Mobile Computing:

How Mobile Devices are Changing the Classic Computing Paradigm

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Abstract

This paper will illustrate how mobile computers and technology is changing and evolving. Slowly the classic computing paradigm of a main unit for processing, a keyboard and mouse for input, and monitor for output is changing. This is a change that faces many hurdles but is an inevitable part of evolution. Mobile computing faces both technological obstacles and consumer acceptance obstacles. I will demonstrate several ways that the technological hurdles are being confronted, including the Future Internet Architecture Program, mobile cloud computing, CogMAC, femtocells, battery alternatives, and carbon based nanotubes. I will then present current technologies that may someday replace modern computers such as new output interfaces and wearable computers, presenting one wearable computer in development, Google Glass, and one that is now in production, the Pebble. Even wearable computers depend on consumer acceptance to be successful. I present the Microsoft Surface RT tablet as an example of a product that has not gained consumer acceptance. Finally, I illustrate how volatile the industry is and how successful a product can be by looking at the iPhone quarterly sales.

Computers are evolving and changing. From the classic model of what is now referred to as Moore's law, which proposed in 1965 that the number of transistors on integrated circuits doubles approximately every two years, we can observe that change is nothing new to computers and that they are clearly getting smaller ("Moore's Law",2005). Today in America we can look around and see mobile devices being used everywhere. From high school students chatting and texting their friends, to healthcare employees entering vital information into handheld tablets, mobile computing has clearly become interwoven with everyday life. In fact mobile computing is now evolving at a much more rapid pace that the traditional personal computer, consisting of a main CPU container for the processing, a keyboard and mouse for input interface, and a monitor for output to the user. In a May 2013 USA Today interview with Qualcomm CEO Paul Jacob, he asserted that there are 6.6 billion mobile connections in the world, with 2 billion having high speed internet access (Maria, 2013). Some world markets could even bypass the traditional PC paradigm, and tablets or smart phones could become the platform that is widely accepted in these areas. One company, for example, is targeting India which has only 11 percent internet accessibility, with inexpensive tablets hoping they will bypass the traditional PC, much as mobile phones have bypassed the traditional land line phone (Regalado, 2013). Clearly mobile computing challenges the classic computing paradigm, however, its continued evolution relies on overcoming both technical and consumer acceptance hurdles.

First, the technical hurdles that face mobile computing have many facets. Foremost today, there is a challenge with connectivity since computing is becoming more and more decentralized and demanding high speed internet access as a normal operating condition. In fact, worldwide internet usage in mobile devices has increased from 1.6 percent in January 2010 to 14.7 percent in January 2013 not even counting tablets (Talbot, 2013). Clearly, frenzied research is taking place in order to support this rapid growth and need for network access. Taking advantage of this desire in the United States, many companies are offering free 802.11 wireless access, commonly referred to as Wi-Fi. Establishments such as Barnes and Noble, Starbucks, and McDonalds provide the service for free as an alternative to high speed data service from wireless carriers, hoping to capitalize and draw additional consumers to their establishments. These wireless "hotspots" work independently of the cellular carrier, utilizing the more traditional 802.11 radio access and internet gateways since most modern smartphones have both cellular and Wi-Fi abilities, Wi-Fi being the substantially faster of the two. Internet access via mobile devices, and the corresponding data download via cellular service, is huge money making business. The wireless carriers take in $1.3 trillion of revenue worldwide from users, with China leading the way in smartphone subscriptions; the revenue substantially more that the hardware manufactures (Regalado, 2013). Meanwhile, the hardware itself has seen an increase in price by more than 50 percent since 2007, also doubling the hardware manufactures revenues, although it still pales in comparison to the carriers (Regalado, 2013). Connectivity is the money maker and will fuel further research to continue this income tidal wave and quench the consumers' ongoing frenzy for connectivity.

The National Science Foundation launched a program in 2010, called Future Internet Architecture Program, which addresses some of the connectivity issues by focusing on improving the Internet itself (Talbot, 2013). The University of California, Rutgers, the University of Pennsylvania, and Carnegie Mellon have all undertaken projects under this program to improve the internet architecture, primarily focusing on obtaining data from closer, decentralized locations as opposed to data centers at a fixed address (Talbot, 2013). A rethinking of the entire Internet could easily transform the mobile computing methods of connectivity, concepts even as simple as no longer switching between cellular carriers and Wi-Fi, but rather combining the data retrieval into one stream (Talbot, 2013).

