

# GreenTouch Open Forum November 2011



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IEEE-SA Standards Board, Corporate Advisory Group Member

IEEE Standards Education Committee (SEC) Member

# Agenda



- Overview of Data Center Trends
- Overview of Networking Energy Saving Trends
  - Introduction and Overview of Energy Efficient Ethernet
  - EEN: Innovating on top of EEE
  - Example Complementary Saving Technologies for Networking
- Overview of Industry Initiatives Related to Energy Savings
- Final Thoughts
- Additional Reading Material and References

# Evolving Computing Models: *Data Center*

1960s:

10K+ Servers



Blade switch or  
top-of-rack pizza box

Uplinks:  
10/40GE

100 Tbps Multi-chassis "Fabric"

Mesh:  
40/100GE

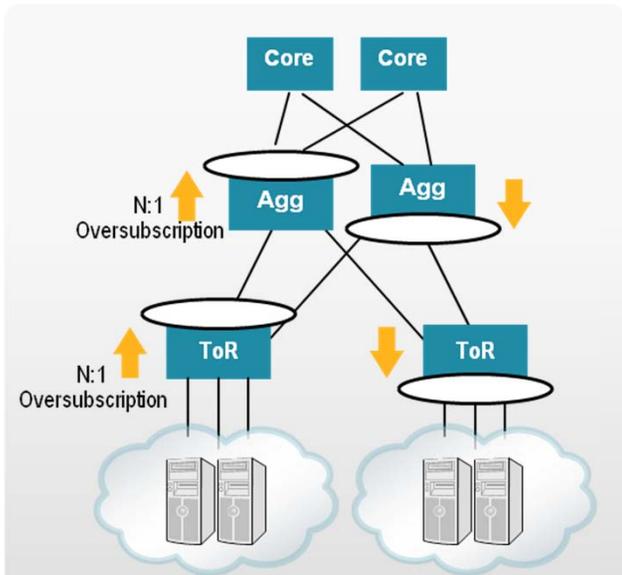


Aggregation  
Switch Layer

Core  
Switch Layer

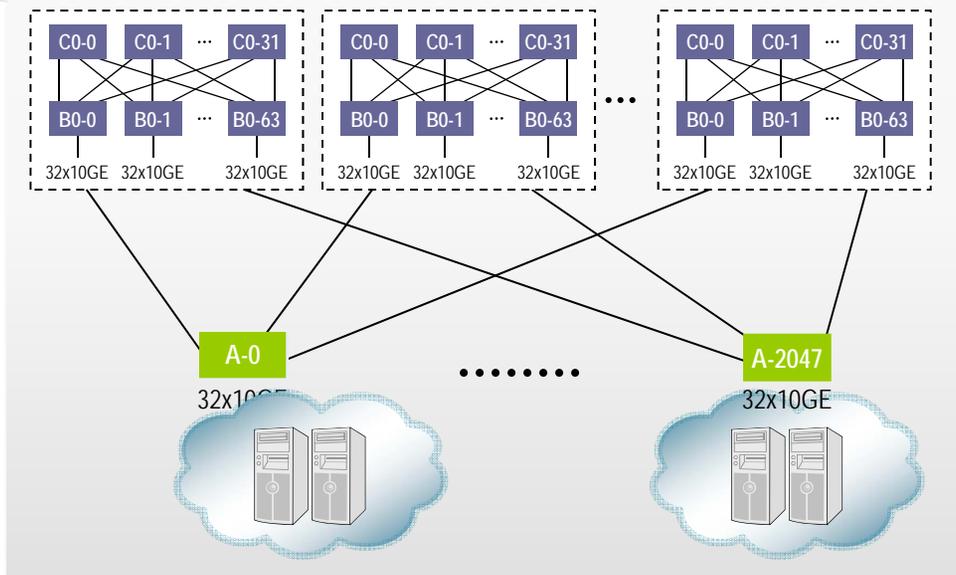


# Data Center Fabric Alternatives



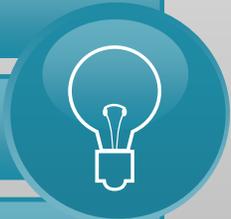
Designed for north-south traffic and N-tiered data center

- Physical Static Servers
- Tiers of Servers
- Single Tenant Data Center



Modular, horizontal scaling, full cross-sectional bandwidth with no locality for apps or storage

- Virtual Machines and Mobility
- Any Application on Any Server
- Multi-tenant Data Centers in Clouds



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# Motivation – A Macro View

- All electronics
  - IT equipment, consumer electronics, telephony
    - Residential, commercial, industrial
  - At least 250 TWh/year
  - \$20 billion/year
    - Based on .08\$/kWh; rates are rising
  - Over 180 million tons of CO<sub>2</sub> per year
    - Roughly equivalent to 35 million cars!
- IT equipment about half of this
  - PCs, displays, printers, servers, network equipment

Numbers represent  
U.S. only

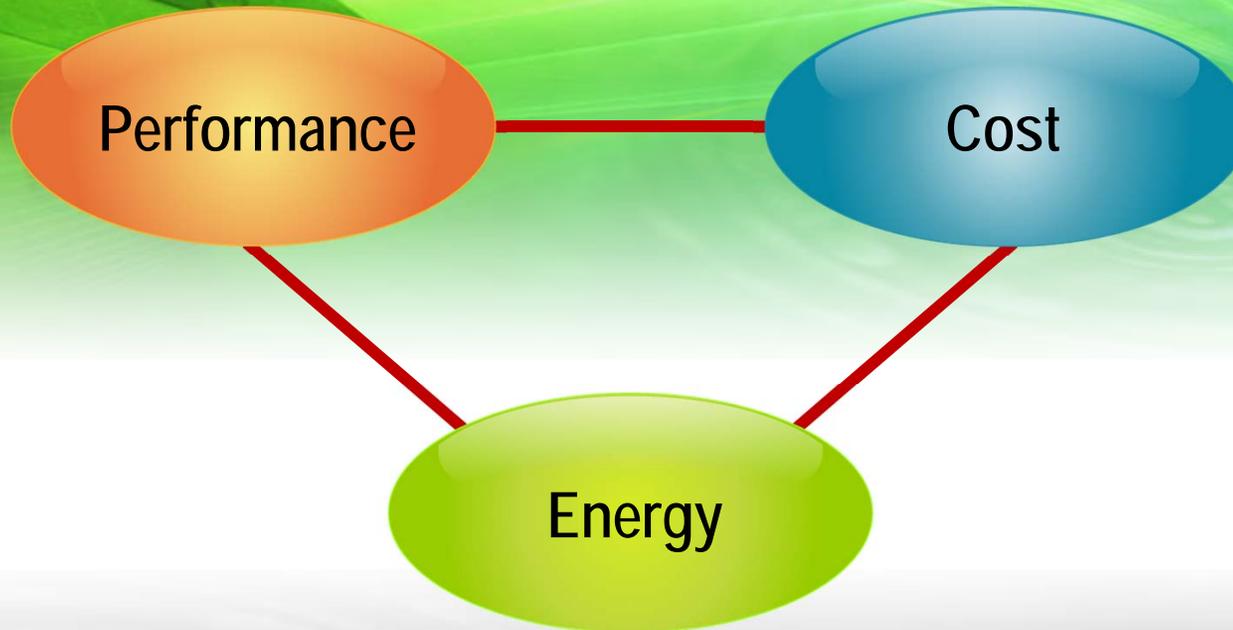
One central baseload  
power plant  
(about 7 TWh/yr)

