REFERENCE ARCHITECTURE

Service Provider
Smart and Secure Home

Cable Residential Gateway Solution for Converged Networks

Cable operators can simplify their infrastructure, gain performance, and reduce costs with Intel's Cable Residential Gateway solution—an open and security-enabled DOCSIS* solution for broadband connectivity

This reference architecture provides a fully functional technical picture for developing a cohesive business solution.

If you are responsible for...

- **Business strategy:** You will better understand how the technology improves business capabilities and functions.
- **Technology decisions:** You will learn about the critical architecture components and how they work together to create a cohesive business solution.

Executive Summary

To remain competitive in a fast-changing market, cable operators are seeking innovative technologies that can provide more for less—more bandwidth, more services, and more efficiency—while at the same time reducing cost and network complexity. Intel® technology can help cable operators achieve these goals through solutions that support a converged network that can carry voice, video, and data services. Intel's end-to-end solutions support every level of the network, from the data center and headend distribution to premises equipment in the home.

This reference architecture focuses on Intel's open and security-enabled Cable Residential Gateway solution, based on the Intel® Puma™ 7 Family. This solution provides a cost-effective cable modem gateway for any OEM. The Intel Puma 7 Family can be used as a simple cable modem that bridges from the Data-Over-Cable Service Interface Specification (DOCSIS*) to Ethernet or as part of a more complex platform that is integrated into a complete home router.

Using solutions from Intel, cable operators can build a converged, future-proof network that will enable them to reduce costs, better engage with customers, and continue to digitally transform their business to support the smart home, cloud-based services, and other opportunities created by the growing Internet of Things.

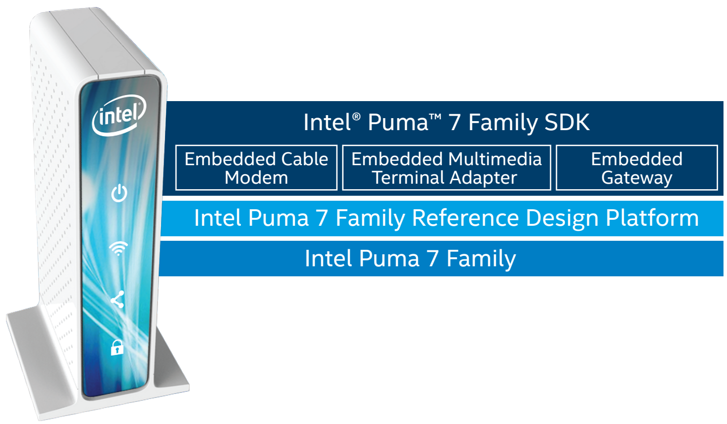

Figure 1. Hardware and software combine to provide cable operators with an end-to-end Cable Residential Gateway solution.

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A Closer Look at DOCSIS*

The Data-Over-Cable Service Interface Specification[1] (DOCSIS) enables cable operators to provide fast broadband over copper wiring. DOCSIS is a standard radio frequency-based interface for modulating IP traffic over a coaxial network. DOCSIS, in use since 1997, uses the 5-204 MHz spectrum for upstream data transmission and 54-1794 MHz for downstream data transmission. The specific frequencies used by an operator depend on the DOCSIS version and the upstream configuration. For instance, legacy cable installations use 5-42 MHz for upstream transmission, whereas a modern DOCSIS 3.1 network can use up to 204 MHz for upstream transmission.

DOCSIS uses many different encoding algorithms for modulating the bits over the coax from Quadrature Phase Shift Keying to Quadrature Amplitude Modulation. The use of more modern modulation schemes like Orthogonal Frequency Division Multiplexing uses the spectrum more efficiently and achieves higher data rates. DOCSIS has gone through at least four major revisions that have increased the overall throughput capability of the specification.

[1] www.cablelabs.com/specs/specification-search/?cat=docsis&scat=docsis-1-0

Introduction: Transitioning DOCSIS* into the Future with Intel® Technology

Cable operators are under competitive pressure from fiber optic carriers. To remain economically viable, they must provide faster services and provide a seamless experience for voice, data, and video services. Recent digital innovations to the Data-Over-Cable Service Interface Specification (DOCSIS* 3.1) have helped, but much more is needed to create a converged, future-proof network.