Another trend that is taking on traditional computing, as well as mobile computing, is the concept of cloud computing. This concept has a potential for immense impact, especially on the mobile computing sector. Foremost, a cloud computing model consists of five essential characteristics: On-demand self-service, broad network access, resource pooling, rapid elasticity, and measured service (Mell & Grance, 2011).The capacity that is provided to the end user can then be broken down into three main service models: software as a service (SaaS), platform as a service (PaaS), and infrastructure as a service (IaaS) (Mell & Grance, 2011). Another aspect of cloud computing also consists of four different deployment models: private cloud, community cloud, public cloud, and the hybrid cloud (Mell & Grance, 2011).

The biggest benefit of the cloud for mobile computing, however, is the ability to offload the heavy processing loads to cloud servers, whereas mobile devices tend to be less powerful and low on resources such as memory. By harnessing the cloud storage resources, for example, data can be stored without taking up precious local resources and have the benefit of being accessible anywhere, from any machine that is compatible. The sensitivity of the processing and data being stored must also be considered, deciding whether a private or public cloud is better suited and dictating information assurance principles. Additionally, a critical factor is that the mobile device must have Internet access with substantial bandwidth as needed, and thus access to the cloud servers being utilized. Depending upon the application, latencies and dropped connections could have catastrophic affects to the processing being performed. Several different models for mobile cloud computing have evolved. One traditional model has mobile devices served by remote cloud servers, another model consists of a virtual resource cloud similar to a peer-to-peer network, and lastly, a model with remote local cloudlets tied to the remote cloud and the mobile device, in an effort to reduce latency and bandwidth issues with the device connection (Fernando, Loke, & Rahayu, 2013).

Yet another way that the increasing complexity of communication networks is being addressed is by projects that, for example, focus on optimization of the link layer in wireless networks. Due to the many parameters involved and that our environment, air, is actually the physical layer and means of data conveyance, an adaptive approach could result in revolutionary increases of data conveyance. CogMAC, presented in a January 2013 article of Wireless Networks Journal, for example, is a project using a new paradigm that use cognition to observe, learn, and act to reconfigure parameters of the link layer accordingly (Filho, Kliazovich, Granelli, Madeira & Fonseca, 2013). This is done by tuning the parameters of the carrier sense multiple access with collision avoidance (CSMA-CA) protocol, by monitoring and adjusting as necessary (Filho, et al., 2013). Through relatively simple algorithms for performance monitoring, performance optimization, and system configuration CogMAC was able to demonstrate an increase of maximized data throughput without adding an unacceptable level of processing delay (Filho, et al., 2013). Although this was accomplished on the 802.11b wireless specification, considered relatively slow today, it has shown potential for the possible use in widespread data transfer and multimedia applications in the future.

Another technology facet challenging mobile devices is that the spectrum of wireless frequencies are narrow and tightly regulated by the Federal Communications Commission (FCC). There has been concern that these wireless bands, which are purchased for billions of dollars by wireless carriers, will become saturated. Some industry experts believe, however, that the spectrum shortage is in fact more of a mismanagement of the spectrums (Talbot, 2013). In real world usage today, cellular outages where the frequencies are overwhelmed are rare and usually at highly specific times and places (Talbot, 2013). The Microsoft Spectrum Observatory was formed and has begun taking measurements in Washington D.C., Redmond and Seattle, Washington as a project to see what spectrums of radio frequencies are actually being used (Talbot, 2013). Many times the bands are parceled out and used inefficiently which can be combated with better management and sharing of wireless frequencies, as was pointed out in a recent advisory report to the White House. Additional measures already being undertaken are, for example the installation of Wi-Fi cellular receivers in sports stadiums and femtocells, small cellular receivers, in homes to help offload the large receiver stations as well as increase cellular coverage and reliability (Talbot, 2013). Both of these technologies utilize high speed internet access to operate and, with this, AT&T feels that the current spectrum crisis has passed, at least through 2015 (Talbot, 2013). After that timeframe the abundance of new technology will have to carry the burden, but, as noted by Microsoft's vice-president of technology, they have a 15 to 20 year backlog of new technologies and architectures to carry them forward (Talbot, 2013). The demands for mobile devices continue driving technology development into new realms.

