kriativ.tech

Edition Nº 11, Vol. I – 04-12-2025
ISSN Print: 1646-9976 | ISSN Online: 2184-223X |
http://www.kriativ-tech.com
DOI: 10.31112/kriativ-tech-2023-06-102

The Era of Mobile Devices

Geraldo Oliveira Sales Junior
ISTEC Lisboa –geraldo.junior@my.istec.pt

Paulo Duarte Branco
Associate Professor at ISTEC Lisboa, CIAC-PLDIS – paulo.duarte@my.istec.pt

Abstract: *The era of mobile devices presents, in chronological order, the technological evolution leading to the current computing configuration as observed at the beginning of the 2020s. Grounded on a literature review, this study highlights the macrostructural events that decisively influenced the development of mobile devices.*

Keywords: *Mobile devices, History of computing, Technological evolution, Digital mobility*

I. Introduction

In early 2020s society, computing is predominantly characterized by the widespread use of mobile devices, contrasting significantly with the traditional computing paradigm, commonly envisioned as consisting of a television-like screen accompanied by a keyboard and subsequently by a pointing device such as a mouse. This scenario aligns with the so-called Post-PC Era, anticipated by David Clark as early as 1999, who foresaw an inevitably heterogeneous future in computing (Alajrami et al., 2016).

However, contemporary younger generations no longer share this conceptual framework in their collective imagination, nor do they fully grasp symbolic references inherited from the traditional computing era. For instance, it is common among younger individuals to express confusion regarding the floppy disk icon representing the "save" function, raising questions such as: What exactly is a floppy disk? Why is it necessary to "save" a file? Why were screens previously unresponsive to touch? These recurring inquiries among young people reflect a paradigmatic shift in their everyday experiences with digital technologies (Ali et al., 2021).

The previously described scenarios exemplify the emerging paradigms of mobile computing, which revolve around portable devices, primarily represented by smartphones and tablets. This article provides a historical account of the technological events that culminated in the contemporary computing landscape.

Initially, the fundamental concepts defining the scope of this study are presented. The structure of the paper is organized as follows: Section 3 describes the research methodology; Section 4 presents the historical review entitled "The Era of Mobile Devices"; Section 5 provides a critical reflection on technological advancements and offers suggestions for future research; finally, Section 6 discusses the main limitations of the study, aiming to enhance methodological transparency and highlight potential avenues for further investigation

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II. Key concept

Undoubtedly, the key concept of this study is the definition of "mobile devices." This term is notably complex to delimit as it requires contextualization specific to each period within the history of computing. It is important to clarify that, for the purposes of this article, "mobile device" refers exclusively to computational mobile devices, specifically those operating on electronic computing technology.

If such a delimitation were not established, it would be necessary to consider the abacus as the earliest computational mobile device, given that its primary function precisely involves performing calculations—that is, computing (Samolu, 2012).

Over the past 70 years, various definitions have been proposed regarding what constitutes a computational mobile device, always contextualized within the prevailing technological environment. In the 1950s, with the advent of the first computers, which occupied significant spaces, often entire rooms, a computational mobile device was conceived as one that could be operated while moving, albeit very limitedly by current standards.

With the predominance of microcomputers, or personal computers, in the computing landscape, the definition of a mobile device shifted to equipment that could be easily transported. Notably, portable computers, or laptops, emerged as the paradigm of computational mobility during this period.

Some years later, with the advent of mobile communication stations, mobile communication devices were defined as equipment that, regardless of weight or dimensions, could be transported in vehicles or even carried by soldiers in large backpacks. Their primary characteristic lay in enabling communication "anywhere," representing a significant advancement in the mobility of information and communication technologies.

At a time when traditional telephony devices were standard and inherently tied to physical cables for voice transmission, mobile communication devices were commercially available but weighed over one kilogram. Nevertheless, these devices represented significant innovation by providing a degree of mobility in personal communications.

Despite their considerable weight, portable computers eventually became commonplace in daily life. However, it was electronic organizers and subsequently personal digital assistants (PDAs) that gained recognition as mobile devices due to their compact size and ease of transport in users' pockets. With the introduction of smartphones and later tablets, these devices unquestionably assumed the role of the quintessential mobile devices in contemporary society.

Currently, wearable devices are increasingly popular and undeniably portable and mobile. Nevertheless, these devices have not yet achieved conceptual and cultural recognition as primary mobile devices within society, a role still predominantly occupied by smartphones and tablets.

III. Research Methodology

The primary objective of this study is to review the scientific literature concerning the history of mobile devices, aiming to identify premises that may guide future research. Conducting a review of previously published studies involves incorporating recent facts, correcting omissions or inaccuracies, and including information made publicly available after the publication of earlier research.