Legacy DOCSIS Systems

Figure 2 shows a basic DOCSIS system (also see the sidebar, "A Closer Look at DOCSIS"). A cable operator connects a common Ethernet router and switching network to its registered domain. This network provides IP connectivity to the cable modem termination system (CMTS). The CMTS translates the IP traffic into DOCSIS service flows over the hybrid fiber coaxial (HFC) network using various encoding algorithms such as quadrature amplitude modulation (QAM). The CMTS also manages the quality of service (QoS) to each of the attached modems. The Community Access Television (CATV) system is multiplexed into the same HFC network using other frequencies.

The DOCSIS signals traverse the HFC network and can be distributed to hundreds of homes. The CMTS contains both the media access control (MAC) and physical layer (PHY) functionality.

DOCSIS cable modems terminate the customer side of the HFC network. The cable modem bridges the DOCSIS network traffic back into standard IP or Ethernet traffic. The cable modem also routes specific services into defined service flows. For instance, telephony services are assigned a different QoS than best-effort Internet traffic. The cable modem can be connected to a separate home router or integrated into the service provider gateway.

The type of infrastructure illustrated in Figure 2 is complex. It requires two separate networks for IP data and video, which can lead to additional operator cost, performance issues, and spectrum management challenges.

Virtualizing the CMTS to Simplify the Network

In legacy DOCSIS systems all CMTS functions, including the forwarding plane and the control plane and the upstream and downstream PHYs, are contained in a single CMTS platform. Emerging DOCSIS systems use Remote PHY specifications, which enable the PHY functionality to reside further down the network, allowing

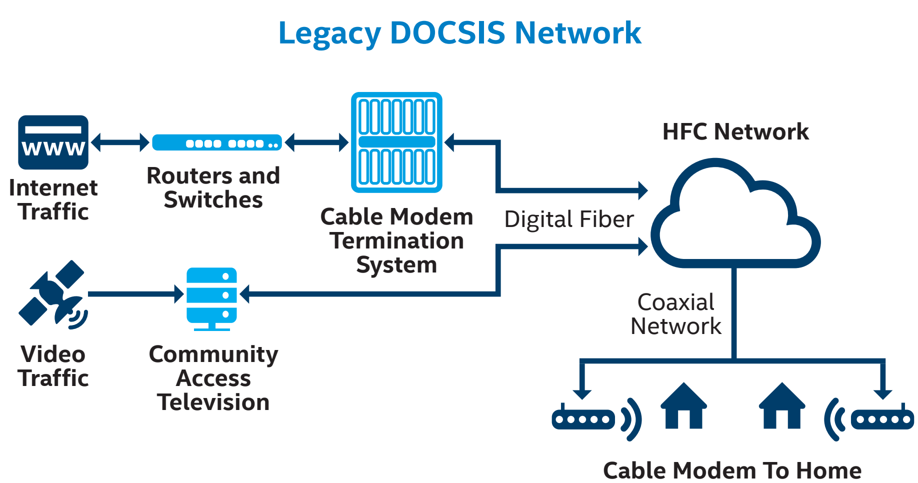


Figure 2. The legacy DOCSIS* network consists of Internet traffic and video traffic that are multiplexed over a hybrid fiber coaxial (HFC) network. Cable modems terminate the system, bringing the network traffic into the home.

the coverage to be much less than 100 homes passed. Remote PHY is enabled either through integrated CMTS, where every functional component is located in the same device, or modular CMTS (mCMTS), which allows the downstream PHY to be separated from the MAC and control plane. The biggest advantage of mCMTS is that headend and hub devices can receive packets of digital video or data from the operator network and then re-packetize the video or data for downstream transmission—a process referred to as "edge QAM" (eQAM). eQAM is a first step toward converging video and data onto a single network. This network of the future is shown in Figure 3.

The Converged Cable Access Platform (CCAP) is a second step toward a converged IP-video network. A CCAP device combines eQAM and CMTS technology functions to support the growth in the number of QAM channels used for narrowcast services, such as video on demand (VOD) and switched digital video (SDV). CCAP is fundamental to operators being able to provide narrowcast services and HDTV content and to support channel bonding in DOCSIS 3.0. Channel bonding enables newer, higher-bandwidth data services. A single CCAP downstream port can provide all of the QAM channels for all digital services in a given service group, achieving maximum density, cost reduction, and operational simplification.

As shown in Figure 4, Intel® technology can help cable operators take advantage of eQAM, remote PHY, and CCAP, because Intel® solutions exist for every level of the DOCSIS network from headend distribution to premises equipment:

- **Virtual CCAP.** Intel offers a number of Field Programmable Gate Array devices to implement all of the CMTS functions—including mCMTS and remote PHY—through high-density logic blocks that can be programmed and changed as the design evolves.
- **Cable Modem Gateway.** The Intel® Puma™ 7 Family of chipsets provides a cost-effective cable modem solution for any OEM. The Intel Puma 7 Family can be used as a simple cable modem that bridges from DOCSIS to Ethernet or as part of a more complex platform that is integrated into a complete home router.

