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NEW WORK ITEM PROPOSAL	
Closing date for voting **2014-03-18**	Reference number (to be given by the Secretariat) **ISO/IEC JTC 1/WG 7**
Date of circulation 2013-12-17	
Secretariat	Proposer: NB of China

A proposal for a new work item within the scope of an existing committee shall be submitted to the secretariat of that committee with a copy to the ITTF and, in the case of a subcommittee, a copy to the JTC 1 secretariat. Proposals not within the scope of JTC 1 shall be submitted to the ITTF.

A new work item proposal may be made by a national body, the JTC 1 secretariat or JTC 1 subcommittee secretariat, another technical committee or subcommittee, a Category A organization in liaison with JTC 1, the technical management board or one of its advisory groups, or the Chief Executive Officer.

The proposal will be circulated to the P-members of JTC 1 or JTC 1 subcommittee for voting, and to the O-members for information.

IMPORTANT NOTE: Proposals without adequate justification risk rejection or referral back to the originator. Guidelines for proposing and justifying a new work item are given overleaf.

Proposal (to be completed by the proposer)

Title of the proposed deliverable*(in the case of an amendment, revision or a new part of an existing publication, show the reference number and current title)*

English title: Internet of Things Reference Architecture (IoT RA)

Scope of the proposed deliverable

This new work item specifies IoT conceptual model, reference architecture from different architectural views, common entities, and interfaces between IoT domains.

Purpose and justification of the proposal*(attach a separate page as annex, if necessary)*

Internet of Things (IoT) has been catchphrase for many years, and it has been gaining more momentum over the last few years as system development and implementation for various applications and services have been adopting and adapting IoT technologies. IoT-based or -applied systems (hereafter "IoT Systems") development and implementation includes, but not limited to, in application/service domain areas of smart grid, smart home/building, smart factory, smart city, intelligent transportation and traffic, logistics and asset/inventory management, retail transactions, e-Health, smart city, public safety, e-Learning, environment monitoring, which are built upon primarily interconnecting smart objects. In most cases, if not all, the smartness comes from smart sensors/devices (including actuators, RFID/reader, etc. – physical smart objects) and smart sensing/processing (including algorithms and software – virtual smart objects) technologies. Additionally, the capability of networks (e.g., Internet, intranet, wireless/wired, cellular, etc.) interconnecting smart physical and virtual objects (and among physical objects and among virtual objects) for data and information communications and exchange is an essential and imperative component of IoT Systems providing the domain applications and services. Furthermore, security and privacy for IoT Systems is another major area of importance in development and implementation.

Although there are standards related or relevant to IoT components and subsystems (e.g., sensor networks, smart sensors/transducers, protocols, wireless, various types of wired and wireless networks, etc.), there presently do not exist dedicated and practical standards to guide IoT Systems development and implementation while the domain applications/services developers are moving forward in developing and implementing IoT Systems without the IoT guiding standards. Without the guiding standards from the beginning, the big scope of IoT of achieving common/open architecture and interoperability among various types IoT Systems will become a challenge and complicated. Therefore, an IoT System's guiding standards such as IoT's Reference Architecture (RA) is urgently needed and should be developed without delay in ISO/IEC JTC 1. Related information is described in *ISO/IEC JTC 1 / WG 7 – WGSN-N507 IoT_Reference_Architecture.pdf.*

This NWIP is being submitted through ISO/IEC JTC 1 WG 7 because the proposer recognizes the WG 7 is the only entity having the term "IoT" in its current Terms of Reference and is currently the most proper JTC 1 group to perform IoT Reference Architecture (IoT RA) standard development. The WG 7 ToR #2 states:

> 2. *In the area of application - oriented sensor networks, identify gaps and commonalities that may impact standardization activities within the scope of JTC 1. Further, share this information with relevant entities within and outside of JTC 1. Unless better pursued within another JTC 1 entity, the following standardization activities may be pursued as projects by this Working Group:*
>
> a) *Addressing the technology gaps within the scope of JTC 1 entities*

b) *Exploiting technology opportunities where it is desirable to provide common approaches to the use of sensor networks across application domains*
c) *Addressing emerging areas related to M2M and IoT*

The proposers believe that the conditional statement "*Unless better pursued within another JTC 1 entity, the following standardization activities may be pursued as projects by this working Group*:" allows the initiation of the IoT RA standard development project in WG 7. If and when a better suited JTC 1 organization is created for IoT, the IoT RA project can be transferred if such decision is made at JTC 1 level. Due to the urgency of having the guiding architectural standards for IoT, this NWIP will allow, if approved, to proceed the development of IoT RA standards without delay.

In the ISO/IEC JTC1 N11894 Resolutions Adopted at the 28th Meeting of ISO/IEC JTC 1, 4-9 November 2013 in Perros-Guirec, France, Resolution 9 provided the revised Terms of Reference for the SWG on Internet of Things (IoT) which is designated as JTC 1 SWG 5. One particular ToR in Resolution 9 related to this NWIP is:

8. *Study IoT Reference Architectures/Frameworks and provide a study report. This study report should be written so it could be referenced in a possible JTC 1 New Work Item Proposal on IoT. The report shall be made available to JTC 1 no later than the 2014 JTC 1 Plenary.*

According to the ISO/IEC Directives, Special Working Group (SWG) falls under "Group having advisory function within a committee (Clause 1.14, ISO/IEC Directives, 4th Edition, 2013), and this type of advisory group can only provide recommendations and is not allowed to initiate or execute standardization projects. As #8 of Resolution 9 states SWG 5 will perform a study of IoT reference architectures/frameworks in order to provide JTC 1 with a study report, not a standard. In fact, the study by SWG 5 Ad-Hoc Group 4 (AHG 4) complements very well with this proposed NWIP both the timing and work contents: (1) the timing because of about 7 months overlap between the SWG 5 AHG 4 study (about a 1-year study period) and the NWI on IoT RA projects (a 3-year default development track) in the beginning; and (2) the contents because of SWG 5 AHG 4 study can provide valuable foundational information on various existing IoT-related reference architectures in the early stage of the IoT RA project. Additionally, the NWI proposers already started developing a working draft of the IoT RA (see Annex A) and survey of the existing IoT RA (e.g., IoT-A) and review of IoT-relevant RAs (e.g., sensor networks) to IoT have been carried out.

The editors/contributors of this NWIP on IoT RA project and the members of SWG 5 AHG 4 can coordinate and collaborate for the SWG 5 AHG 4's study and also for the NWIP on IoT RA in JTC 1 WG 7. In order to do such collaboration, editors will liaise with JTC 1 SWG 5 and its AHG 4. The editors of the NWI from JTC 1 WG 7 plan to actively be involved in SWG 5 AHG 4, and the members of SWG 5 AHG 4 will be invited to actively participate in the NWI on IoT RA standard development. The collaboration between JTC 1 WG 7 and JTC 1 SWG 5 AHG 4 will benefit not only the projects (the study and the NWI on IoT RA standard) in both organizations but also the IoT-related industry because:

- the SWG 5 AHG 4's study directly influences the WG7's IoT RA project positively impacting the IoT RA standard development and the study report becoming a major reference document for the IoT RA standards;
- the SWG 5 AHG 4 members can stay informed on and/or involved in IoT RA standard development during its study and also they can continue participating in the NWI on IoT RA project after the study if desired through direct participation or through liaison relationships;
- there will be no delay in developing the guiding architectural standards for IoT Systems, e.g., IoT RA, promoting common/open architecture and interoperability among various types of IoT Systems; and

having collaboration of two JTC 1 organization can attract additional industry participation both in the study and the NWI on IoT RA standardization project, obtaining useful comments from the IoT-related industry resulting in dedicated, practical, and useable IoT RA standards.

