Mayhem

The Future of Mobile Gaming

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Introduction

Mayhem challenges the idea of leaving childish things behind. Why can't the virtual realities enjoyed by the gamer in youth and at home be integrated into life in the real world? Mayhem is the realization of this dream.

Handheld gaming consoles are becoming increasingly able to satisfy the gamer's desire to take their favorite games out of the home, but Nintendo and Sony are bound by their legacy to design these devices in a way that makes their incorporation into, say, the workplace inappropriate. Additionally, if the mobile gamer is already carrying their smartphone, laptop, or tablet, it is a tough sell convincing them to take along a specialized device to enjoy only on their commute or downtime. This is compounded by the expanding capability of smartphones to satisfy gaming needs.

Rich Gaming Experience • Smartphone Design

Mayhem is an all-in-one device made possible through the synergy of smartphone functionality and a discrete gaming interface.

Contemporary handhelds have made strides in bridging the connectivity gap between smartphones and themselves, but they still lack essential features. Mayhem brings phone and texting capabilities to the platform in a form factor that not only makes these functions possible, but also makes Mayhem as comfortable in the workplace as it is in the rec room.

Free from the demands of a loyal market base, Mayhem is in the unique position as a newcomer to do what Nintendo and Sony cannot; that is, completely redesign how the user interfaces with their handheld gaming console. Mayhem maintains a clean, professional design by replacing obstructive joysticks, buttons, and direction pads with two multi-touch pads flanking the touchscreen display. The gamer still plays in a familiar way, but now the console is all business on the outside.

Proposal Outline

We invite you to read on and let us display the possibility of Mayhem. This report is partitioned into five sections. The first is an outline of how the 18-45 year old market will shape the device requirements. This will be followed by a review of the technologies employed in current popular gaming consoles and smartphones. Then, a forward prediction of such technologies by the 2015 target date is provided. The last two sections are sure to be the most interesting. There, an in depth tour through all aspects of Mayhem's design is given, followed by the rationale behind each design decision.

Mayhem opens the largest gaming market, both in terms of size and dollars spent, to handheld gaming consoles [1] [2]. As such, it is the necessary evolution to ensure the survival of this platform.

Device Requirements

To entice its target market, Mayhem combines a rich gaming experience with smartphone functionality. To direct our design the requirements of both fields are considered.

Gaming Requirements

In essence, a gaming console must enable the user to control the game; provide seamless audio and visual feedback; have space for games to be stored; and include a mechanism for transferring games to and from the device. These data streams must then be coordinated and processed by the system. The following block diagram outlines the essential IO of a contemporary handheld. The user interface employs buttons, touchpads, touchscreens, accelerometers, and gyroscopes to allow for game control; the display and stereo speakers provide feedback to the user; games are stored on internal or external memory and they can be brought to the system either over a network or through a port. In addition to game transfer the modem and antenna also facilitate multiplayer gaming. Mayhem's success depends primarily on satisfying these needs.
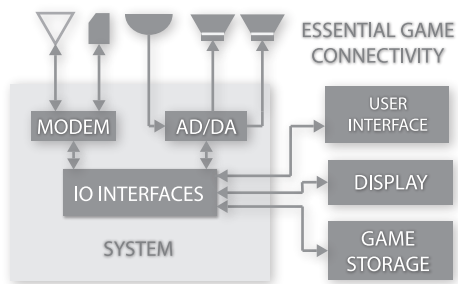
Smartphone Requirements

Parallel to gaming Mayhem incorporates the essential networking functions of a smartphone. Communication requires a link between two parties, and a way for each party to compose and receive messages. The former is carried out over various wireless protocols and the latter can be accomplished either through speaker and microphone, or text and display. Generally, software applications manage this.
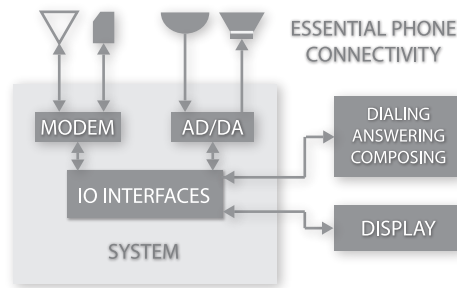
System and OS

A powerful multicore CPU and GPU are needed to handle both the 3D environments that rich gaming demands and also the simultaneous execution of multiple applications. Furthermore, these components must be energy and heat efficient. The operating system must be able to manage resources so as to maximize performance and power conservation, as well as handle events like phone call interrupts.

Appearance and Feel

The market demands a contemporary bar form factor. The device must fit comfortably in the palm of the hand, but also be large enough to be used as a headset and provide a detailed gaming display. The weight of the device must be between 100 and 200 grams. Finally, the battery must be capable of lasting a full day under several gaming hours and standard communications use. From our forthcoming design we expect the device to be priced competitively amongst premium smartphones.

