Mobility is Not PC: Technology-Driven Differentiation in a PC+ World

Executive Summary

While having very different origins, the mobile and PC markets are starting to merge. Smartphones are an extension of the reliable, regulated and high quality feature phone purchased from mobile operators vs. the PC which comes from an open, unregulated, and price-driven beginning. Dividing the middle are media tablets that now offer features from both products and are priced well below the existing PC segment. Industry dynamics have changed considerably over the last 5 years and these very different markets are coming together to build very new and much more personal products.

The inevitable shift from lightly differentiated, general purpose PCs and single app feature phones to more purpose-built, highly differentiated, more personal mobile devices is a fundamental market disruption that changes the way personal computing products are used and designed. This shift and the ecosystems they are creating will change how new technologies are commercialized and deployed. Both markets will need to adapt and change to participate and master this new market or face losing considerable business.

Why is “purpose built” a factor? “Purpose-built” implies that designers know much more about the people who will buy their systems. A new generation of co-designed mobile hardware and software platforms are based on user experience research and enabled by increasingly inexpensive and more capable sensors. As mobile platforms become sophisticated compute and sensor integration platforms, battery power continues to be the center of design consideration. Because the rest of the platform is becoming more user-centered and demanding more of a system’s power budget, the processing complex integrated into a “system-on chip” (SoC) – application processors, graphics processors, DSPs, and fixed-function accelerators – will have to do more within a static power budget. Increasingly sophisticated hardware-software co-design tools and software application programming interfaces (APIs) are enabling this proliferation of processing options.

Where IBM opened the PC market by accident, the disruptive shift to purpose-built personal mobile devices has been enabled and accelerated by the intentional intellectual property (IP) licensing practices of ARM and Qualcomm. ARM’s IP enables the fabless design of increasingly more complex processor-based SoC solutions. Qualcomm enables increasingly faster and higher quality wireless wide-area network (WWAN) based Internet connectivity. The two have contributed to bootstrapping and accelerating the smartphone and touch tablet markets in just a few short years.

Intel and Microsoft are still formidable adversaries, but they are living The Innovator's Dilemma in the mobile market – the business models and processes that worked for them in the PC market are not optimal in the mobile market. Individual component performance is giving way to balanced system designs, where overall user experience determines a superior product.

Intel is intent on participating in smartphone and tablet form factors and appears to be learning fast, specifically in technology R&D and SoC integration and acquired its radio technology. Microsoft is not optimized yet for an app ecosystem and may be hampered by its own PC market business success and inertia.

All of these quickly shifting dynamics pose a challenge for both the PC and mobile ecosystems. The PC ecosystem is challenged with very low growth, compressed margins, channel integration, and a lack of differentiation. Mobile and wireless market players are experiencing a shifting ground and challenges as well, including the handset maker's vertical integration, the resources required to support software ecosystems, and the control of the consumer.

PC Market Dynamics

History

The early PC market was the product of a happy mistake. IBM underestimated the market potential of their entry into the PC market. They created a hardware platform using off-the-shelf components; other vendors were able to copy their platform. Then they let Microsoft retain the rights to sell PC-DOS under their own MS-DOS brand, and the entire market had a unified software development target. Once BIOS had been cleanly reverse-engineered and an open expansion bus created (the "ISA" bus), the market routed completely around IBM's attempts to control it, primarily through large and ultimately futile investments in their MicroChannel expansion bus and OS/2 operating system.

The net effect was a "rising tide lifts all ships" market. If a system vendor could build a 100% compatible PC, they could sell it. If a software developer wrote software to the new standard, it would run on every PC. A virtuous cycle of hardware and software availability coupled with IBM's enterprise and consumer legitimacy created a market that left other personal computing choices behind. Even Apple's prescient Macintosh user interface could not stall the virtuous cycle.

This virtuous cycle of market expansion and software developer attention spurred software developers to add features ahead of hardware's ability to satisfy those feature's performance demands, which spurred hardware developers to innovate faster and accelerate those new features.

Maturity

After three decades of rapid hardware and software co-evolution, the PC market has stalled as measured by per cent growth. At the center of the stall is the simple fact that the performance of personal productivity and a host of other high value applications on the PC platform are "good enough." Outside some specific apps and workloads, consumers and enterprise buyers cannot easily tell the difference between the performance of a three-year-old hardware platform and a current hardware platform because they are both over-performing for basic application suites.

At the same time platform performance has become good enough, external interfaces and network connectivity options have narrowed and standardized on a few undifferentiated options, primarily the headphone/microphone jack, USB, HDMI and Intel's Thunderbolt, RJ45 for Ethernet 10/100/1000, Bluetooth, and 802.11 WiFi.