Is this a Management Systems Standard (MSS)?

Yes ☐ No ☑

Envisaged publication type*(indicate one of the following, if possible)*

☑ International Standard ☐ Technical Specification ☐ Technical Report

Proposed development track ☐ 1 (24 months) ☑ 2 (36 months - default) ☐ 3 (48 months)

Target dates for availability First CD 2015-4-1 Publication 2016-11-1

Known patented items*(see ISO/IEC Directives Part 1 for important guidance)*

Yes ☐ No ☑ If "Yes", provide full information in an annex.

Are there any known accessibility requirements and/or dependencies? Yes ☐ No ☑

If yes, please specify in a separate annex.

Are there any known requirements for cultural and linguistic adaptability? Yes ☐ No ☑

If yes, please specify in a separate annex.

Meeting Information

Estimated number of meetings: 6 Frequency of meetings: 2 per year

Date and place of first meeting (if known): TBD

A listing of relevant documents

ISO/IEC JTC 1 / WG 7 – WGSN-N507 IoT_Reference_Architecture.pdf

A statement from the proposer as to how the proposed work may relate to or impact on existing work, especially existing ISO and IEC deliverables. The proposer should explain how the work differs from apparently similar work, or explain how duplication and conflict will be minimized.*(attach a separate page as annex, if necessary)*

This NWI proposal is for developing International Standard of Internet of Things Reference Architecture (IoT RA). Internet of Things (IoT) includes a variety of technologies, physical and virtual entities that exist in many different domains of applications and services. One of the major IoT subsystems would be sensing devices and a network of smart sensors providing data and information to higher data/information consumers (both human and machines). From this perspective, some components of ISO/IEC 29182 Information technology-Sensor Networks Reference Architecture and ubiquitous Sensor Networks (USN) standards may be referenced in this IoT RA standard. ISO/IEC 29182 Sensor Network Reference Architecture is based on relatively short distance wireless communications between sensor nodes or sensor node gateway and developed service that the nodes could provide. This IoT RA proposal emphasizes more on all kinds of data acquisition methods mainly through smart sensors, smart processing to generate useful information, and communication technology to move data and information from one object to another, which enables delivery of more comprehensive services that an IoT Systems can provide. This proposal will provide IoT conceptual model, IoT conceptual reference model, and IoT reference architecture from the view of IoT System Technology, IoT Communication Technology, and IoT Information Technology. Additionally, other IoT reference architecture representations will be provided such as IoT functional architecture if/when such architectures can be filling any gaps that are not covered by the IoT RA from the three technologies' perspective.

This IoT RA standard may reference other standards in the course of its development; however, any duplication or conflict is not expected. If any duplication or conflict with other existing or developing standards, such will be resolved working closely with the affecting SDOs. To avoid any duplication or conflict from the beginning, the proposers and hosting organization (JTC 1 WG 7 for the current proposal) will actively liaise with other organizations in ISO, IEC, JTC 1, and other SDOs outside of ISO/IEC. These SDOs to liaise will be identified in the first meeting of this proposed project once approved.

A simple and concise statement identifying and describing relevant affected stakeholder categories (including small and medium sized enterprises) and how they will each benefit from or be impacted by the proposed deliverable(s).

Small, medium, and large sized enterprises involved in research, product development, and implementation of IoT related service and applications, especially using the Internet and other networked infrastructures.

Liaisons*(A listing of relevant external international organizations or internal parties (other ISO and/or IEC committees) to be engaged as liaisons in the development of the deliverable(s).)*

ISO/IEC JTC1 SWG 5 and other internal and external organizations for liaison relationship will be identified; and reference & utilize IoT-related project outcomes, e.g., EU Project on IoT-A.

A listing of relevant countries which are not already P-members of the committee.

Preparatory work*(at a minimum an outline should be included with the proposal; ensure that all copyright issues are identified)*

☑ A draft is attached ☐ An existing document is attached to serve as an initial basis ☐ An outline is attached. It is possible to supply a draft by _____

The proposer or the proposer's organization is prepared to undertake the preparatory work required Yes ☑ No ☐

Proposed Project Editor*(include contact information)*	**Name of the Proposer***(include contact information)*
Dr. Jie Shen *shenjie@wsn.cn,* *Gemini A block National Software park, Zhenze Road 18* *Wuxi City Jiangsu Province* *China* *Dr. Haitao Liu* *liuhaitao@wsn.cn,*	*Ms.WANG Zongling* *General Secretary, National Body of China* *Fax:+86 10 82260660* *Email:sac@sac.gov.cn*

Gemini A block National Software park, Zhenze Road 18 *Wuxi City Jiangsu Province* *China*	

Supplementary information relating to the proposal*(Comments of the JTC 1 or SC Secretariat)*

- ☑ This proposal relates to a new ISO/IEC document
- ☐ This proposal relates to the amendment of an existing ISO/IEC document
- ☐ This proposal relates to the revision of an existing ISO/IEC document
- ☐ This proposal relates to a multi-part standard consisting of _____ parts
- ☐ This proposal relates to the adoption as an active project of an item currently registered as a Preliminary Work Item
- ☐ This proposal relates to the re-establishment of a cancelled project as an active project
- ☐ This proposal requires the service of a maintenance agency. If yes, has a potential candidate been identified? Please identify_____
- ☐ This proposal requires the service of a registration authority. If yes, has a potential candidate been identified? Please identify_____
- ☐ This proposal is submitted with a CD for simultaneous NP and CD balloting
- ☐ Other: _____

Voting information– The ballot associated with this proposal comprises a vote on (check only one):

- ☑ Adoption of the proposal as a new project (Stage 10.99)
- ☐ Adoption of the proposal as a new project and the associated draft as a working draft (WD) (Stage 20.20)
- ☐ Adoption of the proposal as a new project and the associated draft as a committee draft (CD) (Stage 30.20)
- ☐ Other: _____

It is proposed to assign this new item to:☑JTC 1/WG 7☐ a new JTC 1 subcommittee

Annex(es) are included with this proposal *(give details)*

Annex A –A draft of NWIP

Use this form to propose:

a) a new ISO/IEC document(including a new part to an existing ISO/IEC document), or the amendment/revision of an existing ISO/IEC document;
b) the establishment as an active project of a preliminary work item, or the re-establishment of a cancelled project;
c) the change in the type of an existing publication, e.g. conversion of a Technical Specification into an International Standard.

This form is not intended for use to propose an action following a systematic review - use ISO Form 21 for that purpose.

Proposals for correction (i.e. proposals for a Technical Corrigendum) should be submitted in writing directly to the secretariat concerned.