Current State of Technology

The possibility of Mayhem gains traction upon comparing the technologies used in today's portable electronics. The PlayStation Vita, Nintendo 3DS, iPhone 5, and Galaxy S III are selected to represent where technology is today, and used to show that the distinction between handheld gaming consoles and smartphones is becoming increasingly blurred. These devices are investigated in particular because they represent the current state of the art in handheld gaming and best selling smartphones, respectively. Refer to Table 1 in the Appendix for a detailed comparison of the specifications of each device.

Each of these devices incorporates "system on a chip" (SoC) technology. Apple's A6 for the iPhone, or Samsung's Exynos 4 for the Galaxy S III are typical SoC examples. From an SoC currently on the market we see that not only are the core system components like the CPU, GPU, memory ports, and peripheral interfaces included, but network transmitters/receivers, image sensors, AD/DA convertors, and power management systems are also. Furthermore, SoCs can provide support for Bluetooth, Wi-Fi, GPS, near field communication, and motion sensors [3]. This union of systems into a single IC reflects how mobile electronics are becoming increasingly more powerful and compact.

Processor

The above representatives all make use of an independent GPU to complement the CPU. Each of these components is dual or quad core, and have clock speeds around 1.4 GHz. As for the CPU memory cache, there is typically 1MB stored in the secondary cache, and 16-32kB in the primary cache [4]. ARM is the near consensus manufacturer across all devices boasting a 90% market share [5]. HD video content and gaming necessitate the need for an independent GPU. Integrated GPUs, like the Adreno 320, enhance the user's experience of HTML5, web browsing, 3D games, 3D user interfaces, and other graphics applications [6]. Though there are many new smartphones with quadcore processors, most of the apps in the cyber market today do not fully benefit from this yet. Apps today are generally built for single or dual core processors [7].

Operating System

A clear line divides the classification of mobile operating systems into two categories: those specifically for gaming, and those specifically for phones. Although popular smartphone operating systems such as Android, iOS, and Windows Phone 8 have begun to support 3D graphics, their capabilities are still fairly limited in comparison with dedicated gaming systems such as the Vita or 3DS. These devices still have their own separate purposes, and their operating systems are designed as such [8].

Memory and Storage

Mobile devices today, including Galaxy S3 and iPhone 5, use Low Power Double Data-Rate 2 (LPDDR2) RAM, an international standard established by JEDEC in 2009 which brings operation voltages as low as 1.2V [9]. The total system memories in these devices range from capacities of 128MB to 1GB. Note also, from the aforementioned table, that the Vita and 3DS have dedicated GPU VRAM. This seems like an obvious addition given their higher graphics sophistication.

Today's mobile devices include main storage systems using NAND flash based Solid State Drives (SSD) [10] [11] [12]. In addition to being hundreds or even thousands times faster than

traditional hard disk drives, they are also smaller and more energy efficient [13]. In addition to the main storage drive, devices like the Galaxy S3 and PSVita provide a slot for external, removable memory cards. Samsung's Galaxy S3, for example, is compatible with Micro SD cards with capacities up to 64GB [14], and read speeds around 30MB/s [15]. A removable storage card is used as the primary mode of game transfer for both the PSVita and 3DS.

Software

The PS Vita supports a wide range of AV content, shown under "Multimedia" in the Table on page 9, and to stay competitive, Mayhem must have the same capabilities. PS Vita also has a bundle of native applications related to gaming: a "PS Store" to sell games, videos and other content; gaming social network applications such as "Party", "Near", "Friends", "Group Messaging"; and leaderboard application such as "Trophies". PS Vita is also capable of accessing and operating a PS3™ system in a remote location.

Among common phone applications, the iPhone includes novel apps like Facetime for video calling; Passbook for easy online payments; and the App Store for purchase of new applications.

Input/Output System

There are several mechanisms common to most mobile devices that enable user input; such as, touchscreens, front and rear cameras, motion sensing systems, buttons, and microphones. Furthermore, displays, speakers, audio jacks, and vibration are included to provide user feedback.

The displays of current devices range in size from 3.5 to 5 inches, have resolutions between 800x240 to 1280x720, are OLED or LCD, and employ capacitive type Multi touch technology Touchscreens have become more compact by

moving away from placing a clear touch sensitive panel over a generic display, such as GlideTouch offered by Cirque [16], towards fully integrated touch displays like AMOLED or TFT-LCD offered by Samsung Display [17]. Nintendo is the only device considered whose display is 3D enabled.