Mobile devices are clearly challenged by the demand for smaller size, which, in addition to connectivity, also means a challenge in powering these small, power-hungry devices. Most mobile technology today is powered by rechargeable batteries, of which 70 percent are lithium ion (Li-ion) cells (Hodges, 2013). The evolution of battery technology has been relatively slow, however, with a 5 percent capacity increase per year being considered good (Hodges, 2013). Clearly, this is at a much slower pace than other facets of technology, with only new chemistry accelerating the evolution, such as the transition from nickel to lithium cells (Hodges, 2013). Currently thin-film batteries, grapheme-based batteries, and refillable fuel cells are being researched and developed as promising alternatives to current Li-Ion batteries(Hodges, 2013). Another perspective of this issue is also considering the whole process of recharging the mobile devices. Both the speed of recharging and the means by which the charging is accomplished are being considered. One example of progression on this principle is the refining of super capacitors, now in development for more than 50 years but previously limited by power density, and can both deliver and receive energy very quickly (Hodges, 2013). Thanks to recent electric car developments, progress has been made on the density problem (Hodges, 2013). Another possibility is outright eliminating cables and connectors, by which the recharging process could also be simplified. A possible system being explored by Intel is very similar to Radio Frequency Identification (RFID) tag principles, utilizing radio waves from nearby radio transmitters to power devices (Hodges, 2013). Yet another completely different option is to not even require batteries, instead utilizing kinetic energy. These ideas and many other developments will continue to propel mobile computing platforms forward past technological hurdles. Just as computers used to take up entire rooms and massive amounts of power, personal computers, and now small handheld mobile devices are constantly evolving, challenging how we even think of computing.

Tomorrows mobile computer, in fact, may not even be in a format that is recognizable by today's standards. The concept of ubiquitous computing, or UbiComp for short, has been around for a while and suggests that computers will become very intimate. Perhaps the ultimate mobile computer; wearable, or even in the body as nanobots, these computers will be designed more for emotion and social connections rather than usability and utility (Bell, Brooke, Churchill, & Paulos, 2003). As Yvonne Rogers describes in her paper on Mark Weisner, one of the forefathers of UbiComp, "the world would be similar to the world of landed aristocracy in Victorian England who's day-to-day live was supported by a raft of servants that were deemed to be invisible to them" (Rogers, 2006). Computers would, by Roger's assertion, become actively engaged with humans and enable them to do what they want or need without any consideration or forethought (Rogers, 2006). One big difference from traditional computers is that UbiComp requires a rethinking of interfaces such as displays and controls. A multidisciplinary approach to creating these computers would be necessary, possibly combining traditional computing with artificial and ambient intelligence into a holistic framework (Zaharakis & Komninos, 2012). Ubiquitous computing not only relies on mobile computing, but an entire framework of distributed computing and applications. Ultimately the computers themselves disappear into the world around us and become present only through the nature of implicit interaction, such as merely being present (Zaharakis & Komninos, 2012).

Currently there is no single UbiComp operating system that supports a ubiquitous environment with heterogeneous devices; typically they are supported by a tightly collaborated system of computers and devices managing different interaction capabilities or interfaces (Tandler, 2004). The BEACH software framework in development serves as a framework for interaction with roomware, room elements with information technology, and attempts to allow functionality with heterogenic devices (Tandler, 2004). This innovative thinking has the potential to propel and forever change mobile computing far beyond what can be imagined with today's technology.

The mere presence of your mobile device could interactively change your entire personal surroundings, tailored to your specific needs or preferences. Additionally, privacy concerns have been raised when considering ubiquitous computing and become vividly clear when considering a mobile device interacting with the environment in a synergistic manor to meet a user's desires or requirements without any interaction. Ultimately the user will have to feel comfortable with this technology for it to become mainstream electronics for consumers.

