GreenTouch Open Forum
November 2011

Wael William Diab

Senior Technical Director, Office of the CTO, Broadcom

Vice-Chair, IEEE 802.3 (Ethernet) Working Group

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

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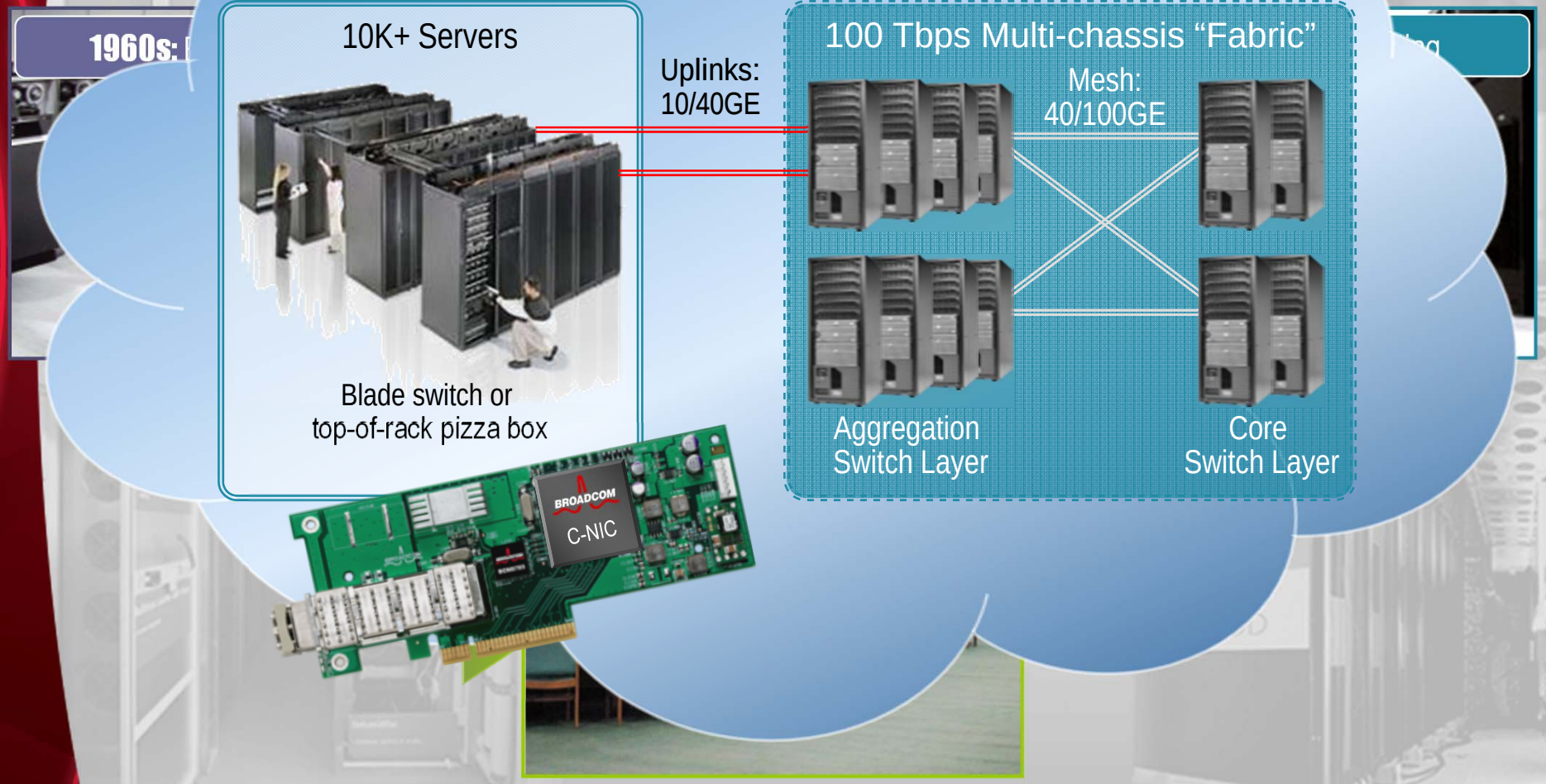
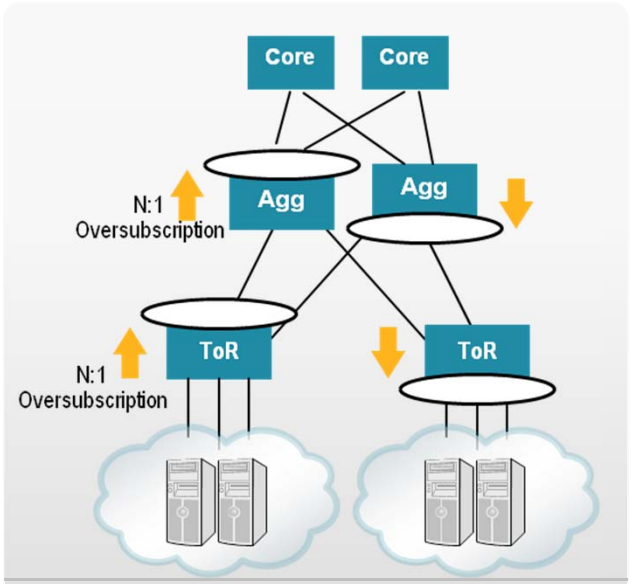
Evolving Computing Models: *Data Center*