This Reference Architecture document focuses on Intel's Cable Residential Gateway solution, based on the Intel Puma 7 Family.

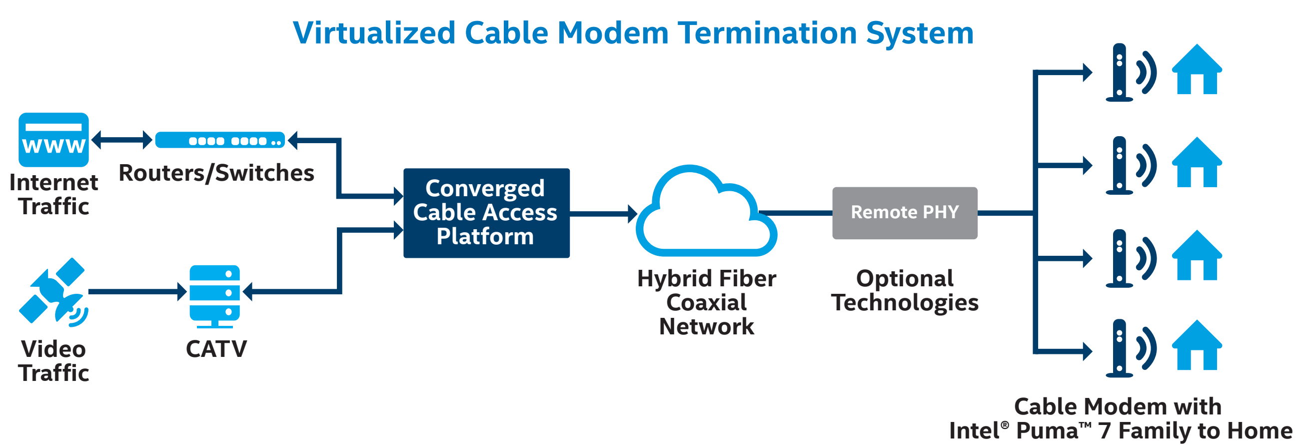


Figure 3. Intel® Puma™ 7 Family technology can help virtualize the cable network, increasing the number of services available to customers as well as enhancing performance.

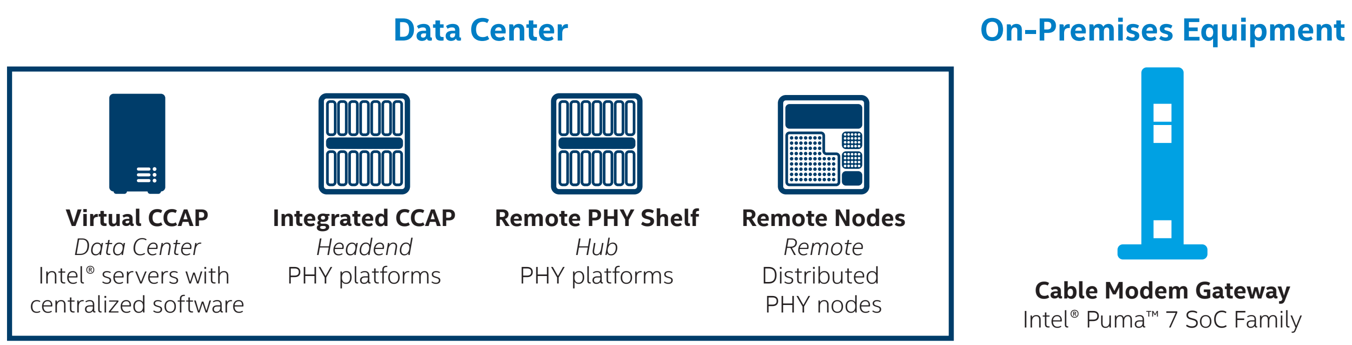


Figure 4. Intel® technology supports converged IP-video network at every component of the DOCSIS* system. This Reference Architecture focuses on the Cable Residential Gateway solution.

Solution Architecture: Cable Residential Gateway Solution

Cable operators are searching for ways to converge networks and provide greater broadband speeds. Intel's Cable Residential Gateway solution provides an open and security-enabled solution for both DOCSIS 3.0 and DOCSIS 3.1 broadband connectivity, routing, firewall, and home network connectivity using Ethernet, Wi-Fi*, and Multimedia over Coax Alliance (MoCA) technologies.

