Intel®
Internet Exchange
Architecture

White Paper

Intel® Internet Exchange Architecture Network Processors

Flexible, Wire-Speed Processing from the Customer Premises to the Network Core

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Abstract

Network processors find widespread application in equipment designed for the customer premises equipment (CPE), access, edge, and core market segments. Going forward, the network will ultimately need to provide the infrastructure for a rich array of intelligent bandwidth-intensive services. The value of network processors in these applications will depend on the degree of service intelligence they can provide to networking equipment. Because of the increasingly complex requirements of the network infrastructure, the key metric of network processor performance is the amount of processing capacity that is available for deep packet inspection at prevailing data rates.

Due to the fact that data rates and processing requirements vary significantly for each segment of the network, a "one size fits all" approach to network processing can no longer deliver a balanced mix of packet-processing performance and cost. To accelerate the industry's ability to deliver next-generation services, Intel has expanded its network processor offerings with the introduction of three new Intel® Internet Exchange Architecture (Intel® IXA) network processor families, designed to meet the respective requirements of CPE, access, edge, and core market segments. These new network processor families enable network equipment vendors to offer their customers the best combination of customizable and upgradable services with wire-speed performance. In addition, each family of network processors provides OEMs with a comprehensive development environment including software, tools and development platforms that can be used to shrink time-to-market and reduce costs.

Market Segment Dynamics Shift

The telecommunications infrastructure and services market segments have experienced significant growth over the past several years. The recent retreat in telecom market segment growth and the resulting contraction of capital expenditures is forcing equipment and service providers to re-evaluate their strategies for the introduction of new products and services. The emphasis has now shifted to meeting the dual challenge of reducing operating costs while simultaneously meeting new market segment demands.

Successfully meeting these new requirements requires efficient migration to new high-value services, which in many cases may require an evolution of the network itself. For example, the network will gradually evolve from an ATM-based to an IP-based infrastructure. During the transition, which could take up to 10 years, networking equipment will likely need to support both protocols, while providing the flexibility to continuously adapt to changing industry standards.

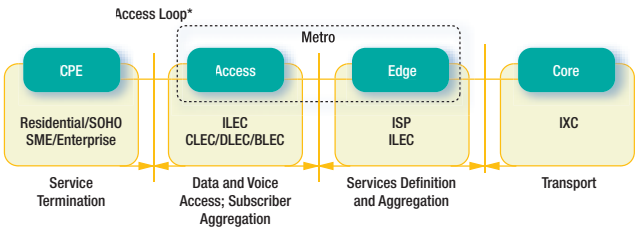
The recent build-out of the network core has created an infrastructure capable of supporting a rich new menu of potential services. But the task of developing the technology to deliver them continues to pose a challenge that requires a new approach to service-delivery:

- The emphasis is shifting from the delivery of raw bandwidth to value-added differentiated services
- Charges are increasingly billed on the basis of content, rather than on minutes of connect time
- "Best effort" delivery methods are being replaced by service-level agreements
- "IP everywhere" is gradually taking the place of multiple independent protocols
- Proprietary interfaces are giving way to standards-based interfaces.

New Market Model Emerges

Deregulation of the telecom network dictates a new market model that is designed to take advantage of the unbundling of equipment from the local loop. This phenomenon provides the opportunity for the emergence of new market models, in which carriers compete on a new basis. Instead of simply charging a flat fee for network access, the new competitive environment allows service providers to capitalize on the rich content and services they can deliver.

One important challenge for the industry is how to minimize operational costs while simultaneously offering new services and maintaining revenue and margins. Service providers will increasingly demand networking equipment that offers flexibility as well as performance, allowing them to add new, billable services while accommodating new standards requirements. These requirements will make the contribution of programmable network processors increasingly important.



