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Software Quality in Mobile Environments: A Comparative Study

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Abstract— **Evaluating Software Quality (SQ) of mobile applications is an active and challenging research topic. This is caused by the limitations of both mobile networks and mobile devices such as low bandwidth, frequent disconnection, low energy and low storage capacity. In order to help programmers, developers and SQ evaluators to deal with the limitations of mobile environments and to achieve a high level of mobile software quality, we have designed two frameworks ISO9126-FRAM and Diffserv-FRAM. ISO9126-FRAM consists in using the SQ standard ISO 9126 in mobile environments while DIFFSERV-FRAM concerns the use of the SQ standard ISO 9126 with the DiffServ Quality of Service (QoS) model to evaluate the software quality in mobile environments. Therefore, the main objective of this study is to present and compare these two frameworks of SQ evaluation to show the disadvantages and advantages of each one. This comparison is based on the Framework Mapping Comparison Method. As a result of this comparison, the correlation between the two frameworks can be strong as it can be weak depending on the studied SQ characteristics. In addition, differences have been identified at the empirical evaluation level of the two frameworks in terms of the encountered difficulties.**

Keywords— ISO 9126; Software quality; Quality of Service; DiffServ; mobile environments; Mapping Comparison Method.

I. Introduction

In today's world, it would be unable to live without mobile technologies which have become an integral part of our daily activities. However, these mobile technologies are characterized by limited resources such as processing power, data storage capability, low energy, low and variable bandwidths [1, 2]; in addition, they are less reliable [3, 4, 5]. These limitations of mobile technologies compromise the ability of the latter to fulfill the requirements of the software quality as a critical driver for successful software [6, 7]. However, there are a limited number of studies that have been launched on the use of the ISO 9126 quality standard to evaluate SQ in mobile environments.

Moreover, to the best of our knowledge, no study has been carried out on the use of ISO 9126 in conjunction with Diffserv model for evaluating SQ in mobile environments.
In our earlier works, two frameworks have been developed for the evaluation of the SQ of mobile applications: ISO9126-FRAM is composed of three steps and was designed to identify the ISO 9126 quality characteristics that are influenced by mobile limitations [8]; and DIFFSERV-FRAM that includes three steps and it is based on the ISO 9126 standard with the QoS DiffServ model [9].

The aim of this study is to compare ISO9126-FRAM and DIFFSERV-FRAM to show their strengths and weaknesses**.** To do that, we have relied on the Framework Mapping Comparison Method which is the most widely used method, applied in different studies [10, 11]. This comparison included the conceptual level i.e. the design of the two frameworks and the empirical level which correspond to a comparison between the two experiments that have been conducted to validate empirically ISO9126-FRAM and DIFFSERV-FRAM.

This paper is organized as follows: Section II presents ISO9126-FRAM and DIFFSERV-FRAM as well as their empirical evaluations. Section III describes the used method for the comparison of the two frameworks. Section IV discusses the results of this comparison. Finally, our findings are discussed and future works are suggested in Section V.

II. Presentation of the frameworks and results of their evaluations

A. ISO9126-FRAM:

The study [8] was based on the ISO 9126 standard, specifically its external quality model, to address the impacts of mobile environments limitations on the SQ of mobile applications. Mobile limitations are divided into two groups: 1) the mobile devices limitations as, limited User Interface, Limited Storage Capacity and Low Energy Autonomy; and 2) the wireless networks limitations which include in particular: Frequent Disconnection, Variable and Lower Bandwidths. To carry out this study, we have developed an analysis process with the aim of taking into account the mobile limitations when using ISO 9126 quality standard. The analysis process involves three steps as shown in Fig 1 and is applied to the following six external quality characteristics: Usability, Functionality, Efficiency, Reliability, Portability and Maintainability.

Table 1 presents the results of the application of the analysis process on the six external quality characteristics.

