Recent Advances Delivered by HTML 5 in Mobile Cloud Computing Applications: A Survey

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ABSTRACT
With the explosive growth of the mobile applications and emerging of Cloud Computing (CC) concept, Mobile Cloud Computing (MCC) has been introduced to be a potential technology for mobile services. MCC refers to an infrastructure where both the data storage and the data processing happen outside of the mobile device. One of the technologies that will advance MCC is the latest version of the Web´s markup language, HTML 5. In this paper, we present a survey of new HTML 5 features with a focus on the enhancement of the current MCC limitations. Specifically, we present the most important features of HTML 5 organized in different categories and their contribution in the deployment of MCC applications. Finally, the results of the research carried out on evaluating HTML 5 in terms of a wide range of applications and specifications are reviewed.

Categories and Subject Descriptors
C.2.4 [**Computer-Communication Networks**]: **Distributed Systems** – *Distributed applications*; H.4.3 [**Information Systems Applications**]: Communications Applications – *Information browsers*; H.5.0 [**Information Interfaces and Presentation**]: General; I.7.2 [**Document and Text Processing**]: Document Preparation – *Markup languages*

General Terms
Languages, Performance, Standardization

Keywords
Cloud computing, mobile phones, data processing, HTML 5

1. INTRODUCTION
Mobile devices are increasingly becoming an important part of human life as the most valuable and convenient communication tools not bounded by time and place. Cloud computing has been widely recognized as the next generation's computing infrastructure. MCC will not provide benefits only to the smart phone users, but will help a broader range of mobile subscribers. MCC has to face many technical challenges ([9], [11]). Nowadays mobile devices using CC, such as conventional mobiles, smartphones and tablets, have unique capabilities and limitations when compared to fixed computing devices. The limitations, which depend on the specific device, mainly include energy efficiency, battery life, processing power, memory, bandwidth-networking functionality, screen size, and data entry capabilities. On the other hand, added capabilities of mobile devices include mobility, geo-location, small size, and the inclusion of a variety of sensors (e.g., motion, orientation) ([11], [27]). In this paper, we analytically present a survey of new HTML 5 features with a focus on the enhancement of the current MCC limitations. The recent rapid advances offered by HTML 5 seem to have opened the road for web-based applications that will work seamlessly on any HTML 5 compliant web browser, on any mobile device. Specifically, we present some of the most important features of HTML 5 organized in different categories and their contribution in the deployment of MCC applications. Also, the research carried out so far in the area is reviewed in order to analyse current trends, as well as missing pieces.

The rest of the paper is organized as follows. In section 2 we analyze the limitations of MCC, while Section 3 presents the contribution of various enhanced features of HTML 5 to dealing with these limitations. Section 4 reports on evaluation results of HTML 5 regarding a wide range of applications and specifications and finally some conclusions are drawn.

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2. ANALYSIS OF MOBILE CLOUD LIMITATIONS
One of the major challenges of MCC technology is to understand both the capabilities and limitations. The limitations, which depend on the specific device, may include energy efficiency, battery life, processing power, memory, bandwidth-networking functionality, screen size, and data entry capabilities. On the other hand, added capabilities of mobile devices include geo-location, small size, mobility, and the inclusion of a variety of sensors ([11], [27]).

2.1 Energy Efficiency – Battery Life
Energy efficiency is a primary consideration for mobile devices. Moreover, CC has the potential to save mobile client energy but the savings from offloading the computation need to exceed the energy cost of the additional communication. Nowadays, smart phones can access multiple wireless networks. As such, users can upload content files via multiple interfaces concurrently. This new operational mode allows greater freedom in minimizing energy consumption for content uploading subject to delay constraints. Use cases are developing towards always on-line connectivity,

high speed wireless communication, high definition multimedia, and rich user interaction. Development of battery technology has not been able to match the power requirements of the increasing resource demand. Battery lifetime is a critical performance metric for mobile devices. To extend battery lifetime, mobile devices during operation, should aim to conserve its energy consumption as much as possible ([17], [21], [28]).