CPE — Customer Premises Equipment
SOHO — Small Office/Home Office
SME — Small to Medium Enterprise
ILEC — Incumbent Local Exchange Carrier
CLEC — Competitive Local Exchange Carrier
DLEC — Data Local Exchange Carrier
BLEC — Building/Business Local Exchange Carrier
IXC — Inter Exchange Carrier

* Also known as Local Loop, or Last Mile

Figure 1. The unbundled broadband network model includes four market segments: CPE, Access, Edge, and Core. The regional metro network connects Access to Edge.

Processing Requirements Differ Across the Network

Each level of the network requires a different mix of processing performance, features, and costs. To meet those needs effectively, network processors must be optimized not only for the specific requirements of the equipment, but also for the services delivered in each segment of the network infrastructure.

CPE Requirements:

Customer premises equipment helps carriers increase revenue by deploying new services to homes and businesses. To be a fully functional part of this "last-mile" infrastructure, CPE devices must be compliant with current and planned services and interoperable with other parts of the network. CPE requirements include:

- Wire-speed performance on the WAN
- High level of integration to support expanded network services
- Interoperability with access equipment at Layers 1 and 2, and with edge equipment at Layer 3 and above in the service provider's network
- Easy configuration and remote management, with headroom for new standards and upgrades
- Low-cost implementation.

Major trend: CPE equipment will require network processing headroom to accommodate the packet handling requirements of new services.

Access Equipment Requirements:

Access equipment provides the first consolidation point as traffic from multiple customer premises begins its journey to the network core. The pervasive use of the Internet in homes and businesses requires large-scale and cost-effective aggregation of multiple low-speed connections to higher speed traffic at successive levels of the network. Access equipment requirements include:

- Support for multiple physical layer interfaces and Layer 2 protocols
- Support for multiple protocol interfaces
- Small footprint, low-power equipment form factors.

Major trend: as demand grows for new network services and as data rates increase, the functionality of today's edge and core equipment will migrate into access products.

Edge Equipment Requirements:

While access equipment collects and distributes multiple data streams from customer premises, the devices at the edge of the network deliver differentiated network services based on traffic characteristics. Edge equipment requirements include:

- Easy service provisioning
- Scalable performance and functionality
- Smooth migration to emerging standards.

Major trend: as the network evolves toward a pure-IP infrastructure, edge devices will increasingly need to support differential packet classification protocols, such as Multi-Protocol Label Switching.

Core Equipment Requirements:

Very high-performance, high-density routing switches reside at the center of the network, aggregating and moving traffic from hundreds of edge devices via multi-gigabit and terabit switching fabrics. Core equipment requirements include:

- Highly scalable switching and routing performance
- High availability, including redundancy and hot-swap functionality
- NEBS-compliant packaging.

Major trend: as services currently implemented in the network core migrate to the edge, core equipment must deliver the highest levels of reliability and packet-forwarding performance.

Intel's Second-Generation Network Processors

Intel is committed to accelerating the industry's ability to deliver new network services. To achieve this objective, Intel is providing network equipment vendors and service providers with three second-generation families of Intel Internet Exchange Architecture (Intel IXA) network processors. Each processor family is optimized for the requirements of targeted network segments, and is complemented by software tools and development platforms to help reduce development cost.

The new Intel IXA network processor families share three key architectural characteristics:

- Microengine technology—a subsystem of fully programmable, multi-threaded RISC processing elements that enable high-performance packet processing in the data plane.
- Intel® XScale™ technology—providing the highest performance-to-power ratio in the industry, with speeds up to 1,000 MIPS and power consumption as low as 10 mW, enabling low-power, high-density processing of control plane applications.
- The Intel® IXA Software Portability Framework—providing the advantages of ease of use, software investment protection, and faster time-to-market through a modular programming framework, code portability and reuse among network processor-based projects as well as future generations of Intel IXA network processors.

High-Speed Data Plane Processing—Hyper Task Chaining

As the network continues to evolve, the value of network processor technology will increasingly depend on intelligent packet processing at wire speed, rather than on raw performance alone. The ability of carriers to provision and bill for new services will require a combination of performance and flexible control over processing resources. As an example, for an OC-192/10 Gbps link, deep packet inspection must occur in an interval as short as 35 nanoseconds. The network processor must perform the necessary Layer-3 through Layer-7 applications on these cells/packets, and then transmit them in the correct sequence and at the required rate without loss.