Another avenue being explored for interacting with mobile computers is pico-projectors, in which the output is projected in a similar manor to larger projection systems. In a survey of users that tried a prototype system, they had surprisingly negative responses and felt anxious about projecting their content on a wall, fearing that personal content, such as text messages, could be made visible (Wilson, Craggs, Robinson, Jones, & Brimble, 2012). Much as cameras, once rarely seen on phones, were thought of as a new form of input device, these pico-projectors could eventually become a new form of output for mobile devices. New laser based projectors are reducing power consumption and high level prototype models are already becoming a reality (Wilson, et al., 2012). In two surveys conducted, insight was gained on both the type of surface that was used for the projection, as well as the data, media and information type that was being projected. It was found that overwhelmingly walls were used as the primary projection surface and the data projected was typically static information in the form of text, with static internet information also leading the study (Wilson, et al., 2012). This information seems to suggest that the new projection technology was still being used in a traditional projector role by subjects.

Another interesting product that is now in final development is Google Glass. This project seems to reinvent the concept of mobile computing, by fitting an android based compact computer into a pair of eyeglass frames. Much like the pico-projector, this item brings the same feeling of reading a projection but eliminating privacy concerns by displaying computing content from a small boom mounted display. Similar viewable output has been around for a long time in an arguably more simplistic form as a helmet mounted system (HMS) primarily for military aviation. The HMS's incorporate tracking and targeting systems as well as tactical information in both day and night ("Helmet Mounted Systems", 2013). The Google glasses are, however, using standard components used by most cellular smart phones today and ultimately expected to be about the same price as a tablet or smartphone. As MIT Technology Review points out, it is a bold move for Google, suggesting they hope to tap some of the mobile device revenue stream (Regalado, 2013). One big question remains, "Will consumers accept it?"

One of the big issues seems to be that consumers are still trying to figure out how the device can be used, although only a limited number have been released to developers at $1500 for each prototype (Simonte, 2013). One of the hyped features seems to be the ability to record, stream, and play back videos, as well as traditional photos. An ESPN reporter, Katie Linendoll, had two NFL players play catch while wearing the glasses and received a favorable response (McNamara, 2013). Great for some training, but as Network World points out, for real game usage, NFL rules would have to be changed for in game communication and durability would certainly need to be addressed in such a rough sport (McNamara, 2013). The display is not the only thing different in Google Glass, the input controls are primarily voice activated and the audio output in the device is conveyed via bone-induction technology (Rivington, 2013). Reportedly there is a touch pad on the side for scrolling, giving a slightly more traditional interface if desired (Simonte, 2013).

Software developers will also need to rethink traditional methodologies for this and other similar new mediums and tailor applications suited to the new interfaces. Sadly, it appears that there is no one dominant application at this point for Google Glass, suggesting that everyone is still unsure of the medium (Simonte, 2013). Perhaps thinking of this device in more of a UbiComp context and allowing this new platform to enhance the world around them will yield greater results. I could foresee a device like this being used at lectures for example. It would have the capability to stream multiple audio languages as well as text and/or sign language for those with disabilities. Additionally, the display could point out and highlight key points or places on stage in real time. One problem I already imagine is the possibility to make recordings when they shouldn't, possibly causing copyright issues or infringing on another person's privacy. Another interesting possibility that has been mentioned, is the use of targeting marketing in the form of advertisements; however Google has stated they have no plans for ads on the device (Simonte, 2013).

The glasses have already been targeted by security professionals, resulting in the first patch from Google (Schwartz, 2013). A vulnerability was exposed and exploited, leading to a full compromise of the machine because the glasses use scanned QR codes for configuration options and, after passing a malicious QR code, was combined with a known Android Web vulnerability (Schwartz, 2013). Truly this shows how rethinking the classic computer paradigm also requires a rethinking of security as well, particularly when new and sometimes combined exploits are developed. Depending upon how these devices end up being used, or in what context, a security compromise could truly have devastating effects, possibly even resulting in bodily harm. One good point, however, is that the Google Glass display merely appears as a small screen. Other companies, such as Microsoft and Apple, are also developing versions of computerized glasses, possibly even utilizing augmented reality (Carlson, 2012). With this technology, the device will actually overlay data onto the live view, much more similar to the aviation HMS.