Adding to the mix, Moore's Law has been relentless. Intel and AMD have consolidated all of the logic required to build a complete PC or x86 server into single SoCs or a scant few chips (two or three). Intel's relentless technology investments and "tick-tock" schedule of interleaved core upgrades and process shrinks has eviscerated the smaller AMD's ability to compete effectively on single threaded performance or price. AMD has occasionally fielded products that were competitive and in some cases more competitive than with Intel's, but has not been able to leverage its unique patent cross-licensing agreement with Intel into a long-term, profitable and market share leading position.

In distant third for PC chipset share, NVIDIA is the sole remaining independent PC logic manufacturer with any scale, driven by their graphics brand and small but stable high margin business in graphics add-in cards for workstations and high-end PC gaming. Outside of those high-end graphics segments, Intel and AMD processor- and chipset-integrated graphics rule the PC market.

Meanwhile, Microsoft consolidated their position as the only PC OS vendor of merit, outside of Apple, who is still a distant second in unit market share. Microsoft's Office productivity suite long ago conquered the market for personal productivity for companies and consumers and is now the best-in-class solution by a wide margin. Microsoft's OS absorbed the web browser, and now their Security Essentials has taken aim at the PC malware protection market. Like NVIDIA on the hardware side, Adobe Systems survived against Microsoft by carving out a profitable niche in high quality graphics and video editing turning it into a defensible, high value niche.

Intel and Microsoft both have business models based on high volume sales of a small number of product variants. They historically targeted those variants at broader, horizontal market segments, and not at individual customer needs and differentiation. Intel and Microsoft have eliminated most significant opportunities for their customers to differentiate their branded platforms.

Compounding the business model issue, most notebook PC buyers no longer care as much about their processor speed, graphics configuration, memory size, disk space, or other component based specs. They do care about notebook weight, screen size, keyboard feel, and shell color – the external and physical properties of their new PC – but battery power is now the last high-ranking technology-based buyer concern.

The result is that PC innovation peaked a few years ago, and since then there has been a massive consolidation of component and system manufacturers and their product brands. It is promising to see all the different and innovative Windows 8-based form factors like convertibles and hybrids, but it is too early to call whether this will be impactful enough to drive significant growth or just keep the PC market from negative growth. Apple's increasing share of the PC market is about to meet AMD's decreasing market share in the low teens. The choice of Windows vs. Apple is becoming a legacy investment vs. style decision, but whether buyers choose a Windows or Apple PC, the odds are overwhelming that they will buy an Intel CPU-based hardware platform. Apple's market share is ascending because Apple's user experience and style choices are differentiated from the rest of the PC market.

PC market competition is now mostly price-driven. Asian manufacturers like Lenovo, ASUS and Acer have routed around multi-national PC vendors to sell directly into major markets under their own brands. Further indication of who is profitable and who is not is the state of consumer PC advertising – the bulk of advertising dollars originate with Intel and Microsoft and are rebated in various forms to their customers. HP, Dell, and the other major market PC vendors link their ad campaigns to in-kind marketing funds from Intel and Microsoft. The industry catch-all phrase for this is "MDF" or market development funds.

Over the past two decades, Intel and Microsoft have both tried to push the other away from the core of the PC market to corner even more of the profits from the platform. Intel has been writing system software for almost two decades in attempts to push platform performance faster than Microsoft has been willing to move, starting with its ill-fated Native Signal Processing (NSP) effort. Intel has invested heavily in Linux and new user interfaces for that OS, especially for use in high-growth emerging regions. Microsoft took an early run at displacing x86 with its late 1990s Windows NT releases for Alpha, MIPS and PowerPC, but x86 volume economics marginalized those competing processor architectures. Microsoft is in the process of launching Windows RT to legitimize ARM-based processors in the core consumer PC market, which, so far, has boosted ARM's credibility while not yet significantly enhancing Microsoft's.

Innovation

The early market provided substantial profits for everyone in the PC value chain. The first two decades of the PC ecosystem were characterized by both point of sale customization and a very active aftermarket upgrade market.

The PC's initial extensibility via the ISA bus and following expansion bus standards enabled rapid hardware responses to new telecom and network standards, as well as improvements in graphics, display technology, user interface innovation (mouse, game controllers, and specialty devices like pen pads), and peripherals like printers, external hard disk drives, etc. In addition, Intel and AMD offered processor speed upgrades within generational families of processor sockets. PCs were expensive purchases and buyers (consumer and commercial) expected that they would be able to upgrade most of the components over time to extend the life of their initial purchase.