Cameras range from .3 to 12 Megapixels. Include features like LED flashes, autofocus, and HD video. The Nintendo 3DS has the novel feature of stereo rear cameras capable of taking 3D photos.

Smartphones, compared to handheld gaming consoles, tend to take a minimalist approach to button implementation. Outside of the standard smartphone buttons, gaming consoles include D-pads, action buttons, Left and Right triggers, start and select buttons, and analog joysticks. The PSVita is unique in that it adds a rear touchpad to enhance user control.

These devices also allow for various levels of connectivity. Device to television interconnectivity via PlayStation 3 and Apple TV is enabled for the PSVita and iPhone [18] [19]. The iPhone 5 is even capable of "mirroring" device video content through AirPlay [18] [20]. The above connections require an intermediary access point, whereas the Nintendo 3DS includes local wireless connection for gameplay between devices [21].

Communication

Games for the PSVita and 3DS are available both as physical "cartridges" and also through digital download. They can be downloaded to the PSVita over Wi-Fi, 3G, or through the PlayStation 3, whereas the 3DS is limited to Wi-Fi only. All iPhone and Galaxy content is available wirelessly over Wi-Fi, 3G, or LTE.

Modern mobile devices support either CDMA or GSM network standards while carriers around the world have recently introduced LTE 4G to

Technology Projection: 2015

provide wireless Internet access. LTE's replacement of 3G is expected to progress rapidly in coming years [22].

To connect with these networks a SIM card is required and today there are three different types: SIM, Micro-SIM and Nano-SIM. The latter, recently introduced by Apple, is 40% smaller than Micro-SIM [23] [24], further reducing space requirements.

Wi-Fi currently follows the IEEE 802.11 standard, with 802.11n being the most recent release [25]. Wi-Fi has a peak transfer rate of 450Mbps, range of 175 feet and operates at a 5Ghz frequency [26].

Near Field Connection (NFC) enables the user to connect with nearby devices at high transfer rates. Despite being new, today's NFC devices (Galaxy S III) allow users to exchange photos, pay using Google Wallet, and unlock doors, within certain proximities. This technology offers a bitrate transfer of 106 kbps, 212 kbps and 424kbps [27].

Power

Lithium-Ion batteries are the dominant power source for mobile devices. Currently, Motorola Droid Razr Maxx, with a rechargeable, 3300 mAh, Li-Ion battery, has the highest power capacity on the market [28]. In comparison, batteries for mobile gaming consoles have much lower capacities, with PSVita and Nintendo 3DS rated at 2210 and1300 mAh, respectively [28] [29]. These lower battery capacities reflect size and style restrictions; for example, the iPhone 5, using a smaller battery, has a slim 7.6mm profile compared to the wider 9.3mm profile of the Razr Maxx.

Processor

ARM is currently developing a new line of 64 bit chips and expects the Cortex-A50 to start appearing in smartphones in 2014. It boasts three times the performance and that it maintains the same energy footprint of existing smartphone processors [28]. Furthermore, ARM claims it can deliver more performance, use less energy, and be 40% smaller than the Cortex-A9 employed in the Vita and Galaxy S III [30].

Operating System

With the upspring of consumers who play games on their mobile phone and the recent decline in sales for physical consoles, it is reasonable to predict that the gaming market will continue to see a rise in demand for mobile games [31]. While the Android and Windows systems are slowly catering to this share of the mobile market by enhancing their gaming capabilities, gaming operating systems have begun working in the opposite direction by integrating phone-like features onto their platforms [32]. In fact, the OS for PSVita was designed to work with phone devices in addition to the Vita console [33]. This is further evidence that the future of mobile gaming will lie in a multi-purpose entertainment device that can fit into one's pocket.

Memory and Storage

The performance of conventional SDRAM keeps improving. Samsung has already begun to mass-produce LPDDR3 chips running at 12.8 GB/s with a capacity of 2GB, and expects to see them in commercial devices in 2013 or 2014 [34]. Another JEDEC standard released in December 2011, the Wide I/O Mobile DRAM, provides bandwidths up to 17GB/s [35]. On the other hand, there are two new interesting

developments; namely, Thyristor-RAM and Z-RAM. Based on Negative Differential Resistance, Thyristor-RAM is currently being studied for its high performance, and scalability. Despite a complex manufacturing process [36], it can write and read data ten times faster than contemporary RAM [37]. One major drawback is its shorter retention time, requiring a higher refresh rate and lowering energy efficiency.

Z-RAM removes the need for capacitors by taking advantage of the Floating Body effect on BJTs [37]. Because it only needs one transistor per bit, it provides a higher density of information while still using silicon. Another advantage is that it can be operated at very low voltages making it more energy efficient, an important quality for a mobile memory system.

