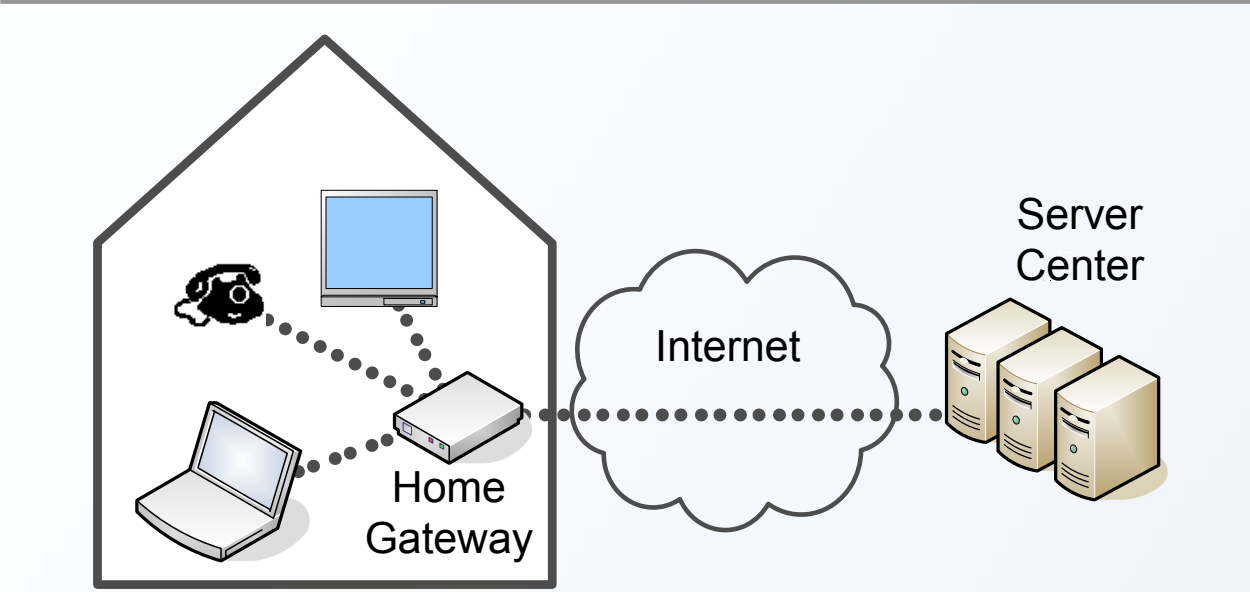# Fundamental Energy Efficiency Measures for Home Gateways
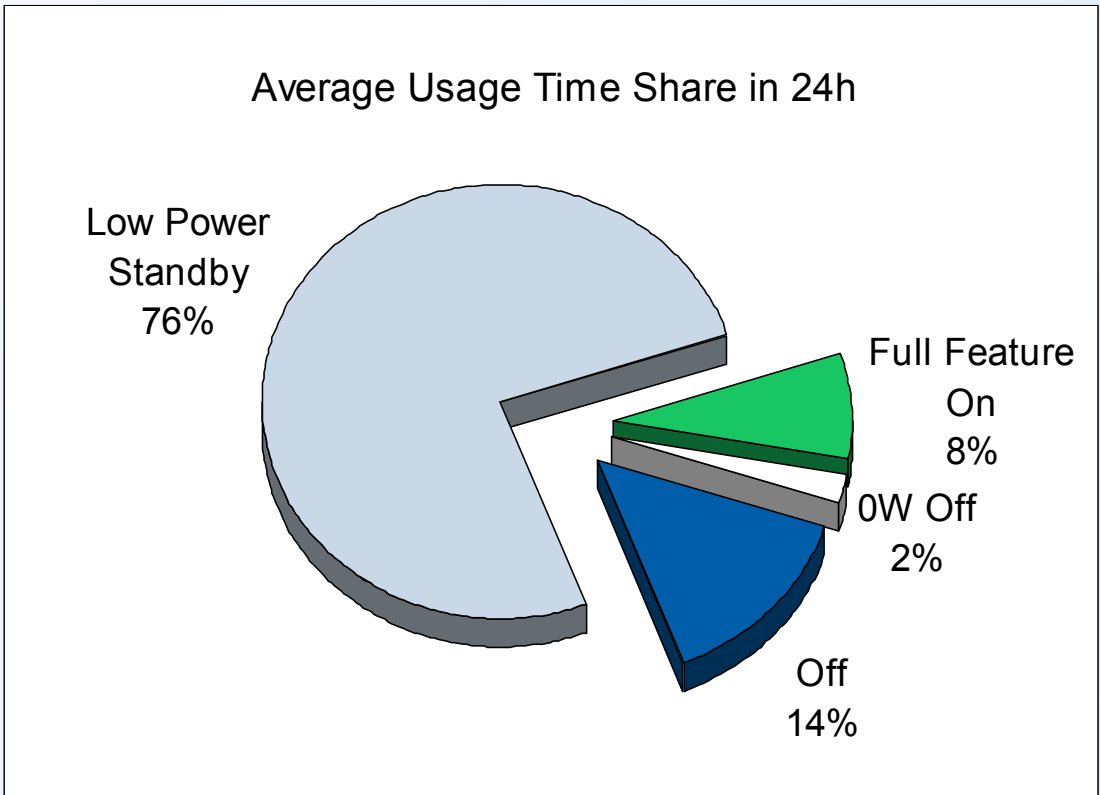
Thomas Zettler, Lantiq GmbH, 81726 Munich, Germany, thomas.zettler@lantiq.com