2.2 Bandwidth – Networking Functionality

Bandwidth is one of the main issues in MCC since the radio resource for wireless networks is much scarce as compared with the traditional wired networks. The mobile communications business is vital to produce innovation regarding cost-efficient, minimum energy consumption, and still ubiquitous wireless broadband access. Recent studies carried out energy optimizations, in order to decrease the energy consumption without losing efficiency of the wireless mesh network. According to a latest findings, mobile data traffic will increase by a factor of 40 between 2009 and 2014; by 2015, two-thirds of world's mobile data will be video (Scalable, 3D, Multi-view). Moreover, novel application, such as machine-to-machine (M2M) communication and CC, will establish various requirements that have to be fulfilled. Cloud networking offers a combination and integration of CC and virtual networking. It is a solution that distributes the benefits of CC more deeply into the network, and provides a tighter integration of virtualization features at computing and networking levels. To support these concepts, open connectivity services need to provide advanced transport and networking mechanisms, making use of network and encoding techniques, and dealing with ubiquitous mobility of user, content and information objects in a unified way ([7], [8], [9], [14], [23]).

2.3 Processing Power – Memory

Mobile devices generally have less memory and processing power than their desktop brethren. One drawback of the capabilities of these devices comes from their power source. Nowadays desktop CPU transitioned to multi-core processor in order to deal with the increasing performance requirements as well as the enlargement of power consumption of single core processors. Mobile processors require the same performance and power consumption. Conventional mobile processors have restrictions in the amount of processing they can handle, which limits implementations of advanced applications. Mobile devices carry out several operations such as browsing, media playback, gaming, text/multimedia messaging, and location-based applications. In order to further enhance the overall performance, mobile devices move to multi-core CPUs ([1], [19]).

2.4 Screen Size

Compared to personal computers (PC), mobile phones have many differences, in which the most obvious is the screen size. A laptop PC usually has a 13 to 15 inch screen with a resolution of 1280×800 or 1440×900. Since today's rich clients are basically designed to suit the screen size of PC, they cannot work well in mobile phones. While screen resolution continues to improve, and color screens are becoming the norm, screen sizes are likely to remain small, as users prefer small and portable devices. It is worth mentioning that the majority of current Web sites are designed for desktop displays. Viewing a Web page designed for desktops becomes a heavy burden on the smaller screen, indicated that small display users spent much more effort and time than their large screen counterparts to perform the same navigation tasks on Web pages designed for large screens ([3], [32]).

2.5 Data Entry Capabilities

With the advance of mobile communication systems, it is essential to integrate enormous heterogeneous data and provide flexible and seamless services. Mobile data management is conventionally organized with both distributed and centralized database, which helps to index and search rapidly. Mobile devices carry lots of different kinds of data, including multimedia files, personal information management data, device profile data, location, map data, and many others kinds of data. Moreover, devices can easily access additional data from the web, or even from surrounding devices via a wireless ad-hoc network. The convergence of mobile, cloud and social computing poses significant technical challenges. The increase in mobile data will come from CC applications that are especially used for storing and sharing special data, as well as for productivity tools ([4], [6], [33]).

3. HTML 5 WEB-BASED MOBILE APPLICATION ADVANCES

Developing mobile applications is not an easy task. Crucial decisions have to be made, such as:

- which *mobile platforms* are targeted?
- which one of the several cross-platform development *frameworks* will be used?
- what kind of application will be developed, a web-based-mobile application, a native application, or a hybrid one?

The rapid advances in HTML 5 ([29], [30]) have resulted in a much more mobile friendly version of the best-known Web language, which seems to have opened the road for web applications that will work on any HTML 5-compliant web browser, whether that browser is on a mobile device or a desktop PC. Web-based-mobile applications based on HTML 5 are getting much more advanced and consequently attracting much more interest in their deployment. Furthermore, HTML 5 provides enhanced functionality without using proprietary technologies ([5], [25]), such as Adobe System's Flash, Apple's QuickTime and Microsoft's Silverlight.

In the following paragraphs we analyze how the new features of HTML 5 contribute in facing the most important limitations of mobile devices reviewed in Section 2. Specifically, we present some of the most important features of HTML 5 under specific categories and their contribution in the deployment of web-based-mobile applications. The features presented are - at least - at the stage of "last call working draft" according to the classification of specifications by W3C, which means that the underlying specification fulfills its requirements and feedback from the community is requested. The results of this analysis are summarized in Table 1.

