QorIQ Layerscape®
A Converged Architecture Approach

The purpose of this document is to describe the comprehensive set of solutions from NXP® enabling a unique and flexible approach to processing multi-protocol access technology via a single programmable architecture. The Layerscape solutions portfolio brings to market a concept first demonstrated by NXP in a collaboration project with Nokia® Bell Labs at Mobile World Congress in February 2016.

The architecture offers an innovative, programmable MAC and PHY layer modem technology, which provides a scalable, unified hardware + software solution that can accommodate multiple modem implementations across Wi-Fi®, 5G and other applications. It optimizes for flexibility, time-to-market and diversification of deployment options.

Introduction

Over the last decade we have experienced rapid growth of broadband access to both consumers and businesses. This growth of broadband services is being driven by multiple factors, namely:

- the fast deployment of public and private Cloud systems
- increasing number of over-the-top (OTT) service providers and content being made available to consumers
- the growth of the IoT and associated big data and analytics

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In turn, all of these factors drive an increase in high bandwidth technologies being deployed to businesses and consumers to achieve ubiquitous coverage.

The deployment of access technologies also requires that service providers achieve continuous CAPEX and OPEX efficiencies, while simultaneously supporting the co-existence of different generations of access technologies deployed in the market.

NXP's Layerscape breaks through the limits imposed by hardwired solutions, freeing enterprises and service providers to reap the benefits of software-defined access. Our technology stands to transform the business model of communication services, be they deployed by enterprises for internal customers or by telecommunications companies for external customers.

Historically, solutions in the market have had most of their key modem technologies implemented in hardwired logic functions due to power, performance and cost. However, they have offered limited programmable options for addressing standards or overall requirements.

NXP developed a new hardware and software architecture enabling a solution, which leverages our networking and wireless domain expertise to solve the challenges of multi-generation support efficiently while delivering a scalable solution for multiple segments.

The Layerscape single hardware/software modem architecture supports multiple modem implementations through firmware loads.

Key components of the architecture are:

- PHY: Single physical layer architecture and implementation across converging wireless and wired standards, providing programmability and flexibility without sacrificing efficiency
- MAC: Tight integration with an optimized packet processing engine that is scalable to support the required multi-Gbps MAC layer throughput
- Packet processing (networking) engine: Seamless integration with networking and control IP designed to support complex packet routing applications, network services, as well as support for remote provisioning and virtualized networks
- SoC: Integrated solution leveraging the key technologies—programmable PHY and MAC, packet engines, ARM® 64b Cores and associated memory, interconnect and high-speed I/O
- Development: An ever-growing software development ecosystem that OEMs and operators can use to speed their time-to-market with differentiated solutions; initial application areas targeted include 802.11/Wi-Fi (2.4/5 and 60 GHz) and 3GPP (5G) wireless access technologies.

Convergence of Access Technologies

The number of connected devices is growing at an exponential rate. The Internet of Things (IoT) is driving the need for secure network connectivity for a wide range of use cases and systems. People, machines, processes and information are all demanding network connections with different performance requirements and consistent, reliable connectivity. We see a rapid growth of various connectivity technologies happening in parallel with a strong demand for well-managed and cost-effective solutions leveraging those technologies.

The continued development from 1G through GSM, WCDMA and LTE/5G wireless access techniques has driven continued evolution from the channel access method, moving from analog through FDMA/TDMA (2G), CDMA (3G) and OFDM(A) (4G/5G). Similarly, other wireless standards (802.11, Digital Audio/Video Broadcasting (DAB/DVB) also use OFDM. This evolution has allowed modern wireless communication systems to be near the Shannon limit of channel efficiency. Also, wired access (Digital Subscriber Line or xDSL) uses OFDM/subchannel based channel access, using similar signal processing techniques as those used in wireless communications.

Similar convergence trends can be observed in the width of the access channel across access methods. LTE-A and 5G channels, Wi-Fi (for example, 802.11ax) and DSL (G.fast) all operate in 100-200 MHz wide channels. Combining this with the trend to reduce the distance between the access point and the user to <1 km (LTE small cells, G.fast), the commonality in deployments becomes apparent.