Introduction

HOME GATEWAY AS CENTRAL HOME „ ALWAYS ON" COMMUNICATION DEVICE

THE CHALLENGE
HOME GATEWAY IS SUPPORTING MULTIPLE STANDARDS AND PROVIDING ALWAYS AVAILABLE SERVICES

Average Usage Time Share in 24h

- Low Power Standby 76%
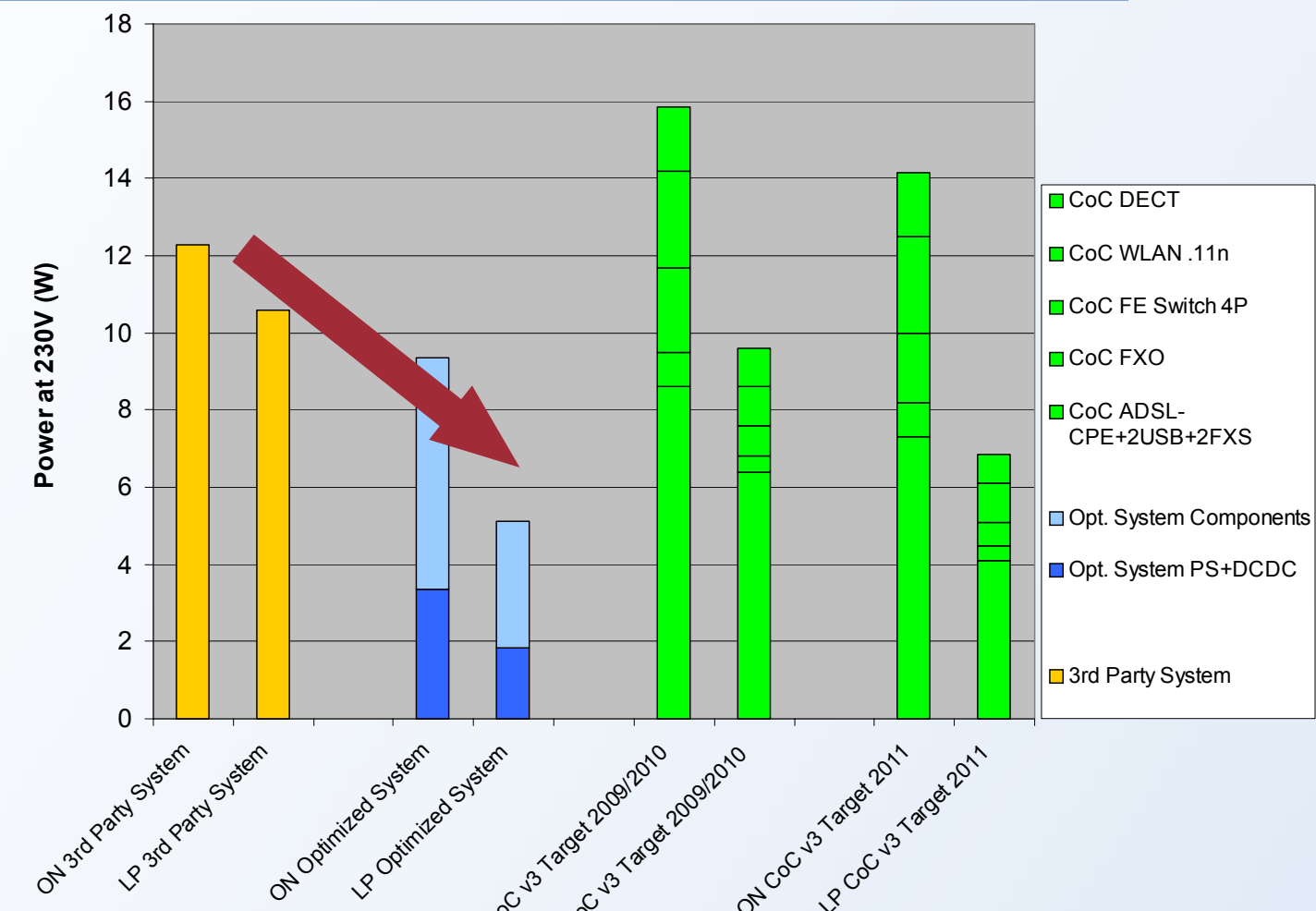- Full Feature On 8%
- 0W Off 2%
- Off 14%