Because of their fast access times, compact size, and small energy footprint, SSD use in mobile devices will continue to increase [38]. The price of SSDs is continuing to fall, currently costing around one dollar per GB [39]. Also, their performance and durability are being improved by new techniques such as the TRIM command that helps solve progressive performance degradation [38]. Removable memory cards also have a promising future, as Micro SD cards are expected to reach a maximum capacity of 2TB [40].

In fact, while each component of the memory or storage system is being improved, more layers of the system are being created. For example, Apple's new iMac and Asus' Zenbook use a magnetic disk combined with an SSD used as cache to balance between cost and performance [39]. Also, new forms of storage are emerging, such as Storage Class Memory, which is both non-volatile and has access times close to DRAM, therefore blurring the distinction between memory and storage [41].

Software

The forward movement of mobile software is difficult to predict; however, there are three apparent trends with traction. They are: ease of access to third party developed applications; a shift from "stand-alone" to "compound" applications; and the increasing presence of HTML5.

Experts have concluded that the future of mobile devices is in software, not hardware. Software has always been a part of the mobile experience, but only recently has it become so important. The iPhone's success can be partly attributed to this signifying that the future of software is to provide a platform that makes it easy to both develop attractive applications and also provide the user with easy access to software. This allows the user to tailor the device to her needs by outfitting it with the software she desires. [42].

Compound mobile applications blend the user's collected personal preferences with services from multiple industries to provide the user with a personalized experience. This move from stand-alone applications to compound ones is the real innovation in mobile software and is seen to transform the way we live and work [43].

The development of HTML5 represents the move away from software being stored on and written for a particular device, towards a native shell that links to an online general application. The Facebook app for the iPad is an example of this. The HTML5 paradigm is projected to dominate, as multimedia based apps driven by ad sales can be done more efficiently in this way; however, it is seen to progressively replace current software as the technology is not yet on the same level [44].

Input/Output System

Samsung projects that future touchscreens will have transparent, nano-pixel, and foldable

features [45]. While electronics including these technologies have been on display as prototypes since 2010 [46] [47], evidence of production models on any scale cannot be found. By analogy, Sony released its first OLED device in 2004 [48], but mainstream usage of OLED touchscreens in mobile devices has only recently been adopted. For this reason it is not expected that foldable displays and the like will be commercially viable in 2015 and that LCD and OLED technologies will therefore remain dominant.

The Wi-Fi Alliance has introduced a new technology called MiracastTM. Miracast is an optional certification program for Wi-Fi enabled electronics permitting direct sharing of video content between two supported devices. Such technology would allow any content displayed on a handheld gaming device to be displayed on another device, such as a TV, through a direct connection between the two; that is, no intermediary access point is needed between two devices with this support. Video is supported up to 1080p at 60fps. Audio is supported up to stereo 16-bit depth with a sample rate of 48kHz [49].

IEEE 802.11ad will become a new standard in wireless communication by 2014. Because it runs on a wider frequency spectrum and has higher transfer rates, it is expected to allow "content sharing and streaming among multiple devices and displays," enabling seamless enjoyment of video games and HD video [50].

Communication

It is projected that packaged games will soon be obsolete. Sales growth of physical game units has decreased since 2007, while sales by digital download have seen double-digit growth over the same period and are projected to comprise 19% of all video game sales by 2016 [51].

Evidence of this trend is seen in the recent bankruptcy filing by Game Group, Europe's largest video game specialist [52].

Sony is expected to integrate cloud gaming into the next generation PlayStation console [53]. Cloud gaming enables users to stream games live over the Internet. It is an attractive alternative to digital download because users would not have to wait for game downloads and it would reduce hard drive requirements.

The transmitter/receiver incorporated into mobile devices requires a power amplifier to produce radio signals. Current power amps are only 35% efficient, says Eta Devices [54], but they have developed a new technology, aimed for use in smartphones, that reduces the amplifier's power consumption by half. This technology, called asymmetric multilevel outphasing, is expected to enter the market in 2013 [54].

Devices using NFC are becoming more prominent due to its fast contactless connection. "According to the estimates, over 30 percent of all phones globally will have NFC built-in within the next four years "[55]. With an expected increase in the usage of NFC, it is likely that this technology will improve in terms of its bitrate transfer.

Power

Battery technology will improve in the coming years both in terms of capacity and charge time. Both of these parameters can be improved by increasing the number of lithium-ion atoms through the replacement of carbon by a silicon and graphene system, which could see battery life increase by 10-15 percent and charge times fall to around 15 minutes [56] [57]. Fast-charge Li-ion batteries are also being developed that can be recharged 30-120 times faster than conventional ones [58].

