

HANDBOOK OF MOBILE APPLICATION DEVELOPMENT: A GUIDE TO SELECTING THE RIGHT ENGINEERING AND QUALITY FEATURES



**Mohamed Sarrab
Hafedh Al-Shihi
Naveen Safia**

Bentham Books

Handbook of Mobile Application Development: A Guide to Selecting the Right Engineering and Quality Features

Authored by

Mohamed Sarrab

Hafedh Al-Shihi

&

Naveen Safia

*Communication and Information Research Center
Sultan Qaboos University
Oman*

**Handbook of Mobile Application Development:
A Guide to Selecting the Right Engineering and Quality Features**

Authors: Mohamed Sarrab, Hafedh Al-Shihi and Naveen Safia

ISBN (Online): 978-981-4998-24-6

ISBN (Print): 978-981-4998-25-3

ISBN (Paperback): 978-981-4998-26-0

©2021, Bentham eBooks imprint.

Published by Bentham Science Publishers Pte. Ltd. Singapore. All Rights Reserved.

BENTHAM SCIENCE PUBLISHERS LTD.

End User License Agreement (for non-institutional, personal use)

This is an agreement between you and Bentham Science Publishers Ltd. Please read this License Agreement carefully before using the book/echapter/ejournal (“**Work**”). Your use of the Work constitutes your agreement to the terms and conditions set forth in this License Agreement. If you do not agree to these terms and conditions then you should not use the Work.

Bentham Science Publishers agrees to grant you a non-exclusive, non-transferable limited license to use the Work subject to and in accordance with the following terms and conditions. This License Agreement is for non-library, personal use only. For a library / institutional / multi user license in respect of the Work, please contact: permission@benthamscience.net.

Usage Rules:

1. All rights reserved: The Work is the subject of copyright and Bentham Science Publishers either owns the Work (and the copyright in it) or is licensed to distribute the Work. You shall not copy, reproduce, modify, remove, delete, augment, add to, publish, transmit, sell, resell, create derivative works from, or in any way exploit the Work or make the Work available for others to do any of the same, in any form or by any means, in whole or in part, in each case without the prior written permission of Bentham Science Publishers, unless stated otherwise in this License Agreement.
2. You may download a copy of the Work on one occasion to one personal computer (including tablet, laptop, desktop, or other such devices). You may make one back-up copy of the Work to avoid losing it.
3. The unauthorised use or distribution of copyrighted or other proprietary content is illegal and could subject you to liability for substantial money damages. You will be liable for any damage resulting from your misuse of the Work or any violation of this License Agreement, including any infringement by you of copyrights or proprietary rights.

Disclaimer:

Bentham Science Publishers does not guarantee that the information in the Work is error-free, or warrant that it will meet your requirements or that access to the Work will be uninterrupted or error-free. The Work is provided "as is" without warranty of any kind, either express or implied or statutory, including, without limitation, implied warranties of merchantability and fitness for a particular purpose. The entire risk as to the results and performance of the Work is assumed by you. No responsibility is assumed by Bentham Science Publishers, its staff, editors and/or authors for any injury and/or damage to persons or property as a matter of products liability, negligence or otherwise, or from any use or operation of any methods, products instruction, advertisements or ideas contained in the Work.

Limitation of Liability:

In no event will Bentham Science Publishers, its staff, editors and/or authors, be liable for any damages, including, without limitation, special, incidental and/or consequential damages and/or damages for lost data and/or profits arising out of (whether directly or indirectly) the use or inability to use the Work. The entire liability of Bentham Science Publishers shall be limited to the amount actually paid by you for the Work.

General:

1. Any dispute or claim arising out of or in connection with this License Agreement or the Work (including non-contractual disputes or claims) will be governed by and construed in accordance with the laws of Singapore. Each party agrees that the courts of the state of Singapore shall have exclusive jurisdiction to settle any dispute or claim arising out of or in connection with this License Agreement or the Work (including non-contractual disputes or claims).
2. Your rights under this License Agreement will automatically terminate without notice and without the

need for a court order if at any point you breach any terms of this License Agreement. In no event will any delay or failure by Bentham Science Publishers in enforcing your compliance with this License Agreement constitute a waiver of any of its rights.

3. You acknowledge that you have read this License Agreement, and agree to be bound by its terms and conditions. To the extent that any other terms and conditions presented on any website of Bentham Science Publishers conflict with, or are inconsistent with, the terms and conditions set out in this License Agreement, you acknowledge that the terms and conditions set out in this License Agreement shall prevail.

Bentham Science Publishers Pte. Ltd.

80 Robinson Road #02-00

Singapore 068898

Singapore

Email: subscriptions@benthamscience.net



CONTENTS

FOREWORD	i
PREFACE	ii
DEDICATION	iv
CHAPTER 1 CAPABILITY: CAN MOBILE APPLICATION PERFORM VALUABLE FUNCTIONS?	1
1. INTRODUCTION	1
2. CAPABILITY	2
3. COMPLETENESS	3
4. ACCURACY	4
5. EFFICIENCY	5
6. INTEROPERABILITY	6
7. CONCURRENCY	7
8. DATA AGNOSTICISM	8
9. EXTENSIBILITY	9
SUMMARY	10
REFERENCES	10
CHAPTER 2 RELIABILITY: CAN A MOBILE APPLICATION BE TRUSTED IN MANY AND DIFFICULT SITUATIONS?	12
1. INTRODUCTION	12
2. RELIABILITY	13
3. STABILITY	13
4. ROBUSTNESS	14
5. RECOVERABILITY	15
6. DATA INTEGRITY	17
7. TRUSTWORTHINESS	18
SUMMARY	19
REFERENCES	19
CHAPTER 3 USABILITY: CAN MOBILE APPLICATIONS BE USED EASILY?	21
1. INTRODUCTION	21
2. USABILITY	22
3. INTUITIVENESS	23
4. MINIMALISM	24
5. LEARNABILITY	25
6. MEMORABILITY	26
7. DISCOVERABILITY	27
8. OPERABILITY	28
9. INTERACTIVITY	29
10. CONTROL	30
11. CLARITY	31
12. ERRORS	31
13. CONSISTENCY	33
14. ACCESSIBILITY	34
15. DOCUMENTATION	35
SUMMARY	36

REFERENCES	36
CHAPTER 4 CHARISMA: DO MOBILE APPLICATIONS HAVE CHARISMA?	39
1. INTRODUCTION	39
2. CHARISMA	40
3. UNIQUENESS	41
4. SATISFACTION	41
5. PROFESSIONALISM	42
6. ATTRACTIVENESS	43
7. CURIOSITY	44
8. ENTRANCEMENT	44
9. HYPE	45
10. EXPECTANCY	45
11. ATTITUDE	46
12. IMPRESSION	46
13. STORY	47
SUMMARY	47
REFERENCES	48
CHAPTER 5 SECURITY: DOES MOBILE APPLICATION PROTECT AGAINST UNWANTED USAGE?	49
1. INTRODUCTION	49
2. SECURITY	49
3. AUTHENTICATION	51
4. AUTHORIZATION	52
5. PRIVACY	53
6. SECURITY HOLES	54
7. SECRECY	55
SUMMARY	56
REFERENCES	56
CHAPTER 6 PERFORMANCE: IS THE MOBILE APPLICATION FAST ENOUGH?	58
1. INTRODUCTION	58
2. PERFORMANCE	58
3. CAPACITY	59
4. RESOURCE UTILIZATION	60
5. RESPONSIVENESS	61
6. AVAILABILITY	62
7. THROUGHPUT	62
8. ENDURANCE	63
9. FEEDBACK	64
10. SCALABILITY	65
SUMMARY	66
REFERENCES	66
CHAPTER 7 MOBILITY: IS THE APPLICATION EASY TO INSTALL, MAINTAIN AND SUPPORT?	68
1. INTRODUCTION	68
2. MOBI-BILITY	69
3. APPLICATION REQUIREMENTS	70
4. INSTALL-ABILITY	70
5. UPGRADABILITY	72
6. UNINSTALLATION	73

7. CONFIGURATION	73
8. DEPLOYABILITY	74
9. MAINTAINABILITY	75
10. TESTABILITY	76
SUMMARY	77
REFERENCES	77
CHAPTER 8 COMPATIBILITY: HOW DOES MOBILE APPLICATION INTERACTS WITH ENVIRONMENTS?	79
1. INTRODUCTION	79
2. COMPATIBILITY	79
3. DEVICE COMPATIBILITY	81
4. OPERATING SYSTEM COMPATIBILITY	82
5. APPLICATION COMPATIBILITY	83
6. CONFIGURATION COMPATIBILITY	84
7. BACKWARD COMPATIBILITY	85
8. FORWARD COMPATIBILITY	86
9. SUSTAINABILITY	87
10. STANDARDS CONFORMANCE	88
SUMMARY	89
REFERENCES	89
APPENDIX	91
MOBILE LEARNING RESEARCH PROJECT	91
RESEARCH OBJECTIVES AND AIMS	92
SCOPE OF THE PROJECT	92
RESEARCH METHODOLOGY	92
WORK PACKAGE 1: RESEARCH BACKGROUND	92
WORK PACKAGE 2: ADVANCED NATIONS M-LEARNING EXPERIENCES	93
WORK PACKAGE 3: CASE STUDY	93
WORK PACKAGE 4: DATA ANALYSIS	93
WORK PACKAGE 5: FRAMEWORK	93
WORK PACKAGE 6: PROTOTYPE IMPLEMENTATION	93
WORK PACKAGE 7: EVALUATION	93
WORK PACKAGE 8: PROJECT DOCUMENTATION	94
PROJECT FINDINGS	94
LIMITATION AND IMPLICATIONS FOR FUTURE STUDIES	95
RECOMMENDATIONS	96
FUTURE CONCERNS AND CHALLENGES	97
SUBJECT INDEX	; 8

FOREWORD

Mobile applications have become ubiquitous and are present in almost all of today's business domains and life aspects. With the increasing prevalence of handheld computing devices (*e.g.*, smartphones), the growth of mobile applications is expected to continue, which will have an impact on academia and industry expectations and standards. That means we, as communities, need more proficient developers to design and develop more efficient, reliable, and secure mobile applications and relevant technologies and platforms.

