Whitepaper

Comparing First and Second Generation Intel® Core™ Processors

Lanner

intel Embedded Alliance

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Abstract

Ever-increasing network traffic keeps system designers of application servers, network appliances, and other packet-processing devices constantly looking for new platforms that can cost effectively increase throughput. For this market, the 2011 introduction of 2nd generation Intel® Core™ processors (based on Intel® microarchitecture formerly codenamed "Sandy Bridge") offers real performance gains over previous generation architecture.

To find out how substantial these gains are, Lanner Electronics, an Associate member of the Intel® Embedded Alliance, conducted research on two generations of processors. Lanner engineers tested the throughput of one platform powered by an Intel® Core™ i5-660 processor at 3.33 GHz (based on the previous generation Intel® microarchitecture formerly codenamed "Nehalem") and one platform powered by the 2nd generation Intel® Core™ i5-2400 processor at 3.1 GHz. Lab results show a uniform 20% increase in network throughput on the 2nd generation Intel Core processor-based system. This increase is found on both 2-port and 4-port configurations of the Intel® 82580 Ethernet controller. When comparing the platforms while using the Intel® 82599 10 Gigabit Ethernet controller, the 2nd generation Intel Core processor-based system performs significantly better across all frame sizes on both short- and long-term tests. This leap in data plane processing by 2nd generation Intel Core processors demonstrates that Intel® processors continue to dominate performance in the network application domain.

Introduction

The beginning of 2011 saw the launch of the 2nd generation Intel Core processors. These processors are the next step in the evolution of parallel multi-core processing, providing unprecedented performance and dynamic scalability. Coupled with the new Intel® 6 Series chipsets, the 2nd generation Intel Core processors provide an excellent solution for performance-hungry, high bandwidth, deep packet inspection and other content-aware network packet-processing applications.[1]

Lanner Electronics Inc., a worldwide leader in manufacturing network appliance hardware, has conducted research into the 2nd generation Intel Core processors with the Intel 6 Series chipset as implemented in our entry-level and mainstream network security platforms. Our findings and results are discussed in this paper.

The scope of this paper will be three-fold. First, the paper will provide some background on the new features and capabilities of the 2nd generation Intel Core processors. We will then empirically compare two generations of platforms based on packet-forwarding capabilities, with the intent of quantifying the improvements of the 2nd generation Intel Core processors in network communication throughput. Finally, we will discuss some ways in which Intel® Ethernet controllers can capitalize on multi-core microcontroller design, as well as their own capabilities, to benefit next generation server farms and data centers.

Background on 2nd Generation Intel® Core™ Processors

The 2nd generation Intel Core processors feature a new microarchitecture fabricated on Intel's cutting-edge 32nm process technology. This microarchitecture introduces a number of new features and capabilities to Intel Core processors, including breakthrough performance in floating point/vector computation for media and other high-performance computing applications. Many of these features help increase their packet processing performance. We won't provide detail on all the new features here, but instead provide a brief overview.

Intel® Advanced Encryption Standard–New Instructions (Intel® AES-NI)

Seven new instructions provide robust encryption without the need for additional appliances or increased performance overhead. By accelerating encryption operations, Intel® AES-NI significantly speeds up data protection. Intel AES-NI can provide up to a 400% boost in IPsec performance compared to a software implementation that does not use Intel AES-NI.[2] Intel AES-NI implements some of the complex and performance-intensive steps of the AES algorithm using hardware to accelerate their execution. Intel AES-NI can also lower the risk of side-channel attacks while improving encryption performance. The AES algorithm is widely used across the software ecosystem to protect network traffic, personal data, and corporate IT infrastructure.

Intel® Advanced Vector Extensions (Intel® AVX) Technology

The new Intel® AVX instruction set (an advanced form of Streaming SIMD Extensions, or SSE) widens the data path from 128 bits to 256 bits, increases the number of operands from two to three, and includes new advanced data rearrangement functions to provide outstanding performance on digital signal processing, image and video processing, and security processing. When AVX instructions are used on 2nd generation Intel Core processors, they can provide up to double peak FLOPS performance compared to using SSE4 instructions. What's more, this performance comes with only a minor increase in power consumption.

Next Generation Intel® Turbo Boost Technology

Many 2nd generation Intel Core processors support Intel® Turbo Boost Technology 2.0. This allows processor to accumulate an "energy budget" during idle periods to allow processor cores to run faster than the base operating frequency to provide remarkable power bursts during intense workloads. Intel Turbo Boost Technology also intelligently delegates power resources when some cores

are idle. In these situations the idle cores are turned off and the spare power budget is used to increase the clock speed on the active cores.