Mayhem's Design

Simplification of the game console's interface is a central tenant of Mayhem's design. The footprint of D-pads, buttons, and joysticks must be minimized in order for Mayhem to blend seamlessly into the real world. The solution is a completely redesigned interface that retains the precision game control of current gaming systems.
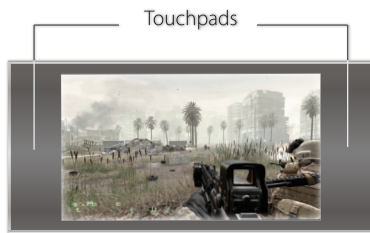
Touchpads

This solution is realized through the addition of four multi-touch pads: two flanking the display and two on the rear. The function of each touchpad is ultimately up to game designers, but it is not hard to envision how this configuration reimagines a traditional set up. For example, moving one thumb over the left frontal pad can control Player movement, while tapping or making gestures with the other thumb on the right pad induces actions. Furthermore, modifier buttons are replaced by the two rear pads, which are positioned to be in the range of the user's middle and ring fingers. Again, taps and multi-finger gestures permit a wide range of control options there.

Touchpads

Stereo Speakers
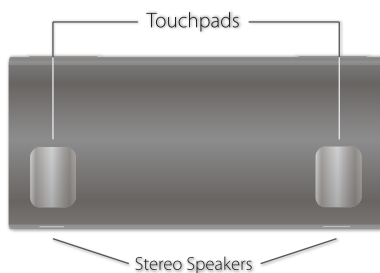
Notice that not all button support has been removed and that two triggers are included at the top of Mayhem when in gaming position. The above features plus an HD touchscreen, motion sensing system, and stereo sound give Mayhem the sophisticated gaming interface needed for games like Call of Duty, Tekken, or Gran Turismo; a first for the smartphone form factor.

Gaming Triggers

Volume   Silent

Earpiece   Mic

Power   SIM   Audio   USB / Micro SD card

The interface has further been designed for portability between gaming and smartphone mode. For example, one trigger is used as a volume control, the other, a silent switch, and a two-fingered swipe along the lower touchpad serves as the traditional smartphone "home" button.

Front and rear cameras (not shown), with HD video capabilities, not only satisfy the social networker's desire to document life, but also open Mayhem to the developing world of augmented reality gaming.

Users can enjoy the rich audio content that Mayhem offers in public thanks to the inclusion of a standard audio jack. This also acts as a mic-IN

for hands-free calls or online gaming.

Storage expansion and device powering are made available through the combination SD card and USB connectivity port. Finally, including a microphone, earpiece, and Nano-SIM card slot completes phone I/O.

Level Next

Moving one step lower Mayhem is turned on revealing an interactive GUI and software support for both gaming and phone functions. The GUI is an icon based sliding screen model such as that found on iOS or Android. The marriage between GUI and touchscreen satisfies requirements like phone control, message composition, and application selection. The following table enumerates the included software and media support.

CELLPHONE APPS	GAMING APPS	MULTIMEDIA
• Phone	• Game Store	Music
• Text messaging	• Voice Chat	—MP3 MPEG-1/2
• Organizer	(multiplayer)	Audio Layer 3, MP4
• Map	• Game community	(MPEG-4 AAC),
• Calendar	• Leader Board	WAVE (Linear PCM)
• Audio/video	• One pre-installed	
player/editor	game	Videos
• Contacts	• Control Settings	—MPEG-4 Simple
• Maps/GPS		Profile (AAC),
• App Store		H.264/MPEG-4 AVC
• Photos		High/Main/Base
• Camera		line
• Social Networking		Profile (AAC)
• Email		
• Internet browser		Photos
• PDF reader		—JPEG (Exif 2.2.1),
• Language		TIFF, BMP, GIF, PNG
commands and		
dictation		(Equiv. PSVita [19])
• Document viewer		
• Voice memo/dial/		
command		
• System Settings		

The included software is divided into two categories comprising the requisite smartphone and gaming interfaces needed. Mayhem is primarily a gaming device so smartphone software is kept to essentials for communication, photography, and media. Instead of directing development resources toward extras like productivity suites, Mayhem relies on third party developed software made available through an online app store.