Table 1: Contribution of HTML 5 Features in Dealing with Mobile Device's Limitations

HTML 5 feature	[2.1] Energy efficiency, battery life	[2.2] Bandwidth – Networking functionality	[2.3] Processing power, memory	[2.4] Screen size	[2.5] Data entry capabilities
[3.1] 2D Vector Graphics (SVG)				√	
[3.1] 2D Programmatic API, HTML <canvas>		√	√		
[3.1] Graphical effects				√	
[3.1] Downloadable fonts			√	√	
[3.2] Video and audio playback			√		
[3.3] New types of form controls		√	√		√
[3.4] Touch-based interactions, Vibration API				√	√
[3.5] Device information, CSS-based adaptation			√	√	√
[3.6] Bidirectional connections		√	√		
[3.6] On-line state		√			
[3.7] Application Cache, Widgets		√			
[3.8] Page visibility detection		√	√		
[3.8] Battery status	√				
[3.8] Threading			√		

3.1 Graphics

Creating and processing graphics, animations and graphical effects on mobile devices with a limited screen size, processing power and memory is not easily accomplished. The most important advances in this area are the integration of SVG graphics ([25], [29]) and the <canvas> element ([25], [26], [29]) added in HTML 5:

- *2D Vector Graphics (SVG) – SVG Tiny 1.2 specification*. The Scalable Vector Graphics (SVG) format, which is an open XML-based file format, gives the chance for compact and high-quality graphics [25]. SVG graphics can be zoomed at the user request, an ability that advances importantly the creation of graphics on mobile devices with limited screen space. Furthermore, SVG graphics can be animated easily constituting the development of advanced and slick interfaces possible, while the application of graphic filters to multimedia content also becomes feasible [29].
- *2D Programmatic API – HTML Canvas 2D Context specification.* The new <canvas> element gives the chance of creating and incorporating graphics, video and animation, usually via Javascript, directly on the web-browser ([2], [26]). Rendering graphics locally helps in dealing with server and bandwidth restrictions [25]. This feature also enables the use of the 2D Programmatic API for processing graphics in a less memory intensive way.
- *Graphical effects – CSS Backgrounds and Borders specification.* The CSS3 set of specifications provides new features for the easy creation of graphical effects, and consequently more attractive web-application interfaces. The aforementioned specification gives the chance for rounded corners, complex background images and box shadow effects. Moreover, working drafts for 2D transforms (*CSS 2D Transforms Module Level 3*), 3D effects (*CSS 3D Transforms Module Level 3*), animations (*CSS Animations, CSS Transitions Module Level 3*), as well as for optimizing the consumption of recourses by animations (*Timing control for script-based animations API*) exist.
- *Downloadable fonts – WOFF File Format 1.0 specification.* The limited set of fonts available in mobile devices can be enriched with fonts that are automatically downloaded through style sheets, giving the chance for creating more attractive graphical interfaces. What is more important is that the size of the downloaded fonts is limited.

3.2 Multimedia

The added <video> and <audio> tags improve the integration of multimedia content in web applications, since media files can be played without external plug-ins ([25], [26], [29]). Moreover, the interaction with multimedia content is enhanced in comparison with plug-ins [29]. Finally, the video tags are codec-neutral, and as such support nonproprietary video formats (i.e., H.264) [25].

3.3 Forms

Text input on mobile devices is not easy for most users, due to their limited keyboards. HTML 5 adds new types of form controls that make input easier [29]:

- *date and time entries* (*HTML 5 Date and Time state of input element*) are supported by a number of dedicated form controls. For example, users can use a native calendar control.
- *customized text entries* (*HTML 5 telephone, email and URL state of input element*) for telephone numbers, email addresses and urls ease the input process of such data. This is accomplished by using virtual keyboards or accessing relevant data from the device (such as the address book).

- the use of a new *pattern attribute* (*HTML 5 pattern attribute*) guides users in entering data, while server-side validation that requires network activity and JavaScript-based validation that requires resources are avoided.