Average usage time shares for home gateway internet devices with use cases Full Feature On, Low Power Standby, Off and 0 W Off based on data from [1]

THE SOLUTION APPROACH
CAREFUL ANALYSIS OF USE CASES. TAKE ADVANTAGE OF UNUSED OR PARTIAL USED HARDWARE BLOCKS
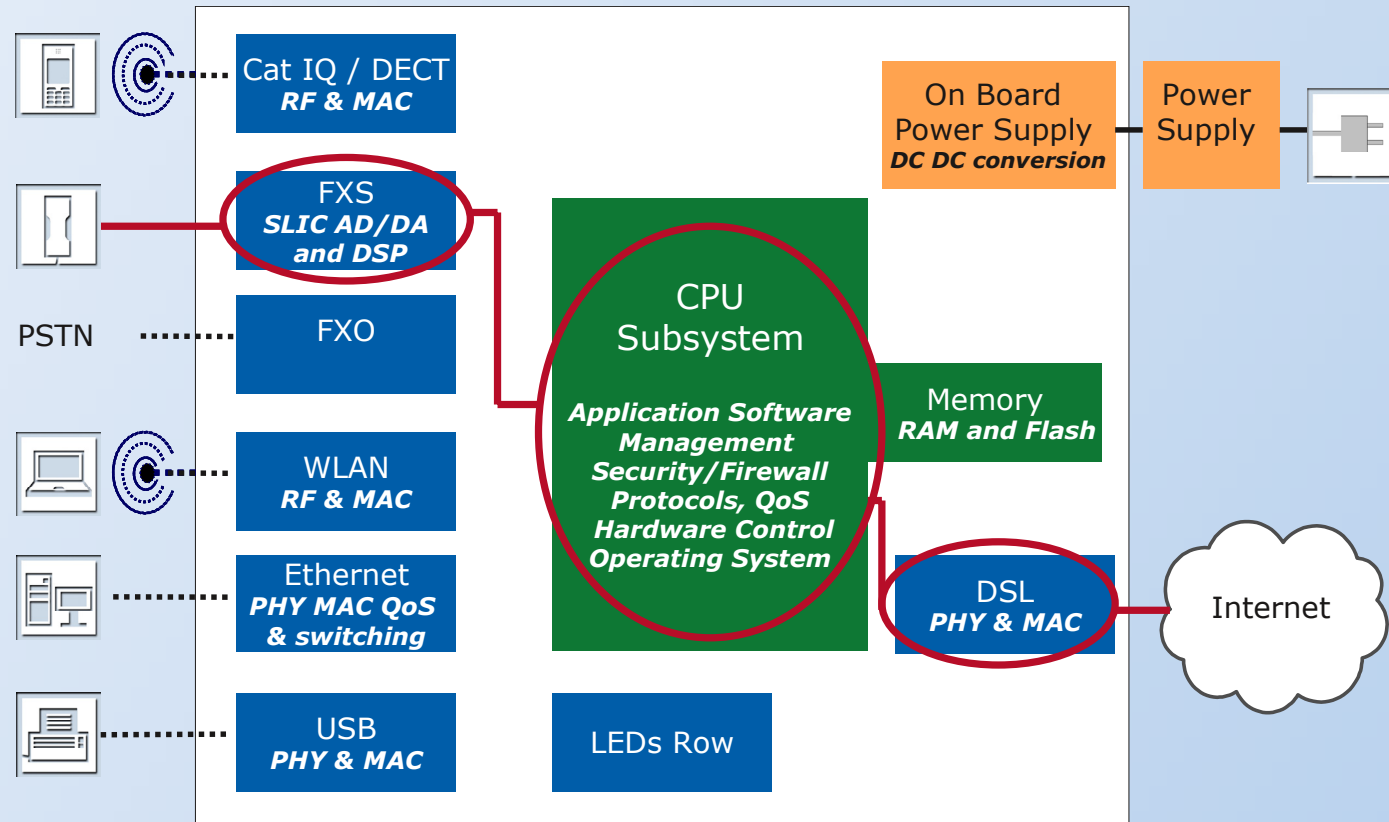
*Functional units of a typical CPE IAD with indication of main activity during a VoIP call.*