Gaming software is further divided between game management and the games themselves. For example, the game store allows games developed by mainstream production companies to be purchased and transferred to the device.
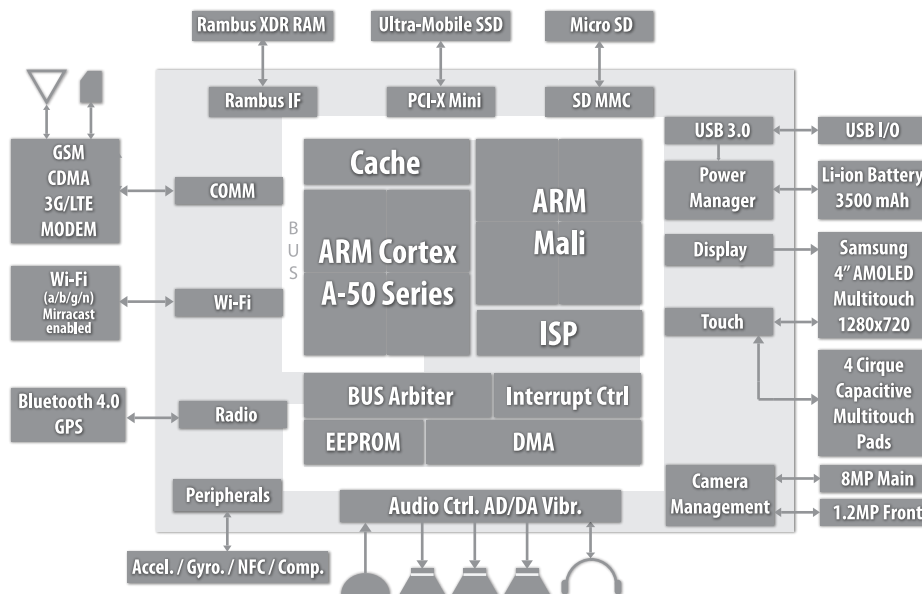
A proprietary Mayhem OS will be developed with the ability to control the GUI and support high-end 3D and 2D games. In accordance with the processor selected the OS will be based on a 64-bit architecture and use a hybrid kernel. For software support, the OS will implement its own custom package manager for installing new applications and games. A development suite will be produced comparable to Apple's Cocoa and Xcode package to facilitate the development of aesthetically coherent third party applications.

The OS will also be responsible for power management. Depending on the state of the phone the Mayhem OS will use existing techniques to reduce the energy consumed by hard disk access, wireless connectivity, and graphics processing [59].

Mayhem is integrated into the home electronics ecosystem allowing for direct wireless mirroring of content to Miracast enabled displays. As the capabilities of portable electronics increase, this feature could actually make Mayhem's successor generations replace the home gaming console entirely. Mayhem can also connect directly to other Mayhem consoles for multiplayer gaming.

Going Inside

A SoC projected to be commercially viable and class leading in 2015 powers Mayhem. Modified with components determined from the technology projections of the last section, the block diagram below shows Mayhem's internal architecture, which is also based on current SoCs offered by STEricsson and TI [3] [60]. On the perimeter of this diagram are the peripheral-interface interconnections.

Arranging peripherals in the above manner allows for a hybrid bus arbitration process, where device priority can both be programmed and also daisy chained. This approach mixes the speed of proximity-determined priority with the flexibility of programmed priority control.

Notice that a DMA module has been included to allow device controllers to access memory, directly, freeing the CPU from controlling this process. Below the DMA there is a system boot EEPROM.

Touring the perimeter of the diagram, it is revealed that all of Mayhem's initial requirements have been satisfied. The user is able to control games through the inclusion of touchpads, a motion sensing system, and a touchscreen. The stereo speakers and 4" AMOLED display provide the

Spiraling out from between the processor and bus arbiter is a representation of the system bus. The memory, communications, power, and IO peripheral modules are placed along the bus by considering three factors. First, there are physical considerations where, for example, the USB and Micro-SD interfaces are placed next to each other because they are neighbors in Mayhem's connectivity slot. Second, like peripherals are placed together and in proximity to the part of the processor they rely on, hence the grouping of the display and camera interfaces near the GPU. Finally, and most important, relative device priority is considered.

requisite audio and visual feedback. Games can be stored on the SSD or SD card and are brought to the gaming system over 3G, LTE, or Wi-Fi through their modems, transmitter/receivers, and antennas. The latter components also satisfy a large portion of Mayhem's communications requirements in that they enable messages to be delivered and received between two parties. Messages can be composed through either the microphone or by typing on the touchscreen keyboard, and they can be received by way of the earpiece speaker or display. Finally all of these various data streams pass through the controllers and interfaces and are coordinated and processed by the CPU, GPU, and main memory.

