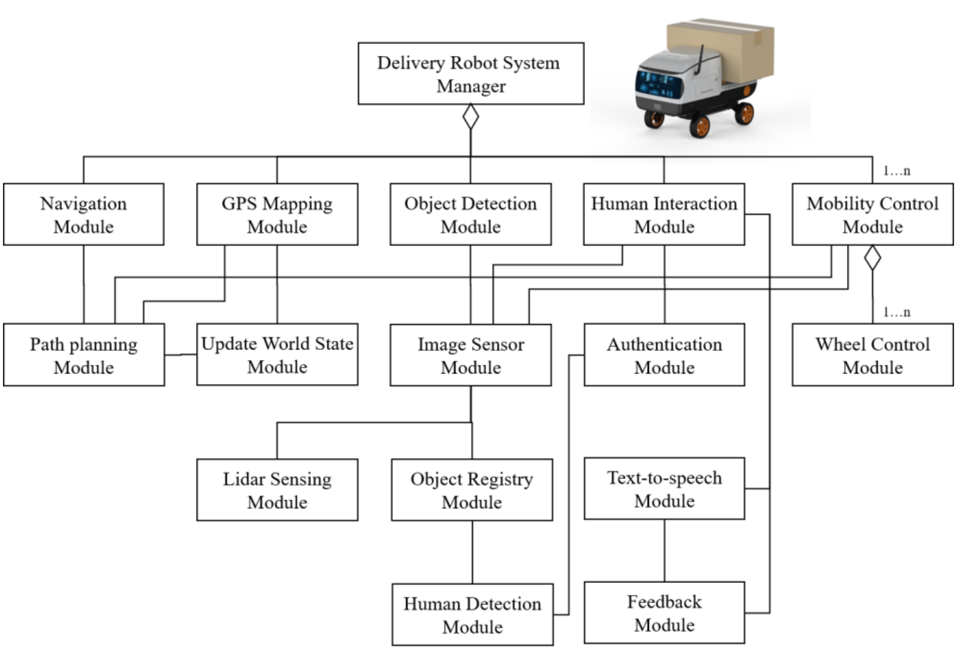


Figure 1 – An ~~delivery robot~~ example ~~for~~of the configurations ~~of~~for module-based robotics service of delivery robot

~~t~~To achieve a delivery service robot. Its main behaviours may be the followings:

- Recognize the commands from authorized individuals
- Move to the specific desired location
- Identify objects and avoid potential hazards during travel

For executing the both behaviours, the SW modules and the HW modules for a delivery service robot are classified which are an identification module, data exchange modules, a security module, a navigation module, an obstacle avoidance module, a safety module, and mobility control modules.

The identification module consists of a personal identification module for face recognition of authorised individuals and an object identification module for recognising safety-related objects. The data exchange module is used to exchange data among the delivery robot, servers, and other robots as appropriate. The commands are encrypted and have an authority to be delivered and read by modules having the correct authority with security module. The navigation module consists of a mapping module, a localization module, and a path panning module to control the mobility and check the path and obstacles. The safety module manages the hazards for the robot including the security risk considerations. The mobility control modules are HW module for controlling the 4 actuators in the wheel modules.

6.2.2 Execution life cycle of robot tasks and behaviours

The execution life cycle can be designed for simulating the robotic tasks and behaviours. Note that the SW modules mainly lead the execution of the robot. The Figure 2 shows a general life cycle of robot tasks to achieve the goal of robotics service. The designed execution life cycle of robot tasks and behaviours including the status of idle, executing, stop with error handling. The information for command, initialize, stop, complete and errors are input to move to other status.

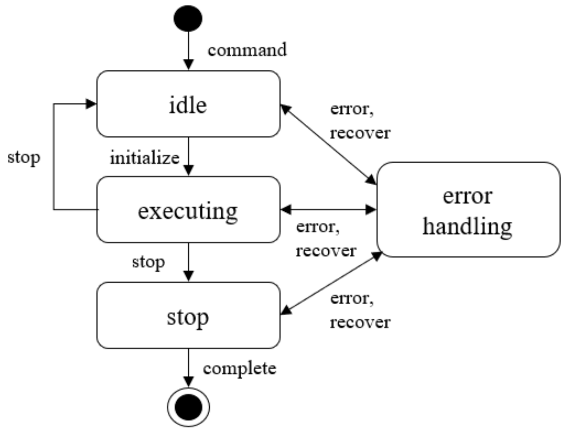


Figure 2 - A general execution life cycle model of robot tasks

The information properties between each status may be different depending on which SW and HW modules are involved. The execution life cycle models commonly are described with the information of properties with general description, functionalities, environments, safety, and security for sharing and supporting to design the frequently performed tasks or behaviours.