Result

Legend:
- CoC DECT
- CoC WLAN .11n
- CoC FE Switch 4P
- CoC FXO
- CoC ADSL-CPE+2USB+2FXS
- Opt. System Components
- Opt. System PS+DCDC
- 3rd Party System

X-axis categories: ON 3rd Party System, LP 3rd Party System, ON Optimized System, LP Optimized System, ON CoC v3 Target 2009/2010, LP CoC v3 Target 2009/2010, ON CoC v3 Target 2011, LP CoC v3 Target 2011

Power consumption of 3rd Party System and Optimized System in comparison with European Code of Conduct [2] (CoC) Power Targets

Power Supply System

Typical IAD On-state power consumption share for categories Power supply (non-optimized DC-DC+ external Power Supply), CPU subsystem and memory, Interface functions
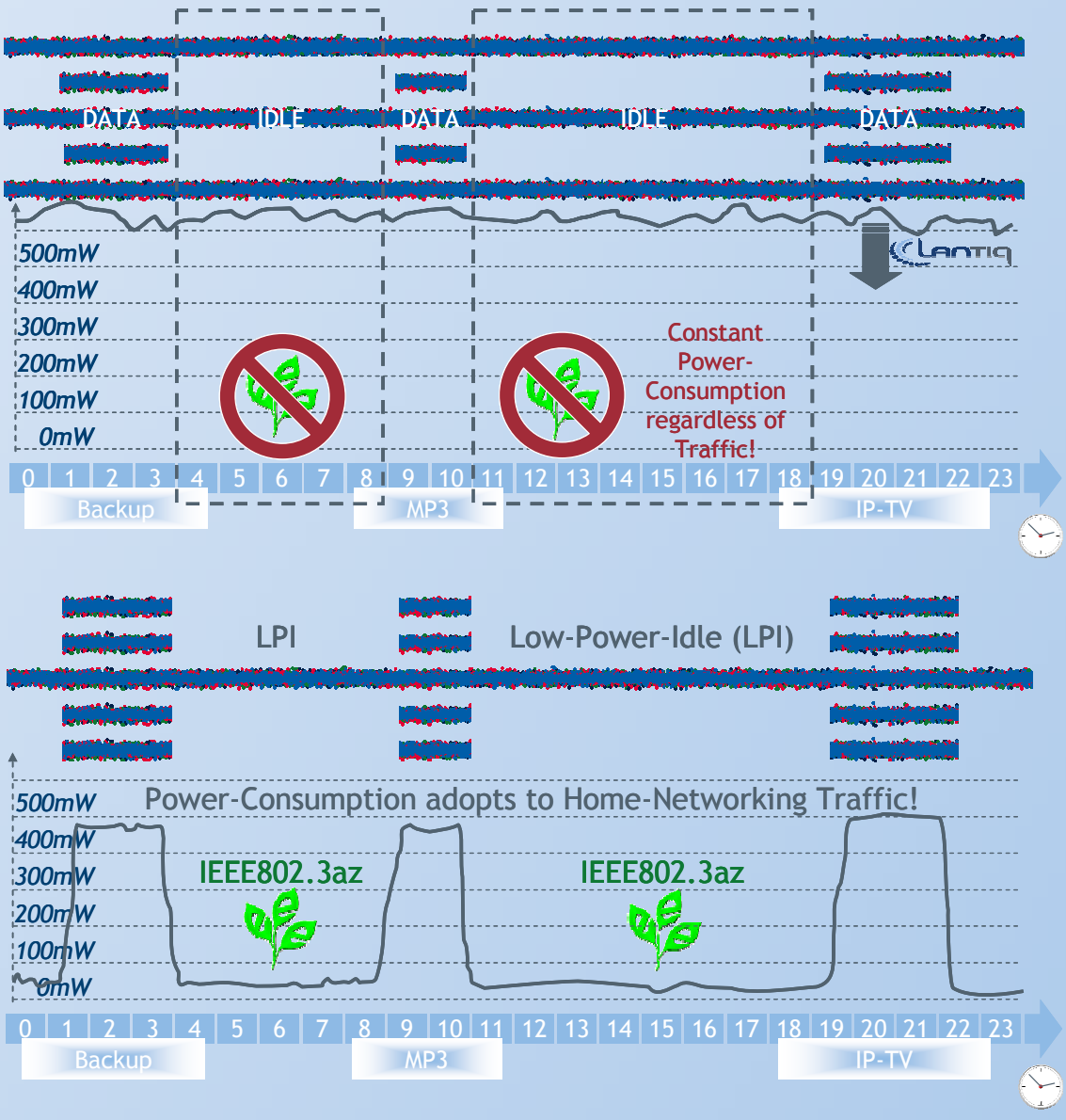

IAD Power Breakdown On-state
- Interface functions
- CPU subsystem + memory
- Power Supply
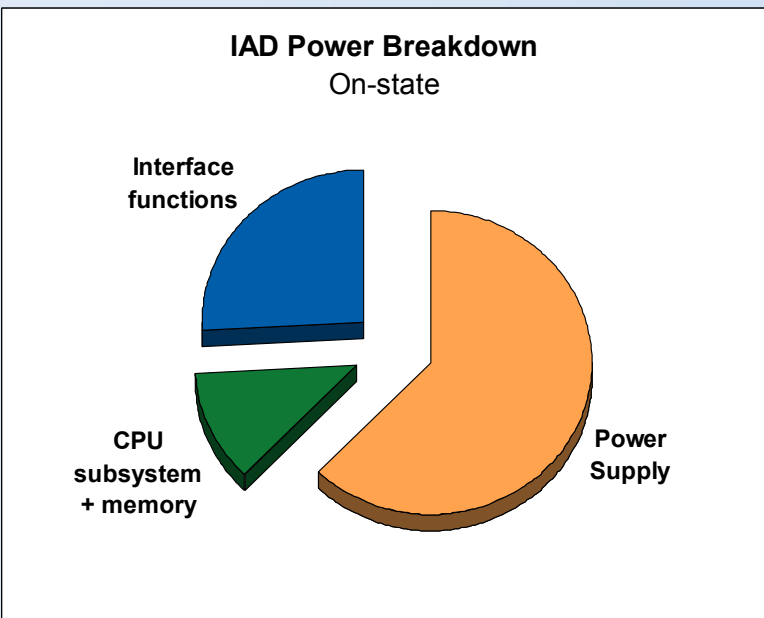
Optimize Supply System: PS:55% + DC-DC:70% ⇥ PS:80% + DC-DC 80% ⇥ 40% Reduction in overall System power consumption

