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Internet of things (IoT) – Real-time IoT framework

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INTERNET OF THINGS (IoT) – REAL-TIME IoT FRAMEWORK

FOREWORD

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ISO/IEC 30165 has been prepared by subcommittee 41: Internet of Things and Digital Twin, of ISO/IEC joint technical committee 1: Information technology. It is an International Standard.

The text of this International Standard is based on the following documents:

FDIS	Report on voting
JTC1-SC41/216/FDIS	JTC1-SC41/229/RVD

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1, available at www.iec.ch/members_experts/refdocs and www.iso.org/directives.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

This document addresses a special kind of IoT system operating in real-time that is called real-time IoT (RT-IoT) systems.

The correct behaviour of a real-time system depends not only on the logical correctness, but also on the timeliness of its actions. Design and development of a real-time system are different from conventional computer systems in terms of real-time OS, embedded development, task scheduling, etc.

[1] [1] emphasizes the requirements of timeliness and predictability in real-time systems as follows.

"The challenges and trade-offs faced by the designers of real-time systems are quite different from those who design general purpose computing systems. To achieve the fundamental requirements of timeliness and predictability, not only do conventional methods for scheduling and resource management have to be redesigned, but new concepts that have not been considered in conventional systems need to be added. New paradigms are necessary to specify and validate real-time systems."

Lack of understanding of real-time systems could lead to unsuccessful RT-IoT system deployment where real-time computation is required. A deployment of an RT-IoT system based on the very general real-time capabilities defined in ISO/IEC 30141 [2] is not enough to fully support real-time requirements. Therefore, it is important to complement the real-time capabilities of IoT reference architecture for RT-IoT systems.

Basically, an RT-IoT system has features of a typical IoT system except real-time capability. ISO/IEC 30141 explains real-time capability of an IoT system as follows:

– a characteristic of a system or mode of operation in which computation is performed during the actual time that an external process occurs, in order that the computation results can be used to control, monitor, or respond in a timely manner to the external process

Considering the characteristics of real-time capability, any IoT system embraces real-time aspects to some extent simply because it continuously interacts with the physical world.

Requirements for real-time capability depend on the peer that an IoT system interfaces with. For example, a human–machine interface guarantees a maximum delay of 250 ms in presenting responses to humans, whereas 150 ms is sufficient in a telephone service. Any IoT system interfacing with physical things guarantees some extent of timeliness because any event in the physical world demands timely adjustment from the IoT system.

This document focuses on real-time capability in addition to very general description given in ISO/IEC 30141, because failing on timing constraints could cause serious damage to an IoT system or to its environment, including injury or even death of people involved. Certain RT-IoT systems, such as industrial IoT (IIoT) systems and cyber-physical systems (CPS), consider time as of high importance.

The purpose of this document is to provide a guideline for deploying an RT-IoT system to avoid pitfalls that usually occur during real-time system developments.

1 Numbers in square brackets refer to the Bibliography.

INTERNET OF THINGS (IoT) –
REAL-TIME IoT FRAMEWORK

1 Scope

This document specifies the framework of a real-time IoT (RT-IoT) system, including:

– RT-IoT system conceptual model based on domain-based IoT reference model defined in ISO/IEC 30141;

– impacts of real-time parameters in terms of four viewpoints (time, communication, control and computation).

2 Normative references

There are no normative references in this document.

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1.1
real-time IoT
RT-IoT
IoT system with timing constraints

Note 1 to entry: Correct behaviour of an RT-IoT system depends not only on the logical correctness, but also on being able to meet timing constraints.

3.1.2
timeliness
property of meeting timing constraints, finishing before the deadline and giving compulsory response

3.2 Abbreviated terms

2G/3G/4G	second/third/fourth generation mobile networks
5G	fifth generation mobile networks
AI	artificial intelligence
ASD	application and service domain
CPU	central process unit
IoT	Internet of Things
LAN	local area network
OMD	operation and management domain
PED	physical entity domain

QoS	Quality of Service
RAID	resource access and interchange domain
RT	real time
TSN	time-sensitive networking
UD	user domain

4 Conceptual model

4.1 General

Figure 1 illustrates the conceptual model based on the IoT reference architecture in ISO/IEC 30141. The conceptual model of an RT-IoT system inherits domain-based reference model and extends it in terms of timing constraints.

