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WHITE PAPER

Mobile Industry Confronts the Device Energy Gap

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IDC OPINION

The shift from voice to data usage on mobile devices, with its demand for feature–rich handsets that require ever-so-much-more information processing and improved size of displays, is throwing the power limitations of mobile devices into greater relief. The energy gap on mobile devices is real, and growing. While the demand for power on mobile devices has increased tremendously – owing to several factors, ranging from growth in device features and functionalities associated with the rise of smartphones, proliferation of mobile access networks, burgeoning of data applications that require increased and faster processing, rise in cumulative use of applications and services by mobile subscribers and the concomitant need for bigger and better displays that need to be powered fairly continuously – and will continue to grow, the supply of power has failed to keep pace, largely owing to limited improvements in battery technology. Confronted with the rising mobile device energy gap, which is only likely to widen over time as the culture of mobile data consumption takes hold and mobile device users seek to do more with their devices, mobile industry players are striving to eke out energy efficiencies through better optimization of resources at various levels of the system. IDC investigated the efforts and initiatives that various industry players – from mobile operators and their device vendors to device component suppliers like chipset and power amplifier manufacturers, as well as battery, display and mobile software vendors – may be pursuing to improve the mobile device power budget. IDC's research revealed:

- There is no silver bullet that can address the current, and growing, energy gap on mobile devices. Addressing the issue will require an industry-wide effort, if device power budget is not to hobble the rising culture of mobile data consumption.

- Market leaders in every level of the mobile value chain were seeking to eke out efficiencies, some more successfully than others, through better optimization of products and processes. *Cumulatively,* the efforts and initiatives of different industry players could make a sizeable contribution to bridging the energy gap. However, these efforts, *even in the aggregate,* may not erase the whole deficit.

- Slow improvements in battery technology remain a constraint. The paradigm shift from lithium ion to fuel cell batteries is unlikely anytime soon.

- Since displays constitute one of the most power hungry elements on the mobile device – in some data intensive use case scenarios, between 40% and 50% of the power budget – a paradigm shift away from the currently prevalent transmissive displays that are "highly inefficient" in terms of power consumption, could likely make the most sizeable contribution to mobile device power budget.

METHODOLOGY

This White Paper is based on primary research, which took the form of in-depth interviews with key executives of leading industry firms across the world conducted by IDC analysts, most often in person (although some of the interviews were phone based). The companies included leading mobile phone operators in several developed and developing countries, leading device vendors in North America and Western Europe, some leading chipset and power amplifier vendors in North America, a number of key battery and display vendors in Asia, and many leading mobile software vendors in North America and Western Europe. Additional information for the white paper was culled from web sites and other publicly available marketing collateral, including conference presentations. The foundation of this white paper was IDC's overall body of research in the area of mobile and wireless communications, and our understanding of the key technology and usage trends pertaining to mobile devices.

The principal goal of this White Paper was to investigate the initiatives that mobile operators, their device vendors, and the latter's component suppliers may have undertaken, and may be pursuing, to address the imminent, and growing, energy gap on mobile devices in the wake of the culture of mobile data consumption currently taking shape.

IN THIS WHITE PAPER

This White Paper addresses the efforts and initiatives of various mobile industry players to address the current, and rising, "energy gap" on mobile devices. It seeks to delineate the challenges faced by these players and their efforts and initiatives with respect to improving mobile device power budgets that are becoming increasingly salient in the unfolding universe of mobile data consumption.

SITUATION OVERVIEW

The cell phone has, in recent years, emerged as the singular laboratory for testing the limits of technological convergence. Driven by digitization, and aided by advances in processing and display technologies, as well as improvements in memory and miniaturization, the cell phone has increasingly appropriated key attributes of many useful consumer devices, from music players and radios to digital cameras and television, to arguably emerge as the device of choice at the center of our digital lives.

The increasing proliferation of smartphones – phones based on high-level operating systems, like Symbian, Blackberry, Windows Mobile, Mac OS-X and Android, among others – that can support a growing plethora of third party applications, and the broad availability of multiple high-speed wireless access networks, both cellular and non-cellular, is helping usher in a culture of mobile data consumption.

Mobile operators and their device vendors, along with new market entrants anchored in a Web 2.0 worldview, are designing and offering innovative and attractive services – from music and messaging, to browsing, navigation, gaming and video, to name but a few – that users can consume on their mobile phones. Leading mobile industry players, both network operators and device vendors, are now aspiring to offer integrated, context-based Internet services that can be accessed from anywhere on mobile devices. Device vendors are increasingly equipping their devices with bigger and better displays, complete with touch screens, to offer enhanced user experience.

The emerging culture of mobile data consumption has seen a concomitant rise in new mobile use cases and usage models. Key among these are more active usage time – as people use the device for, say, messaging and navigation and music – and the requirement that the mobile device now remain "always on." The problem, of course, is that increased cumulative usage on a mobile device that is "always on" drains the battery, creating a major gap between the demand for and supply of energy required to power the device.

To provide a sense of the impact of the "always-on" feature on a mobile device: A typical high-end mobile device equipped with multiple radios (say, cellular, WiFi and Bluetooth) and supporting a host of features (say, e-mail, presence/chat, downloads and over-the-air data synchronization), can see roughly half its battery drain during a 24-hour period – *even without the user doing anything actively on the device*.

The 'always-on' feature, in the presence of multiple radios, can drain nearly half the battery even in a passive mode.