6.3 Robotics ecosystem

This clause describes a robotics ecosystem through roles and sub-roles or stakeholder's related with robotics. It defines necessary activities for roles providing and consuming robotics services as well as relationships between roles.

Robotics service ecosystem includes following roles:

- Robotics equipment provider;
- Robotics application provider;
- Robotics platform provider;
- Robotics system integrator;
- Robotics customer: uses robotics services.

The Figure 6-2 shows robotics ecosystem.

[Editor's Note on 2021-03-04] The grouping of the role can be considered, if necessary.

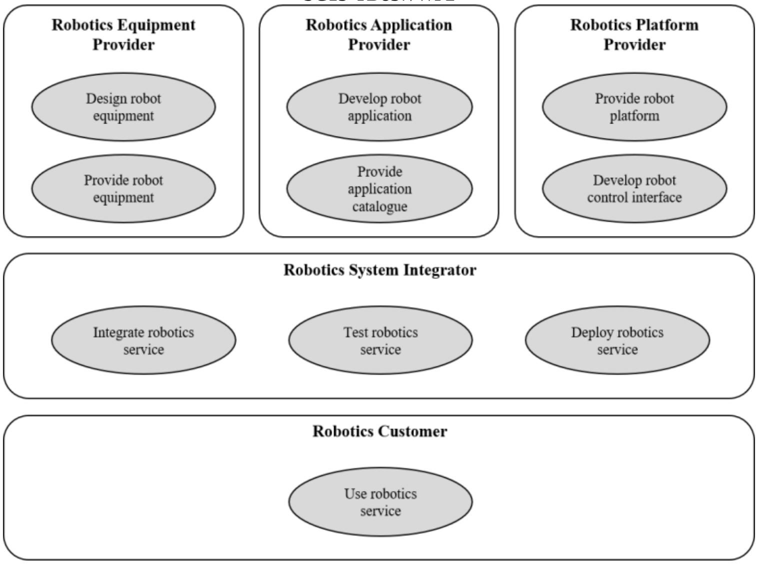


Figure 6-2 –Robotics ecosystem

6.3.1 Robotics equipment provider

A robotics equipment provider manufactures hardware equipment for robotics such as sensors, skeletons, cameras, and motors.
NOTE – The robotics equipment includes the devices which can support robot operations such as sensors, motors, and cameras.

The robotics equipment provider’s activities include:

– design robot equipment;

– provide robot equipment.

6.3.2 Robotics application provider

A robotics application provider provides robot applications including machine intelligence models.

The robotics application provider's activities include:

– develop robot application;

– provide application catalogue.

6.3.3 Robotics platform provider

A robotics platform provider provides robot platform such as robot operating system (ROS).

The robotics platform provider's activities include:

– provide robot platform;

– develop robot control interface.

6.3.4 Robotics system integrator

A robotics system integrator provides the integration of equipment and application utilizing the robotics platform.

The robotics system integrator's activities include:

– integrate robotics service;
– test robotics service;
– deploy robotics service.

6.3.5 Robotics customer

A robotics customer uses robotics services. The robotics customer can be an end-user of robotics ecosystem who develops robots with robotics services.

The robotics customer's activities include:

– Use robotics service.

[Editor’s Note on 2020-07-27] Contributions for robotics ecosystems are invited including relationships among robotics service stakeholders. The roles and sub-roles also should be presented for the stakeholders.

7 Introduction to robotics as a service

This clause describes a cloud computing based robotics system context that is effective for supporting robotics services and applications.

Robotics as a service (RaaS) is a cloud service category in which the capabilities provided to the cloud service customer is the provision and use of robotics services. It provides common capabilities such as storage, generic computation and artificial intelligence to robotics in cloud computing environment. It aims at facilitating the process of making and using robotics, such as reducing cost and shortening the production cycle. In addition, it naturally provides an environment for multi-agents learning and collaboration which are critical for robotic applications.

7.1 System context of robotics as a service

[Editor’s Note on 2020-07-27] The clause will include the cloud computing based robotics system context, and roles, sub-roles, and activities of cloud computing based robotics system will be provided. Contributions are invited.