Solution Overview and Benefits

The Cable Residential Gateway solution, based on the Intel Puma 7 Family, offers several primary benefits to cable operators:

- Increased performance
- Reduced network complexity
- Future-proofing

These same benefits can be passed on to the broadband consumer, increasing a cable operator's competitive edge.

Solution Architecture Details

As shown in Figure 1, the Cable Residential Gateway solution consists of both hardware and software. Customers can choose between two reference designs to jumpstart their own product development. OEMs can use the reference designs to develop their own software applications and Intel Puma 7 Family hardware platforms. The reference designs include the Intel Puma 7 Family SDK that can be compiled and downloaded to the reference system and are available for purchase or evaluation through an Intel Field Sales Representative.

- Basic cable modem reference design
- Integrated gateway reference design

Introducing the Intel® Puma™ 7 Family

The newest Intel Puma 7 Family expands the capability of its predecessors to offer a higher-bandwidth-capable device. The Intel Puma 7 Family is flexible enough to handle a diversity of WAN interfaces, including DOCSIS 3.1* and Fiber and provides multi-gigabit delivery capability to the premises equipment. The Intel Puma 7 Family is built on Intel's latest 14nm process technology and brings scalable x86 technology architectural innovations to the home gateway market. It implements a packet processing core that ushers in a speed boost to provide multi-gigabit broadband services to subscribers.

Here are a few highlights of Intel Puma 7 Family's capabilities:[2]

- **Performance leadership.** Has 5x the performance of our previous generation Intel® Puma™ home gateway at the same power envelope to provide full Wi-Fi* support, IoT, security, and other services on chip.[3]
- **Energy-efficient system power.** Intel's first home gateway SoC manufactured on our 14nm process node. It provides compliance to evolving power regulation standards and enables small form factor, fan-less designs.
- **Rich home network ecosystem.** The platform supports a wide range of validated third-party technologies from 4×4 Wi-Fi to voice-recognition digital service providers giving OEMs the flexibility to meet customer performance and cost requirements. The Intel Puma 7 Family interfaces to a number of peripheral devices using the PCIe*, UART, RGMII, SGMII, eSATA, USB, and I2C buses.
- **Architecture consistency.** OEMs can reuse their existing Intel Puma Family codebase and hardware toolkit to monetize their R&D investment with fast scaling and rapid time to market.
- **Networking accelerators.** Incorporates a powerful programmable packet accelerator, which is designed to support evolving networking topologies and protocols with full offloading capabilities.
- **Open platform.** Allows for speedy development and deployment through its architecture-agnostic SDK, ability to run Linux* natively, and included support for other operating systems in a virtual machine.
- **14nm process technology.** The latest volume manufacturing process node, Intel's industry-leading 14nm process was designed from the ground up to take advantage of the latest 3D transistors allowing for more transistors and lower power consumption.
- **x86 platform scalability.** Supports x86 technologies like Intel® Virtualization Technology (Intel® VT), Data Plane Development Kit (DPDK) libraries, and Hyperscan on Intel® processors to provide additional performance-enhancing features in the silicon.

Based on a dual-core Intel® Atom™ processor with support for Intel VT and the DPDK, the Intel Puma 7 Family will enable operators to leverage their investments in Network Function Virtualization and software-defined networks to bring innovative new services using the residential gateway.

[2] blogs.intel.com/technology/2015/09/unleashing-multi-gibabit-performance

[3] Results have been estimated or simulated using internal Intel analysis or architecture simulation or modeling, and provided to you for informational purposes. Any differences in your system hardware, software or configuration may affect your actual performance. See **blogs.intel.com/technology/2015/09/unleashing-multi-gibabit-performance**

Basic Cable Modem Reference Design

For basic cable modem or Embedded Multimedia Terminal Adapter (eMTA) configuration, the network architect can use the Intel Puma 7 Family data modem form factor reference design platform (sometimes referred to as the "Small Blue Box"). This reference design provides simple DOCSIS-to-Ethernet bridging to provide Gigabit service to the premises. This platform provides upstream DOCSIS capability to 85 MHz. It is capable of 32 downstream channels, eight upstream channels, two upstream OFDMA (Orthogonal Frequency-Division Multiple Access) channels and two downstream OFDMA channels. It provides two 1000 Base TX Ethernet jacks for connecting to the customer's home network. Figure 5 shows the high-level circuit design of the Small Blue Box reference design.

