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**Introduction**

With the increasing incidence of chronic diseases, the need to control health care costs and aging populations, connected health technologies are becoming increasingly important. The Continua aggregation manager (AM) will be an essential device in the connected health system, enabling personal health devices to log data into a remote electronic health record (EHR) for family and clinical review. The AM can take the form of a cell phone, a personal computer or a dedicated device.

This paper presents three different system solutions for an AM. These include a high-performance digital visual interface (DVI) AM (comprising hardware-accelerated, high-definition [HD] audio/visual [AV] codecs and a 3-D accelerated user interface [UI]), a reduced-cost DVI AM (comprising software-based, standard-definition [SD] AV codecs) and a low-power AM (supporting software-based audio codecs).

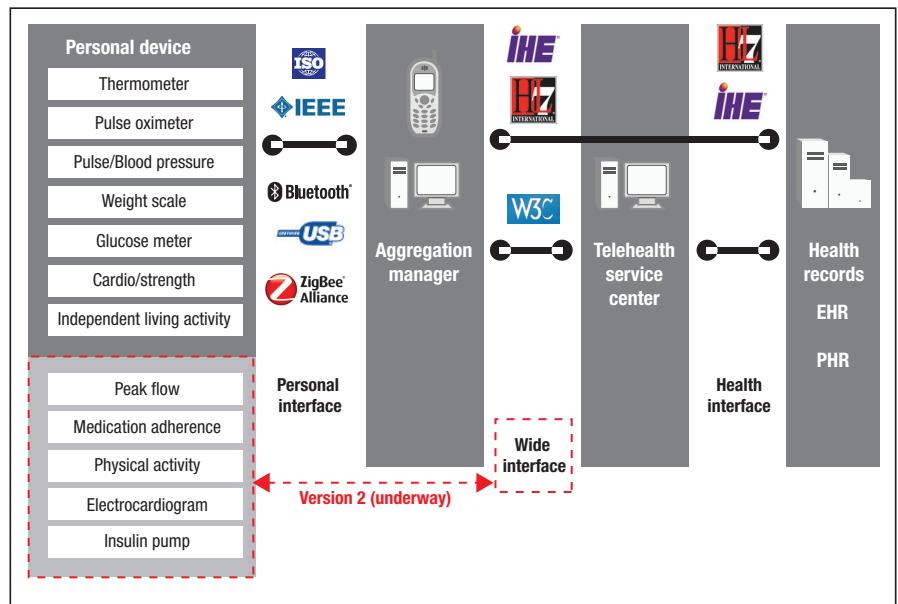
# Aggregation managers for the connected health system

## Continua interoperability

The Continua Health Alliance comprises a group of health device original equipment manufacturers (OEMs), service providers and silicon vendors working to provide interoperability guidelines for personal health devices and aggregation managers (AMs). Although the 1.0 release of the guidelines identified *Bluetooth*® and universal serial bus (USB) as standard interfaces, future releases of the guidelines will include *Bluetooth*® low energy (BLE) technology and ZigBee as low-power personal area network (PAN) and local area network (LAN) interfaces, respectively.

OEMs currently use a combination of Ethernet, Wi-Fi and cellular interfaces, such as GSM for the AM wide area network (WAN) interface. To be a Continua Certified AM, the device must integrate at least one PAN or low-power LAN interface and a WAN or Internet protocol interface. Because many vendors wish to be interoperable with as many devices as possible, multiple low-power LAN/PAN and WAN interfaces are often integrated.

A Continua AM can take on various form factors. In some cases, this might be a PC or mobile phone. In other cases, it might be a media device connecting to existing or integrated displays. In low-power form factors, the AM can also be a low-power, wearable device. Because many vendors choose to implement both media-centric devices and low-power wearable devices, this white paper presents media-centric AM and low-power AM preintegrated designs.



▲ Figure 1: AM in the medical ecosystem (Source: Continua overview presentation)

## DVI aggregation manager media processors

The DVI AM media processor from Texas Instruments Incorporated (TI) is an ARM® Cortex™-A8-based architecture providing audio, camera and video media interfaces. Device vendors wishing to enable HD video streaming should use TI's OMAP3530 media processor, which incorporates an HD video accelerator. Device vendors not requiring HD (720p) video streaming should use the lower cost AM3517, which supports HD (720p/1080i) UIs over DVI but does not incorporate an HD video accelerator. Both media processors come with recent Linux distributions (which can support Ubuntu/Android UIs) and are code compatible.