Guidelines on the completion of a proposal for a new work item (see also the ISO/IEC Directives Part 1and the associated ISO/IEC JTC 1 Supplement)

a) **Title of the proposed deliverable:** Indicate the subject of the proposed new work item.

b) **Scope of the proposed deliverable:** Give a clear indication of the coverage of the proposed new work item. Indicate, for example, if this is a proposal for a new publication, or a proposed change (amendment/revision). It is often helpful to indicate what is not covered (exclusions).

c) **Envisaged publication type:** Details of the types of ISO/IEC deliverable available are given in the ISO/IEC Directives, Part 1 and/or the associated JTC 1 Supplement.

d) **Purpose and justification of the proposal:** Give details based on a critical study of the following elements wherever practicable. *Wherever possible reference should be made to information contained in the related Business Plan*.

1) The specific aims and reason for the standardization activity, with particular emphasis on the aspects of standardization to be covered, the problems it is expected to solve or the difficulties it is intended to overcome.
2) The main interests that might benefit from or be affected by the activity, such as industry, consumers, trade, governments, distributors.
3) Feasibility of the activity: Are there factors that could hinder the successful establishment or global application of the standard?
4) Timeliness of the standard to be produced: Is the technology reasonably stabilized? If not, how much time is likely to be available before advances in technology may render the proposed standard outdated? Is the proposed standard required as a basis for the future development of the technology in question, or for adoption in a future regulatory system?
5) Urgency of the activity, considering the needs of other fields or organizations. Indicate target date and, when a series of standards is proposed, suggest priorities.
6) The benefits to be gained by the implementation of the proposed standard; alternatively, the loss or disadvantage(s) if no standard is established within a reasonable time. Data such as product volume or value of trade should be included and quantified.
7) If the standardization activity is, or is likely to be, the subject of regulations or to require the harmonization of existing regulations, this should be indicated.
8) If a series of new work items is proposed having a common purpose and justification, a common proposal may be drafted including all elements to be clarified and enumerating the titles and scopes of each individual item.

e) **Relevant documents**: List any known relevant documents (such as standards and regulations), regardless of their source.

NOTE: The following criteria f) and g) do not mandate any feature for adaptability to culture, language, human functioning or context of use. The following criteria require that if any features are provided for adapting to culture, language, human functioning or context of use by the new Work Item proposal, then the proposer is required to identify these features.

f) **Accessibility**: Indicate here whether the proposed standard takes into account diverse human functioning and diverse contexts of use. If so, indicate how it is addressed in your project plan. Indicate how the guidelines of ISO/IEC Guide 71 (Guidelines for standards developers to address the needs of older persons and persons with disabilities), ISO/IEC TR 29138-1 (Information technology -- Accessibility considerations for people with disabilities -- Part 1: User needs summary), and ISO TR 22411 (Ergonomics data and guidelines for the application of ISO/IEC Guide 71 to products and services to address the needs of older persons and persons with disabilities) have been implemented in the proposal, or why they are not deemed to be relevant.

g) **Cultural and linguistic adaptability**: Indicate here if cultural and natural language adaptability is applicable to your project. If so, indicate how it is addressed in your project plan. Typical examples of requirements include:

1) for text or speech, the user shall be able to choose the natural language of input and output sentences and the language captured shall be identified;
2) for character coding, the code shall be clearly identified for correct input and rendering;
3) for sorted lists, linguistic user order expectations shall be respected (see ISO/IEC 14651 International string ordering and comparison);
4) cultural variations in the way concepts are perceived in different countries shall be respected; and
5) input methods used in a given country shall also be supported.

For a list of what is required in most IT products, see ISO/IEC TR 19764 (Guidelines, methodology, and reference criteria for cultural and linguistic adaptability in information technology products) and ISO/IEC TR 11017 (Framework for internationalization).

h) **Liaisons**: List the relevant external international organizations or internal parties (other ISO and/or IEC committees) to be engaged as liaisons in the development of the deliverable(s).

i) **Preparatory Work**: When the proposer considers that an existing well-established document may be acceptable as a standard (with or without amendment), indicate this with appropriate justification and attach a copy to the proposal. In this case, provide the document publication date, implementation history and national/global adoption experience.

Annex A

Internet of Things Reference Archtecture (IoT RA)

Pre-Working Draft

Please, see from the next page.

ISO/IEC JTC 1/WG 7 N 000

Date: 2013-12-05

ISO/IEC Pre-WD xxxxx

ISO/IEC JTC 1/WG 7

Secretariat: KSA

Information technology — Internet of Things Reference Architecture (IoT RA)

Document type: International standard
Document subtype: if applicable
Document stage: (20) Preparation
Document language: E

Copyright notice

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO/IEC xxxxx was prepared by Working Group ISO/IEC JTC 1/WG 7.

Introduction

Internet of Things (IoT) has been catchphrase for many years, and it has been gaining more momentum over the last few years as system development and implementation for various applications and services have been adopting and adapting IoT technologies. IoT-based or -applied systems (hereafter "IoT Systems") development and implementation includes, but not limited to, in application/service domain areas of smart grid, smart home/building, smart factory, smart city, intelligent transportation and traffic, logistics and asset/inventory management, retail transactions, e-Health, smart city, public safety, e-Learning, environment monitoring, which are built upon primarily interconnecting smart objects. In most cases, if not all, the smartness comes from smart sensors/devices (including actuators, RFID/reader, etc. – physical smart objects) and smart sensing/processing (including algorithms and software – virtual smart objects) technologies. Additionally, the capability of networks (e.g., Internet, intranet, wireless/wired, cellular, etc.) interconnecting smart physical and virtual objects (and among physical objects and among virtual objects) for data and information communications and exchange is an essential and imperative component of IoT Systems providing the domain applications and services. Furthermore, security and privacy for IoT Systems is another major area of importance in development and implementation.

Although there are standards related or relevant to IoT components and subsystems (e.g., sensor networks, smart sensors/transducers, protocols, wireless, various types of wired and wireless networks, etc.), there presently do not exist dedicated and practical standards to guide IoT Systems development and implementation while the domain applications/services developers are moving forward in developing and implementing IoT Systems without the IoT guiding standards. Without the guiding standards from the beginning, the big scope of IoT of achieving common/open architecture and interoperability among various types IoT Systems will become a challenge and complicated. Therefore, an IoT System's guiding standards such as IoT's Reference Architecture (RA) is urgently needed and should be developed without delay in ISO/IEC JTC 1. Therefore, this Internet of Things Reference Architecture (IoT RA) International Standard is the response to the urgent need of the guiding standards for IoT.

The purposes of ISO/IEC xxxxx of International Standard (IS) are to:

- provide guidance to facilitate the design and development of IoT Systems,
- promote open and common guiding architecture leading to seamless interoperability of IoT Systems, and
- make IoT Systems' components plug-and-play, so that it becomes easy to add/remove IoT Systems components to/from the IoT Systems.

In addition to the main body of the IoT RA standards, two informative annexes are in this document. They are:

- Annex A – Review/Study of IoT Reference Models/Architectures/Frameworks Relevant to the IoT RA
- Annex B – Example of System Architecture Development from the IoT RA

These annexes are to assist the user of this IS with comprehensive understanding of the information behind the IoT RA presented in this standard document as well as with effective and efficient adoption and adaptation of this IoT RA for developers' target IoT Systems Architecture development for required IoT applications and services.