IDC believes the mobile device energy gap – the chasm between supply and demand of power – is only likely to widen over time as the culture of mobile data consumption takes hold and mobile users seek to do more with their devices. Part of the reason is that the lithium-ion battery technology, anchored in material sciences, lends itself only to marginal and low incremental improvements. And the paradigm shift to fuel-cell batteries, according to best industry estimates, is unlikely before the latter half of the next decade – for reasons discussed below.

Shift to fuel-cell batteries is unlikely before the latter half of the next decade.

Industry players across the mobile value chain are cognizant of the energy challenge, and are striving to eke out energy efficiencies through technology improvements and better optimization of products and processes. Most recognize that the solution must be found in a collaborative and cumulative, industrywide effort. We delineate the initiatives and efforts of various players below.

However, we must observe that even as every leading player appropriately underlines the need for collaboration and optimization – and there is little doubt that every player honestly believes in these principles – we fear the net result in the end, despite everybody's best efforts, may be less than optimal. This is because every technology, and technology artifact, is the codification of the goals and assumptions of its designers. As a result, optimization as a construct does not exist in a vacuum, but is circumscribed by the strategic intent and goals of various industry players involved. Since the goals of various players are, at times, different and in contradiction – in part, because various collaborators are often also competing to extend their influence across the value chain and control/direct the user experience as well as to further their corporate and strategic goals – it begs the question: optimized to what end, and for whose needs? To put it simply, optimization is a function of tradeoffs one makes in designing and architecting different elements of a system, and different players may be marching to different tunes. The industry's increasing shift toward "openness," for all its merits, can also negatively impact device power budget optimization efforts as some players, perhaps willingly, make certain choices in pursuit of "cool."

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FINDINGS

We present here the key findings from our detailed interviews with leading players in key categories of the mobile value chain.

MOBILE OPERATORS

Mobile operators in both developed and developing economies are cognizant of, and concerned about, mobile device power budgets, albeit for different reasons. Mobile operators in developed economies seeking to grow data revenues in the face of eroding voice revenues, are concerned about mobile device power budgets since poor availability of energy, quite directly, impacts their potential revenue earning capability. The less the available power on a device, the less consumption of services by a subscriber, as an operator summed it up.

Further, these operators are cognizant that the use of various apps and services, *cumulatively,* can wreak havoc on the device power budget. Last but not least, they recognize that the 'always on' requirement for these devices serves to deplete available energy even in the absence of active use by the device owner.

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Operators in developing economies have similar concerns for high-end devices; but, in addition, they seek better power budgets because a high percentage of their entry-level device users often have poor access to the electrical power supply and phones must be equipped with batteries that hold the charge for extended periods of time, preferably multiple days.

However, efforts to address mobile device power budgets varies among these players, in part because of the variance in access to technology and R&D resources and, in part, because the balance of power between operators and device vendors varies across regions. Mobile operators in developed countries have traditionally demonstrated greater control over their markets.

While mobile operators in developing economies do work with their device vendors on features and functionalities and suggest usage profiles, they largely tend to defer to their device vendors on the power issue, and do little beyond exhorting them to greater efficiencies. As a result, we focus here on the efforts of leading mobile operators in developed economies. However, like their developed market brethren, mobile operators in developing economies strive to contribute through optimizing their networks, and deploying them as densely as economic considerations allow them.

These mobile operators vigorously scan the technology environment and routinely work, beyond device vendors themselves, with component suppliers – from chipset and power amplifier suppliers to software, battery and display vendors – to explore possibilities of greater efficiency. In the end, however, the operators translate their efforts into delineating requirements at the system level – i.e., the device level – and rarely, if ever, directly influence the device vendors' choice of a specific component technology or supplier.

So, for instance, equipped with their own technology labs and R&D centers, leading operators engage with chipset and software vendors to optimize radio resources and to prioritize and strategize which functional block needs to be powered and when, and suggest the kind of tradeoffs that may or may not be acceptable – discernible latency in initiation and functioning of applications that may undermine user experience being among the least acceptable. They work on optimization issues with power amplifier vendors to help them establish appropriate power modes that best address the actual usage conditions of the their mobile subscribers.

Similarly, in their work with software vendors, operators seek to ensure that the operating software is sufficiently smart with respect to device power budget – in that it powers down, or at least makes dormant, the functional blocks that are not critical for the running of an application. In their work with app developers, operators seek to ensure interactional efficiency of an app – both, in terms of how an app utilizes network resources and how it "speaks to" another application.

But, perhaps, the most important initiative on the part of mobile operators with respect to device power budgets is their effort to build appropriate user profiles and device use cases. These allow the operator to segment the market and design appropriate device and service strategies for each segment. Additionally, it allows the operators to create device specifications – which feature and functionality might be incorporated in which device for which user segment – and articulate requirements that device vendors may use in designing and building their portfolio of offerings. These profiles and use cases have the additional merit of forcing device vendors to better integrate apps and utilize the best-of-breed technology components to meet the power requirements set forth by operators.

The most important initiative of mobile operators with respect to device power budgets is their effort to build appropriate use profiles and device use cases.

Further, it ensures against device vendors packing too many features in their devices to enhance their own brands – raising the bill of materials, and thus, cost, of the device. Mobile operators, especially those given to subsidizing mobile devices, are particularly reluctant to underwrite features that do not correspond to their prescribed use cases. Mobile operators who do not subsidize devices also frown at feature packing since the higher cost puts the device out of reach of consumers and, by inference, inhibit the use of services – the principal source of operator revenue.