Device vendors looking for increased video performance up to full HD 1080p should use the OMAP4430 processor, which is an ARM Cortex-A9 dual-core processor.

## HD video streaming

The OMAP3530 high-performance, low-power mobile applications processor integrates the ARM Cortex-A8 processor with TI's C64x+™ DSP hardware-accelerated video processor and relevant peripherals.

The OMAP35x evaluation module includes open-source Linux and drivers, along with Code Sourcery tools and a digital video software development kit (DVSDK). Included in the DVSDK are production-ready, easy-to-use audio and video codecs for hardware-accelerated video processors based on TI DaVinci™ technology. These codecs are preintegrated with Linux and network peripherals to support real-time 720p video streaming. SD codecs are available free from TI, while HD codecs are available through TI's Third-Party Network.

The OMAP4430 processor integrates ARM Cortex-A9 dual cores with a hardware-accelerated video processor. It supports full HD 1080p video streaming (or 720p two-way video conferencing), among other multimedia-rich features.

## Low power aggregation manager processors

For lower power/cost designs, TI's Stellaris® ARM Cortex-M3-based microcontroller is available. In addition to simultaneous interfaces, including Ethernet MAC/PHY and USB On-The-Go, the LM3S9B96 development kit adds several features that enhance the overall user experience, such as an integrated 3.5-inch, color QVGA LCD with a resistive touch interface, a thumbwheel potentiometer (for menu navigation), a user LED and pushbutton, a MicroSD card slot, and 1 MB of serial flash memory. The LM3S9B96 development kit comes with an expansion board that can work with TI's CC2530 ZigBee SoC, CC2540 Bluetooth low energy SoC and CC2570 ANT Network Processor (NWP).

Software tools suite choices in the kit include:

- Evaluation versions of ARM's RealView microcontroller development kit
- IAR Embedded Workbench Kickstart Edition
- Code Red Technologies' Red Suite
- CodeSourcery Sourcery G++ GNU tools

In addition to the ROM-based SafeRTOS included in the LM3S9B96 microcontroller, ported demos of RTOSs include:

- FreeRTOS.org
- Micrium  $\mu$ C/OS-II with  $\mu$ C/Probe embedded system monitoring
- Express Logic ThreadX
- CMX Systems CMX-RTX
- Keil RTX
- IAR PowerPac
- SEGGER embOS
- Quadros RTX
- MicroDigital's SMX
- RoweBot's Unison ultra-tiny embedded Linux- and POSIX-compatible RTOS
- SCIOPTA's real-time operating system for safety-critical applications

## Aggregation manager connectivity

TI's AM reference designs include two Continua WAN interfaces (Ethernet and Wi-Fi), a low-power LAN interface (ZigBee) and four PAN interfaces (USB, *Bluetooth*, *Bluetooth* low energy and ANT).

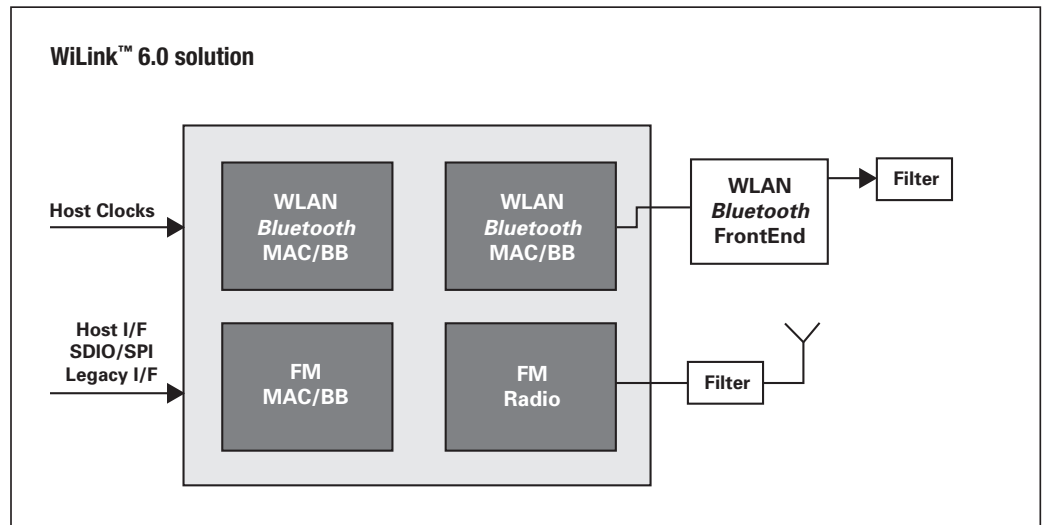
### Wi-Fi

TI's WiLink™ 6.0 (WL127x) solution is a highly integrated, 65-nm offering that integrates WLAN, *Bluetooth* and FM cores onto a true single chip. The WiLink 6.0 solution supports the latest standards, including 802.11 a/b/g/n and various *Bluetooth* technology generations. It is designed for the mobile devices like smartphones and other battery-operated devices that require robust connectivity at low power conservation.