Today, the technologies summarized above are being deployed in various use cases and systems. In many cases, user access will be provided by multiple access technologies simultaneously, where each technology is optimized toward a single aspect of the user experience. Examples include Wi-Fi access for in-house high bandwidth, sub-6GHz small cell and macro LTE for outdoor coverage and mmWave system for hot-spots to name a few.

While the listed technologies do exhibit some common access channel methods, a wide range of implementations have existed because of a lack of unifying technology, until now. The NXP Layerscape family of system-on-chip solutions leverages the technology convergence trends and addresses the need for flexibility to provide an efficient approach. The Layerscape portfolio also provides products across access technologies with a wide range of deployment options across markets and development flexibility.

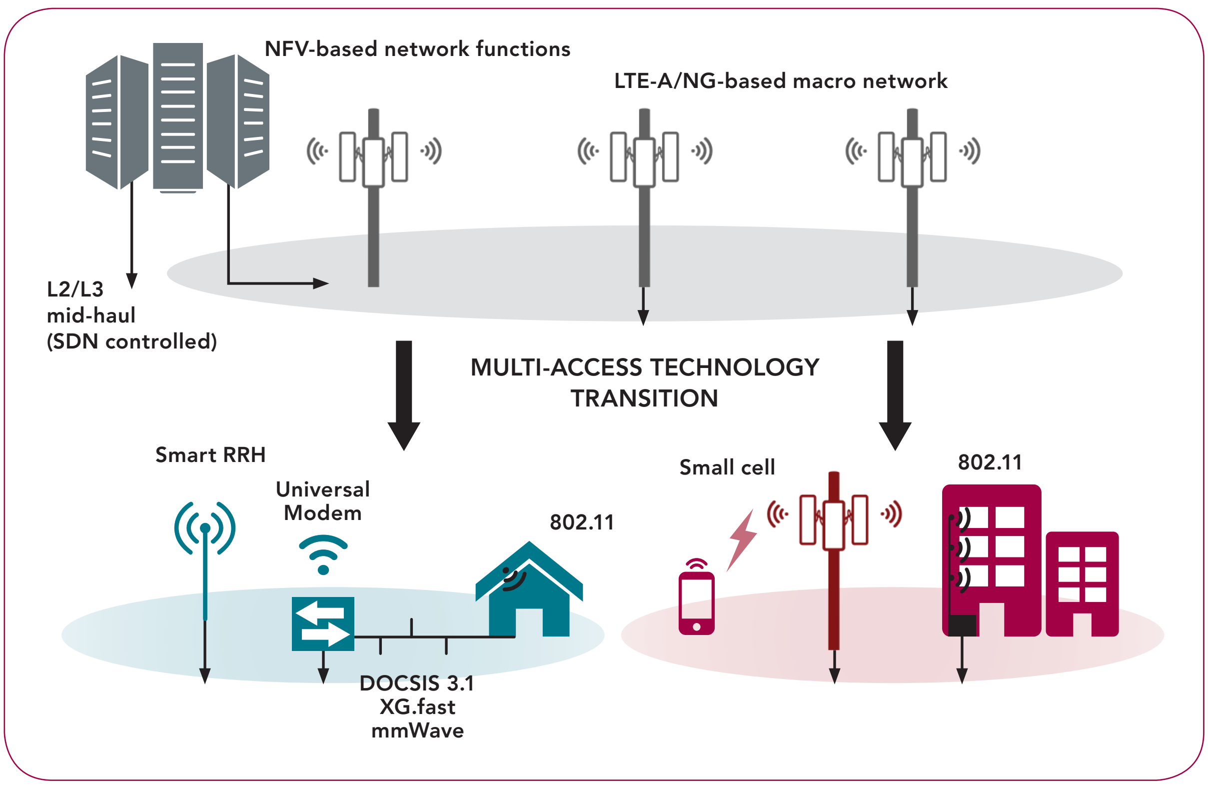

Figure 1: Access technology transition

NXP has developed several key technologies; when combined together, they enable the announced architecture and associated solutions described below.

Introduction to the Acceleration Technology

NXP is deploying an innovative programmable accelerator engine for signal processing which is scalable and suitable for a broad range of applications, from low-complexity short-range modems to highly complex macrocellular base stations and convolutional neural networks. This acceleration technology is used as a math coprocessor or as a data-plane accelerator on a chip, combined with a standard general-purpose host processor.