System Agent

A new System Agent anchors the I/O system and provides 16 PCI Express 2.0 lanes, a Power Control Unit (PCU), Direct Media Interface (DMI), a dual-channel memory controller, and a display engine. The System Agent connects to the rest of the processor components through an innovative ring interconnect that enables scalable, high-bandwidth communications between processor cores and processor graphics, allowing them to share common last-level cache. Taking advantage of this ring interconnect, the System Agent provides a high-bandwidth, low-latency interface to both DRAM and I/O.

New "Cool" Microprocessor Enhancement Features

New "cool" microprocessor enhancement features, including a new memory port design, help boost performance up to 30 percent relative to the previous generation, while saving power. The new memory ports enable 2nd generation Intel Core processors to execute more instructions per clock cycle (IPC) than the previous generation. There are now two load/store ports. The new design uses symmetric address ports so that each port can service a load or store address, resulting in double the load bandwidth. This new flexibility significantly improves effective bandwidth, providing the highest percentage gain in IPC. Other enhancements contribute to these processors' greater throughput, lower power and shorter pipeline.

Integrated Graphics Processor and Memory Controller

A fully integrated graphics processing unit (GPU) and memory controller improves graphics performance while reducing bill of materials (BOM) and power requirement. While the integration of a GPU was first seen in first generation Intel Core i5 desktop processors, the processors contain two dies: the actual 32nm processor with the I/O connections and a 45nm graphics controller with the memory interface. 2nd generation Intel Core processors incorporate an advanced graphics processing unit (GPU), plus memory controller (display, I/O and memory controller), all on the same piece of 32nm silicon to provide performance levels that previously required a separate graphics card.

Enhancements, Improvements and Carry Overs

In addition to the new features described, 2nd generation Intel Core processors also offer enhancements to previous features and technologies that contribute to easier manageability, improved throughput, greater scalability, and energy-efficient performance.

- Dual-core and quad-core configurations improve the performance and efficiency of multi-threaded applications.
- Intel® Hyper-Threading Technology (Intel® HT Technology), as in the previous generation, enables running two tasks at the same time per core and provides significant performance and energy-saving benefits depending on the application.

- Improved Intel® vPro™ technology offers intelligent, hardware-assisted remote management, virtualization, and security features that help reduce total cost of ownership.
- Enhanced Serial ATA (SATA) support enables up to 6Gb/s transfer rates for optimal data access with up to two SATA ports
- Updated Direct Media Interface (DMI 2.0) doubles the transfer rate to 20Gb/s with a x4 link compared to DMI 1.0.

Two Generations of Intel® Microarchitecture-based Platforms: Methodology of Testing

Data plane packet processing involves moving data from an I/O device to system memory, classifying the data and then moving the data to a destination I/O device as quickly as possible. At the high speeds of modern communication, this puts pressure on the system bus as data is moved between I/O devices and system memory, and the processors classifying the data.

Lanner engineers used the Ixia Packet Processing Engine to provide the packet-processing workloads necessary to compare the 2nd generation Intel Core i5-2400 processor at 3.1 GHz against the previous generation Intel Core i5-660 processor at 3.33 GHz.

Intel® Microarchitecture Test Configuration

An Ixia Packet Generator creates packet traffic for both received and transmitted traffic (RX and TX), and is capable of using both 1 and 10 gigabit Ethernet links that are connected to the system under test (SUT), as shown in Figure 1.