The WiLink 6.0 is accompanied by an external off-the-shelf switched-mode power supply (SMPS) and front-end module. The front-end module contains a PA, a balun and a three-way radio-frequency switch.

TI's WiLink 6.0 solution is a triple-radio design that employs special techniques to address radio coexistence challenges. Special care is taken in the integration of WLAN and *Bluetooth* because both operate on the same frequency band. A proprietary set of algorithms addresses this issue to allow the use of a single antenna shared between WLAN and *Bluetooth* for the 2.4-GHz band.

Overall solution size is sometimes a key factor in mobile devices. Because of the small footprint of the WiLink 6.0 solution, core device, the resulting total size is less than 80 mm.



▲ Figure 2: WiLink™ 6.0 solution block diagram

The WiLink 6.0 solution is supplied with a comprehensive software package for development and integration of the device core functions. The complete package is named MCP (mobile connectivity package) and contains all related software content required to run the product.

The WLAN driver provided with the package provides a wide range of capabilities, including multiple roles support (STA, AP, P2P) and related connection management activities; security (supplicant interface); quality of service; and scan and roaming support, with external hooks for end-user applications. Supporting documentation can be found on TI's website at [www.ti.com/connectivitywiki](http://www.ti.com/connectivitywiki).

TI offers the WL127x in a completely certified module through LS Research. The TiWi module is a high-performance 2.4-GHz IEEE 802.11 a/b/g/n and *Bluetooth* 2.1+EDR radio in a cost-effective, precertified footprint.



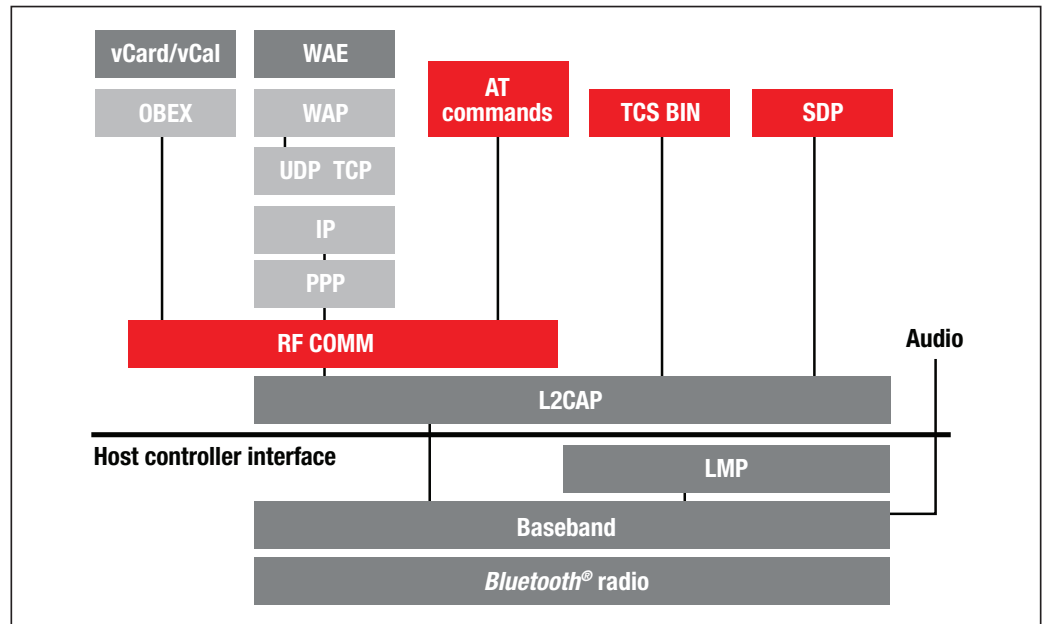
▲ Figure 3: WL1271 module

The module realizes the necessary PHY/MAC layers to support WLAN applications in conjunction with a host processor over a SDIO/WSPI interface. The module also provides a *Bluetooth* platform through the HCI transport layer. Both WLAN and *Bluetooth* share the same antenna port.