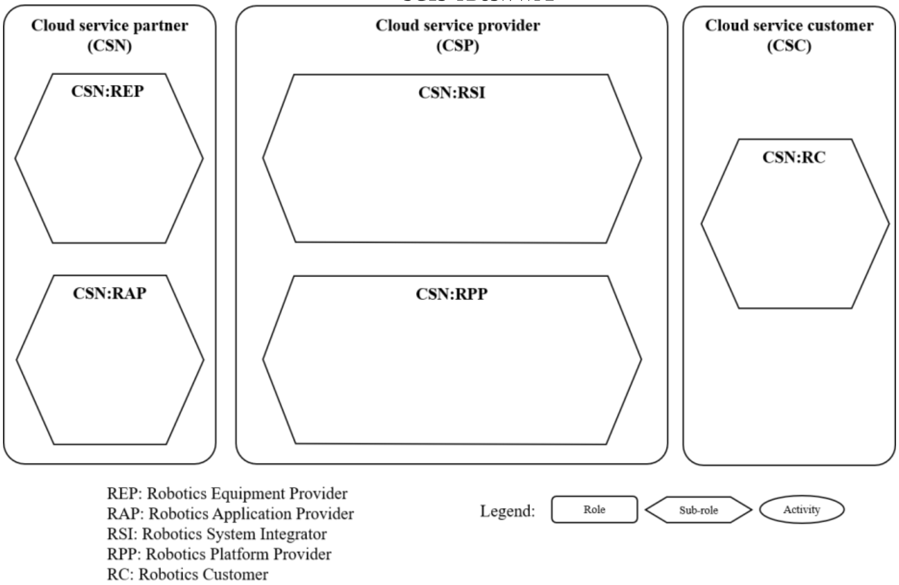


Figure 7-1 – RaaS system context

[Editor's Note on 2021-07] The Figure 7-1 shows temporal system context for common understanding of the roles and sub roles to develop the use cases.

System context of RaaS provides additional sub-roles and activities based on the architectural user view defined in [ITU-T Y.3502]. This clause describes how cloud computing supports the four main roles in a RaaS ecosystem: robot hardware provider, robot software provider, robot provider, and robot customer.

Figure 7-1 illustrates the cloud computing sub-roles for RaaS.

7.2 Relationships between robotics ecosystem and RaaS system context

[Editor's Note on 2020-07-27] The clause will include the relationships between robotics ecosystem and cloud computing based robotics system context. The benefits of cloud computing for robotics can be included for this clause. Contributions are invited.

Cloud computing sub-roles can be mapped to robotics service roles as shown in Table 7-2. The sub-roles of cloud service provider (CSP), the cloud service partner (CSN), and CSC mapped with the roles and sub-roles of robotics service ecosystems.

Table 7-2 – Mapping table between robotics service ecosystem and RaaS System context

Robotics service ecosystem	RaaS System context
Robotics equipment provider	CSN: REP (Robotics equipment provider)
Robotics application provider	CSN: RAP (Robotics application provider)

Robotics platform provider	CSP: RPP (Robotics platform provider)
Robotics system integrator	CSP: RSP (Robotics system integrator)
Robotics customer	CSC: RC (Robotics customer)

[Editor's Note on 2021-07] The mapping table between robotics service ecosystem and RaaS system context are provided to develop use cases with common terminologies. The table will be updated with further discussions.

8 Functional requirements of cloud computing for robotics as a service

This clause describes the requirements for robotics as a service.

[Editor's Note on 2020-07-27] This clause will describe the functional requirements for cloud computing capabilities which can provide robotics services. Contributions are invited for the requirements with the specific scenarios or use cases of cloud computing based robotics as a service.

9 Security considerations

It is recommended that the security framework for cloud computing described in [b-ITU-T X.1601] be considered for the robotics as a service. [b-ITU-T X.1601] analyses security threats and challenges in the cloud computing environment and describes security capabilities that could mitigate these threats and meet security challenges.

[b-ITU-T X.1631] provides guidelines supporting the implementation of information security controls for cloud service customers and cloud service providers. Many of the guidelines guide the cloud service providers to assist the cloud service customers in implementing the controls and guide the cloud service customers 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.

Relevant security requirements of [b-ITU-T Y.2201], [b-ITU-T Y.2701] and applicable X, Y and M series of ITU-T Recommendations need to be taken into consideration, including access control, authentication, data confidentiality, data retention policy, network security, data integrity, availability and privacy.

Appendix I.
Use case of robotics as a service

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

The use cases in this appendix provide examples of RaaS with the functionalities of robotics related functional requirements of RaaS.

