Purpose

As cell phones and tablets become smarter and smarter, wouldn’t it be great if other consumer electronics (CE) devices, like Set Top boxes, DVD or Blu-Ray Disk players and televisions, also were as smart? What kinds of cool new features could be added to TV viewing and in-home entertainment, if Set Top Boxes, DVRs or televisions were as smart as your smartphone?

The research suggests that consumers are, in fact, interested in smart, connected CE devices and there is growing evidence on the demand for such products. For example, according to data from Screen Digest, an arm of global information company IHS®, there is increasing consumer demand for Internet-connected televisions, despite a decline in overall global television shipments. IHS research shows that in 2012, there were 66 million smart TVs shipped across the globe, marking a 27 percent jump over 2011. IHS anticipates this figure should rise to 141 million units shipped in 2015, which IHS says would mark the first time the majority of sets shipped would be smart TVs. In 2016, the number is projected to bump by more than 25 million units to 173 million.

This white paper, from the Marvell® Video Systems Architecture team, identifies hardware and software enhancements Marvell has made to enable Android™ as a CE-grade operating system (OS) to help OEMs come to market more quickly with innovative smart CE devices. Specifically, this paper describes a software architecture that integrates seamlessly with Android and addresses wide ranging issues, such as resource management, security, Digital Rights Management (DRM), Picture Quality /Audio Quality (PQ/AQ) tuning and players for baseband and RF sources for various geographies. It also addresses user interface (UI) considerations and integration of third-party native applications. The software architecture includes a native media player that provides a hardware abstraction and fits within the media player framework that Android exposes.

Background

Android™ is one of the most popular operating systems for smart phone and tablet applications and is well-featured to tackle the market requirements for those segments. However, consumer electronics devices, such as Set Top Boxes, DVD/Blu-Ray Disk players and TVs, have different requirements that Android does not fully support.

Traditionally CE devices have been more of a closed platform, using proprietary software stacks from the CE OEM or a handful of CE middleware providers. During the past five years, there has been a significant uptick in the enablement of Over-The-Top Content (OTT) video services and other Web 2.0 Applications. OTT allows Broadband delivery of video and audio without the Internet Service Provider being involved in the control or distribution of the content itself, creating a more hybrid environment of Broadband delivery and traditional delivery. The world at large is embracing this hybrid environment - a combination of traditional content delivery mechanisms (i.e. Cable, Satellite or Terrestrial), Physical Media (i.e. DVDs, Blu-Ray disks) and OTT.

Legacy middleware is equipped to handle the traditional delivery mechanisms, but lacks support for Web 2.0 standards (OTT, DRMs, Social, etc.). OEMs see Android as an enabler of this hybrid world, because Android is built for mobile devices where the pace of innovation in the Applications, as well as Content Delivery mechanisms, is much faster than CE devices.

Additional reasons for Android building momentum in the CE space are:

- It is a rich development platform with a broad developer community.
- Android allows OEMs to build an “open/closed” platform at the same time – the openness of the Android software developer kit invites developers to build apps, while allowing the OEM to define the hardware platform. The Apps run on that specific hardware platform.
- Google TV™ is a good example of Android being enhanced for CE devices, but there are markets where Google TV is not available at present. Marvell is filling that gap by providing for OEMs the latest Android releases customized for CE devices. Currently Google TV is on legacy
Android releases. Since some CE OEMs need a recent version of Android, they can’t use Google TV.

What are the challenges in using Android for CE devices?

Android has no support for TV/STB functionality; so in the past, OEMs have designed “bolt-on” solutions. Traditionally, OEMs have taken a separate module and bolted it on to deliver hybrid features. This increases the BOM for CE devices, which tend to be very cost sensitive. In many cases, OEMs were using a two-chip solution, one running a TV/STB stack and another running Android. In other cases, rather than a hardware bolt-on, the Broadcast TV stack has a software bolt-on (for example, a Native app implemented using a different application framework) and an external entity, such as an App Manager, that manages the switching between the Native and Android world.