BROADCOM. Connecting everything®

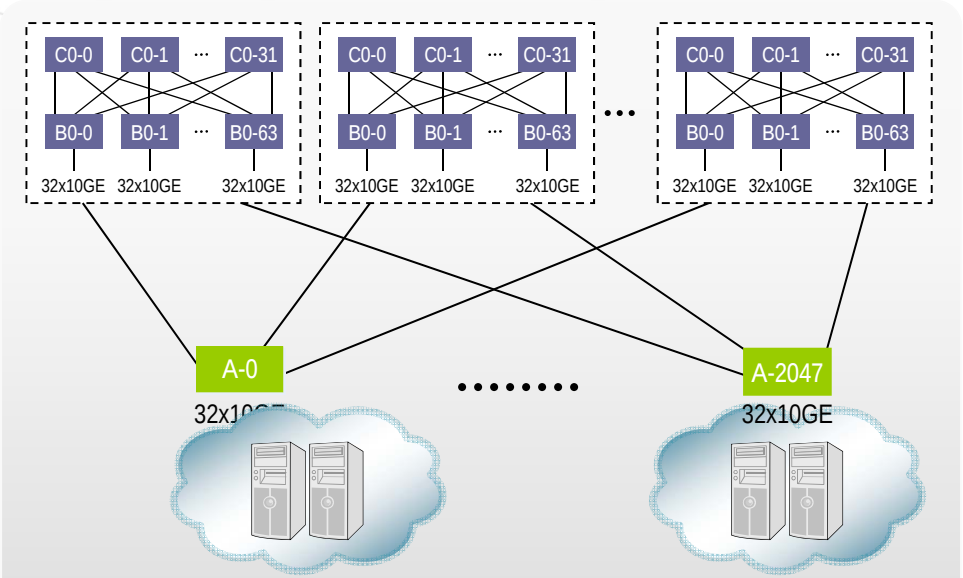


Data Center Fabric Alternatives



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

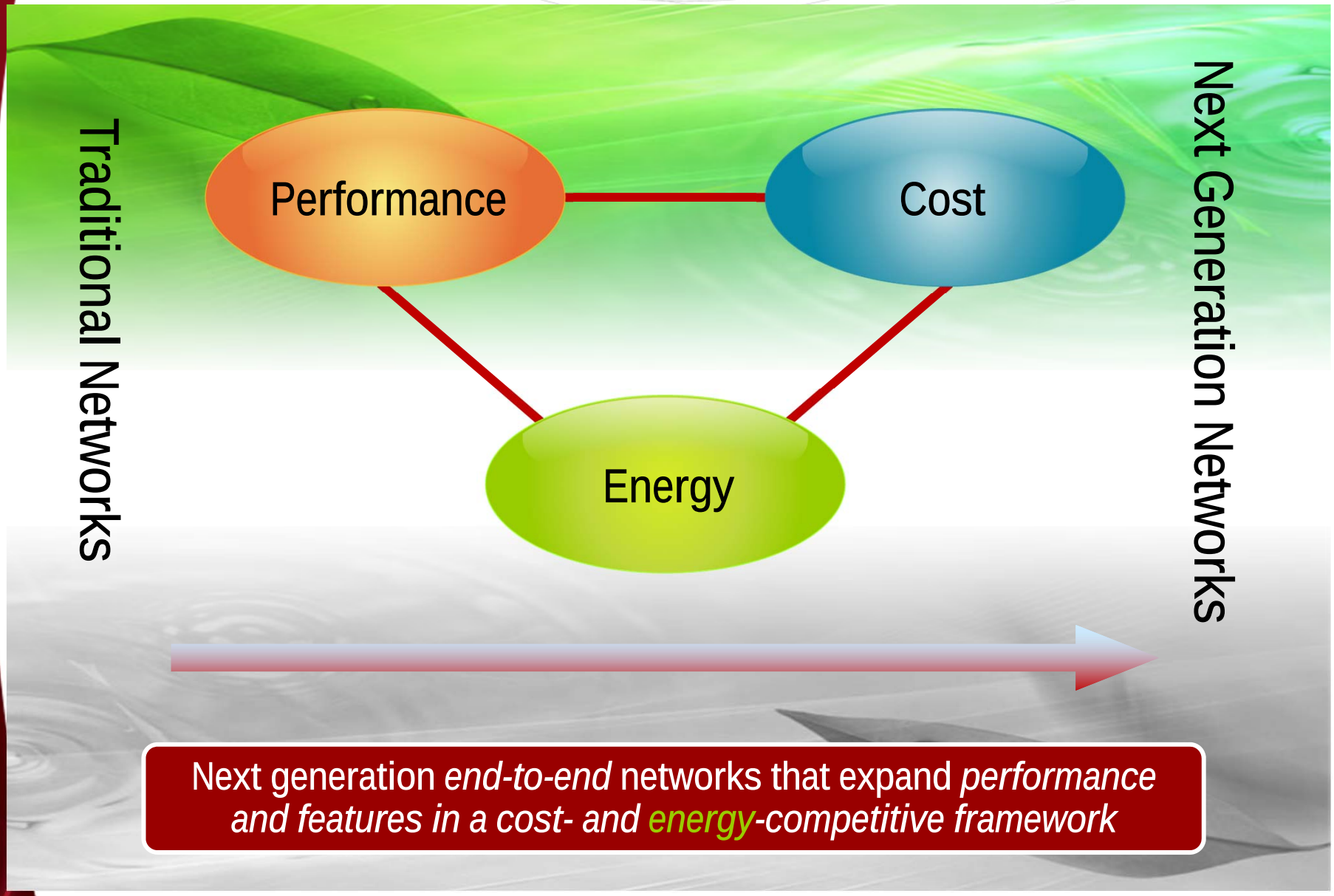
- All electronics
  - IT equipment, consumer electronics, telephony
    - Residential, commercial, industrial
  - At least 250 TWh/year
  - $20 billion/year
    - Based on .08$/kWh; rates are rising
  - Over 180 million tons of CO_2 per year
    - Roughly equivalent to 35 million cars!
- IT equipment about half of this
  - PCs, displays, printers, servers, network equipment

Numbers represent U.S. only

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

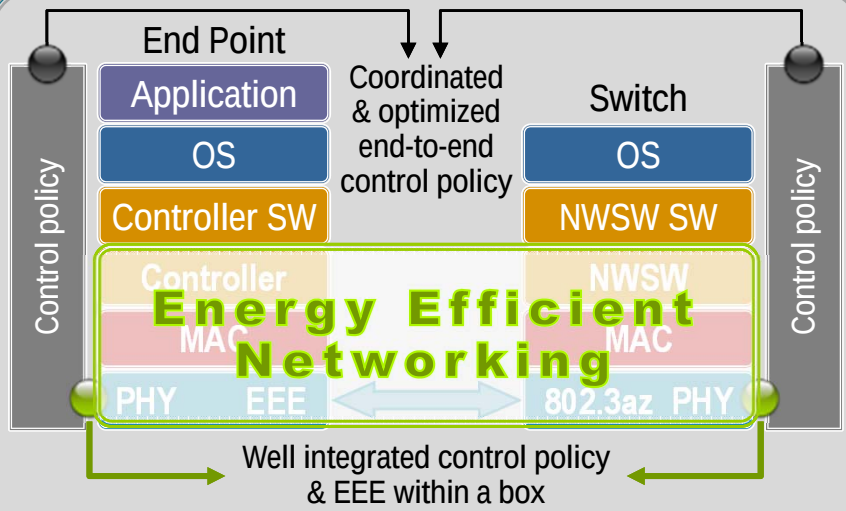
PCs etc. are digitally networked now — *Consumer Electronics* (CE) will be soon

Evolution in Network Architecture

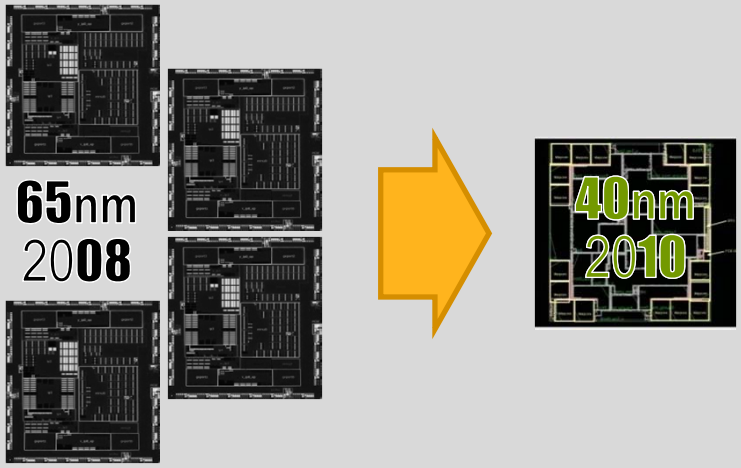


Delivering on Energy Efficiency in Data Centers

Energy Efficient Ethernet



Energy Efficient Networking



Process & Integration Efficiencies

Saves 20W-60W per port!