This book will be a great addition to the literature to serve as a practical reference for students, researchers, and business communities who have an interest in learning about mobile computing and its features and design aspects. The book is written in a concise and conversational style that is easy to read and understand even though it discusses a great deal of very difficult relevant concepts from technical and design perspectives. The book talks about introductory topics such as the potential and the features of mobile general-purpose systems as well as very advanced concepts, including performance and security of mobile applications and the roadblocks expected during their evolution process.

Another interesting area the authors cover in this book is the quality, practicality, and effectiveness metrics that should be considered when evaluating mobile software systems. The solid research experience professor Sarrab has on mobile development and software system research speaks volumes about the effectiveness, practicality, and quality of the research findings introduced in this book.

I believe that this will be a good contribution to academia, research, and industry communities. I believe readers who are interested in getting familiar with and exposed to the mobile application's development life cycle and challenges will like it and will use it as a valuable reference. In academia, the book can also be used as a textbook for a course on mobile computing literacy and quality. I anticipate that a broader audience from industry-oriented communities, people who want to educate themselves on the topic, and also users who plan to take advantage of mobile applications to run their business operations and expand their customer populations will find this book to be very interesting and useful.

In short, the book has a lot to offer to both communities from academia and industry and is a valuable addition to the literature. It is written in a very practical and concise manner that makes it easy to read and a great one to carry as a reference.

Saleh M. Alnaeli
University of Wisconsin-Stout
Menomonie, Wisconsin
USA

PREFACE

This handbook is a complete encyclopedia about engineering requirements and quality characteristics that users, developers, and marketers of mobile applications should be aware of, and it provides detailed definitions, descriptions, and those features that overlap and are often confused. Today almost everyone uses a mobile phone with a good number of applications. However, not everyone knows its full advantage. In addition, this book helps in exploiting all the apps efficiently, thereby optimizing their use. Sometimes, when one buys a latest phone from a simpler version, it is so confusing that it is common to make mistakes. Some of these mistakes are undone easily, but some have locked the device to be made accessible by the distributor, and still, some are locked forever. Especially if you have bought it in one place and traveled to another country/continent. Mobile apps are distinguished, and studies are divided into eight different angles: capability, reliability, usability, charisma, security, performance, mobility, and compatibility. They are further divided into subsections for clarity. Every chapter has an introduction to all points discussed and a picture projects the different subsections in a user-friendly way. It not only describes each function but also sheds light on the perceptions of users. It is completely from the user's perspective. It is extremely useful to developers as it does highlight some performance issues like delay issue if the user misuses the app, he blames the app for 2 to 3 seconds of waiting time which is considered as delay, while a computer start time is about a minute with much more performance capacity. Also, the challenges are different types of users, different mobile phones with different capacities, with much varied and continually updated mobile apps.

This guide shows you how to:

1. Think through the design instead of just throwing UI elements.
2. Allow an intuitive design flow to emerging from your app.
3. Sketch and wireframe apps more effectively.
4. Reflect key differences among smartphones, tablets, and desktops.
5. Design for visual appeal without compromising usability.
6. Work effectively with programmers.
7. Make sure your apps are accessible to everyone.
8. Get usable feedback, and understand what it is telling you.
9. Learn valuable lessons from today's most successful apps.
10. Refresh your designs in new apps and future versions.
11. Discover new tools for designing more successfully.

CONSENT FOR PUBLICATION

Not applicable.

CONFLICT OF INTEREST

The authors [*Mohamed Sarrab, Hafedh Al-Shihi, and Naveen Safia*] of the enclosed manuscript titled: "Handbook of Mobile Application Development: A Guide to Selecting the Right Engineering, and Quality Features" have research support from The Research Council - Sultanate of Oman. Project [code: ORG/ICT/13/002]. Project title: M-Learning in Oman: Development, Adoption, and Dissemination..

ACKNOWLEDGEMENTS

In the name of Allah, the Most Gracious and the Most Merciful, I give thanks to Him for supporting us with the strength to complete this book. Without His support, none of this effort would have been possible. This book could not have been possibly completed without the recommendations, support, and advice of many people.

The idea for this book was generated because of the mobile learning research project. This research project is funded by The Research Council (TRC) of the Sultanate of Oman: under Grant No: ORG/SQU/ICT/13/006, (www.trc.gov.om). Project details are attached in appendix I. Thanks to The Research Council (TRC) of the Sultanate of Oman for taking a leadership role in this innovative research and for funding this important mobile learning project.

Mohamed Sarrab

Hafedh Al-Shihi

&

Naveen Safia

Communication and Information Research Center
Sultan Qaboos University
Oman

DEDICATION

Dedicated to
This book is dedicated to,
All mobile application developers.

Especially the great ones.

CHAPTER 1

Capability: Can Mobile Application Perform Valuable Functions?

Abstract: This chapter discusses the capability of a mobile application as one of the main qualitative characteristics. The chapter focuses on the completeness of the mobile application and the availability of all important functions. The features of accuracy and the efficiency of performance in mobile applications are explored and discussed. This chapter focuses on the best way in which the different features interact with each other and discusses the ability to perform multiple parallel tasks at the same time. Besides, this chapter pays emphasis to the support provided to all possible data formats. Finally, it discusses the ability to add features or change the current behavior of the application.

Keywords: Accuracy, Application Behavior, Capability, Completeness, Efficiency, Mobile Application, Multiple Parallel Tasks, Performance, Qualitative Characteristics.

1. INTRODUCTION

This chapter focuses on the capability of a mobile application as one of the main qualitative characteristics. The chapter is divided into seven sections. Section 1.1 is the introduction and section 1.2 is a pictorial representation of all the subsections of the chapter. Section 1.3 discusses in detail the completeness of the mobile application and the availability of all important functions. Section 1.4 explores the feature of accuracy in the mobile application. Section 1.5 discusses the efficiency of performance in a mobile application. Section 1.6 mainly focuses on the best way in which the different features interact with each other. Section 1.7 discusses the ability to perform multiple parallel tasks at the same time and section 1.8 focuses on the support provided to all possible data formats. Finally, section 1.9 discusses the ability to add features or change the current behavior of the application.

2. CAPABILITY

Generally, the capability of a mobile application is to measure the ability of the final product of the application to achieve its objectives, especially concerning its overall mission, in which the product shows the ability to perform valuable functions. The capability of mobile applications can be measured through seven parameters. They are completeness, accuracy, efficiency, interoperability, concurrency, data agnosticism, and extensibility, as shown in Fig. (1).

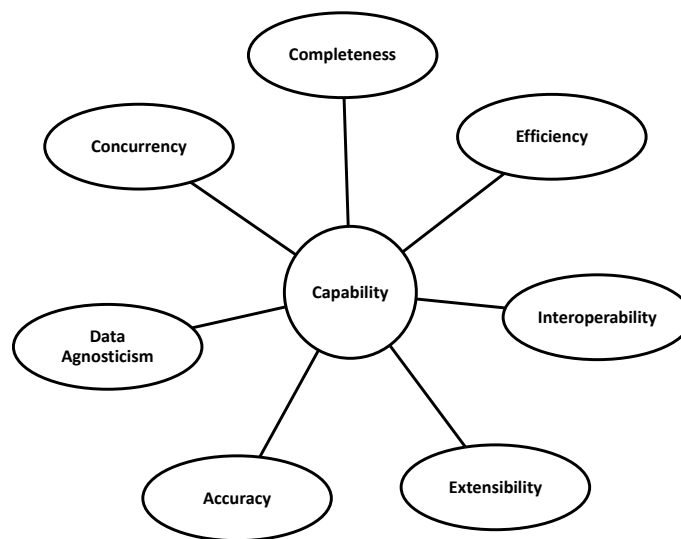


Fig. (1). Mobile Application Capability Factors.

Completeness refers to the availability of all functions the end-users want. On the other hand, accuracy is concerned with the correctness of the produced output in the right format. The efficiency of the mobile application is about the functions it performs efficiently, while interoperability considers the best way in which different features interact with each other. The feature of concurrency in the mobile application is concerned with the ability to perform multiple tasks at the same time and run parallel to other processes. Data agnosticism is about supporting different data formats, while extensibility is the ability to extend its features. The mobile application allows specific customers or third parties to change behavior or add additional features.

3. COMPLETENESS

The completeness of a mobile application is concerned with the availability of all important functions that are required by the stakeholders. It is a developed application component, where each function is described by a specification of the mobile application and which can be achieved by at least one functional execution path, operate as specified, and in as much detail as possible. Checking the mobile application for completeness is a very critical process as the specified application requirements have been developed and documented based on functions of all mobile applications, which are required to satisfy the stakeholder's objectives with their associated environmental performance, and other non-functional characteristics of the mobile application.