3.4 User Interactions

Besides the traditional interactions based on keyboards and mouses, mobile device users can use other ways of interactions, such as touch-based interactions (*Touch-Events Specification*), voice interactions (under exploration) and haptic feedback (*Vibration API*). Moreover, there is a need to make web-applications able to react not just to specific user commands entered by key presses and touch events, but also to more abstract commands, such as an "undo" command no matter how the user gives this command. It is obvious that advances in the area of user interactions will enhance data and command entry, and will contribute to the creation of more attractive and user-friendly web-applications.

3.5 Device Adaptation

Mobile devices are characterized by great variations, such as screen size and resolution, type of keyboard and so on. Having the ability to retrieve data regarding the device (*Device information – Device Description Repository Simple API*) that is accessing a web page is of great importance. This data can be used for adapting the layout and behavior (*CSS-based adaptation – Media Queries specification*) of web-application.

3.6 Network

Establishing high quality network connectivity is crucial for mobile devices, since the Web provides both content and processing power that constitutes important limitations of mobile devices. Several features have emerged towards establishing enhanced networking connectivity, such as bidirectional connections and on-line state [29].

The *WebSocket API* specification offers bidirectional, more flexible and less resource intensive network connectivity in comparison with XMLHttpRequest. Furthermore, the *online DOM state* specification determines the existence or absence of network connectivity, and in the former case the type of network.

3.7 Offline Applications – Packaging

An important aspect of users' experience on using applications on mobile devices is connected to their permanent availability, even when the device is off-line ([25], [26], [29]), as well as to their distribution. Both these issues refer to web-application packaging, which is supported in the following ways [29]:

- a manifest of files that the browser must keep in cache is defined, in order to allow off-line access to a web application (*HTML 5 Application Cache*). AppCache lets both data and programming code of online applications to be stored locally [25].
- a framework for distributing web applications as zip files completed by a configuration file is defined (*Widget Packaging and Configuration*)

In recent literature ([2], [25]), HTML's support for client-side SQL database for storing an application's data is referenced. However, things change fast and the work around this kind of support with client-side SQL-based database has been abandoned and substituted by the *Index Database API* [29]. This API defines a database of values and hierarchical objects that can be queried and updated very efficiently [29].

3.8 Performance & Optimization

Performance plays a vital role in enhancing user experience on mobile devices, due to their CPU and battery limitations. HTML 5 offers the following features:

- *Page Visibility detection – Page Visibility API.* The usage of resources is adjusted based on the needs of the application [29]. For example, when a page is minimized the network activity is reduced.
- *Threading – Web workers*. The most resource-consuming operations are offloaded into a background process, keeping the user interface responsive ([25], [29]).
- *Battery status – Battery Status Events.* The use of resources is adjusted to the current level of power available in the battery [29].

4. NEW EVALUATION TESTS OF HTML 5 SPECIFICATIONS

HTML 5 has brought new advances in several aspects of computing. Due to this reason several new books, such as [10] and [19], describe the new potentials. Although, HTML 5 is still evolving, the majority of mobile browsers currently support a lot of its features. This section provides several reported evaluation results of HTML 5 regarding a wide range of applications and specifications.

4.1 Execution of Web Applications

In [15], Martinsen et al. reported the comparative results of the execution behavior of four different JavaScript benchmark suites. These application classes also included HTML 5 demo applications. Their results showed that, the execution time for web applications usually increases due to just-in-time compilation. Furthermore, they have reported large differences in the execution behavior among web based applications especially at the bytecode level.

4.2 Mobile Devices

Recently, PerfMarks (open-source project maintained by spaceport.io) performed a thorough test on a variety of devices (either iOS or Android) for the needs of their PerfMarks report [24]. The aim was to present some comparative results on the performance of HTML 5 web applications on various combinations of hardware and software. This is very crucial, in order to provide a ranking between mobile platforms that deliver improved HTML 5 experience. According to their results, they found that iOS enabled devices have around three times better HTML 5 performance than Android enabled devices. Unfortunately, although Microsoft is an HTML 5 supporter, window mobile devices were not included in the tests.