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Each cell of Table 1 shows whether there is an impact of a mobile limitation on a SQ characteristic. We noticed that:

1. Reliability is limited by Variable Bandwidth, Frequent Disconnection, and Limited Energy Autonomy. During the evaluation of this characteristic, these three limitations should be considered by using the ISO 9216 metrics or by providing others for mobile environments. For the cases of the following pairs (Efficiency, Lower Bandwidth and Limited Storage Capacity) and (Usability, Limited User Interface), they are similar to the case of the reliability.
2. Portability is influenced by Limited User Interface and Limited Storage Capacity. These two limitations should be taken into consideration by proposing new metrics specific to mobile environments during the evaluation of this characteristic.
3. Functionality is not limited by mobile limitations if we take into account the recommendation included in ISO 25010. Therefore, this characteristic can be evaluated in the same way as a fixed environment;

Regarding Maintainability no recommendation has been provided. Therefore, other measures should be proposed more particularly for the two attributes: stability and testability, to see whether or not mobile limitations have an influence on the maintainability characteristic.

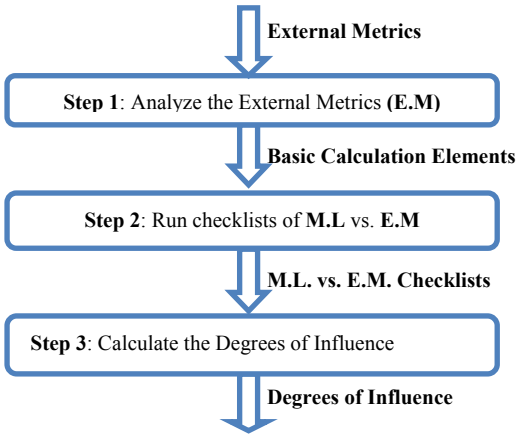

Fig.1. Analysis Process using ISO 9126[16]

B. Empirical Evaluation of ISO9126-FRAM:

To evaluate empirically the findings of ISO9126-FRAM as shown in Table 1, in particular those concerning the usability characteristic, an experiment [12] has been conducted for highlighting the influence of mobile limitations on the usability of mobile applications running under the different existing operating systems such as iOS, Android and Symbian. To do this, we have relied on the ISO 9241-11:1998 and the ISO 25062:2006 standards for the evaluation of the mobile usability. Thirty-two users participated in the experiment with different types of smart phones; they have been asked to carry out specific tasks of Google Maps and Google Apps as test cases, for raising mobile usability issues. In order to assess the level of the user satisfaction, the Questionnaire for User Satisfaction Interaction (QUIS 7.0) has been employed [13]. Since the experiment was based on the two standards ISO 9241-11:1998 and ISO 25062:2006 and in order to evaluate the Effectiveness and Efficiency attributes, a number of objective measures as shown in Fig.2, were collected through observation and video recording of the accomplishment of tasks.

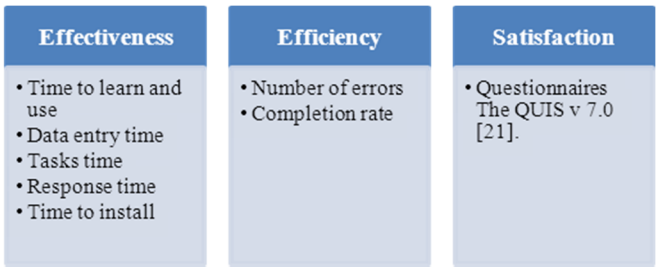

Fig.2. Usability Objective and Subjective measures [12].

Fig.3 indicates the variation of usability objective measures for both Google Apps and Google Maps in terms of types of devices [12].

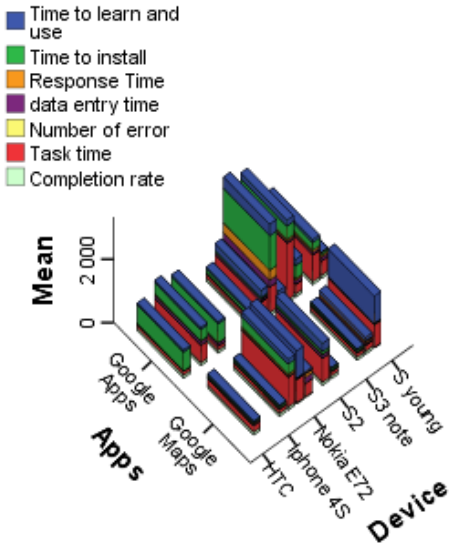

Fig.3. Mean of objective measures for Google Maps and Google Apps in terms of types of devices [12].