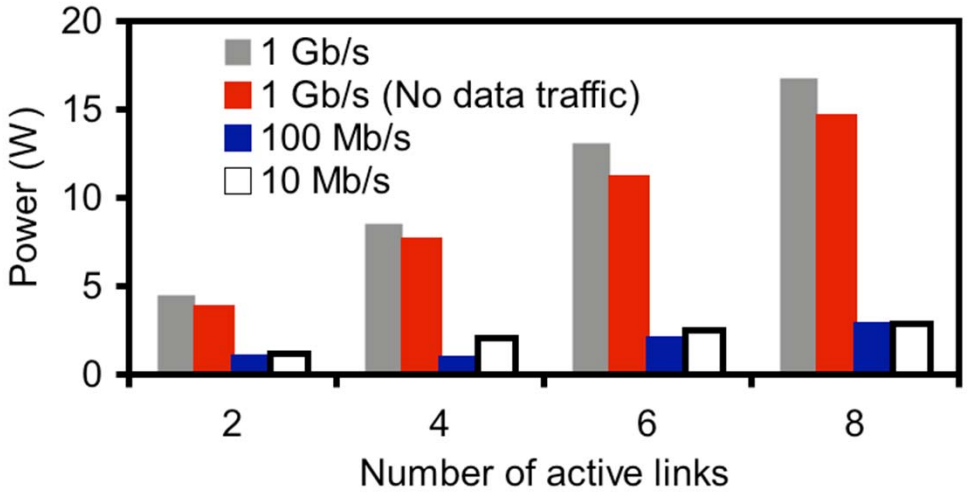
Stateless & Stateful Offloads

OVERVIEW OF EEE

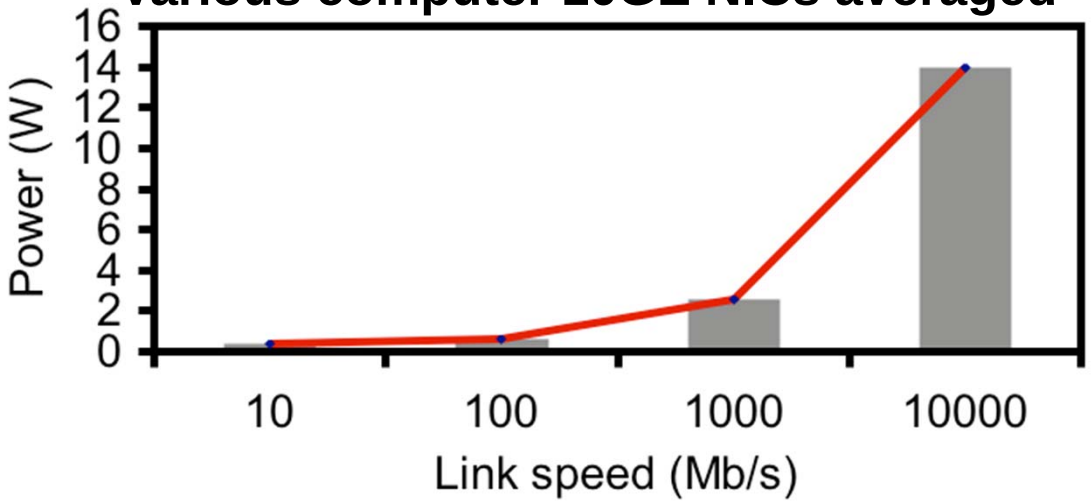
Motivation – A Link Perspective

- **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

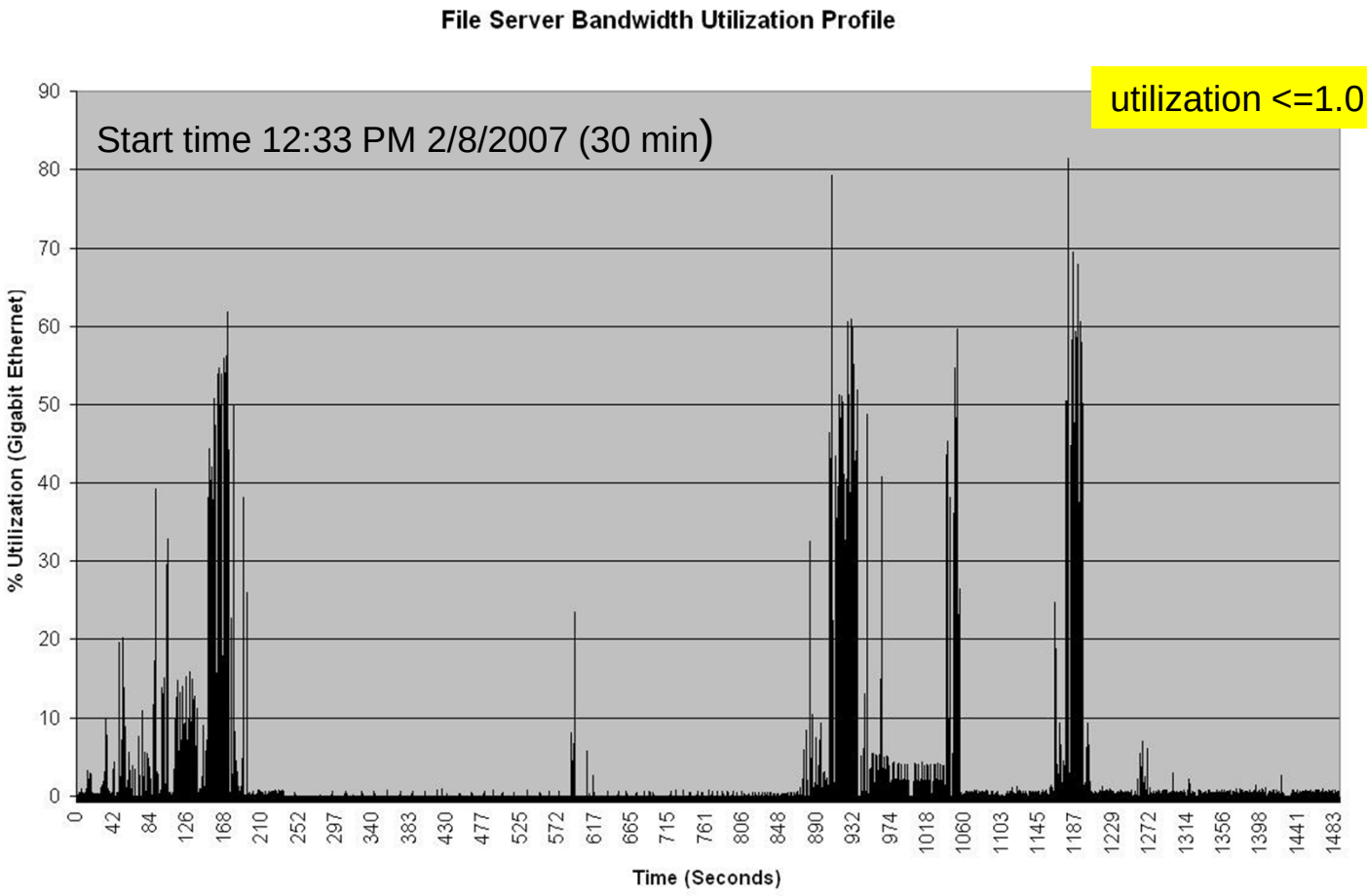


Results from 1st order (rough) measurements – all incremental AC power

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)