PCs etc. are digitally networked now — *Consumer Electronics (CE)* will be soon

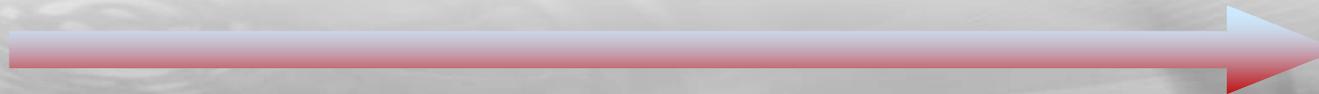


# Evolution in Network Architecture

Traditional Networks



Next Generation Networks



Next generation *end-to-end* networks that expand *performance* and features in a *cost-* and *energy-*competitive framework

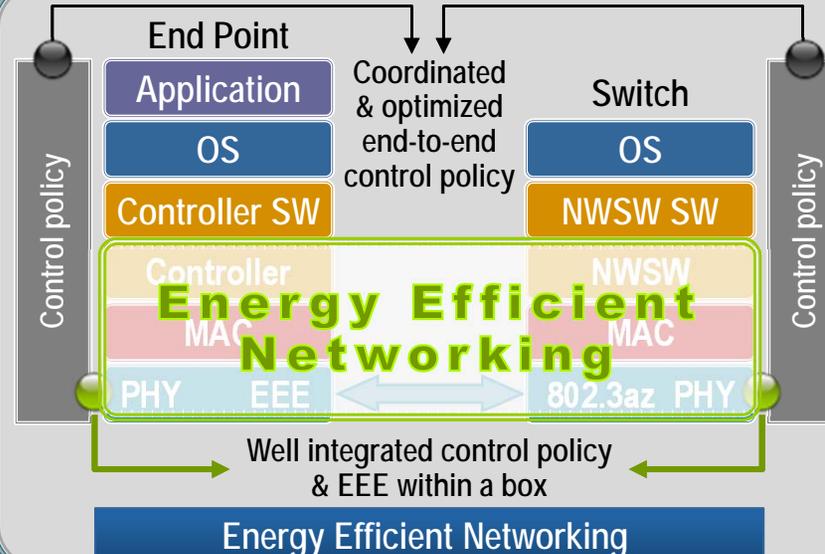
# Delivering on Energy Efficiency in Data Centers



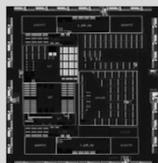
IEEE Std.  
802.3az-2010



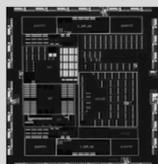
Energy Efficient Ethernet



Energy Efficient Networking



65nm  
2008



40nm  
2010

Process & Integration Efficiencies



Saves 20W-60W per port!

Stateless & Stateful Offloads

# OVERVIEW OF EEE

# Motivation – A Link Perspective



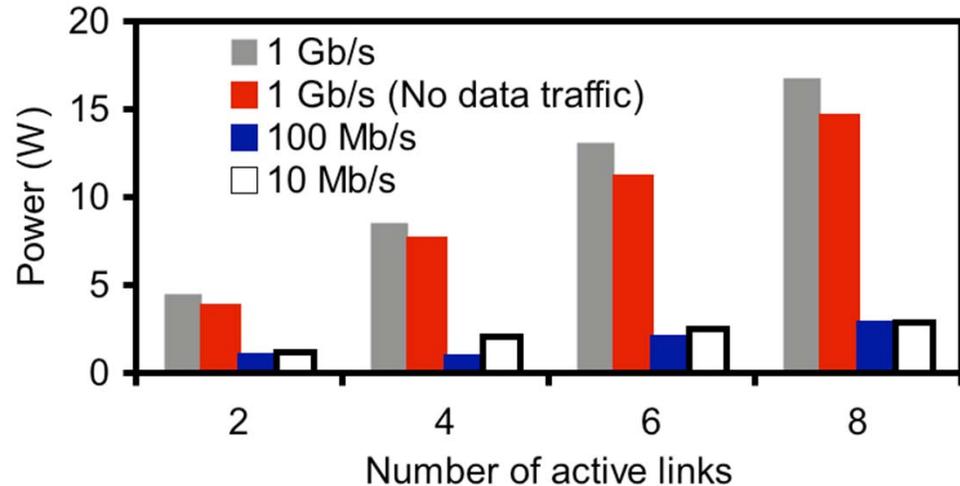
- **High port count triple speed switches**

- Linear relationship of power consumption to number of active links
- Aggregate savings attractive in putting inactive links in LPI