As mobile devices become more complex and come equipped with more features, and as use cases proliferate to include greater device utilization in both sunlit and dark conditions, mobile operators are becoming more interested in device displays – in part, because these displays are growing in size (in service of user interface and experience) and, in part , because they constitute one of the major source of power consumption on a mobile device. Use cases that involve web browsing, navigation, music videos, for instance, require sharper rendering of information and faster "refreshes," both of which have implications for device power budgets. Breakthrough in display technology is one of the key elements on the wish list of several operators.

Breakthrough in display technology is a key item on the wish list of several operators.

Critics of mobile operators, however, argue that many mobile operators are not pulling their weight in the industry's struggle to bridge the energy gap on devices. Some critics note that these operators could more effectively contribute to the struggle by better optimizing their networks – for instance, by improving network radio parameters (particularly the timers in the network radio resource controllers that define the time of device transition from a more power-consuming to a less power consuming state), by improving radio protocol efficiency with respect to discontinuous transmissions, and by facilitating better bearer selection such that the device can select the closest, and most power efficient, bearer at any given time.

Some others note that a thin network deployment often forces a device to ramp up power to interact with a network, with an unfortunate effect on the device power budget, and that operators could help address the issue through network densification. The problem, of course, is cost. Many of the leading operators are looking at femtocells as a means of both expanding their network reach and addressing this issue.

MOBILE DEVICE VENDORS

Mobile device vendors are the designers and builders of the device. Because their brand names are tied to the unit and its value in its entirety, they are not only careful about optimizing each component or element but also about optimizing the functional inter-relationships among components to ensure the best user experience for their customers. Mobile device vendors, like almost everybody else charged with designing functional artifacts, are faced with the need to make choices between sometimes contradictory mandates. But beyond that, their work in designing and building the mobile devices is governed, beyond facilitating mobility, by three principal concerns: power budget, spectral efficiencies and user experience. These vendors are particularly alive to the power budget issue because they recognize that a power-dead device is little more than an expensive paperweight.

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Since they work with limited real-estate – in response to user preferences for smaller and sleeker devices – device vendors tend to make critical choices with an eye to optimizing elements from the get go, like when they lay out the "board" that defines the device. The user profile to which a device is being built governs the choice of chipsets and chipset architectures and of operating systems, since different operating systems better support different features and functions and have different power overheads, and depending on the intrinsic complexity of the OS may keep more hardware busy, impacting power. An operating system must, to be effective, schedule tasks intelligently and elegantly.

Many vendors hold that real time dynamic OS is more power efficient than most high-level operating systems (HLOS), because the latter tend to cause more stress on the hardware. The trade-off is that the HLOS can support more feature/functionalities and, in supporting third party applications, lends itself to user customization and, thus, to potentially greater data usage. The choice of an operating system is also often informed by the demands of mobile operators and their stated requirements.

Device vendors work with both chipset and software vendors in their first round of optimization, ensuring that appropriate drivers are in place for various functionalities – video, music, gaming, messaging, etc. – that would need to be built into the system. Depending on what might constitute the signature feature or features on the device, vendors decide whether or not special, stand-alone processors are warranted, since all choices involve tradeoffs.

Related choices are then made, again with an eye toward power budgets – for instance, whether or not voice codecs should remain in the DSP, where radio antennas and power amplifiers may be placed on the device, what shape and size of battery may be used, etc. Achieving radio and spectral efficiencies are critical because the routine scanning for networks can constitute an immense power drain.

The toughest task for device vendors, perhaps, is the optimization of applications, since users tend to be paying for the experience, as Apple has so eloquently demonstrated. This means device vendors, as principal integrators, must ensure that chipsets and software are properly geared to delivering stellar device performance – commonly understood by the user as faster processing, adequate memory and quick app response time (both as she launches an app and/or switches between apps).

The toughest task for device vendors, perhaps, is the optimization of applications for power.

In a mature marketplace, one assumes that there are few secrets with respect to availability of tools. And most device vendors have well staffed teams scanning the global marketplace for best of breed technologies. So, if some device vendors are more successful at optimizing their device power and performance, the answer must lie either in their assumptions about use cases or in their implementation.

The latter, we believe, can sometimes be a function of a vendor's corporate strategy. Some vendors who, as a matter of corporate strategy, choose to maintain an end to end control over the system – RIM and Apple come to mind – sometimes do better at optimizing power and the user experience. Being a relatively self-contained system they incur, what economists might call, lower transaction costs (i.e., costs of coordination) that then yield more optimized returns.

CHIPSET VENDORS

Most industry players look to chipset vendors to help address mobile device power budget issues, in large part because, beyond architecting their own efficiencies, chipset vendors can influence and help improve the energy efficiency of the entire mobile system. This is because the chipset effectively governs the power resource allocation for various functions on a mobile device, as well as those that allow the mobile device to "speak" to the network.

As we investigated the efforts and initiatives of this family of mobile industry players, three things became clear.. First, that every leading chipset vendor has, essentially, the same tool box and, as a result, a vendor's advantage over another probably lies more in how it mixes, matches and utilizes the tools available to all, rather than in any differential access to the tools themselves. The greater share of the device system a leading chipset vendor controls, the more influence it can wield over the overall system efficiency.

Second, that the debate over power (energy) versus performance (processing) in the mobile device context is quickly being resolved in favor of energy efficiency. Third, while the speed of processors designed by different companies may vary, chipset vendors providing apps processors to the mobile world predominantly utilize ARM cores to provide high-speed processing at low levels of power consumption.