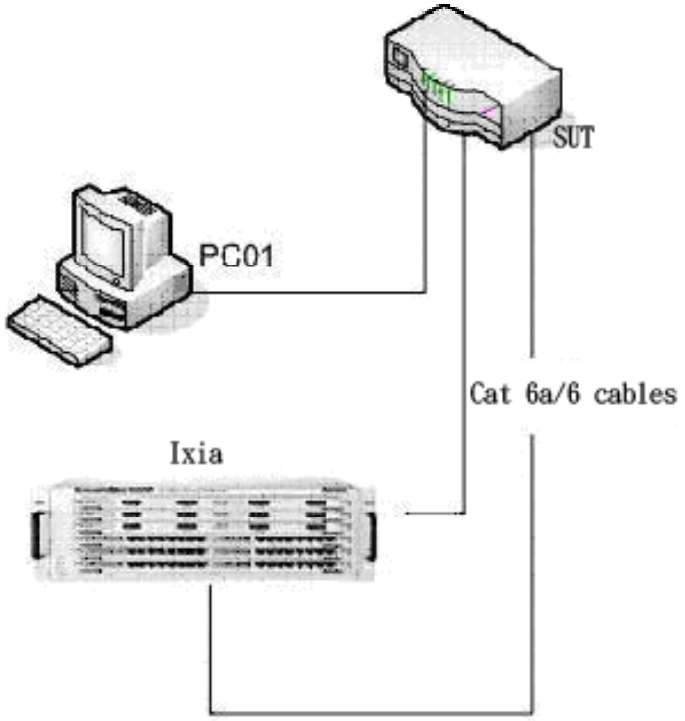

Figure 1. Test Environment

In the first test, one SUT is equipped with the previous generation Intel Core i5-660processor and the other with the 2nd generation Intel Core i5-2400 processor. Each is subjected to 2 or 4 ports of Gigabit Ethernet interfaces producing a maximum load up to 2 or 4 gigabits per second (Gbps).

In the second test, each SUT is subjected to 2 ports of 10 Gigabit Ethernet interfaces producing a maximum load up to 40 gigabits per second.

The test environment was carefully planned so that the compared processors ran at similar frequencies and the connected Ethernet interfaces had exactly the same setup. The following table specifies the configurations on the test environment.

Lanner Model[3]	FW-8865	FW-8760
CPU	2nd generation Intel® Core™ i5-2400 processor at 3.1 GHz (4 cores and 4 threads)	Previous generation Intel® Core™ i5-660 processor at 3.33 GHz (2 cores and 4 threads)
PCH (Platform Controller Hub)	Intel® Q67 Express chipset	Intel® 3450 chipset
RAM	DDR3 1333MHz , Non-ECC (4 modules of 2 GB RAM and 8 GB in total capacity)	
Storage	SATA II with maximum speed to 3Gbps, total capacity 500G	
LAN Module/ Cables	■ Intel® 82580 Gigabit Ethernet – IG425 (2 PORTS) and IG804 (4 PORTS) ■ Category 6a (100m) ■ Intel® 82599 10G Gigabit Ethernet – NM-IXN201A 2-port optical fiber connector ■ Category 6 optical fiber cable (3.1m)	
LAN Interface Technology to the PCH	PCIe 2.0	
Software	Cent OS 5.5; LAN driver for IXN201A is IXGBE-3.1.17; LAN driver for IG425 and IG804 is IGB-2.2.9	
System Power Required	270W	220W
Test Tool	Ixia 400T	

Packet Forwarding Test Results

Each SUT operates in duplex forwarding mode, where all processor cores handle 2 or 4 Gigabit Ethernet networking interfaces operating at a full line rate. Load tests were repeated for different frame sizes; each test runs for a duration of 30 seconds. Tests were conducted with common packet sizes such as 128, 256, 512, 1024, 1280 and 1540 bytes. Figure 2 shows the maximum throughput based on the number of ports on each platform with respect to packet size.

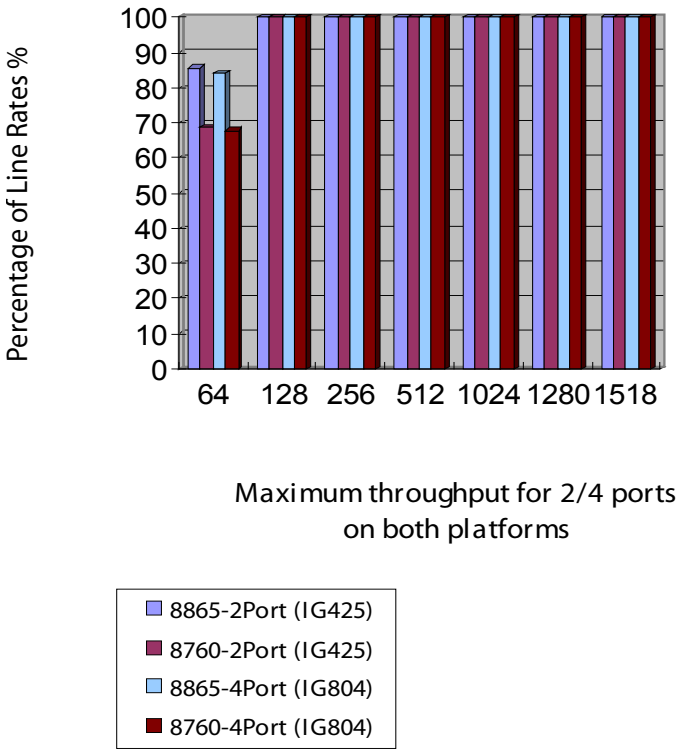

Figure 2. Duplex Forwarding Results by Packet Size. (FW-8865 uses 2nd generation Intel® Core™ i5-2400 processor at 3.1 GHz. FW-8760 uses previous generation Intel® Core™ i5-660 processor at 3.33 GHz.)