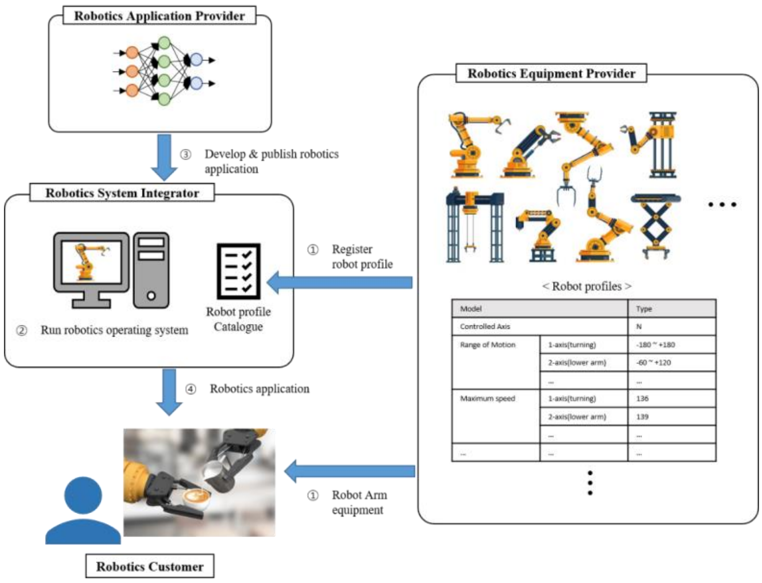
[Editor's Note] The use cases for Appendix I should contain examples of RaaS services for deriving functional requirements of RaaS. The use case will include the following scenario, but not limited to,

- deploying the distributed robot intelligence model
- management of robotics hardware/device profile for cloud services;
- discovery and publishing RaaS service to customer;
- eventing the abnormality of robot equipment;
- operating autonomous and distributed system of robots;
- enhancement of robotics intelligence using cloud services;
- contracting SLA related RaaS;
- etc.

I.1 Registration of robot profiles & development of robot applications using the profiles.

Title	Registration of robot profiles & development of robot applications using the profiles.
Description	This use case describes procedures of developing robotics applications with registration of robot profiles. For developing robotics applications, the task should be designed with considerations of robot equipment profiles and their constrictions. For example, if the robotics developer wants to develop the robot baristas which can make the coffee with robot arm, they need to consider the restrictions of robot arm such as range of motion, speed of motion, grip strength, and etc. The followings are general steps for developing the robotics applications in this use case. 1) CSN:REP registers robotics profiles in equipment catalogue of robotic s system integrator. 2) CSP:RSI runs robotics operating system & publish equipment catalogu e. 3) CSN:RAP develops the robotics applications with robot profiles in equ ipment catalogue. A. CSN:RAP requests the robotics profiles for certain tasks. NOTE – CSP:RSI manages the robotics task with equipment by fe edback of CSN:RAP. B. CSN:RAP designs the task in the testbed of robotics operating sys tems. C. CSN:RAP tests the performance of robotics applications and publi shes the developed applications. NOTE – The metadata are included in robotics applications for de scriptions of used equipment, target task.

<table>
<tr><td></td><td>4) CSC:RC use robotics application.</td></tr>
<tr><td>Role/Sub-role</td><td>CSP:RSI (Robotics System Integrator)
CSN:REP (Robotics Equipment Provider)
CSN:RAP (Robotics Application Provider)
CSC:RC (Robotics Customer)</td></tr>
<tr><td>Figure (optional)</td><td>The following figures shows the registration of robot profiles and development of robot applications.

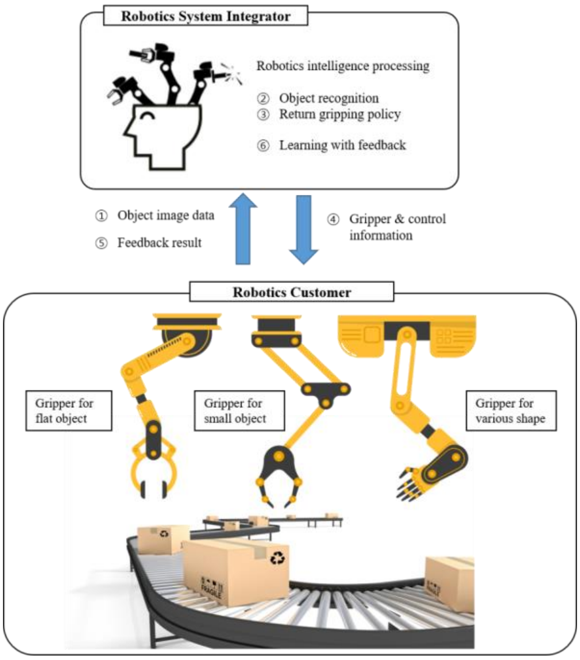


</td></tr>
<tr><td>Pre-conditions
(optional)</td><td>RC can purchase robot equipment from REP.
RPP (Robotics Platform Provider) provide the robotics operating system with the software-based robot control interface and test bed.
RSI provide the computing resources for robotics operating system to RAP and RC.</td></tr>
<tr><td>Post-conditions
(optional)</td><td></td></tr>
<tr><td>Derived requirements</td><td>It is required for the CSP:RSI to provide registry of the robot profile catalogue to CSN:REP.
NOTE - The robot profile catalogue provides the information of each robot such as the equipment specifications of robot, the available robotic task, and etc.
It is required that the CSP:RSI provides registry to store the equipment specifications in robot profile catalogue to CSN:REP.</td></tr>
</table>

