INTERNATIONAL TELECOMMUNICATION UNION

TELECOMMUNICATION STANDARDIZATION SECTOR

STUDY PERIOD 2017-2020

SG13-TD838/WP2

STUDY GROUP 13

Original: English

Question(s): 17/13 Virtual, 29 November-10 December 2021

TD

Source: Editors

Title: Living lists of ITU-T Y.RaaS-reqts: "Cloud computing - functional requirements for robotics as a service"

Purpose: Information

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

Abstract: This is the living lists for draft Recommendation Y.RaaS-reqts (Cloud computing - functional requirements for robotics as a service) based on the results of Q17/13 meeting which was held via virtual in 29 November -10 December 2021.

This document is based on the following documents.

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 modification

During this meeting, it is agreed as follows:

- Update the analysis of robotics development methodology and its related standardization work in living list #4.

<Living List structure and procedures>

The following Living List structure and procedures are intended to progress the work on WP2/13 related Recommendations.

1. Structure

A. List of Items

- Title of item

B. Description of each item

- Title
- Description of the problem and possible solutions
- List of documents addressing the issue
- Intermediate agreements

2. Status of proposals

Status of proposals

U – Under study

P – Provisionally agreed

F – Frozen

3. Guidelines

- Insertion of an issue into the Living List is generally based on contributions and requires a general agreement that the issue is important for further consideration.
- Proposal should include texts conforming to the Recommendation structure and provide for enhancements and/or modifications of the relevant parts of the Recommendation.
- An issue is deleted from the Living List if no contributions addressing the issue have been provided in a long period and there is a general consensus for its removal.
- When an item is added to the living list, its status is U by default.
- Transition from U to P may happen at the next meeting if there is a consensus on the solution proposed in the form of modifications to the current text of the Recommendation and if no contradicting contribution is provided.
- Transition from P to F may happen at the next meeting if no contribution contradicts the provisionally agreed text and there is consensus.
- When contribution (s) are provided contradicting the existing text with status “P” and no consensus is achieved on the contribution, the status of the existing text is unchanged. Transition from P to U happens only if consensus is achieved on the contradicting contribution.
- Frozen texts are inserted in the updated version of the Recommendation if there is consensus.

4. Operational rules

- All proposed modifications to the Recommendation should be made available to the ITU-T meetings in a PC compatible electronic version.

Living lists for Y.RaaS-reqts

No.	Title of Living Lists	Status
1	Concept of robotics as a service	U (Virtual, 20-31 July 2020)
2	Robotics related works	R (Virtual, 20-31 July 2020)
3	Stakeholders analysis in industrial robotics ecosystem	R (Virtual, 1-12 March 2021)
4	Analysis of robotics development methodology and its related standardization work	R (Virtual, 29 November – 10 December 2021)

Status : U – Under study, P – Provisionally agreed, F – Frozen, R – for Reference

Living list #1: Concept of Robotics as a service

In general, cloud robotics can be understood as enabling the advantage of cloud computing in the field of robotics. To this end, it is necessary for CSPs to provide robotics services for cloud robotics service provider. Currently, different concepts and definitions of RaaS (Robotics as a Service) exist in the ICT domain.

Concept of RaaS is:

- A subscription-based service model in which a user receives a robot service by leasing a robot device and accessing a cloud-based subscription service without purchasing equipment [b-Forbes];

  [Contributor's Note] The concept of RaaS from [b-Forbes] can be utilized for designing an ecosystem of robotics

- The business model whereby robotic platforms functioned on cloud-platforms that were sold as a service to end-users [b-ABIR];

- A cloud computing unit that facilitates the seamless integration of robot and embedded devices into Web and cloud computing environment [b-Wikipedia].

  [Contributor's Note] The concepts of RaaS from [b-ABIR] and [b-Wikipedia] can be utilized for designing cloud based RaaS service.

- A service model for cloud robotics [b-BerkleyUniv.];

Figure 1. Concept of RaaS [b-BerkleyUniv.]

Living list #2: Robotics related works

(1) [#Platform, #Opensource] **Raputa** is an open source cloud robotics framework, and aims at building low- cost, lightweight autonomous mobile robots with high-level intelligence distributed in the cloud, enabling such robots to offload some of their **heavy computation** and **seamlessly learn** and **share experiences** with one another.