Unique benefits of the programmable accelerator engine include:

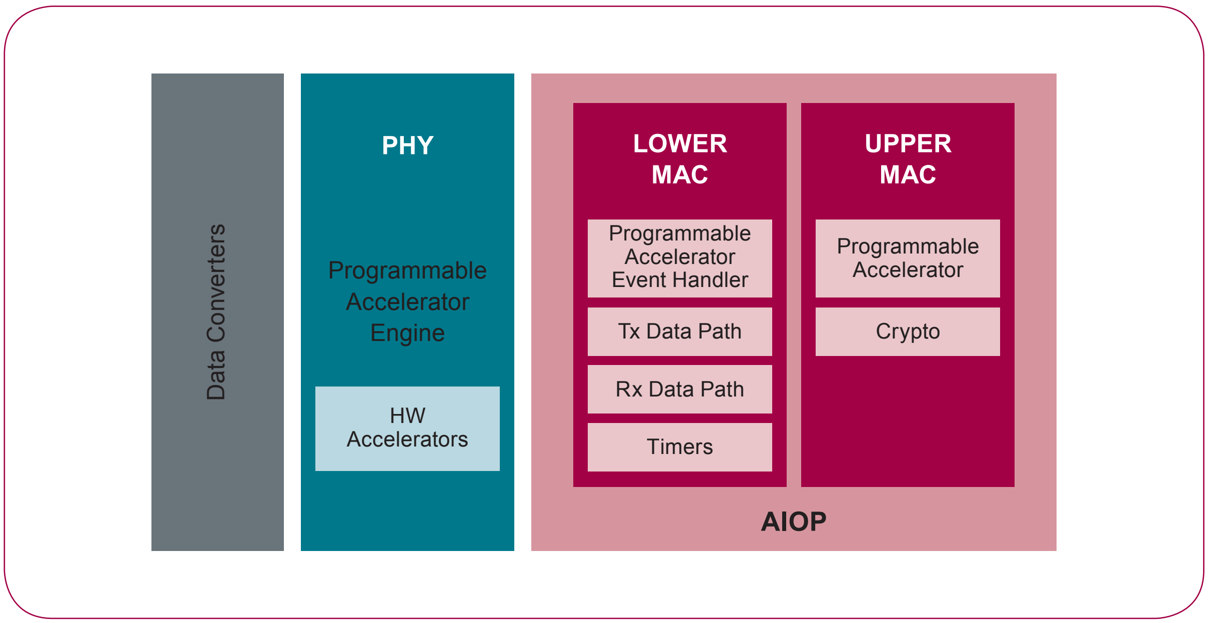

Figure 2: Programmable accelerator engine

- Configurability to balance between power and performance on a per-product basis.
- Multiple native execution units with support for various data types. Flexible environment supporting simplification of algorithm implementation and co-design with simulation environments
- Best-in-class performance and efficiency as measured in die size and power consumption with an instruction set tuned for efficiency of communications algorithms

The programmable accelerator approach also leverages the Layerscape Advanced IO Processor (AIOP) for accelerating network/packet processing acceleration. Combined with tightly coupled Ethernet interfacing and protocol acceleration (for example: ciphering), these blocks off-load fast path packet processing from the general-purpose (ARM) cores on the SoC.

Flexibility across protocols is provided by the AIOP, which is fully C-programmable and optimized for networking applications. AIOP hardware support for high-performance frame processing includes:

- Ordinary run-to-completion C-language programming
- Full flexibility for "any" protocol implementation through low-latency access to packet headers and payload with a memory subsystem that is optimized for packet processing
- Hardware acceleration for common packet-processing operations, including accelerator latency hiding support; protocol specific custom hardware accelerators are also supported