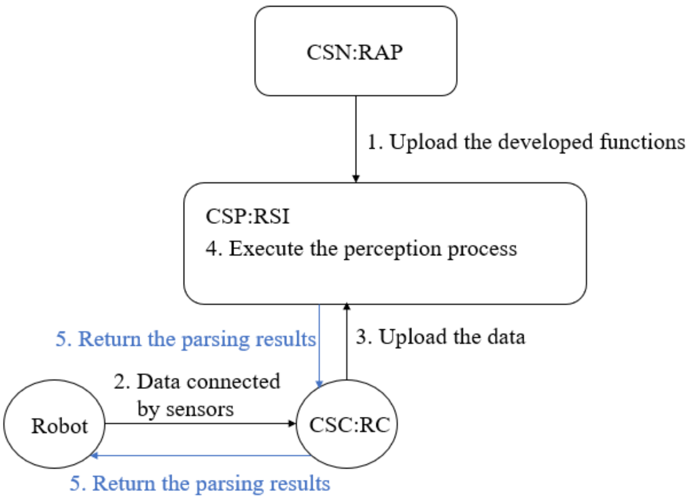
	NOTE – The equipment specification provides the hardware performance or its restrictions for the robotic task. For example, the equipment specifications of robot arms describe the number of controllable arms or joints, the range of motion, the directions of axis, maximum strength, maximum speed, and etc. It is recommended that CSP:RSI provide the available robotic task for the equipment. NOTE – The various robotic equipment executes their own robot tasks. The robot task for the certain equipment can be collected from CSN: REP. It is required for the CSP:RSI provide the registry to store the applicable robotic task for each equipment to the CSN:RAP. It is recommended that the CSP:RSI support the multiple available robot tasks for each robotic equipment. NOTE – The robotics equipment can be categorized high-level types such as the robotics arm, terrain mobility, drone, humanoid, and etc. And the certain type of equipment can execute multiple available robot tasks which are developed CSN:RAP.

I.2 Robotics intelligence processing using RaaS in the environment of industrial roller conveyor with multi-gripper.

Title	Robotics intelligence processing using RaaS in the environment of industrial roller conveyor with multi-gripper.
Description	This use case provides the industrial robotics system with multiple gripper in RaaS environment. The multiple grippers are used for supporting various object in real-world. It may be required the different type of gripper for gripping certain object. For example, the two-finger gripper is easy to grip stick-shaped object such as screwdriver, but difficult to grip flat object. Multiple gripper can support the various object in the industrial manufacturer. The gripping tasks are executed by the robotics intelligence algorithm in RaaS. In this use case, the real-time operating of robotics system. The followings are steps of robotics intelligence processing for operating the industrial systems. 1) CSC:RC transmits the object image data to CSP:RSI 2) CSP:RSI predicts the object and return the gripping policy. 3) CSP:RSI sends the gripper type and control message. 4) CSC:RC executes the task and return feedback. 5) CSP:RSI updates the learning algorithm with feedback.
Role/Sub-role	CSP:RSI (Robotics System Integrator) CSN:REP (Robotics Equipment Provider) CSN:RAP (Robotics Application Provider) CSC:RC (Robotics Customer)
Figure (optional)	The following figures shows the multi-gripper robotics system with RaaS.

	
Pre-conditions (optional)	RAP design and publish the robotics intelligence algorithm for multiple gripper. CSP:RSI run the robotics operating systems in advance.
Post-conditions (optional)	CSP:RSI compute the robotics intelligence processing algorithms continuously until user's request.
Derived requirements	It is required for the CSP:RSI to provide real-time network connections upon request between CSP:RSI and CSC:RC. It is recommended for the CSP:RSI to provide the encapsulation of robot control massage for security. NOTE – The encapsulation encodes the robot control message with protocols that encrypt and authenticate the message. It is required for the CSP:RSI to provide registry of the result of robot control massage. It is recommended that the CSP:RSI request the feedback result for the robot control message to CSC:RC. NOTE –The feedback result support to operate the robot system and enhance the robot intelligence. It is required for the CSP:RSI to alert the abnormalities of robot executions.