4.3 Multimedia Content

Moreno et al. in [18] have recently introduced an evaluation study of the new HTML 5 standard regarding to the accessibility requirements for the multimedia players as well as an accessible HTML 5 Media Player. The authors presented a very interesting new idea, since the necessity of the installation of a required plug-ins by the user before he/she accesses video, is usually a problem.

However, the new HTML 5 standard is in position to deliver a solution to this problem.

4.4 Browser Support

There is a growing interest, regarding how well a browser supports the forthcoming HTML 5 standard and various other specifications. Although, the specification is evolving, the majority of the most well-known browser manufacturers are trying to optimize their browser behavior. Therefore, specialized web sites [12] have emerged in order to evaluate the performance of the users' browsers. This test, evaluates not only specifications of the HTML 5 but also several other specifications created by the W3C HTML working group in order to support audio and video codecs, as also SVG or MathML embedding in plain HTML documents.

Moreover, the scope of the HTML 5 Test Suite Results in [31] is to assist the implementers to deliver optimized applications that support HTML 5. The test suite currently contains the evaluations of 907 tests that are available online.

4.5 Security

Recently Lyne published a report in [13], which warns users to evaluate their use of cloud services. This report by SOPHOS clearly mentions that HTML 5 not only enables new capabilities, but also introduces new risks. These concerns are mainly focused on browser vulnerabilities and privacy issues.

4.6 Use in the Web Mapping Client OpenLayers

Sauerwein in his B.Sc. Thesis [22] evaluated several new HTML 5 elements and interfaces regarding their use in the OpenLayers JavaScript library. OpenLayers is widely used in order to embed interactive maps into a website. The Thesis studied the canvas element (an interface for drawing graphics), and on the Web Worker API, (it is used for executing JavaScript files in background). His results shown that the currently used technology SVG (Scalable Vector Graphics) to render vector geometries, will not be replaced by canvas. However, canvas may create new ways for the visualization of geographic data, that were not possible using JavaScript inside the browser up to now. Moreover, Sauerwein found that although web workers are a promising option to execute pixel-based graphic operations, data exchange with web workers can be proved to be a serious weakness.

4.7 Pervasive Computing

Melamed and Clayton in [16] have evaluated a number of platforms (e.g., J2ME and native Smartphone) against requirements of a development platform for pervasive media applications. Their analysis is based on a variety of pervasive media applications, such as games and tourism based applications. This paper also describes the advantages and disadvantages of HTML 5 compared to other existing solutions.

5. CONCLUSIONS

MCC offers many possibilities, but on the other hand there are several limitations as well. HTML 5 seems to offer a number of important new and enhanced features that have opened the road for web applications that will work on any HTML 5 compliant web browser, whether that browser is on a mobile device or a desktop PC. Especially, web-based mobile applications that are the focus of the paper seem to be favored importantly. SVG graphics, integrated multimedia, enhanced data entry and user interactions, device adaptation, enhanced networking connectivity and the ability to work offline are some of HTML's 5 features that help deal more effectively with the limitations of MCC.

In this paper, we surveyed several examples illustrating how these new HTML 5 features can facilitate the development of MCC. The results of the corresponding studies so far can be summarized as follows: HTML 5 gives a solution to the problem of requiring plug-ins for delivering multimedia content [18]; the new <canvas> element offers new possibilities for the visualization of geographic data [22]; although web workers are a promising option for executing pixel-based graphic operations, data exchange with them can be proved to be a serious weakness [22]. Studies have also been carried out for comparing the performance of HTML 5 web applications on iOS and Android enabled mobile devices that favored the iOS platform [24], while specialized sites for evaluating the HTML 5 performance of web browsers have emerged [12].

The exploration of the contribution provided by HTML 5 features in dealing with the limitations of mobile devices, which is summarized in Table 1, showed that HTML 5 in MCC mostly contributes in bandwidth and network functionality, and processing power and memory. However, more research results for evaluating the actual contribution of HTML 5 features on these limitations are required. Finally, critical assessment of various HTML 5 features, regarding MCC applications, constitutes a future research goal.

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