Minimum active functions for the Code of Conduct [2] Low-Power-State use case
- A DSL IP connection is required to receive VoIP calls. For transmission of IP stream the physical layer must be kept active which means that DSL tones are permanently active and analyzed in the system.
- WLAN base station function must be capable of performing association of new mobile devices to the WLAN network and maintain the wireless link to previously associated devices. For this the WLAN has to transmit beacon and to operate the receive path. In general Wi-Fi standards must be fulfilled.
- Ethernet link detection must be active and attached devices must be managed when requesting new link and 802.3 standards must be fulfilled.
- For DECT / CatIQ cordless telephony interface incoming call detection must be assured. Therefore DECT/ Cat IQ scanning is active or beacon is send. Ringing must be delivered. This is required for all telephony interfaces.
- The telephone interface FXS has to detect off-hook. Attached telephones must be fed.
- Incoming calls at the FXO telephone interface must be detected.
- Attachment of new devices to USB must be recognized.
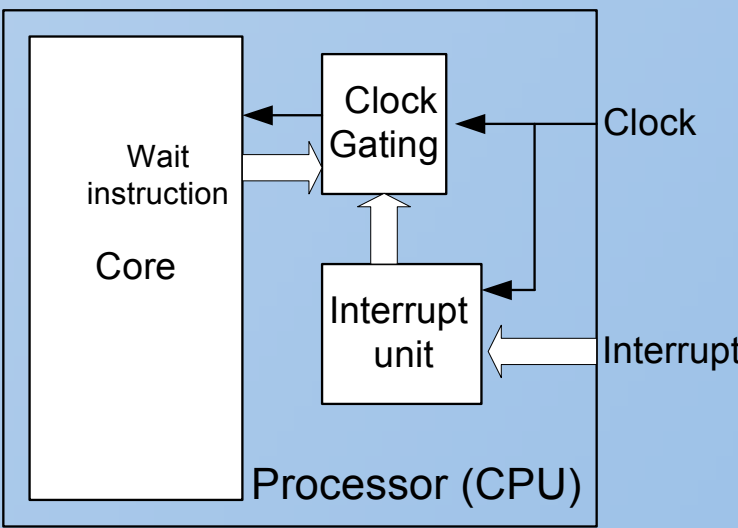
Interface System Architecture

xDSL :   Full support of L2 and L3 power saving Modes
Ethernet : Energy Efficient Ethernet EEE [3], Low Power Link Detection
WLAN: Noise dependent TX Power adaption, Interrupt free Beacon Only Mode
DECT / CatIQ: Low Power NEMO Mode, Interrupt free Beacon Only Mode
FXS Telephony: Low Power Standby Mode, Automated High Voltage Reduction, Automatic Phone Plug Detection
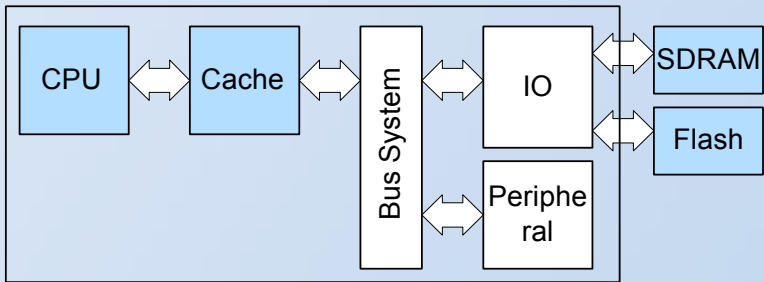USB: Full Suspend Resume support

LPI   Low-Power-Idle (LPI)