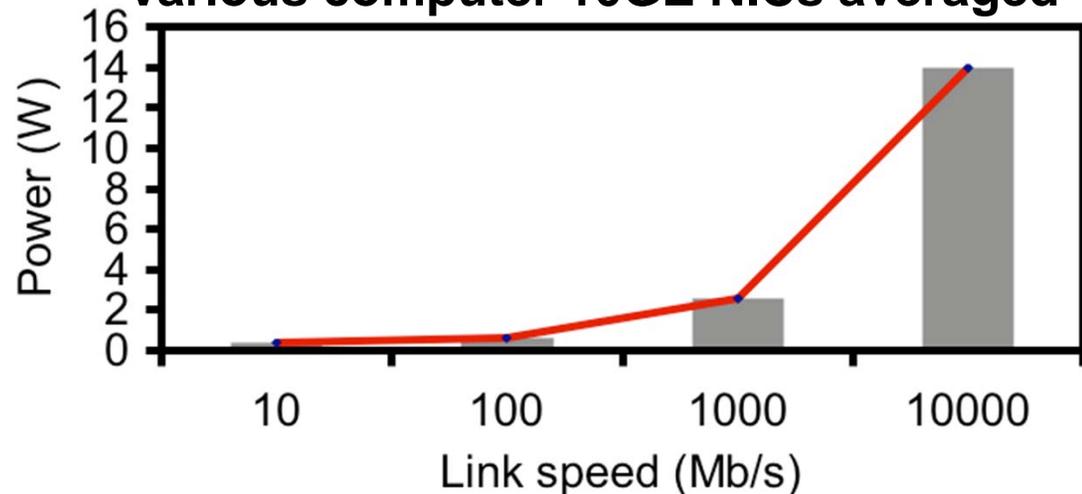
- **Low port count 10G systems**

- Idle power savings on a single link attractive

Typical switch with 24 ports 10/100/1000 Mb/s



Various computer 10GE NICs averaged

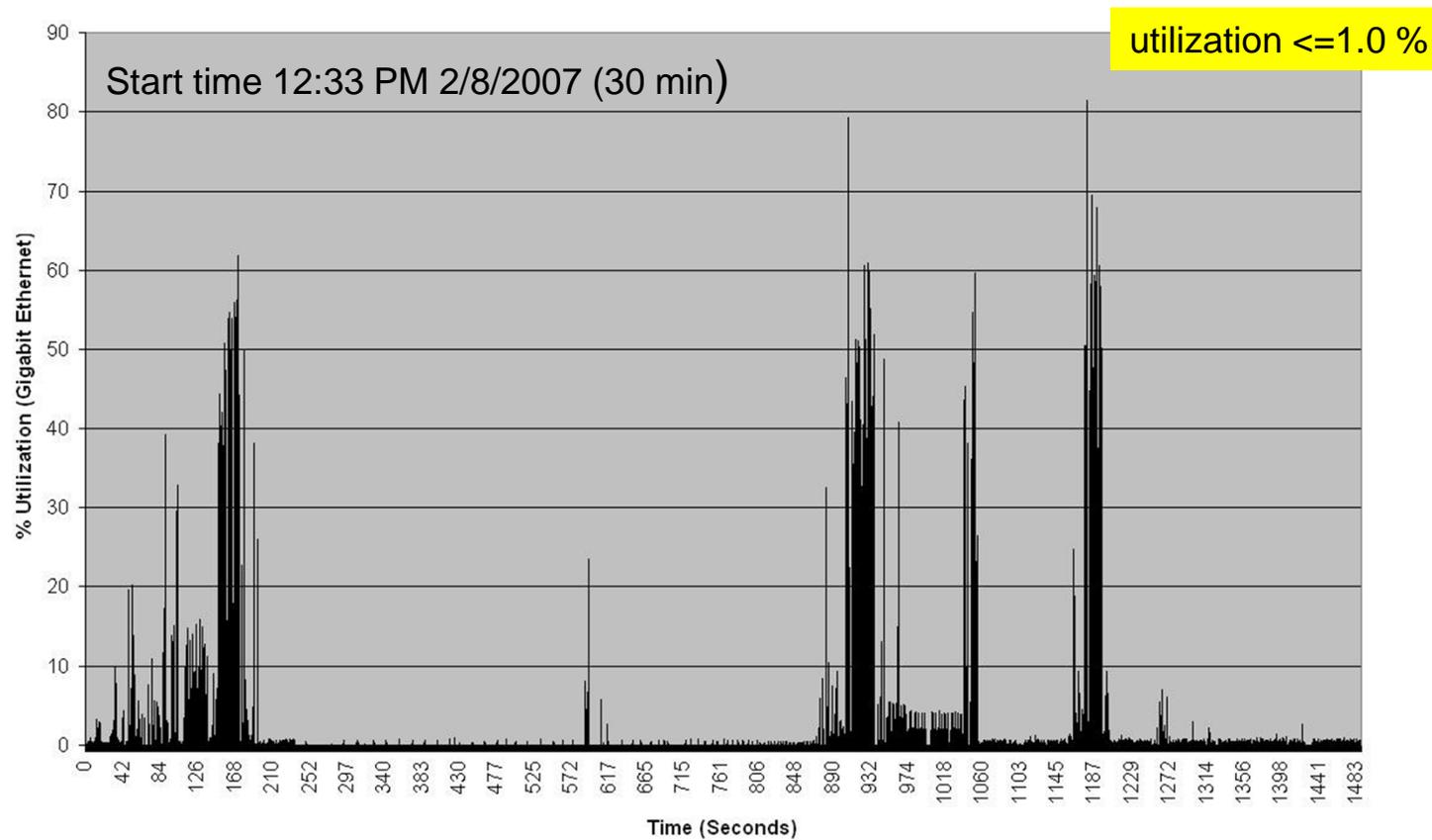


*Results from 1<sup>st</sup> order (rough) measurements – all incremental AC power  
Power numbers based on public IEEE presentation in 2006. Not state of the art*

# Ethernet Traffic Profiles

- Snapshot of a File Server with 1 Gb Ethernet link
  - Shows time versus utilization (trace from LBNL)

File Server Bandwidth Utilization Profile



# Energy Efficient Ethernet (EEE) Overview



- EEE specifies protocols that enable energy savings during periods of low utilization.

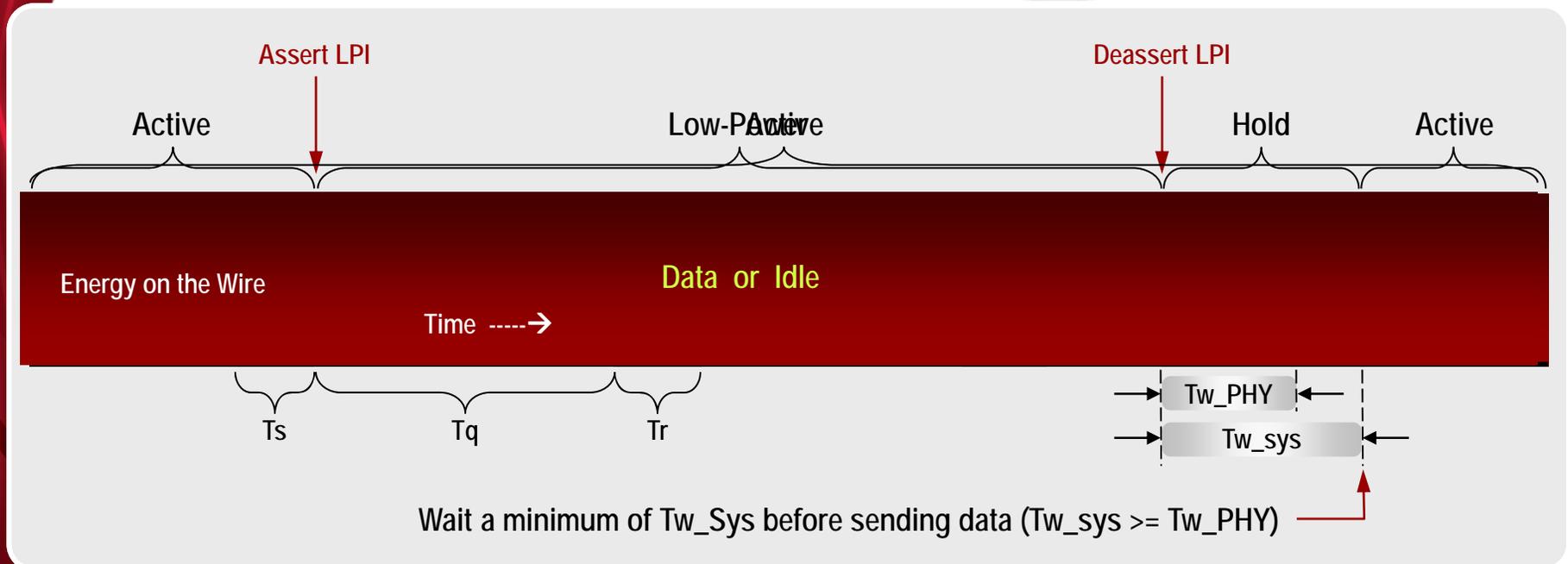
- IEEE Std 802.3az™-2010 (Amendment to IEEE Std 802.3-2008) PHYs:

- 100BASE-TX
  - 1000BASE-T
  - 10GBASE-T
  - 10GBASE-KR
  - 10GBASE-KX4.
- } Twisted-Pair  
Copper PHYs