### Bluetooth technology

The *Bluetooth* interface on the WL1271 supports *Bluetooth* 1.2 (1 Mbps) and *Bluetooth* 2.0 + EDR (2-3 Mbps). This device leverages the open-source Blue-Z stack, which is part of the OMAP3530 processor and AM3517 Linux base ports. Figure 4 shows a standard *Bluetooth* stack.

The Continua PAN interface requires a new profile called HDP (health device profile), which is currently available for integration through open source. This profile is built on an additional abstraction layer called MCAP. Because *Bluetooth* was not originally designed to operate on inexpensive coin-cell batteries, the *Bluetooth* SIG is introducing a new derivative called *Bluetooth* low energy technology (BLE).



▲ Figure 4: Standard Bluetooth<sup>®</sup> stack

### Bluetooth low energy technology

Unlike *Bluetooth*, *Bluetooth* low energy technology is a connectionless protocol. This significantly reduces the amount of time the radio must be on for applications that require very low cost, low-power wireless connectivity. *Bluetooth* low energy technology will open up *Bluetooth* to a variety of new markets, including health care, sports and fitness, security, mobile and PC accessories, and home entertainment.

*Bluetooth* low energy technology will be integrated into existing *Bluetooth* chipsets in what is referred to as dual-mode support and will additionally be available as a low-energy-only solution called single mode. In many (but not all) use cases, the dual-mode device will be incorporated into a cellular phone, PC, car or other less power-constrained devices that already use *Bluetooth* technology or have a desire to add *Bluetooth* support.

These devices will support the existing *Bluetooth* ecosystem (for example, cellular phones supporting hands-free headsets) and, with the dual-mode support, also allow single-mode low-energy sensors and devices to “attach.”

The single-mode chip will be designed into power-constrained devices (for example, coin-cell devices lasting a year or more) to support the various markets and applications in the low-power RF space.

As a contributing member and leader in the *Bluetooth* low energy technology space, TI is in a unique position to release single- and dual-mode chips in 2010 shortly after the final ratification of the specification.

TI's BLE single-mode solution, the CC2540, is optimized to support *Bluetooth* low energy technology. The CC2540 offers up to +5-dBm output power with - 93-dBm receive sensitivity; has flexible memory options; and comes with a wide range of supported peripherals, including a power five-channel DMA, 21 GPIOs, two USARTs, Full Speed USB 2.0, on-board AES encryption/decryption engine and timers. The CC2540 comes as a 40-pin 6 x 6 QFN solution and is flash programmable.


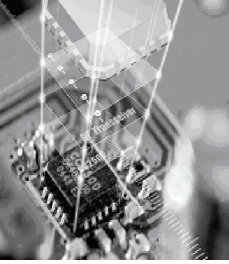
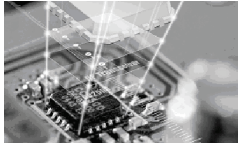

As a total solution provider, TI not only has the hardware but provides the fully compliant software protocol stack for single-mode *Bluetooth* low energy technology, including master and slave and all required profile roles. The stack is power-optimized for optimal performance with all applications and includes tools, sample application code, profile support, drivers, development boards, documentation and everything else needed to easily develop a single-mode *Bluetooth* low energy solution with ease.

