Applying Quality Requirements Framework to an IoT System

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***Abstract*—Modern information and communication technology systems more focus on their quality requirements since they have been increasing their complexity. This paper shows how the quality requirements framework of the ISO/IEC 25030 can be applied to an Internet of things application, Elderly monitoring system. The results of this application indicate the usefulness of the framework.**

Keywords. Quality requirements; SQuaRE; IoT.

I. INTRODUCTION

Information and Communication Technology (ICT) systems are increasingly used to perform a wide variety of organizational functions and personal activities. The quality of these products enables and impacts various business, regulatory and information technology stakeholders. High-quality ICT systems are hence essential to provide value, and avoid potential negative consequences, for the stakeholders.

To develop such high-quality ICT systems, it is important to define quality requirements, because finding the right balance of quality requirements, in addition to well-specified functional requirements, is a critical success factor to meet the stakeholders' objectives.

Furthermore, the complexity of ICT systems has grown exponentially with the advent of modern digital technologies like Internet of Things (IoT). This has also led to focus on more and more quality requirements that are critical to modern ICT systems.

ISO/IEC 25030 Quality requirements has been published in 2007, and its revision process has been going on to expand its scope from software to ICT systems [1]. The standard belongs to ISO/IEC 25000 series: Systems and software Quality Requirements and Evaluation (SQuaRE) has been developed as the successor of the other standards on product-related quality, including ISO/IEC 9126.

This paper shows how the quality requirements framework of the ISO/IEC 25030 revision works [1], in case that it is applied to an IoT system. Section II explains the quality requirements framework and section III describe the target IoT system, and then the framework is applied to the system in section IV.

II. QUALITY REQUIREMENTS FRAMEWORK

A. Architecture of the SQuaRE series

The SQuaRE series consists of five main divisions and on extension division. The divisions within the SQuaRE series are:

- **ISO/IEC 2500n - Quality Management Division**. The standards that form this division define all common models, terms and definitions used by all other standards in the SQuaRE series. The division also provides requirements and guidance for the planning and management of a project.
- **ISO/IEC 2501n - Quality Model Division**. The standards that form this division provide quality models for system/software products, quality in use, data, and IT services. Practical guidance on the use of the quality model is also provided.
- **ISO/IEC 2502n - Quality Measurement Division**. The standards that form this division include a system/software product quality measurement reference model, definitions of quality measures, and practical guidance for their application. This division presents internal measures of software quality, external measures of software quality, quality in use measures and data quality measures. Quality measure elements forming foundations for the quality measures are defined and presented.
- **ISO/IEC 2503n - Quality Requirements Division**. The standard that forms this division helps specifying quality requirements. These quality requirements can be used in the process of quality requirements elicitation for a system/software product to be developed, designing a process for achieving necessary quality, or as inputs for an evaluation process.
- **ISO/IEC 2504n - Quality Evaluation Division**. The standards that form this division provide requirements, recommendations and guidelines for system/software product evaluation, whether performed by independent evaluators, acquirers or developers. The support for documenting a measure as an Evaluation Module is also presented.

B. Quality requirements and quality models/measures

Quality In Use Requirements (QIURs) specify the required levels of quality from the stakeholders' point of view. These requirements are derived from the needs of various stakeholders. QIURs relate to the outcome when the product is used in a particular context of use, and QIURs can be used as the target for validation of the product.

QIURs can be specified using quality in use model (ISO/IEC 25010 [2]) and measures (ISO/IEC 25022 [4]). **Figure 1** describes characteristics and subcharacteristics of quality in use model.

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Effectiveness	Efficiency	Satisfaction	Freedom from risk	Context coverage
Effectiveness	Efficiency	Usefulness Trust Pleasure Comfort	Economic risk mitigation Health and safety risk mitigation Environmental risk mitigation	Context completeness Flexibility

Figure 1. Quality in use model [2]

Product Quality Requirements (PQRs) specify levels of quality required from the viewpoint of the ICT product. Most of them are derived from stakeholder quality requirements including QIURs, which can be used as targets for verification and validation of the target ICT product.

PQRs can be specified using product quality model (ISO/IEC 25010[2]) and measures (ISO/IEC 25023[5]). Figure 2 describes characteristics and subcharacteristics of product quality model.