A specification is comprehensive, complete if all parts exist, and every part is completely developed. There are many properties that a mobile software specification must exhibit to ensure its completeness. To check the completeness of the mobile application, it is important to verify whether there are missing functions that are part of the developed application, but they are not called for in the specification's missing. Thus, the process of completeness of the mobile application varies if all the necessary components of the application are available and if any application process fails due to lack of resources or programming. The final product of the mobile application is a complete implementation of the functional specification. The functional specification is an official document for developers, which describes the intended capabilities of the targeted application in detail and the way of interaction with the users

The functional specification can be defined as a type of manual, guideline, or continuing reference point for the application developer. A tool for tracing requirements can be used to check the completeness of the mobile application if designers, engineers, and stakeholders feel the specified requirements meet the objectives. The requirement tracing is conducted throughout the development cycle of the application, which can be confirmed at each technical review for all old and new requirements.

The process of completeness verification checks the application's functional performance, environmental interface, operations and maintenance support, training, development, testing, production, deployment, as well as non-functional features such as availability, reliability, safety, and security. The purpose of tracing requirements is to ensure that the requirements continue to meet the needs and expectations of the stakeholders of the application (Margaret, 2007).

Reliability: Can a Mobile Application be Trusted in Many and Difficult Situations?

Abstract: This chapter discusses the reliability of a mobile application as one of the main quality attributes. This chapter considers the stability of a mobile application in terms of providing a mobile application without errors in the script or unhandled exceptions, or any other types of crashes. The focus is on the ability of a mobile application to discover, adapt, prevent, and recover from any mobile operational issues. This chapter emphasizes the possibility of the mobile operation to recover after any fatal mistake and continue to use the same mobile application even after a serious problem. Besides, it focuses on data integrity and discusses different behavioral issues of the application, such as predictability, consistency, and trustworthiness.

Keywords: Behavioral Issues, Consistency, Data Integrity, Fatal Mistake, Mobile Application, Operational Issues, Predictability, Qualitative Characteristics, Reliability, Stability, Trustworthiness.

1. INTRODUCTION

The present chapter discusses the reliability of a mobile application as one of the main quality attributes. This chapter is divided into seven sections. Section 2.1 is the introduction, leading to the graphic representation in the next section 2.2. Further, section 2.3 discusses the stability of a mobile application in terms of providing a mobile application without errors in the script or unhandled exceptions, or any other types of crashes. Section 2.4 focuses on the ability of a mobile application to discover, adapt, prevent, and recover from any mobile operational issues. Section 2.5 discusses the possibility of the mobile operation recovering after any fatal mistake and continue to use the same mobile application even after a serious problem. Section 2.6 focuses on data integrity. It keeps all types of data intact throughout the application. Section 2.7 discusses behavioral issues of the application, such as predictability, consistency, and trustworthiness.

2. RELIABILITY

Reliability in a mobile application is about the trust of the final product in many different situations as well as difficult situations. The reliability of a mobile application can be measured through features such as stability, robustness, stress handling, recoverability, data integrity, safety, disaster recovery, and trustworthiness. Fig. (2) presents the mobile application reliability factors.

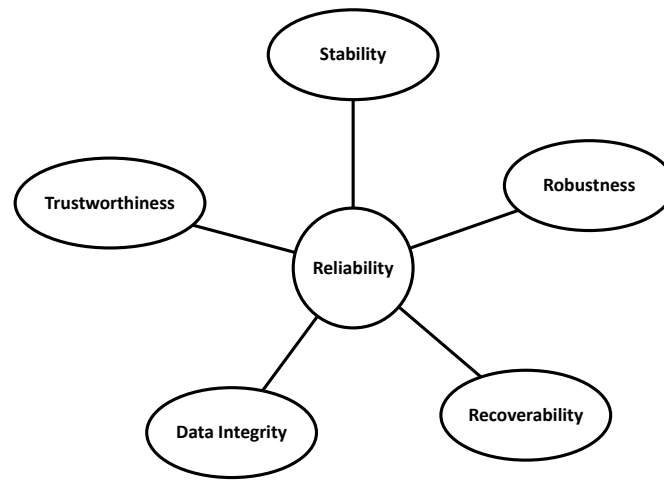


Fig. (2). Mobile Application Reliability Factors.

Stability refers to the ability of the final product to perform without crashes, script errors, or any exceptional problems that the mobile application cannot handle. Robustness refers to the ability to handle anticipated as well as unanticipated errors gracefully in the application. Recoverability is about the possibility of being able to recover and continue using the mobile application after a fatal error. Data integrity is defined as keeping all types of data intact in the product throughout the application. Trustworthiness refers to the application's behavior, such as predictability, consistency, and trustworthiness.

3. STABILITY

Stability in mobile computing focuses on the performance of the final product without crashes, script errors, and unhandled exceptions. Mobile application stability is about verifying the steadiness of the application in terms of its performance. In other words, it is about performing many software and hardware tasks over a period of time without the application getting locked, crashing, or restarting. A mobile application can crash during installing, executing, or

launching. Any exceptions may occur due to some specific features of the device not being able to fit with the executed mobile application.

The main reason causing the application to crash during installation is that the mobile computing device capabilities may not support a particular mobile application requirement. This can occur because the application requests more resources than the device capability, or it can occur because a wrong application release has been downloaded (version) or platform. However, a native mobile application that is developed for a specific device normally runs without any problem.

A mobile application may crash during execution because the exceptions are not handled properly. If all possible exceptions are not specified and handled as part of the application development, it might lead to a crash when any user performs instructions that aggravate the exception. The best approach to solve exceptional issues is to list all exceptions as nonfunctional requirements and use clear coding guidelines to ensure that all the said functions have their exceptional handling routines. An exception testing procedure will help to ensure that all possible exceptions are covered before real-time use.

A mobile application may crash while launching due to inadequate resources in the device and corrupt cache from the previous launch. These issues can be fixed easily using real testing of mobile devices. Real and on-time device testing helps to specify the issues that can lead to a crash while launching (Jithesh *et al.*, 2012).

In 2014, a study was conducted by Ian to observe application behavior in the latest versions of the most common mobile operating systems: iOS and Android. It was found that the Google operating system was the most stable platform of all the available operating systems. This study investigated by measuring the application crash rate across both operating systems with a huge sample size of one billion mobile users for one month. But it dismissed the stigma that iOS applications are the most stable. While iOS versions 6, 7.0, and 7.1 had an application crash-rate of 2.5%, 2.1%, and 1.7% respectively, different releases in Google performed better across the board as Android 2.3 has 1.7% crash rate, and other released versions since 4.0 got just 0.7% application crash rates (Ian, 2014).

4. ROBUSTNESS

Robustness is one of the key quality attributes of any software which is defined by the IEEE standard as the degree of the correct function of a software system or component with the existence of stressful environmental conditions or invalid inputs (Arcuri and Briand, 2011), (Shahrokhni and Feldt, 2013). The term, robust

CHAPTER 3

Usability: Can Mobile Applications Be Used Easily?

Abstract: This chapter discusses the usability of a mobile application as one of the main qualitative attributes. The chapter focuses on the users' expectations about usability and the redundancy of content or appearance of the product. It discusses how fast and easy it to learn the use of the mobile application is by memorizing what has been learned from the application. Moreover, it emphasizes the application's capabilities to recover the required information. It discusses how experienced mobile users can perform common tasks very fast and the possibilities of interacting with other applications. This chapter emphasizes protection against making mistakes and meeting the accessibility standards, which apply to the mobile application.

Keywords: Capabilities, Easy to Learn, Experienced Mobile Users, Interaction, Mobile Application, Qualitative Characteristics, Redundancy, Usability, Users' Expectation.

1. INTRODUCTION

This chapter focuses on the usability of a mobile application as one of the main qualitative attributes. This chapter is divided into fifteen sections. The chapter begins with an introduction, Section 3.1, followed by a pictorial representation of the sub-themes of usability in section 3.2. These sub-themes will be discussed in the following sub-sections. Section 3.3 discusses the users' expectations about usability. Section 3.4 focuses on the redundancy of content or appearance of the product. Section 3.5 discusses how fast and easy to learn the use of the mobile application is. Section 3.6 focuses on the memorization ability of what has been learned from the mobile application. Section 3.7 focuses on the application capabilities and information that can be discovered. Section 3.8 discusses how experienced mobile users can perform common tasks very fast. Section 3.9 focuses on the possibilities of interacting with other applications. Section 3.10 discusses the feelings of users in control over the proceedings of the mobile application. Section 3.11 focuses on the use of clear language with an emphasis on understanding easily. Section 3.12 focuses on protection against making mistakes. Section 3.13 discusses the behavior of the application. Section 3.14

focuses on meeting the accessibility standards, which are applicable to the mobile application. Finally, section 3.15 discusses how to provide the help function for users and match the functions with the application.