Based on this premise, a bibliographic search was conducted across scientific databases such as Springer, ACM Digital Library, IEEE Xplore, Scopus, and the Fundação para a Ciência e a Tecnologia (FCT). The search employed terms such as "mobile device age," "mobile device," "mobile computer," "cellphone history," and "dispositivos móveis." However, this search did not yield significant historical records related to the topic.

An examination of IEEE historical yearbooks similarly revealed a lack of specific studies focused on mobile devices. Nonetheless, it was observed that many historically oriented works did not rely on scientific articles or traditional academic sources but rather on alternative documentation such as books and historical accounts from manufacturers.

Consequently, this article adopts a similar approach, utilizing the same types of bibliographic sources employed in these historical studies. The entire research process relied on publications with varying levels of specialization, prioritizing credible sources and only occasionally referencing enthusiasts' accounts and users' historical records.

IV. The Era of Mobile Devices

Transistors were initially theorized by William Shockley in 1945 under the designation "solid-state valves" (Miller, 2023). However, the experimental validation of this device's physical feasibility was not achieved until a few years later. Notably, it was Walter Brattain and John Bardeen—scientists equally prominent as Shockley—who successfully conducted the validating experiment

two years after the theoretical proposal. According to Miller (2023), this significant achievement materialized in December 1947 at Bell Labs.

In June of the following year, Bell Labs officially announced the invention of the transistor. Nevertheless, at that time, transistors were not yet implemented in contemporary computers, which continued to rely on less reliable vacuum tubes. The application of transistors in computational systems required further simplification and improvement. Approximately ten years passed before Bell Labs licensed the technology, enabling it to achieve practical, concrete applications (Miller, 2023).

Consequently, in 1958, Jack Kilby at Texas Instruments invented the integrated circuit, significantly altering transistor construction methods. Previously manufactured as separate semiconductor components, transistors began to be integrated into a single component (Brock & Laws, 2012; Miller, 2023). This advancement marked the birth of the modern chip.

Since that innovation, the transistor manufacturing process has continuously evolved (Miller, 2023). Thirteen years following its inception, the transistor underwent substantial technological advancement with the emergence of integrated circuits. However, large-scale commercial applications remained uncertain until 1957 when the Soviet satellite Sputnik commenced orbiting Earth. The United States' response arrived through NASA, which placed its first significant order with the then-new Fairchild Semiconductor—founded, among others, by prominent engineers Bob Noyce and Gordon Moore, previously collaborators with William Shockley (Miller, 2023).

Miller (2023) highlights a consensus at the time regarding the superiority of transistor-based computers compared to vacuum tube counterparts. The Apollo program, emblematic of the American ambition to surpass the Soviet Union by landing the first human on the Moon, demanded specific computational requirements: spacecraft guidance systems, including landing operations, had to be contained within the rocket. The Apollo Guidance Computer (AGC), as it became known, presented a technical challenge as formidable as the lunar landing itself. Preliminary studies indicated that a computer with these capabilities would be refrigerator-sized, consuming power beyond onboard generation capacities. However, with Fairchild's Micrologic chip's advent, this vision became attainable. At launch in 1961, the AGC weighed over 30 kilograms yet occupied merely 0.03 cubic meters, maintaining power consumption compatible with the rocket's onboard systems (Miller, 2023).

In this context, the first genuinely mobile computer emerged, gaining renown from its inception, achieving literal and symbolic prominence. The Apollo Guidance Computer (AGC) was roughly a thousand times more compact than the iconic ENIAC, developed about fifteen years earlier at the University of Pennsylvania's Engineering School (Apollo Guidance Computer - Wikipedia.org, 2024; Miller, 2023).

The earliest research efforts in radio-wave communication date back to the interwar period and, like transistor technology, required considerable time to yield practical outcomes. In 1956, Ericsson introduced the Mobile Telephone System A (MTA), considered the first automatic mobile telephone system (Ericcsson.com, 2024). The devices, weighing approximately 40 kilograms, were installed in vehicles belonging to Sweden's emergency response system, marking a significant milestone in communication mobility.

It took nearly two decades for the first truly portable communication device to emerge commercially and become relatively accessible to the public. In 1973, Motorola launched the DynaTAC 8000X, regarded as the first device approaching the contemporary concept of a mobile phone, despite weighing approximately 1.4 kilograms and providing only 30 minutes of talk-time autonomy (Motorola DynaTAC - Wikipedia.org, 2024). Mobile cellular networks were introduced in 1979, beginning with the Japanese company NTT, which implemented an analog wireless cellular network. Later the same year, Comvik debuted a similar network in Sweden (History of mobile phones - Wikipedia.org, 2024).