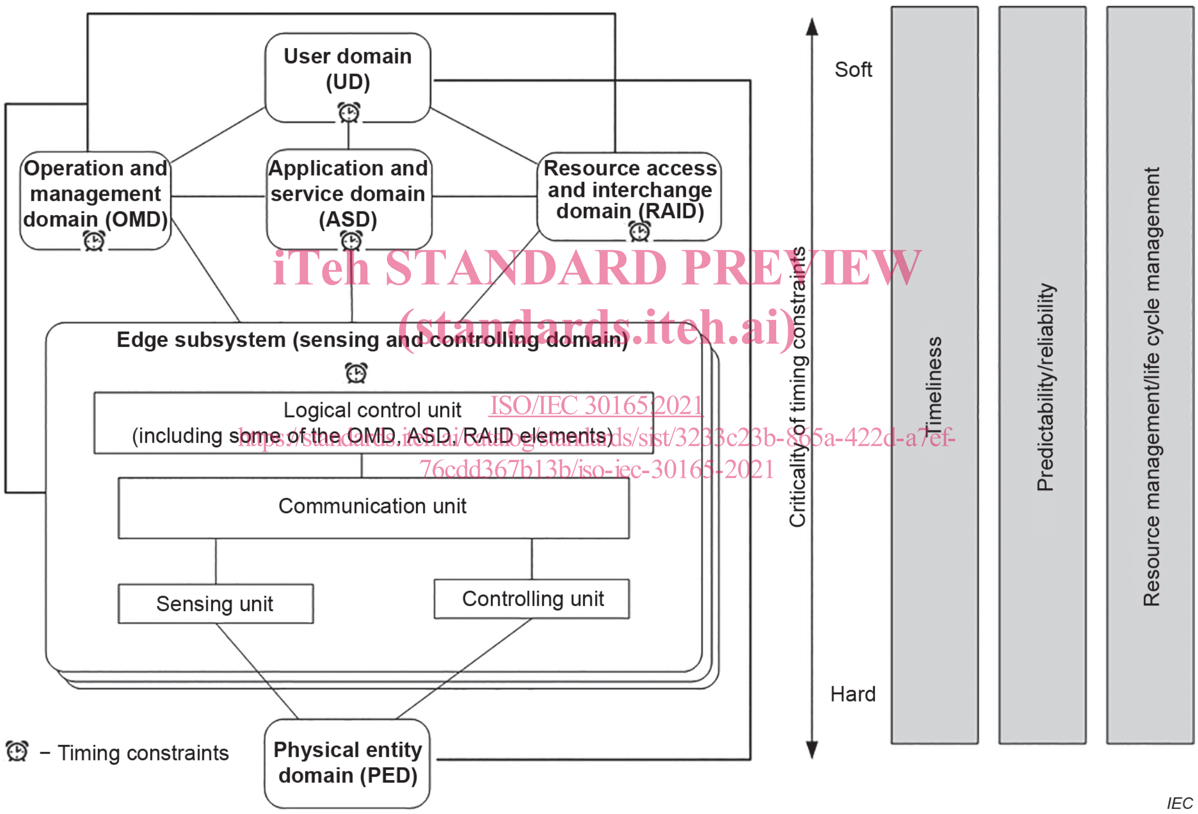

Figure 1 – RT-IoT system conceptual model

4.2 The six domains

First of all, an RT-IoT system is still an IoT system. Its conceptual model is extended from that of the six domain model for an IoT system.

4.3 Edge sub-system

The edge sub-system is an entity of an RT-IoT system, which encompasses IoT device entity and IoT gateway entity defined in ISO/IEC 30141.

An RT-IoT system can be deployed at different scales from large scale that has a number of edge sub-systems to small scale that has limited number of edge sub-systems.

As an IoT sub-system, the edge sub-system also includes some elements of other domains to be a complete functioning system; it is a small scale RT-IoT system. A large scale IoT system could be a system of multiple collaborating IoT systems. This document and ISO/IEC 30141 should be referenced in designing a system of multiple collaborating RT-IoT systems.

The edge sub-system is in some ways similar to edge computing system described in other literature.

4.4 Timing constraints

Timing constraints are the major characteristics of an RT-IoT system. Timing constraints could be within a domain or between domains, could be local or global.

Each domain and each functional component need to have a sense of time. For those domains or functional components involved in a shared timing constraint, their local clock should be synchronized with a master clock. It could be a single master clock in the whole system. On top of this, the timing constraints could be defined and satisfied.

Timing constraints are classified into two categories according to the consequence that violating the timing constraints causes in an RT-IoT system. Hard real-time sometimes requires that a deadline should never be missed, otherwise catastrophes can happen. In soft real-time, the timing constraints could be violated without causing significant consequence.