2. USABILITY

Complex mobile applications have found their way into the modern lives of users. As a consequence, mobile developers can see the benefits of designing and developing their applications from the user perspective rather than technology-oriented methods. The main attributes which reflect the usability of a mobile application are intuitiveness, minimalism, learnability, memorability, discoverability, operability, interactivity, control, clarity, errors, consistency, accessibility, and documentation. As illustrated in Fig. (3), Mobile Application Usability Factors

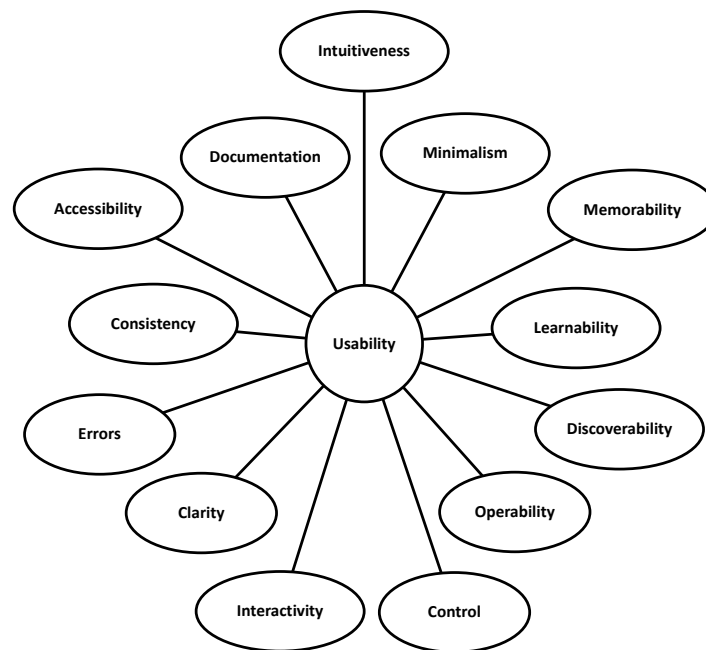


Fig. (3). Mobile Application Usability Factors.

The intuitive mobile application considers the expectations of users, such as having a user-friendly interface. Minimalism is all about the redundancy in the content or appearance of the product. Learnability considers how fast or easy it is for the learner to learn the use of the mobile application. Memorability focuses on the ability to remember what is learned from using the mobile application.

Discoverability focuses on the application's capabilities and information that can be discovered by exploring the user interface. Operability deals with the speed at which experienced users can perform common tasks. Interactivity is about easy-to-understand possibilities of interacting with other applications. Control is about the user's feeling of being in control over the proceedings of the mobile application. Clarity is focused on explicitly stating every detail in clear language. Errors are about how difficult to make mistakes as well as fixing them easily if any mistakes occur. Consistency relates to behaving in the same way throughout the application. Accessibility focuses on meeting the accessibility standards that are applicable to mobile applications. Documentation is about providing help and matching with functionality.

Each of these qualitative attributes has an impact on the overall usability of the mobile application, which can be used to evaluate the usability feature of the application. Mobile devices that are small in size have limited ways to interact. Issues such as the limited input modalities, poor connectivity, and small screen size also affect the usability feature of mobile applications.

3. INTUITIVENESS

Intuitive mobile applications relate to the expectations of the users and have a user-friendly interface. Mobile applications are termed intuitive when the users understand the function of the application and behavior without any need for special training, experimentation, or assistance. For this level of intuition, mobile users require prior information, either from other mobile applications in use or from experience in the real world. For example, in the case of a hybrid link, users can click on it if they knew from their experience of using other mobile applications or software. Alternatively, in the case of a push button, users who know from the real world can click on it to perform some tasks or make something happen. Thus, intuitiveness in a mobile application can be broken down into two requirements: consistency and affordance.

Consistency is about making a correct prediction and affordance is about predicting what is going to happen based on appearance. Moreover, the mobile application is intuitive if it has an appropriate combination of expectation, efficiency, responsiveness, affordance, explorability, forgiveness and at the same time, it causes no frustration to the user. The functional expectation of the mobile application is that the mobile user interface delivers the predictable output and expected results, with no surprising incidents. These user expectations are based on real-world experiences. The efficiency of the mobile application relates to the user interface which enables the users to act with less effort although the clear intention is the user interface that delivers the user expected results the first time.

CHAPTER 4

Charisma: Do Mobile Applications have Charisma?

Abstract: This chapter focuses on the charisma of a mobile application as one of the main qualitative characteristics. The chapter begins with the uniqueness of the mobile application and explores user satisfaction while using the mobile application. This chapter discusses the professionalism displayed by the application and mainly emphasizes the best features of the mobile application that can attract users. It also discusses the curiosity feature and focuses on the entrancement of mobile applications. The chapter considers the hype of mobile applications and discusses the expectancy and attitude of mobile applications.

Keywords: Best Features, Charisma, Curiosity, Entrancement, Expectancy and Attitude of Mobile Applications, Mobile Application, Qualitative Characteristics, Uniqueness of Mobile Application, User Satisfaction.

1. INTRODUCTION

This chapter focuses on the charisma of a mobile application as one of the main qualitative characteristics in a mobile application. This chapter is divided into eleven sections. The chapter begins with an introduction followed by section 4.2 with a pictorial representation of the different subsections that add to the charisma of the mobile application. Section 4.3 discusses the uniqueness of the mobile application and section 4.4 explores user satisfaction while using the mobile application. Section 4.5 discusses the professionalism displayed by the application, and section 4.6 focuses on the best features of the mobile application that attracts users. Section 4.7 discusses the curiosity of the mobile application, and section 4.8 focuses on the entrancement of mobile applications. Section 4.9 considers the hype of mobile applications, whereas sections 4.10 and 4.11 discuss the expectancy and attitude of mobile applications, respectively. Section 4.12 discusses the user's impression. Finally, section 4.13 discusses the story behind developing mobile applications.

2. CHARISMA

The new Oxford American Dictionary (Oxford, 2010) defines charisma as a compelling attractiveness or charm that can inspire devotion in others'. While this might be true with humans, mobile applications also have a set of factors that make them worthwhile and, at times, compelling too in the eyes of users. What makes people devote more attention to WhatsApp as opposed to other similar messaging applications? Why do we choose to use one photo-editing app over the other?

Moreover, when searching for new applications in any category, what makes you choose one app over the other?

In this chapter, we explore eleven factors that add charisma to mobile applications (see Fig. 4). Mobile application developers aim to increase the charm of their applications by incorporating as many attractive features as possible. As we believe the list need not be comprehensive, it records the most vital charismatic elements of a mobile app.



Fig. (4). Mobile Application Charisma Determinants.

Subsequent sections describe each of the eleven mobile application factors that contribute to charisma: uniqueness, satisfaction, professionalism, attractiveness,

curiosity, entrancement, hype, expectancy, attitude, directness, and story. Applications in different categories may incorporate different sets of these factors. For example, business and productivity applications may incorporate professionalism more as opposed to apps in the entertainment and game categories where attractiveness is vital.

3. UNIQUENESS

Innovation is the key in mobile applications, and usually, the early adopters of exclusive and distinct features take the lead. In mobile applications, 'uniqueness' refers to how distinguishable the application is from the other applications and whether it offers something that no other application does. This is hard to accomplish as mobile applications become more mature in certain categories. Laggards and latecomers in mobile application development tend to follow leaders in the field. After all, this is what is benchmarking as a management tool suggests. See for example how the messaging application 'Telegram' tried to distinguish itself from the ubiquitous 'WhatsApp' by adding killer features such as increasing the number of users in chat groups (currently 100 users in WhatsApp and 200 in Telegram) in addition to waiving file size restrictions when sharing media files (16 MB restriction in WhatsApp).

Unfortunately, 'uniqueness' does not mean exclusiveness, as mobile developers tend to imitate what users like in other apps more often than innovating new features. This has forced several companies to file lawsuits against each other in an attempt to protect their intellectual properties and/or discourage developers from following them. The well-known battle in the court of law between Apple and Samsung is a very good example here. Nevertheless, developers must continuously strive to offer unique features to stay competitive, as 'uniqueness' tends to fade out over time. That is why 'WhatsApp' had to introduce voice calling lately in response to users' demands and the proliferation of messaging apps with the same feature (Shafiriri and Levy, 2018).

4. SATISFACTION

What makes users use one mobile application over another in the same category? Why 'Evernote' is more popular than so many other note-taking applications? Why do we choose to download a different web browser or email client when all mobile devices come with stock mobile browsers and emails? Users tend to like, get used to, and are more satisfied with certain mobile apps than others. This leads to the question, what shapes this satisfaction?

CHAPTER 5

Security: Does Mobile Application Protect Against Unwanted Usage?

Abstract: This chapter focuses on the security of a mobile application as one of the main qualitative characteristics. The chapter emphasizes the authentication process in the mobile application and explores the authorization mechanism used for a mobile application. It also discusses the users' and applications' information privacy and mainly focuses on mobile application security holes. Finally, it discusses the potential risks of how the personal information of users is treated.

Keywords: Application Information Privacy, Application Security Holes, Authorization Mechanisms, Authentication Process, Mobile Application, Potential Risks, Qualitative Characteristics, Secrecy, Security, User Privacy.

1. INTRODUCTION

This chapter focuses on the security of a mobile application as one of the main qualitative characteristics. This chapter is divided into five sections. The chapter begins with an introduction to the chapter followed by section 5.2 with a pictorial representation of the different subsections that add to the security of the mobile application. Section 5.3 discusses the authentication process in the mobile application and section 5.4 explores the authorization mechanism using a mobile application. Section 5.5 discusses the users' and applications' information privacy and section 5.6 mainly focuses on the mobile application security holes. Finally, section 5.7 discusses the potential risks of the way in which the personal information of users is treated.