COMMENTS on Annex A: A review or study of the existing IoT reference models/architectures/frameworks relevant to the IoT RA are presented in this annex. In fact, the output document of the new scope of JTC 1 SWG on IoT (SWG 5) from the 2013 JTC 1 Plenary (that is Resolution 9 Item 8 "*Study IoT Reference Architectures/Frameworks and provide a study report. This study report should be written so it could be referenced in a possible JTC 1 New Work Item Proposal on IoT. The report shall be made available to JTC 1 no later than the 2014 JTC 1 Plenary.*") would be a perfect fit for this annex.

COMMENTS on Annex B: An example of developing a System Architecture from the IoT RAs will be presented in this annex to assist the IoT developers and architects.

Information technology — Internet of Things Reference Architecture (IoT RA)

1 Scope

This International Standard (IS) specifies not only Internet of Things (IoT) conceptual model by identifying and defining the IoT domains but also IoT reference architecture (RA) from various architectural views/perspectives by detailing the model with identifying each IoT domain's entities and defining high-level inter- and intra-domain interfaces among the domain entities. This IoT RA IS focuses on the re-usability of the IoT Reference Architecture (IoT RA) by IoT systems developers and implementers for their target application(s) and services.

2 Normative References

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO/IEC 29182-2 *Information technology – Sensor Network: Sensor Network Reference Architecture (SNRA) – Part 2: Vocabulary/Terminology*

COMMENTS: Other Normative References To be Listed

3 Terms and Definitions

COMMENTS: To be listed as this IS develops

4 Symbols (and abbreviated terms)

IS International Standard

IoT Internet of Things

RA Reference Architecture

COMMENTS: More to be listed as this IS develops

5 Introduction

5.1 General Discussion on Internet of Things Reference Architecture (IoT RA)

This International Standard provides Internet of Things Reference Architecture (IoT RA) consistent with the general requirements presented in the sub-clauses of Clauses 6, 7, and 8.

The IoT RA is a *generalized* system-level architecture of IoT Systems that share common domains. Therefore, an IoT system's architecture being developed for certain application or services may reuse some, most, or all of the reference architecture domains and entities. The reused domains and entities fit his or her IoT system's application or service architecture while ignoring the rest of domains and entities in the IoT RA. On the other hand, he or she may add certain domains and/or entities in his or her application or service architecture if they are not found in the IoT RA. These added domains and/or entities need to be added when the IoT RA is updated. Additionally, the IoT RA could provide technical standards and policies for building a specific IoT system's architecture.

The IoT RA provides a *consistent point of departure* for developing and implementing IoT Systems' architectural solutions so that each IoT system's development and implementation:

a) follows a consistent decomposition and design pattern;
b) reduces cost by exploiting opportunities for reuse of services, products, data definitions, etc.;
c) reduces schedule by starting with already existing and comprehensive IoT RA that can be tailored for a target IoT system's architecture; and
d) reduces risk by:
   — incorporating required global capabilities; and
   — taking advantaged of lessons learned and related expertise embedded in the IoT RA.

The IoT RA not only outlines "what" the overall structured approach is for facilitating interoperability among IoT Systems from the descriptions of architectural structure but also indicates "how" the architecture and its domains/entities will operate from the development of interface definitions. In short, the IoT RA provides rules and guidance for developing a IoT system's architecture and the interfaces within the architecture.

Each developer (e.g., typically an architect for architecture development) will have specific systems requirements for application and service capabilities that a target IoT system should meet. Although the systems requirements can vary from one IoT system to next, the IoT RA provides the common architectural starting point with the same rules and guidance which the developers/architects follow when the developers reuse the IoT RA,. Following the same rules and guidance provided by the IoT RA ensures the development of IoT Systems that are interoperable and interacting seamlessly.

5.2 Internet of Things (IoT) Systems Characteristics

COMMENTS: This section will discuss about the IoT Systems characteristics, including Information Sharing, Collaboration, Interoperability, and other characteristics when this IS develops.

5.3 IoT Systems' Conceptual Model

The IoT RA is described by its key enabling technology areas: (1) IoT system of interest; (2) communications technology; and (3) information technology. The IoT system of interest is an IoT system for its target applications/services (e.g., agricultural systems, environmental systems, smart grid systems, smart home/building, smart city, etc.) which this IoT RA international standard will not architecturally describe. Rather, generalized IoT system will be architecturally described. Both the communications technology and information technology that are and will likely be used by IoT Systems are architecturally described in this IoT RA standard.

Prior to describing the IoT RA, a conceptual model is described pictorially in Figure 1. In Figure 1, the IoT Systems domains are identified and defined. These domains are the domains of the IoT RA.

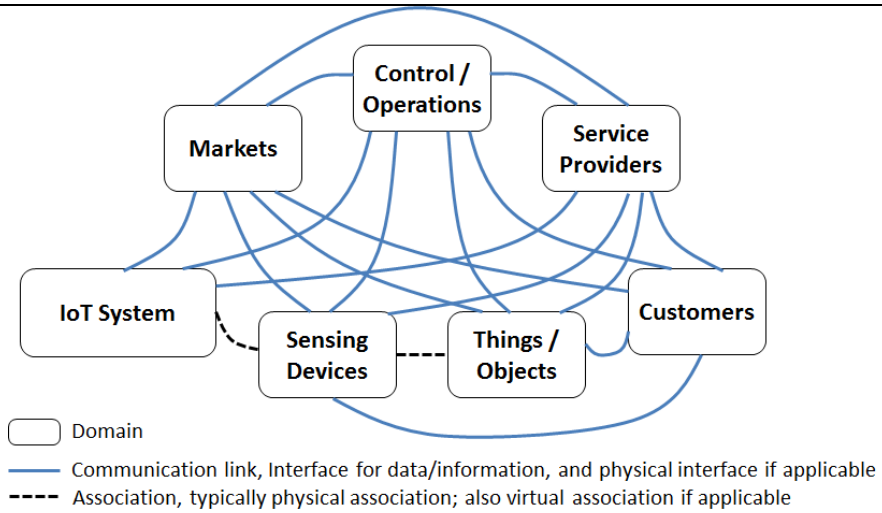

Figure 1. IoT Systems' conceptual model.

The domains common to IoT Systems are identified as follows:

- *IoT System*: Domain representing an IoT system that is to be developed, implemented, and operated (e.g., for smart grid, the IoT system includes bulk generation, transmission, and distribution). This domain includes descriptions of target applications and services of the IoT system.
- *Sensing Devices*: Domain representing all physical entities that have one or more types of sensing mechanism for physical environments.
- *Things/Objects*: Physical entities (things) and virtual entities (objects) that are associated with an IoT system in the IoT System of Interest domain for supporting the IoT system's applications and services. These entities typically do not have the sensing mechanism.
- *Control/Operations*: Domain representing organizations that manages the system activities of an IoT system in the IoT System of Interest domain.
- *Service Providers*: Domain representing organizations providing IoT services using the IoT system in the IoT System of Interest domain.
- *Customers*: Domain representing the end user of goods (both tangible and intangible) and services provided by the organizations in Service Providers domain or by the IoT system in IoT System of Interest.
- *Markets*: Domain representing operators and participants in the IoT system and service provider markets.

