QoC-aware meta-model to identify and qualify situations on the internet of things environment

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Abstract . In the internet of things world, sensors continually generate contextual information that is the core stone for understanding and adapting to the environment according to the user situation. However, diversity of contextual data sources, its imperfection nature and the complexity to identify and model the pertinent situation make it more challenging. Consequently, using a technique like the quality of context to ensure the system quality requirement and having a generic model of context and situation is crucial. Recently, many domain-specific models and few generic meta-models have been proposed to cope with these concerns, but rarely are those that handle context, situation, and quality of context (QoC). In this paper, we introduce a general and extensible QoC-aware meta-model describing both situation and context with their relevant quality of context. Furthermore, we propose a process that a developer or a designer should follow to model and infer situations with adequate quality level. We dementated our model with a prototype application for medical alert.

Keywords: Meta-model, Situation, Context, Quality of Context, Internet of things.

1 INTRODUCTION

The internet of things has achieved enormous success in the last decades due to the large and rapid development of technologies like mobile phones, and sensors but still, the wiser vision where every device is completely embedded [1] isn't completely accomplished. This vision faces different challenges. One of those core challenges is situation and context awareness that is the ability of a system to sense and adapt to the environment surrounding it. To identify a situation, researchers have used multiple techniques and methods like specification-based and learning-based techniques [2]. Furthermore, researchers also presented meta-models and tools to specify a situation for a certain application through a Model-Driven technique that gives the opportunity to model a situation in a generic way. Most researchers expect the contextual data to be correct and ignore the aspect of the imperfection. Moreover, a technique like the quality of context must be used to handle and ensure an adequate quality level of the contextual data. In this paper, we introduce a generic and extensible QoC-aware situation meta-model helping designers and developer to identify and qualify situations on the internet of things environment. We also propose a process that assists developers to create their own model and describe situations with adequate quality level.

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2 RELATED WORK

2.1 Quality of Context

The contextual information is characterized by their imperfection nature which can be imprecise, ambiguous and erroneous [3]. Accordingly, Quality of Context (QoC) is essential to ensure the worthiness of the collected contextual data. QoC stand for every information that outlines the quality level of context information and it's represented as a set of parameters like accuracy and completeness. QoC was firstly introduced by [4] as "any information that describes the quality of information that is used as context information". Researchers in [5] claimed that this definition ignores the subjective view of the concept and doesn't involve the consumer satisfaction and define it as "Quality of context indicates the degree of conformity of the context collected by sensors to the prevailing situation in the environment and the requirements of a particular context consumer". The definition of [4] is considered as the accepted definition of this article. Many works have proposed their own vision of QoC and their own parameters of measuring the quality and modeling QoC. [6] presented a list of quality parameters (precision, probability of correctness, trust-worthiness, resolution and up-to-dateness). [7] investigated the quality of context parameters and compared them with the quality concepts proposed by ISO. The age and precision where the adopted parameters. [8] contributed in solving conflict during the life cycle of context by choosing the contextual object with the highest quality based one four parameters. Authors in [9] proposed the most completed list of quality of context parameters with mathematical calculation formula for each parameter. In the part of modeling QoC, [10] proposed QoCIM, an UML meta-model that allows developers to define and create any quality parameter. Recently, [11] developed a three-layer framework where every layer has its QoC parameters and the context situation layer has credibility as new QoC proposed parameter.

2.2 Generic Models

Researchers in [12] has presented the first model-driven development of context-aware services based on an UML meta-model .the contextUML model represent context as atomic and composite and context sources as service community , after that [13] proposed a model driven architecture to create a context-aware service based on a context meta-model. The model was expended with OCL rules to avoid invalid instances dentition and to specify the context situation. [14] designed a generic and extensible model-driven process for creating a context and quality-aware application. The proposed process separates the context-aware designer that express the application needs conform to a meta-model CA3M completed with QoC from the context manager which handle the implementation of those needs. [15] proposed a domain-specific language based on an UML entity-based model for context modeling which provides a high level of abstraction without including implementation detail to generate software artifact. [16] introduced MLcontext, a language with a quality of information meta-model and a contextual situation meta-model that provide the composition, the parameterization of a

situation and the quality level to generate artifact code for context-aware applications. [17] presented a model-based approach for context aware-application that capture dynamically the context change. The proposed approach is used by programmers to develop a context-aware application.