As we can see from the graph, for transfers of 64 bytes (which is an indicator of processing power), the line-rate throughput performance of the 2nd generation Intel Core i5-2400 processor-based server exceeds that of the previous generation Intel Core i5-660 processor-based server by approximately 20%.

The second test using the 10G Gigabit Ethernet module was even more revealing. Since the Intel 82599 10G Gigabit Ethernet module cannot accommodate 4 ports, Lanner engineers designed 2 stress tests: a 30-second test to mimic short-term throughout and a 14-

hour test to mimic a time-intensive transfer.

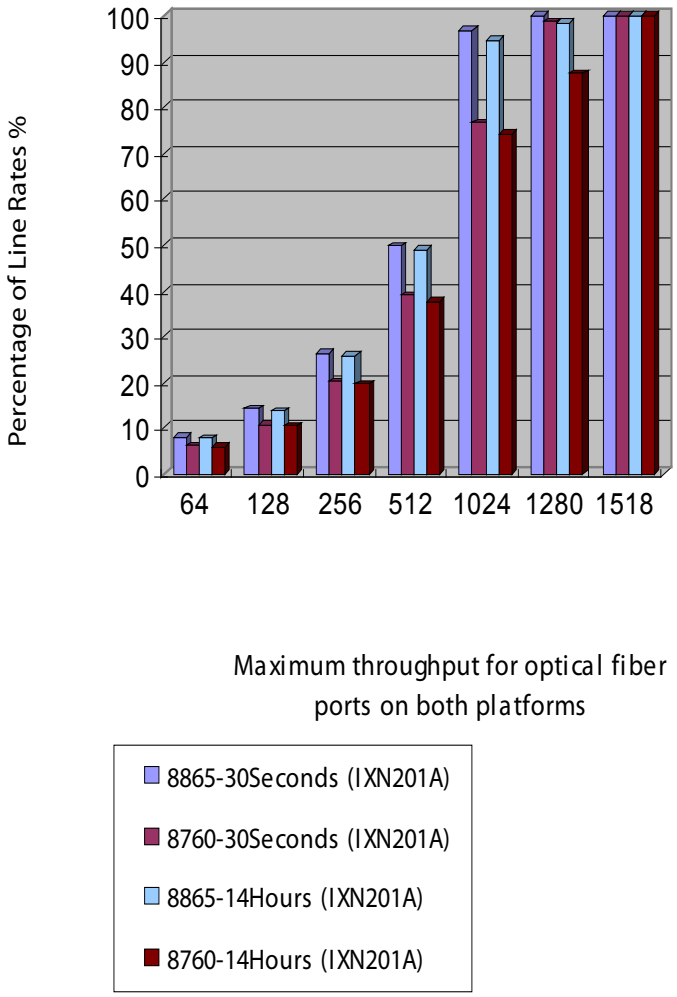

Figure 3. Duplex Forwarding Results by Packet Size. (FW-8865 uses 2nd generation Intel® Core™ i5-2400 processor at 3.1 GHz. FW-8760 uses previous generation Intel® Core™ i5-660 processor at 3.33 GHz.)

Test results show (Figure 3) that the 2nd generation Intel Core i5-2400 processor-based platform has significantly better throughput across all frame sizes in both short- and long-term tests.

Intel® LAN Controller Advantages

Support of Standard Secured Protocols for Remote Management

The Intelligent Platform Management Interface (IPMI) defines a common platform instrumentation to enable interoperability between baseboard and chassis, baseboard and management software, and among servers. Almost all server-grade LAN modules from Intel have IPMI pass-through capability to support remote management. The remote management is accomplished via IPMI and the Network Controller Sideband Interface (NC-SI), which allows the connection of intelligent hardware—i.e., the Baseboard Management Controller (BMC)—to the Network Interface Controller (NIC) in server computer systems. The BMC can directly access and monitor the platform instrumentation. This happens regardless of the state of the processor or operating systems. Hence, it is possible to diagnose and repair many failure modes as long as the appliance is connected to power and LAN.