Wearable technology may be the next step in mobile computing; however, most devices are still in development. One device, called Pebble, has taken a slightly different path but in contrast, is already in production. The goal of the designer in the Netherlands was not to create a new wearable device, but rather to simply view his phone without crashing his bike (Pavlus, 2013). What evolved was a watch like device, which is simply a different interface to an existing smartphone. The designer purposefully kept it simplistic, using it to display a watch, caller ID, texts, and control music playlists for example, whereas to not reinvent the already existing smart phone (Pavlus, 2013). Simply worn like a watch, it connects via Bluetooth and has a 144×168 1-bit display, a 3-axis accelerometer and a Cortex-M3 ARM microprocessor ("Develop for

Pebble", 2013). The device is customizable, has several small applications available, and even offers an open development kit for full custom application development. The watch like device works with Apple IPhones, Android phones, is being sold already, and currently has a retail price of $150 ("Pebble",2013). Amazingly this project was funded simply by an online fund-raising platform, raising more than $10 million, a record, and indicating a clear desire by investors and consumers for such a device (Pavlus, 2013).

When it comes to mobile technology, consumer acceptance is clearly a major hurdle, especially when redefining the computing paradigm. Microsoft, an industry giant, has been struggling with that acceptance recently with a tablet they developed and released, the Surface RT. The device was highly publicized and had high expectations by Microsoft, but recently has been described as "an epic flop" in Information Week and resulted in a $900 million write down (Endler, 2013). One issue is that the tablet uses a special version of Windows 8, Windows RT, that is designed to run on ARM-licensed processors such as the tablet uses. Most smartphones today use ARM processors and Microsoft is attempting to merge code bases between the different platforms, phones, tablets, and desktops, as well as give a consistent feel to consumers (Keizer, 2013). I recently purchased a used Surface RT tablet myself from an unhappy consumer and discovered the one huge pitfall is that the only programs that run on the device are those purchased and downloaded from a limited selection in the Microsoft online store. Microsoft does offer a slightly larger, more powerful version of the tablet, the Surface Pro that runs a traditional Microsoft OS however, at a larger price. As a move to stimulate sales, Microsoft has dropped the price on the Surface RT tablet by $150, to a retail price of $350 for a 32 gigabyte model.

Even traditional smart phones themselves have been transforming. Initially having small physical keys, most have moved to touch screen interfaces utilizing capacitive touchscreen panels to receive input. Notably, Apple with their release of the iPhone in 2007, and improved models in subsequent years, has truly pushed the limit of what was once though possible on a smart phone. With the ongoing quest for smaller and lighter devices ,surprisingly the latest trend seems to be larger screens. Some manufacturers like Apple are rumored to have decided at the last moment to implement a larger screen on their next generation phone, and causing manufacturing delays (Zeman, 2013). Rumors and speculation has become commonplace for consumers in the mobile technology realm, many manufacturers shrouding their next device in secrecy in this highly competitive market. Many times consumers are in a frenzy by the time a product is released, such as with each generation of the iPhone, which sold 47789 units in the first Quarter of 2013 for $30,660 million of revenue ("Apple Reports Record Results", 2013).

If mobile devices are designed to meet the wants and needs of consumers it will sell. Scientists and engineers will continue research and development into new realms. Technology itself will continue to evolve, with developments such as the latest nanotube computer transistors. These carbon molecule based transistors in development by IBM are reported to run three times faster on only one third of the power of their silicon counterparts (Talbot, 2013). This technology will eventually make its way into mobile computing devices, providing new development opportunities not even imaginable today. I have highlighted how new technologies and programs like the Future Internet Architecture Program, mobile cloud computing, CogMAC, femtocells, battery alternatives, and carbon based nanotubes have been developed to help overcome technological hurdles. Clearly though, another part of the equation is the consumer demand and desire to implement the new technology. New methodologies like ubiquitous computing, new interfaces like pico-projectors and wearable computers such as Google Glass and Pebble will continue to materialize in an attempt to satisfy consumers. Engineers can and will continue to design new interfaces and ways of interacting with mobile devices, and many will make interesting scientific projects. Market testing and consumer research also has to be completed. Ultimately, unless there is consumer acceptance, there is little chance that a mobile device will gain acceptance and possibly change the classic computing paradigm.

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