Energy Efficient Ethernet (EEE) Overview

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

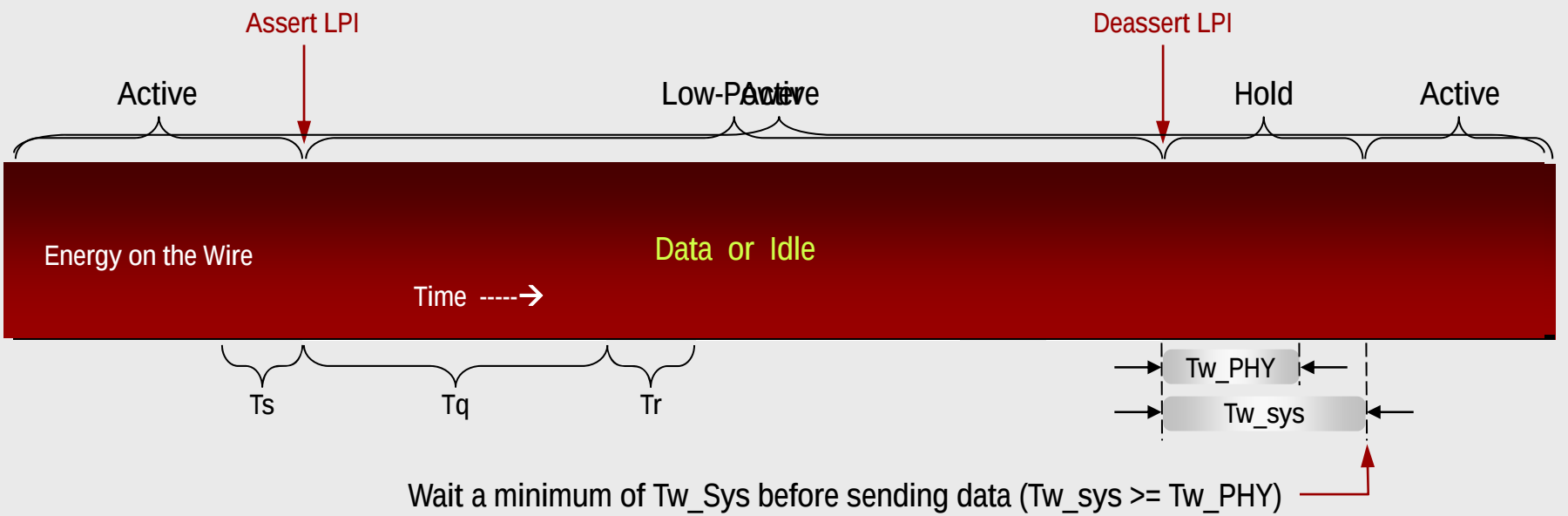
- IEEE Std 802.3az™-2010 (Amendment to IEEE Std 802.3-2008) PHYs:
  - 100BASE-TX
  - 1000BASE-T
  - 10GBASE-T

  } Twisted-Pair Copper PHYs

  - 10GBASE-KR
  - 10GBASE-KX4.

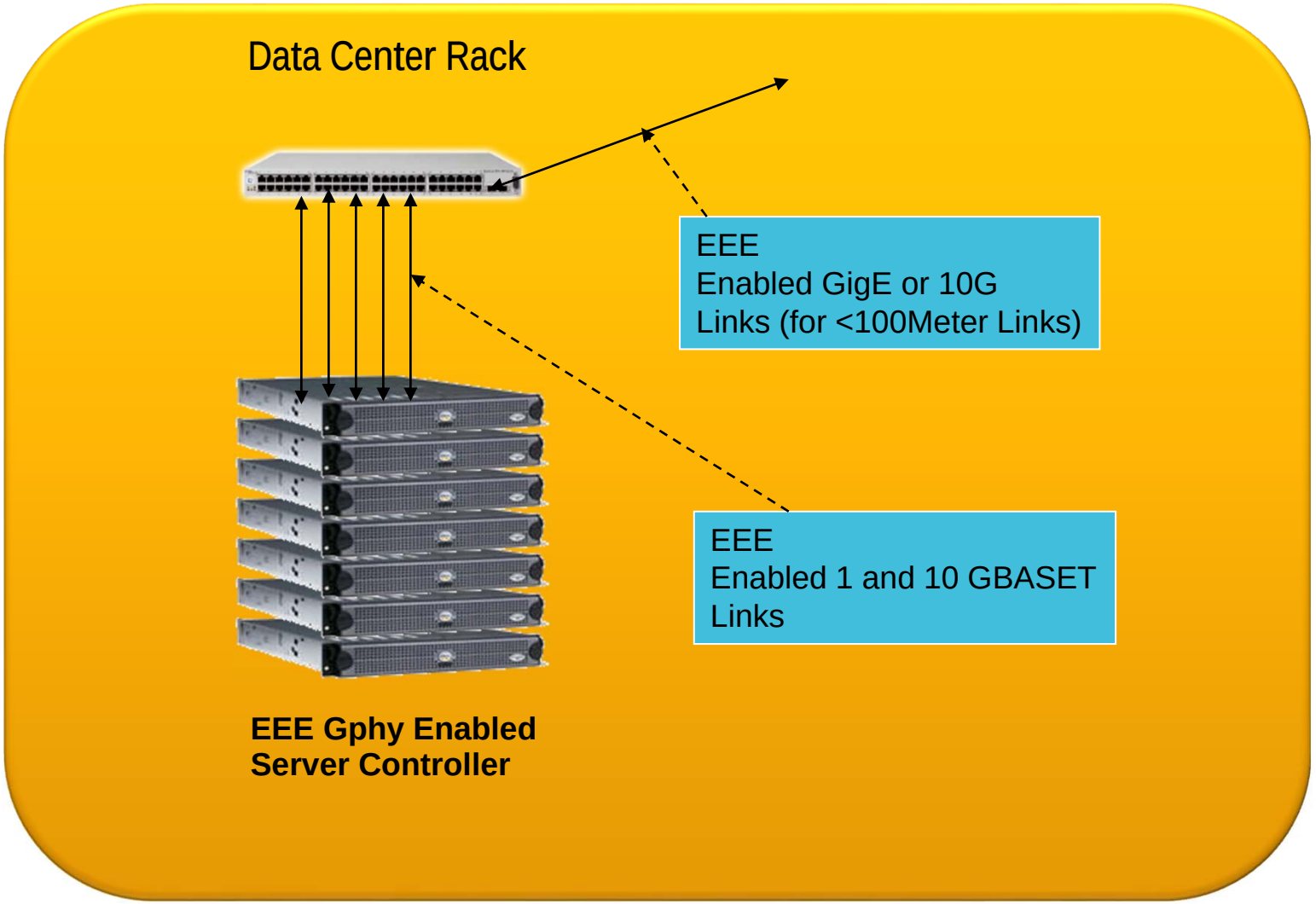
- EEE uses Low-Power IDLE (LPI) to signal transitions to and from lower levels of energy consumption.

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: Tw_PHY <= 30 usec
  - 1000BASE-T: Tw_PHY <= 16.5 usec
  - 10GBASE-T: Tw_PHY < ~8 usec (2 modes)