Integrated Gateway Reference Design

Other versions of the Intel Puma 7 Family allow the flexibility for the network architect to also build a fully integrated gateway that is capable of voice, video, and data services. The Intel Puma 7 Family software development and reference design platform (sometimes referred to as the "Blue Box") is the starting point for a fully integrated gateway product. It provides the same functionality of the Small Blue Box but adds home router functionality.

The WAN buses on the Intel Puma 7 Family provide multiple Media Independent Interface (MII) buses for connectivity to the desired PHY layer devices. This reference design can support either a DOCSIS RF (radio frequency) connection using the F connector and the Serialize/Deserializer (SerDes) interfaces or through small form-factor pluggable (SFP) optics connected to the 1.5G Serial Gigabit MII bus. The four Peripheral Component Interconnect Express (PCIe*) 2.0 buses provide flexibility to connect to any LAN PHY interfaces. Each bus is capable of 500 MB/s of data transfer. This reference design provides connectivity using the Intel® XWAY™ WAV524 (5 GHz) 802.11ac and Intel® XWAY™ WAV514 (2.4 GHz) PCI* cards. The Intel® XWAY™ WAV500 Wi-Fi driver technology supports the latest Wave 2 11ac specification, while also supporting intelligent band-steering and the highest packet-per-second processing in the industry—all with full CPU offloading. The Wi-Fi cards are certified by the FCC and European Telecommunications Standards Institute. The Intel Puma 7 Family integrates a MoCA core for IP connectivity over the coaxial network. This MoCA core can be used for bridging to Wi-Fi extenders or for connecting to existing video devices. Figure 6 shows, on the next page, the high-level circuit design of the Blue Box reference design.

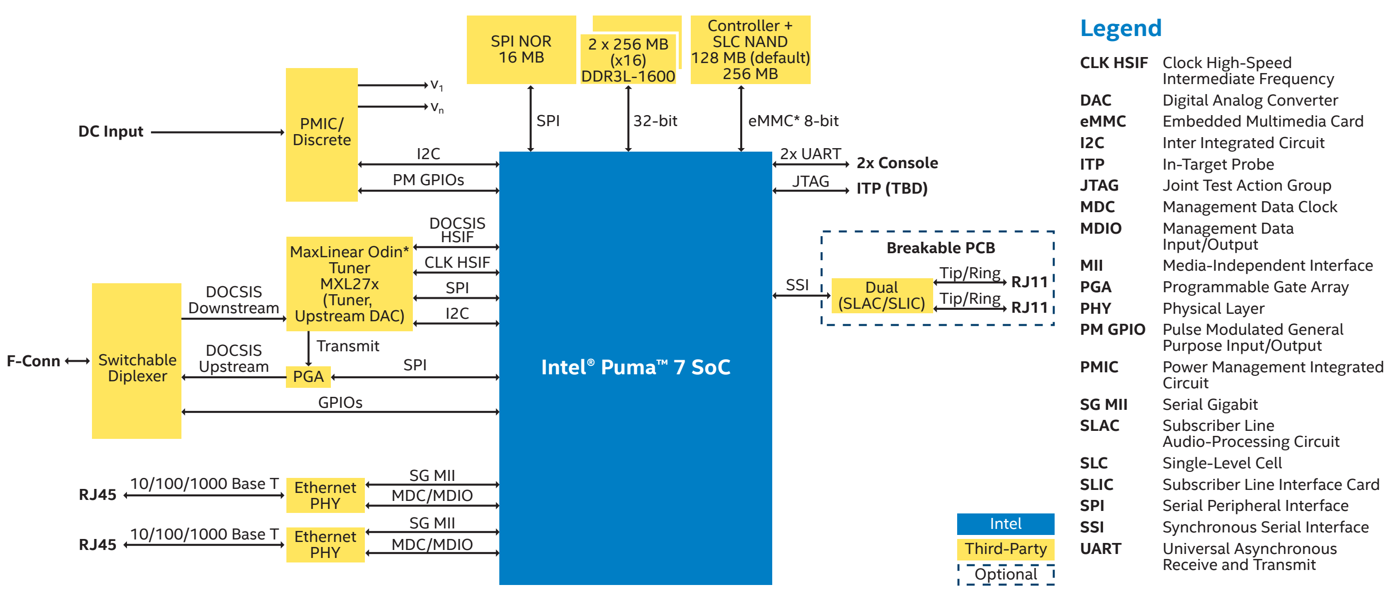


Figure 5. The circuit design for the Intel® Puma™ 7 SoC data modem form factor reference design platform provides simple DOCSIS*-to-Ethernet bridging to provide Gigabit service to the premises.