The edge sub-system interacts with the physical world generally under the requirements of hard real-time. The delay of time is shorter as the edge sub-system is closer to the physical world. This is indicated with the word hard at the bottom in Figure 1. However, the criticality of implementing and handling timing constraints becomes soft far away from the PED, where more computation power is usually available such as OMD and UD. This is indicated with the word soft at the top in Figure 1.

NOTE This document provides a guideline for deploying an RT-IoT system. While it covers in general terms, future documents will cover many related topics in more detail, such as the following.

– Support of timeliness, availability, and predictability in the vertical dimension. The timely delivery of data from an IoT device to the cloud, and vice versa.
– Real-time constraints across multiple applications.
– Real-time resource management in complex cases.
– The life-cycle management. Design and validation of an RT-IoT system depends on specific application area and follows specific practices. It might include, for instance, certification.
– Other new technologies referenced in Annex A.

5 Viewpoints of RT-IoT system conceptual model

5.1 Time view

5.1.1 General

Time view represents time-related characteristics of an RT-IoT system. Entities of an RT-IoT system should have a common understanding of the clock to reference the time, although the precision can differ in each entity. Figure 2 shows the RT-IoT system time view.

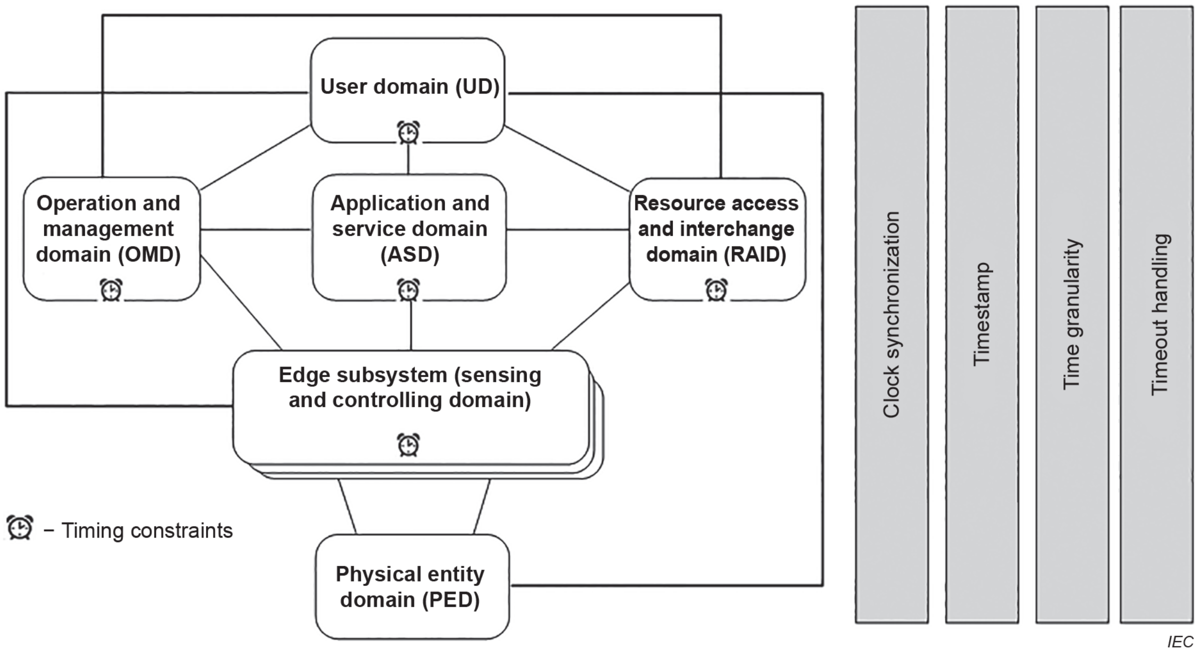

Figure 2 – RT-IoT system time view

5.1.2 Clock synchronization

In an RT-IoT system, all functional components should have a clock that is synchronized to a master clock for distributed timing constraints, if the components together are required to meet certain timing constraints. However, a master clock is optionally synchronized to the global standard time. In some cases, a component's clock may be of different synchronization precision, or even not synchronized.

IEC 61588 [3] defines a precision clock synchronization protocol for networked measurement and control systems.

The Internet has a high accuracy in time with the help of several international atomic clocks. An IoT system could synchronize with the Internet time, referencing of which could be important in troubleshooting, legal context, etc. The NTP (Network Time Protocol) standard [4] defines a synchronization protocol used on Internet.

5.1.3 Timestamp

In an RT-IoT system, events, data, actions, etc., are all able to be timestamped.

5.1.4 Time granularity

An RT-IoT system should support appropriate time granularity, or length of time defined in the timing constraints.