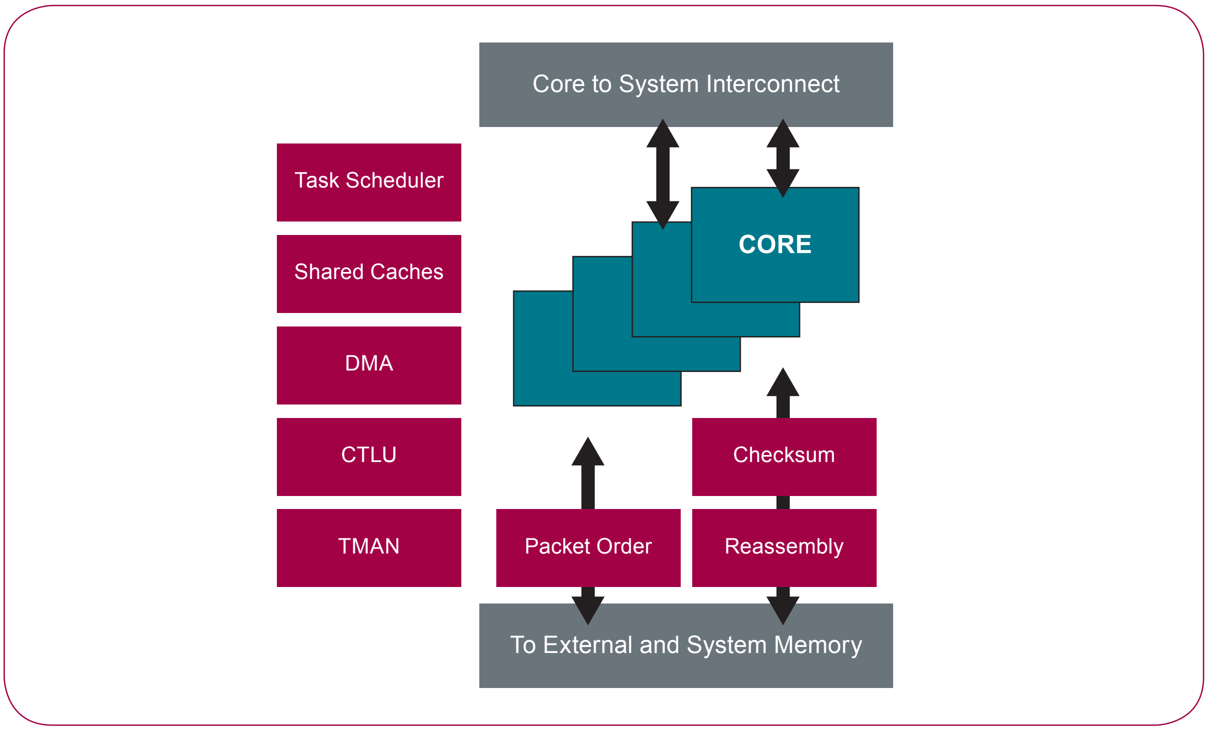

Figure 3: Networking Acceleration Architecture (AIOP)

AIOP provides the functionalities of a network processor unit (NPU)—mainly memory latency hiding and hardware acceleration for common packet processing functions—without any of the penalties historically associated with NPUs: programmability, scalability and simplicity.

These building blocks—the Programmable Accelerator Engine plus AIOP combined with the Layerscape chassis—implement an efficient, highly programmable, and therefore flexible unified access platform.

QorIQ Layerscape LA1575 SoC

The first member of the NXP solutions portfolio leveraging the platform is the QorIQ Layerscape LA1575 SoC solution.