As a result of this empirical study, the findings basically prove what we have found in [8]: the Limited User Interface has a strong influence on the usability characteristic. Concerning the Limited Storage Capacity, it has a weak influence on the software usability characteristic compared to other ISO 9126 characteristics.

Fig.4 shows the median values of the screen evaluation in terms of the different types of devices [12]. Furthermore, other problems which are related to the software and the mobile context were raised such as: the low and variable bandwidth of the network, the absence of online assistance and user guides.

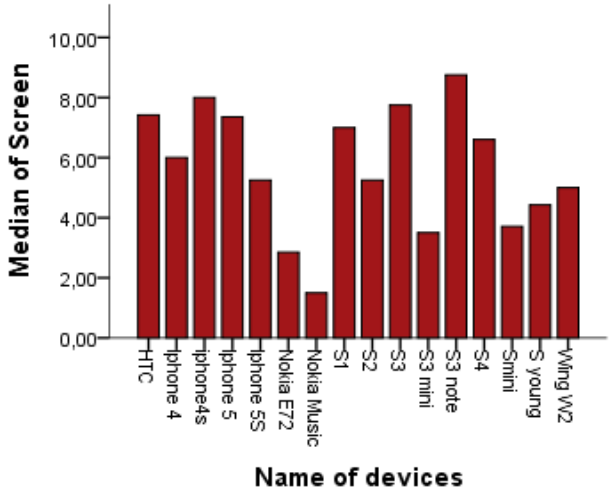

Fig. 4. Screen evaluation median values in terms of devices names [12].

C. *DIFFSERV-FRAM presentation:*

A study carried out in [9] was based on the ISO 9126 standard in order to investigate the application-level quality, with the DiffServ model as the most widely used QoS model that focuses on the network-level quality. To do that, an analysis process was developed in order to take benefits of both ISO 9126 and DiffServ to help quality evaluators and designers in achieving a high quality level in mobile environments. The process is composed of three steps as shown in Fig.5.

The results of step 2 are shown in Table 2. The purpose of Step 3 is to identify correlations between ISO 9126 characteristics and DiffServ classes in terms of mobile limitations as summarized in Table 3. To do this, the results found in [8] and Table 2 were analyzed which indicates the limitations shared between a DiffServ class and a software quality characteristic.

D. *Empirical Evaluation of DIFFSERV-FRAM:*

An experiment was performed in [14] for evaluating empirically the results summarized in Table 3, in particular those concerning the usability characteristic. First, in order to highlight the influence of mobile limitations on DiffServ classes, we have used Sensorly as a tool for evaluating the QoS of mobile networks. Seventeen users participated in the experiment; they have been invited to launch tests under various situations of use, at different time periods and in various geographical zones. The results of this testing are represented as a set of parameters as shown in Fig.6: Upload (Mbps), Ping (ms), Google.com Loading Time (s), Youtube.com Loading Time (s), Download (Mbps), and Facebook.com Loading Time (s). Then, a correlation between this experiment and that of the mobile Usability evaluation [12] conducted for validating empirically the first framework [8], has been carried out.

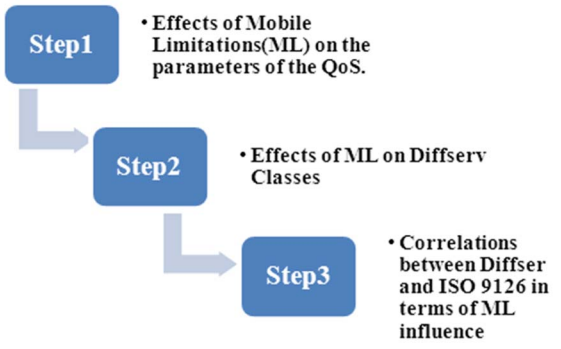

Fig.5. Analysis Process using ISO 9126 with Diffserv model [9].