Marvell is rising to the challenge to resolve this issue for CE device OEMs with a focus on ensuring that Marvell silicon and software can enable a superior Android experience for this new world order of media content delivery and rich Internet applications for CE devices. By using the Marvell® ARMADA® 1500 all-in-one HD media System-on-Chip (SOC), CE OEMs can put both solutions into one package, integrating the TV into the Android software solution, for a lower cost, single-package solution. To do this, Marvell has developed the Marvell® ARMADA® Accelerated Android (Marvell A3CE) software development kit (SDK) for OEMs. Below are block diagrams showing the hardware and software implementation. The first block diagram depicts an Android-powered Digital TV using the Marvell ARMADA 1500, and the second diagram shows the A3CE SDK.

FIGURE 1. BLOCK DIAGRAM DEPICTING ANDROID-BASED DIGITAL TV POWERED BY MARVELL ARMADA 1500
The A3CE software stack is composed of the following layers:

**Applications** – A3CE augments Android by adding CE-specific applications, such as an overscan app and a factory mode app. Applications and features specific to a phone experience have been removed and the launcher and settings applications are designed so as to not obstruct background video.

**Middleware** – A3CE adds substantial functionality in this layer. The Marvell Media Player provides a rich set of codecs to support CE-grade content playback. The Universal Player extends the media framework by adding support for physical sources like HDMI, CVBS, Tuner, etc. Region-specific TV stacks (ATSC, DVB, China ATV, etc.) are integrated into the Universal Player.

**Platform Support** – A3CE introduces a resource manager to arbitrate control over finite hardware resources such as the video decoder. The various players in the middleware interact with the resource manager, making it transparent to the applications. A Streaming Control Manager provides a centralized service for PQ/AQ settings that is crucial in CE devices. A settings application provides the user-level GUI to control settings, such as brightness, etc. Middleware components interact with the Streaming Control Manager to automatically apply source-specific settings on a source change.

**Porting Android for CE devices**

With the public release of Android™ 4.0 (Ice Cream Sandwich), Marvell released A3CE SDK for its Marvell 88DE3100/ARMADA 1500 SoC. This SDK includes:
- Linux™ kernel 3.x with SMP support
- Hardware accelerated video decoders which support two full HD streams decoding
• Audio decoders supported by dedicated DSP core
• Various DRM schemes supported by dedicated secure processor
• TS de-multiplexing handled by dedicated processor
• High quality video/image processing subsystem that implements Marvell QDEO™ video processing, performing 3D de-interlacing, scaling, noise reduction, compression artifact reduction and adaptive contrast enhancement
• HDMI v1.4 Rx/Tx with HDCP
• Board Support Package (BSP) drivers for embedded high-performance GPU core
• Resource Manager which coordinates the whole system hardware resource usage
• Modules to support UVC USB camera and UAC USB microphone audio input
• Modules to support Bluetooth HID, A2DP, HSP, HFP, etc.
• Middleware modules such as, players for media playback, which support streams from TV input sources, DVB/ATSC/ISDB/IPTV as well as local files, DLNA contents, etc.
• Middleware modules for OTA, Factory mode, OOBE, Overscan, CEC service, etc.
• Applications such as Universal Player, Marvell Player, Skype™, Factory Mode tool, Netflix®, YouTube™ and games.

Marvell will also support the latest Android™ Jelly Bean release on Marvell’s next generation of HD media processors. Jelly Bean on the next-generation Marvell HD media processors will support the media codec API allowing video encoding, video composition with graphics and better security.

To meet the requirements for HD graphics for a CE device, Marvell ARMADA 1500 integrates the Vivante® GC1000 Graphics core to provide acceleration to 2D and 3D graphics display. In order to achieve the composition rate of the UI layers very close to the refresh rate (60Hz) of the display, the Marvell Android SDK has been optimized for SurfaceFlinger by using the SoC hardware capabilities to compose multiple graphics surfaces. This SDK also fully supports OpenGL® ES 2.0, EGL and Gralloc, which are required by Android v.4.0. Skia is also accelerated by ARM® NEON™ instructions to get much better performance, as those applications are configured to use software renderer.