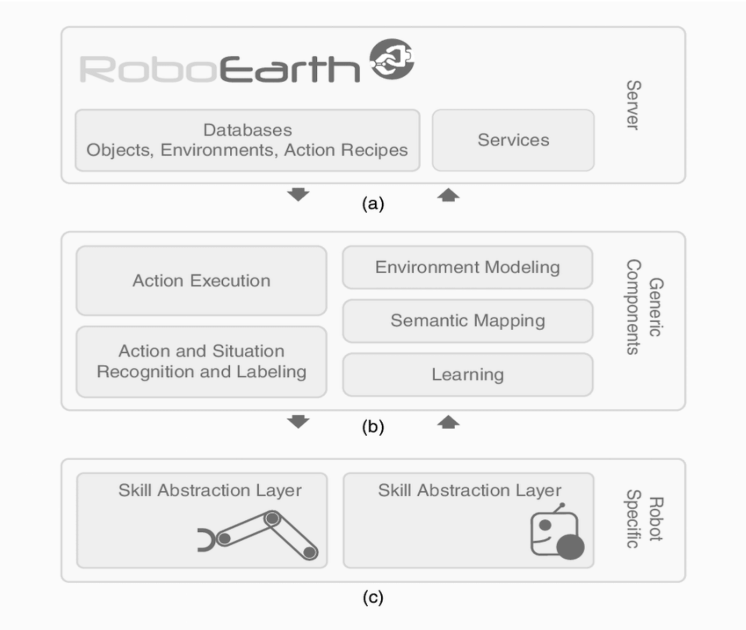


Figure 3. Raputa Cloud engine RoboEarth's three-layered architecture

(2) [#PaaS, #RaaS] **AWS RoboMaker** is a cloud service for robotic developers to simulate, test and securely deploy robotic applications at scale. It provides

- Fully-managed, scalable infrastructure for simulation that customers use for multi-robot simulati on
- CI/CD integration with regression testing in simulation.
- IDE, fleet management capabilities, ROS extensions,
- Seamless integration with various Amazon and AWS services to empower customers to innovat e and provide best-of-class robotic solutions.

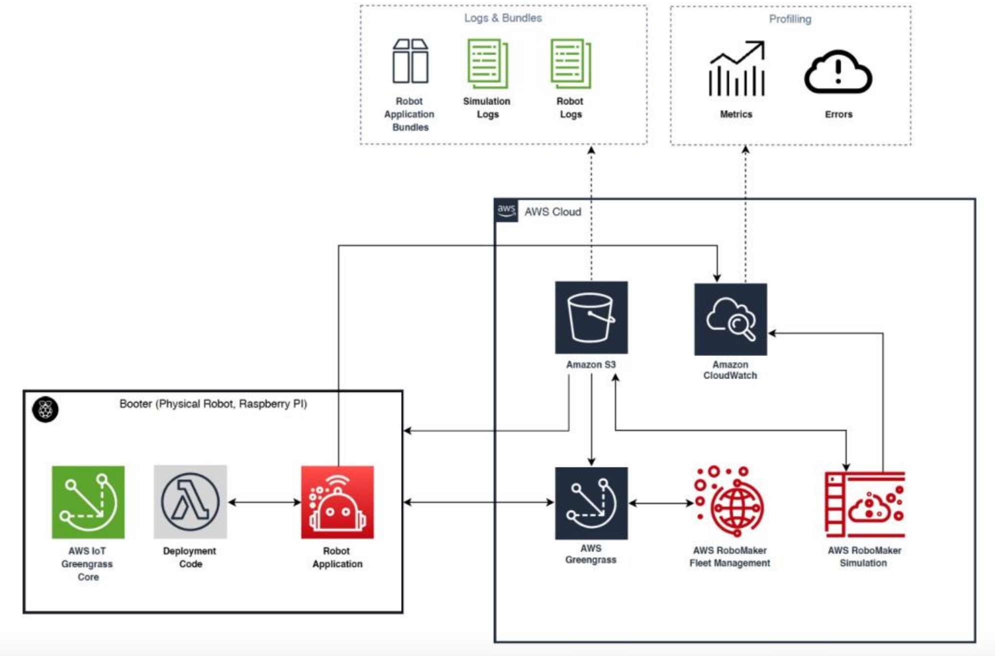


Figure 4. AWS RoboMaker architecture

(3) [#PaaS, #Opensource, #AI, #Big data] **Google's Cloud Robotics Core** is a platform that provides infrastructure to building and running robotics solutions for business automation. It offers:

- Access to updated libraries of images, maps, and object/product data for Big Data integration;
- Access to parallel grid computing on demand for learning, statistical analysis and motion planni ng to ease cloud computing;
- Robots and systems in power to control policies, outcomes, and sharing trajectories;
- Use of crowdsourcing to tap human skills to analyze video and images, learning, classification a nd error recovery. The Cloud additionally can provide access to publications, datasets, models, s imulation tools, benchmarks and open-source software.