EEE Application – Data Center



INNOVATING ON TOP OF EEE

Framework

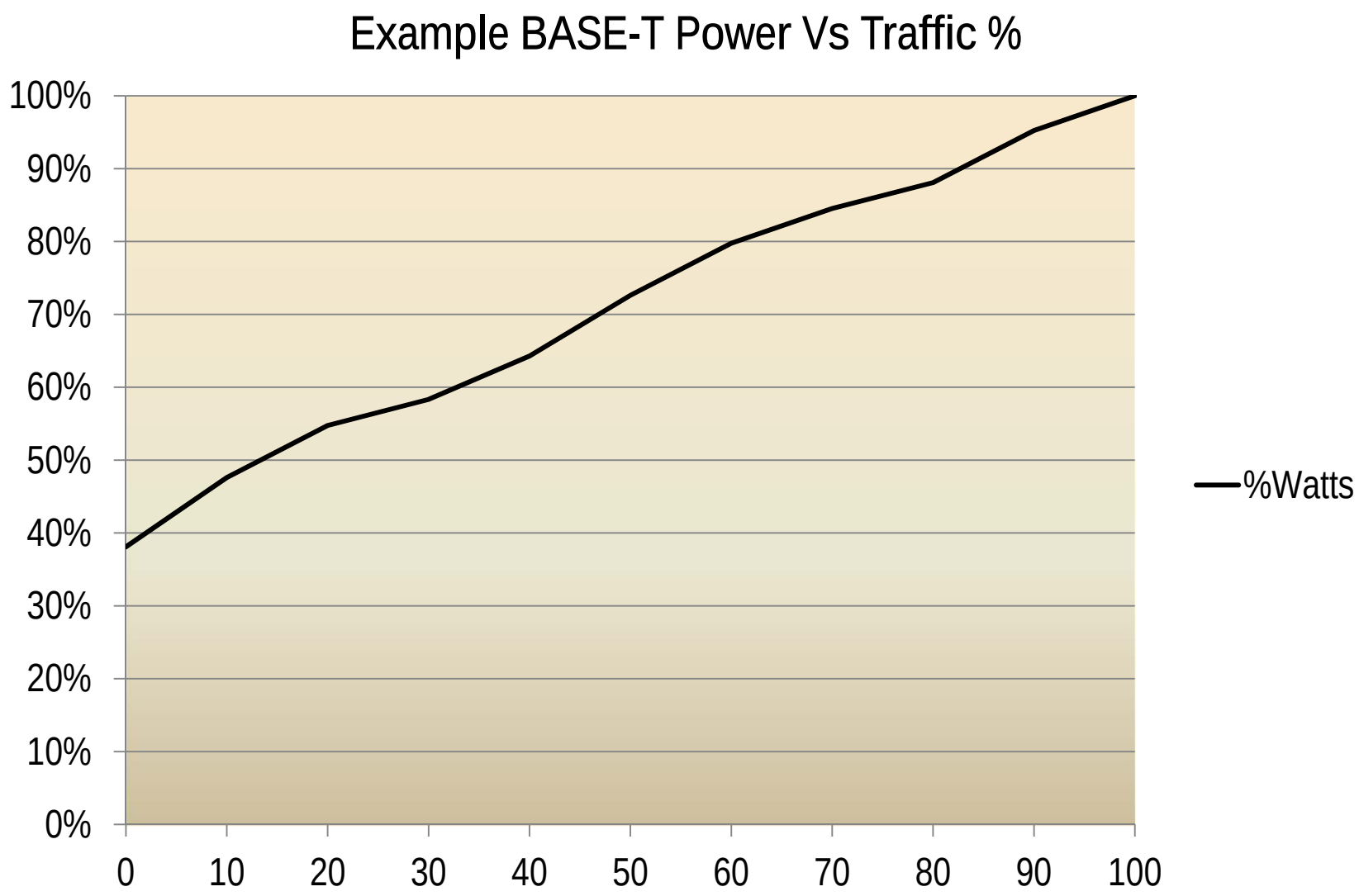
- Savings: Additional savings in and beyond the physical layer
  - Enhancements and implementation of the PHY layer
  - Savings above the PHY layer
  - Complementary savings technologies
- Performance: It is important to save energy *without compromising performance.* An example of this is the technologies 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?

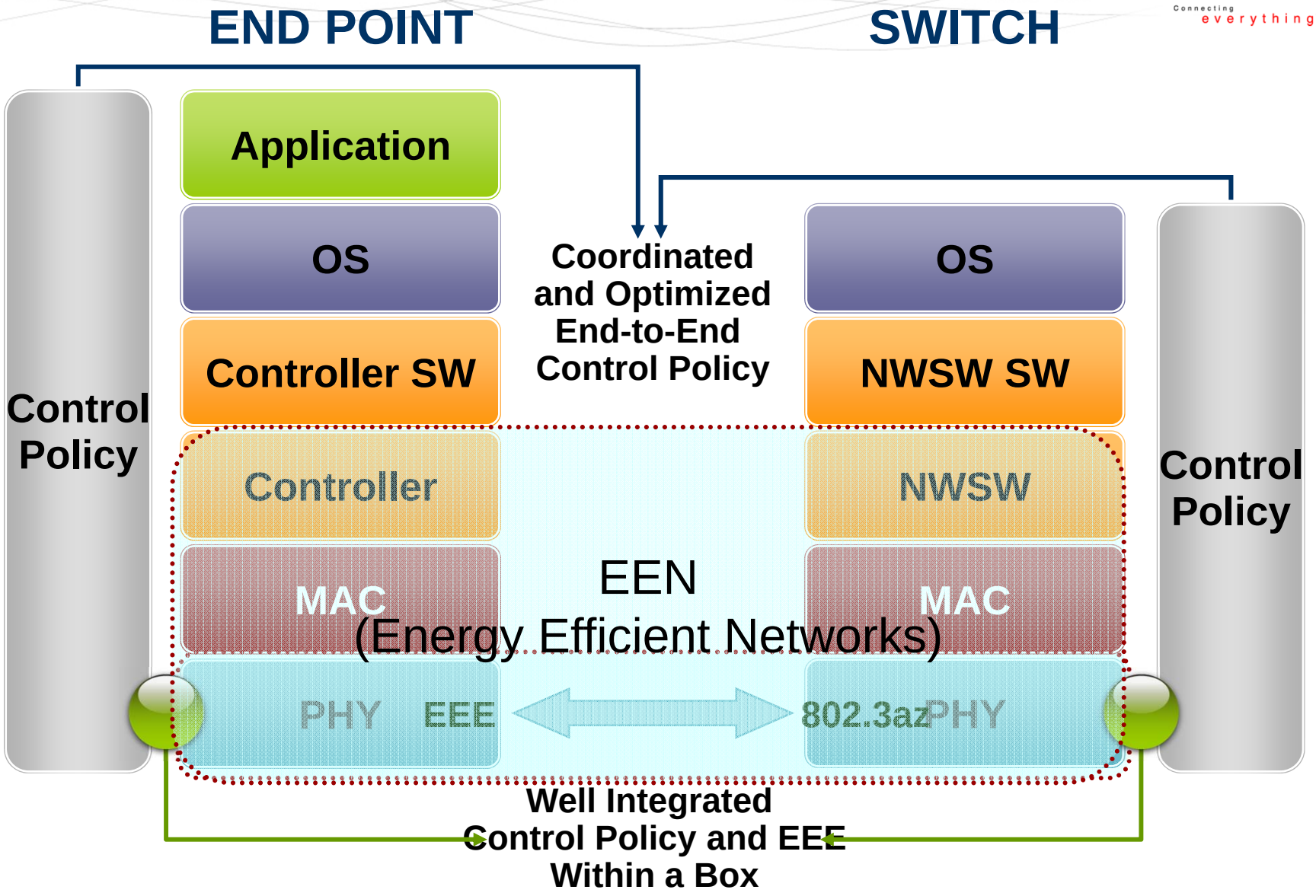
- Energy consumption is overall usage over a period of time T
  - Think of your monthly electricity bill
- Mathematically

  $E_T = [P_{active} * T_{active}] + [P_{idle} * T_{idle}];$ where $T = T_{active} + T_{idle}$
- Savings (Min E_T) can be achieved in any combination of 3 ways
  - Minimize P_{active}
    - Example *innovation* green modes, lower energy process node, clock frequency management, energy efficient memories
  - Minimize P_{idle}
    - Power down *additional* subsystems
    - Support *Layer 2* for additional savings across the link
  - Maximize T_{idle}
    - *Comprehensive* control policy