The debate over power versus performance in the mobile device context is quickly being resolved in favor of energy efficiency.

The efforts of semiconductor players can be discussed along several vectors, principally, the fragmentation of processors into "islands" (or domains) of power, reducing the geometry of chipsets, multi-core processing, and platform- or system-level power management. The first three lend themselves to voltage and frequency scaling in the hardware, the last to such scaling in the software. We should like to note here that the discussion is primarily focused on chipsets designed for digital processing rather than for analog or RF processing.

Islands of power: Power management in mobile phones from a chipset perspective is essentially about energy efficiency (power/time) – or, how much can get done over a period of time. This concern with energy permeates all aspects of the chipset design, including the processor itself (along with the power management integrated circuits, or PMICs), timing controls in firmware, and even the operating system.

Concern with energy efficiency permeates all aspects of the chipset design.

Architecturally, power savings can best be managed by segregating mobile phone operations into separate domains, or operating environments, each of which may have different power requirements. Each of these domains is optimized based on the most likely functions and utilities it addresses, functions that may vary between those that require intense processing and those that do not. The idea behind segregation of the processor is to optimize the performance of the isolated blocks to various identifiable functional modes – such as, say, web browsing, music and text messaging – each of which might require a different power state.

The recognition of these functional modes and power states, and the switching across them, is handled by the power management subsystem working in conjunction with the operating system and the timing devices typically embedded in the processor.

Specifically for processors, controlling the voltage/frequency scaling has the most impact on power management and is the first of at least two knobs in micro-architecture power management. Since power is a direct function of both voltage and frequency, both voltage and frequency can be tailored to required functions. Optimizing power management is a trade-off between increasing the number of power states in an active environment versus managing the resultant complexity of these multiple states.

While the first knob in the micro-architecture power management from a processor standpoint is voltage and frequency scaling, the second knob is optimizing the actual performance efficiency of the processor at a given power level.

Reduced geometries: As process geometries have decreased from 130nm to 110nm and then via 90nm and 65nm to 45nm, the industry has realized tremendous savings in the power required to run a circuit. However, as we approach 45nm and move toward still smaller geometries, the nominal operating voltage required to activate the transistor is rapidly reaching its threshold. The physics of the transistors emerges as the limiting factor.

As process geometries have decreased, the industry has realized tremendous savings in the power required to run a circuit.

In addition, smaller process geometries are burdened with the cost of leakage within the transistors themselves. According to some experts, below 45nm, the power losses due to leakage approach in magnitude to the power gains from a smaller process node. To contain leakage, some leading vendors are experimenting with high K metal gates that have thicker metal oxides and can control leakage.

Multi-core processing: The use of multi-core processing for mobile devices is also a trend that is gaining salience. So, for instance, ARM foresees a synthesizable core with a micro architecture that can be configured into one to four processors. This would provide multitasking and scalability for multithreaded applications with memory "coherency". This configuration would offer the ability to turn off sections of the processor to conserve power, scale power as needed, and still offer maximum processing capabilities for processing intensive activities. The actual efficiency improvement is difficult to quantify because it depends on the specific app under consideration and the usage profiles.

The multi-core approach is, in some respects, similar to the power islands/domains approach, in that some processor cores can be powered down, and re-activated, depending on the processing needs of the system. The flexibility that it would offer would extend beyond power and energy issues, to include thermal load balancing. The downside, however, is the added silicon cost, which could be a problem, particularly for consumer mobile devices such as smart phones and, potentially, mobile internet devices.

Platform- or system-level power management: Some chipset vendors are focused on improving the efficiency of "power delivery," the process of managing the routing of power around the processor by reducing the number of voltage rails. By managing voltage through intelligence at the chip rather than at the battery level, vendors believe they can garner efficiencies in putting associated components to sleep and waking them up on an as-needed basis.

While the industry will probably never consolidate to a single voltage on a mobile phone, there is opportunity to reduce that number by designing with the entire system in mind, rather than a single component. Such a platform power management approach is anchored in a nested vector approach, and entails the consideration of the entire system design.

Power management is increasingly becoming a system level effort. The silicon itself, the subsystem design, the operating system and other software – all are invoked to play a part in optimizing a solution. Since greater control over the hardware and software environments enables a much more integrated and efficient outcome, power optimized platform is increasingly attracting the interest of leading vendors.

Power management on chipsets is increasingly becoming a system level effort.

However, despite their efforts at designing efficient and effective power management architectures and schemes, chipset vendors can only impact a modest part of the larger mobile device energy gap. In other words, there is only so much they can do.

POWER AMPLIFIER VENDORS

For power amplifier vendors, the biggest opportunity for power savings on a mobile device is to be found in the transmission side of the signal path because a relatively large amount of power is required to amplify the signal before it can be sent out to the mobile base station. Power amplifier vendors currently face two big challenges: size constraints and increased performance requirements.

Power amplifier vendors currently face two big challenges: size and increased performance requirements.

As mobile phones continue to shrink in size and especially in thickness, the power amplifiers are being forced to shrink also to accommodate the smaller, sleeker form factor. The challenge is that power amplifiers are inherently inefficient – with mid to high 20% efficiencies – and generate a tremendous amount of heat. Shrinking the size limits the surface area available for dissipation of heat. The power amplifier cannot be clocked down to reduce power/heat like the processor typically can.

