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Experimental analysis of connectivity management in mobile operating systems

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ABSTRACT

We are immerse in a world that becomes more and more mobile every day, with ubiquitous connectivity and increasing demand for mobile services. Current mobile terminals support several access technologies, enabling users to gain connectivity in a plethora of scenarios and favoring their mobility. However, the management of network connectivity using multiple interfaces is still starting to be deployed. The lack of smart connectivity management in multi-interface devices forces applications to be explicitly aware of the variations in the connectivity state (changes in active interface, simultaneous access from several interfaces, etc.). In this paper, we analyze the present state of the connection management and handover capabilities in the three major mobile operating systems (OSes): Android, iOS and Windows. To this aim, we conduct a thorough experimental study on the connectivity management of each operating system, including several versions of the OS on different mobile terminals, analyzing the differences and similarities between them. Moreover, in order to assess how mobility is handled and how this can affect the final user, we perform an exhaustive experimental analysis on application behavior in intra- and inter-technology handover. Based on this experience, we identify open issues in the smartphone connectivity management policies and implementations, highlighting easy to deploy yet unimplemented improvements, as well as potential integration of mobility protocols.

1. Introduction & motivation

In the last years we have witnessed the market explosion of a new kind of handheld device, the smartphone. At this point in time it is clear that these devices are going to keep a steady market penetration and are going to be a major source of revenue and data traffic for network operators. According to [1], smartphones account for 88% of the growth of global mobile devices and connections in 2014, with 439 million net additions in this year. Even though they represent just the 29% of global handsets in use, they are responsible for 69% of the total handset traffic, which clearly shows the major adoption of this technology. The use of smartphones has also modified the traditional patterns of mobile data consumption. The typical smartphone user is craving for data-based services, imposing a high burden on the operators, which see their investments on network deployments pushed to the limits due to greater bandwidth requirements. Due to the shift in user profile and data service demand experienced in the recent years, smartphones have become a powerful tool in most people's daily life. In addition, the enhanced capabilities and fast upgrades of hardware in handheld devices have considerably increased their usage. These facts pave the way to advanced research and development that

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relies on the use of smartphones for carrying out innovative tasks, mostly related to health care or behavioral studies and using the smartphone as a measurement instrument [2]. Moreover, there is a trend towards specialized, almost personalized services, which could benefit from an accurate knowledge on the capabilities supported by smartphones and how they manage their resources.

The current offer in the market is very wide, in terms of manufacturers, hardware resources and operating systems, but do the majority of the devices behave similarly? Is there any difference in the management of their own resources? Is the access to an application homogenized across the different systems? Is the network connectivity management standardized in all the various devices? Answering these questions could back the actual research on mobile devices and their applications to make daily tasks easier, but also more demanding use cases, applied to different fields. However, mainly because these details remain closed by manufacturers, most of this information is still missing or disregarded in research, which focuses on measuring performance or developing applications to serve specific purposes.

Smartphone users have one common and defining characteristic, they move. The need for supporting data services on the move has shaped the design of the cellular network, which must deploy access and core networks able to redirect users' traffic to their current location. In addition to the obvious problem of designing such networks, current smartphones support several wireless technologies, such as IEEE 802.11 [3], complementing the cellular connection. This heterogeneity brings new opportunities and challenges to the industry, since the additional technologies can be used to offload the traffic from the cellular network to local accesses, such as the broadband connection usually deployed at home.

The smartphone operating system provides a set of mobility-related functions from which an application can benefit in case it decides to handle mobility. These functionalities depend on the operating system (e.g., Android, iOS, Windows Phone 8) and include connectivity events such as network up or down events, and commands exposed to the application layer to extract information on connection availability. Usually the terminal connectivity is handled by a service widely known as the *Connection Manager*, in charge of deciding which is the best connection for the terminal in a specific moment, and the application has to deal with those decisions.

This work focuses on the analysis of the current state of the art on the mobility support at the Connection Manager in different terminals, providing a functional view of the differences between the major operating systems and the different improvements that can be done to optimize the mobile user experience. Our main contributions are:

- We analyze the default network connectivity management of the three currently most popular families of mobile OSes: Android, iOS and Windows Phone 8,[1] including iOS8 and Android Lollipop, in their latest versions supported to date. We test the same OS versions in different terminals, to avoid biased conclusions, derived from the performance of the terminal rather than from the OS behavior.
- We study how the smartphones running these different OSes perform inter- and intra-technology handover, considering the most widely used access networks: cellular and IEEE 802.11. For this study, we measure the handover latency in different scenarios and we evaluate the differences and similarities in the management and configuration of the networking parameters in each device.
- We evaluate how the handover performance affects the user experience by considering different applications, and whether they can survive to a change in connectivity: changes in IP address and changes in access technology.
- As a result of our experimentation, we identify the challenges and open issues that are present in current smartphones and discuss on potential improvements for the connectivity management that are feasible but not yet implemented and on the integration of connectivity management with current mobility protocols.

The rest of the paper is structured as follows: In Section 2 we present the related work available in the literature and compare it to our work. We present some background of the implementation of the network management in the systems under study, analyzing their main similarities and differences in Section 3. In Section 4 we present the experimental deployment, and in Section 5 we evaluate the initial attachment to the access network performed by the systems under study. In Section 6 we present a detailed analysis of the handover and how the connection manager of the three families of OSes handle the changes in connectivity, both inter- and intra-technology, making this analysis extensive to the management of this change in connectivity by some popular applications. Section 7 summarizes our main results and highlights our findings comparing all the studied systems. In Section 8 we identify open issues and improvements to tackle the shortcomings of the network management in mobile devices, in light of the data extracted from our experiments. We also discuss on the integration with mobility protocols. Finally, Section 9 concludes the article and presents guidelines for our future work.

2. Related work

A significant part of the previous works in the literature analyzes the energy consumption of smartphones, however, we focus on the connectivity management. We have compiled in Table 1 the previous works that address network performance in smartphones for a better comparison. Network connectivity has been addressed, but mostly in terms of application usage and traffic patterns. For instance, [4] conducted a thorough study of application popularity and usage, characterizing the patterns followed by different demographic groups of users and the traffic generated. Their study confirms the high diversity in smartphone usage, leading to the conclusion that the tools in use may provide acceptable performance in average, but it could be considerably enhanced by some specific knowledge on applications

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