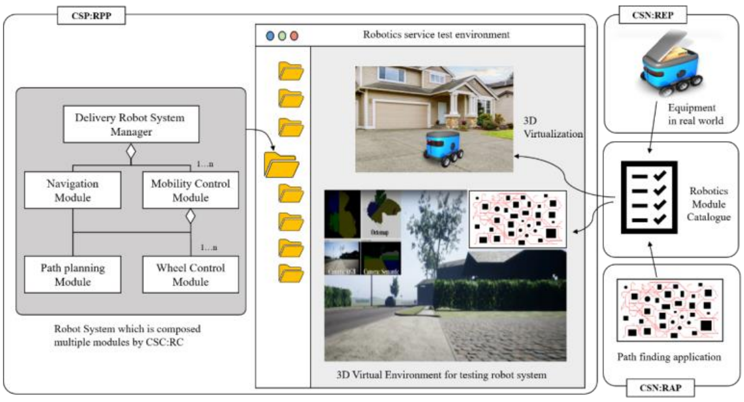
I.3 Enhancement of robotics intelligence using RaaS-Environment perception.

Title	Enhancement of robotics intelligence using RaaS-Environment perception.
Description	Environment perception aims to endow a robot the capabilities of seeing and understanding its environments, such as being aware of the nearby objects with locations and size. It is a fundamental step for further tasks. The key technologies of environment perception usually involve image segmentation, object detection and etc, which is very suitable to be implemented in the cloud. The interactions of using environment service include steps as follows: 1) CSN:RAP develops perception functions and upload to the CSP:RSI. CSP:RSI stores the functions. 2) CSC:RC acquires data from robot sensors such as 2D camera, 3D camera or 3D Lidars. 3) CSC:RC request the perception service and upload the sensor data in the cloud, which might be 2D only or 2D/3D fused. Calibration data might also be needed according to the specifications of CSP:RSI. 4) CSP:RSI accepts the request with the attached sensor data and execute perception process to parse the data. 5) CSP:RSI returns the parsing results to the robot. Parsing results may include a set of segmented items, with each item identified by object type, related region (segmented mask), confidence and etc. For simplicity, detection box might be alternative to segment mask.
Role/Sub-role	CSN: RAP, CSP: RSI, CSC:RC
Figure (optional)	The following figure shows the workflow of accessing perception service. 

Pre-conditions (optional)	The customer has created accounts and subscribed the perception services for the robots.
Post-conditions (optional)	
Derived requirements	~~It is required that CSN: RAP provide registry of the perception functions (tasks?) and catalogue to CSP:RSI.~~ It is required that CSP: RSI provide registry of the available robotics tasks in robotics hardware catalogue to CSN:RAP. It is recommended that CSN: RAP register the available robotics tasks of the robots in robotics hardware catalogue. NOTE – The available robotics tasks are developed by CSN:RAP and managed by CSP:RSI with pair of tasks and equipment. The available robotics tasks include the environment perception with visual sensor, gripping object with robotic arms, and etc. It is recommended that CSP support searching of available robotics tasks based on the robotics equipment. NOTE - CSP:RSI can optionally provide searching algorithms to recommend tasks suitable for the robotics equipment. ~~It is required that CSP provides the operations(control?) of perception.~~ ~~NOTE – The operations of perception include initiate, stop, and resume of perception.~~ It is recommended that CSP:RSI provide lifecycle management of robotics task. [Editor's NOTE on 2021-07] - Further discussion for lifecycle management of robotics task are needed. The general lifecycle for robots such as 'Environment Recognition', 'Situation Perception', and 'React' should be analysed and clarified with the input/output data for each step such as 'Environment', 'Situation', 'Policy/planning'. The contributions are invited. ~~It is recommended that CSP provide visualization of perception results.~~ It is required that the CSP:RPP provide the monitoring of robotic tasks. NOTE – The monitoring of robotic tasks provide the information to track the process of robot task, environment surrounding robot . It is recommended that the CSP:RPP provide the graphical user interface for monitoring the robotic tasks.

I.4 Developing and testing RaaS applications.

Title	Developing and testing ~~RaaS~~ robotics applications for navigation task.