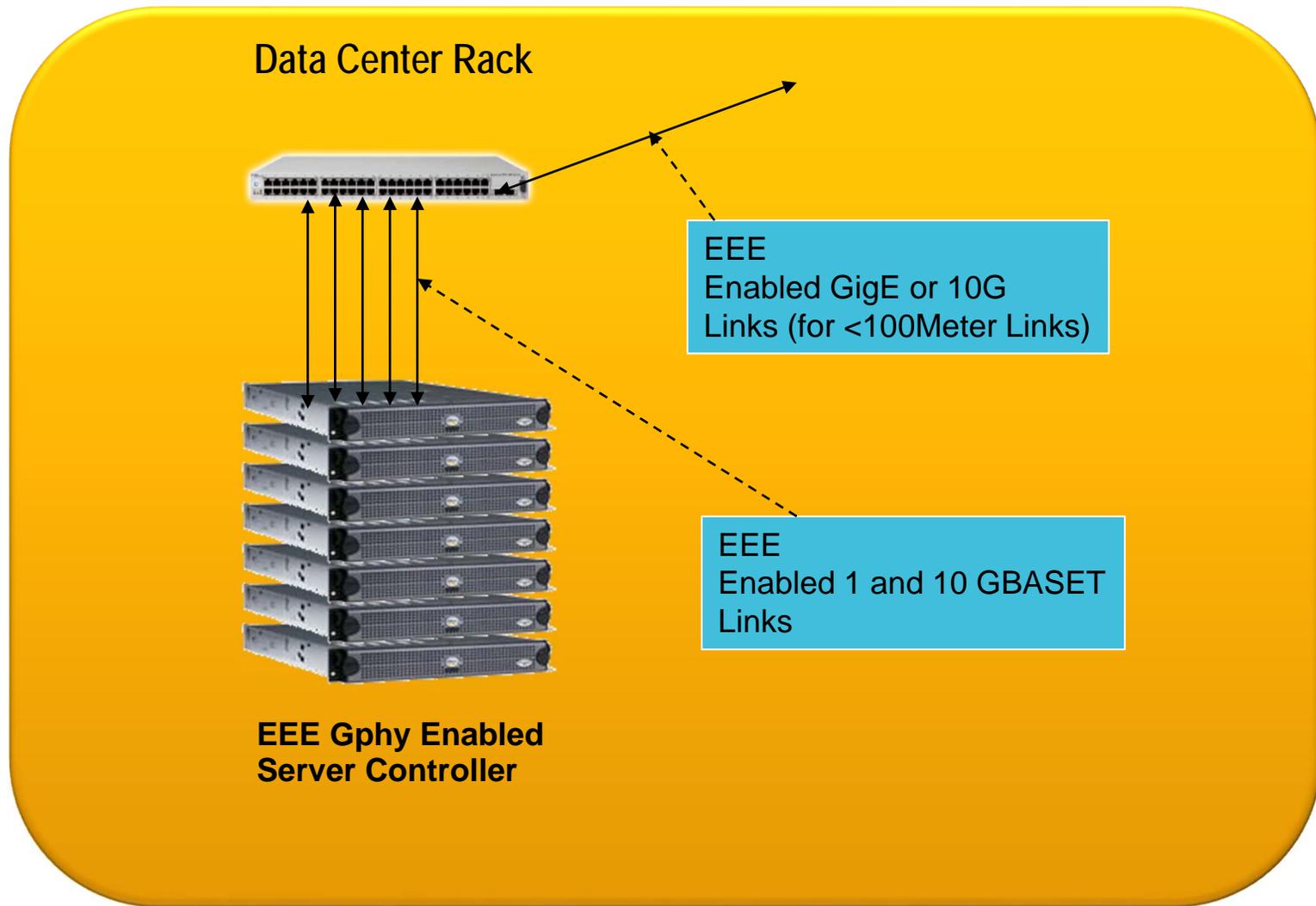
- EEE uses Low-Power IDLE (LPI) to signal transitions to and from lower levels of energy consumption.

# EEE Low Power Idle Overview



- Low Power Idle (LPI) – PHY powers down during idle periods
- During power-down, maintain coefficients and synchronization to allow rapid return to Active state
- Wake times for the respective twisted-pair PHYs
  - 100BASE-TX:  $T_{w\_PHY} \leq 30$  usec
  - 1000BASE-T:  $T_{w\_PHY} \leq 16.5$  usec
  - 10GBASE-T:  $T_{w\_PHY} < \sim 8$  usec (2 modes)

# EEE Application – Data Center



# INNOVATING ON TOP OF EEE

# Framework



- **Savings: Additional savings in and beyond the physical layer**
  - Enhancements and implementation of the PHY layer
  - Savings above the PHY layer
  - Complementary savings technologies
- **Performance: It is important to save energy *without compromising performance*. An example of this is the technologies behind the control policy.**
- **Time to Market: Accelerating adoption to increase the overall savings is key and innovation here can also help**

# Energy Savings Framework: Where does the Energy Savings Come from?

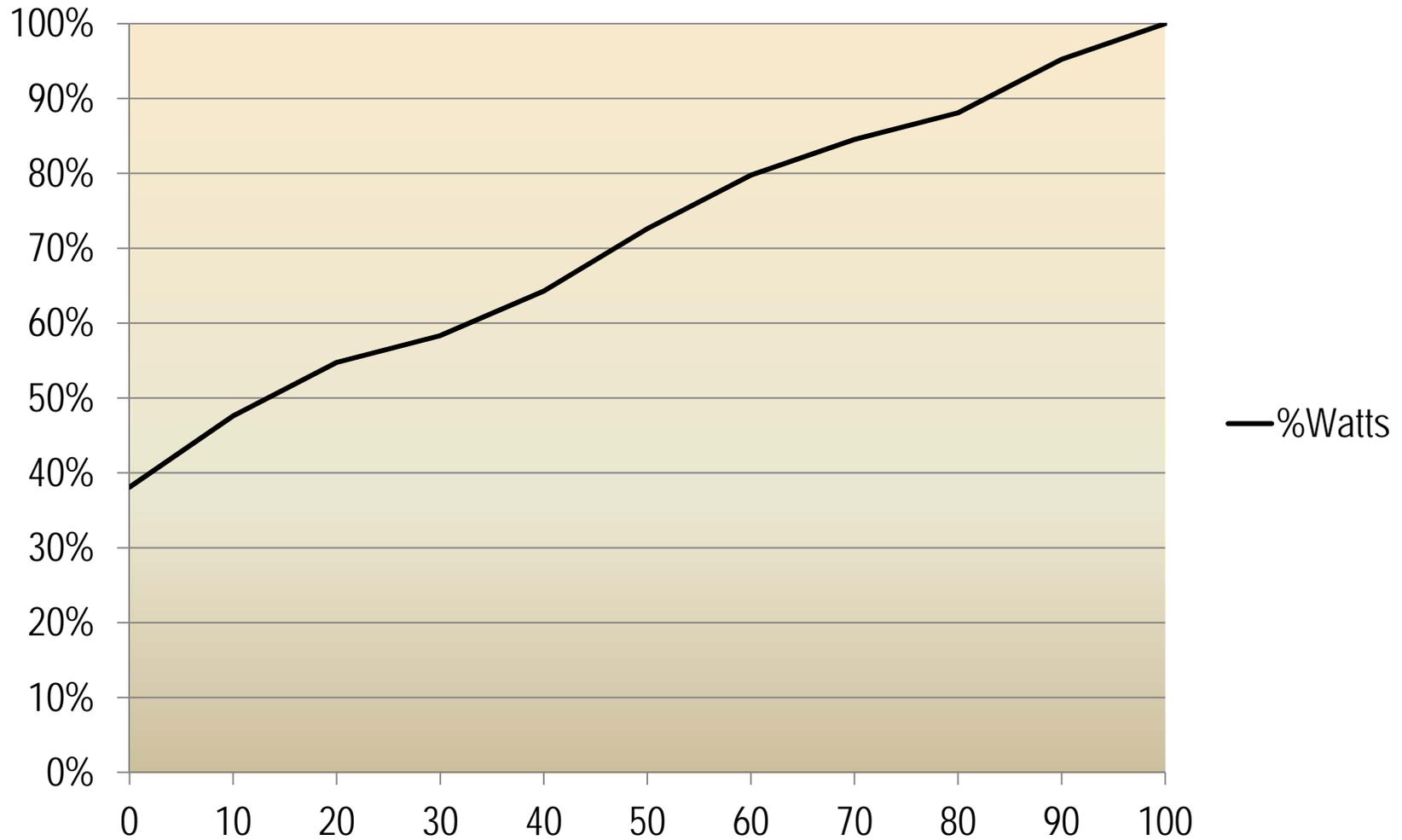


- Energy consumption is overall usage over a period of time T
  - Think of your monthly electricity bill
- Mathematically
$$E_T = [P_{\text{active}} * T_{\text{active}}] + [P_{\text{idle}} * T_{\text{idle}}]; \quad \text{where } T = T_{\text{active}} + T_{\text{idle}}$$
- Savings (Min  $E_T$ ) can be achieved in any combination of 3 ways
  - Minimize  $P_{\text{active}}$ 
    - Example *innovation* green modes, lower energy process node, clock frequency management, energy efficient memories
  - Minimize  $P_{\text{idle}}$ 
    - Power down *additional* subsystems
    - Support *Layer 2* for additional savings across the link
  - Maximize  $T_{\text{idle}}$ 
    - *Comprehensive* control policy