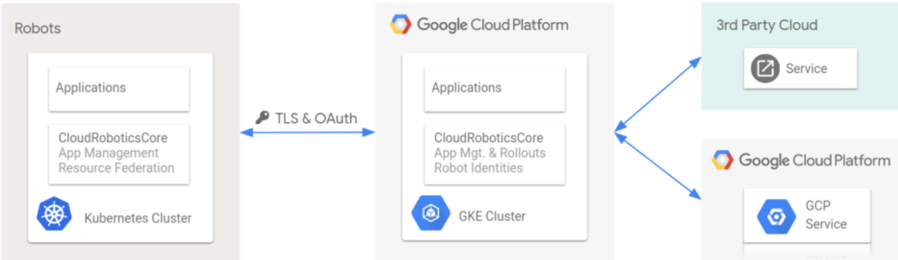


Figure 5. Google Cloud Robotics Core

(4) [#ML, #AI&Reasoning, #Big data processing] **RoboBrain** is a large-scale computational system that learns from publicly available Internet resources, computer simulations, and real-life robot trials. It accumulates everything robotics into a comprehensive and interconnected knowledge base. Applications include prototyping for robotics research, household robots, and self-driving cars.

(5) [#Opensource, #Framework for Robot] ROS, C2RO, MRDS, REALabs, Rospeex, DAvinCi, GostaiNet, etc.

Table 1. Comparative analysis on cloud robotics platforms

Cloud Robotic Platform	Description	Open Source	Underlying model or architecture	Compatibility with other platforms	Sharing to other robots
Rapyuta	Robotics framework building low-cost, lightweight autonomous mobile robots with high-level intelligence distributed in the cloud	Y	Elastic computing model	High	Y
AWS RoboMaker	Cloud solution for robotic developers to simulate, test and securely deploy robotic applications	N	Customized ROS	High	Y
Cloud Robotics Core	Infrastructure to building and running robotics solutions for business automation	Y	Kubernetes on Robot	High	Y
RoboBrain	A large-scale computational system that learns from publicly available Internet resources, computer simulations, and real-life robot trials	Y	Mapping the human brain	Moderate	N
ROS	A flexible framework for writing robot software.	Y	Publish/subscribe message passing architecture	High	Y
C2RO	Artificial intelligence and computer vision	N	Hybrid cloud robotics model	Moderate	Y

Cloud Robotic Platform	Description	Open Source	Underlying model or architecture	Compatibility with other platforms	Sharing to other robots
	solutions for mobile robots				
MRDS	Windows-based environment for robot control and simulation	N	Service Oriented Architecture	Moderate	N
REALabs	Cloud computing platform for supporting network robotics	Y	Platform as a Service (PaaS) model	Low	Y
Rospeex	A cloud robotics platform for human-robot spoken dialogues	N	Node structure model	Moderate	Y
DAvinCi	Distributed agent with collective intelligence to produce 3D-models of environments for robots during simultaneous localization and mapping	Y	Combination of distributed ROS architecture, HDFS and Hadoop Map/Reduce Framework	Moderate	Y
GostaiNet	Enables robots to perform face detection, speech recognition and other tasks remotely	Y	GostaiNet cloud computing architecture	Moderate	Y

Living list #3: Stakeholders analysis in industrial robotics ecosystem

The below figure shows the key players of the industrial robotics ecosystem in the real-field. The robotics ecosystem consists of robotic equipment manufacturers, robotic OS provider, robotic application provider, and robotic system integrators.