The 1980s proved particularly significant for the evolution of this initial and iconic mobile device. This period marked the beginning of an era characterized by accessible and widely disseminated mobile computing, the effects of which profoundly influenced society in the 2020s. The subsequent four decades following the 1980s

are distinguished by intense and continuous technological evolution, featuring successive redefinitions and overlapping of the very concept of a mobile device.

In this context, the first personal computers emerged—low-cost computational devices widely available commercially and accessible beyond military, scientific research, and large corporate domains. In 1984, Apple introduced the Macintosh, the first personal computer incorporating a graphical user interface, marking a turning point in how individuals interacted with technology. Just a year later, in 1985, Quality Communications, now known as Qualcomm, was established and would significantly influence the development of mobile communications (Qualcomm, 2024).

While Apple distinguished itself by marketing pre-assembled personal computers during a time when such devices typically came as self-assembly kits (HEATH & BEST, 2011; Wondery, 2024), Qualcomm had a distinct purpose. The company aimed to develop technologies capable of encoding more information within the same radio spectrum space, optimizing mobile communication efficiency and quality (Miller, 2023).

Qualcomm's proposal in radio-wave communication was groundbreaking. At the time, conventional systems operated on a single frequency, alternately sharing the channel during intervals of silence between calls. Qualcomm, in contrast, proposed using multiple frequencies to transmit call data simultaneously, accommodating significantly more communications within the available spectrum (Miller, 2023). However, this approach required computational power that was unavailable at the time and only became feasible with advances in microprocessors. Hence, it was essentially a bet based on the continued validity of Moore's Law (Moore, 2021), which proved correct over time (Miller, 2023).

The 1990s saw the emergence of digital mobile telephone networks, commonly known as 2G networks (Miller, 2023). Advances in integrated circuits enabled significantly smaller devices, facilitating the exchange of text messages between mobile devices for the first time. The first direct mobile-to-mobile text messaging service was introduced in Finland in 1993. Later in the decade, in 1998, the first mobile payment system was tested in Finland and Sweden, allowing users to purchase products such as beverages from vending machines using only their mobile phones (History of mobile phones - Wikipedia.org, 2024).

The early 1990s also witnessed the emergence of electronic organizers, with Casio as a leading manufacturer. These devices can be considered the first truly portable computers, albeit with limited computational capabilities. They were compact enough to fit in a shirt pocket and offered specific functions such as a diary, calendar, and contact list. Equipped with small screens and reduced keyboards, they were well-suited to their compact size (Electronic organizer - Wikipedia.org, 2024).

Palm Inc. was founded in 1992 but gained prominence in the late 1990s with the popularization of Personal Digital Assistants (PDAs). Devices such as the Palm Pilot, Palm III, and Treo marked a significant trend by eliminating the physical keyboard and adopting a form factor closely resembling modern smartphones. These devices operated using a special stylus and featured a handwriting recognition system based on the Graffiti alphabet, specifically developed for the Palm OS (Graffiti (Palm OS) - Wikipedia.org, 2024).

In 1999, the market saw the introduction of mobile phones with innovative features such as built-in digital cameras, memory card usage, and Internet access. That same year, the Japanese company NTT DoCoMo launched the first mobile Internet access service, marking a turning point in the role of mobile phones as tools for both communication and information access (History of mobile phones - Wikipedia.org, 2024).

The early 2000s ushered in the introduction of third-generation (3G) mobile networks, accompanied by a significant reduction in mobile device costs. Simultaneously, these devices began incorporating new technological features, making Internet access increasingly affordable and widespread. One of the main innovations of this period was the ability to access email directly from mobile devices. In this context, BlackBerry stood out in the business segment, becoming a reference due to its signature devices equipped with compact yet complete QWERTY keyboards (BlackBerry -

Wikipedia.org, 2024).

In 2001, a new revolution in digital mobility began with the launch of Apple's iPod (iPod - Wikipedia.org, 2024). Although other digital music players had existed for years, the iPod was the first to achieve massive commercial success. It is frequently cited as a landmark in the transformation of the music industry, introducing an integrated digital store and making digital music acquisition a widespread and accessible practice. The iPod was widely compared to Sony's Walkman—an iconic 1980s device that popularized the concept of portable analog music listening (Sony.com, 2024).

