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Introduction

Organizations can get the most from the energy we use today while moving the world toward more sustainable energy consumption, management, and growth by designing and applying more innovative technologies.

Using the right technology in the right areas of your business allows you to reduce waste and institute energy efficiencies that quickly translate to growth in customer base, increased market share, and enhanced shareholder value. With increasing pressures to become more environmentally responsible, failure to focus on environmental goals can have many negative repercussions.

By choosing energy-efficient HP products, consolidating with HP solutions that streamline or displace inefficient products and processes, and controlling energy use with HP solutions that intelligently manage consumption, customers are cutting their technology’s energy use and costs in half while improving performance.

Data consumption at a typical office environment is growing at a furious pace prompting IT to consider upgrading network equipment from the edge all the way to the core. Over the past few years there has been awareness over rising energy costs. When customers choose HP Networking equipment they achieve substantial energy savings with little to no penalty to throughput or latency. The energy savings summarized here were observed and analyzed by a third party.

HP Networking

HP is one of the fastest growing networking vendors in the industry. Networking is not new to HP. The HP Networking division established in 1985 has a long history of innovation. The HP Networking vision has been to deliver outstanding innovations to solve key customer problems such as limited flexibility performance, higher TCO driven by complicated proprietary standards. HP standards-based products using ProVision ASICs and unified software, offer excellent balance between performance, features and price and have been instrumental in adding true value to customers. Our vision to develop networking solutions that adapt to changing business needs is enabling our customers to be successful. Gartner has ranked us in the leadership quadrant for networking for over two years, lauding HP as having a vision as well as the ability to execute (http://www.gartner.com/technology/media-products/reprints/hpprocurve/article3/article3.html).

Our corporate focus on environmental consciousness and responsibility pervades all our product lines. HP Networking has a range of products covering every business need from the edge to the core. The HP ProCurve Manager (PCM) software delivers unparalleled manageability while the HP ProVision ASIC that powers the E-Series products such as the E8200, E5400, and E3500 Switch series is truly a switch on a chip, delivering enormous costs savings to the consumer.

Introducing HP Adaptive-Power Architecture

Traditional networking equipment has been designed with a primary goal to achieve line rate and to increase packet processing performance while decreasing switch latency, power, size, and cost. However, networking equipment designs from most vendors focus on reducing peak power consumption.

HP Networking platforms, built completely around HP Provision Architecture and Silicon, achieve substantial power savings for all customers and all deployment situations.

The design principles driving the Adaptive-Power silicon architecture include:

- Power consumption should scale with utilization.
- Power consumption should be reduced during idle periods.
- Networking performance should never be compromised by power saving features.

HP Networking is introducing Adaptive-Power silicon tailored to the vision of the Adaptive-Power architecture.

The Adaptive-Power Architecture from HP Networking was inspired by the realization that, for the majority of time networking equipment operates; it does not experience maximum processing load or throughput.

With HP Networking Adaptive-Power Architecture, network equipment power consumption can scale automatically with ports active, traffic intensity, type of traffic, layer 2, and layer 3 active table depths, classification complexity, and application environment.

With HP Networking’s first release of the Adaptive-Power Architecture, HP went beyond network software manageability tools and focused on how to reduce power consumption deep inside the switching platform. The Adaptive-Power Architecture relies on new ASICs and hardware platforms designed from the ground up to reduce power consumption as a function of utilization.
Typically, 60 percent of power consumption in networking equipment is associated with packet-processing silicon and packet-processing support silicon such as memories (DRAM and TCAM’s). Figures 1 and 2 show the maximum switch power consumption happens at the packet processing subsystem. To increase power savings, the best place to start is to reduce the power consumption associated with packet processing.

Power consumption in silicon in general and packet processing specifically is a function of:

- **Dynamic losses:** With synchronous silicon designs, at every active clock tick, energy is burned. Dynamic losses are directly related to the speed of clocks and the number of clock circuits and associated logic. Dynamic losses represent 30-70 percent of a typical packet processor.

- **Static/leakage losses:** There is some energy loss in circuits even without clocks toggling. This type of loss, unfortunately, is growing significantly as silicon geometries shrink. One of the primary power loss factors in sub-90nm silicon is leakage associated with memories, particularly large DRAM’s (Dynamic Random Access Memory) and TCAM’s (Ternary Random Access Memory) used in packet buffers, L2, L3, classifiers, and statistic tables.