**ZigBee Interface**

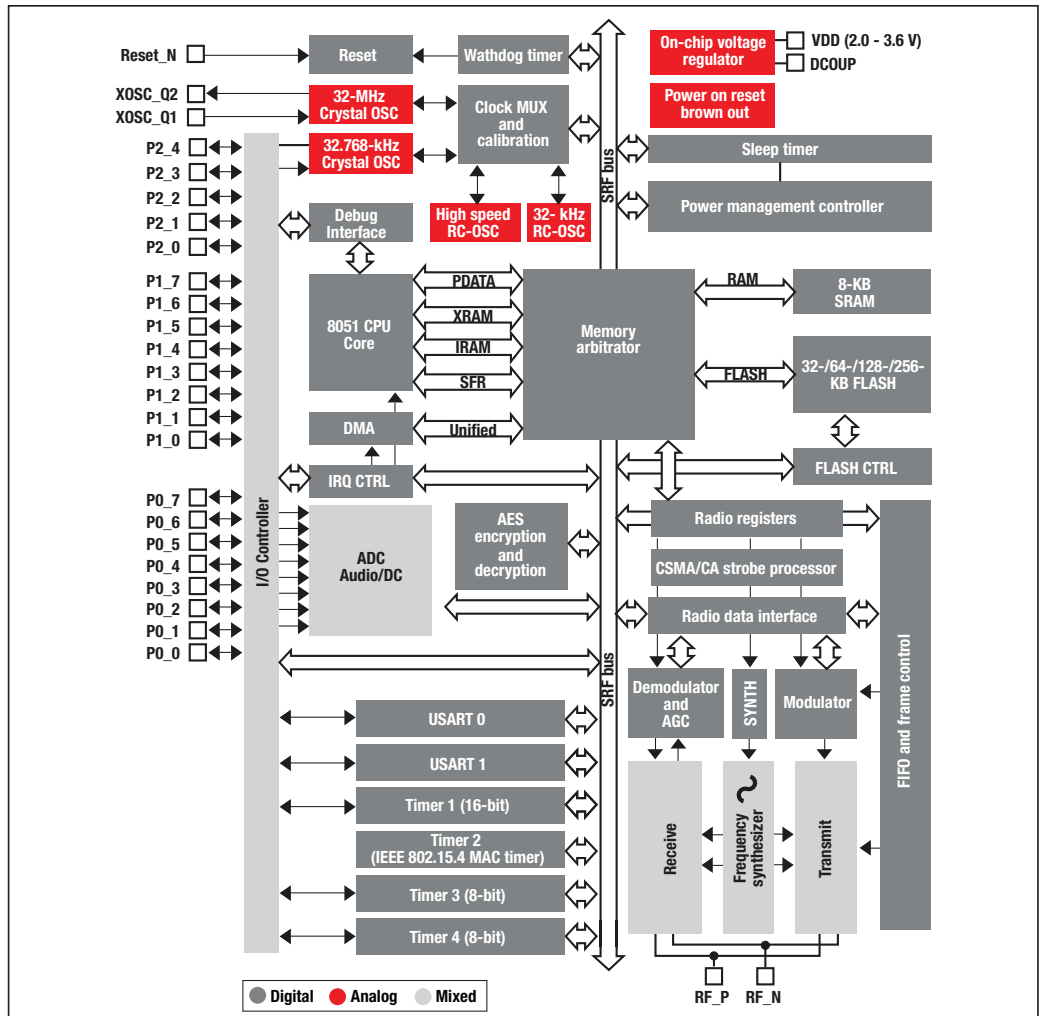
ZigBee health care products will be used in a variety of settings, including at home or in private outpatient residences, recreation centers, retirement communities and nursing homes. ZigBee has been selected by the Continua Alliance because ZigBee technology is targeted for low-power, battery-operated devices. Low-power sensing and monitoring is the sweet spot for 802.15.4 radios, which consume less power and provide longer battery life for medical devices.

The ZigBee Health Care (ZHC) technical working group has released the ZHC application profile for early adopters. This specification provides interoperability among various vendors. Such robust features let it coexist with other radio protocols and provide secure, low-packet error-rate data transfer.

TI provides a one-stop shop hardware reference design and software with the CC2530 or CC2520/ MSP430™ development kits, which are available at [www.ti.com/lprf](http://www.ti.com/lprf). For customers who do not want to design and certify their own radio platform, TI offers several module partners who provide FCC-certified ZigBee modules complete with antenna and software.

	<b>SoC</b> <ul style="list-style-type: none"> <li>• Small footprint</li> <li>• High integration</li> <li>• Low cost</li> </ul>	<b>Co-processor</b> <ul style="list-style-type: none"> <li>• Flexible</li> <li>• Easy to use</li> <li>• Reduced time to market</li> </ul> 	<b>Dual-chip</b> <ul style="list-style-type: none"> <li>• Ultra-low-power</li> <li>• High performance</li> </ul>
<b>Application</b>	CC2530	Any processor (e.g. MSP430 or Stellaris ARM)	MSP430 or Stellaris ARM
<b>Protocol stack</b>		CC2530 based co-processor with embedded stack and uart/spi/usb interface 	
<b>Radio</b>			CC2520
<b>RF front end (optional)</b>	CC2590/CC2591	CC2590/CC2591	CC2590/CC2591