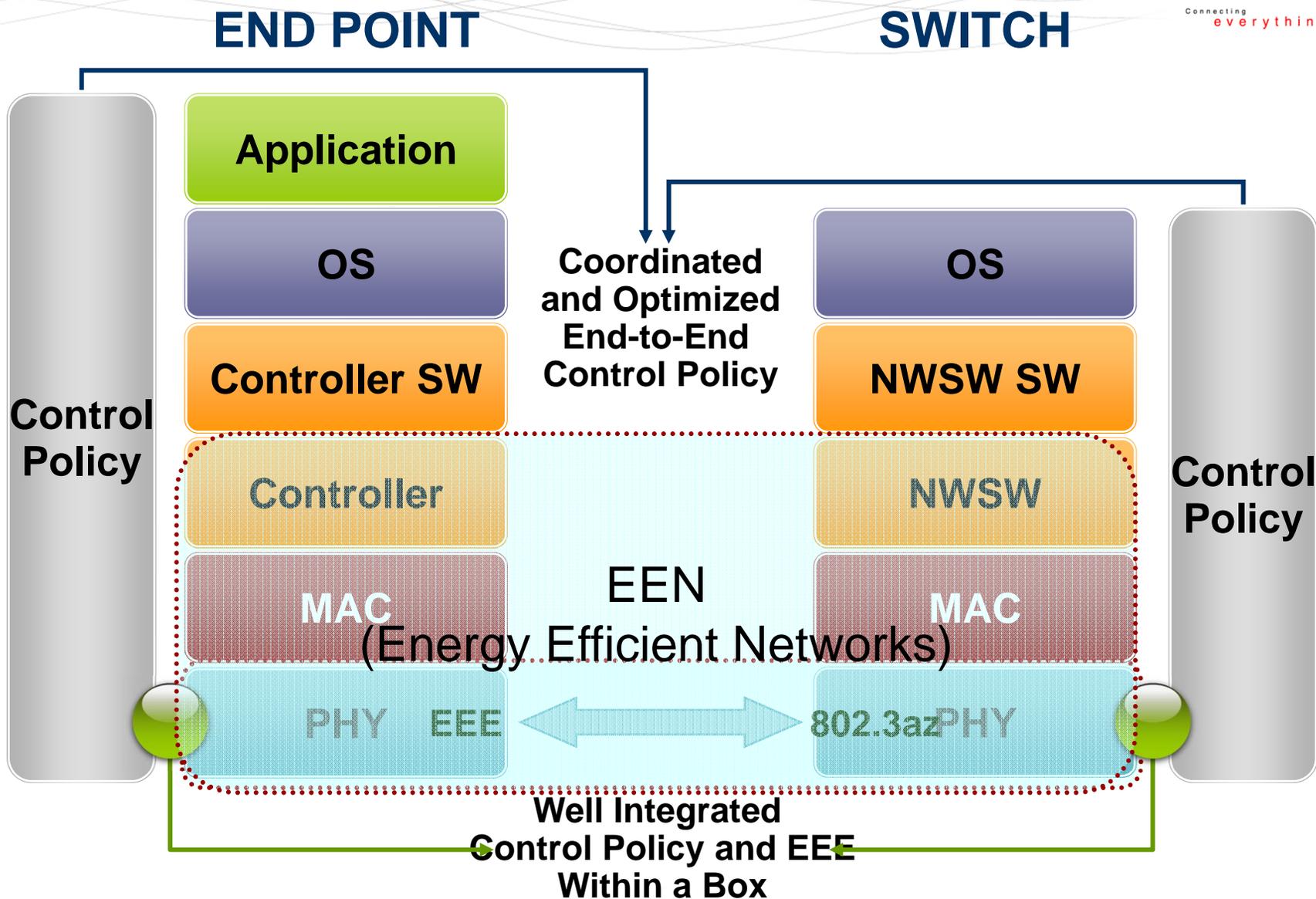
# Example Power vs. Traffic Duty Cycle



## Example BASE-T Power Vs Traffic %



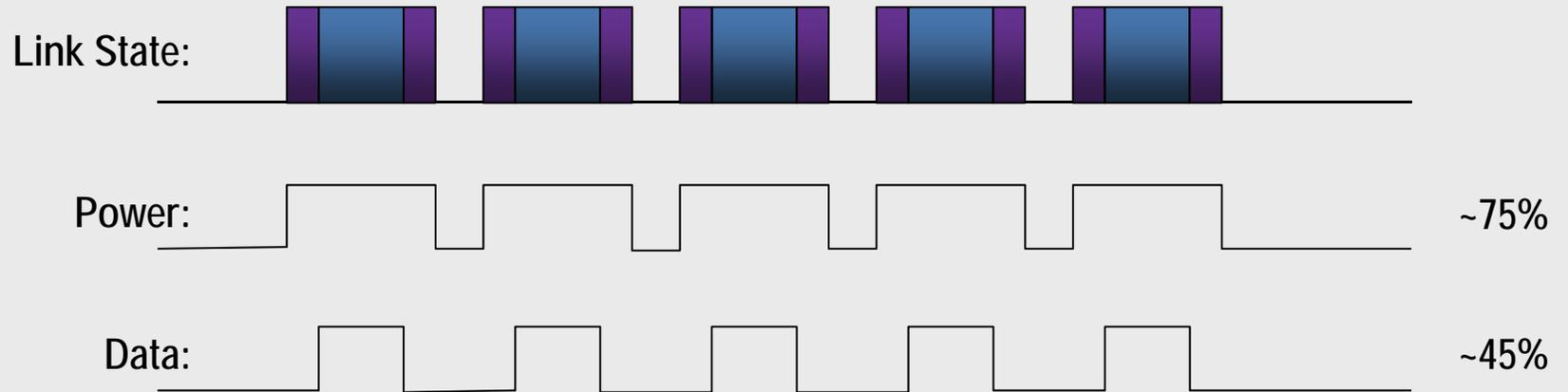
# End-to-End Savings



# In-System Control Policy



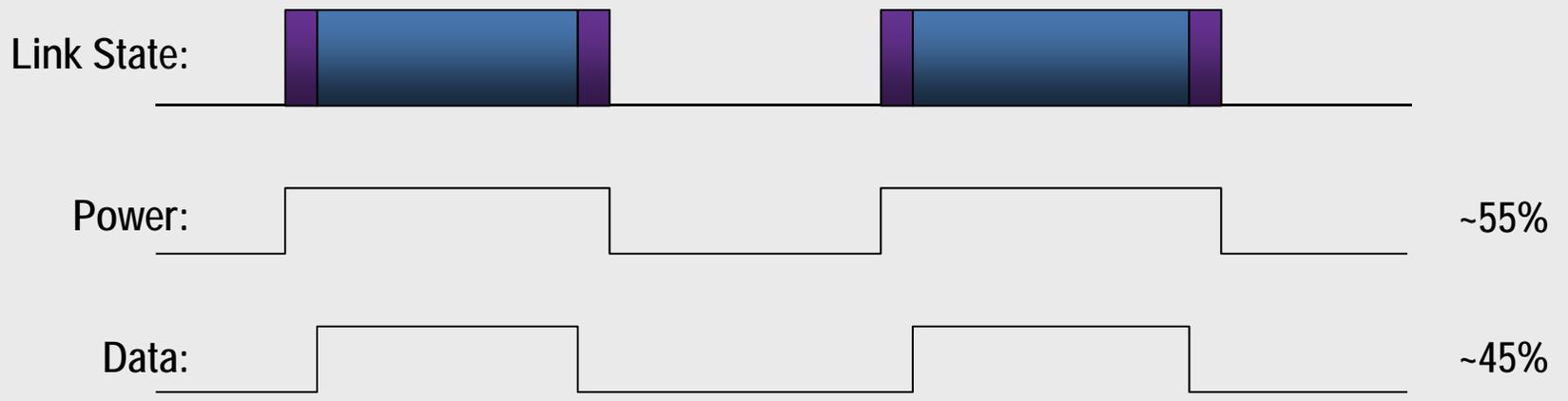