2. SECURITY

Security in the mobile application is the enforcement of access, use, and data protection measures for a separate application. Examples of such applications in security regulations and policies include corporate authentication, data wipe, data encryption, app-level VPN, and copy/paste protection. Security policies and regulations can be applied in the application development process, later after the

application is compiled with app wrapping or with software development kits (SDKs). Mobile malware usually taps weaknesses and bugs in the development of mobile applications and they attack. Even before exploitation of vulnerability to bugs, attackers can gain a public copy of an application and reverse engineer it (Al-Emran, 2020).

Mobile application developers should be skilled in detecting, fixing, and blocking security vulnerabilities to provide solid applications against tampering and reverse engineering. However, mobile application consumers still represent an application development, as it may not undergo a solid and appropriate security check process. Fig. (5) illustrates the mobile application security factors.

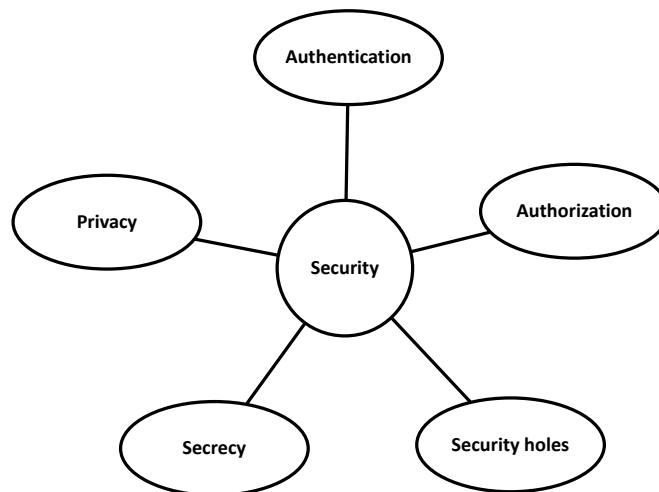


Fig. (5). Mobile Application Security Factors.

Authentication of the mobile application is the identification of users to access and use the application, but the authorization is the permission given to authenticated mobile application users about what they can see and do. Privacy in a mobile application is referred to as the capability to protect data and not disclose this data to unauthorized users of the application.

Security holes in a mobile application are related to the detection and closing of social engineering vulnerabilities. The secrecy of mobile applications is to prevent disclosing any type of information about the underlying systems under any circumstances. Invulnerability is the ability of the application to withstand penetration efforts. Mobile applications should be free of viruses as they will not transport or appear as a virus. Mobile applications should be compliant with different security standards.

3. AUTHENTICATION

The most essential requirement to build a mobile application that is fully secure is to have a solution to authenticate users for an application. The authentication process in mobile applications verifies whether application users are those who they claim to be, using their identity and credentials (for example, username and password). User identification of mobile applications is a logical entity used to identify mobile application users. User identification is used to distinguish between different users who attempt to access or use the mobile application. User identification is one of the most popular authentication mechanisms that is utilized within different computing applications. Irrespective of the user types and rights, every mobile application user has a unique ID (identification) that distinguishes users from other mobile application users. Usually, in an authentication mechanism, the user ID is used in conjunction with a password. The mobile application end-user has to provide both the credentials (ID and password) correctly to gain access to the application. Moreover, administrators can track user activity, assign user rights, and manage overall operations on a particular mobile application (Ulrike, 2014).

Today many breaches are found in mobile applications because of weak authentication mechanisms, from cracked passwords to unlocked mobile devices. In some cases, there is no authentication mechanism at all. Many awkward and expensive incidents could be avoided with the use of a robust authentication mechanism to access mobile applications. Planning a strategy for authentication of mobile applications needs to consider enforceability and strength with usability. That should be able to satisfy security and user requirements. It is common to use the password for the authentication mechanism to authenticate users of the mobile application. But we also know that generally, mobile application access passwords might be easily guessed. Thus users should be forced to have rules regarding complexity, length, and timeout. If a wrong password is used, the phone becomes inactive for a while. Saving the user name and password on the phone should also be discouraged. With these measures, it is possible to make the mobile application very hard to access by anyone other than the users.

Some mobile applications support a two-step verification mechanism using the application itself. For example, a mobile application for twitter permits users to enable login verification. Whenever user endeavors to log into the Twitter application from another device, where the user has to verify that login attempt from the mobile application on a phone device. Twitter inspects to guarantee the user has access to the phone before he/ she attempts to log in. Apple has a two-

Performance: Is the Mobile Application Fast Enough?

Abstract: This chapter discusses performance as one of the main qualitative characteristics of a mobile application. It focuses on the limitations of mobile applications in different circumstances. This chapter explores appropriate usage of memory and storage and emphasizes the speed of performing any task or action. It discusses the application availability when needed and mainly focuses on the ability of the application to process many tasks. Besides, it explores how the application can deal with the long-time loading and focuses on the appropriateness of application feedback. Finally, this chapter explores how an application can scale up, scale down, or scale-out.

Keywords: Application Feedback, Availability, Long Time Loading, Mobile Application, Performance, Qualitative Characteristics, Speed of Performing, Usage of Memory and Storage.

1. INTRODUCTION

This chapter focuses on performance as one of the main qualitative characteristics of a mobile application. The chapter is divided into ten sections, where section 6.1 is the introduction and section 6.2 is a pictorial representation of all the subsections of the chapter. Section 6.3 discusses the limitations of mobile applications in different circumstances. Section 6.4 explores the appropriate usage of memory and storage. Section 6.5 discusses the speed of performing any task or action. Section 6.6 discusses application availability when needed. Section 6.7 mainly focuses on the ability of the application to process many tasks. Section 6.8 explores how the application can deal with the long-time loading, and section 6.9 focuses on the appropriateness of application feedback. Section 6.10 discusses how an application can scale up, scale down, or scale-out.

2. PERFORMANCE

Generally, performance is about the user's perception of the appropriateness of the

application's performance. The application's performance is measured by its responsiveness and how quickly it starts up the process, and how well an application consumes the device memory and power. In a mobile application, performance can be measured through different factors, including capacity, resource utilization, responsiveness, availability, throughput, endurance, feedback, and scalability (see Fig. 6).

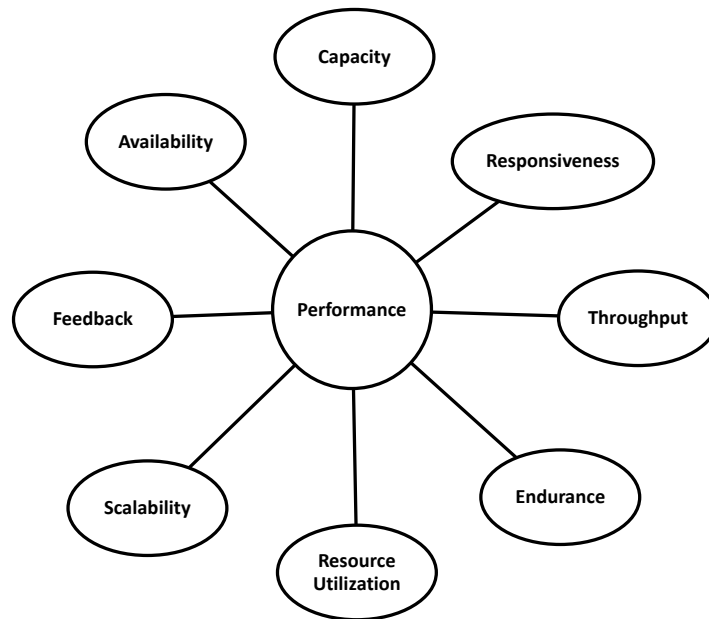


Fig. (6). Mobile Application Performance Factors.

3. CAPACITY

Capacity has always been crucial to the success of mobile technology in general and mobile learning in particular. Even if there are small improvements in the capacity of mobile applications and technology, it leads to better performance and more user satisfaction. Mobile technology provides users the same access level anytime and anywhere *via* mobile devices with more benefits in terms of increased functions to allow users to engage and interact with mobile applications in novel and compelling ways.

Developing a successful mobile application requires a rigorous analysis of the available technological infrastructure and capacity. It also requires proper planning and considering the demands of the new program, which include software, hardware, technical support, and broadband access.

Developers of mobile applications should consider some important factors such as the capacity which is required to install the application on different mobile devices. Due to the limitations of computational power and memory capacity in mobile devices, the developers have to remove or modify some of the functions such as high image resolution or many windows of the user interface to ensure the usability of the designed mobile application. The wireless connectivity should be available and reliable throughout a study campus to get the maximum benefit. The increase in the usage of a mobile application requires extra data storage capacity.

Improved mobile infrastructure is very important to achieve the full advantage offered by the technological revolution. Better capacity for the wireless network is required for users to improve mobile accessibility level and get the benefit of the available multi-media resources that are offered online. This involves simplifying and creating faster mobile networks. Therefore, the mobile application developer should think about the future connectives through wireless networks. As wifi connection alone cannot support the broadband demand of heavy multimedia resources (AppDynamics, 2015).

4. RESOURCE UTILIZATION

Each mobile application consists of different resources for mobile devices. Device memory and storage utilization of mobile devices are effective factors of performance in a mobile application. The base resources such as battery, CPU, and memory can influence each other; for example, CPU performance speed affects memory usage and CPU utilization affects battery consumption (Rawassizadeh, 2009).

In designing a mobile application, it is essential to consider different constraints of the target device resource including appropriate use of storage and memory. Every decision in designing should take into consideration of the limited memory and storage capacity of the target device. The processor's speed of the device and reading from memory and writing from memory all have an impact on the overall application's performance.