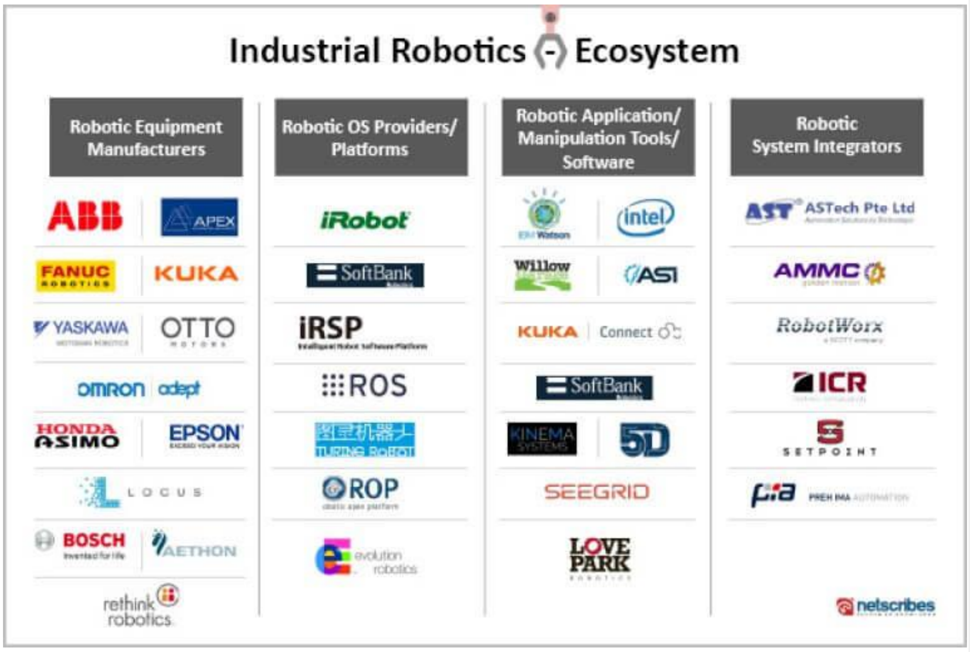


Figure 5 The industrial robotics ecosystem

The industrial robotics ecosystem can be matched with following robotics service ecosystem of Y.RaaS-reqts

Industrial robotics ecosystem (Figure 5)	Robotics service ecosystem
Robotic equipment manufacturers	Robotics equipment provider
Robotic application/manipulation tools/software	Robotics application provider
Robotic OS provicers/platforms	Robotics platform provider
Robotic system integrators	Robotics system integrator
	Robotics customer: uses robotics services

Living list #4: Analysis of robotics development methodology and its related standardization work

1. The module-based development in robotics

Producing or designing 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. Therefore, the modularity in robotics for developing robot is inevitable and many open source communities are sharing their robot module with the package of the service for robotics. Robot developer usually designs the robot by integrating or combining the modules in the robot operating systems. The followings are the example of module-based robotics developments [2]:

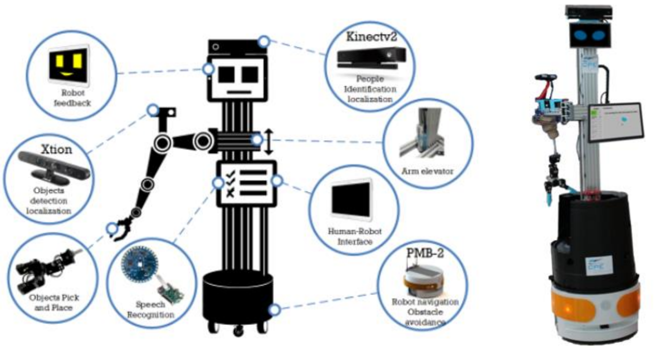
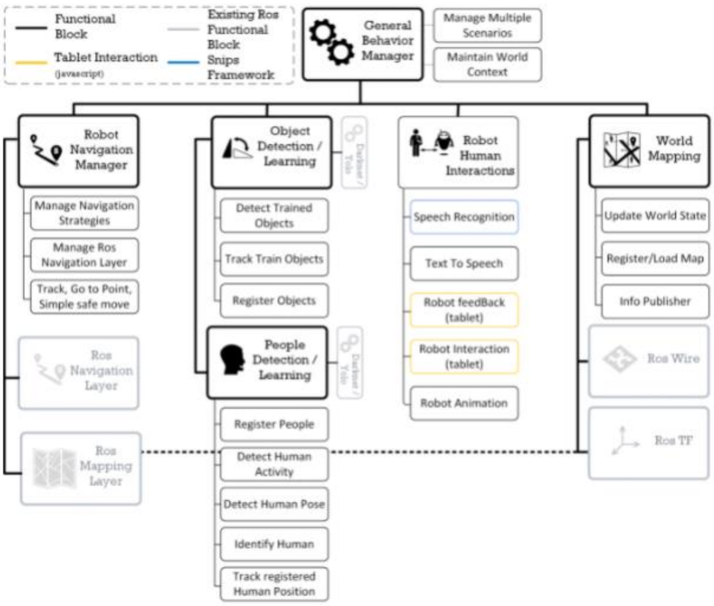