## No Control Policy



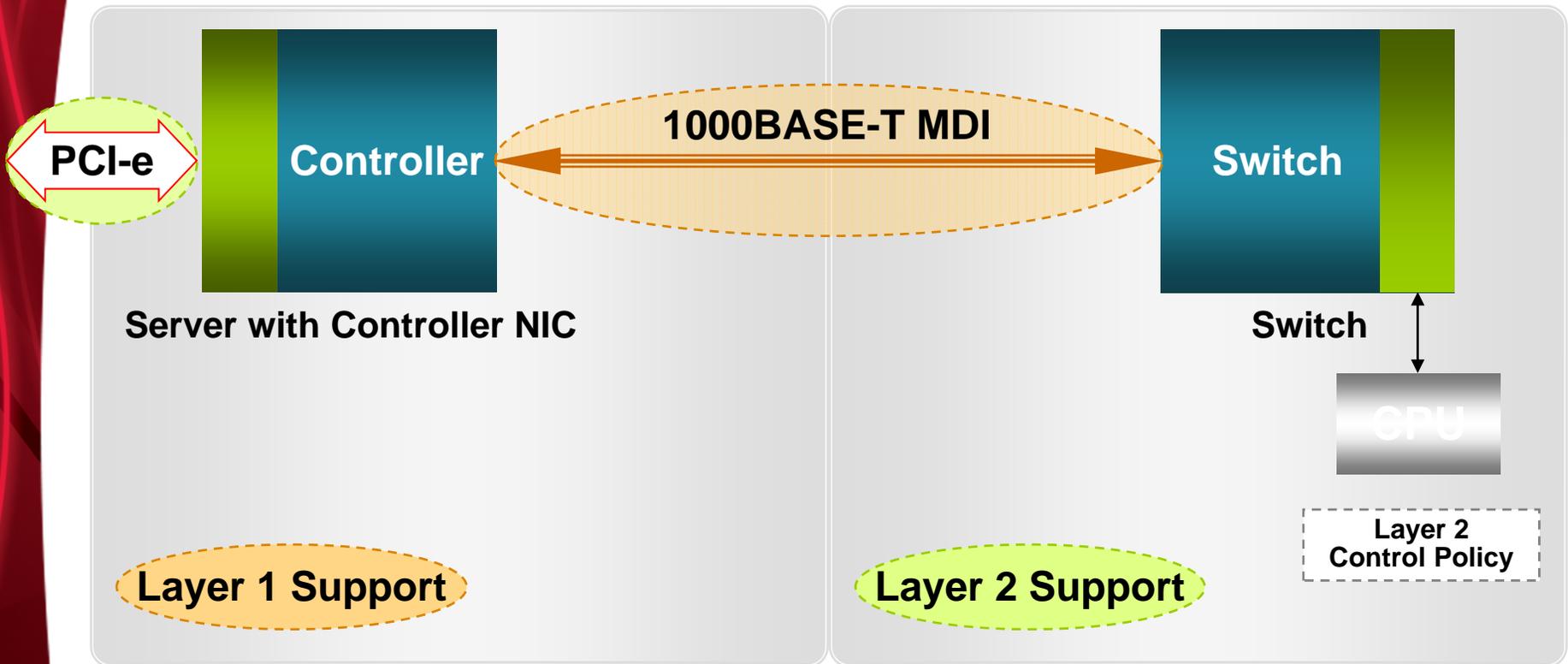
# In-System Control Policy



## With Broadcom EEE Control Policy

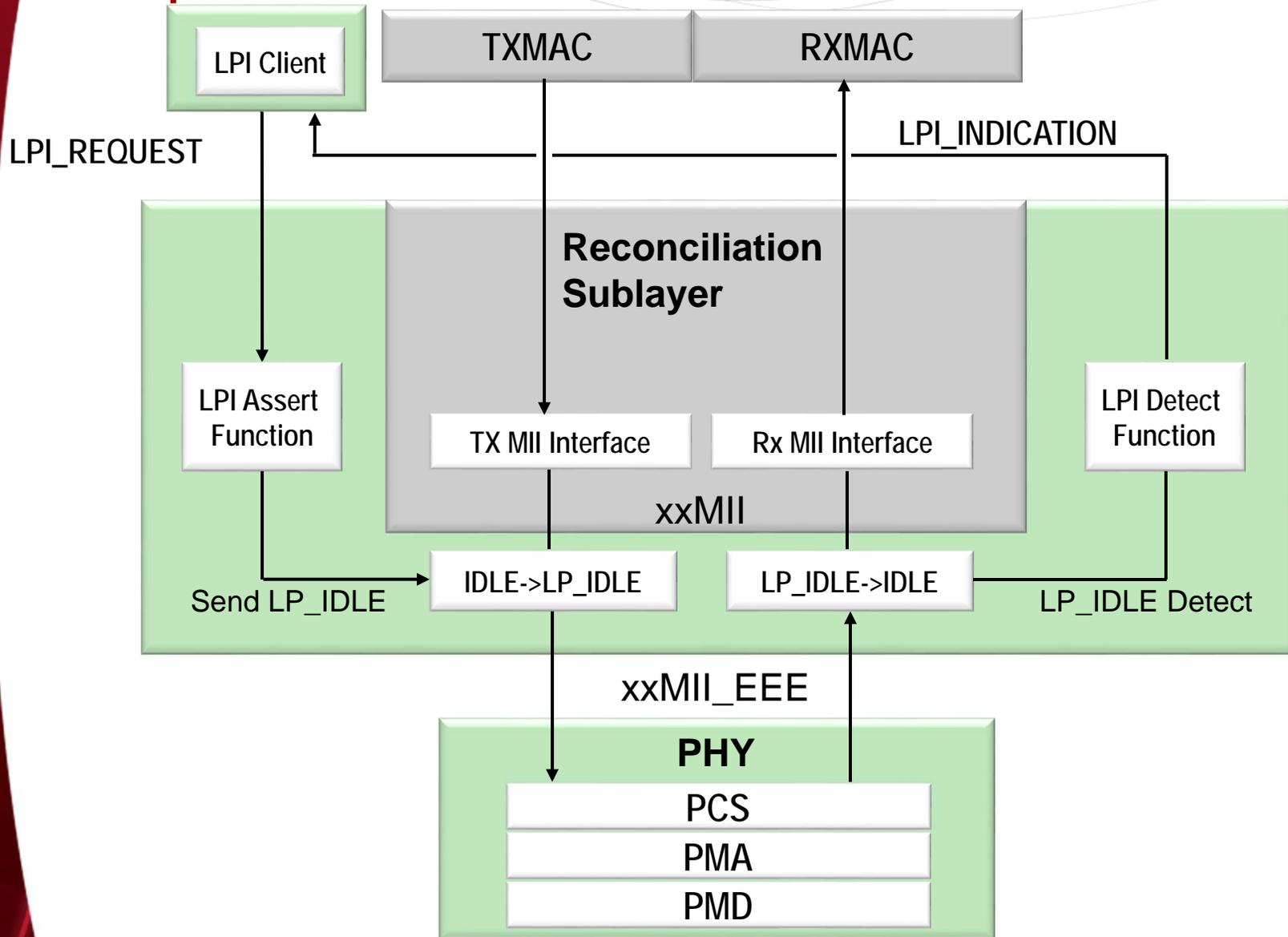


# EEE Enhanced Layer 2 Operations

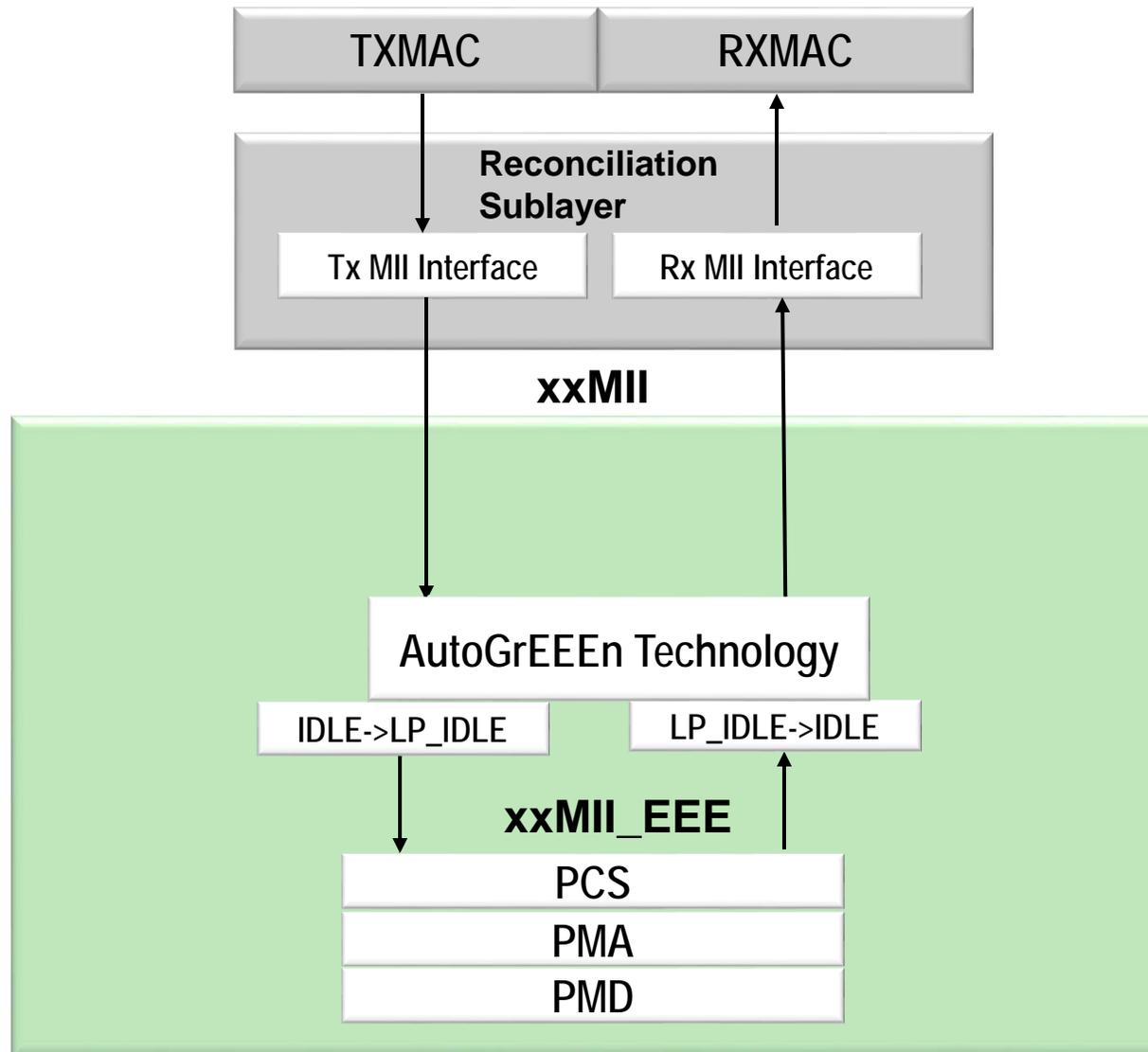


- Opportunity to save additional power within a box (link partner)
  - *Additional circuits beyond the PHY can be turned off*
  - Also applies to *cascaded interfaces (e.g. XAUI / 10GBASE-T / KR / XFI)*
- Additional RX wakeup time negotiated using 802.3az's Layer 2 — *Standards based*