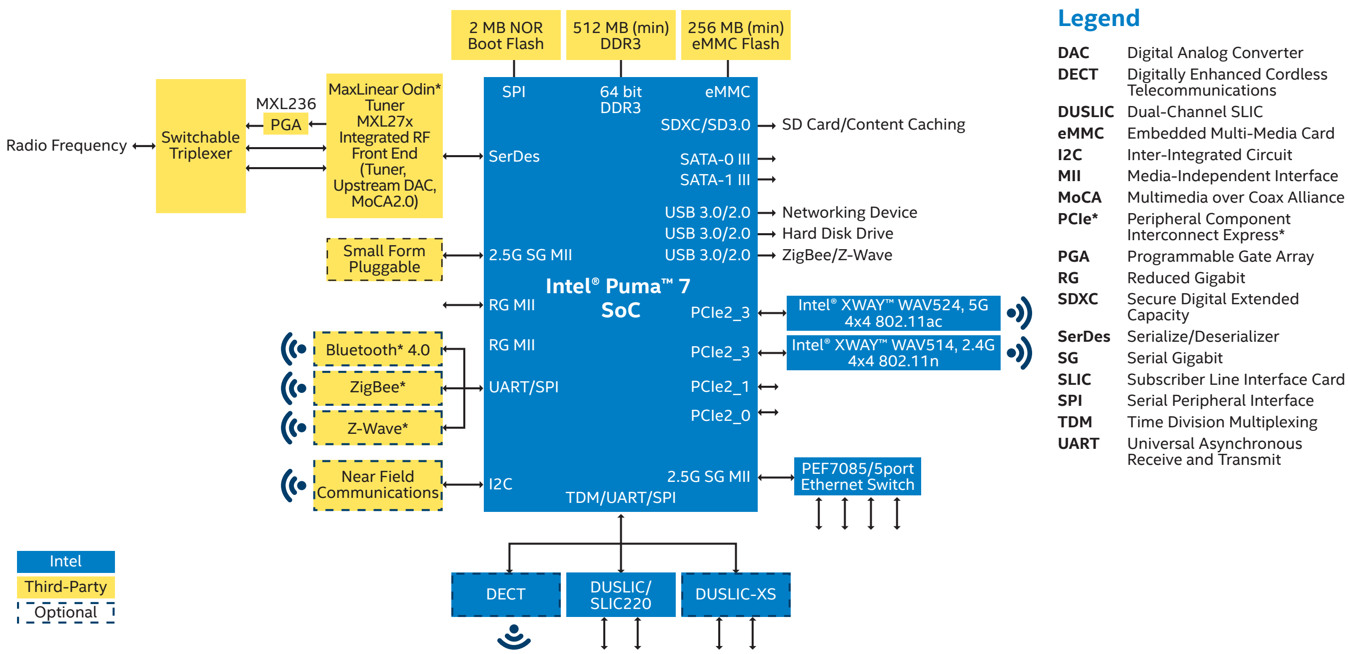


Figure 6. The circuit design for the Intel® Puma™ 7 SoC software development and reference platform supports a fully integrated gateway that is capable of voice, video, and data services.

This reference design also provides lower speed buses for connectivity to interfaces like Bluetooth*, ZigBee*, and Z-Wave*:

- Universal Asynchronous Receive and Transmit (UART)
- Serial Peripheral Interface (SPI)
- Inter-Integrated Circuit

Interfaces for Near Field Communication and for connecting to standard telephony applications are also available. Typical Subscriber Line Interface Card or Digitally Enhanced Cordless Telecommunications circuits can be connected to the Time Division Multiplexing, UART, and SPI buses for bridging to telephones.

Storage Considerations

Network architects can choose between two options for supporting storage applications in the Intel Puma 7 Family:

- For larger density storage the Intel Puma 7 Family provides two Serial AT Attachment buses.
- To support a security-enabled digital flash card, the Intel Puma 7 Family also offers a Secure Digital Extended Capacity interface.

These storage interfaces allow the cable operator to provide services such as video content caching, content storage using DVRs, and customer data backup.

Intel Puma 7 Family SDK

The Intel Puma 7 Family SDK provides a flexible environment for implementing network connectivity and a cable operator's applications. The Intel Puma 7 Family SDK consists of three main software modules:

- Embedded Cable Modem (eCM). Basic DOCSIS cable modem functionality.
- Embedded Multimedia Terminal Adapter (eMTA). Embedded voice functionality.
- Embedded Gateway (eGW). Higher-layer OSI (Open Systems Interconnection) support.