Design Rationale

Integrating smartphone functionality into the portable gaming platform is necessary. Not only are game sales for smartphones taking from the handheld console market, but also the release of high quality games like Assassins Creed and Infinity Blade shows that the gameplay gap between smartphones and their traditional counterparts is becoming increasingly narrow [61]. Gamers who play on their mobile phone make up the largest and fastest growing demographic of American online gamers and their numbers are projected to see double-digit growth into 2015 [62]. Furthermore, of the current 102 million mobile gamers in the US, 75% use a smartphone, and this figure is expected to grow to 86.4% by 2016 [62]. Smartphone gamers have seen a 98% increase in 2011, with considerable growth anticipated to continue through 2016 [62]. Conversely, with the exception of Japan, handheld console saturation in global markets is minimal and decreasing [61]. For these reasons we have not only incorporated smartphone functionality from a hardware perspective, we have also taken a cue from smartphone design in the appearance and feel of our product. Our product looks professional, fits in the palm of your hand, and can be carried around in your pocket.

Processor

Mayhem will use an ARM A-50 series processor for the following three reasons. First, the extensive implementation of ARM processors in the mobile market speaks to its capability of satisfying Mayhem's computational needs, power requirements, and cost aims. Second, the A-50 moves to a 64-bit architecture and ARM boasts a three-time performance increase while reducing energy consumption and size when compared with the A-9 [30] [31]. Finally, the timing of the A-50's announcement aligns perfectly for a 2015 release. For example, the A-15 series was announced in Q3 2010 [63], but only in Q3 2012 did TI release an SoC with the chipset embedded [64]. The A-50 series has just been announced making a Q3 2014 release of an A-50 powered SoC highly likely, which is just in time for Mayhem's 2015 debut. For analogous reasons and compatibility we have selected the Mali series of ARM GPU's. This GPU has support for Open GL ES 1.1/2.0 enabling the rendering of rich 3D content [65].

Operating System and Software

The vast majority of mobile operating systems, with the exception of Android, are closed-source and proprietary [66]. The Vita and 3DS run under unique proprietary operating systems custom-tailored to meet game developers needs [67]. Thus, while Android allows for a large community of developers to create custom apps and software, Mayhem's design is gaming console first, and will focus on soliciting professionally developed title games. A less-sophisticated development API will still be available for amateur users to use, however.

Matching the processor's architecture, the operating system must use 64-bit addressing and the instruction set will be based on ARMv8 [68].

The OS will run using a hybrid kernel in order to take advantage of the benefits of both monolithic and microkernels. As for the software layer, a packaging system allows software to be added fairly easily, thus enhancing modularity of the system, a standard in today's mobile OS.

Surprisingly, there are more mobile gamers than there are mobile music listeners, mobile video watchers, and mobile social networkers [62]. Thus we have relegated music, video, and social

networking software to a secondary design focus, to focus on maximizing the gaming experience.

Memory and Storage

Based on the current state of RAM technologies and their future trends, the main memory system for Mayhem will be the Rambus Mobile XDR architecture. Although Thyristor-RAM and especially Z-RAM seem to be good replacements for DRAM, they are still under development and, unlike the above processors, they do not meet Mayhem's release schedule. Rambus, on the other hand, is ready for manufacturing and has the highest bandwidth currently on the market. Rambus is likely to retain this position, by enabling an upgrade of its memory capacity without compromising performance, through Dynamic Point-to-Point technology. Moreover, Very Low-Swing Differential Signaling and clock pausing techniques make this subsystem very energy-efficient, allowing the user to enjoy extended battery life [69]. Finally, it integrates DRAM with its interface, so it is compatible with SoC environments.

For storage, Mayhem incorporates an Ultra-Mobile SSD and a Micro-SD card. Because SSD's are smaller and faster than their magnetic counterparts, they are ideal for Mayhem's performance requirements and size restrictions. Furthermore, while a traditional HDD involves a moving mechanical head, the SSD has no moving parts, which makes mobile devices more stable and reliable in case of shock. An 8 GB SSD is both economical and sufficient to store the Mayhem OS and native applications [70]. The bulk of storage is supplied by a Micro-SD card, which has a capacity up to 128 GB.

Communication

Mayhem is designed for digital download to be the primary way in which games are purchased for and transmitted to the console. In addition to its rapidly expanding adoption, digital download has the advantage of capitalizing on impulsive purchases. That is, the user can buy a new game with their credit card whenever and wherever they feel so inclined. This will serve as the primary profit vehicle to ensure Mayhem's return on investment. In addition to making Mayhem a smartphone and enabling online gaming by connecting it to global mobile networks, the GSM, CDMA, 3G, LTE, and Wi-Fi modems provide assurance that the user can always be connected to the app and game stores; therefore investment in these components and their antennas can be a considerably large portion of Mayhem's budget.

One large assumption is that Eta Device's power amplifier technology will be ready for SoC integration before Mayhem's production. Inclusion of this technology would greatly reduce power consumption while the device is connected to 3G or LTE networks making online mobile gaming a real possibility.