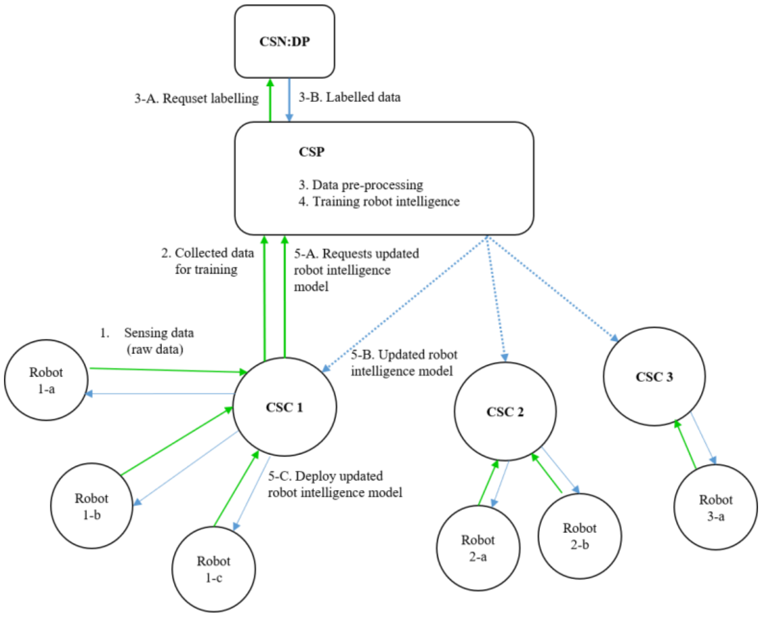
Description	~~[Editor's Note on 2021-07] The use case is suggested during the RGM meeting in July, 2021. Initially it provides the functional requirements related to developing and testing RaaS applications with visualization tools.~~This use case provides the developing and testing related functions of RaaS. The robotics developer (CSC:RC) wants to develop the delivery robots which requires navigation systems for achieving the task. He/she decides to develop and test the navigation module in cloud computing environment. The developer builds the robotics system which execute the go-to-delivery task by composing some HW and SW modules from the robotics module catalogue. The robotics system is simply built to perform only navigation task for testing with cost and resource efficiency in cloud. The followings are the summarized steps of developing and testing robotics applications. 6) CSC:RC search the HW and SW module for composing delivery robot system. 7) CSC:RC requests navigation module including path planning module, and mobility control module with wheel-based robot. 8) CSP:RSI provides the resources for developing and testing environments for CSC:RC 9) CSC:RC configures among modules from catalogue and builds the composed modules in serviced cloud computing environment. 10) CSP:RPP provides the testing environment for their HW modules with physical engines which are virtualizing real world. ~~6)~~11) CSC:RC tests their robotics system, monitors the implementations, and get the test results from CSP:RPP
Role/Sub-role	
Figure (optional)	~~[Editor's Note on 2021-07] The figure may include the general process or method for developing robotics applications.~~ 
Pre-conditions (optional)	

Post-conditions (optional)	
Derived requirements	[Editor's Note on 2021-12-07] The roles for the activities related with robotics IDE and simulation environments should be clarified between CSP and CSN. It needs to be analysed with the roles and activities for PaaS. It is required for CSP:RSI to provide integrated developing environment (IDE) for the robotics to the CSN:RAP. NOTE – The IDE for the robotics applications provide robot interaction language, capabilities of building code, GUI, and etc. It is required for CSP:RSI to maintain the resources for simulation environment. It is required for CSP:~~RSI~~ RPP to provide virtualized simulation ~~tools~~ environments for testing robotics applications. NOTE – The virtualized simulation environments simulate the real-world environment with physical engines. It is required for CSP:RPP to provide the HW configuration tools in virtualized simulation environment for the CSN:REP. It is required that CSP:RPP support registry of HW module in the robotics service catalogue. It is recommended that the CSP:~~RSI~~RPP provide visualiz~~ation toolse~~d graphical user interface to ~~CSN:RAP for simulation of robotics applications.~~monitors the robotics task in the simulation environment. It is recommended that the CSN:REP registers the ~~visualization~~ visualized models of robotics ~~applications.~~HW. NOTE – The GUI (Graphical User Interface) tools for visualization can be designed by CSN:RAP. NOTE – The graphical model of HW module from CSN:REP can be designed to mimic or express their products. It is required that the CSP:RSI ~~record~~ provide the pre-defined descriptors ~~logfiles~~ for the ~~environments of~~HW modules for CSN:REP ~~robotics application~~. NOTE – The ~~logfiles~~ pre-defined descriptors for the environments includes the information of available robotics platform, target robot task, equipment specification, and etc.

서식 있음: 양쪽, 줄 간격: 1줄

I.5 Deploying the distributed robot intelligence model using RaaS & cloud service.

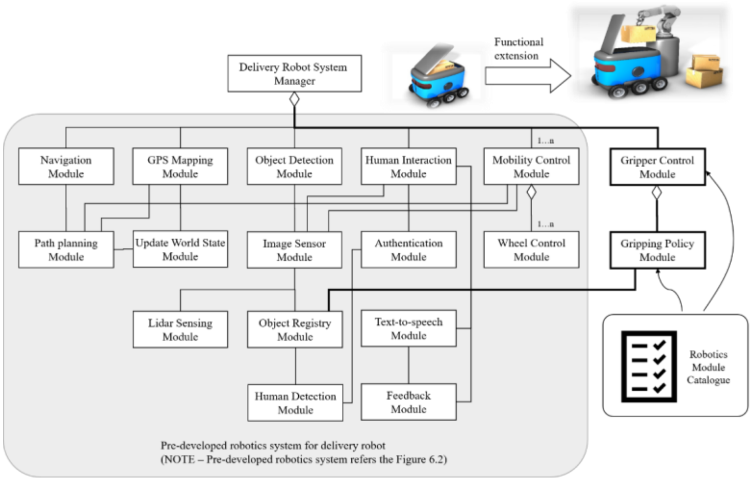
Title	Deploying the distributed robot intelligence model using RaaS & cloud service.