Example Power vs. Traffic Duty Cycle

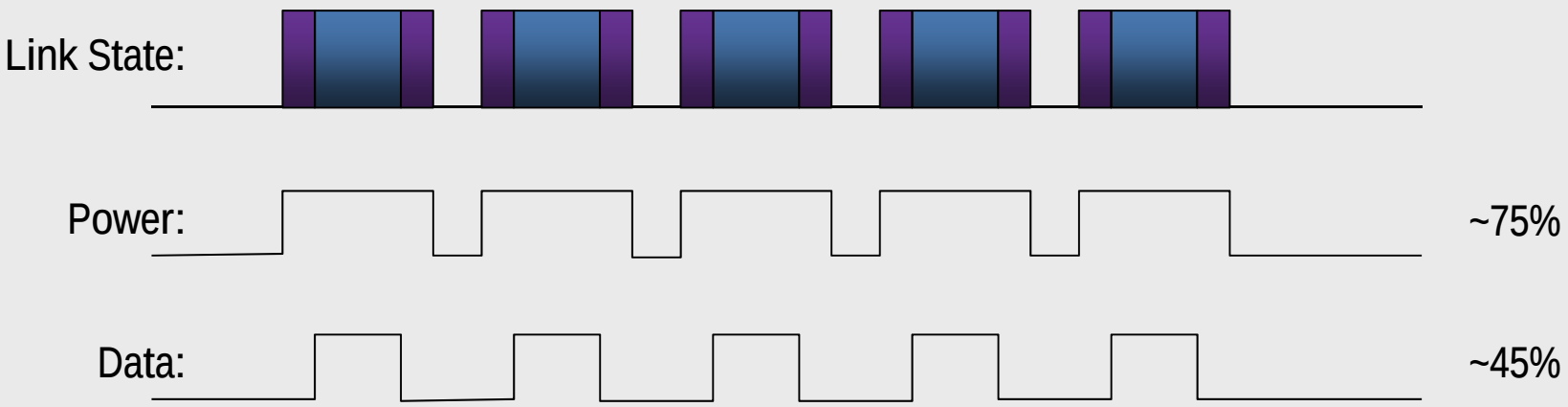


End-to-End Savings



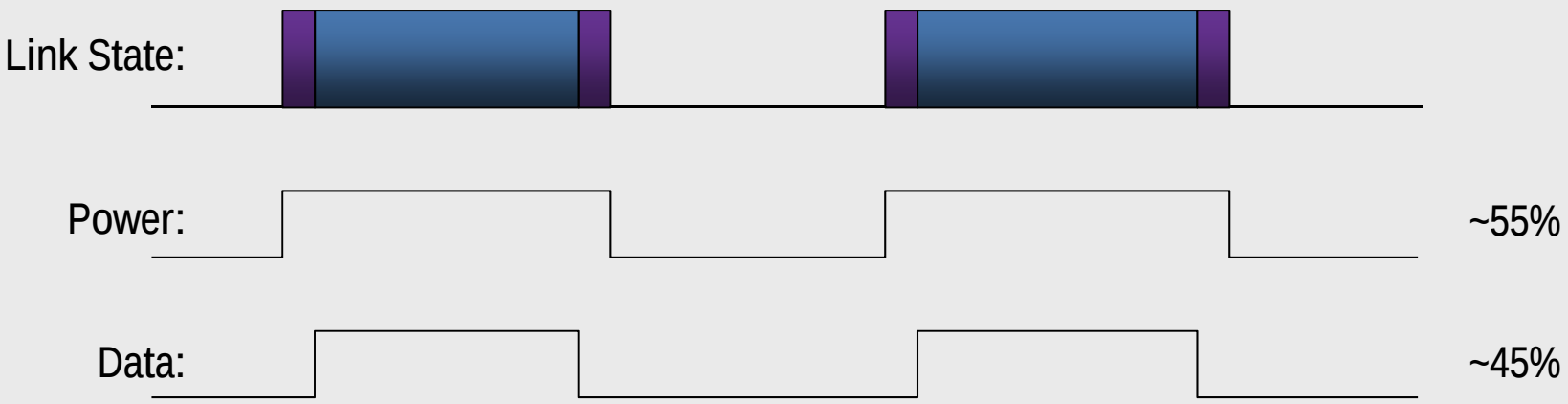
In-System Control Policy

No Control Policy

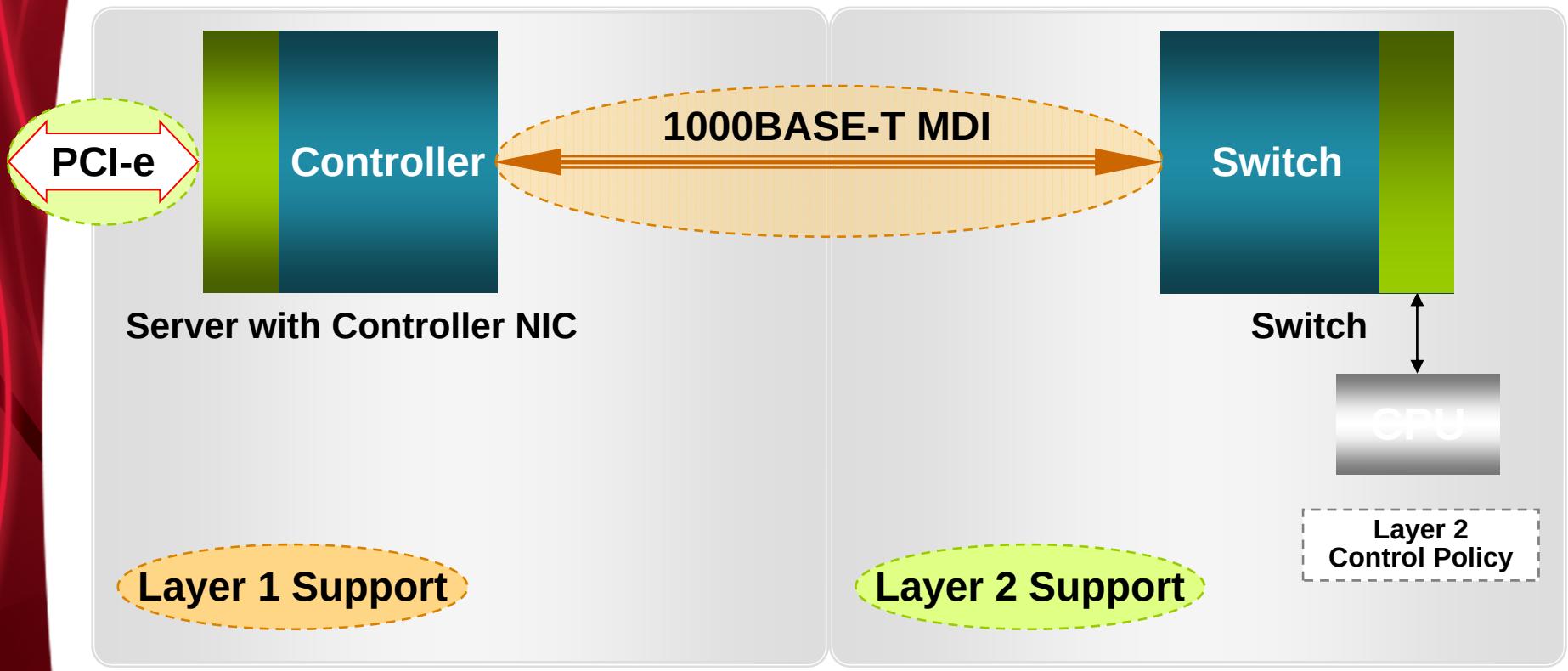


In-System Control Policy

With Broadcom EEE Control Policy

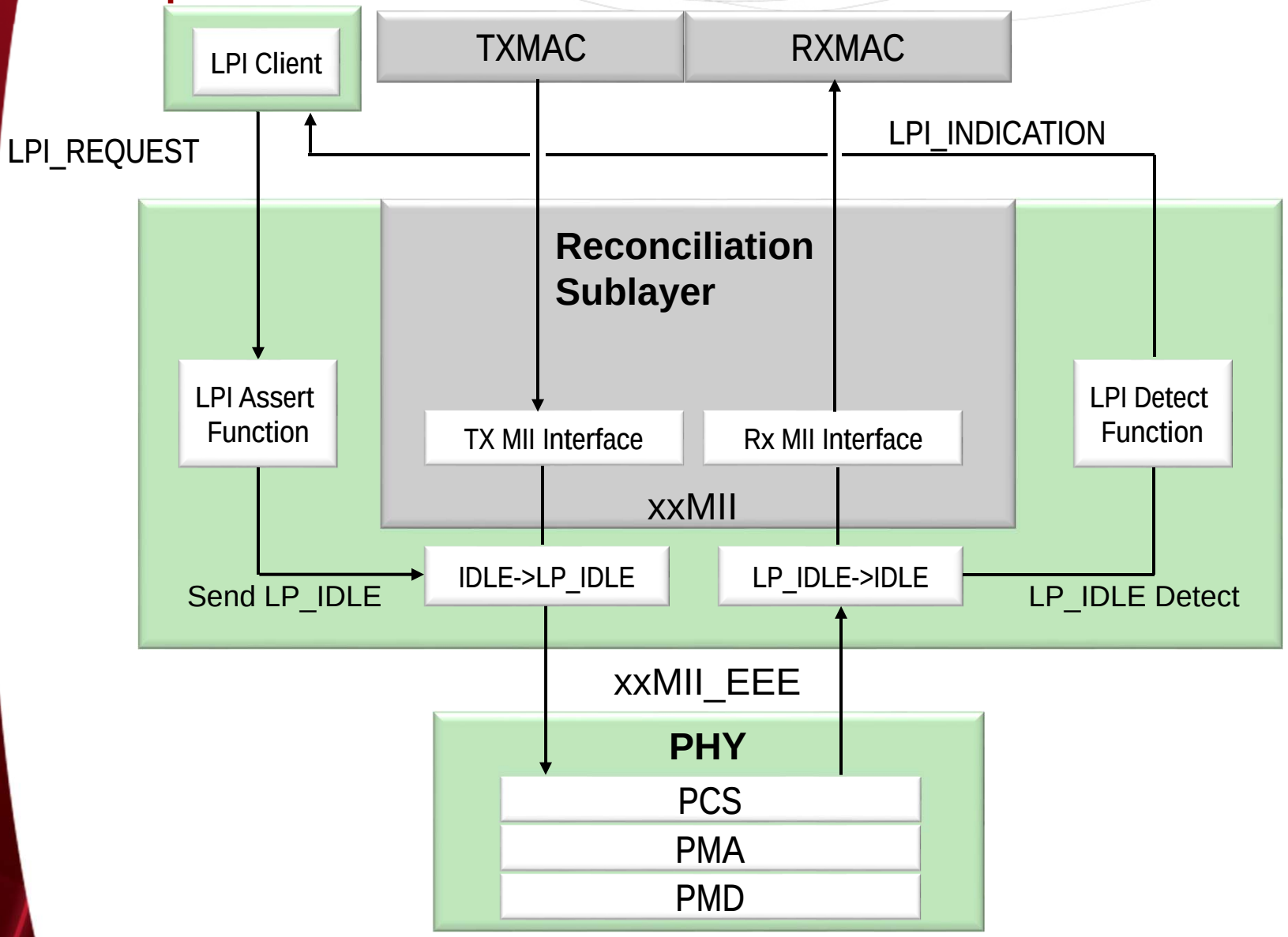