From 1981 through Y2K the entire PC ecosystem thrived on continuous innovation and a virtuous cycle. But post-Y2K the PC market matured:

- Comparatively large chassis volumes do not mandate highly integrated single-chip SoC solutions. The continuing feud between Intel and AMD focused on primarily on performance, but not on single-chip solutions until very recently.
- Hardware's delivered performance caught and passed most software applications' performance demands. Leading-edge PC games and vertical market numerically-intensive workstation applications are the last hold-outs where PCs do not have enough performance, but they are comparatively tiny markets.
- Focusing almost exclusively on performance meant investing in performance tuning design teams and state-of-the-art process technology ahead of the rest of the market. Jerry Sanders, AMD's founder, has been widely quoted after saying "real men have fabs." While that was true then, the corollary to Moore's Law is "your next fab will be twice as expensive as the last." As performance became less of a sales driver and as AMD fell farther behind Intel on process technology, AMD spun-out their fab as GLOBALFOUNDRIES.
- Demand for ever smaller and thinner notebook PCs significantly reduced upgradeability as a purchase consideration.
- USB enabled user interface and other peripheral devices to be moved outside of the chassis and the initial purchase experience as a separate upgrade purchase.
- Continuing feature integration into the PC processor and chipset silicon obviated the need for widespread graphics and networking cards, while new digital display standards enabled even the smallest of PC chassis to use the latest high-definition external displays. Chipset integration now provides cost and pricing advantage, but little performance or feature differentiation advantage.

The latest innovation in the PC market is style-driven, a prime indicator of a mature market. With the advent of Apple's iPad, Apple has also been driving its MacBook product line to very slim "z-height" or thickness. With just a few notebook product SKUs (two MacBook Air and two MacBook Pro models), Apple can afford to spend a lot of R&D producing a very thin product and pay for that R&D by employing boutique branding and pricing strategies.

Intel has responded by developing a line of "Ultrabook" branded board designs and specifications for its customers, but Intel's PC vendor customers have been challenged

so far in selling those Ultrabooks against Apple's MacBook products at similar prices. It seems that when consumers are presented with an option to buy expensive Ultrabooks or expensive MacBooks, they prefer the MacBook brand caché. If price is a consumer's prime concern, today they spend much less money buying a notebook, trending toward even lower priced, full-featured notebooks. Intel's latest designs for Windows 8-based convertibles, tablets, and touch-based and lower priced Ultrabooks could turn the tide, but it is too early to tell as they are just now entering the market.

Key areas where innovation still matters in the classic PC market:

- **Keyboards and precision pointing** – synonymous with "productivity," the keyboard and mouse are tied to Microsoft's Office suite and Adobe's high-end photo/video editing products. With the introduction of Windows 8 and RT, this may morph over the next couple of years into a generic "clamshell" form factor value statement.
- **Natural user interface**- Intel calls this "Perceptual Computing", where users can interact with their future PC through voice, air-touch, and even automatic interaction through advanced sensors.
- **Portability and mobility** – PC notebooks are still striving for a true full day of battery power. Given that battery charge density has plateaued and form factor volume is decreasing, this translates directly into lowering processor power, but Intel's current generation of Core-branded processor cores were designed with different goals in mind, but Haswell-based designs could deliver this.
- **Sensors** – so far the PC market is slow-following the smartphone and tablet markets for sensor integration. Intel is integrating more sensors into their current generation of reference designs, but that increases platform cost and Intel is not willing to sacrifice margin to stabilize overall platform cost for their customers.
- **Design** – PC makers see the success Apple has with sexy designs and have followed suit. In the future, it will be even more important for them to be experts in industrial design for future PC tablets, convertibles, and hybrids.

Mobile Application Platform Market Dynamics

History

The mobile computing market did not coalesce around a single platform, in stark contrast to the PC market. It was the product of the feature phone, various experiments in mobile productivity ("personal digital assistants") crossed with the evolution of high-bandwidth WLAN (wireless local area network) and WWAN deployments. Therefore, until recently there has been no "rising tide lifts all ships" effect in the mobile market.

Before the advent of application stores and app ecosystems, individual companies invested in integrated hardware and software product stacks and then succeeded or failed on their own. There are still vestiges of this early market in the market; one example is Samsung's Kies software products.

The principal design center for cellphone platforms was and continues to be, for smartphone and media tablets, a dependable, reliable, and high quality experience. Each smartphone was and still is tested by each carrier and government regulators. Consider E911. When a caller dials their emergency service, it must connect 100% of the time. There is no room for error. The phone cannot reboot, blue screen, or get bogged down by a background virus scanner. This design principle in cellphones carried over to today's smartphones and media tablets. The mobile industry is now taking this principle to converged devices like PC hybrids and convertibles like Microsoft Surface.

The key innovation vectors for these markets have been WWAN and usage model evolution:

- **WWAN evolution** – reduce modem and transceiver solution size, power demands, and cost while improving range, quality of service, and bandwidth.
- **Usage model evolution** – start with simply making a phone call, then add features and organizer functions on the way to becoming an application platform; increase screen size and incorporate more sensors to improve user experience while maintaining a full day of productive battery life between charges.