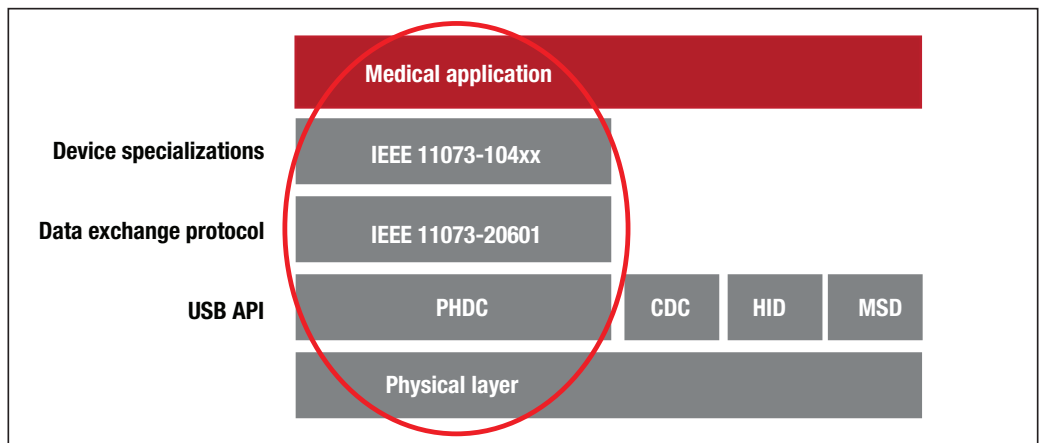
▲ Figure 5: Three paths to ZigBee



▲ Figure 6: CC2530 ZigBee system-on-chip block diagram

### USB

Both AM media and low-power processors integrate a USB host capable of supporting as many as three clients. TI will offer code for the PHDC profiles to interested customers. The PHDC profile, shown in Figure 7, is an essential component of the Continua stack. Required IEEE-11073 layers can be implemented by working with partners such as S3 or Lamprey Networks.



▲ Figure 7 : Medical device profile

**ANT**

Like Bluetooth low energy technology, ANT is a connectionless protocol. ANT has been in existence for some time and has many products in the market today, specifically in the areas of sports and fitness. ANT was developed by a small team in a private organization with focused goals, not by a consortium of contributing member companies. The ANT stack is compact, scalable, flexible, focused and proven in a market where millions of devices are operational today.

ANT+ extends ANT to support interoperability through member-defined public profiles that can be available within six months after aligning stakeholders. As a proprietary protocol, ANT is focused on specific solutions, thereby reducing power and complexity. Although ANT is not currently Continua Certified, TI offers ANT solutions that enable interoperability with existing health devices in the market while enabling future pin-compatible *Bluetooth* low energy devices to also be supported.

View demos of ANT on the WiLink 6.0 smartphone at [www.ti.com/ant-wl127x-video](http://www.ti.com/ant-wl127x-video) and the CC2570 stand-alone at [www.ti.com/ant-alliance-video](http://www.ti.com/ant-alliance-video).

The following profiles are currently supported by ANT:

- Heart rate monitor
- Speed and distance monitor
- Bicycle speed
- Bicycle cadence
- Bicycle power
- Weight scale
- Fitness equipment
- Multisport speed and distance monitor
- Blood pressure
- Blood glucose (alpha)
- Calorimeter profile (pre-alpha)
- Electric bicycle assist (pre-alpha)



## Power management

The TPS65950 analog companion chip, designed to work with OMAP35x devices, contains buck converters, low-dropout regulators (LDOs), a charger module, an entire audio module with digital filters, input amplifiers and output class-D amplifiers. The TPS65950 IC provides several additional functions, such as a high-speed USB physical layer (PHY) transceiver. Its functions include:

- **System clock manager**

- Generates a 32-kHz clock from a crystal or an external sine wave and delivers a square digital waveform to the entire system.
- Collects all high-frequency clock requests from the system and forwards the demand to the system clock source.
- Buffers the high-frequency clock from the source and delivers a square digital waveform to the entire applicative system.

- **Power on and reset management**

- Push-button debouncing starts the state machine (master configuration).
- Controls the reset release of the OMAP3530 processor.
- Controls the warm reset steps when instructed to do so by the OMAP3530 processor or the user.
- Can control the power-on sequence of an auxiliary subsystem.