EEE Enhanced Layer 2 Operations

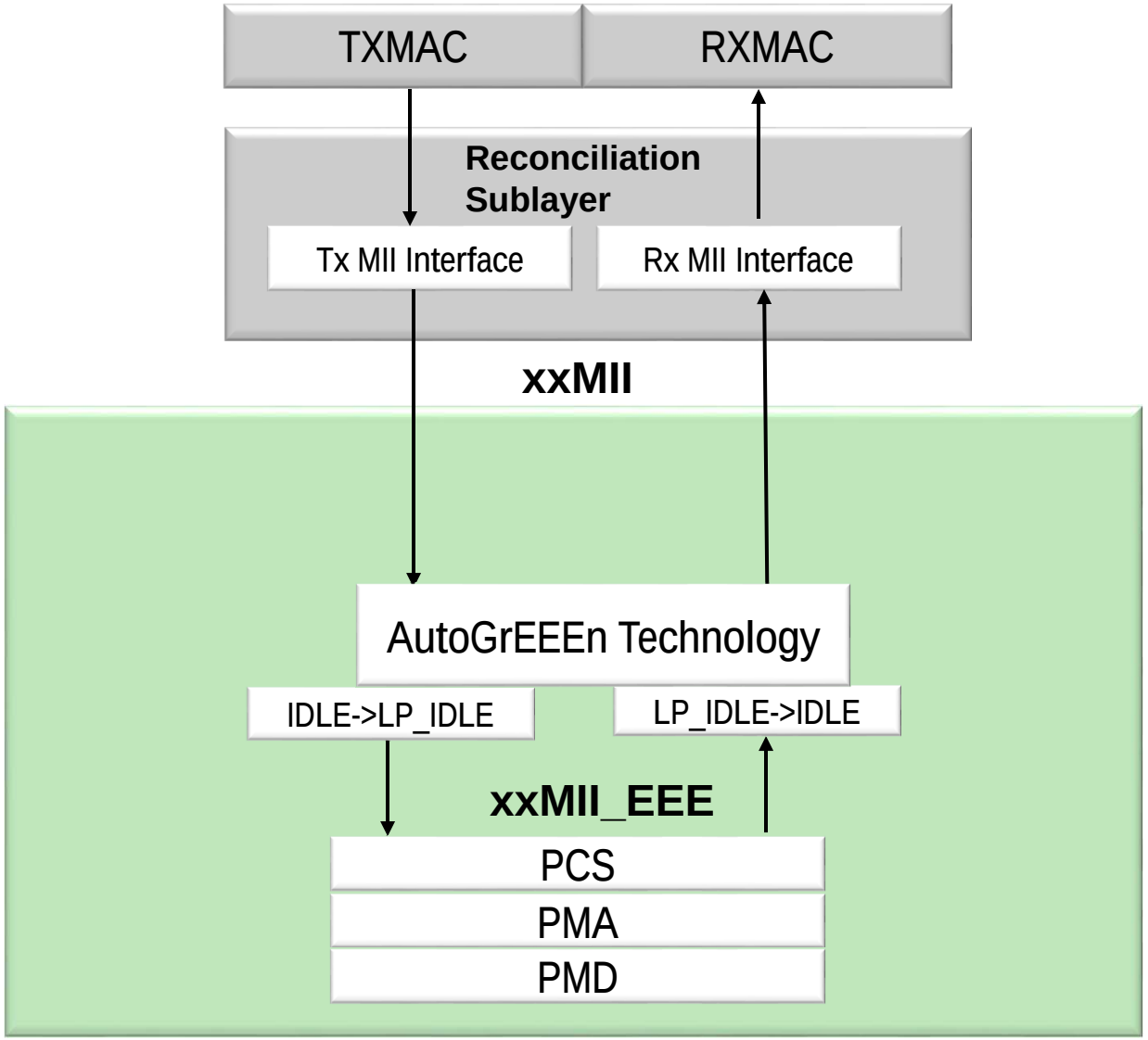


- Opportunity to save additional power within a box (link partner)
  - *Additional circuits beyond the PHY can be turned off*
  - Also applies to *cascaded interfaces (e.g. XAUI / 10GBASE-T / KR / XFI)*
- Additional RX wakeup time negotiated using 802.3az's Layer 2 — *Standards based*