Memory and storage utilization on a mobile device is constrained by its hardware capability and unreliable network connections. For the best memory and storage utilization, the developers must consider three factors: the effect of high latency, intermittent connectivity, and low bandwidth on the overall application design. The impact of performance in an application can be minimized by designing efficient memory, storage access and always using a data reader when reading and not writing data. Moreover, the developer should consider programming an application for data integrity. Any data files that remain open while the power of

Mobility: Is the Application Easy to Install, Maintain and Support?

Abstract: This chapter discusses the mobility of mobile applications as one of the main qualitative characteristics. It focuses on the requirements of the application to determine the types of mobile devices to support, considering the different features of the devices such as performance of the processor in terms of speed, the capacity of memory and storage, screen resolution and screen size, and availability of suitable environment for the tool development. This chapter explores the installability of the mobile application and emphasizes how mobile applications can be upgraded. It mainly focuses on the uninstallation of mobile applications and their configuration by focusing on deployability and the most important factors to provide maintenance. Finally, the chapter ends by exploring the testability of mobile applications.

Keywords: Deployability, Memory Capacity and Storage, Mobility, Mobile Application, Performance, Qualitative Characteristics, Screen Resolution, Screen Size Install-Ability, Speed, Testability, Uninstallation.

1. INTRODUCTION

This chapter focuses on the mobility of mobile applications as one of the main qualitative characteristics. This chapter has been divided into eight sections. The chapter starts with the introduction in section 7.1, followed by the pictorial representation in section 7.2. Section 7.3 discusses requirements of the application to determine the types of mobile devices to support, considering the different features of the devices such as performance of the processor in terms of speed, memory and storage capacity, screen resolution and screen size, and availability of suitable environment for the tool development. Section 7.4 explores the installability of the mobile application. Section 7.5 discusses how a mobile application can be upgraded. Section 7.6 mainly focuses on the uninstallation of a mobile application. Section 7.7 explores the configuration of a mobile application, and section 7.8 focuses on the deployability of a mobile application. Section 7.9 discusses the most important factors to provide maintenance of the mobile application. Finally, section 7.10 explores the testability of a mobile application.

2. MOBI-BILITY

Generally, the mobi-bility of a mobile application is the measure of the ability of the final application product and how easy it is to install, maintain and support, especially about its overall application mission where the application product shows the ability to perform valuable functions. Mobile application mobi-bility can be measured through application requirements, installability, upgradability, uninstallation, configuration, deployability, maintainability, and testability (see Fig. 7).

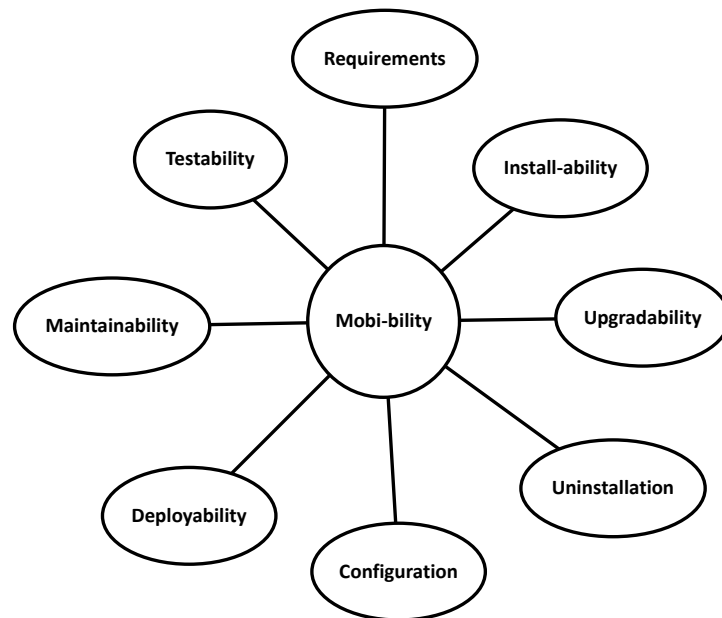


Fig. (7). Mobile Application Mobi-bility Factors.

Mobile application requirements are mainly focused on the ability to run on supported configurations, as well as handling various environments or missing components. Installability is closely related to how an application can be installed on target platforms. Upgradability is concerned with the ease of upgrading to a newer version without loss of settings and different component configurations. Uninstallation is the reversal. It focused on the removal of resources in case the user is not satisfied with installing an application. Configuration considers how easily the installation can be configured in different ways or places to support user needs. Deploy-ability is concentrated on how an application can be deployed in different types of restricted environments. Maintainability is how easy to maintain the application and support the users. Testability is how effectively the deployed application can be tested by the users.

3. APPLICATION REQUIREMENTS

Determining the different types of mobile devices to support considers the device features such as performance of the processor in terms of speed, memory and storage capacity, screen resolution and screen size, and availability of development tool environment. In addition to these factors, user constraints and general requirements of a specific hardware device might be needed, such as a camera and global positioning system (GPS). This may affect not only the type of mobile application but also the choice of a hardware device.

In designing device configuration management, it is necessary to consider handling device resets as well as how such mobile applications will be configured from a host computer or over the air. The design of a mobile application should ensure support in the restoration of configuration after a planned or unplanned device reset. The design of a mobile application should also consider the synchronization of configuration information with the host computer or over the air. If the mobile application has mobility, then it can run on supported configurations, and handle various environments or missing components (Luer and Rosenblum, 2001).

Mobile application composition consists of components configuration and additional functional design and implementation which is not available in components. Two methods of configuration connection and adaptation should be supported. When a decision has been made to re-use a selected component, it will have to be configured within the environment. Components have to be linked and connected to be able to cooperate. To simplify, the connector works as a link between the required services and provided services. It can be said that a connector establishes the fulfillment of the requirements. However, connectors are more complex and it is useful to have the connectors encapsulate functions that logically belong within a shared infrastructure (Shaw and Garlan, 1996), (Dashofy *et al.*, 1999). Adaptation of component configuration increases the value of the components (Bosch, 1998). The more adaptable and flexible the component is, the more frequently it will be reused. In the design process of mobile applications its necessary to meet any of the required qualitative attributes and it should consider the possible impact on other requirements.

4. INSTALL-ABILITY

A mobile platform is the operating system for mobile devices referred to as a mobile operating system (mobile OS), including smartphones, tablets, PDAs, or other mobile devices. Currently, there are different software platforms, these

CHAPTER 8

Compatibility: How does Mobile Application Interacts with Environments?

Abstract: This chapter discusses mobile application compatibility as one of the main quality characteristics. This chapter explores mobile operating system compatibility and discusses how a mobile application can be compatible. It mainly focuses on the most suitable application to blend within environment configuration. It also discusses the backward and forward compatibilities and focuses on the sustainability of the application. Finally, the chapter discusses conforming standards of the application.

Keywords: Application Sustainability, Backward Compatibilities, Compatibility, Environment Configuration, Forward Compatibilities, Mobile Application, Performance, Qualitative Characteristics, Suitability.

1. INTRODUCTION

This chapter focuses on mobile application compatibility as one of the main quality characteristics. This chapter is divided into eight sections. Section 8.1 starts with the introduction, followed by the pictorial representation of the subsections of compatibility. Section 8.3 discusses mobile device compatibility, while section 8.4 explores mobile operating system compatibility. Section 8.5 discusses how a mobile application can be compatible. Section 8.6 mainly focuses on the most suitable application to blend within environment configuration. Sections 8.7 and 8.8 discuss the backward and forward compatibilities, and 8.9 focuses on the sustainability of the application. Finally, section 8.10 discusses conforming standards of the application.

2. COMPATIBILITY

Mobile application compatibility refers to the ability of a mobile application to run on more than one device, including laptops, tablets, and smartphones. Windows is the only environment that supports tablet/desktop compatibility; however, cross-platform compatibility is only supported by Blackberry.

To provide a compatible mobile application, it is very important to have a consistent application with a hardware environment that enables a steady experience for consumers as well as manufacturers to differentiate and reduce the cost and overheads associated with compatibility. Mobile application compatibility can be measured through device compatibility, operating system compatibility, application compatibility, configuration compatibility, backward compatibility, forward compatibility, sustainability, and standards conformance, as illustrated in Fig. (8). Device compatibility is about how an application is used with applicable configurations of hardware components. Operating system compatibility is focused on how an application can run on intended operating system versions. Application compatibility is about how an application and its data work together and also with other applications.

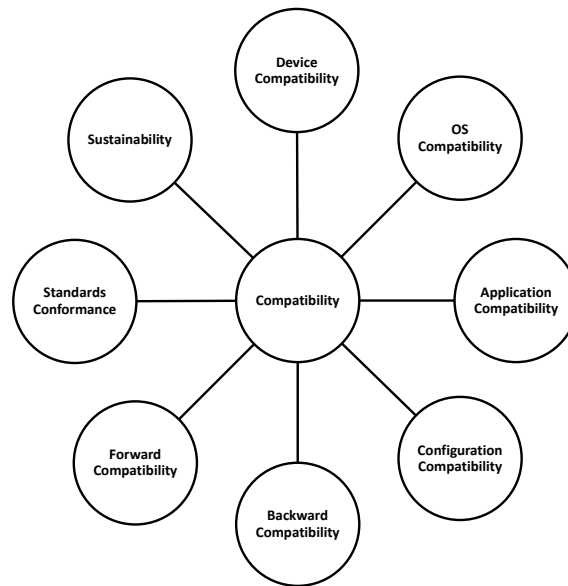


Fig. (8). Mobile Application Compatibility Influencing Factors.