There were two transition points that most influenced the transition from PC to mobile:

- **Email** – RIM pioneered turning handsets into mobile email clients. Their initial market was mostly enterprise; companies that valued mobile access to email bought millions of Blackberries for their employees. As consumers started to integrate email into their lives, more phone platforms offered email access.
- **Apps** – touch differentiated Apple's iPhone usage model, but it was not until Apple's App Store ramped up that the iPhone moved from boutique to mainstream. The difference between mobile apps and PC applications is that PC applications are expensive – not an impulse purchase, buyers do their homework and rely on reviews and ratings – while mobile apps are priced so that most are $10US and below – easy to try without due diligence and then upgrade to a better app if and when one becomes available.

Retrospective – High-End Phone Comparison 2003 to 2013

	2003 Feature Phone	2013 Smartphone
Network	2G; 3G just coming online	4G; 4G LTE just coming online
OS	Bulk of market is proprietary; first RIM Blackberry ships, as does Microsoft Windows Mobile 2003	Google Android, Apple iOS, Microsoft Windows Phone; Nokia, Blackberry in decline
Apps	Built-in, written by vendor; downloads emerging	OS ecosystem-aligned app stores
Memory	Enough for a few lightweight features and apps	16-32GB+, enough for audio play lists and video downloads
Display	3-4 rows of monochrome dot matrix characters moving to low resolution bitmaps	720-1080p with full-motion video playback
Primary Interaction	Physical number keys or alphabetic keys	Touch with virtual keyboard and voice recognition
Camera	Crossover – more phones sold with than without	Two (front and back) are becoming standard
Battery life	All day voice standby; replaceable battery for longer talk times	All day with background tasks, light email, and voice standby; replaceable battery is differentiator
Form Factor	Candy bar – thick and chunky	Slab – thin matters

At the point where basic productivity apps became available, the combination of always-connected mobility, email, and a growing number of useful apps propelled smartphones and then tablets into competition with the maturing PC market for consumers' disposable income.

The mobile computing market currently has two major ecosystems, Google's Android and Apple's iOS. Both have approximately 700,000 apps available, with Apple at 35 billion app downloads and Play at 25 billion (both as of September 2012).

In addition, Microsoft has clear aspirations for Windows Phones and Windows 8 RT for ARM-based tablets and clamshells. Microsoft recently reported they have 100,000 phone apps. Amazon is rumored to be considering a stronger role in designing SoCs for its own devices and content plus Android app store. Designing endpoint platforms is not a stretch for Amazon, they design their own book readers and tablets in their Lab126 platform design shop.

Further, there are dozens of handset and tablet designers supporting numerous merchant and custom SoC design houses.

The mobility-enabling shift in SoC design is a simple combination of three trends:

1. **ARM's ecosystem and design tools:** The ARM ecosystem has reached a sufficient state of maturity that any well-funded products company can resource an ARM SoC design effort. The biggest challenge is writing software to enable new hardware features, not designing the hardware itself.

2. **Processing off-load engines:** General purpose graphics processors, DSPs, and fixed-function accelerators enable SoC designers to optimize their choices between programmability, performance, cost (die size) and power consumption.
3. **Merchant semiconductor foundries:** With AMD's spin-out of GLOBALFOUNDRIES and investments made by TSMC and other merchant fabs, it is possible for SoC design teams to have their designs cost-effectively manufactured in volume with leading-edge process technology, without owning their own fabs.

The net effect is that fabless design and contract manufacturing of ARM-based SoCs has already become a commodity. SoC vendors have adapted by driving differentiation with value-added intellectual property, notably in processing offload acceleration. In the mobile market, the top differentiators for system design complexity, battery life, and Internet access data rates are currently processing offload engines and WWAN, both baseband and transceiver designs. New interaction methods and more reactive user experiences are driving SoC designers to make novel optimization choices. Delivering processing offload acceleration also requires substantial investments in developer tools and software APIs in order to keep pace with market innovation.

Designing WWAN solutions requires heavy investment in generating IP for next generation standards, as well as in testing and qualifying solutions with customers to support a wide range of customer form factors and power budgets.

Key Ecosystem Participants

Key players in the mobile ecosystem competitive arena are:

Category	Vendor	4G WWAN	Processor	SoC Design	SoC Fab	System Design
Licensable IP	ARM	N/A	ARM design	N/A	N/A	N/A
	Qualcomm	QCOM	ARM license	Yes	No	No
Vertical Hardware Platform	Samsung	QCOM	ARM license	Yes	Yes	Yes
	Intel	Intel	Intel x86 design	Yes	Yes	Yes
	NVIDIA	NVIDIA	ARM license	Yes	No	No
	MediaTek	QCOM	ARM license	Yes	No	No
	HiSilicon	QCOM	ARM license	Yes	No	Yes
	Apple	QCOM	ARM license	Yes	No	Yes
Vertical OS, App & Content Ecosystem	Google (Motorola)	QCOM	ARM license/ Intel x86 Platform	No	No	Yes
	Amazon	QCOM	Rumored	No	No	Yes
	Microsoft	QCOM	ARM license	No	No	Yes