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



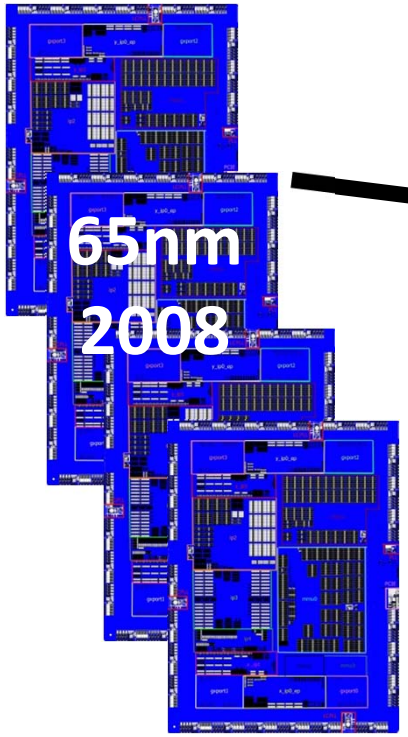
AutoGrEEEn^{tm} LPI Reference Layer Diagram: Reuses Legacy MAC. Time-to-market innovation



COMPLEMENTARY SAVING TECHNOLOGIES

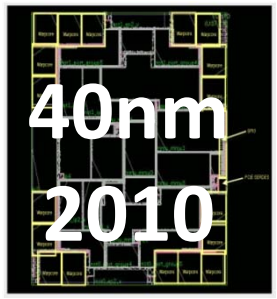
Power Efficiency in Process Evolution

Multi-die Switch Fabric



Higher power with external I/O

Single die high BW Fabric

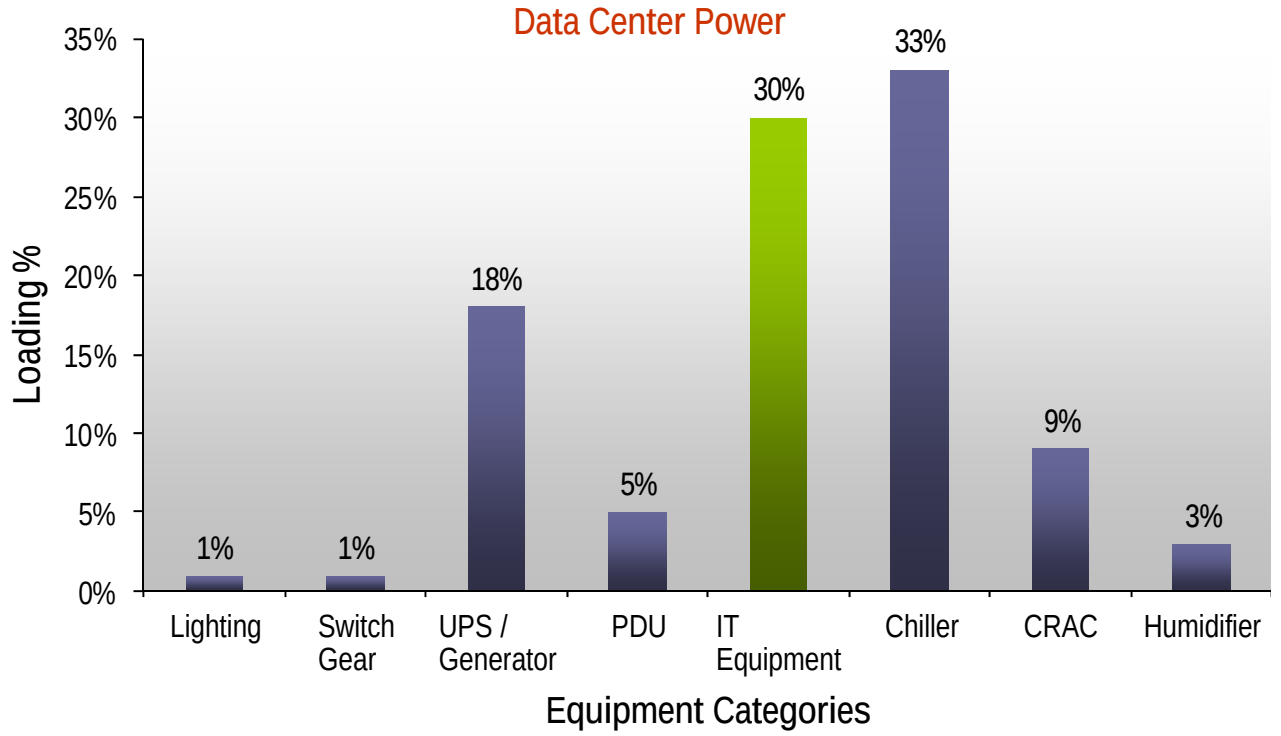


Lower power process node with internal I/O

Broadcom is leading the way to the latest process nodes

Improve Data Center Power Efficiency

Offload Significantly Improves Performance / Watt



Offload Provides Data Centers

- Improved PUE (Power Utilization Efficiency)
- Permanent power savings for right-sizing
  - 50-70% additional power savings
  - Lowers non-IT infrastructure CAPEX

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

Server Side Energy Efficiency

Stateful Offloads

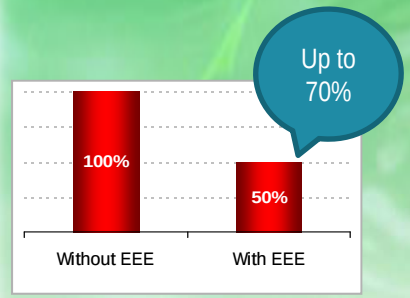
Power and performance optimization for Maximum Link Utilization

Switch

Energy Efficient Networking

Control Policy Driven (L2-L4)

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?

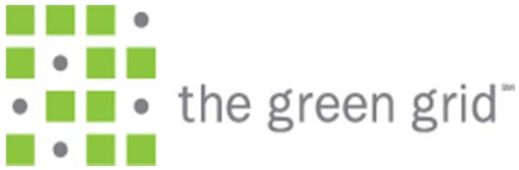
- Energy efficiency likely a key objective in future Ethernet standards. Upcoming ones include
  - IEEE P802.3bj 100G Cu and Backplane Task Force
    - *EEE objective just added!*
  - Next generation BASE-T
  - SIEPON

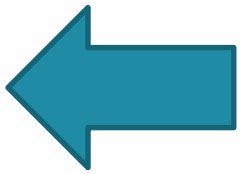
- Control policy work

Regulatory Initiatives

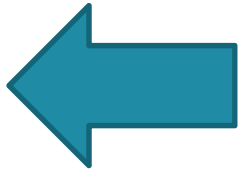
- Tremendous activity in this area
- Below are some examples of regulatory initiatives
- Energy Star
  - Computers, Servers, Storage, SNE and LNE (future project)
  - Touches on all aspects of ICT including data center
  - EEE being considered in the various projects
- EU CoC
  - EEE being considered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

Example of Industry Consortia Working on Green

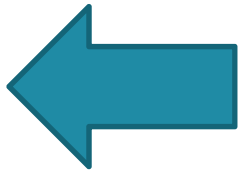




Data Center Scope



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

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

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