# EEE LPI Layer Reference Diagram: Requires New MAC and PHY Silicon



# AutoGrEEEn™ LPI Reference Layer Diagram: Reuses Legacy MAC. Time-to-market innovation

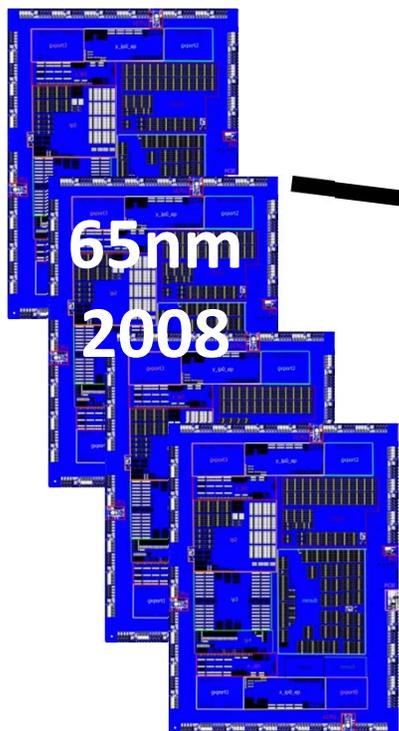


# COMPLEMENTARY SAVING TECHNOLOGIES

# Power Efficiency in Process Evolution

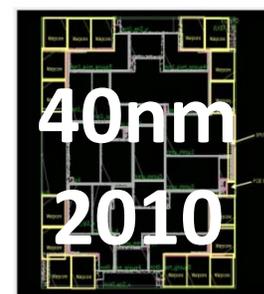


Multi-die Switch Fabric



Higher power with external I/O

Single die high BW Fabric

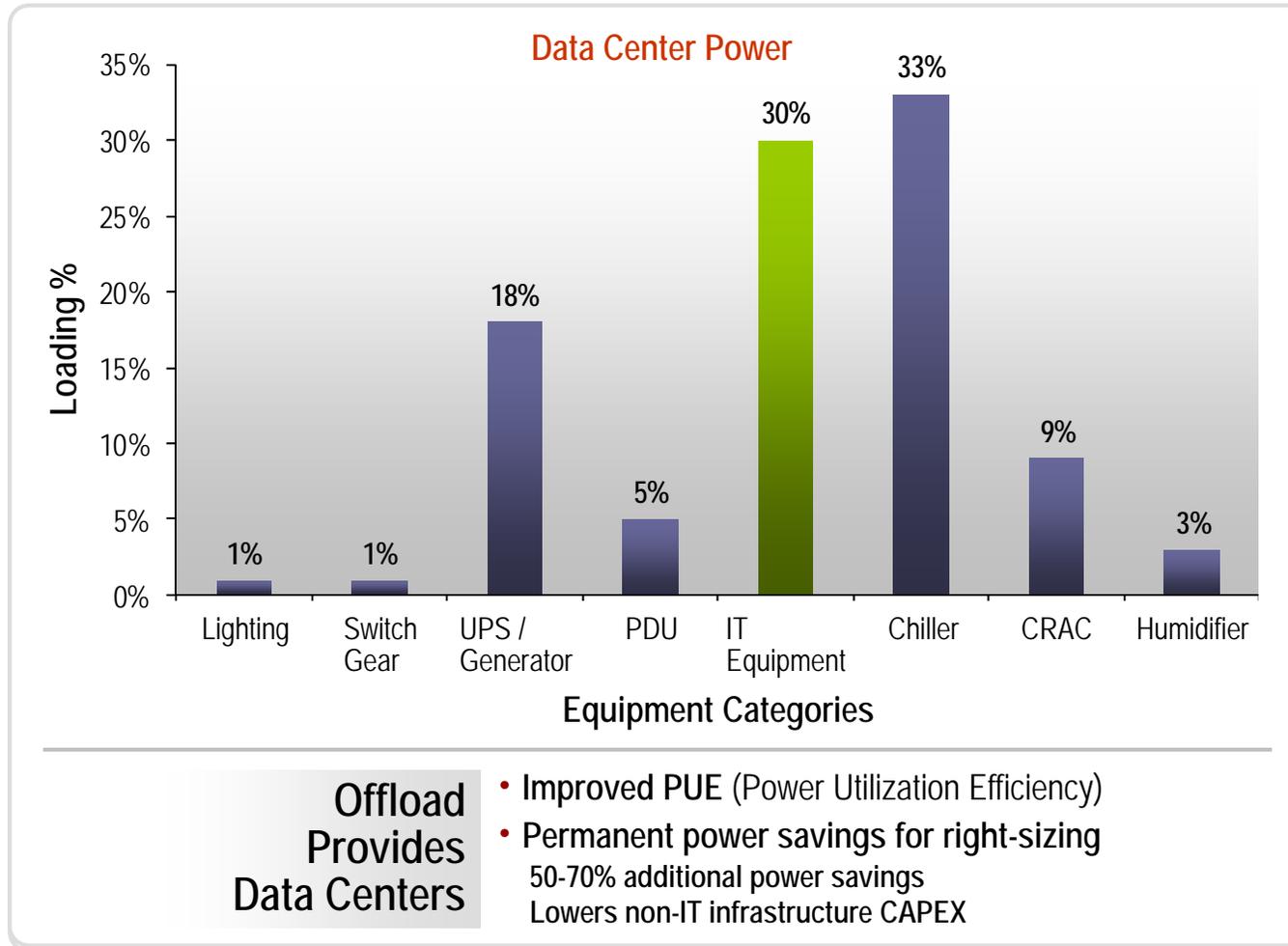


Lower power process node with internal I/O

*Broadcom is leading the way to the latest process nodes*

# Improve Data Center Power Efficiency

*Offload Significantly Improves Performance / Watt*



**Broadcom hardware offload saves per port of power while delivering higher throughput**

# Server Side Energy Efficiency

120W per server

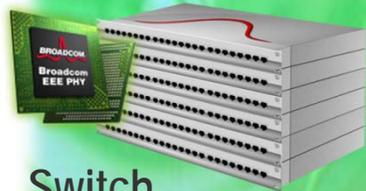


Stateful Offloads



Power and performance optimization for Maximum Link Utilization

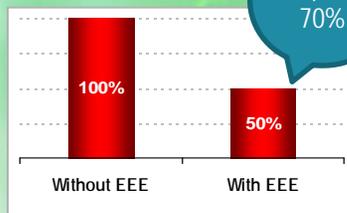
Energy Efficient Networking  
Control Policy Driven (L2-L4)



Switch



Server



PHY Level – 802.3az  
Server, Storage, Switch



Power optimization for Low Link Utilization

*Reduced power across full spectrum of data traffic patterns*

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# What's on the Horizon for Energy Saving Standards?



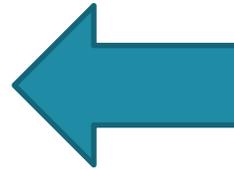
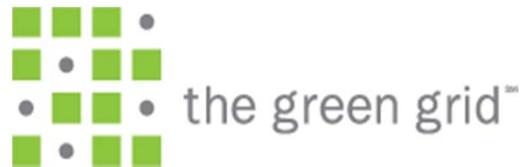
- Energy efficiency likely a key objective in future Ethernet standards. Upcoming ones include
  - IEEE P802.3bj 100G Cu and Backplane Task Force
    - *EEE objective just added!*
  - Next generation BASE-T
  - SIEPON
  
- Control policy work

# Regulatory Initiatives

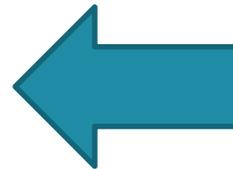


- Tremendous activity in this area
- Below are some examples of regulatory initiatives
- Energy Star
  - Computers, Servers, Storage, SNE and LNE (future project)
  - Touches on all aspects of ICT including data center
  - EEE being considered in the various projects
- EU CoC
  - EEE being considered
- Others

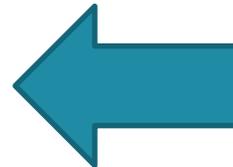
# Example of Industry Consortia Working on Green



Data Center  
Scope



Network Element Scope  
Data Center and  
Enterprise



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# Final Thoughts



- **IEEE Std 802.3az-2010 is a building block for energy efficient innovation in wired networks**
  - Provides a foundation at the physical layer for energy efficiency
- **One size does not fit all**
  - Applications and their requirements differ in terms of what works and what does not for energy savings
    - Performance – savings tradeoff
    - E.g. a data center vs. a home network; not all data centers are the same
  - When considering the system in which EEE runs, other factors need to be taken into account such as control policy, system management and system savings
- **EEE, as with traditional Ethernet, allows for a variety of applications and their requirements to run, giving the users and end-users the flexibility to innovate on top of the standard and complement with other savings technologies**

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# Additional Reading Materials and Resources



## EEN White Paper

- English:

<http://www.broadcom.com/collateral/wp/EEE-WP101-R.pdf>

## Wikibon Whitepaper

- Networks Go GrEEn:

[http://wikibon.org/wiki/v/Networks\\_Go\\_GrEEN](http://wikibon.org/wiki/v/Networks_Go_GrEEN)

## IEEE P802.3az Web Area

<http://www.ieee802.org/3/az>

# Broadcom WINS EEE Award!



Broadcom wins 2010 Best Electronic Design Award for its broad and extensive new portfolio of EEE products

- ED Award (under Communications – Wired Category):

<http://electronicdesign.com/article/news/Electronic-Design-Announces-2010-Best-Electronic-Design-Award-Winners.aspx>

- ED Article that was the basis of the award:

<http://electronicdesign.com/article/communications/IEEE-And-Broadcom-Bring-Forth-Energy-Efficient-Ethernet.aspx>

- Broadcom press release on the award:

<http://www.broadcom.com/press/release.php?id=s542639>

# TechAmerica 2011 Innovator Award!



Award for Green Tech / Smart Grid area

- Broadcom press release on the award:

<http://www.broadcom.com/press/release.php?id=s614065>



Thank You

[www.broadcom.com](http://www.broadcom.com)