Entities are generally located inside a domain and are connected to each other through one or more interfaces. Each technology driven IoT RA (e.g., IoT system of interest, communications technology, and information technology) has entities that are closely map to its technology. However, each entity can map to an appropriate entity or entities in other IoT RA. Examples of the entities are both physical (e.g., actuators, communication networks, computer systems) and virtual (e.g. software, functions, databases). For distinction between physical entities and virtual entities, the terms, things and objects are used, respectively, in this IoT RA standard.

Interfaces are logical connections from one entity to another that support one or more data flows implemented with one or more data links. In case of Information Technology, data flows are used instead of interfaces. These data flows are application-level communications from entities that provide data to entities that consume data.

5.4 Detailed Description of the IOT RA Domains

5.4.1 IoT System Domain

The IoT System Domain houses entities that are common to many IoT Systems with varying applications and services, which means that, in this IoT RA, no specific/target IoT system is described because an owner or developer of a IoT system will choose the a target IoT systems for its system architecture development based on this IoT RA.

The IoT System Domain communicates at least with the Control/Operations Domain, the Markets Domain, and

the Sensing Devices, Domain. This domain also indirectly communicates with the Service Providers Domain, the Customers Domain, and the Things/Objects Domain which is through the Sensing Devices Domain.

5.4.2 Sensing Devices Domain

The Sensing Devices Domain includes all type of devices that have one or more sensing mechanisms in order to sense physical environment. Sensing devices are necessary for the operations and functions of an IoT system in the IoT System Domain. The sensing devices in this domain may be owned by the owners of the Control/Operations Domain, the organizations in the Service Providers Domain, or the customers in the Customers Domain. Additionally, these sensing devices, depending on an IoT system in the IoT System Domain, can be accessed to provide data, information, services at a sensor and device level, to the Control/Operation Domain, Service Providers Domain, and/or the Customers Domain. Furthermore, the sensing devices can mainly controlled by the entities in the Control/Operations Domain; however, depending on ownership of these sensing devices, the entities in the Service Providers Domain and the entities in the Customers domain may also have control over the sensing devices.

Architecturally, the sensing devices reside in the Sensing Devices Domain even though some sensing devices are physically located with or attached to Things (e.g., physical entities) in the Things/Objects Domain. For example, an RFID or barcode physically attached to a thing resides in the Sensing Devices Domain, not in the Things/Objects Domain. An association or a mapping between the RFID/barcode and the thing will be clearly identified through the association/mapping (e.g., a physical interface between them) in the reference architecture.

This domain communicates with the Control/Operations Domain, the Service Providers Domain, the Markets Domain, the IoT System Domain, the Things/Objects Domain, and the Customers Domain.

5.4.3 Things/Objects Domain

The Things/Objects Domain includes all type of physical things and virtual objects that are associated with an IoT system in the IoT System Domain through the sensing devices in the Sensors Devices Domain. The things and objects in the Things/Objects Domain can be owned by the owners of the Control/Operations Domain, the organizations in the Service Providers Domain, or the users in the Customers Domain. Many of things and objects in this domain are associated with the sensing devices in the Sensing Devices Domain; however, there are things and objects that are not associated with the sensing devices in the Sensing Devices Domain (e.g., no sensing devices such as an RFID or a barcode on the things in this domain).

This domain communicates with the Control/Operations Domain, the Service Providers Domain, the Sensing Devices Domain, the Customers Domain, and the Markets Domain.

5.4.4 Control/Operations Domain

The Control/Operations Domain includes distinctive operation and control entities associated with an IoT system in the IoT System Domain. For example, if the IoT System Domain is for smart grid, the entities in this domain control the IoT System Domain's entities that are bulk generation, transmission, and distribution. Therefore, the entities in this domain are the controlling mechanism and functions that keep the IoT system operating as intended.

The primary interface of each entity in the Control/Operations Domain is to its appropriate entities in other domains, especially in the IoT System Domain. Additionally, some operation and control entity in this domain can interface with the entities in the Customer Domain where the customer has controllable entities affecting certain controllable IoT system entities in the IoT System domain.

The entities in the control and operations domain may be owned by an organization such as an individual, a company, or a government. Or, more than one organization can own the entities. Depending on different business situations, the owner or owners of the entities in the Control/Operations Domain can also own the entities in the IoT System Domain, the Sensing Devices Domain, and/or the Things/Objects Domain. The owner of the Control/Operations Domain could also own the organizations in the Service Providers Domain.

This domain communicates with the Market Domain, the Service Providers Domain, the IoT System Domain, the Sensing Devices Domain, the Things/Objects Domain, and the Customers Domain.

5.4.5 Service Providers Domain

The Service Providers Domain contains entities that may belong to third parties which provide services associated with an IoT system in the IoT System Domain. However, the service providers may belong to the owner or one of the owners of the Control/Operations Domain.

The Service Providers Domain is the connection between the IoT system markets (in the Market Domain) and the end users (the Customers Domain). There are many business models for IoT system's service providers. The business model that commonly and popularly adopted by service providers today for various target IoT systems' applications and services are likely found in the current service providers who are successful in its business. The service providers can also provide the services that are core services associated with an IoT system in the IoT System Domain.

This domain communicates with the Control/Operations Domain, the Markets Domain, the Sensing Devices Domain, the Things/Objects Domain, and the Customers Domain.

5.4.6 Customers Domain

The Customer Domain includes many types of customers connected to an IoT system in the IoT System Domain. These customers could be individual users, residential customers, commercial or industrial organizations, or a government branch. Each type of the customer may have several different entities employed in its application. These entities are dependent on the size and type of the customer as well as its connections to an IoT system.

This domain communicates with the Control/Operations Domain, the Service Providers Domain, the Markets Domain, the Sensing Devices Domain, and the Things/Objects Domain.

5.4.7 Markets Domain

The Markets Domain reflects market operations associated with an IoT system in the IoT System Domain and the organizations in the Service Providers Domain.

The Markets Domain is logically connected with an IoT system in the IoT Systems Domain, sensing devices in the Sensing Devices Domain, things and objects in the Things/Objects Domain, and also potentially the end users in the Customers Domain. Markets can be influenced by an IoT system's entities, but it can also be influenced by the Control/Operations Domain. Additionally, when new markets emerge, customers may seek to interact directly with marketplaces.

This domain communicates with the Control/Operations Domain, the Service providers Domain, the IoT System Domain, the Sensing Devices Domain, the Things/Objects Domain, and the Customers Domain.

6 IoT Conceptual Reference Model (RM)

From the IoT conceptual model shown in Figure 1, an IoT Conceptual Reference Model (RM) is developed and shown in Figure 2. This RM is an intermediate step to IoT RAs showing entities (e.g., actors), information networks, gateways, and communication paths so that the IoT RAs can be better understood by the IoT RAs' users in order to use the IoT RAs more effectively.

Some of the top level IoT systems' general requirements listed in Clause 7 are associated with this IoT Conceptual RM mainly for the information networks that provide connectivity for communications paths among the entities within each domain (e.g., intra-domain communications path) and that for across different domains (e.g., inter-domain communications path). This RM also shows the major gateways that are needed for the information networks to provide the connectivity between the IoT domains.

From this RM is the foundation for developing the IoT RAs using the three main technology areas (e.g., IoT Systems of Interest, IoT Communications Technology, and IoT Information Technology) are derived as shown in Clause 8.

FIGURE TO BE INSERTED

Figure 2. IOT Conceptual Reference Mode.