Functional suitability	Performance efficiency	Compatibility	Usability
Functional completeness Functional correctness Functional appropriateness	Time-behavior Resource utilization Capacity	Co-existence Interoperability	Appropriateness recognisability Learnability Operability User error protection Use interface aesthetics Accessibility

Reliability	Portability	Maintain-ability	Security
Maturity Availability Fault tolerance Recoverability	Adaptability Installability Replaceability	Modularity Reusability Analysability Modifiability Testability	Confidentiality Integrity Non-repudiation Accountability Authenticity

Figure 2. Product quality model [2]

The Data Quality Requirements (DQRs) specify levels of quality required for the data associated with the product. These include requirements derived from QIURs and PQRs of input and output products. DQRs can be used for verification and validation from the data side.

Inherent	Inherent & System dependent	System dependent
Accuracy Completeness Consistency Credibility Currentness	Accessibility Compliance Confidentiality Efficiency Precision Traceability Understandability	Availability Portability Recoverability

Figure 3. Data quality model [3]

DQRs can be specified using data quality model (ISO/IEC 25012[3]) and measures (ISO/IEC 25024[6]). Figure 3 describes 15 characteristics of data quality model, which are categorized by inherent and/or system dependent.

C. *Quality requiremnets framework*

The revision of ISO/IEC 25030[1] will provide a framework for quality requirements, which consists of concept of the quality requirements, and processes and methods to elicit, define, use and govern them.

There are three important points:

- To elicit quality requirements, not only direct users of the ICT product but also indirect users (using results of the product) and other stakeholders, such as developers, regulatory body, and society at large should be taken into account.
- QIURs should be considered first because most of PQRs are derived from QIURs, and they should be deployed into PQRSs and DQRs of its sub-products (smaller ICT products, software, data, hardware and communication facilities) to meet them.
- Quality requirements should be defined quantitatively, in order not to be vague and unverifiable requirements that depend on subjective judgement for their interpretation.

III. IoT SYSTEM AND TARGET SYSTEM

A. *Characteristics of IoT systems*

The IoT envisages a future in which digital and physical things or objects can be connected by means of suitable information and communication technologies, to enable a range of applications and services. The IoT's characteristics include [7]:

- many relevant stakeholders involvement
- device and network heterogeneity and openness
- resource constrained
- spontaneous interaction
- increased security attack-surface

These characteristics will make development of the diverse applications and services a very challenging task.

B. *Target system*

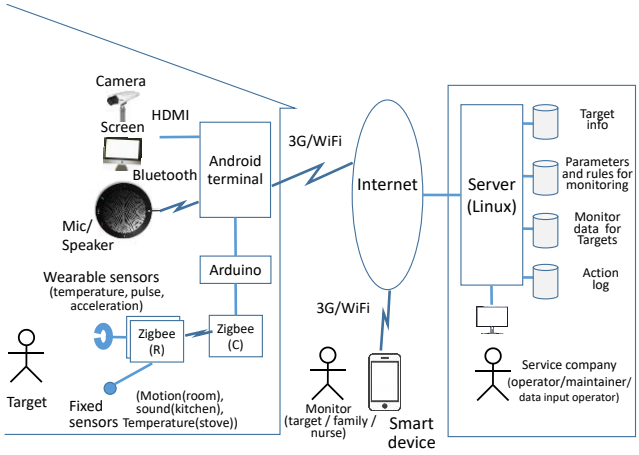

Figure 4. Elderly monitoring system [8]

The target IoT system, to which SQuaRE's quality requirements framework is applied, is Elderly monitoring system. Figure 4 shows its system architecture.

Figure 5 describes use cases of elderly monitoring system.