Power

Mayhem is both a gaming console and a smartphone, so the rechargeable, internal, Li-ion battery must be able to hold charge for at least a full day assuming that the user is gaming for several hours. However, an informed engineering decision must be withheld until all systems are optimized and working in unison before the sweet spot that both minimizes size and maximize capacity can be determined.

With the exception of the transmitter/receiver power amp, Mayhem's design calls for production ready hardware components. This means that systems integration and development can start today, giving Mayhem's design team two full years to ensure that all hardware and software resources are utilized to their full potential. With your help, Mayhem can be ready to ship as a class leading and innovative handheld gaming console in 2015.

Appendix

Table 1:

	PS Vita	3DS	iPhone 5	Galaxy S III
CPU	ARM Cortex A9 – quad core	ARM 11 MPCore –dual core	Apple A6 –1.2 GHz – dual core	ARM Cortex A9 –1.4 GHz – quad core
GPU	ARM SGX543MP4+	PICA A200	ARM SGX543MP3	ARM Mali–400MP
OS	Proprietary	Proprietary	iOS6	Android v4.0.4
Memory	Internal: Main 512MB VRAM 128MB External: PlayStation Vita card	Internal: Storage 2GB VRAM 6MB FCRAM 128MB External: 2GB SD	Internal: Storage 16/32/64 GB DRAM 1GB	Internal: Storage 16/32/64 GB RAM 1GB External: microSD/SDHC
Display	5" OLED Multi-Touch 960 x 544	Upper: 3.5" LED 800 x 240 3D Lower: 3" LED touch 480 x 320	4" LED Multi-Touch 1136 x 640	4.8" Super AMOLED 1280 x 720
Featured IO	Front/Rear Camera Rear Touchpad Stereo Speakers 6–axis Motion Sensor Control Pad Joysticks	Front/2Rear Cameras Stereo Speakers Accelerometer Gyroscope Contol Pad Circle Pad Stylus	Front/Rear Camera LED Flash Accelerometer Gyroscope	Front/Rear Camera LED Flash Hand Motions
Connectivity	3G HSDPA/HSUPA Wi-Fi IEEE 802.11b/g/n Bluetooth 2.1 +EDR	Wi-Fi IEEE 802.11b/g	GSM(850, 900, 1800, 1900, 2100) CDMA(800, 850, 900, 1800, 1900, 2100) 3G LTE Wi-Fi IEEE 802.11a/b/g/n Bluetooth 4.0	GSM(Depends on market) CDMA(Depends on market) 3G LTE Wi-Fi IEEE 802.11a/b/g/n Bluetooth 4.0
Power	Li-ion 2210 mAh Game: 3~5h Video: 5h	Battery Pack Li-ion 1300 mAh Game: 3~8h	Li-ion Talk: 8h Internet: 8h Video: 10h	Li-ion 2100 mAh Talk: 11~21h

Compiled from [8] [12] [16] [17] [19] [26] [27]

i.

Design Team

Kevin Dam:
Operating System • Communications

Andrew Jesson:
Layout • Editing • Market Research • I/O
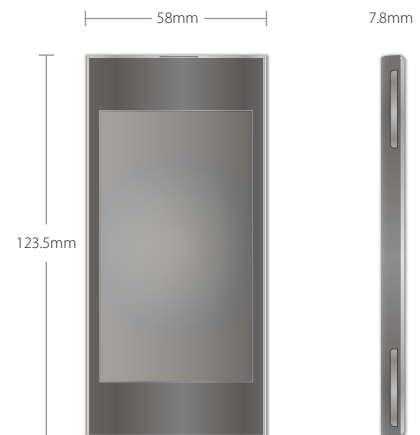
Mathieu Wang:
Memory • Storage

Hai Sin Yip:
Processor • Communications

Ze Qian Zhang:
Power • Software • Team Coordination

Team Hours (58.5 total):

Date	Ze	Kevin	Mathieu	Andrew	Hai Sin
01-Oct	1	.5	.5	.5	.5
08-Oct	1	.5	2	1	1
15-Oct	1	1	1	2	1
22-Oct	1	.5	1	2	1
29-Oct	1	1	2	2	2
5-Nov	1	1	1	2	1
12-Nov	2	2	1	1	1
19-Nov	1	3	1.5	2	2
26-Nov	2	1	1	2	2
Total	11	10.5	11	14.5	11.5

58mm   7.8mm

123.5mm

3D Models, Tables, and other graphics designed from basic geometric shapes by Andrew Jesson in Illustrator and SketchUp. The Device's front panel is inspired by the Apple iPhone 4. Call of Duty Modern Warfare image credit: http://www.ngohq.com/

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