NOTES:

- N/A= Not Applicable
- System design= designs or expected to design sellable phone
- TI excluded given their market exit announcement

ARM
ARM has the most widely licensed application processor Instruction Set Architecture (ISA) on the market today, and their System-on-Chip (SoC) product portfolio includes substantial depth in general and market segment specific functional blocks and tools for SoC design. ARM invests heavily in their application processor roadmap, typically introducing two or three new designs each year. They work closely with the top tier of merchant semiconductor fabs, notably TSMC and GLOBALFOUNDRIES, to speed licensees' time-to-market while boosting performance and product quality.

ARM's maniacal focus on remaining a pure-play R&D and intellectual property licensing business coupled with their end-to-end "design tools to manufacturing quality" view of customer service have created the conditions for their customers to compete effectively with Intel. With a large number of licensees aiming at this market, the ARM ecosystem will put pressure on Intel to step up its product cadence and rate of innovation.

NVIDIA
NVIDIA is currently on their third generation of mobile silicon, the Tegra 3. They could be the industry "dark horse" given their graphics leadership, secrecy and overall aggressive tactics. While not necessarily driving high market share in smartphones or tablets, they have captured key design wins inside the Microsoft Surface RT tablet and Google's Nexus 7 tablet. This was accomplished with the industry's first quad core-based mobile SOC but a bit behind on the graphics hardware as of this publish date. NVIDIA compensated for this with extensive amount of software work, which they are very well known for in the industry. Of the hardware makers, NVIDIA is distinct in that it has experience and success in both the PC *and* the mobile space.

Qualcomm
Qualcomm licenses the WWAN and WLAN baseband and transceiver technology at the heart of mobile Internet access. Their heavy wireless R&D investment has placed them on the leading edge of 3G and now 4G (ODFM5) technology licensing and products. Radio and antenna design are arcane arts that demand experimenting with systems built in a target manufacturing technology in that they can't be done without building product-quality silicon and systems. Each new radio takes substantial investment in debugging the hardware and software integration of a baseband processor, radio and power management functions, and a communications protocol stack. It is complicated and difficult and requires sustained R&D investment.

Therefore, Qualcomm's business model is a little more complicated than ARM's, as it was comparatively easy to design their own ARM-based processors, chipsets, and SoCs for mobile endpoints once they had their radios designed. Their products integrate applications processors, graphics and multimedia, radio baseband processors and transceivers, and sensors. Their customers have a choice of licensing radio technologies, buying specific blocks, or buying a complete system design.

Qualcomm ships more integrated DSPs than any other SoC manufacturer and enables third party software developers and system manufacturers to program the DSP offload processors in their recent Snapdragon processors. Their goal is to allow their ecosystem partners to integrate proprietary algorithms and to update their products with the latest multimedia standards while minimizing power consumption.

Samsung

With Android now at 75% of smartphones sold, Samsung's commanding share of Android phones put it in a market leadership position. They also have opportunity in Microsoft's Windows 8 RT ecosystem. Samsung has complete vertical control over their smartphone and tablet platforms:

- They license application processors from ARM and wireless technology from Qualcomm.
- They have large, well-funded SoC design teams and have designed several generations of smartphone chipsets and SoCs.
- They are a major semiconductor manufacturer and don't have to contract manufacture at fabs like TSMC or GLOBALFOUNDRIES.
- They build most of their own components for smartphones in-house, including manufacturing their own displays, power regulators, flash memory, etc.
- They are a world leader in manufacturing consumer electronics for retail sale.

Samsung wants to be the world's premier consumer electronics manufacturer, which puts it into direct competition with Apple, for whom it manufactured many critical early generation iPhone components. Apple is rumored to divorce itself from Samsung due to Samsung's success in enabling Google's Android mobile ecosystem with superior client hardware platforms.

Intel

Intel has the biggest opportunity in the Google Android and Microsoft Windows 8 ecosystems. In this new mobile market Intel carries less weight than in its core PC market, but they are still a formidable competitor:

- Afford huge R&D investments.
- Own their own processor core and SoC technologies.
- Have their own WLAN and WWAN technologies.
- Major semiconductor manufacturer and have industry-leading process technologies – literally second to none.
- Build all of the logic components for smartphones in-house, and have clear line of sight to DRAM and flash memory supply through their relationships and flash joint venture with Micron.
- Close relationships with ODMs capable of building low-cost smartphones and tablets.