- **Power management**

- Integrates several power supplies (DC/DC, SMPS or LDO types) to meet system demands in terms of currents and voltages.
- Processor power companion, providing all required power supplies and power-management functions (dynamic voltage scaling, SmartReflex™ technology) to the OMAP3530 processor. SmartReflex technology is controlled through a dedicated high-speed inter-integrated circuit (I<sup>2</sup>C) link.
- Can control the activation of additional power resources (external LDOs).

- **System management**

TPS65950 modes of operation and states are entirely configurable through register access using the high-speed I<sup>2</sup>C configuration interface. Additionally, the TPS65950 implements:

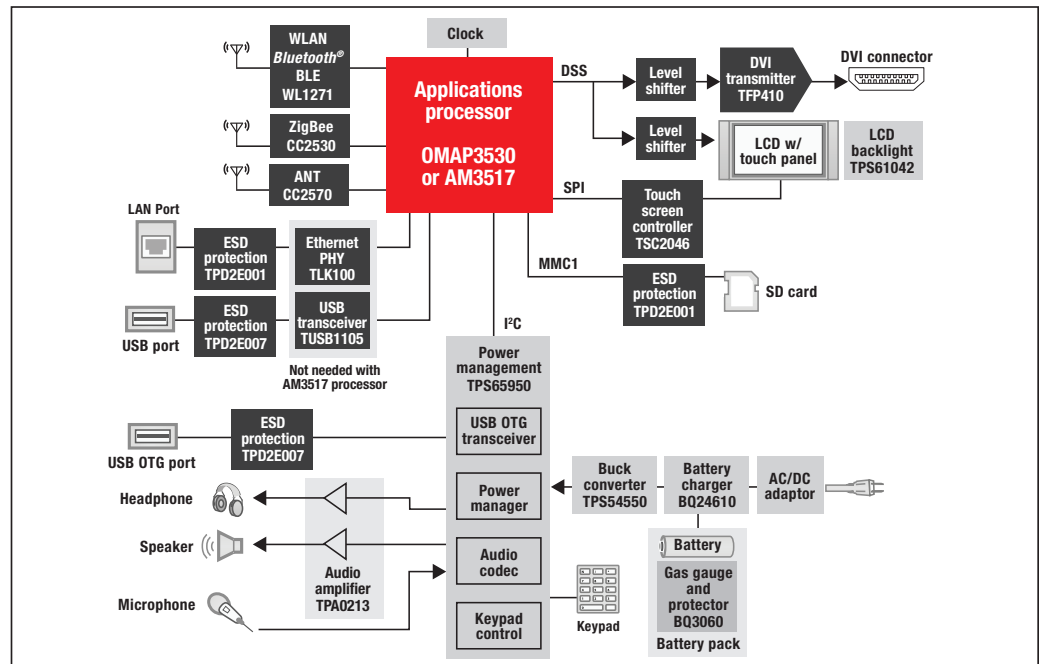
- Several functional interrupts that can be routed to one or two targets.
- Internal and external signal monitoring, with the analog-to-digital conversions requested by software or hardware.
- Secure software access protocols for digital rights management.

**Analog**

The TFP410 is a DVI 1.0-compliant digital transmitter that supports display resolutions ranging from VGA to UXGA in 24-bit, true-color pixel format. Some of the advantages of this universal interface include selectable bus widths, adjustable signal levels, and differential and single-ended clocking. The adjustable 1.1- to 1.8-V digital interface provides a low-EMI, high-speed bus that connects seamlessly with 12- or 24-bit interfaces.

When an LCD display is used in the system, LCD power, LED backlight and touch-screen controllers should be considered. The TSC2046 is a four-wire touch-screen controller with an on-chip 2.5-V reference that can be used for the auxiliary input, battery monitor and temperature measurement modes. The TPS61042 is a high-frequency boost converter with constant-current output that drives white LEDs for LCD backlight.