Intel's store-and-forward network processor architecture is ideally suited to this challenge, providing a high-performance, OEM-programmable platform for implementing new data-plane applications. The multiprocessing subsystem of the second-generation network processor ensures that aggregate processing capacity is available to enable rich packet/cell processing, even for 10 Gbps wire speeds in applications that traditionally required high-speed ASICs. In addition, the highly parallel design of the microengines allows a single-stream, packet/cell analysis problem such as routing to be decomposed into multiple, sequential tasks, including packet-receive, route table look-up, and packet classification. The performance and flexibility provided by this software-defined processing pipeline allows multiple tasks to be completed simultaneously while preserving data and time dependencies. As network requirements evolve, this powerful and flexible network processor design will enable OEMs to easily scale performance and add features to meet new requirements.

The microengine design of its second-generation network processors constitutes the first implementation of Intel's Hyper Task Chaining technology. This unique network processing approach allows a single stream packet/cell processing problem to be decomposed into multiple, sequential tasks that can be easily linked together. Patented memory register technologies enable data and event signals to be shared among threads and microengines at virtually "zero latency," while maintaining coherency. Other innovations, known as Ring Buffers, establish FIFO "producer-consumer" relationships among microengines, providing a highly efficient mechanism for flexibly linking tasks among multiple software pipelines. Through this combination of flexible software pipelining and fast inter-process communication, Hyper Task Chaining enables Intel IXA network processors designed for access, edge, and core applications to perform complex processing at wire speed.

Integrated Application Processing in the Control Plane—Intel® XScale™ Technology

Intel's patented microengine technology is complemented by an integrated high-performance, low-power processing core. The Intel XScale core is designed to handle a broad range of complex processing tasks, including application processing, communication with the backplane, managing and updating data structures shared with the microengines such as routing tables, and setting up and controlling media and switch fabric devices. In addition, the Intel XScale core handles exception packets that require additional complex processing.

Intel XScale technology achieves its high performance through Intel® Superpipelined Technology, a multi-stage, high-efficiency processing pipeline architecture that minimizes latency and enables high clock speeds with ultra-low power consumption. Based on the ARM* Version 5TE instruction set, Intel XScale technology delivers industry-leading mWatt/MIPS performance, while preserving software compatibility with Intel's first-generation network processors. In Intel's second-generation network processors, both the microengines and the Intel XScale core are combined in a single chip. This integrated approach gives OEMs significant flexibility in matching processing tasks to resources, and minimizes integration costs.

Easy Code Development and Reuse—Intel® IXA Portability Framework

To gain maximum benefit from the power and flexibility of new generations of network processors, developers need access to equally powerful tool suites to preserve their investments in existing applications and speed development of new features and services. The Intel® IXA Portability Framework enables fast and cost-effective code development while protecting software investments through software portability and the reuse of code for the microengines and the Intel XScale control processor across current and future generations of Intel IXA network processors. It enables development of modular, portable code blocks and integration of third-party software products for longer product life and easier maintenance, while eliminating the time-consuming development of crucial infrastructure software.

The Intel IXA Portability Framework includes:

- A modular programming model to enable optimal application partitioning across microengines and threads, and facilitate the integration of customer-developed, third-party and Intel®-supplied building blocks. The modular model enables software components to be flexibly mixed, matched and reused into a single managed pipeline. This model facilitates the retargeting of code between Intel IXA network processors with differing numbers of microengines and threads, simplifying code reuse.
- Optimized microengine libraries and tools that provide continuity between changes in the microengine instruction set and architecture to enable interoperability across multiple hardware configurations.
- Intel XScale technology source code libraries to enable modular core component development and enhance portability between multiple operating environments.
- A library of standards-based Network Processor Forum (NPF) APIs for communication with control plane protocol stacks.