Power-Consumption adopts to Home-Networking Traffic!
IEEE802.3az   IEEE802.3az

*EEE Energy Efficient Ethernet [3] (source M. Traeber)*

Hardware

- Low Power Technology
- Automated local Hardware Clock Gating
- Peripheral Level Clock Gating
- Global Clock Gating
- Processor Instruction based Clock Gating
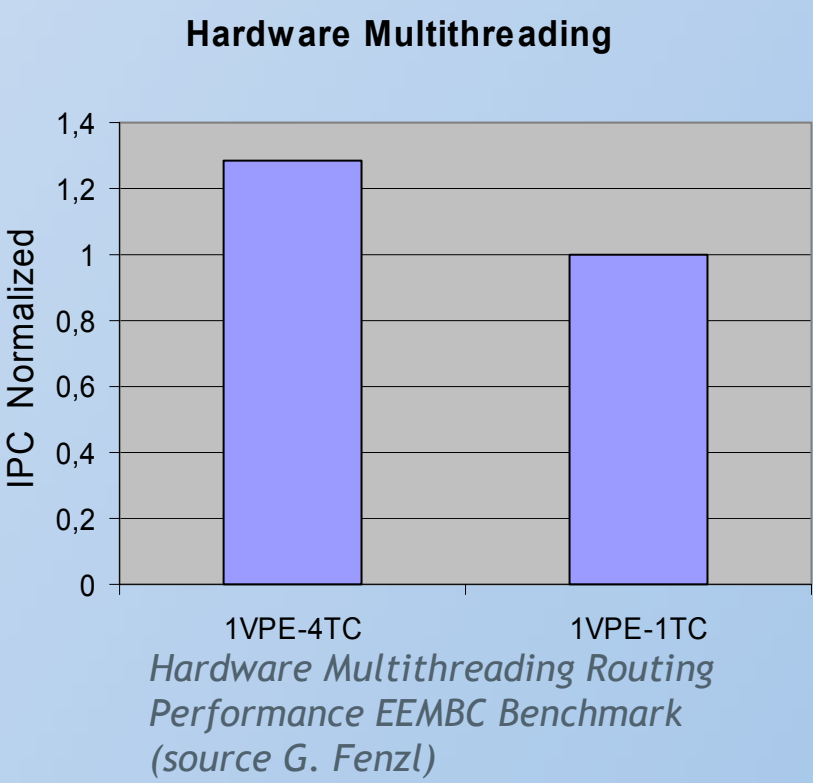- Dynamic Voltage Scaling
- Power Islands

Processor (CPU): Wait instruction, Core, Clock Gating, Clock, Interrupt unit, Interrupt