Further, power amplifier suppliers are often forced to decide between integration and efficiency. Most semiconductor content in a mobile phone is rapidly evolving to CMOS processes that enables rapid scaling to smaller process nodes, as evident from shrinking processor geometries. Reduction in die size has afforded power savings on processors, with the added benefit of component integration into monolithic devices. Power amplifiers tend to be excluded from integration trends because they typically use different – for instance GaAs, SiGe or GaN – processes instead of CMOS. (There are a few companies that are developing CMOS power amplifiers, but their use is most efficient for lower frequency ranges.)

Power amplifier vendors are also faced with the need to accommodate higher data rates associated with newer air-interface standards that enable higher network throughputs but which also translate into higher power requirements. Mobile data usage, which requires greater network bandwidth, is more power intensive.

In response to these challenges, power amplifier suppliers have started to look closer at actual mobile phone use cases, and are seeking to design products that have multiple – from two to four – modes of operation, each optimized for maximum efficiency and power use. One mode may be high power to accommodate communication with a BTS on the edge of a cell or for data-intensive communications where QoS is important while another may be set at medium power to accommodate simple text messaging, while a third may be set to low power when the mobile phone is in standby mode. The modes are activated and deactivated by "mode-control" algorithms, typically in the baseband.

Incorporating power mode switching into a power amplifier's design currently constitutes the biggest opportunity for power savings in this mobile device sub-system. Over the next several years, the opportunities for additional power-saving amplifier designs will be focused on two areas, according to experts in the field: better understanding of mobile device usage conditions and designing power amplifiers optimized to Pmax (maximum power) such that, at that mode, the units consume less power and generate less heat.

SOFTWARE VENDORS

The operating system is an integral and critical part of the mobile device as a system, in that it manages resources and enables features and functionalities on the device – from base applications (like call management/history, clock and calculator, phone book, information storage and retrieval) and multimedia and user interface framework (for instance, audio/video/image capture and display, touch-screens) to a broad range of other features like browsers, text-messaging and e-mail, app synchronization, thumb-wheels and keyboards, to list but a few.

As mobile device hardware evolved over time (following improvements in processing, memory, displays, etc.) and increased in complexity, the limitations of the original, and proprietary, real-time operating systems that anchored the interface between device hardware, applications and the end user in the 1970s and 1980s became increasingly evident.

This led to the evolution, in the 1990s, of high-level operating system (HLOS) that offered a broader set of features and functionalities and were capable of running complex applications written in standard development languages – a fact that has invited third-party app developers to the mobile space in droves. The downside is that these HLOS come with a certain amount of power overheads.

High level mobile operating systems support more functionalities but come with power overheads.

Currently popular mobile high level operating systems include the market leader, Symbian, RIM's Blackberry, Microsoft's Windows Mobile, Google's Android, Apple's MAC OS-X, Linux, and Palm's Pre. The HLOS vendors routinely offer enhancements to their respective HLOS, through advanced reference designs, new software development tools, along with improvements in the real-time kernel as well as in new security, device management, and user interface feature support. Current versions of most HLOS allow device vendors to select features – like music, gaming, video, enterprise related functions – on an individual basis. This lowers the OS overhead and facilitates the design and manufacture of more optimized mobile devices.

Vendors of mobile device operating systems are very alive to power budget issues. The principal areas of focus for these vendors are conserving power through the design of the OS architecture that supports intelligent information routing protocols and enables fast dormancy of unnecessary functional blocks as appropriate. A modular architecture that allows developers to choose desired feature sets and building and incorporation of software stacks that control and manage bugs and applications in a more optimized manner are key to the conservation of energy.

OS vendors seek to conserve power through architectures that enable intelligent information routing protocols.

Most HLOS vendors make their software development toolkits available to their developers, and delineate APIs that third-party developers may use to write more power efficient apps. However, the penchant of apps developers and device vendors to exploit state-of-the-art technologies and functionalities in pursuit of "cool" – accelerometers, proclivity to incorporate presence and graphic-laden apps come to mind! – often undermines power conservation efforts.

The penchant of app developers and device vendors for “cool” often times undermines power conservation efforts.

The industry's increasing turn to an "open," or less controlled, OS environment – irrespective of its other merits – also has some unfortunate effects on power consumption. It would seem that vendors like RIM and Apple who have chosen to maintain an end-to-end control over the process may be somewhat better positioned to realize power efficiencies through tighter integration of hardware and software. RIM has the added advantage of having created a NOC (network operating center) that allows the vendor to garner efficiencies from their "push" email methodology. To compensate for lack of an end-to-end control, some HLOS vendors – Microsoft is a notable example – have articulated strict device power budget guidelines, which they expect their device vendors and app developers to follow.

In parting, it may be worth mentioning that while all HLOS vendors strive to realize, and facilitate, energy related efficiencies, some are more successful than others – to a large extent, as a result of inherent overheads that derive from attempts to shoehorn into their OS features and functionalities deemed necessary to further corporate goals and vision. But then, it would be naïve to expect that technologies exist in a vacuum, unaffected by strategic goals and intents of their providers.

BATTERY VENDORS

Mobile device batteries, unfortunately, have not kept pace with the remarkable improvements in some other mobile device components – such as radios, memory and processing. The tepid growth in battery power has imposed significant limitations on the potential use of mobile devices and, by extension on mobile data consumption.

The issue with mobile phone batteries is that the lithium ion battery, anchored in material sciences, has not demonstrated significant efficiency improvements over the past decade. Patented in 1988, lithium-ion batteries, that replaced the Nickel Metal Hydride batteries, first appeared on Motorola phones in 1994. The lithium-ion battery chemistry has not changed much over last 15 years, and device vendors note that the power efficiency that can be wrought from these batteries is reaching its limit.