Personal Digital Assistants (PDAs) ultimately could not withstand the rapid evolution of mobile phones, which became increasingly accessible and popular. Companies such as Palm and others that developed solutions based on Microsoft's Windows CE operating system eventually exited the market (Windows Embedded Compact - Wikipedia.org, 2024). Palm attempted to adapt by launching a line of PDAs with integrated communication functionalities, such as the Palm Treo, but this effort came too late. Mobile phones had already evolved beyond voice communication devices with PDA-like features to become fully functional general-purpose mini-computers, capable of Internet access and broad functional versatility.

The year 2007 was marked by the announcement of the iPhone, introduced by Apple on January 9 (iPhone - Wikipedia.org, 2024). Distinguishing itself from all existing smartphones at the time, the iPhone eliminated the traditional physical keyboard—a hallmark of BlackBerry devices—and introduced an innovative interface based on gestures performed on a touchscreen that covered the entire front surface of the device. In many ways, this new paradigm revived the former format of PDAs. That same year, Google announced the Android operating system, designed to be adopted by any interested mobile phone manufacturer (Android - Wikipedia.org, 2024), offering a free and license-free alternative. These innovations led to the gradual displacement of then-dominant mobile systems and devices, such as those from Nokia, BlackBerry, Ericsson, and Sony.

In 2008, another major milestone in the era of mobile devices occurred when Steve Jobs unveiled the MacBook Air, an ultra-thin and lightweight laptop, which he famously pulled from a paper envelope to highlight its portability (MackBook Air - Wikipedia.org, 2024).

The following year, in 2009, fourth-generation (4G) mobile networks emerged, significantly increasing mobile Internet access speeds (History of mobile phones - Wikipedia.org, 2024). The combination of increasingly advanced mobile devices and high-speed communication networks enabled the development of complex applications and the emergence of new markets, such as music and video streaming services. Simultaneously, the app stores of iOS and Android systems revolutionized software distribution and consumption, fundamentally transforming the digital ecosystem.

Throughout the 2010s, disruptive global applications emerged, profoundly transforming various sectors of society. Successive revolutions were observed in areas such as passenger transport (Uber), food delivery (iFood), accommodation (Airbnb), music consumption (Spotify), instant communication (WhatsApp), photo sharing (Instagram), and news dissemination (Twitter), among others. Through these services, individuals began to access information and follow events in real time, anywhere and at any time. They now use their mobile devices daily, often unaware that they hold in their hands a portable computer with processing power hundreds of millions of times greater than that of the first mobile computer—the one that guided the mission of the first human to set foot on the Moon.

V. Conclusion

Just over 60 years ago, the first Apollo program flights launched equipped with the earliest mobile computers—direct outcomes of the integrated circuit revolution initiated by the development of transistors. These six decades have been marked by successive technological evolutions and revolutions in computing. Although relatively recent, the era of mobile devices has been defined by remarkable technological advancement. While the Apollo mission's computer relied on approximately 4,100 silicon-based integrated circuits, today's smartphones incorporate

processors containing over 19 billion transistors (Apollo Guidance Computer - Wikipedia.org, 2024; Apple A17 - Wikipedia.org, 2024).

According to recent data from the United Nations, the number of mobile devices—specifically smartphones—now equals 78% of the global population (United Nations, 2024). While different fields of knowledge use various terms to describe this period, such as "global society" or "post-industrial society," it is undeniable that from a technological and computational perspective, we are living in the era of mobile devices.

This study provided a historical overview of the key milestones in the emergence and evolution of mobile devices, beginning with the invention of the transistor—a foundational element without which subsequent technological advances would not have been possible, and the mobile device era might have remained purely fictional.

However, given the defined scope, this study did not delve into the causes and consequences of the technical developments discussed, which presents a potential direction for future research. In addition to updating the historical record in the coming years, another relevant research avenue could focus on constructing regional contexts to analyze, for instance, the impact of mobile devices on the economic and social development of different regions.

VI. Study Limitations

This study is predominantly descriptive and exploratory in nature, focusing on a historical literature review. While appropriate for the proposed objective, this approach entails certain limitations. First, the lack of specific and systematized scientific sources on the history of mobile devices necessitated the use of alternative materials, such as historical accounts from manufacturers, popular science articles, and encyclopedic entries. Although these sources were carefully selected, they do not offer the same level of empirical robustness as traditional academic databases

Additionally, the study does not engage in a causal analysis of the technological phenomena discussed, nor does it explore in depth the socioeconomic and cultural impacts of mobile device evolution across different geographic contexts. The investigation is also limited to a global overview, without addressing regional particularities or disparities in technology access and use.

These limitations highlight opportunities for future research that could complement the perspective presented here through empirical studies, comparative analyses, and interdisciplinary approaches.

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