Android is targeted for handheld devices and critical UI elements (like the launcher or the settings screen) are designed for a touch screen experience. For CE devices, a 10-foot UI experience is desired. A3CE incorporates a 10-foot UI for the launcher and settings. The UI experience is carefully designed to not interfere with background video. This allows picture adjustments to be visible to the user and not be obscured by the graphics. A3CE also removes the settings that do not make sense in a CE device context (such as battery level, phone options, etc.)

As the basic human–machine input interface, remote controllers play a very important role in current CE devices. With current advanced technology, the remote controller is not limited to emit key input events, but also support voice input (integrated microphone on the RC), touchpad, gesture inputs, mouse inputs, etc. This SDK supports USB HID, Bluetooth HID, as well as voice input from Bluetooth (BT) or USB microphone. This SDK has integrated BlueZ® stack and UAC with Linux ALSA driver, which is connected to AudioFlinger, to support various voice applications.

Android’s Camera Service is used to support video applications. Marvell ARMADA 1500 Android SDK supports V4L2/ UVC camera video input. Captured video raw data can be encoded by the SoC hardware or software encoder or could use the embedded encoder in the camera module. Video chat applications such as Skype™, Google Talk® and QQ are also supported in this SDK.

The A3CE SDK supports power management states to comply with strict regulations governing the standby power being consumed by CE devices, while offering user convenience of fast boot from standby states. As shown in Figure 3, the SDK supports four power modes: on/off/standby/refresh. In standby, only a micro-controller monitoring wakeup event is running. The SoC and all the peripheral devices are powered off. The power consumption will be less than 100mW in standby state. Wakeup events from “standby” to “on” state include RC events, VFD button pressed events, WOL, Wi-Fi, CEC, etc. The difference between standby and suspend is: in suspend state, DRAM is in “self refresh”, all the software and hardware context is kept in DRAM, and the microcontroller is powered on. So from “suspend” state to the “on” state, the system will be transformed very quickly (<5s); this is also called the “fast reboot.” In suspend state, the power consumption is usually less than 1W - a little more than standby mode.
Evolving Android for CE devices

FIGURE 3. POWER MANAGEMENT STATE MACHINES

Universal Player

A3CE extends the Android media framework to support physical sources by using designated Universal Resource Identifier (URI) addresses to identify the physical source. An application can trigger source selection by “playing” the URI corresponding to a source. The media framework invokes the correct player (baseband player for HDMI, ATSC Player for DTV) depending on the URI. The designated player is responsible for setting up the streaming graph and actually changing to the source. Deeper source related controls are handled outside of the media framework by direct Java Native Interface (JNI) calls from the application to the specific player.

The Universal Player includes support for various 3D video formats. Automatic detection of 3D content is supported for sources where such signaling is present. The Universal Player supports forcing the mode to 3D manually (typically used for Top/Bottom, SBS content.) 3D detection and control APIs are supported through JNI.

Marvell Media Player

By leveraging the powerful hardware accelerated A/V decoders in the Marvell ARMADA 1500, Marvell Media players can support two full HD video streams decoding at the same time. Video decoders accelerated by hardware include MPEG2, H.264, VC-1, MPEG4, WMV9, RMV, DIVX, AVS, MJPEG/ JPEG, VP6/8, etc. Audio codecs supported are Dolby® Digital, DTS, PCM, MP3, AAC, HE-AAC, MPEG Audio, WMA, FLAC, VORBIS, RA, LPCM and more. Figure 4 shows the block diagram of the Marvell Media Player.
The Marvell Media Player leverages FFmpeg to load the streams from the network or local storage, and parse the container header and filter out Audio/video data into separate buffers. Then it will connect Audio/Video buffers with Marvell Present Engine (PE) to configure and control modules such as Audio/Video decoders, APP/ VPP, Audio output, video output, and so forth. With the strong power of FFmpeg, almost all the known container formats are supported, such as .avi, .divx, .mkv, .ts, .m2ts, .mpg, .vob, .mpeg, .wmv, .asf, .mov, .mp4, .webm, .rmvb and .flv.