Configuration of compatibility is the ability of the application to blend within the used environment configurations. Backward compatibility is about comparing the application with its last version to check the application can do everything as the previous version. Forward Compatibility is about the application's ability to use interfaces of future versions. Sustainability affects the environment by power-saving modes, energy efficiency, and telecommuting. Conforming to standards is the application conforms to the applicable laws, ethics, regulations, or standards.

3. DEVICE COMPATIBILITY

A mobile application developer should focus on what can be expected from a compatible device in terms of application and device capabilities. The tablet and smartphone are a mix of partial and complete control of the vendor. In case the vendor provides both the operating system and the hardware as well, then there is greater control over the product results. However, if there is not hardware control, there will be many different features for the devices using the same operating system. Consistency is very important because inconsistency can be confusing, and competition among mobile vendors using the same operating system might lead to clever innovations very quickly. BlackBerry and Apple have the greatest control over their devices such as tablets and smartphones whereas both companies produce their hardware and operating systems. Google produces an Android operating system, and several tablets and phone providers create the hardware.

The Android operating system runs on many different devices, with the ability for every hardware vendor to include their application assortment and make their user interface changes. BlackBerry devices can also run Android applications, along with their applications. Google Android phone applications run on Android tablets whereas Apple iPhone applications run on iPad tablets. Using different approaches, Android tablets and Apple iPads can scale their used applications to fill the screen whereas mobile application developers only need to create one version of their application, and the user only needs to purchase one app. Moreover, the Windows Phone operating system is developed by Microsoft, while Nokia and others build smartphone hardware. Microsoft also produces Windows RT and Windows 8 operating systems for tablets of different hardware vendors. Microsoft also creates its hardware in the form of a Windows tablet in this case it completely controls the final product.

Windows 8 OS is the most significant tablet device compatibility for more than two decades. All the current Windows applications can also run on Windows 8 touchscreen tablets instead of laptops. All other mobile devices run only their native programs based on their platforms. For example, iOS applications run only on Apple devices; Windows Phone applications run only on Windows Phone, and Android applications run on Android devices. Providing a consistent mobile application with a hardware environment is very important, developers cannot develop different versions for different devices (Hyung and Young, 2011).

APPENDIX

MOBILE LEARNING RESEARCH PROJECT

Mobile learning is a new research area that has become an emerging technology for modern education systems, which can be used to enhance the overall users' learning experience. The research on this project focused mainly on analyzing the influencing factors of adopting and disseminating M-learning in Oman, which includes cultural, social, and educational factors. This is a detailed state-of-the-art review analysis of different Mobile learning approaches and documents several learned lessons from educationally advanced countries about Mobile learning adoption. That helps in exploiting Mobile learning efficiently, thereby optimizing their use. The project has discussed factors driving the adoption of M-learning in Omani higher education including (ease of use, usefulness, enjoyment, suitability, social and economic). The project has also analyzed mobile platforms based on system, information, and service quality characteristics. In this report, Mobile learning is studied from three different angles including:

- Dissemination.
- Development.
- Adoption.

Moreover, the project provides the different type of studies:

- An empirical analysis of mobile learning awareness and acceptance in higher education.
- An empirical study of factors driving the adoption of mobile learning in Omani education.
- An empirical study on mobile platforms selection, based on system, information, and service quality characteristics.
- System quality characteristics for selecting mobile learning applications.
- A model for mobile learning non-functional requirement elicitation.
- Mobile learning key influencing factors adoption based on analytic hierarchy process.
- Development and validation of mobile learning acceptance measure (MLAM).
- A quality model of technical aspects for mobile learning services. proposing a new requirements engineering framework for m-learning applications.
- New requirements engineering framework for m-learning applications.
- A new design approach for m-learning applications.
- New software development process for mobile learning.
- A quality model of technical aspects for mobile learning services: an empirical investigation.

The outcomes of the project are made publicly available at the SQU website and *via* other channels. They will be further disseminated and used for the improvement of the Mobile learning initiatives as well as for propagation of their use.

RESEARCH OBJECTIVES AND AIMS

The main and central research objectives that were investigated in this project are:

Addressing the influencing factors of the adoption and dissemination of M-learning initiatives in Oman

The research focused on studying the influencing factors of adopting and disseminating M-learning in Oman. These include cultural and social factors, educational factors, architecture and design of M-learning, security and privacy issues, and accessibility concerns. Besides, the project was attempted to identify the major barriers to the uptake of M-learning in Oman and propose efficient solutions to overcome such barriers.

Developing Socio-technical didactical M-learning framework for higher education in Oman

The research work provided a socio-technical didactical M-learning adoption framework. It is the first time that such work is being developed in the region and especially in Oman. The project also produced a profile of M-learning users in Oman and provided the basic characteristics of those users. The project endeavors to analyze advanced nations' experiences in M-learning and the implications of these experiences on the Omani situation. The project provided a prototype implementation guided by the results found from the literature review and the M-learning exploratory case study.

SCOPE OF THE PROJECT

Wireless mobile communication technology is widely used worldwide and it supports a wide range of services including learning. The proposal project explored the impacts of national issues on M-learning in Oman and use advanced nations' experiences benchmarks for drawing lessons for Oman. This research attempted to provide a type of socio-technical didactical framework for evaluating M-learning initiatives and fostering adoption. The scope of the study is within the context of higher education learning in Oman. The research data, especially the survey data will be collected from different higher education institutes and universities within Oman.

The study endeavors to provide a profile of M-learning users in Oman that describes the users' basic characteristics. The project discussed the major obstacles to the adoption of M-learning and proposed effective solutions to overcome them.

RESEARCH METHODOLOGY

The research methodology was composed of eight work packages. One addressed the research background; six packages are devoted to scientific research work packages. The last work package focused on writing up the project's final report.

WORK PACKAGE 1: RESEARCH BACKGROUND

The research background was started with a theoretical literature review including a primary

assessment of other approaches related to the M-learning initiative in other countries. To achieve the objectives of this work package, digital resources such as the Google search engine, IEEE Xplore, SpringerLink, ACM Digital Library, and CiteSeer were used.

WORK PACKAGE 2: ADVANCED NATIONS M-LEARNING EXPERIENCES

In this background, the search process was carried out on advanced nations' M-learning experiences to identify possible lessons for and solutions to barriers facing the take-up of M-learning.

WORK PACKAGE 3: CASE STUDY

An exploratory case study on Oman was conducted to test the extent to which the barriers and solutions are drawn from the large western and eastern-centric literature apply in the Omani situation.

WORK PACKAGE 4: DATA ANALYSIS

Qualitative and quantitative methodologies were used to analyze the data gathered from interviews and surveys respectively in the previous work packages using any statistical analysis tool (SPSS).

WORK PACKAGE 5: FRAMEWORK

As mentioned earlier in the main research contribution that the research focused on providing a new socio-technical didactical M-learning adoption framework. Therefore, this work package focused on the design of the framework architecture to capture the research objectives as expressed in the project objectives. This work package also specified all components of the proposed framework.

WORK PACKAGE 6: PROTOTYPE IMPLEMENTATION

This work package described the design and implementation of the project prototype, which depends on the completion of the all above-mentioned work packages. A prototype implementation was developed to show the feasibility of the provided framework that considers a set of non-functional requirements such as performance, security, privacy, and accessibility.

WORK PACKAGE 7: EVALUATION

The evaluation phase is a systematic investigation phase of the worth or significance of the objectives. Evaluation normally involves some standards, criteria, measures of success, or objectives that describe the value of the object. Evaluation can identify criteria for success, lessons to learn, objectives to achieve, ways to improve the work, and the means to move forward. The main target of the project evaluation work package is to assess the degree to which project objectives were achieved, provide recommendations for project improvement and examine the changes that resulted from doing the project. Selecting an evaluation type

SUBJECT INDEX

A

Accessibility 22, 23, 34, 35, 43
 issues 34
 standards, applicable international 35
 web content 35
 Access permissions 55
 Active-matrix organic light emitting diode (AMOLED) 43
 Americans with disabilities act (ADA) 34, 89
 Android 28, 64, 71, 81, 85, 86
 developers 28
 devices 81, 85, 86
 Google play and Apple apps 18
 mobile applications 54
 open kang project (AOKP) 71
 phones 64
 tablets 64, 81
 Android application 74, 85
 descriptor element 74
 development 85
 App interface design 43
 Apple 15, 28, 81, 82, 85, 87
 applications on iPhones 87
 apps 18
 developer team 28
 devices 81, 82, 85
 iOS 15
 iPads 81
 iPhone applications 81
 Application 3, 4, 6, 7, 8, 9, 14, 15, 16, 17, 25, 26, 29, 30, 31, 32, 34, 35, 49, 52, 54, 58, 62, 63, 64, 65, 72, 73, 74, 75, 79, 80, 81, 84, 85, 86, 87, 88, 89
 architecture 65
 authorization process 52
 data storage 17
 developers 3, 4, 29, 31, 54, 72, 84
 development process 49
 feedback 58
 guidelines 31
 host specifications 63
 hardware 8

 hybrid 7, 84
 information privacy 49
 internet-based 84
 iOS 14, 73, 81
 manifest Android 74
 mobile platform-agnostic 9
 non-mobile 89
 program interface (API) 29, 30, 85
 robust 15
 sustainability 79, 88, 89
 Application crash 14, 16
 rates 14
 Apps 25, 40, 41, 42, 43, 44, 45, 46, 47, 48, 81, 84, 87
 downloaded 42
 health 42
 hybrid 25
 web 25
 Authentication mechanism(s) 51
 popular 51
 robust 51
 weak 51