TABLE I. EVALUATION OF THE DEGREE OF INFLUENCE OF THE MOBILE LIMITATIONS ON ISO 9126 CHARACTERISTICS [9]

Characteristic	Frequent Disconnection	Lower Bandwidth	Variable Bandwidth	Limited Energy Autonomy	Limited Storage Capacity	Limited User Interface
Fun.	O	O	O	O	X	X
Rel.	X	O	X	X	O	O
Usa.	O	O	O	O	O	X
Effi.	O	X	O	O	X	O
Mai.	? More external metrics should be proposed, especially for the Stability and Testability attributes					
Port.	O	O	O	O	X More external metrics should be proposed	

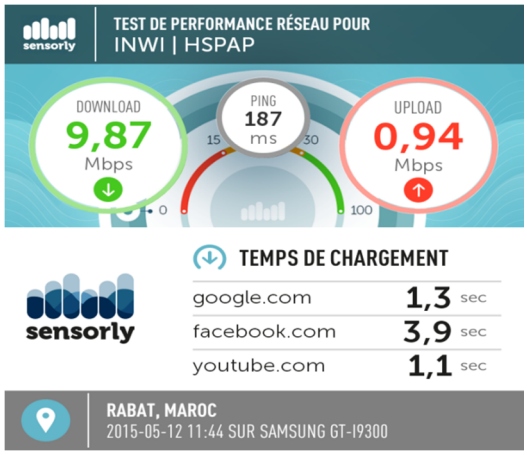

Fig.6. Sensorly mobile application [14].

Fig.7 presents the variation of Facebook.com Loading Time, Google.com Loading Time, and Youtube.com Loading Time in terms of the period and the situation of use [14]. It is noted that the loading time of Google.com is large

against other web sites loading times. The maximum is reached between 1p.m.-6p.m. outside buildings and between 12a.m.-1p.m. on board the train.

As an outcome of this empirical evaluation [14], the EF and AF classes are influenced by Low Bandwidth, Variable Bandwidth, Limited User Interface, Low storage Capacity in addition to Low Energy. However, the usability characteristic is also strongly influenced by Limited User Interface, but weakly impacted by Low Storage Capacity, Low Bandwidth and Variable Bandwidth [12]. Hence, the consideration of these limitations in the evaluation of the usability characteristic of mobile applications may be leaded to EF or AF classes [14].

Regarding the BE Class, it is impacted by Low Bandwidth, Variable Bandwidth and Limited User Interface, it may be deduced that the Low Storage Capacity limitation must be taken into account during the evaluation of the mobile usability [14].

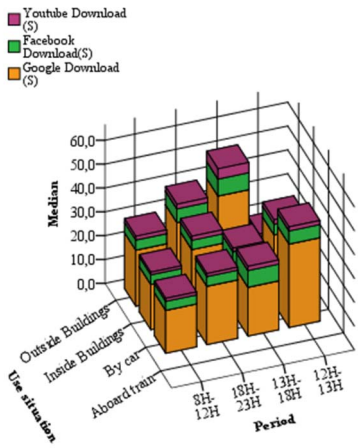

Fig.7. Median values of Google.com, Facebbok.com and Youtube.com Loading Times in terms of the period and the situation of use [14].

III. Frameworks Comparison Methods:

There have been a number of studies comparing the most widely used Software Process Improvement (SPI) such as ISO 9001,CMM, ISO 9000, SPICE, etc. for example:

- El-Emam [10] presented a comparison to illustrate differences between SPICE and ISO 9000.
- Paulk [11] performed a comparison between ISO 9001 and CMM.
- Tingey enabled a detailed comparison between ISO 9000, Malcolm Baldridge, and the SEI CMM for software [13].