Extended Support of New Protocols and Offload Engines on the 10 Gigabit Ethernet LAN Modules

To meet the trend of unified infrastructure for Storage Area Network (SAN) and LAN, an Intel® 82599 10 Gigabit LAN controller provides the functionality necessary for migrating to a converged network. In a typical data center, a SAN is often used and connected via Fibre Channel (FC) fabric. In order to consolidate Fiber Channel-based storage and Ethernet-based data traffic, Fiber Channel over Ethernet (FCoE) is used to carry storage traffic over Ethernet. Below we list a few new features of the Intel 82599 10 Gigabit LAN controller that contribute to particularly effective use of FCoE.

- FCoE Transmit Segmentation – Enables the FCoE initiator to transmit multiple FCoE packets up to a complete FC sequence with a single header in host memory (single instruction), thus reducing processor overhead.

- FCoE Tx/Rx CRC Offload – Offloads receive FC CRC integrity check while tracking the CRC bytes and FC padding bytes.
- FCoE Coalescing and Direct Data Placement – Saves CPU cycles by reducing the data copy and also minimizes CPU processing by posting only the packet's headers that are required for software.
- UDP/TCP and IP Checksum Offloads/SCTP Receive and Transmit Checksum Offloads, Stateless Offloads – Uses hardware assistance to automatically compute the checksum in the network adapter prior to transmission onto the network or upon reception from the network for validation.
- Intel® Ethernet FCoE Boot – Allows the administrator to install FCoE to boot an operating system from a remote target.

Intel® Virtualization Technology (Intel® VT) for Connectivity

Using the same manufacturer for both processor and Ethernet controller chips, original equipment manufacturers (OEMs) can dramatically reduce the amount of time they spend testing third-party components and apply that time instead to designing the best system. In fact, by choosing a solution from the 2nd generation Intel® Core™ VPro™ processor family, OEMs can easily add additional features and capabilities into their solutions for a more competitive product.

2nd generation Intel® Core™ VPro™ processors provides Intel® vPro™ technology, a set of security and manageability capabilities delivered through the processor, Intel® chipset and network adapter. One capability of particular interest for packet-processing devices is Intel® Virtualization Technology (Intel® VT).[4] Intel VT provides hardware-assisted virtualization support, performing certain virtualization tasks, like memory address translation, in hardware. This reduces the overhead and footprint of virtualization software and improves performance.

2nd generation Intel® Core™ VPro™ processors, such as the Intel Core i5-2400 processor used in this study, are particularly valuable when enabling increased virtual machine densities to boost server utilization or provide better redundancy. As more and more virtual machines run in parallel on the same hardware, the load on the Ethernet switching function, which forwards each network flow to the destination virtual machine, intensifies. Using a 2nd generation Intel Core vPro processor with Intel VT enabled allows you to make use of Intel® VT for Connectivity (Intel VT-c), a collection of I/O virtualization technologies that enables lower CPU utilization, reduced system latency, and improved networking and I/O throughput. With Intel VT-c, Ethernet switching functions can be offloaded from the hypervisor software to further improve overall performance in virtualized systems. [5]

Two platform-level technologies of Intel VT-c that work together to deliver next-generation virtualized I/O are Virtual Machine Device Queues (VMDQ) and Virtual Machine Direct Connect (VMDc).

- Virtual Machine Device Queues (VMDQ) VMDQ improves data processing and processor utilization by offloading the sorting and queuing tasks to the I/O controller from the VMM. A recent improve-

ment improves offloading the switching overhead between the different virtual machines on the server.

- Virtual Machine Direct Connect (VMDc) VMDc provides near native-performance by providing dedicated I/O to virtual machines, bypassing the software virtual switch in the hypervisor completely. An Intel publication has shown that with Intel VT-c the throughput of the port(s) can be more than doubled.

Advanced Interrupt-handling Features with MSI-X

One of the features of Intel® architecture (IA) is its ability to spread interrupts evenly among multiple cores. Spreading interrupts among processor cores can reduce processing time, thereby eliminating bottlenecks.