Figure 1 The conceptual architectures of the robot secretary

Figure 2 - The integrated module-based system architecture of the robot secretary

There are many advantages of module-based robotics developments. The followings are the part of the advantages of modularity:

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



2. Robotics module related standardizations

i. Robot related standardizations in ITU-T

There are several work items for robot in the ITU-T. The following are the approved and developing standards in ITU-T:

- ITU-T F.746.9: Requirements and architecture for indoor conversational robot system (Approved in 2019);
- ITU-T F.AI-RPAS: Technical requirements and evaluation methods for a robotic process automation system (Consented target is 2023);
- ITU-T M.rrsp: Requirements for robot-based on-site smart patrol of telecommunication network (Consented target is 2022).

The ITU-T F.746.9 already provide their requirements with the concepts of modular based architecture for robot system with associations of natural language processing. F.AI-RPAS and M.rrsp are the developing standards for robot, and they might use the concept of modular based robot system. However, the development of the documents are premature to discuss robot modules.

ii. Robot related standardizations in ISO TC299 - Robotics

ISO TC299, the robotics group, are developing several standards related modular-based robotics. 'ISO/DIS 22166-1: Robotics — Modularity for service robots —Part 1: General requirements' provides the concepts and its characteristics of the modularity for robots [3]. The standardization is based on the terminologies of 'ISO/DIS 8373:2020: Robotics — Vocabulary' [4]. The above standards provide the definitions of module;

3.3.11.
modularity
characteristics which allow systems to be separated into discrete modules and recombined

3.3.12.
module
component or assembly of components with defined interfaces accompanied with property profiles to facilitate system design, integration, interoperability, and re-use.
3.3.19.
robot module
module intended to be used as part of a modular robot system

3. The concepts of modularity

Modularity is broadly used concept in many areas such as science, technology, industry, and even in culture. Modularity is the degree to which a system's components may be separated and recombined, often with the benefit of flexibility and variety in use. [1]

The meaning of the word "modularity" can vary somewhat based on context such as science, technology, industry, and culture. The followings are the contextual examples of modularity in the fields of technology and industry [1]

Technology

- In modular programming, modularity refers to the compartmentalization and interrelation of **the parts of a software package**.
- In software design, modularity refers to a logical partitioning of the "software design" that allows complex software to be manageable for the purpose of implementation and maintenance. **The logic of partitioning** may be based on related functions, implementation considerations, data links, or other criteria.
- In self-reconfiguring modular robotics, modularity refers to **the ability of the robotic system to automatically achieve different morphologies** to execute the task at hand.

Industry

- In modular construction, modules are a bundle of **redundant project components** that are produced en masse prior to installation. Building components are often arranged into modules in the industrialization of construction.
- In industrial design, modularity refers to an engineering technique that builds larger systems by combining **smaller subsystems**.
- In manufacturing, modularity typically refers to modular design, either as the use of **exchangeable parts or options** in the fabrication of an object or the design and manufacture of modular components.

4. The module standardizations in vary fields

In the standardization work, the concepts of module and modularity are also used in vary fields. The followings are the defined and used concepts of modules in standardization work.

ITU-T

- **module** [ITU-T X.680(02/2021)]: One or more instances of the use of the ASN.1 notation for type, value, value set, information object class, information object, and information object set (as well as the parameterized variant of those), encapsulated using the ASN.

- **module** [ITU-T X.292 (05/2002)]: Self-contained collection of TTCN objects. All referenced objects are either explicitly defined in the Module, are imported from other sources or are defined as external objects in the module.

ISO

- **module** [ISO 30042:2019]: list of permissible data categories (3.8) and constraints on them that are used in the design of a TBX-compliant terminological data collection (3.29)

- **module** [ISO/IEC TS 20540:2018]: set of hardware, software, and/or firmware that implements security functions and are contained within the cryptographic boundary.

- **module** [ISO 14451-1:2013]: generic term f or airbag modules, seatbelt pretensioners and actuators.

- **module** [ISO 7240-1:2014]: part of a software program that fulfils specified functions

[1] https://en.wikipedia.org/wiki/Modularity

[2] https://robocup-lyontech.github.io/opl/

[3] https://www.iso.org/standard/72715.html

[4] https://www.iso.org/standard/75539.html