2.3 Domain Dependent Models

CARA [18] presented a contextual medical model composed of case-based context model representing the user, his physiology, area and the objects in interaction. This last is used to generate a high-level context for a fuzzy model to deduct the medical situation throw KNN, case-based and fuzzy sets reasoning. [19] contributed with fuzzy ontology model for situation and context in a u-learning domain where they described situations as a set of specific context taxonomy for learners with fuzzy attributes that been used with fuzzy rules and evidence theory. In activities of daily living, [20] has used an ontological model for situations when those last are activities described by their dependencies as set of observations presented as RDF graphs and extracted with SPARQL CONSTRUCT graph patterns. [21] has suggested a context model constructed from three ontologies: a user ontology , a physical environment , and a proactive ontology which contains the events and the appropriate action to manipulate a situation.

According to Table 1, we concluded that few are models that take into consideration QoC. Although the generic models proposed gives us the possibility to use it under all domains it's restricted to logic rules-based reasoning which is often not enough. The domain-specific models have proposed multiple techniques that enforce the learning.
Facing this situation, we propose a generic model that consider context, situation, and quality of context and give the developer the freedom of using the appropriate reasoning method depending on his environment and his needs.

3 QOC-AWARE SITUATION META-MODEL CONSTRUCTION

To create our proposed meta-model, we conducted considerable studies about the proposal context taxonomy for generic and domain dependent meta-models ..We also addressed the problem of context source and the quality of context to create our meta-model which is a combination of three meta-models: 1) the context taxonomy meta-model, 2) the context source meta-model and 3) the QoC meta-model.

3.1 Context Taxonomy Meta-model

Many context taxonomies have been suggested for the domain dependent models in [18-21]. However, they couldn’t be used in a generic way. We had analyzed the classification of context represented in the generic meta-models and we founded that the categorization in [15] was the one that covered all the types of context.

Approaches	*Model type*	*Reasoning*	*Qoc*	*Context taxonomy*	*Context sources*	*Historic context*
Quan et al [12]	Generic UML Model	OCL Rules	√		Context Service Community, Context Service	
Achilleos et al, [13]	Generic UML Model	OCL Rules	**X**	Identity, time, location, activity, preference, secondary	Static, Profiled, sensed, derived	**X**
chabridon et al, [14]	Generic UML Model		√		Context collectors (sensed)	**X**
Hoyos et al , [15, 16]	Generic UML Model	Rules	√	Physic,Environmen, Computational, Task Personal, Social,		√
Jaouadi et al, [17]	Generic UML Model	Rules	**X**		Derived, Profiled Sensed,User Defined	√
Yuan et al, [18]	Health model	Fuzzy Rules, Case-based Reasoning, and KNN	**X**	Physiology, Personal, Environmental, activity, event, medical condition		√
Souabni et al, [19]	U-learning ontology model	Fuzzy Rules and Dempster's combination rules	**X**	User, location, time, physical condition, learning needs', technology, social		√
Medistskos and Kompatisiaris, [20]	Ambient ontology model	SPARQL query, OWL2	**X**	Object,posture ,location , action (event observation)		√
[Machado et al, [21]	Ambient ontology model	Rules, Bayesian Networks	**X**	User ontology, Physical Environment Ontology, Proactive Ontology		√

Table 1. Comparison between generic and dependent domain model that tackled situation, context and QoC

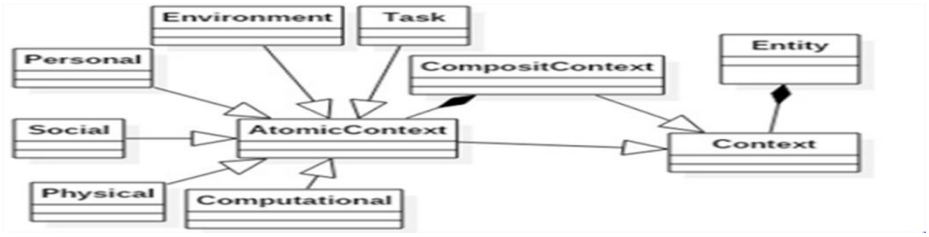

Fig.2. Context taxonomy meta-model

Fig. 2 shows an excerpt of the context taxonomy meta-model, where Context is every information about an Entity and could be a set of **AtomicContext** and/or **Composit-Context**. This last is an aggregation of **AtomicContext** that's one of the five taxonomies (personal, social, physical, environment, computational or task) [15].