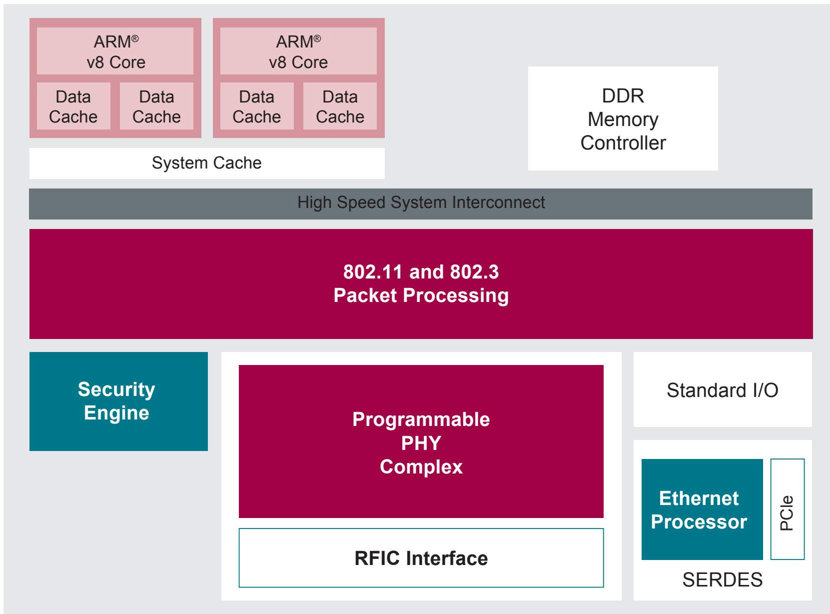

Figure 4: Product Example: LA1575

Layerscape is targeting both infrastructure and customer premises equipment (CPE) markets, with the first product, LA1575, focused on Enterprise/Customer Premises solutions deployments.

The LA1575 integrates baseband, PHY and networking functions that are historically implemented on separate chips:

- Multicore 64b ARM GPP subsystem for implementation of networking stacks for native or virtualized custom applications
- AIOP for networking/packet processing offload MAC layer protocol implementation as well as seamless bridging between these functions
- Programmable Accelerator for physical layer modem implementation for Wi-Fi and wireless backhaul
- SoC infrastructure and I/O minimizing external components required to build a complete access point or a CPE unit

Leveraging the LA1575, NXP implements industry solutions in multiple application segments. One example is the WLAN access point which integrates multiple radio technologies and enables the users in an enterprise to leverage both 802.11ad and 802.11ax enabled devices on the local area network.