The eCM and eMTA modules execute on the network processor, while the eGW module runs on the application processor. Figure 7 shows the SDK components.

eCM Module

The eCM module, shown on the left side of Figure 7, is the basis for all DOCSIS processing. The eCM module contains three DOCSIS functions: MAC, data path, and management. DOCSIS MAC is the termination function of the DOCSIS network. It manages the upstream and downstream channels, administers the cable modem control, enforces QoS, and enforces the DOCSIS security using BPI (Baseline Privacy Interface).

The DOCSIS data path function provides the DOCSIS bridging to IP, traffic classifiers, and filtering and connectivity to the other internal modules. The DOCSIS management function implements the management of the cable modem using SNMP (Simple Network Management Protocol) and includes a command-line interface and software download and debugging functionality.

eMTA Module

The eMTA module, shown in the middle of Figure 7, serves as the primary interface for voice functionality. The eMTA module is connected to the eCM module through the DOCSIS data path function and the eSAFE interface. The eMTA module contains functions for provisioning, signaling, management, and voice interfaces. The eMTA provisioning provides the DHCP, TFTP, and other eMTA provisioning services. The eMTA signaling implements the NCS or SIP functionality, voice QoS, and voice interface to the external voice circuits. The eMTA management function is used for configuring the voice services.

eGW Module

The eGW module, shown on the right side of Figure 7, provides higher-level OSI networking layer support as well as the basic connectivity to the LAN in the home. It connects the DOCSIS data path to the IP forwarding logic in the eCM module for IP connectivity to the WAN, implements the key router, firewall, IPv6/IPv4 coexistence, IP forwarding logic to the LAN components, and more. The eGW module also implements a provisioning module that is used for RIP, DNS, DHCP, and other protocol implementations that are needed in the gateway. The eGW module also implements a management module where the gateway can be configured and monitored remotely using traditional SNMP or other protocols like TR-069 or HTTP.

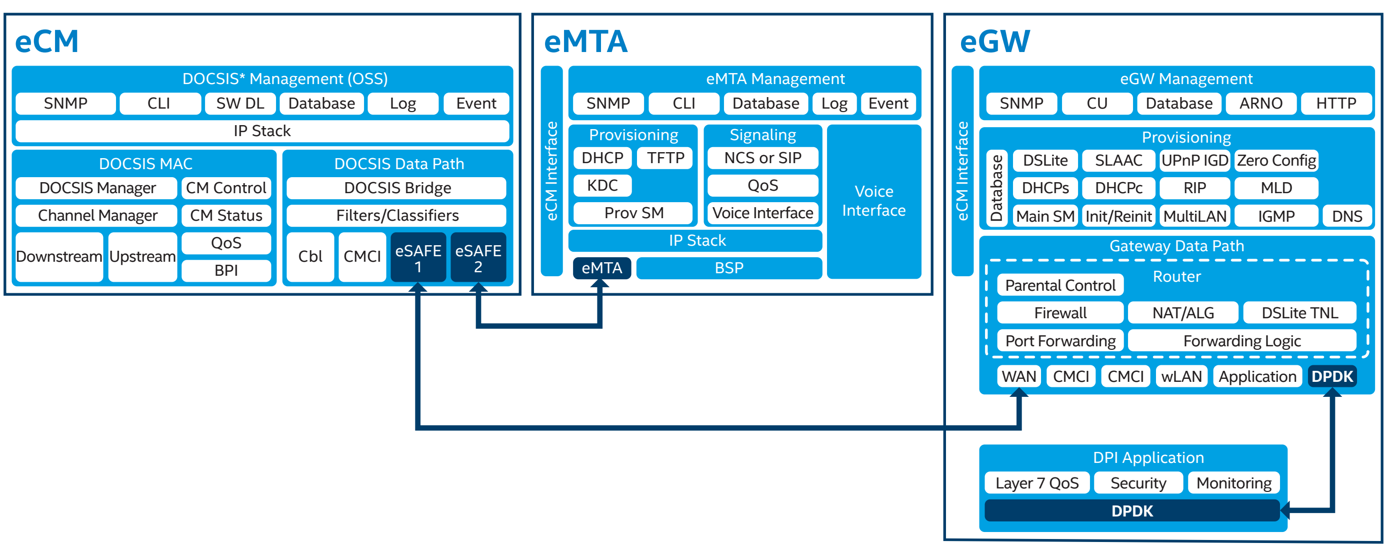
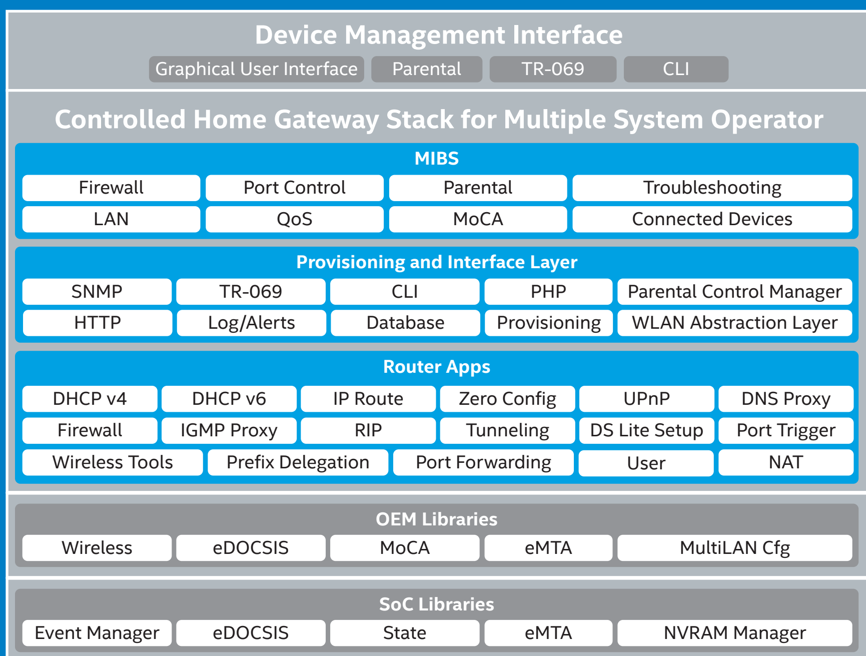