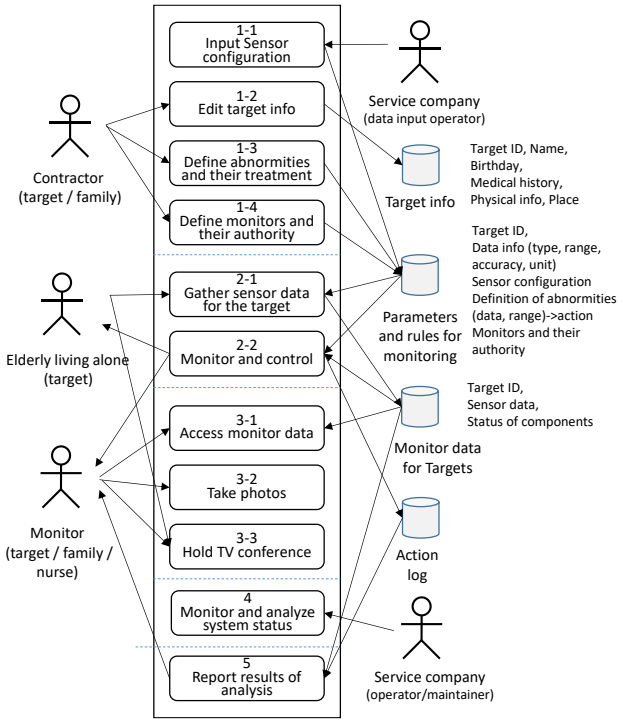

Figure 5. Use cases of elderly monitoring system (written by the author)

IV. APPLICATION OF THE FRAMEWORK

A. *Stakeholder identification and select important QIURs*

The quality requirements framework needs identification of stakeholders of the target system, including not only direct users but also indirect user and other stakeholders.

Table 1 lists identified stakeholders for the elderly monitoring system, including:

- Direct user: contractor, elderly living alone, family, nurse, and service company's operators
- Indirect user: service company's managers
- Other stakeholder: Developer, Ambulance

For all stakeholders, their goals to achieve through using the target system are extracted. The direct users must have use case of the system **(**Figure 5) in which they involved for achieving their goal. The indirect users and other stakeholders do not use the system directly, and the former uses the results of the system and the latter may get influenced from the system in an indirect way. Therefore, they do not have relevant use cases.

Based on stakeholders' goals and use cases, important quality in use characteristics/subcharacteristics (Table 1) should be selected with target outcomes and consequences.

Table 1. QIURs selection based on stakeholders' goal

Stakeholder	Goal	Use case	QIUR (with target outcomes and consequences)
Service company's manager (**indirect user**)	Customer satisfaction	NA	**Usefulness** **Trust**
	Prevention from incidents	NA	**Freedom from risks:** prevention from * incidents by system faults or malfunctions * incidents by normal operation * privacy leakage * malfunction by malicious attach
Service company's operator (**direct user**)	Monitor all equipment, and take actions if something wrong with them.	4	**Efficiency**: system monitor and control **Effectiveness**: preventive actions before disfunction or malfunction
	Maintain and update system and equipment.	1−1	**Efficiency:** maintenance activities
Contractor (**direct user**)	Inform the service company of what he/she wants them to do.	1−2 1−3	**Efficiency**: operation for input **Freedom from risks**: prevention from wrong input
Elderly living alone (**direct user**)	Detect designated abnormalities for the target, and take actions.	2−2	**Effectiveness**: early treatment **Trust**: correct results on good timing
	Obtain his/her own current body condition and behavioral pattern.	5	**Effectiveness**: obtain info on current body condition and behavioral pattern to provide objective insights.
Family (**direct user**)	Confirm target's normality.	3−1 3−2	**Effectiveness**: see target's condition anytime and anywhere
	Be informed of target's serious abnormalities.	2−2	**Trust**: correct results on good timing
			Freedom from risks: prevention from * overlook of serious abnormalities * unnecessary notice on trivial abnormalities
Nurse (**direct user**)	Confirm target's normality.	3−1 3−2	**Effectiveness**: remote nursing **Efficiency**: early notice of patient's abnormalities
	Be informed of target's all abnormalities.	2−2	**Effectiveness**: early treatment **Trust**: correct results on good timing
			Freedom from risks: prevention from overlook of serious abnormalities
	Create reports for asking doctors to diagnose abnormalities.	5	**Efficiency**: automatic reporting
Developer (**Other stakeholder**)	Achieve QCD goal	NA	**Efficiency**: development activities
	Update the system to implement new functions periodically	NA	**Efficiency**: maintenance activities
Ambulance (**Other stakeholder**)	Dispatch ambulance cars on demand (by nurse's call)	NA	**Freedom from risks**: prevention from unnecessary dispatches of ambulance cars

* direct user: person who interacts with the product
* indirect user: person who receives output from a system, but does not interact with the system, for example executive manager, service acquirer

B. *Drivation of PQRs and DQRs*

Figure 6 describes how quality requirements derive others in the system hierarchy.