All battery manufacturers are roughly using the same materials, and there is little difference in the energy density of batteries from different brands. Device vendors are often reluctant to seek denser batteries– that promise higher capacity – in part, owing to safety concerns and, in part, because relative gain is less than commensurate with the corresponding rise in cost.

However, given their efficient properties – lithium ion batteries boast one of the best energy-to-weight ratios, sport no memory effect, and affect a slow loss of charge when not in use – lithium-ion batteries are likely to remain the battery of choice for the foreseeable future.

Because they offer great energy-to-weight ratios, lithium-ion batteries are likely to remain the battery of choice for the foreseeable future.

While battery vendors are experimenting with newer chemistries – such as either lithium sulfur, or replacing cobalt with manganese in the cathode – most device vendors worry that nothing currently comes close to the power requirements implied in most mobile device use profiles, nor to the battery life cycle, temperature, durability and associated features that they expect of batteries. Further, they fear that gains from newer chemistries may be neutralized by battery re-qualification costs.

Interviews with leading battery vendors in Asia yielded some interesting insights. The most remarkable of these were that a) the battery manufacturers were focused on the safety element (safeguarding against internal short circuits, improving manufacturing processes to guard against contamination by metallic particles), and b) they were focused on improving the durability of their products. The vendors' focus on safety and durability implied they were keen on product improvements that translate into enhancing the power of the brand. Only one executive augmented his response by talking about initiatives to improve power.

The leading battery vendors are frustrated with the industry's contradictory requirements – of improved capacity and reduced battery size. Beyond experimenting with new materials for higher capacity, these vendors are seeking to increase densification by toying with voltage in their next generation lithium-ion batteries, colloquially referred to as Lithium-ion+.

The leading battery vendors are frustrated with the industry's contradictory requirements – of improved capacity and reduced battery size.

Some vendors are seeking to keep the charging voltage for next generation high-capacity lithium ion batteries at 4.2V, same as that for current lithium ion batteries, and reducing the optimum discharge cut-off voltage to 2.0V, thus expanding the range of voltage used. Further, they are seeking to enhance capacity by using alloy based negative electrodes rather than carbon based ones. The challenge, of course, is that while manipulating voltage boundaries might increase battery density, it might have unfortunate implications for other device elements. For instance, the power amplifiers on a mobile device are currently tuned to the current lithium ion battery range of 3V to 4V, and may need to change if the voltage is lowered to 2V.

Currently, the battery industry seems to have three possible approaches to addressing the power issue: mechanical, chemical, or paradigm shift to fuel cells. In the mechanical approach, the chemistry would remain the same, but its packaging would become more efficient. But this approach is likely to eke out only a further 5% efficiency. In the chemical approach, vendors could consider different materials to be used in the composition of the batteries. The problem is that batteries based on new materials would have to be re-tested and re-certified, among other things, for safety. Also, changed battery chemistry would alter behavior of the battery that could affect other device components, particularly the electronics. As the battery profile changes, device vendors would have to recalibrate measures on electronic components. So, for instance, the battery and other electronic components currently work at 3V, and while it is possible to decrease that voltage, it would likely bring down the efficiency of the device as a system. To compensate for this, chipsets and power amplifiers may have to be redesigned, imposing serious costs on the device vendors, not least of which might be the intangible cost of coordinating complexity that is often paid in the curreny of time. In addition, backward compatibility would be seriously compromised.

In the case of fuel cells, the secret is that the battery does not have to carry its own oxidant, but uses oxygen from the air. This allows for higher output per unit of volume – in other words, greater power efficiency. Fuels cells, or DFMCs (Direct Methanol Fuel Cells) as they are popularly known, have been discussed for the past several years, and constitute a major paradigm shift in battery technology. However, despite demonstration of prototypes by some leading Japanese vendors, most industry experts, including the battery vendors themselves, note that fuels cells are still in a difficult development phase and are unlikely to reach the market in meaningful quantities before the second half of the next decade.

The challenge is not merely the development of fuel cells, appropriate in size and form factor for mobile phones and their test and certification for safety and efficiency. It is also the development of a distribution network that can make them widely available. Mobile device vendors, at this point, are unsure of the cost the fuel cell battery technology might impose on their current production processes and the implications it might have for various electronic and non-electronic components that they employ to build their devices.

The challenge is not merely the development of fuel cells, appropriate in size and form factor for mobile phones, but also the development of a distribution network.

DISPLAY VENDORS

Mobile device displays are increasingly becoming the center of the industry's attention – as much for the positive implications they hold for user interface and user experience as for the negative implications they hold for power budgets on these devices. According to most industry experts, current device displays, for all their other merits, are extremely energy inefficient. As noted before, in certain data intensive use scenarios, they can consume roughly 40% to 50% of the mobile device's available energy budget.

There are, currently, four approaches to mobile device flat-panel displays: 1) Transmissive, such as the currently popular Liquid Crystal Displays that require to be powered by backlights, 2) OLEDs, or Organic Light Emitting Diodes, that use organic materials to generate light when exposed to electric current, 3) Reflective, that harness ambient light in the environment without need for supplemental illumination, except for dark conditions, and 4) Transflective, a hybrid combination of transmissive and reflective, that seek to overcome the poor performance of transmissive LCDs in sunlit environments.

The transmissive technology is highly energy inefficient.