Intel's PC products design and manufacturing philosophy is a lot like Henry Ford's – everyone gets the same product, with some minor differences in performance. They are a single vendor without a custom SoC design methodology; they are competing with

a host of ARM licensees building custom products and with overlapping cadences. Intel will have to step up its SoC design processes and number of products in-flight to compete better against the ARM community. Perhaps Intel's most limiting strategy is its focus on keeping as many compute tasks on its application processor cores for as long as possible. That said Intel already built a reasonably competitive smartphone hardware platform, called Medfield, with its ODM partners and is learning fast. Medfield did utilize a complete SOC approach and utilized third party IP from Imagination for GPU and video and Silicon Hive for the ISP (Image Signal Processor)..

The downside to Intel's fab competitiveness is the huge investment it makes in maintaining its process technology lead over the rest of the industry. Intel may have to slow its rate of semiconductor process investment if the PC market declines faster than Intel's competitiveness increases in newer markets. The other hedge against that downside is if Intel places a major push to open its fabs. They are doing that today, but not in a big way.

Apple

Apple invented the end-to-end app ecosystem when it invented the applications store concept with its aptly branded "App Store." Furthermore, Apple pioneered a vertically integrated products and services stack where it owns all of the margin control points:

- Apple designs its own client hardware platforms and then contract manufactures them at lowest cost, therefore capturing a layer of margins that would have gone to value-added design services and 3rd party hardware manufacturer brand value.
- Apple is now designing its own client processor system-on-chip (SoC) to absorb margins that would have gone to a branded SoC design company such as Intel or Qualcomm.
- Apple rules the mobile hardware supply chain for commodity components through volume purchasing contracts driven by the brand value it has created.
- Apple writes all of the critical software in its vertical stack – iOS, iTunes, and App Store.

Google

Google is the only currently viable end-to-end ecosystem competitor to Apple's vertically integrated powerhouse. The major difference between the two is their business models:

- Apple's business model is to sell a content/app-based experience. Apple has been called a vertically-integrated branding company. The iPhone is a critical component of the experience.
- Google's business model is to sell advertising; to everyone, everywhere, all of the time. To do that their advertising must be context-relevant, regardless of the platform or circumstance. Ad relevance is built by profiles, knowing what the user is doing, where they are doing it, with which they are doing it with, and ultimately why they are doing it.

To Google, the smartphone is a sensor and display platform aimed at improving the relevance of their advertising and hence improving their ad click-through rates. Smartphone sensors stream real-time data to big data analytics in their cloud, which then figure out a consumer's real-time physical context to determine which ads will be most relevant to display.

Google's position in the current mobile industry is analogous to Microsoft's in the early PC market – they want to enable all hardware manufacturers because they want their ads to show everywhere. Google has the cash to negotiate whatever agreements they desire for IP, client hardware, content, etc. They can control the rest of their value chain as needed. Unfortunately, wireless carriers can't figure out how to make more money with Google than they can with Apple, and Google doesn't seem to be interested in solving that problem yet. And they haven't figured out how to reward the rest of the mobile hardware manufacturers to invest in keeping up with Apple and Samsung.

Amazon

Amazon has the potential to dominate the tablet market leveraging its book reader and video business and online store. Through its Kindle Fire tablet line, Amazon has experimented with aligning with Google. At this point it is unclear whether it is in Amazon's long-term interests to do so, but in the short-term the tentative nature of their relationship is slowing Google's tablet momentum. Amazon's value is content – they own the online market for the printed word and can rival Apple in negotiations with audio and video content owners.

Amazon can also compete with Apple in acquiring low-cost mobile hardware platforms through their existing value chain relationships and volume purchasing power. They already design their own book readers in their Lab126 platform design subsidiary.

Microsoft

Microsoft, like Intel, is under assault from tablets and smartphones. It has fielded experiments in both form factors but has not been successful to-date. They have placed a substantial bet in both markets with Windows Phone and Windows 8 RT – both of which initially run on ARM SoCs. Surface Pro will run on Intel X86. Windows 8 RT is a game changer for ARM, in that it legitimized ARM for use with Microsoft's enterprise-class OS and its industry leading Office personal productivity suite. The challenge for Microsoft is that it must become the third viable mobile ecosystem as a declining PC market diminishes the value of its PC OS franchise.

Microsoft's current management is finding it difficult to avoid The Innovator's Dilemma. Their current PC customers and sales channels restrict their mainstream client hardware activities. Microsoft designs and contract manufactures game consoles and human interface peripherals, but they ran into recent PR and relationship problems with their PC customer base by designing a "reference" branded tablet platform and it is not clear how that will resolve over the next year. Given Microsoft's recent "services" and "devices" position, it appears Microsoft is in the device category for a long time.

Innovation

The mobile market has two primary vectors for **economic innovation** – the further commercialization and cost reduction of processor and SoC technologies and consumer preference for "purpose-built" over general-purpose PC products.