There are five critical power management features inside V2 zl modules platforms:

- HP Networking Adaptive-Power Provision Silicon.
- Module-level Adaptive-Power voltage controls
- Individual module power and voltage telemetry
- Energy Efficient Ethernet Port Power Controls
- PoE Power Controls

HP Networking’s ProVision, Gen 5 ASIC’s (Application Specific Integrated Circuit) have been completely redesigned to reduce power consumption. The first deployment of the Adaptive-Power Architecture is inside the V2 zl modules 10/100 MbE, 1 GbE, and 10 GbE modular chassis switches. Here are some of the key technology innovations inside HP Networking Adaptive-Power ASIC’s:

**Adaptive Power Silicon—Efficient memory architecture**

The industry-standard packet processor architecture used in most products today is built around a packet

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1 Power Conversion subsystem power consumption is included in each of the subsystems power allocation
processor silicon device and a number of DRAM and/or TCAM devices for specific storage needs. Figure 3 shows a standard packet processor architecture—focusing and highlighting primary areas of power consumption.

The traditional architecture has some great performance characteristics, like high performance data path, packet processing with deep external memory tables, and packet buffers for congestion management. However, one drawback is that it does not make efficient use of the energy needed to support the external tables and packet buffers. A simple test of why this power consumption model is not efficient can be shown if you were to disable all classification rules and see if the power consumption goes down. Nearly all switches on the market today will not decrease power consumption when ACL rules are disabled or L2 or L3 tables are decreased in active entries.

In contrast to the industry, HP Networking silicon is architected around internal memory vs. external table and packet storage memories. With the Adaptive-Power Architecture, power consumption is reduced...
in memories by innovative design where clocks are disabled to various memories when memory access is not required. Further, memory-based tables are physically sub-partitioned and dynamically re-organized so parts of the memory devices can be shut-down if not needed over time.

**Optimizing silicon process losses with Adaptive-Power Architecture**

Within every silicon wafer produced, semiconductor process speed varies greatly across the wafer so that some chips are fast while other slow—this effect is amplified with smaller geometry, sub-90nm silicon devices now employed in 1G and 10G switch silicon packet processing devices. Since all chips produced need to deliver line-rate performance, all chips in traditional networking equipment needed to be operated at a high voltage to insure at speed operation for both slower and higher speed silicon.

With Adaptive-Power silicon, each chip manufactured is calibrated and identified for process speed. This allows Adaptive-Power platforms to operate at the exact voltage and power level required to operate at necessary line rate speed.

This affords huge power savings for higher speed silicon because power consumption is proportional to the square of the voltage applied—so even a 5 percent decrease in voltage can produce 10 percent associated power savings. And there is no penalty for platforms with lower speed silicon operating at higher voltages because lower speed silicon consumes less power for any given voltage than faster silicon.

So, with the Adaptive-Power Architecture, silicon voltages are scaled so all platforms consumes the least amount of power necessary for line rate operation.

**Adaptive-Power Silicon “smart” gating**

Architecture reduces Dynamic Power Demand

With large complex, pipelined synchronous architectures one power optimization in the silicon industry is the use of a technique called clock gating where a clock is shut off to a portion of logic to reduce dynamic power consumption. Simply put, clock gating shuts off clocks to portions of logic and there is no dynamic loss while the clock is gated off (Please refer to figure 5).

One example of clock gating power reduction is the amount of power used when a laptop is placed in “sleep” or “hibernation” modes. You can see the dramatic power savings potential of clock gating with the example of a laptop.

However, directly applying clock gating techniques that work well with general purpose computing machines don’t work well at all for networking and

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**Figure 5: Clock gating power control in Adaptive-Power Architecture**

![Clock gating power control in Adaptive-Power Architecture](image-url)
communication systems. Networking applications are inherently time, latency, and throughput sensitive. Imagine, for example, how latency would increase astronomically or how much packet loss would be experienced if you had to rely on your PC to come out of sleep to handle a newly arrived packet stream?

In order to take advantage the power savings afforded by clock gating without impacting latency and throughput, HP Networking had to develop a special approach to clock gating—smart clock gating. Compared with traditional clock gating approaches, there is similar power savings gained but without the loss of performance.