3.2 Quality of Context Meta-model

To construct our QoC meta-model we wanted to give a semantic way to describe QoC parameters due to the naming problem of the quality parameters. Since some parameters are more important than others, we added the weight and the level (**QoC PWeight**,**QoC PLevel**) to the parameters.

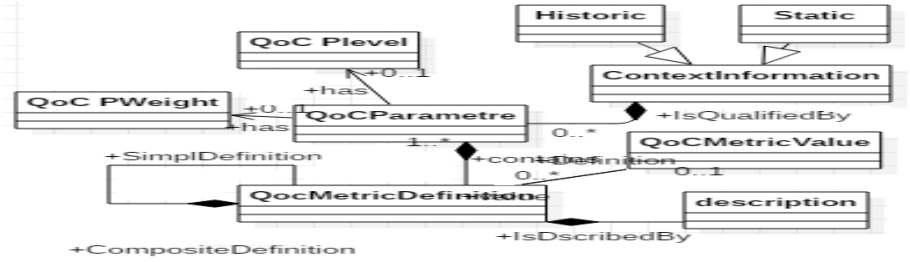

Fig. 3. QoC meta-model

Fig. 3. illustrates the QoC meta-model mainly inspired by [10], where every **Context-tInformation** is either Historic if does change over time or Static otherwise and it's qualified by **QoCParamtre** which contains a definition **QoCMetricDefinition** that could be a simple or a composite one and could be described with further key words or informal definition in the description class. Every **QoCMetricDefinition** instantiate a **QoCMetricValue** representing valuation of the **QoCParmetre**.

3.3 Context Source Meta-model

Context information could have multiple sources. For that, a classification of sources is essential to choose the appropriate method to manage this information. The chosen classification is inspired by [17] and illustrated in Fig 4.

Profiled are the information constructed from the user **profile**,**Derived** are the information deducted from other contextual information, **UserDefined** are the information introduced directly by the user and Sensed are the information gathered from physical sensors .The **ContextAssociation** have a method of acquisition from the Provider that has a **ProviderMethod** and every Provider is located in an Entity.

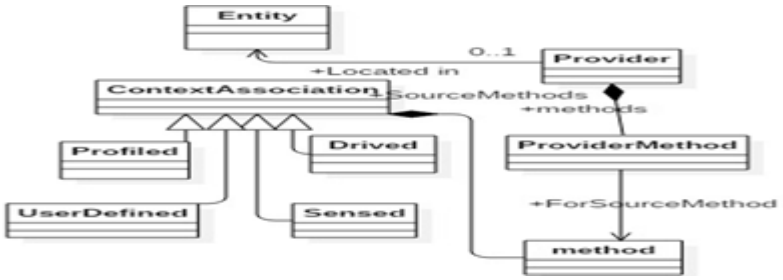

Fig. 4. Context source meta-model

3.4 QoC-aware Situation meta-model

After defining the context taxonomy and its sources with the quality of context meta-model and adding the notion of **Situation** which is described using a composition of context concerning an Entity we obtained the global QoC-aware situation meta-model (Fig 5).

Our meta-model is characterized by its domain independency and promote universal modeling of context and situation. Furthermore, it integrates the quality of context in a way to ensure well definition of quality parameters and does not consider that the only way to infer.

4 PROCESS OF QOC–AWARE SITUATION IDENTIFICATION SYSTEM

To build a reactive system, we must be aware of the environment, the quality of the data we are using, and be able to identify the situation the user is currently having it. To deal with those problems, we propose a complete process of identifying situation base on our QoC-aware situation meta-model.

Our building process shown in Fig 6 starts with context acquisition and labeling where the developer chooses the sensors of the system and adopted techniques of acquisition to capture the data.