B

Backward compatibility 80, 85, 86
 Bada 15, 71
 platform 71
 systems 15
 Bandwidth simulations 63
 Battery 16, 60
 consumption 60
 failure 16
 Blackberry 64, 71, 79, 81, 82
 devices 81
 handheld devices 82
 phone accessing 64
 Black box concept 6
 Blogging 44
 Broadband access 59
 Browsers, stock mobile 41
 Bug(s) 15, 35, 46, 50, 72, 76, 87
 fixing 46

popping 35
Business applications 29

C

Communications and video accessibility act (CVAA) 34, 89
Compatibility 79, 80, 83, 84
 cross-platform 79, 83
 mobile allocation 80
 multi-device 84
Connectors encapsulate functions 70
CPU 60
 performance 60
 utilization 60
CyanogenMod community 71

D

Data 54
 application's 54
 sensitive 54
Database management system 9
Design-related complicated issues 26
Developers work 31
Devices 4, 5, 6, 9, 14, 43, 51, 52, 53, 54, 59, 60, 61, 68, 71, 74, 80, 81, 82, 83, 84, 85, 86
 agnosticism 9
 backward-compatible 85
 compatibility 80, 81, 84
 local 54
 memory 59, 60
 phone 51, 71
 processor 4, 5
Display 32, 74
 resolution 74
 text information 32

E

Efficiency test 5
E-learning system 52
Elegant/clever programming techniques 6
Emotion user interface (EMUI) 71
Entrancement of mobile applications 39
Environments 8, 84
 multi-OS computing 84
 multiple computing 8

Errors 4, 12, 13, 16, 17, 19, 22, 23, 31, 32, 62, 75, 85
 fatal 13, 16
 repair 32
 script 13, 19
 spelling 31, 32
Events 7, 16, 46, 47
 external 7
Experience, mobile end-user 16

F

Features 24, 43, 75, 76
 amusing 43
 improving 75
 updated 76
 visibility 24
Fluid processing 43
Focus 87
 non-technical issues 87
 technical issues 87
Functional execution path 3

G

Games 30, 44, 61
 online 30
Global positioning system (GPS) 70
Google 54, 73, 75, 71, 73
 AOSP 71
 Maps 73
 market 54, 75
 play 54
 talk 73
Google's 9, 71
 android 9
 AOSP 71

H

Hardware 16, 27, 34, 43, 45, 59, 64, 65, 66, 70, 71, 80, 81, 82, 83, 85, 86, 89
 device 27, 70, 86
 environment 80, 81, 89
 features 71
 issues 16, 82
 malfunctions 17
 smartphone 81
Health-related measurements 42

Human-computer interaction domain 29

I

Information 28, 35, 49, 56, 62

- accessing 62
- good-quality 28
- privacy 49, 56
- repository 35

Information technology 5, 9, 32

- leaders 32
- software quality 5

Instagram 47

Interaction process 29

Interactive mobile applications 29

Interface 22, 23, 27, 29, 42, 80, 85

- application program 29, 85
- computer system/program 42

Internet protocol (IP) 55

Interoperability 2, 6, 7, 8

- developing 6
- term 6

Interoperability support 86

Intuitive mobile applications 22, 23

iPhone 45, 52, 64, 71, 72, 73, 74, 82, 86, 87

- developed 82
- devices 82
- new 45

iPod Touch 82

Issue tracking software 4

K

Key performance indicators (KPIs) 62

L

Laws in mobile computing 88

Learnability of mobile applications 26

Legal 34, 88

- responsibility 34
- values 88

Liquid crystal displays (LCD) 43

M

Measure, mobile application throughput 62

Memory 5, 6, 32, 58, 60, 61, 62, 66, 68, 70, 77
and storage utilization 60

designing efficient 60

usage of 58, 60

Microsoft mobile 71

Mi user interface (MIUI) 71

Mobile 6, 7, 8, 10, 12, 15, 17, 24, 27, 28, 29,
35, 43, 45, 60, 61, 64, 70, 71, 79, 82, 83,
84, 89

customized 84

explored 89

games 29

hardware 28

industry 6

manufacturers 43, 45

networks 60, 61, 64

operation 12

phones 28

processor 29

programming 17

proprietary 71, 82

system extension 10

web applications 35, 83

Mobile app(s) 40, 41, 42, 43, 44, 45, 46, 48

category 42

developers 43, 48

development 43

device 43

Mobile appliances 2, 8, 10, 13, 24, 25, 50, 60,
62, 66, 69, 73, 74, 75, 76, 81, 82, 83, 84

capability factors 2

charisma determinants 40

code 10, 76

developers 24, 50, 60, 62, 65, 66, 74, 75,
76, 81, 82, 83, 84

game 25

installation wizard 75

interoperability issues 73

maintenance issues 75

mobi-bility factors 69

reliability factors 13

Mobile application(s) 22, 25, 61, 76, 87

optimizing 61

quality 61, 76

stores 87

super minimalistic to-do list 25

sustainable 76

upgrade 24

usability factors 22

Mobile application security 49, 50, 54, 56

factors 50

holes 49, 56

mechanism 54
Mobile computing 7, 8, 9, 13, 15, 16, 17, 24,
28, 29, 86, 88
concurrency in 7
interactive 29
Mobile computing 14, 85, 88
backward compatibility 85
device capabilities 14
technology 88
Mobile developers 6, 10, 22, 41, 42, 45, 74
forces 6
Mobile device 15, 66, 82, 83
functions 15
industry 83
manufacturers 82
platforms 66
Mobile platforms 6, 7, 9, 15, 32, 34, 46, 63,
70, 84
iOS, popular 15
Mobile software 3, 8, 18, 27, 29, 30, 33, 88
applications 27, 29, 30, 33, 88
specification 3

N

Network 5, 60, 61, 62, 63, 65
traditional 61
wireless 60
Non-functional features 3

O

Operating system 73, 79, 80, 82, 89
compatibility 79, 80, 82, 89
component 73

P

Personal information management (PIM) 82
Power, computational 60
Privacy policy, applicable 54
Programming 3, 5, 7, 9, 29, 31, 60
code 31
languages 7, 9, 31
real-time 7
structured object-oriented 5
style 31
Program(s) 29, 75
piracy 75

non-interactive mobile 29

Q

Quad ultra high definition (QUHD) 43
Quality attributes 5, 9, 76
static 5

R

Resources 3, 5, 7, 14, 16, 52, 53, 60, 61, 65,
66, 69, 73, 75
heavy multimedia 60
mobile applications install application 73
target device 60

S

Samsung electronics 71
Screen size install-ability 68
Security 49, 46, 50, 54, 55
holes 50, 54
issues 46
policies and regulations 49
properties 55
regulations 49
Social engineering techniques 55
Software application 5, 9, 26, 27, 28, 34, 50,
65, 75, 76, 85
data-agnostic mobile 9
development 76
evolution 75
kits (SDKs) 50, 85
SQL server mobile 17
Squarespace mobile application 25
Storage 17, 60, 68, 70, 77
access 60
capacity 60, 68, 70, 77
device 17
System 7, 8, 16, 26, 32, 35, 50, 55, 73
concurrent mobile 8
developing concurrent mobile 7

T

Technology-oriented methods 22
Test 15, 16, 28, 44, 46, 63, 64, 76, 77, 84, 85
mobile applications 16, 84
mobile application compatibility 85

TeuxDeux mobile application 25
Throughput 62, 63
 measurement 62
 process 63
Tools 3, 4, 29, 43, 44, 45, 46, 47, 76
 dependency injection 4
 effective marketing 44
 latest mobile 45
Twenty-first century communications 34
Twitter 51, 52
Two-step verification mechanism 51

U

Uninstallation services 73
Uninstalled mechanism, default 73
Unique device identifiers (UDIDs) 55
Updates, regular application 72
Usability 25, 26, 36
 attributes 25, 26
 expectation 36
User(s) 4, 7, 8, 16, 23, 24, 25, 26, 27, 28, 29,
 30, 32, 33, 34, 35, 39, 41, 42, 44, 45, 46,
 47, 49, 51, 52, 53, 55, 59, 60, 61, 64, 65,
 84, 88
 authenticate 51
 casual mobile 26
 communications 53
 data 4, 84
 feedback 65
 interactions 16, 29, 33, 88
 interface 23, 24, 25, 26, 28, 29, 32, 33, 60,
 64
 mobile device 8
 mobile phone 30
 privacy 49
 software 27
 support mobile 29
 target mobile 64
 satisfaction 39, 59
User authorization 52, 53
 of mobile application 52
 process 53

V

Video 47, 89
 accessibility act 89
 messaging feature 47

Virtualized mobile devices 16

W

Web 6, 7, 34, 44, 47, 61, 83, 86, 87
 browser button 61
 enabled mobile device 83
 non-mobile 34
 service 87
Web application 30, 83, 84, 89
 program interfaces 30
 single 83
Websites 29, 30, 44
 blacklisted 30
WhatsApp 40, 41
Windows 73, 81
 applications 81
 mobile platforms 73
 phone applications 81
 RT and Windows 8 81
 tablet 81