HP Networking’s Adaptive Power Architecture has designed clock gating techniques across 50 percent of the die and functional blocks using proprietary smart clock gating insuring performance is never compromised while minimizing power consumption. The smart clock gate governors must be able to coordinate and anticipate traffic flow through the chip to insure that specific resources are turned off when they will not be needed and, very importantly, turned on just before they need to be used so that throughput and latency never are impaired.

Adaptive-Power Silicon Port Power Control

Most traditional packet processing silicon does not automatically disable port-specific logic inside the packet processor. One of the reasons for this is often that much port logic is shared between ports so can’t be disabled in a given port without disabling lots of functions necessary for the other active ports.

Unfortunately, with traditional switch approaches this means there is only minimal—if any—power savings when a port is disabled and not connected. The Adaptive-Power Silicon offerings from HP Networking disable many port-specific logic functions when single ports are disabled.

Adaptive-Power Architecture, inside V2 zl modules platforms

We’ve already discussed the benefits of HP Networking’s Adaptive-Power silicon and its significant features are discussed in all versions of the V2 zl modules—from 10/100 MbE to 10 GbE module configurations—all silicon versions and modes used in the platforms uses Adaptive-Power silicon.

The other significant platform Adaptive-Power features in the platforms are described in the next sections.

Module-level Adaptive-Power voltage controls

Each Adaptive-Power Architecture has local power conversion that can make:

- Micro voltage adjustments to tune silicon power rails based on ASIC process speed to decrease power loss due to silicon process variation
- Macro voltage adjustments based on IO application requirements (lower voltages for 1 GbE port vs. 10 GbE port for example)
With these module level voltage controls, there are some substantial power savings. Micro voltage adjustment allows tuning the dominant core power rail power supplies to least required levels and saves more than 15 percent of module power for fast silicon die. Macro voltage adjustments allow savings based on module application—savings for 1 GbE module applications is about 5 percent of ASIC power.

**Individual module power and voltage telemetry**

The ability to provide a more intelligent understanding of network element power consumption and what changes to network configuration and topology would reduce power consumption depends on network element power telemetry.

In order to provide a detailed understanding of power consumption at any given time during operation, each V2 zl module has telemetry circuitry providing real-time power monitoring on each of 6-14 voltage rails.

Future releases of management tools such as HP Professional Management center (PMC) and Intelligent Management center (IMC) will be able to incorporate telemetry data to provide detailed network power consumption reports. Management tools could also be evolved to optimize power consumption via PoE, EEE configuration, and network port assignments.

**Adaptive power management using PMC+**

HP Networking PCM+ is a Windows®-based network management application designed to deliver detailed management of HP Networking devices. HP Networking PCM+ is designed to provide cost-effective management, enhanced security features, and extensibility for small, medium-sized, and large networks, including remote sites. It offers analysis of network traffic, advanced virtual LAN (VLAN) management, and centralized policy, configuration management, and supports management of HP Networking products.

**PoE+ Power Controls**

One often overlooked area for savings in terms of power for network devices, especially Power over-Ethernet (PoE) devices, is that many PoE devices can be powered off when not in use. Just as you would turn off the lights or coffee pots in your office when you leave at night, or over the weekend, consider a bank of PoE devices that are only used during business hours.

HP Networking platforms have had configurable power saving controls that can disable PoE+ power to different loads based on policy. HP PMC utility, PMC+ has the capability to create schedule-driven policies that can trigger at specified times on an hourly,
To enable the power saving policy on the HP networking switch, PCM Plus can be configured to schedule a turn off time and a turn on time for specific POE-connected devices. This can be done by product groups or custom groups (groups of devices defined by the customer). PoE+ ports can be disabled based on time of day, day of week, etc. With PoE+ ports consuming up to 30W/port, the network power savings with smart PoE+ power controls is substantial.

Table 1 illustrates an example of energy usage with and without PMC+ PoE scripting. Assume a business has 1,000 IP phones, each drawing 5 watts when idle. If these phones are left on all of the time, 168 hours per week, even at idle they will consume 43,680 kilowatt-hour(s) per year. But if you use PCM+ to disable PoE power to those phones after working hours and on weekends, they draw power for only 9 hours a day, for a total of 45 hours per week. Their annual power consumption is reduced to 11,700 kilowatt-hour(s). Disabling PoE power to the phones in this example saves some 31,980 kilowatt-hour(s) of electricity, reduces the carbon footprint of the business, and provides significant cost reductions.