Figure 7. The basic Intel® Puma™ 7 Family SDK software stack consists of three software modules.

Reference Design Kit* (RDK) Support

The Intel® Puma™ 7 Family SDK supports the Reference Design Kit (RDK), which is a pre-integrated software bundle that provides a common framework for powering customer-premises equipment. It represents an industry effort to standardize cable modem components for open source. The Intel Puma 7 Family SDK provides full support for the RDK through the RDK's SoC Hardware Abstraction layer. The Linux*-based architecture leverages the Embedded Cable Modem (eCM) software module to route IP traffic to the RDK-B middleware. The RDK-B middleware implements the embedded gateway (eGW) functionality as well as all the operational control interfaces for the operator. Operator- and service-specific applications can be built above the RDK-B stack.

The Intel Puma 7 Family SDK is extremely flexible. It can support different open source solutions like OpenWrt* or RDK-B. OEMs can also develop their own solutions or port other open source solutions if they are required.



Reference Design Kit (RDK) Software Diagram

Summary

DOCSIS serves millions of subscribers today and will continue to deliver broadband services to commercial and residential customers. Cable operators can rely on Intel technology to build solutions for every aspect of DOCSIS—the virtualized CMTS in the data center, remote PHY at the edge or in the HFC network, and the cable modem and gateway in the home (as described in this Reference Architecture). Intel offers an end-to-end solution to forward-thinking cable operators who want to build a converged DOCSIS system for video, voice, and data services.

Solutions Proven by Your Peers

The Cable Residential Gateway solution, powered by Intel technology, provides an on-premise foundation for a converged DOCSIS network. This and other solutions are based on real-world experience gathered from customers who have successfully tested, piloted, and/or deployed the solutions in specific use cases. The solution architects and technology experts for this solution reference architecture include:

- **Chris Cholas**, Gateway Solutions Architect, Service Provider Group, Intel Corporation
- **Lance Koenders**, Global Segment Director, Clients & Connected Home, Service Provider Group, Intel Corporation

Intel Solution Architects are technology experts who work with the world's largest and most successful companies to design business solutions that solve pressing business challenges. These solutions are based on real-world experience gathered from customers who have successfully tested, piloted, and/or deployed these solutions in specific business use cases.

Find the solution that's right for your organization. Contact your Intel representative or visit **intel.com/communications.**

Learn More

You may also find the following resources useful:

- **CableLabs DOCSIS Specifications**
- **DOCSIS 3.1 Application Note**
- **Intel Puma 7 Family**
- **RDK – Reference Development Kit**