Intel® Gigabit and 10 Gigabit Ethernet controllers employ an improved MSI-X technology to minimize the overhead of interrupts and allow load balancing of interrupt handling between different cores and processors. For more information, see "Assigning Interrupts to Processor Cores using an Intel® 82575/82576 or 82598/82599 Ethernet Controller" (http://download.intel.com/design/network/applnots/319935.pdf). The Intel Ethernet Controller Resource page also provides additional techniques for tuning supported adapters (see www.intel.com/products/ethernet/resource.htm).

Applications

There are many ways for system designers to take advantage of all the performance advantages, as well as the new and enhanced capabilities of 2nd generation Intel Core processors on network platforms.

Application Servers

Intel AVX has been in the foreground since the release of the 2nd generation Intel Core processors. Intel AVX brings greater compute capacity for a wide variety of applications and usage models. Web servers which need heavy XML string and text processing will benefit from these instructions to improve performance of string and text processing operations. Other applications that benefit are those that require intensive floating point calculation. These include audio processing and audio codecs (e.g., virtual education), image and video editing applications (e.g., digital content creation), financial services analysis and modeling software (e.g., e-commerce or operations research), and manufacturing and engineering software (e.g., enterprise resource planning or data mining).

VOIP/Triple-play Gateway or Data Servers

In an era where corporate espionage and identity theft run rampant, all outgoing and received data needs a protection scheme. Be it corporate or personal, all information when sent through the cloud is at risk. Many Internet sites use protocols like Transport Layer Security (TLS) or Secure Sockets Layer (SSL) in order to provide this protection. Most network appliances use AES as the standard for encrypting data on the physical drives, wireless communi-

cation, and services over the public networks (VPN, VOIP, electronic banking, etc.). With Intel AES-NI, 2nd generation Intel Core processors provide an excellent way to accelerate encryption operations and reduce the impact of data protection on performance.

Conclusion

2nd generation Intel Core processors with the Intel® AVX instruction set bring a new solution for packet-processing devices that will deliver real performance gains over previous generation architecture. Results from testing done by Lanner Electronics show a uniform 20% increase in network throughput with a 2nd generation Intel Core processor-based system over a previous generation system.

2nd generation Intel Core vPro processors offer all these advantages, plus additional capabilities. These include remote manageability, improved workload consolidation, lower CPU utilization, reduced system latency, and improved networking and I/O throughput.

You can learn more about network appliances using 2nd generation Intel Core processors by visiting the Lanner Electronics website (www.lannerinc.com). To learn more about 2nd generation Intel Core processors for embedded applications, visit edc.intel.com/Platforms/Core-Q67-B65.

1) The add-on capabilities with hardware acceleration are only available on high-end platforms.

2) Hoban, Adrian, "Using Intel® AES New Instructions and PCLMULQDQ to Significantly Improve IPSec Performance on Linux," Intel white paper, August 2010.

3) In accordance with Intel's classification of processors which divide its product line based on the density of performance, Lanner would offer 3 product groups of 2nd generation Intel® Core™ processors from low to high: Entry level, Mainstream Platform, and Performance Server. Lanner products exhibit leading-edge design and manufacture based on Lanner Electronics® trusted supply line of scalable Intel® based products and services.

4) Intel VT comprises of Intel Virtualization Technology (Intel VT-x), Intel Virtualization Technology for Directed I/O (Intel VT-d), and Intel Virtualization Technology for Connectivity (Intel VT-C). It requires a computer system with an enabled Intel® processor, BIOS, virtual machine monitor (VMM) and, for some uses, certain platform software enabled for it.

5) Refer to the publications from Intel Virtualization: A Superior Hardware Platform for Server Virtualization (ftp://download.intel.com/technology/virtualization/320426.pdf).

About Lanner Electronics Inc.

Founded in 1986 and publicly listed (TAIEX 6245) since 2003, Lanner Electronics, Inc. is an ISO 9001 certified designer and manufacturer of network application platforms, network video platforms and applied computing hardware for first-tier companies. Lanner's expertise also extends to include driver and firmware support, enabling customers to optimize hardware and software communication to achieve faster time to market. With headquarters in Taipei, Taiwan and branches in the U.S. and China, Lanner is uniquely positioned to deliver custom technical solutions with localized, value-added service.

About the Intel® Embedded Alliance

The Intel® Embedded Alliance is a global ecosystem program dedicated to providing OEMs and developers with the advanced hardware, software, tools, and systems integration they need to advance innovation, set new performance standards, and speed time to market. Learn more about the Alliance at: http://intel.com/go/eca.

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