Similar to POE power scheduling, PMC+ can be scheduled to turn off LEDs during off business hours when no one is around to look at the LEDs and turn off power to specific slots within a chassis when not being used.

Energy Efficient Ethernet Port Power Controls

Energy Efficient Ethernet (EEE) is a physical layer standard that reduces network power consumption by disabling transmit logic when there are idle periods. The key to achieving the benefits of EEE is when port traffic is underutilized. Industry sources believe that average traffic intensity is less than 10 percent of peak traffic loads. EEE works right out of the box, and does not need any management software that requires additional overhead or monitoring. When two EEE devices are connected the consumer starts realizing the energy savings right away.

Depending on traffic patterns and idle periods, power savings can be fairly substantial because PHY power consumption is second only to Packet Processing silicon (refer to Figure 1). And because EEE is a inter-network versus internal power saving mechanisms, power savings is achieved on both the receiver and the transmitter switch. The periods of power saving enablement are controlled by a standard link protocol negotiated on both sides of a link. Thus, the energy savings are real time and can be realized across the connected network devices and is based on industry standards.

HP Networking was one of the lead contributors to the EEE standard and is committed to deploying EEE enabled switching equipment as widely as possible. EEE fundamentally aligns to a primary goal of the Adaptive-Power Architecture—power should scale with utilization—and the V2 zl modules platforms are the first EEE enabled switches in the networking industry.

Independent power measurement

HP commissioned a study by Tolly group on the performance, power efficiency and TCO of the E8200 and the E5400 series products in Nov 2010. Tolly group after a comprehensive study concluded that:

“The PoE+ enabled E8212 consumed 369W on average; while the PoE enabled Catalyst 4506 consumed 468W. This represents a power savings of ~21 percent with the E8212, resulting in about $360 savings in electric and cooling costs per switch over a 3-year period compared to an identically configured Catalyst 4506. Similarly, the E5412 consumed 332W versus 447W consumed by a four-switch stack of Catalyst 3750-X switches. This represents almost ~26 percent power savings and $420 in electric and cooling cost savings with a E5412 compared to a stack of Catalyst 3750-X over a 3-year period. Finally, a 48-port E5406 chassis consumed 5 percent less power than a comparable Catalyst 3750-X fixed port switch.”

HP Networking’s hard work designing a purpose built ASIC from the ground up paid off, delivering substantial savings for the enterprise.

“Over a period of 3 years, the E8212 cost $222 per Gbps of throughput delivered, compared to $2,119 for the Cisco Catalyst 4506. Put in another way, the E8212 consumed 2.3 watts per Gbps of throughput

<table>
<thead>
<tr>
<th>No. of IP phones</th>
<th>Watts/Phone at Idle</th>
<th>Hrs/week</th>
<th>Energy consumed/year</th>
<th>Energy cost/year (@ US$0.11/kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PoE off time</td>
<td>1000</td>
<td>5</td>
<td>168</td>
<td>43,680 kW</td>
</tr>
<tr>
<td>PoE on time</td>
<td>1000</td>
<td>5</td>
<td>45</td>
<td>11,700 kW</td>
</tr>
<tr>
<td>Total savings by efficient power management</td>
<td></td>
<td></td>
<td>31,980 kW</td>
<td>$3517</td>
</tr>
</tbody>
</table>

delivered, while the Catalyst 4506 consumed 9x more power at 20.8 watts per Gbps. Similarly, the E5412 cost $139 per Gbps compared to $1,177 per Gbps for the 4-switch stack of the Catalyst 3750-X over a 3-year period. In other words, the E5412 consumed 2 watts per Gbps of throughput delivered, while the Catalyst 3750-X consumed 4x more power at 8 watts per Gbps over a 3-year deployment period.

Summary

When customers choose HP Networking equipment, they can be sure that through our research and innovation, their equipment will have the best-in-class energy efficiency and configurability. By enabling EEE, HP Networking has adopted standards that enable simple plug and play power savings without the need for cumbersome management software or licenses. With the Adaptive power management architecture, best in class design principles were implemented to enable power saving at the ASIC, module and LAN deployment levels.