7 IoT Systems General Requirements

7.1 General Requirements of IoT System of Interest

COMMENTS: The general requirements for the IoT System of Interest will be developed by the inputs from the contributors, from other available IoT related documents, and from practices as this document develops.

The general requirements commonly found in IoT Systems are listed below.

7.2 General Requirements of IoT Communications Technology

COMMENTS: The general requirements for the IoT Communications Technology will be developed by the inputs from contributors, from other available IoT related documents, and from practices as this document develops.

The general requirements commonly found in IoT Communication Technology are listed below.

7.3 General Requirements of IoT Information Technology

COMMENTS: The general requirements for the IoT Information Technology will be developed by the inputs from contributors, from other available IoT related documents and from practices as this document develops.

The general requirements commonly found in IoT Information Technology are listed below.

7.4 Other Relevant IoT Systems Requirements

COMMENTS: The general requirements that do not belong to any of the above technology areas are listed in this clause.

8 Internet of Things Reference Architectures (IoT RAs)

COMMENTS: This section will be further developed – more details and depth will be added to the diagrams. The entity descriptions will be enhanced and refined. The interface descriptions will be added for the detailed architectural diagram. The reference architecture diagrams shown in this document are the starting point for discussion and subject to enhancement and detailing in architectural depth.

8.1 Introduction

Furthering the IoT Conceptual Reference Model shown in Figure 2 into the IoT RAs, the common entities in each domain from various IoT Systems are identified and described. The specific entities that are not common to the various IoT Systems are not described in this standard, but these specific entities are left to be described by the owner or the developer of the IoT system.

In this standard, the IoT RA is described using the domains identified in Figure 1, extending the model in Figure 1 to three IoT RAs described with common entities and interfaces in each domain for various IoT system's applications and services.

In this standard, IoT RA describe the reference architecture from the key technologies that enables the "an IoT System" in the IoT System Domain. In most IoT Systems, there are three main technologies involved: (1) an IoT system supporting intended applications and services; (2) communication technology utilized by the IoT system, by information system, and linking the various domains for data/information transmission and reception; and (3) information technology implemented for the IoT system and providing necessary data/information to various data/information consumers.

Therefore, in this standard, the IoT RA is described by the three IoT RAs which are: (1) IoT System of Interest Reference Architecture (IoT-SIRA); (2) Communications Technology Reference Architecture (IoT-CTRA); and (3) IoT Information Technology Reference Architecture (IoT ITRA).

8.2 IoT System of Interest Reference Architecture (IoT SIRA)

COMMENTS: The IoT Systems of Interest Reference Architecture (IoT SIRA) is not a complete one. This architectural diagram will be further developed with finalized entities in each domain and interface definitions for intra-domain connectivity (among the entities within a domain) and inter-domain connectivity (among the domains and the entities in different domains). It is expected that the IoT SIRA would be a complex architecture when it is represented in a diagram.

In Figure 3, IoT Systems of Interest Reference Architecture (IoT SIRA) is shown along with all the entities involved and the interfaces among them. The entity descriptions are presented in Table 1. The interfaces are numbered in Figure 3, and the interface descriptions (or definitions) are presented in Table 2.

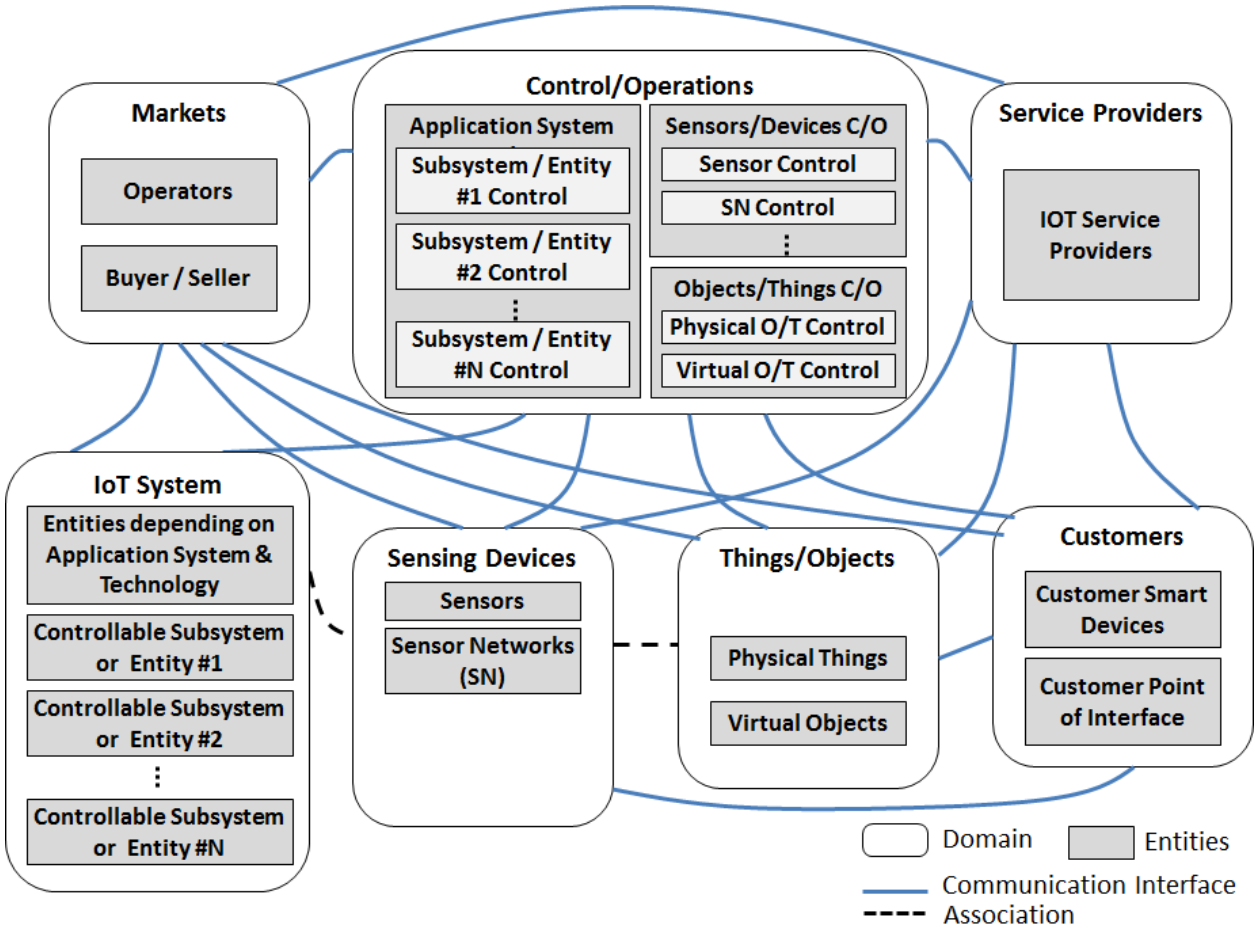

Figure 3. IOT System of Interest Reference Architecture (IoT SIRA) – *COMMENTS: This architecture diagram will be further developed with complete entities in each domain and the interfaces among them*.