Before the PC, processors were custom designed to address specific markets. Brands that succeeded over the long term addressed more general markets. The PC market introduced the concept of a single processor architecture (with minor variants) that spanned both system vendors and a wide range of market needs – a general purpose platform that suited a rapidly evolving market. However, transferring the economic burden of designing and manufacturing processors to one company in the end transferred a large amount of the margin in that industry to that same company.

ARM's business model takes and additional step down the path of commercialization. It consolidates R&D but disaggregates design and manufacturing, enable a community of design teams to address purpose-built opportunities as they see market opportunity – some will opt for more mass market, general solutions and some will focus on specialty niches. The market risk and the opportunities are spread among many companies.

The practical reality for the mobile market is that economic innovation is dependent on participation in an app ecosystem. Google and perhaps Microsoft operate the only large scale ecosystems that will remain open to third-party SoC and hardware platform manufacturers through the next five years.

Feature innovation is loosely aimed at two goals – increased mobility and portability and better user experiences (UX) with continuous improvements in human-computer interface (HCI) technologies. A sampling of feature innovation:

- **Mobility** – thin form factors, integrated form factors, battery charge lasts all day
- **Connectivity** – multiple radios, broadband wireless docking
- **Service availability** – instant on, connected standby, quality of wireless connection
- **Experience** – new interaction modes, high definition displays and ability to use external displays, more sensor integration, wireless battery charging

Local sensor processing, the ability to summarize video, audio, and tactile data to figure out what a device's user is doing, plus processing all of the hardware platform's sensor data to augment the traditional user feedback, will become a platform performance differentiator. There will be many innovative choices around using purpose-built function blocks, graphics-unit computing, arrays of small cores, etc. to process and integrate sensor input in real-time.

Battery and power management

Battery research for mobile products address central platform issues in economics, form factors, and feature sets that drive new user experiences. It is currently focused on

faster charging, wider operational temperatures, and better current and voltage management to incrementally extend battery life.

Radically new technologies aimed at step function increases in charge density (the amount of power that can be stored in a given volume of material) are not expected in the mass market over the next few years.

The impact is that there will not be substantially more power budget available to the processor SoC over the next few years. Incremental power surpluses will most likely go to higher resolution, brighter displays, new and enhanced sensors, and higher-bandwidth radios.

If the Mobile Market Operated Like the PC Market

Looking at the differences between the PC and mobile markets' history and current states, what might happen to push the mobile market into a duopoly or monopoly market?

The PC market is arguably a duopoly. In its current mature state, two companies are reaping the vast majority of the profit in the PC ecosystem:

- **Intel:** Has out-invested and out-maneuvered its only long-term x86 licensee, AMD, to dominate profits in the hardware platform. While other companies tried to work around Intel's intellectual property to create competitive x86 cores in the 1990s, none competed long-term as Intel added new features and hence new IP to their instruction set over time (IBM, Citrix, TI, VIA; AMD bought NexGen).
- **Microsoft:** Has out-maneuvered IBM and Apple to maintain its dominant OS position, and consolidated personal productivity software despite the best efforts of many vendors. In recent years it drove margins out of the web browser business and is doing the same to the PC anti-virus and malware protection market today.

If we look at the tablet market today, it is dominated by one company – Apple, but 7" competitors are starting to catch up, mainly from the Nexus 7, Amazon Kindle Fire, and offerings from Barnes & Noble. It's not due solely to the iPad's processor SoC, the user experience, the physical design, the App Store, or any other single feature. As in the smartphone market, eventually one or more vendors participating in another ecosystem will assemble enough of a competitive story to push Apple back into their high-end boutique niche.

Can Intel or Microsoft leverage their PC duopoly status into a commanding position in the mobile market? While they both have formidable cash reserves and R&D capabilities, they are both challenged by business models and processes grounded in PC market dynamics. The degree of success in Windows RT, Phone 8 and RT will help determine the final outcome.

More innovative PC form factors exist for Windows than ever before. The PC is changing to look more like a mobile device than ever before, and if Microsoft can get traction with PC Windows, specifically the Metro interface, this value will translate to a higher probability of success in smartphones.

One other vector to consider is the quality and reliability of the end product and service. Think if your smartphone worked like your Windows 8 PC. Windows and the platforms have made enormous strides, but isn't yet as reliable as a smartphone.