Transmissive: The LCD based transmissive approach was first introduced in the late 1960s and has since evolved to include a thin film transistor (TFT) backplane for higher resolution, faster frame rates that support video and greater contrast. The technology dominates the mobile space; more than 90% of devices currently use LCD displays. Unfortunately, the technology is also highly energy inefficient, in that only about 5% to 6% of the backlight that powers the LCD gets through to the viewer, according to most experts, including LCD vendors. The rest is either discarded by the polarizers (employed to turn pixels on or off) or absorbed by the color filters.

Leading vendors, understandably, are focusing their efforts on improving polarization (through wire grid polarizers) and color filter performance (through Color Field Sequential methodologies, which is essentially the elimination of color filters). Some industry players are also focused on improving the efficiency of the drivers and manipulating backlight in an effort to optimize it for different display content and viewing conditions. One expert, the R&D chief of a major display company, suggested that the industry may see advances by middle of the next decade that could allow almost 12% of the backlight to go through. However, he noted that not all of the efficiencies would be dedicated to transmission; about one-third of the gained efficiencies were likely to be dedicated to brightness.

OLEDs: OLEDs invite positive comparisons to LCD-based approaches – for good reason. To the extent that they are like self-emissive tiny light bulbs, OLEDs do not need an external backlight source, are about one third the bulk of a typical color liquid crystal, have a wider view angle and switch faster than LCDs, enabling smoother video. For this reason, OLEDs are making some inroads in high-end mobile devices.

However, OLEDs also face some challenges. For starters, OLEDS are inefficient when it comes to converting electrical power into light. As an industry expert, who was in R&D for nine years, six of which he spent leading the company's OLED research team, noted, he and his company had somewhat retreated from OLED for the time being because the "metal complex" currently used is expensive ("50 times more expensive than gold") and inefficient, and because there is, currently, no material available to replace the existing metal complex. OLEDs are seen as the technological future, but said to make poor business sense at present.

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Further, since the organic materials are susceptible to contamination by water and oxygen, encapsulating and sealing them against the elements raises manufacturing cost and complexity since it requires new tooling and fabrication facilities.

Reflective: Reflective displays were invented primarily to address shortcomings of transmissive and emissive displays, namely, power consumption and poor readability in bright sunlit environments. With efficient use of ambient light, reflective displays eliminate the backlight requirements and offer both significant power savings and paper like visual experience across a wide range of ambient lighting conditions – in fact, in all except conditions of complete darkness (when a front light is deployed). In eliminating the need for backlighting, reflective displays seek to realize major power efficiencies.

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Currently, backlight constitutes the single major power consuming element in displays. A typical 2.2 inch LCD backlight, according to broad industry consensus, consumes 200 mW to 250 mW, while the display panel itself may consume about 20 mW. IDC believes the trend towards larger displays with higher resolutions and more brightness is likely to further aggravate the power situation.

Transflective: Transflective displays seek to improve upon the outdoor performance of transmissive LCDs, where bright sunlight quickly overpowers the LCD backlight, by deploying reflectors. In bright sunlight, the backlight is switched off and reflectors used to leverage the sunlight to power the LCDs. Theoretically, this should fix the problem, but in reality, say industry experts, this approach makes for a somewhat poorer viewing experience – in the dark, it is less effective than a purely transmissive display; in the light, less effective than a purely reflective one. Inserting the reflector into the pixel limits the area available for transmission of light, severely limiting gains that might translate into better viewability of content. However, since they improve viewability in sunlight conditions, some vendors find the transflective approach an attractive proposition. For that reason, transflective methodologies are gaining reasonable foothold in the market.

Paradigm shift? Given the inherent inefficiencies of LCDs and OLEDs with reference to power consumption, reflective methodologies might well constitute a major paradigm shift in display technologies. Two companies – Qualcomm MEMS Technologies in the US and Liquavista, a Philips spin-off, in Europe – are actively exploring the possibilities of reflective approaches to mobile display, hoping to impact the power conundrum confronting the mobile industry.

Reflective methodologies might well constitute a major paradigm shift in display technologies.

It may merit mention that there are other players in the market – eInk comes to mind – who are also pursuing reflective methodologies for displays. However, since their version of the technology does not lend itself to video, we are not considering them here.

For sure, Qualcomm's and Liquavista's actual methodologies vary in important ways. Liquavista, for instance, employs an electro-wetting methodology, in which voltage is used to modify the wetting properties of a solid substrate, while Qualcomm employs an interferometric modulation (or IMOD) approach, in which light is caused to interfere with itself, as part of a micro-electro-mechanical system (MEMS) that requires neither backlighting nor organic materials to operate. Qualcomm's display technology carries the brand name "mirasol."

Beyond their salutary and direct impact on power budgets on mobile devices, reflective technologies, in leveraging ambient light and eliminating the need for backlights, may contribute to routine better viewability under normal ambient light conditions. This should constitute a major benefit to mobile operators and device vendors in many third world tropical countries in that sharper viewing enjoyed by their subscribers would not be at the cost of mobile device energy budgets.

We briefly discuss below the Qualcomm approach to elaborate on some of the benefits reflective methodologies may bring to the mobile device energy gap debate.

CASE STUDY: MIRASOL DISPLAY

Qualcomm's mirasol display consists of a glass substrate coated with thin films. Under the glass is a reflective conductive membrane, separated from the glass by a thin air gap. When a voltage is applied to the membrane, the electrostatic impulse draws the membrane towards the glass. In this state, the IMOD element appears black as the sunlight is absorbed. The application of a lower voltage level returns the membrane to its original position, allowing the pixel to appear bright and colored – much like the wings of a butterfly shimmer and emanate rich colors. The color is generated by the interference of light, a process, that Qualcomm holds, is more efficient than the use of color filters.