The entities in each IoT domain for the IoT SIRA have rather generic names. This is because the IoT System of Interest covers all different types of IoT systems. When this IOT SIRA is adopted and reused by a developer's architect, these generic entities in each IoT domains will become specific entities for the IoT system (e.g., smart grid, smart house/building, smart city, etc.) that is selected and being developed. Additional entities that are unique to the selected IoT system shall be added to the IoT SIRA to completely describe the selected IoT system and its applications and services.

The common entities found in the IoT domains for IoT SIRA are shown in Table 1 below.

Table 1. Common Entities of the IoT SIRA (COMMENTS: The entities listed in this table may not be complete list of the entities in each domain. Additional entities will be listed as they are determined as this document develops)**.**

IoT Domains	Domain Entities

IoT Domains	Domain Entities
IoT System Domain	**COMMENTS**: Generic and common to various entities in IoT System Domain will be identified and listed here as this document develops.
Sensing Devices Domain	• Sensors • Sensor Nodes • Sensor Networks
Things/Objects Domain	• Physical Things • Virtual Objects
Control/Operations Domain	• IoT System Control/Operations • Sensing Devices Control/Operations • Things/Objects Control/Operations
Service Providers Domain	• IoT Service Provider Organizations
Customers Domain	• End-Point Smart Devices • Customer Point of Interface
Markets Domain	• Operators • Sellers • Buyers

The IoT SIRA interface descriptions/definitions are listed in Table 2 according to the interface numbers found in Figure 3 above.

Table 2. IoT SIRA Interface Descriptions/Definitions (COMMENTS: The interface descriptions/definitions will be developed when the IoT SIRA is completed)**.**

SI IF#	Entity 1	Entity 2	Descriptions/Comments
SI-1			
SI-2			
SI-3			
SI-4			
SI-N			

8.3 IoT Communications Technology Reference Architecture (IoT CTRA)

In Figure 4, IoT Communication Technology Reference Architecture (IoT CIRA) is shown along with all the entities involved and the interfaces among them. The entity descriptions are presented in Table 3. The interfaces are numbered in Figure 4, and the interface descriptions (or definitions) are presented in Table 4.

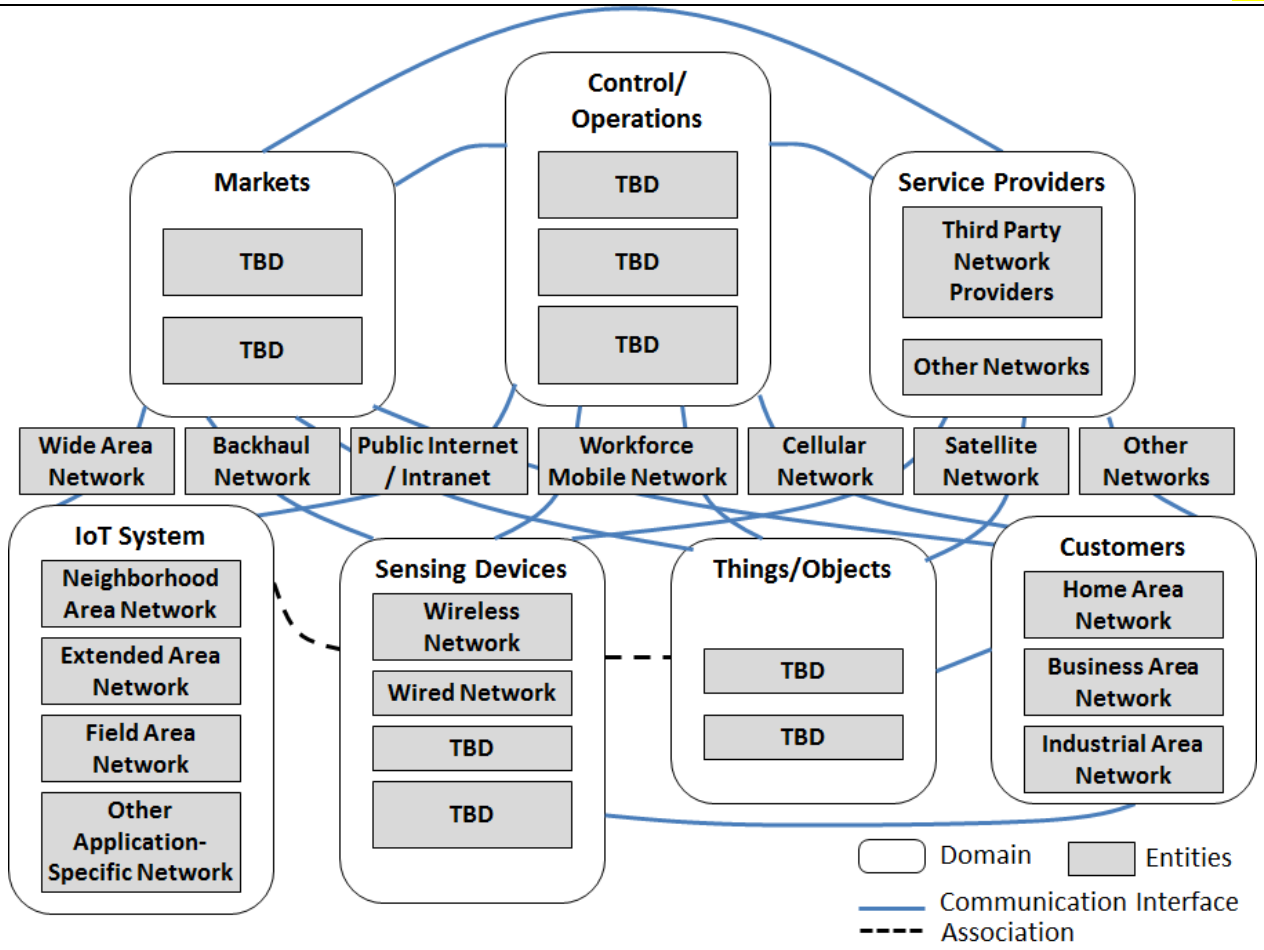

Figure 4. IOT Communications Technology Reference Architecture (IoT CTRA) – *COMMENTS: This architecture diagram will be further developed with complete entities in each domain and the interfaces among them r*.

The common entities found in the IoT domains for IoT CTRA are shown in Table 3 below.

Table 3. Common Entities of the IoT CTRA (COMMENTS: The entities listed in this table may not be complete list of the entities in each domain. Additional entities will be listed as they are determined as this document develops)**.**

IoT Domains	Domain Entities
IoT System Domain	• Neighborhood Area Network • Extended Area Network • Field Area Network
Sensing Devices Domain	• Local Area Network • Various types of wireless network, e.g., Wi-Fi, ZigBee, etc.
Things/Objects Domain	• To be determined as this document develops
Control/Operations Domain	• To be determined as this document develops
Service Providers Domain	• Third Party Network Providers • Other Networks
Customers Domain	• Home Area Network • Business/Building Area Network • Industrial Area Network
Markets Domain	• To be determined as this document develops

Additionally there are network entities outside the IoT domains. They are:

- Wide Area Network;
- Backhaul Network;
- Public Internet / Intranet;
- Workforce Mobile Network;
- Cellular Network;
- Satellite Network; and
- Other Networks.

The IoT CTRA interface descriptions/definitions are listed in Table 4 according to the interface numbers found in Figure 4 above.