Comparing the PC and Mobile Markets and Products

	Personal Computer	Mobile
Processor Core	Intel x86 dominates, some AMD; Windows RT enables ARM	ARM licensees dominate; Intel and MIPs re-entering
Graphics	Intel, AMD, NVIDIA	Imagination , Qualcomm, NVIDIA, ARM
Design Goals	General purpose compatibility One instruction set Processor first	Purpose-built, complete feature set CPU, GPU, DSP and fixed function Balanced, reliable, dependable design
Fab Process	Aggressive processes for competitive performance	Standard processes for competitive cost and time-to-market
SoC Integration	Slower, not a focus for performance	Faster, integrated features matter and contribute to market churn
Channel	Primarily retail, etail, direct	Primarily carrier-driven
Ecosystem	Intel controls hardware platform features and value; Microsoft controls software platform features and value	Two viable ecosystems today: Google Android and Apple iOS; Amazon and/or Microsoft could create next viable ecosystem
UX Customization	Solely Microsoft's domain	Google allows; Apple and Microsoft control theirs
User Interaction	WIMP (windows, icons, menus and pointer) plus multimedia; Microsoft Win8 adds native touch	Touch, moving to new interaction modes with more sensors and increasing local processing capability

Markets have momentum and inertia. Google and Apple have huge smartphone and tablet momentum. Microsoft and Amazon would like to create alternative ecosystems but will have a hard time doing so with any speed, barring any huge mistakes from Google or Apple.

Intel's situation is different, but still challenged. Given that Intel can enter Google's ecosystem as a competitive vertical smartphone and tablet manufacturer, Intel can compete head-on with Samsung and all other platform manufacturers in the market. Intel will be challenged to displace Samsung and other vendors to the point of reaching a hardware monopoly by the end of this decade. Intel is placing large investments to participate in the mobile market, in particular acquiring Infineon's WWAN technologies and products. Intel has designed a "Moore's Law" radio technology, where traditional analog radio functions are converted to the digital domain in a logic-compatible transistor form, so that the radio transistors can be co-located on the same chip with the

rest of Intel's SoC logic. Intel is also doubling down on fab technology and capacity by quickly moving to 14nm when the ARM contingent will still be at 20 and 28nm.

If third-party merchant SoC providers cannot provide a relevant TTM, feature, or cost advantage, vertically integrated hardware manufacturers could force third-party merchant SoC manufacturers out of the mobile market. Apple, Samsung, and Intel all design their own SoCs and Amazon could well make the same choice. If Microsoft and Google stay friendly to multiple hardware platforms, the mobile market may still be dominated by Samsung and Intel hardware platforms. This might force Qualcomm to invest in its own vertical hardware solution in order to prevent being restricted to an ARM-style pure-play R&D business model and perhaps recapture its ongoing investments in SoC R&D. If this happens, Qualcomm should not have significant challenges in doing so as they did this before.

Conclusion

Current profit pools are a great way to look at a static market, but a poor way to look at emerging and high-growth markets. Financial markets long ago figured out how to tap into the wisdom of the crowd, and the crowd-sourced futures market they created is called a "stock market." The current mobile ecosystem contenders Apple, Amazon and Google have been rated by the stock market has having a strong future. Samsung, likewise, is considered a strong future contender. ARM and Qualcomm have been graded better than the PC incumbents for providing mobile-enabling technologies, but not as well as the current mobile ecosystem contenders, as they won't participate in content and app aggregation.

Conversely, Microsoft and Intel are undergoing an expensive divorce and have been graded as lacking vision and future prospects, *although they are still two of the most profitable companies on Earth*. If the stock market graded them solely on profitability and current competitive position, they would both have much different share valuations and market caps.

The differentiating business models and technologies where innovation will matter are:

1. **User-centered design and ethnographic research:** will provide design purpose and goals as purpose-built designs have become the norm in the mobile market.
2. **SoC ecosystem and time-to-market design:** the ability to tap into a wide range of system IP as opposed to succumbing to "not invented here" syndrome will determine who can get to market faster with new, high value features. This favors ARM licensees with a time-to-market advantage.
3. **Sensor technologies, compute offload engines, and integration:** user experience and new value-added features related to "natural user interfaces" are increasingly used to competitively differentiate hardware platforms and will become a target for integration to reduce costs. Manufacturing will be vital, too, as the better the transistors and fab technology, more can be integrated or can be integrated less expensively and at lower power.

4. **WWAN and WLAN integration:** the ability to integrate and shrink radio designs will be a first order differentiator in lowering silicon costs and determining solution margins.

The PC market has enjoyed rapid processor and compute capability evolution, but slow feature evolution. The PC market has currently stalled, as consumers are choosing to buy new phones and tablets and ride out their PC for longer periods of times. The mobile market is different – with ARM and Qualcomm licensing the technology basis, a larger ecosystem of hardware vendors have accelerated innovation, resulting in a competitive proliferation of new form factors and user experiences. The mobile market is currently in growth mode with a lot more upside considering the related Internet of Things (IoT) and Machine to Machine (M2M) growth opportunities.

The mobile and PC markets came from very different roots with different dynamics and the markets are now converging. Each ecosystem is managing and sometimes struggling through all of the disruption. The winners and losers will be determined by how quickly they can adapt and differentiate. Those stuck in the past are, and will continue to fade away, while those able to change will take advantage of the benefits of the "new" converged market.

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