The advantage of the reflective methodology, according to Qualcomm, is two-fold. First, no supplemental illumination beyond sunlight is needed, except when it is totally dark. In fact, notes Qualcomm, even in conditions of darkness, mirasol displays deliver better performance owing to their efficient reflectors, requiring much less power than LCD displays, which can virtually be used as flashlights in the dark. (To be fair, LCD proponents are working on backlight dimming technologies to gain efficiencies in precisely these conditions.)

The advantage of the reflective methodology, says Qualcomm, is two-fold: little need for supplemental illumination and bi-stability.

Second, the bi-stability of the IMOD elements that allows a displayed image to be maintained with near-zero power – in sharp contrast to, say, an LCD display that requires 60 updates per second to maintain contrast and image quality. As a result, Qualcomm says, in a typically-lit office environment reading text, a mirasol display may consume a single milli-watt or less of power while a TFT-LCD display may consume 20 milli-watts for the panel and over 200 milliwatt for the backlight.

While mirasol displays expend power predominantly only when the content is changing, Qualcomm argues this advantage remains even while displaying video content. During video, mirasol displays consume somewhere between one-half and the equivalent of a typical LCD panel, i.e, between 10 and 20 milliwatts.

CHALLENGES/OPPORTUNITIES

Reflective display proponents like Qualcomm and Liquavista hold that their displays consume between one-tenth and one-hundredth the power of an LCD display under various, but equivalent, conditions. If these claims have merit, this new paradigm of powering displays should have a serious impact on the way the mobile industry thinks about device power budgets.

Reflective display proponents hold that their displays consume between one-tenth and one-hundredth the power of an LCD display.

What makes reflective display methodologies an attractive proposition, assuming the order-of-magnitude energy gains claimed by their proponents are correct, is primarily, of course, the impact they have on the mobile device power budget – that is, their contribution to lessening the energy gap. But there might be secondary and tertiary benefits that reverberate across the entire mobile handset value chain. For instance, enjoying greater relief from power constraints, handset manufacturers might be able to exploit better industrial design options and app developers may further push the boundaries on features and functionalities to take apps to a whole new level of cool. Likewise, mobile operators may expect higher data ARPUs when an increase in power budgets allow subscribers to use their devices more intensively and over a longer period. Last but not least, the mobile user may be the grand beneficiary in being able to use her device for greater productivity and entertainment with little fear of being saddled with a power-dead device in the middle of the day, or worse, in the middle of a task.

However, there are some important challenges that reflective display proponents must first overcome. First among these is a start-up's basic conundrum: How to achieve price parity with the incumbent product or technology? Typically, a new technology, lacking cost advantages that come with scale, makes headway in the market on the wings of performance. Reflective display providers must demonstrate convincingly their technology's advantages in the regular marketplace and beyond the controlled environment of their labs to find market acceptance.

Second, and related to the above, is the issue of establishing the necessary production processes that are stable and capable of delivering consistent quality. Both reflective display proponents have sought to adopt, and adapt, tools and elements of manufacturing processes used by LCD vendors. But even then, we expect that building the required production infrastructure and supply chain for a new display technology cannot be without challenges.

Third, initial reflective displays are likely to be small in size and monochromatic, that is, they will, of necessity, have to start at the low end of the market, transitioning to larger diagonal displays and color only over time. However, the irony they face is that given their high initial costs, they would be more affordable for the high-end market, which may also stand more to gain from their performance.

Qualcomm's earliest design wins – a voice centric device with Hisense, the Chinese vendor, and a monitoring device with Showcare, the Korean vendor – illustrate the point. However, Qualcomm has since moved on to announce additional design wins for color displays with Utah-based SkullCandy, a maker of wireless headsets with integrated MP3 players. Continuing to progress, Qualcomm is now working with LG Electronics to integrate their displays into mobile handsets.

CONCLUSION

As the still nascent culture of mobile data consumption assumes clearer shape, facilitated by high-end devices and networks and the availability of attractive useful and usable mobile applications, mobile users will likely utilize their mobile devices for a greater variety of functions that range, beyond voice, to both productivity and entertainment. The resultant intense use of the mobile device by their owners is likely to create ever increasing demands on the mobile device power budgets.

Given the differential trajectories of the demand for and supply of power on mobile devices – with the supply side seriously constrained by slow improvements in battery technology – the imminent mobile device energy gap is only likely to grow over the next few years, unless some component-level breakthrough happens. The demand for bigger and better displays that may anchor improved user interfaces and deliver improved user experience is only going to further exacerbate matters, especially since displays consume between 40% and 50% of a device power budget and the currently prevalent transmissive LCD display technology is particularly inefficient in its use of energy. As noted above, it is roughly only 5% efficient.

The imminent mobile device energy gap is only likely to grow over the next few years, unless some component-level breakthrough happens

As a result, leading players in the mobile value chain are, appropriately, striving – individually and in collaboration with one another – to eke out power efficiencies. While these effort and initiatives of various industry players will surely yield power efficiencies, these, even in the aggregate, may fail to completely bridge the potentially widening energy gap.

Since device displays constitute one of the larger units of energy consumption on a device, perhaps, this is the realm from which sizeable efficiencies may emanate. Reflective display technologies that leverage the natural ambience may well provide a meaningful contribution to the mobile device power budget debate.