Description	The robots are distributed across multiple locations. The robot intelligence is trained by collected data from robots in different locations. The robot customer can update their robot intelligence without stopping their robot operations. The followings are specific procedures for updating and deploying robot intelligence. 1) CSC collects the raw data from the robots including sensor data, motor data, and related data 2) CSC stores the training data and model in the cloud. 3) CSP performs the data pre-processing including data transformation, data cleaning, and labelling. A. CSP requests labelling task to CSN:DP if the robot task requires labelling data. B. CSN:DP provides labelled data to CSP. 4) CSP trains robot intelligence with the training data and model from the distributed CSCs. 5) The updated robot intelligence is stored and deployed when it is requested from CSC. A. CSC requests the updated models to CSP. B. CSP deploys the updated models to CSC. C. CSC operates the updated model in their systems.
Role/Sub-role	CSP, CSN, CSC [Contributor's Note on 2021-01-27] The roles will be modified of the system context of RaaS are defined.
Figure (optional)	The following figure shows the workflow of developing robots using RaaS.  Figure – Workflow of developing robots using RaaS

Pre-conditions (optional)	
Post-conditions (optional)	
Derived requirements	(High-Level requirements for RaaS)

I.6 Extension of robotics application with modules in service catalogue

Title	Extension of robotics application with modules in service catalogue
Description	The robotics developer wants to extend their delivery robot to have the abilities to grip the objects and load the objects. Rather than developing the new module for gripping, they search the pre-designed modules for new abilities in the robotics service profile catalogue. The developer finds the gripper control module and gripping policy module and integrate them into their delivery robot system manager which are already deployed in his/her cloud computing resources. The input/output data and interfaces for new modules are provided from the robotics service profiles catalogue. For the gripping policy module, it requires image data of gripping object. The developer composes the new gripping policy module with the object registry module which is in the pre-developed robotics system. The module utilizes the data from the object registry module for executing the gripping task.
Role/Sub-role	CSN: RAP, CSP: RSI, CSC:RC

Figure (optional)	 Figure 1 The extension of gripping related modules in delivery robot system
Pre-conditions (optional)	The CSC already built the robot system with the cloud computing resources and environment. The CSN:RAP provides the interface and input/output data with the guidance of the robotics module.
Post-conditions (optional)	The CSP provides the testing environments for the updated robotics task for CSC.
Derived requirements	[Editor's Note on 2021-12-07] The terminology for robotics service catalogue should be clarified among service catalogue, robotics service catalogue, robotics module catalogue. [Editor's Note on 2021-12-07] The roles for the activities related with service catalogue should be clarified between CSP and CSN. It is required for CSP:RSI to provide integrated developing environment (IDE) for the robotics to the CSN:RAP. It is required that CSP:RSI support the list of available modules for the robotics task for CSC:RC. It is recommended that CSP:RSI provide the list of proper modules for CSC:RC on request. NOTE – For creating list about proper modules, CSP may request the user experiences of modules to CSC:RC or guideline of modules to CSN:RAP or CSN:REP. It is recommended that CSP:RPP provide the functionality to make free-text annotation for the robotics modules to CSN:RAP, CSN:REP or CSC:RC. NOTE – The annotation may be used for sharing the usage of robotics modules and performances of the modules.

	It is required that CSP:RSI provide the configurations to connect the modules. It is required for CSP:RPP to support the module connectivity among provisioned modules. It is required for CSP:RSI to maintain the registry for robotics service profiles catalogues for CSN. It is recommended that the CSN:RAP registers the robotics module with guidance of applicable robotics task.

Appendix II

Use case of robotics as a service for application perspectives

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

II.1 Use case of developing robotics services

Title	Use case of developing robotics services
Description	
Role/Sub-role	
Figure (optional)	
Pre-conditions (optional)	
Post-conditions (optional)	
Derived requirements	

Bibliography

[b-ISO/DIS 8373] Draft International Standard ISO/DIS 8373 (2020), *Robotics - Vocabulary.*

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

[b-ITU-T Y.1631] Recommendation ITU-T X.1631 (2015), *Information technology – Security techniques – Code of practice for information security controls based on ISO/IEC 27002 for cloud services.*

[b-ITU-T Y.2201] Recommendation ITU-T Y.2201 (2011), *Requirements and capabilities for ITU-T NGN*.

[b-ITU-T Y.2701] Recommendation ITU-T Y.2701 (2007), *Security requirements for NGN release 1*.

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