The Marvell Media player also supports multiple streaming protocols such as RTP, RTSP, HTTP, HTTP Live Streaming, Unicast and Multicast.

**OpenMAX IL**

Marvell also supports an OpenMAX® IL-based media pipeline on Android Jelly Bean. OpenMAX IL is an open standard for media processing acceleration. It serves the purpose of a hardware abstraction layer for the Android media frameworks. It allows flexible connection of media processing elements into a complete graph from input to output. Each element can be implemented in hardware or software.

Marvell’s OpenMAX® IL implementation is based on Marvell’s ARMADA Media Pipeline (AMP) drivers.
Security

A key incentive for people to get a CE device into their living room is to enjoy a wide selection of high quality content. For Marvell, this means supporting several DRM systems:

- AACS, used on Blu-ray discs
- CSS, used on DVDs
- Microsoft® PlayReady™, used by Netflix
- Google Widevine® DRM
- DVB-CSA, used for broadcast TV in Europe and elsewhere

A successful DRM implementation must be secure. A cornerstone of security in a consumer device is the Secure Boot process, which ensures that only legitimate software can run. This is the way to ensure that not only digital media content, but also personal information like payment details, are always treated by the software according to applicable laws and commercial agreements.

To boot securely, the main CPU starts executing from ROM code, which is considered tamper-proof. The ROM code is the first step in a chain of boot steps, where each step decrypts and authenticates the next step, so that none of the steps can be tampered with. The last stage is the Linux kernel itself. Decryption and authentication is performed by a dedicated Secure CPU executing out of ROM. The figure below illustrates Marvell’s secure boot process.

![Secure Boot Process Diagram](image)

**FIGURE 6. MARVELL’S SECURE BOOT PROCESS**

The open nature of an Android system presents special challenges for the system security, since additional software can be installed and run. The rest of the system must be constructed in a way so that any user-installed applications can never violate the security policies of the system or access confidential data. The Android system already has many mechanisms for isolating applications and enforcing security policy. To enable a second line of defense, Marvell has added hardware-based security assisted by the SoC. There are two main areas secured by hardware: cryptographic keys and the trusted video path.

Cryptographic keys are protected by encrypting them with other keys, sometimes in several steps. This concept is called a Key Ladder as shown in Figure 7 below. Keys needed to descramble content are received in protected form over the public broadcast or network. A secret key is needed to derive the clear content key, which is then stored in a key table. The Transport Stream Processor can use hardware crypto functions to descramble data using the key, but cannot read the key value itself. Thus the actual content key is never revealed outside the Secure CPU and its key table.
FIGURE 7. ENCRYPTION SECURITY ENABLED BY MARVELL’S KEY LADDER APPROACH

The diagram below shows how a trusted video path is achieved by re-encrypting descrambled video content in local memory before storing it in DRAM.

FIGURE 8. TRUSTED VIDEO PATH
Conclusion

In conclusion, by developing an elegant and comprehensive Android-based hardware/software solution, Marvell helps enable OEMs to come to market more quickly with new and innovative “smart” CE devices. New content can be developed for the new hybrid environment enabling OTT content, video services and other Web 2.0 applications without having to add cost with bolt-on solutions. With its Marvell ARMADA 1500 SOC and the A3CE SDK, Marvell is bridging the development gap for Android-based CE devices. This white paper offers a serious, robust solution to enable Android as a CE-grade OS for devices like Set-Top Boxes, DVRs, Blu-Ray Disk Players and Smart TVs. Marvell is offering a software architecture that integrates seamlessly with Android, while addressing issues of resource management, security, PQ/AQ tuning, players for baseband and RF sources for various geographies, UI considerations and integration of third-party native applications. By using the Marvell Android for CE solutions and tools, OEMs are enabled to build a superior Android experience for this new world order of media content delivery and rich Internet applications for CE devices.

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