**DVI Aggregation Manager Systems**

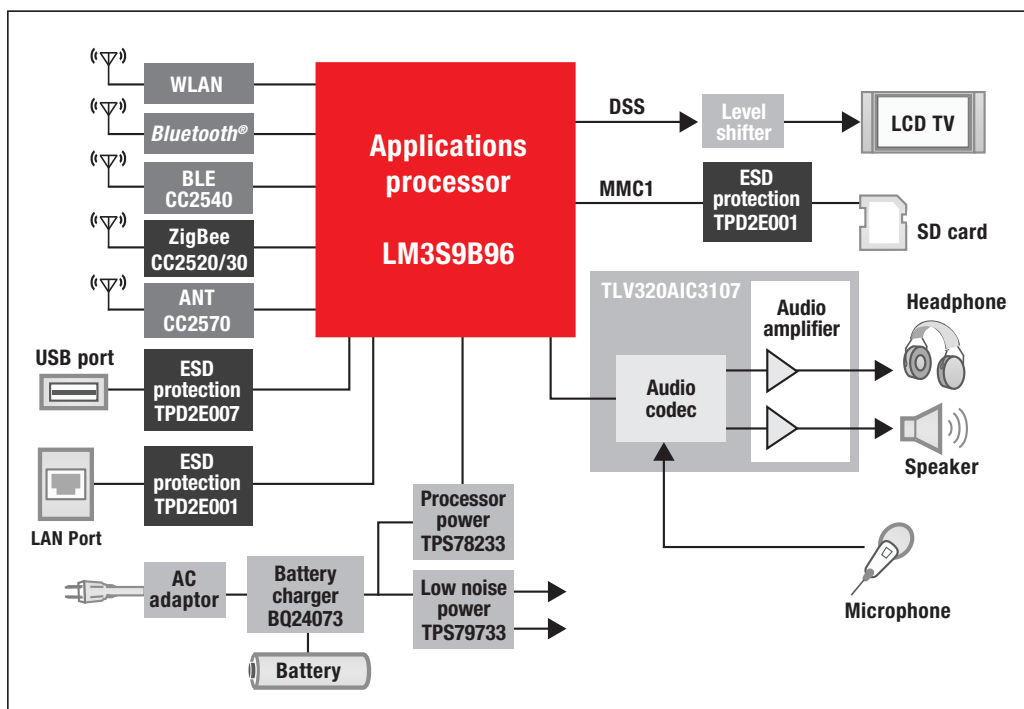


▲ Figure 8: DVI AM block diagram

**DVI AM main IC components**

Part number	Description	Notes
<b>Main IC components</b>		
OMAP3530/AM3517	HD processor with or without HD codec accelerator	AM3517 integrates USB 2.0 and Ethernet
WL1271	WLAN, Bluetooth, Bluetooth low energy or ANT	
CC2530	ZigBee system-on-chip (SoC)	
CC2540	Bluetooth low energy SoC	Not needed with WL1271
CC2570	ANT NWP	Not needed with WL1271
TPS65950	PMU for OMAP35x	
TFP410	PanelBus DVI transmitter 165 MHz	
TPA0213	Integrated speaker and headphone amplifier	
TPS79633	LCD power	For systems with LCD display
TPS61042	LED backlight	For systems with LCD display
TSC2046	Touch-screen controller	For systems with LCD display
BQ24610	Switch-mode Li-ion battery charger	For systems with rechargeable Li-ion battery
BQ3060	Li-ion battery gas gauge	For systems with rechargeable Li-ion battery

## Low Power Aggregation Manager Systems



▲ Figure 9: Low-power AM block diagram

### Low-power AM main IC components

Part Number	Description	Notes
<b>Main IC components</b>		
LM3S9B92 / LM3S9B96	Stellaris® ARM® Cortex™-M3-based MCUs	Integrated Ethernet and USB 2.0 On-The-Go
CC2520	Zigbee transceiver	
CC2530	Zigbee SoC	
CC2540	Bluetooth low energy technology SoC	Pending specification
CC2570	ANT NWP	
TPS78233	150 mA, 3,3-V LDO	
TPS79733	50 mA, 3.3V LDO	
TLV320AIC3107	Audio codec with integrated headphone and speaker amp	

### For more information

- The Continua version 1.0 design guidelines are available at [www.continuaalliance.org/products/design-guidelines.html](http://www.continuaalliance.org/products/design-guidelines.html).
- The new Low-Power RF selection guide, with new products, updated selection tables, and tools, software and technical documents is available at [www.ti.com/lprfguide](http://www.ti.com/lprfguide).
- Software and hardware updates, developer's news and the latest application and design notes are available in the Low-Power RF newsletter at [www.ti.com/lprfnewsletter](http://www.ti.com/lprfnewsletter).
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Data Converters	<a href="http://dataconverter.ti.com">dataconverter.ti.com</a>	Automotive	<a href="http://www.ti.com/automotive">www.ti.com/automotive</a>
DLP® Products	<a href="http://www.dlp.com">www.dlp.com</a>	Communications and Telecom	<a href="http://www.ti.com/communications">www.ti.com/communications</a>
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