Processor System

CPU, Cache, Bus System, IO, Peripheral, SDRAM, Flash

The Memory Wall Issue [4, 5]
Increase in processor speed is much higher than corresponding increase in (off-chip) memory speed. Leads to generation of energy wasting stall cycles.
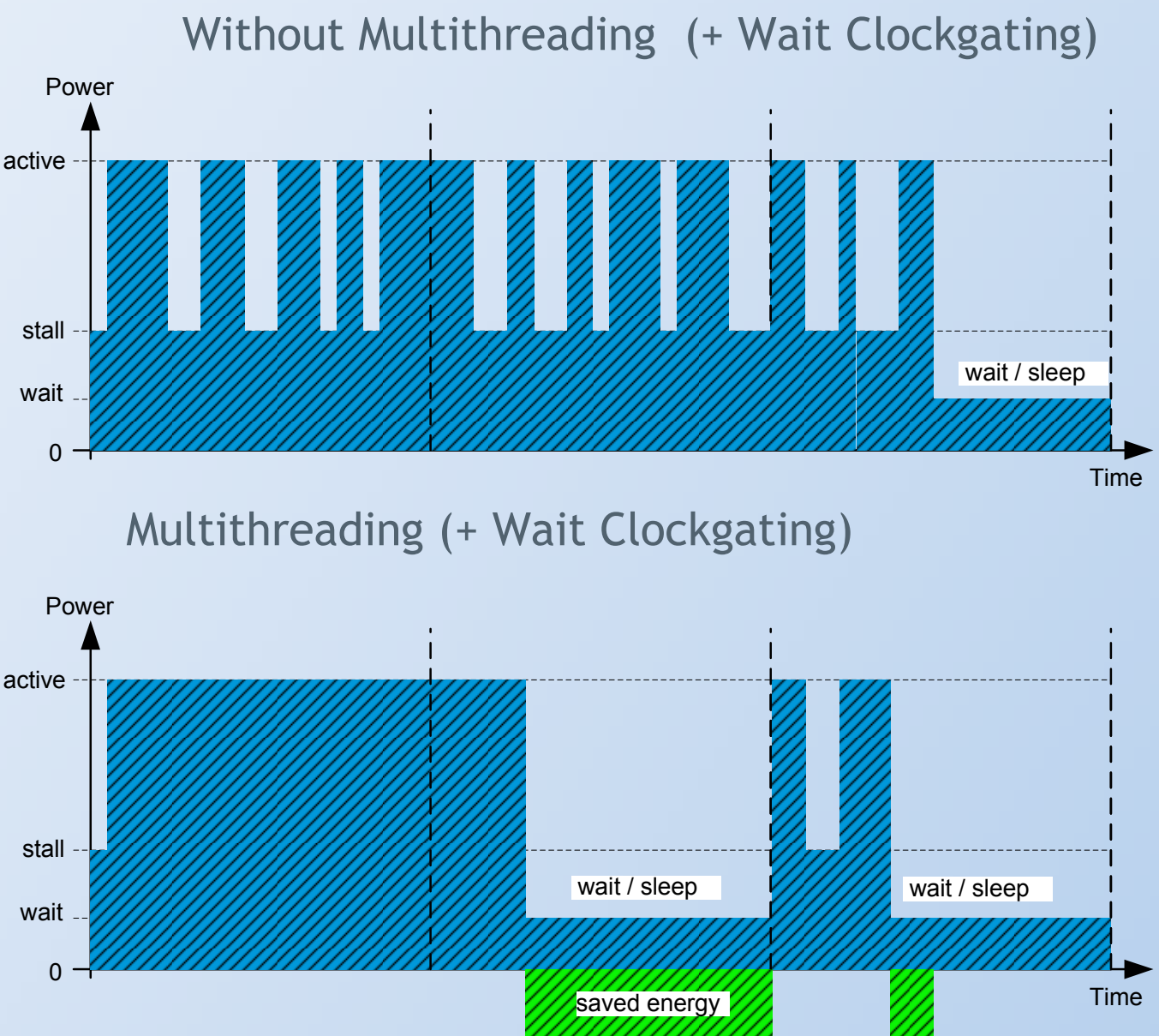
Optimizing the Processor Memory system
✓ Cache Size
✓ Multi Way Caches
✓ Tightly coupled Memories
✓ Hiding of Cache Latency by Multi- Threading

Without Multithreading (+ Wait Clockgating)

Power: active, stall, wait; wait / sleep; Time

Multithreading (+ Wait Clockgating)

Power: active, stall, wait; wait / sleep; Saved energy; Time

Hardware Multithreading

IPC Normalized: 1VPE-4TC ≈ 1.3, 1VPE-1TC = 1.0

Hardware Multithreading Routing Performance EEMBC Benchmark (source G. Fenzl)

Software / Firmware

- Implementation of low level saving protocols
- Adaption of Hardware States to the Application Performance Requirement
- In time Activation of Power Saving Functions like DRAM Power Down
- Operating System Support for optimum Energy Efficiency (for example advanced WAIT instruction)
- Abstraction of Hardware Functionality with system states similar to ACPI [6]
- API making Power saving functions available to Application

Further Steps

⇥Integration of "Always On" products to Home Gateway thereby improving overall system power
⇥Enabling attached products to enter lower power states
⇥Further Architecture optimization for higher functionality
⇥Intelligent Control of Household Devices
⇥E- metering

REFERENCES
[1] N. F. Nissen, German-French Expert Workshop on Standby and IPP 31.05.2007, Berlin, "Status of the EuP Preparatory Study Lot 6 on Standby and Off-mode Losses", foil 55, Fraunhofer-Institut für Zuverlässigkeit und Mikrointegration IZM, Dept. Environmental Engineering

[2] European Commission, Joint Research Centre, "Code of Conduct on Energy Consumption of Broadband Equipment", Version 3, 18 November 2008

[3] IEEE Energy Efficient Ethernet Task Force, "Draft Amendment to IEEE Std 802.3-2008, IEEE 802.3az"

[4] P. Machanik, "Approaches to Addressing the Memory Wall", TR Nov. 2002, U. Brisbane

[5] Peter Marwedel, "Memory-architecture aware compilation", Universität Dortmund

[6] Advanced Configuration and Power Interface Specification Rev 3.0b ACPI