Independent power measurement and analysis has proved that these innovations actually deliver value in realizable dollars to the consumer and do provide continual incremental savings over the life of the networking deployment.
### Table 2: Power Savings when using HP Networking E8200/E5400 switches (Tolly Report)

#### Power utilization efficiency (Watts per Gbps of throughput delivered)

<table>
<thead>
<tr>
<th>Solution under test</th>
<th>Solution port configuration</th>
<th>Projected 3-year power and cooling cost* (US$)</th>
<th>Power and cooling costs in a 5,000-port deployment</th>
<th>Additional power and cooling cost over HP E5412</th>
<th>Additional power and cooling cost over HP E8212</th>
</tr>
</thead>
<tbody>
<tr>
<td>HP E8212</td>
<td>144 GbE PoE+ports, 2x 10 GbE ports in a pair</td>
<td>$1,350</td>
<td>$47,250.35</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HP E5412</td>
<td>144 GbE PoE+ports, 2x 10 GbE ports in a pair</td>
<td>$1,266</td>
<td>$44,306.50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cisco Catalyst 3750-X</td>
<td>Stack of four switches with 72 PoE and 72 non-PoE GbE ports, 2x 10 GbE ports: (WS-C3750X-24-T-S, WS-C3750X-24-P-S, WS-C3750X-48-P-S and WS-C3750X-48-T-S)</td>
<td>$1,634</td>
<td>$57,188.60</td>
<td>$12,882.10</td>
<td>$9,938.25</td>
</tr>
<tr>
<td>Cisco Catalyst 4506</td>
<td>144 GbE PoE ports in Snake Config, 2x 10 GbE ports in a pair, two PSUs (one power input to each)</td>
<td>$1,710</td>
<td>$59,837.05</td>
<td>$15,530.55</td>
<td>$12,586.70</td>
</tr>
</tbody>
</table>

* Formula used = (W_{ATIS}/1000)*(3*365*24)*(0.1046)*(1.33), where
  - W_{ATIS} = ATIS weighted average power in Watts
  - 3*365*24 = 3 years @ 365 days/yr @ 24 hrs/day
  - 0.1046 = U.S. Average retail cost (in US$) of commercial grade power as of June 2010 as per Dept. of Energy Electric Power Monthly (http://www.eia.doe.gov/cneaf/electricity/epm/table5_6_a.html)
  - 1.33 = Factor to account for power costs plus cooling costs @ 33% of power costs.

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Source: Tolly, September 2010
## Table 3: Weighted Average Power Consumption when using HP Networking E8200/E5400 switches (Tolly Report)

**Weighted power consumption of Access Switches with 48 PoE+/PoE GbE ports as per ATIS recommendations**

<table>
<thead>
<tr>
<th>Switch Model</th>
<th>Power Consumption (Watts)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HP E5406</td>
<td>126</td>
</tr>
<tr>
<td>Cisco Catalyst 3750-X in a 4-Switch Stack</td>
<td>132</td>
</tr>
</tbody>
</table>

**Weighted power consumption of Access Switches with up to 144 PoE/PoE+ GbE ports and two 10 GbE ports as per ATIS recommendations**

<table>
<thead>
<tr>
<th>Switch Model</th>
<th>Power Consumption (Watts)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HP E8212</td>
<td>369</td>
</tr>
<tr>
<td>HP E5412</td>
<td>346</td>
</tr>
<tr>
<td>Cisco Catalyst 3750-X in a 4-Switch Stack</td>
<td>447</td>
</tr>
<tr>
<td>Cisco Catalyst 4506</td>
<td>468</td>
</tr>
</tbody>
</table>

Source: Tolly, September 2010

ATIS-weighted Power ($W_{ATIS}$) = 0.1*(Power draw @ 0% load) + 0.8*(Power draw @ 10% load) + 0.1*(Power draw @ 100% load), as defined in ATIS standards ATIS-0600015.03.2009 and ATIS-0600015.2009

Note: Test traffic consisted of an Internet Mix (iMIX) distribution of TCP packet sizes: 57% at 64-bytes, 7% at 570-bytes, 16% at 594-bytes and 20% at 1,518-bytes