The goal of comparing frameworks is to provide an overview of their similarities and their differences. According to Halvorsen, there are four categories of comparison methods which are [15]:

- *Characteristics comparison method:* is relied on a set of pre-established characteristics presented on a table format. It provides a high level comparison with very few details and it is well adapted for an extensive overview of frameworks [16, 17, 18].
- *Framework mapping comparison method:* consists of identifying correlations and overlaps between compared frameworks, and consequently creating a map of these correlations or concepts [10, 11, 19, 20]. As a result, we may obtain a strong correlation, weak correlation or no correlation as proposed by Tingey in [21]. Furthermore, this comparison method can be carried out on a high or a low level according to the amount of existing details.
- *Bilateral comparison method:* The principle of this method consists in comparing two frameworks textually, i.e. comparing textual phrases [10, 11]. It is often a summary and even a detailed explanation of results provided by other comparison methods.
- *Needs mapping comparison method:* It is not a direct comparison between frameworks. Instead, it takes into consideration organizational and environmental types of needs in the selection of adequate frameworks [15].

TABLE II. EVALUATION OF THE DEGREE OF INFLUENCE OF THE MOBILE LIMITATIONS ON ISO 9126 CHARACTERISTICS [9].

Diffserv Classes / Limitations	EF Class	AF Class	BE Class
Frequent disconnection	X	X	X
Low Bandwidth	X	X	
Variable Bandwidth	X	X	
Low energy	X	X	X
Low Storage Capacity	X	X	
Limited User Interface	**X**	**X**	**X**

IV. Discussion and Interpretation:

In order to compare the two frameworks presented in Section II, we have opted for the mapping comparison method since it has been used in several studies in software engineering [11, 19]; for example: a comparison that has been made between SPICE and the ISO 9000 [10], and a mapping between the ISO/IEC 12207, SPICE, the CMM v1.1 and the CMM v2.0 Draft C [20]. Furthermore, it allows to reduce redundancy and to minimize the effort required for the use of multiple frameworks in an organization [15]. There is another motivation behind the use of this method: we have already conducted two experiments for the empirical evaluation of both frameworks as indicated in Section II. These evaluations with quantitative analysis and findings may specify the general focus and the content as suggested by Halvorsen in [15].

A. *Frameworks Comparison: Conceptual level:*

First, we have started with a mapping at the conceptual level based on the two analysis processes as indicated in Section II. The results are displayed in a visual representation in the form of a Venn diagram as illustrated in Fig.8. Each framework is represented by a circle. Each overlap area represents an intersection between the two frameworks, while the differences correspond to non-overlapping parts.

According to this mapping, it can therefore be seen that ISO9126-FRAM was applied specifically to the ISO 9126 external quality metrics unlike DIFFSERV-FRAM that was applied to all Diffserv classes.

The external quality is defined as "the totality of characteristics of the software product from an external view. It is the quality when the software is executed, which is typically measured and evaluated while testing in a simulated environment with simulated data using external metrics" [22]. We can deduce that the first framework corresponds to the quality at the application level while the second it focuses on the network-level quality.

TABLE III. CORRELATION BETWEEN ISO 9126 CHARACTERISTICS AND DIFFSERV CLASSES IN TERMS OF INFLUENCE OF MOBILE LIMITATIONS [9].

Characteristic	EF Class	AF Class	BE Class
Functionality	- Limited User Interface - Low storage capacity	- Limited User Interface - Low storage capacity	- Limited User Interface
Reliability	- Frequent disconnection - Variable bandwidth - low energy	- Frequent disconnection - Variable bandwidth -Low energy	- Frequent disconnection - low energy
Usability	- Limited User Interface	- Limited User Interface	- Limited User Interface
Efficiency	- Low bandwidth - Low storage capacity	- Low bandwidth - Low storage capacity	
Maintainability	? More external metrics should be proposed, especially for the Stability and Testability attributes		
Portability	- Limited User Interface - Low storage capacity	- Limited User Interface - Low storage capacity	- Limited User Interface

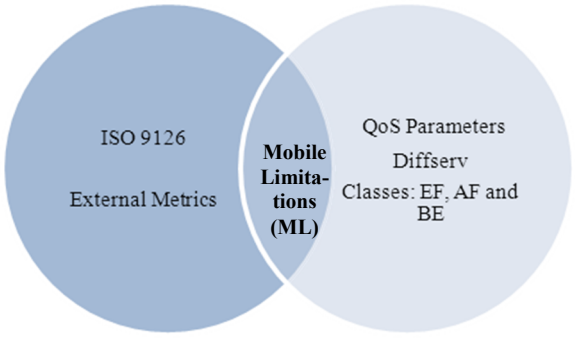

Fig.8. Mapping between the two frameworks at the conceptual level.