Table 4. IoT CTRA Interface Descriptions/Definitions (COMMENTS: The interface descriptions/definitions will be developed when the IoT CTRA is completed)**.**

SI IF#	**Entity 1**	**Entity 2**	**Descriptions/Comments**
CT-1			
CT-2			
CT-3			
CT-4			
CT-N			

8.4 IoT Information Technology Reference Architecture (IoT ITRA)

In Figure 5, IoT Information Technology Reference Architecture (IoT ITRA) is shown along with all the entities involved and the interfaces among them. The entity descriptions are presented in Table 5. The interfaces are numbered in Figure 5, and the interface descriptions (or definitions) are presented in Table 6.

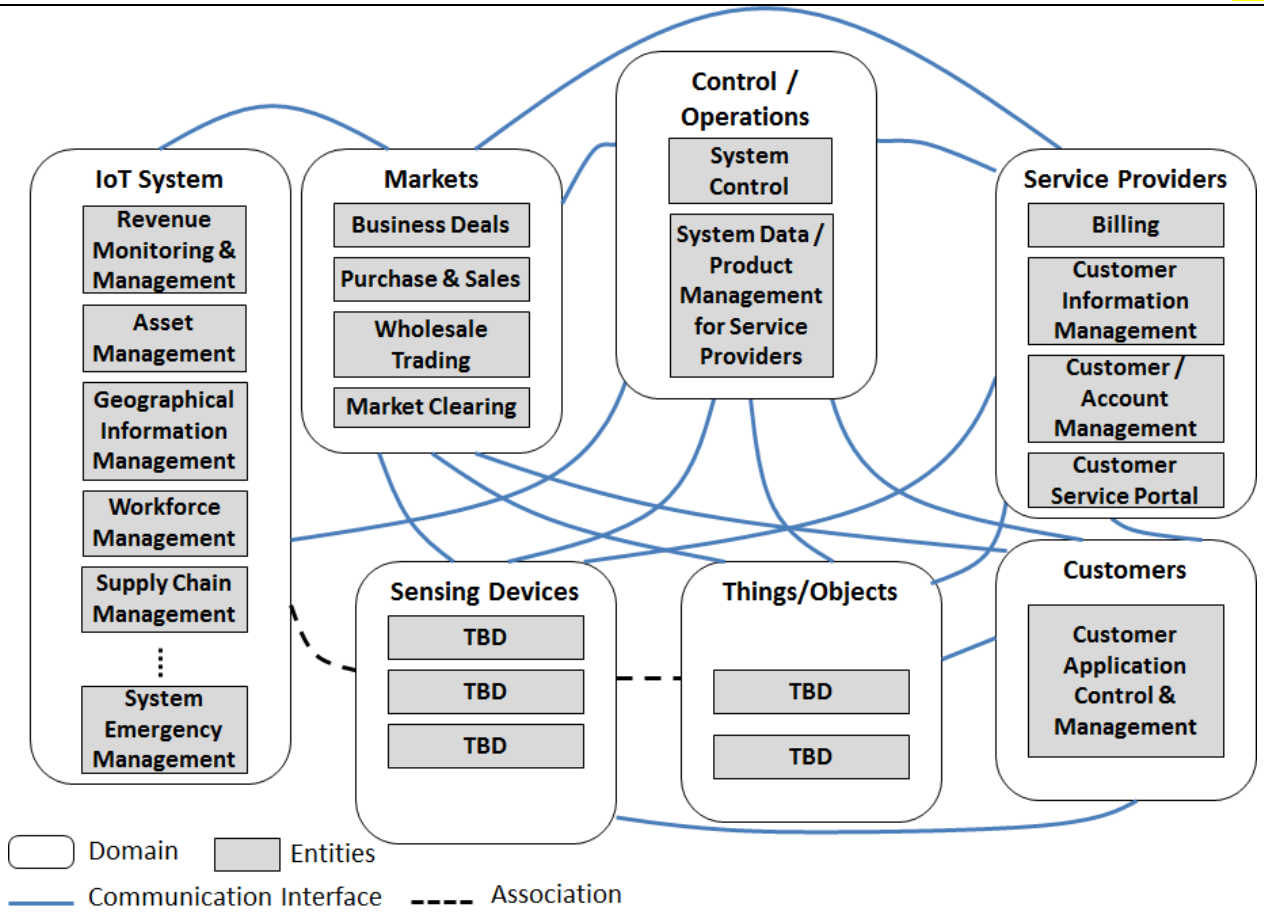

Figure 5. IOT Information Technology Reference Architecture (IoT ITRA) – *COMMENTS: This architecture diagram will be further developed with complete entities in each domain and the interfaces among them*.

The common entities found in the IoT domains for IoT ITRA are shown in Table 5 below.

Table 5. Common Entities of the IoT ITRA (COMMENTS: The entities listed in this table may not be complete list of the entities in each domain. Additional entities will be listed as they are determined as this document develops)**.**

IoT Domains	**Domain Entities**
IoT System Domain	• Revenue Monitoring and Management • Asset Management • Geographical Information Management • Workforce Management • Supply Chain Management • System Emergency Management
Sensing Devices Domain	• To be determined as this document develops
Things/Objects Domain	• To be determined as this document develops
Control/Operations Domain	• IoT System Control/Operations (e.g., top level plant control, process control for an IoT system) • System Data / Product Management for the organizations in the Service Providers Domain
Service Providers Domain	• Billing • Customer Information & Databases • Customer/Account Management • Customer Service Portal
Customers Domain	• Customer Application Control and Management

IoT Domains	Domain Entities
Markets Domain	• Business Deals (e.g., collaboration for profit, acquisition, seller-buyer transaction, retails, etc.) • Purchasing and Sales • Wholesale Trading • Market Clearing

The IoT ITRA interface descriptions/definitions are listed in Table 6 according to the interface numbers found in Figure 5 above.

Table 6. IoT ITRA Interface Descriptions/Definitions (COMMENTS: The interface descriptions/definitions will be developed when the IoT ITRA is completed)**.**

SI IF#	Entity 1	Entity 2	Descriptions/Comments
IT-1			
IT-2			
IT-3			
IT-4			
IT-N			

9 Other IoT Reference Architecture Representations

COMMENTS: In this clause, other types of IoT RA will be presented such as IoT functional architecture, etc. if/when such architectures can be filling any gaps that are not covered by the IoT RAs presented in Clause 8 above.

Annex A – Review/Study of IoT Reference Models/Architectures/Frameworks Relevant to the IoT RA
(*Informative*)

COMMENTS: A review or study of the existing IoT reference models/architectures/frameworks relevant to the IoT RA are presented in this annex. In fact, the output document of the new scope of JTC 1 SWG on IoT (SWG 5) from the 2013 JTC 1 Plenary (that is Resolution 9 Item 8 "*Study IoT Reference Architectures/Frameworks and provide a study report. This study report should be written so it could be referenced in a possible JTC 1 New Work Item Proposal on IoT. The report shall be made available to JTC 1 no later than the 2014 JTC 1 Plenary.*") would be a perfect fit for this annex.

Annex B – Example of System Architecture Development from the IoT RA
(*Informative*)

COMMENTS: An example of developing a System Architecture from the IoT RAs will be presented in this annex to assist the IoT developers and architects.

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COMMENTS: Additional bibliographies will be added as this document develops.