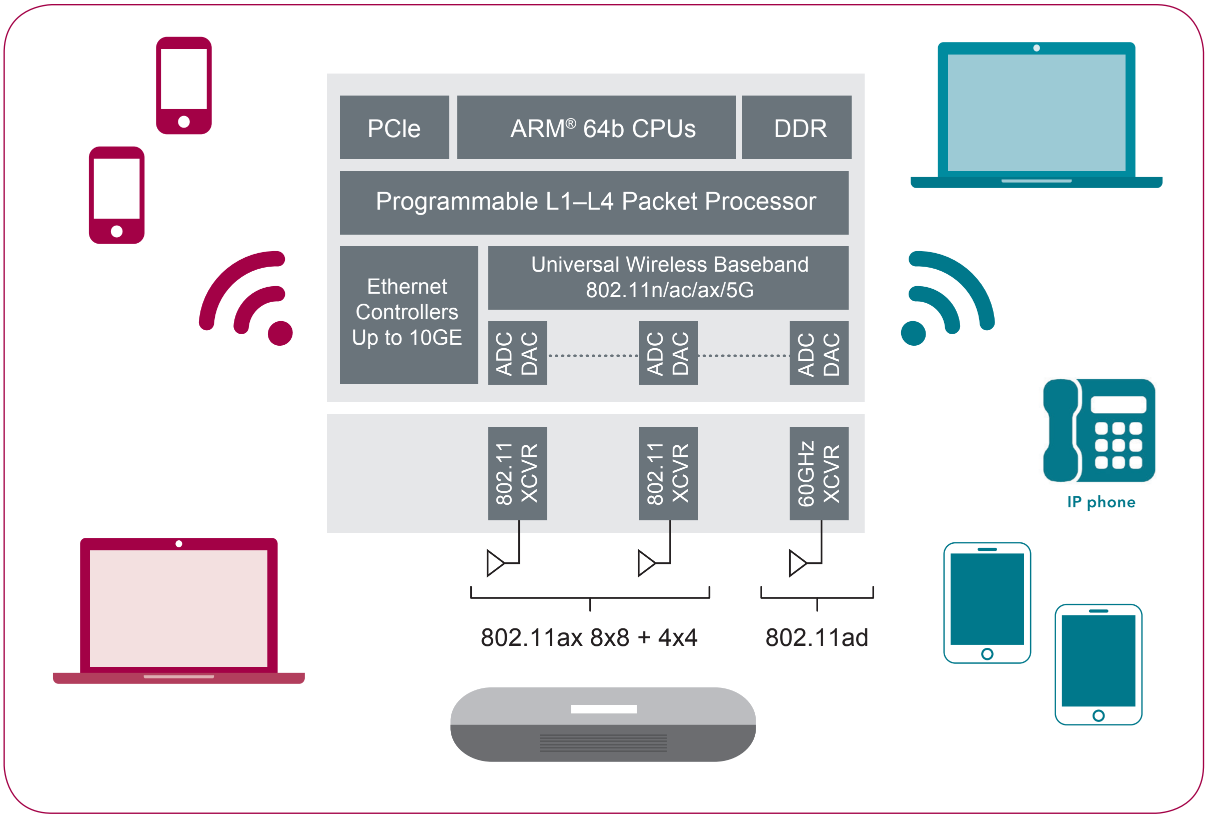

Figure 5: LA1575 Deployment Example

This solution provides a path to addressing the market needs and challenges identified at the beginning of this paper—namely providing the capability to meet the needs of bandwidth-hungry users and applications while still providing for backward compatibility for existing user devices and network systems. The announced solution and system enables an efficient and programmable solution to provide for flexibility and deployment ease.

To illustrate the benefits of the described solution, let's review a use case with an enterprise access point deployment. In that scenario, assume a company is adding a 60 GHz radio module to an existing Wi-Fi access point to meet bandwidth demand for new wireless use cases. Assume an 802.11ad module costs $150 and installation costs another $50. The addition on its own is not a huge expense, but a new 60 GHz Wi-Fi standard, 802.11ay, is on the cusp of being standardized. The case for an upgradeable radio is clear and like past pre-standard Wi-Fi deployments.

A bigger benefit to a software-defined radio in the 60 GHz band is that real-world performance is likely to arise as a problem. The enterprise could spend hours of troubleshooting (assume five hours at $200 per hour for a consultant) and perhaps scrap the 60 GHz Wi-Fi deployment, owing to poor network performance. However, as 60 GHz Wi-Fi vendors gain field experience with the phased antenna arrays and associated signal processing, they will upgrade their algorithms.

A fully programmable physical layer, including antenna processing, will help enable vendors to implement these upgrades on existing customer hardware. Thus, the enterprise's initial expense of $200 per node is its final expense and not a precursor to expenses several times greater for upgrades and debugging.

Fully software-defined physical layers could completely transform the industry. Communications gear has historically been deployed in a rip-and-replace cycle. To deploy new services or technologies, businesses and service providers replaced old equipment with new equipment. From a technology perspective, this yielded a stair-step experience: a step up in capex for installing new gear followed by a plateau of no capex during which users experienced the upgraded network.

Equipment based on NXP's Layerscape technology can help smooth this experience: users get new network services or better performance more often, equipment hardware lifecycles are longer, and network upgrades are more frequent and less expensive because they are based on software. Mirroring this shift from hardware to software is a shift in cash flow from large capital investment lumps depreciated over several years to smaller annual operational expenses for new software, acquired as needed to increment the network's capabilities. In summary, the network has become more consumable.

Contributors

Wim Rouwet
Senior Principal Engineer, Systems and Architecture, NXP Digital Networking

Nikolay Guenov
Director, Product Management, NXP Digital Networking

Joe Byrne
Senior Strategic Marketing Manager, NXP Digital Networking

How to Reach Us:

Home Page: **www.nxp.com**
Web Support: **www.nxp.com/support**

USA/Europe or Locations Not Listed:
NXP Semiconductor
Technical Information Center, EL516
2100 East Elliot Road
Tempe, Arizona 85284
+1-800-521-6274 or +1-480-768-2130
www.nxp.com/support

Europe, Middle East, and Africa:
NXPHalbleiter Deutschland GmbH
Technical Information Center
Schatzbogen 7
81829 Muenchen, Germany
+44 1296 380 456 (English)
+46 8 52200080 (English)
+49 89 92103 559 (German)
+33 1 69 35 48 48 (French)
www.nxp.com/support

Japan:
NXP Semiconductor
ARCO Tower 15F
1-8-1, Shimo-Meguro, Meguro-ku,
Tokyo 153-0064, Japan
0120 191014 or +81 3 5437 9125
support.japan@nxp.com

Asia/Pacific:
NXP Semiconductor Hong Kong Ltd.
Technical Information Center
2 Dai King Street
Tai Po Industrial Estate
Tai Po, N.T., Hong Kong
+800 2666 8080
support.asia@nxp.com

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