Being fast or quick does not mean being real-time. The time unit measured in real-time constraints could be large or small, but the key is for the system to be timely and predictable.

Different IoT systems could have different time granularity. A driverless car needs to react to external events in microseconds, whereas a smart building adjusts room temperature in minutes. Within an RT-IoT system, the actuator can act in milliseconds, but the self-diagnostics routine could run intermittently in the background. Hard real-time systems could be systems with large time granularity, and vice versa. For example, distributed control systems in the process control industry are often hard real-time systems, although their control cycles are often in seconds.

5.1.5 Timeout handling

An RT-IoT system should implement a timeout handling mechanism.

While an RT-IoT system should finish all tasks within the deadlines. One major feature of a real-time system is its component handling timeouts. There are different handling approaches. Some applications allow rolling back the modification. A process application can entail opening a relieving valve after a task misses the deadline. In other cases, the system is simply rebooted.

5.2 Communication view

5.2.1 General

The need for timely interaction between different elements entails real-time support from the communication networks. Deterministic network capability, if needed for timeliness, is essential. Timeliness of communication is achieved through properties such as bandwidth management, latency, and redundancy management.

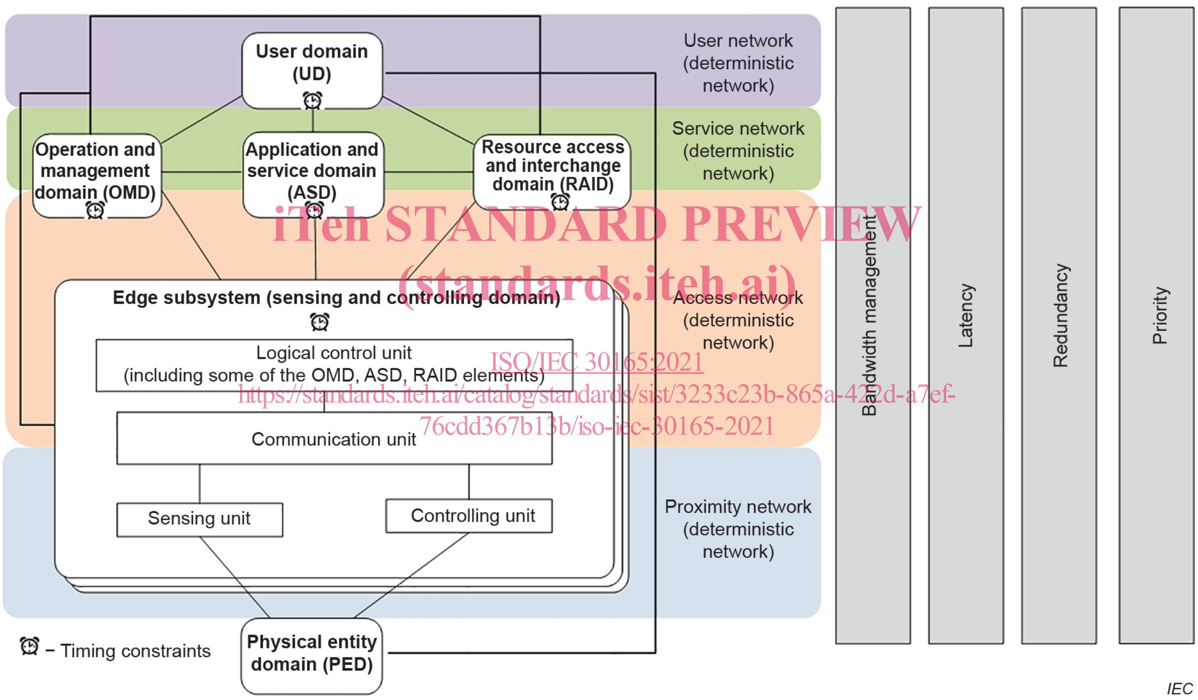

Figure 3 – RT-IoT system communication view

Of the networks in an IoT system, the field level networks are usually fieldbuses and usually provide hard real-time support. Soft real-time support is expected at the administrative level, i.e. actions involving a human to manage the system.

There are different network topologies and technologies among the four network types in Figure 3. They are explained in ISO/IEC 30141 [2]. Some IoT devices are part of a fixed installation and can be connected to a wired or wireless network, and some IoT devices are mobile and hence connected to a wireless network, and each network technology has a different and potentially varying latency. Regardless of all those differences, a network should provide different degrees of timing support. In an RT-IoT system, a mobile device's wireless communication could also meet stringent timing constraints.