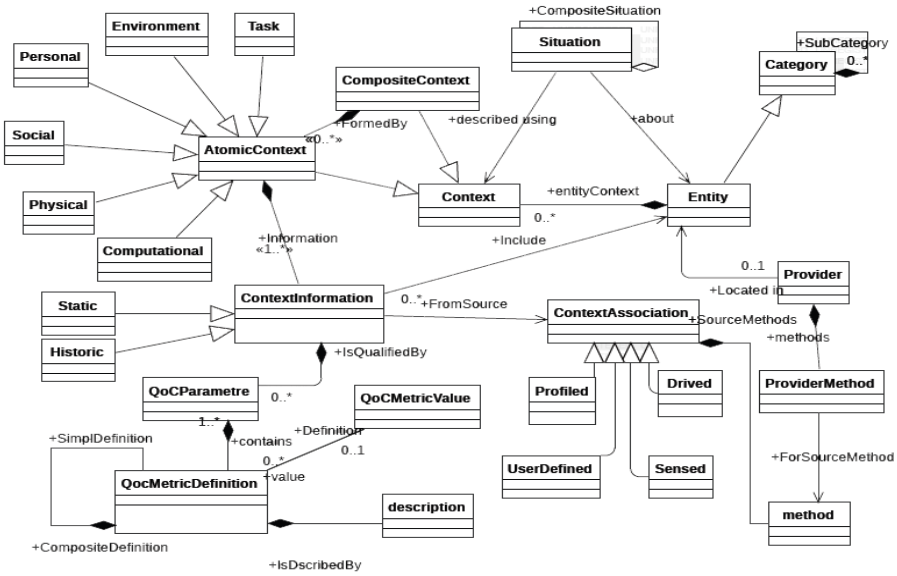

Fig. 5. *QoC-aware Situation Meta-model*

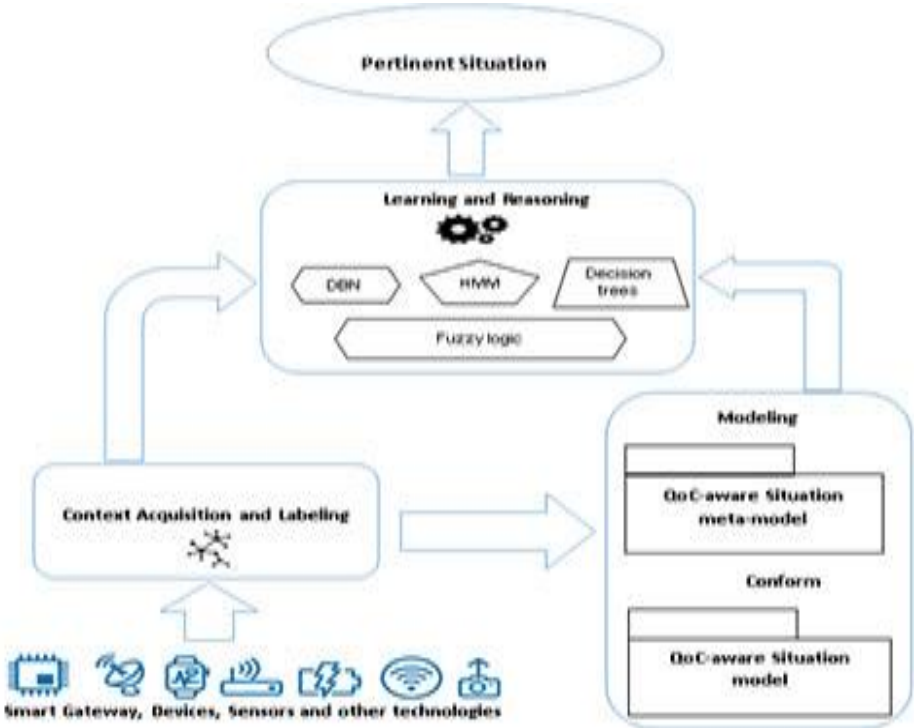

Fig. 6. The process of QoC–aware situation identification System

The next phase is the modeling were the developer create his own domain dependent model conform to the QoC-aware situation meta-model to represent the situation with the chosen quality parameters and the context taxonomy and sources. The last phase is the learning and reasoning were the appropriate method of learning is selected according to the type of data and the specificity of the domain to be able to recognize the pertinent situation.