The primary source of quality requirements is the users, from whom first QIURs for the information system including the target entities are elicited and documented. Then, they evolve into PQRs and DQRs for the target entities. Other stakeholders, such as developers and regulatory bodies, also give some quality requirements on the target entities. Finally, other entities give some requirements as constraints to the target entities, including non-target ICT products, software and data which are connected to or used in the targets, and hardware and communication which are used in them.

Table 2 shows how to derive PQRs and DQRs from QIURs which are partially selected from Table 1. For PQRs and DQRs, important product quality characteristics/ subcharacteristics (Figure 2) and data quality characteristics/ subcharacteristics (Figure 3) are selected to meet the corresponding QIURs.

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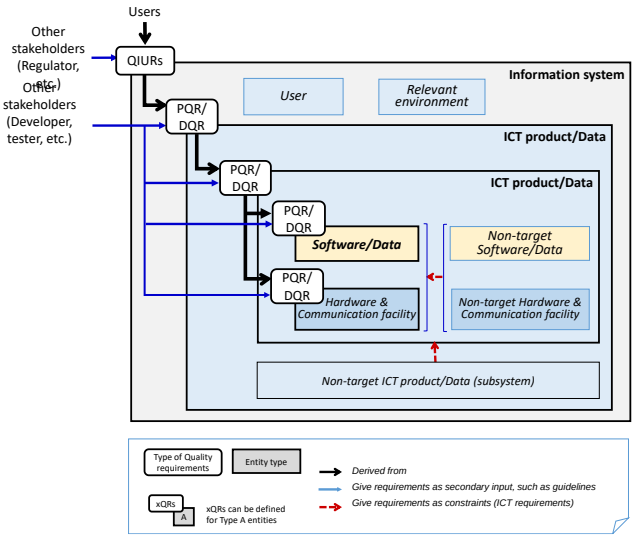

Figure 6. Derivation of quality requirements [1]

Some PQRs for the target product may be deployed into subcomponents to meet them (denoted with ->). DQRs are identified for the data files or data base used in the system (Figure 6).

Table 2. Derivation PQRs and DQRs from QIURs

Stakeholder	Use case	QIUR (with target outcomes and consequences)	PQR	DQR
Service company's manager (**indirect user**)	NA	**Freedom from risks:** prevention from		
		* incidents by system faults or malfunctions	**Maturity** ->**Availability** for server ->**Maturity** for IoT devices	**Recoverability** of all data
			Time-behavior ->Throughput of server	**Efficiency** and **Accessibility** on Monitor data for target
		* incidents by normal operation	**Maturity**: exhaustive testing	**Consistency** and **Currentness** on Monitor data for target
		* privacy leakage	**Confidentiality** on server	**Confidentiality** on Target info
		* malfunction by malicious attach	**Integrity**: IoT devices, network	**Traceability** on Parameters and rules for monitoring
Contractor (**direct user**)	1-2 1-3	**Efficiency**: operation for input	**Operability** and **Accessability** on Web user interface	**Understandability** on Parameters and rules for monitoring
		Freedom from risks: prevention from wrong input	**Learnability** and **User error protection** on : Web user interface	**Accuracy**, **Completeness** and **Consistency** on Parameters and rules for monitoring
Elderly living alone (**direct user**)	2-2	**Effectiveness**: early treatment **Trust**: correct results on good timing	**Functional suitability** and **Functional completeness** for detecting abnormalities	
	5	**Effectiveness**: obtain info on current body condition and behavioral pattern to provide objective insights.	**Functional suitability**: inclusion of useful information	**Understandability** of reports

V. SUMMARY AND FUTURE WORK

Modern ICT systems like IoT systems should put more focus on their quality requirements. This paper provides the brief introduction of ISO/IEC 25000 (SQuaRE) series, which define quality models and measures, and how to define quality requirements and evaluate quality of the ICT products.

And then, the IoT systems' unique characteristics compared to the other information systems are mentioned, including many relevant stakeholders' involvement, device and network level heterogeneity and openness, resource constrained, spontaneous interaction, and increased security attack-surface, which may make development of the diverse applications and services a very challenging task.

To solve this problem, we apply the quality requirements framework of the ISO/IEC 25030 revision to an IoT system, Elderly monitoring system. The results of this application make us believe the usefulness of the framework.

More application of the framework to a variety of IoT systems and much larger scale ones should be needed to clarify its limitations and problems.

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