On the other hand, for getting an idea of the degree of the correlation between the two frameworks in terms of mobile limitations, we have focused on the results of Table 3. We can notice that the Reliability and the Efficiency are the software quality characteristics, the most correlated with Diffserv classes in terms of mobile limitations influence. This is due to the fact that these two characteristics are dependent on the environment of the execution of the software and that the Diffserv model is representing the quality at the network level, unlike the ISO 9126 standard which concentrates on the application level quality.

As a conclusion, we can notice that 1) the correlation between the two frameworks becomes strong when it comes for characteristics that are strongly dependent on the constraints of the execution environment such as Reliability and Efficiency, and 2) this correlation is getting weak for the characteristics corresponding to the presentation layer, which are related to the mobile devices and to the user interface such as Usability and Maintainability.

B. *Frameworks Comparison: Empirical level:*

It consists of a comparison based on the two experiments that have been conducted for the empirical evaluations of the two frameworks [20, 22], as explained in Section II. The experiment concerning the first framework was not at all easy, and it was restricted by several constraints related mainly to the number of users and the type of environments where the experiment was carried out. The sample of this experiment was small and it has been launched in a controlled environment which was far from any interruptions and noise. We have opted for this choice because 1) the evaluation of usability is not at all easy in a real environment, it depends on a number of parameters such as: the noise, the disturbance, in addition to the data collection which is a complex task especially when users are moving; and 2) the small number of users is due to a lack of time and money to recruit additional users. Therefore, it was difficult to generalize the obtained results of this study for all types of mobile applications. Contrary to the experiment of ISO9126-FRAM, the empirical evaluation of DIFFSERV-FRAM was easy because it was based on a tool that was installed on smart phones. Users were just brought to launch it, anywhere during specific time periods. Then, the results have been sent by email with specific details about the

location, the exact time of the test launch and the data generated. Table 4 present a summary of the comparison of the two frameworks ISO9126-FRAM and DIFFSERV-FRAM on both levels: Conceptual level and Empirical level.

TABLE IV. A COMPARISON SUMMARY OF ISO9126-FRAM AND DIFFSERV-FRAM.

	ISO9126-FRAM	DIFFSERV-FRAM
Empirical Level	- Small sample(32 users) - manual tests - Controlled environment - Difficult experiment	- 17 users - Automatic tests via Sensorly tool for the evaluation of Qos. - Real environment - Different situations of use - Different time periods - Different geographical zones - Easy experiment
Conceptuel Level	-Applied to ISO 9126 External quality -Software Quality at the application level	-All Diffserv Model classes - Software Quality at the network level

v. Conclusion

This article has presented a comparison between two frameworks for the evaluation of the software quality of mobile applications; the first one concerned the use of ISO 9126 while the second is focusing on the use of ISO 9126 with Diffserv model to evaluate software quality of applications running in mobile environments. To do this, we have used the Framework Mapping Comparison method as the most popular comparison method. First, we have started by a comparison at the conceptual level to show the degree of correlation between the two frameworks in terms of mobile limitations influence. We have found that this correlation depends on the characteristics: it is strong for characteristics related to the runtime environment such as Reliability and Efficiency but it is weak for those related to the presentation layer such as Usability and Maintainability. This is due to the fact that ISO 9126 is applied to the software quality at the application level while the Diffserv model focuses on the quality at the network-level. Second, we have investigated a comparison between the empirical evaluations of the two frameworks. We have found that the first experiment was not obvious because of several constraints in comparison with the second experiment which was simple and easy.

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