5 Case study: medical alert application

In hospital, every doctor carry a smartphone equipped with WIFI ,GPS,3G, and Bluetooth and where he receive important alert and information .In the other side the location and the medical device monitoring the patient health condition are connected to the hospital server. In case of emergency situation, the system should identify the closest specialized doctor relaying on the technologies cited earlier and the quality of context parameters like UptoDateness and accurency to choose the most reliable location and provide him with the case and shortest path to the patient. Fig 8 present an excerpt of medical alert model created from QoC and situation meta-model by defining the situation, entities, context taxonomy and type and the QoC parameter required for medical alert application. For the reasoning and due to the simplicity of the example rule based technique is enough. We use OCL rules.This OCL rules illustrate the logical expression determinate the occurrence of the situation in particular contextual condition. To define a cardiology emergency situation a patient must have a pulse upper then 120 beat per minute

Context s: Situation
s.name='emergency situation'-> **drive inv: if any**(e:entity|e.name='Julia').EntityContext->(h:physical| |name=pulse| pulse>120)**then** true **else** false **endif**.

An addition we need to identify the nearest cardiology doctor relaying on the QoC parameter

Context si:Situation
si.name='emergency alert'->**drive inv**: **if any** (e.entity| e.name='sami').EntityContext->(e:envirement|e.name='cardiology')**and** (en:envirement |en.name='location') .From-> (sp1:sensed provider |sp.name='wifi')**or**(sp2:sensed provider |sp2.name='3G cell id')**or**(sp3:sensed provider |sp3.name='bluetooth')**or**(sp4:sensed provider |sp.name='GPS')**and**en.QualifiedBy(p1:QoCParameter|p1.name='UptoDateness').has (ql=QoCLevel|ql.value='0.8') and(p1:QoCParameter |p1.name='Accuracy ').has(ql=QoCLevel|ql.value='0.8') **then** true **else** false **endif**.

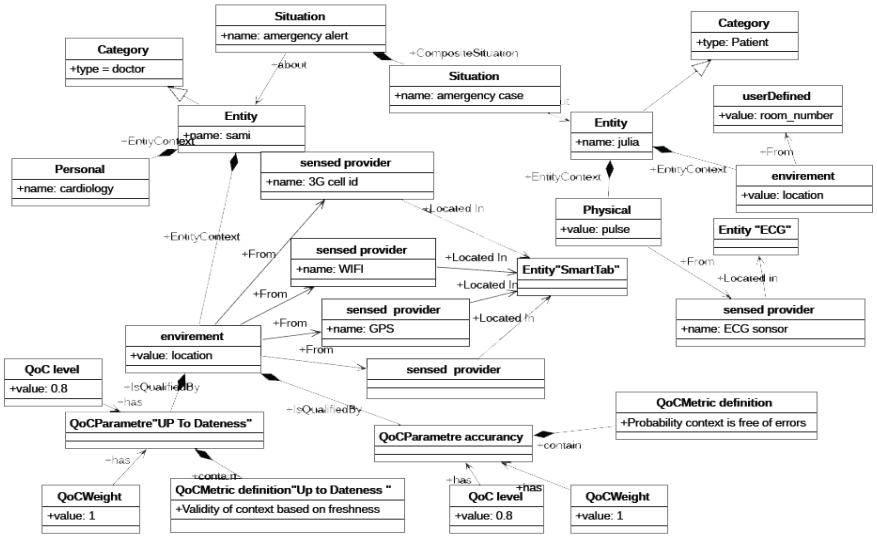

Fig. 8. Medical alert QoC and Situation model

6 CONCLUSION AND PERSPECTIVES

In this paper, we have presented a generic and extensible QoC-aware situation meta-model helping designers and developer to identify and qualify situations on the internet of things environment. The proposed meta-model is constructed by merging three meta-models: 1) context taxonomy meta-model, 2) context sources meta-model, and 3) quality of context meta-model. We have also described our process of identifying the pertinent situation for a specific domain based on our meta-model and the labeled contextual information and the learning and the reasoning methods depending on the chosen environment. In addition, we have presented a medical alert use case to show the feasibility of our approach. For the reasoning part we have proposed a set of OCL rules due to the simplicity of the example.

Although, this work can be continued is several ways. As ongoing work, we plane to evaluate the effectiveness and usability of our QoC-aware situation meta-model for smart health environment monitoring where we will a more powerful reasoning technique like Bayesian networks, Hidden Markov models, Decision trees, etc.

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