Intel® IXA Network Processor Families: from CPE to Core

In addition to the wide range of networking applications supported by the first generation of Intel IXA network processors, the latest Intel® network processor families are designed for delivering multiple services in CPE applications, wide area networking at up to OC-48/2.5 Gbs line rates, and the specialized requirements of core applications at OC-192/10 Gbs.

Intel® IXP425 Network Processor for CPE

The Intel® IXP425 network processor family for CPE applications provides single-chip integration of a programmable, high-performance Intel XScale core for application processing with three network processor engines for wire-speed packet handling. The Intel IXP425 network processor also features integrated WAN/LAN interfaces and support for voice, video, security, and network management services. The parallel processing architecture of Intel IXP425 network processors, combined with a range of available core speeds, enables developers to match processing capabilities to their application requirements. With its associated software and Development Platform, the Intel IXP425 network processor family is the foundation of a total development environment for fast time-to-market, last-mile applications such as customer premises equipment and remote DSLAMs for multi-dwelling units (apartments, hotels).

Intel® IXP2400 Network Processor for Access and Edge Applications

The Intel® IXP2400 processor is the midrange performance member of Intel's second-generation network processor family. It is designed for a wide range of access and edge applications including multi-service switches, routers, broadband access devices, and wireless infrastructure systems, at wire speeds from OC-12 to OC-48/2.5 Gbps. With eight multi-threaded microengines and an integrated Intel XScale core, the Intel IXP2400 processor-based designs provides a logical next step for developers looking to increase performance or add features to Intel® IXP1200-based designs.

Intel® IXP2800 Network Processor for Edge and Core Applications

The Intel® IXP2800 network processor is the highest performance member of Intel's second-generation network processor family. It combines 16 fully programmable multi-threaded microengines for packet forwarding and traffic management with an Intel XScale core on a single chip. The network processor is capable of performing more than 25 giga-operations per second, enabling 10 Gbps wire-speed processing even for minimum 40-byte Packet-over-Sonet.

Development Environment and Tools

For CPE applications, the Intel IXP425 Network Processor Development Platform provides a powerful tool for developing and verifying hardware and software for the IXP425 network processor. Developers can use this flexible and extendable platform to jump-start their designs to conduct rapid initial chip evaluation, chip performance evaluation, product development and prototyping.

For other applications, Intel provides a comprehensive development environment that enables customers to rapidly develop new applications for the Intel IXP2400 and Intel IXP2800 network processors and to migrate existing applications from the Intel IXP1200 network processor family. The development environment includes the Intel® IXA Software Developers Kit (Intel® IXA SDK) 3.0 that provides high-level tools, embedded real-time operating systems, the Intel® IXA Software Portability Framework and libraries. The SDK enables customers to evaluate, demonstrate, and tune performance of the network processor to meet specific product requirements. The hardware development platforms are configured with Intel IXP2400 or Intel IXP2800 network processor base cards and a choice of modular media cards within an industry-standard form factor chassis for maximum design flexibility.

Intel's Technology Leadership

Intel's expertise in communications technology and development further enhances the customer benefits of these new network processors and development tools. The company's widely recognized leadership in semiconductor manufacturing processes and technologies ensures that new network processor design will be able to take full advantage of shrinking die sizes and associated improvements in component integration. As an example, these enhancements will allow the new architectures to continue to scale features and performance beyond 10 Gbps. Equally important, Intel will continue to encourage an extensive community of third-party developers for its network processors. Through its active support for hardware and software developers, Intel ensures that customers have the broadest available choice of networking components and development solutions.

Summary

Intel has significantly expanded its network processor offerings to support the full range of packet inspection and forwarding requirements, from customer premises to the network core. Intel has introduced three new, second-generation processor families, each tailored to the unique characteristics of the CPE, access, edge, and core market segments. With this approach, Intel is working to ensure that network equipment vendors can offer their customers the best combination of customizable/upgradable services and wire-speed performance, while minimizing development time and costs.

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