Moving Toward Energy Efficient Access Networks

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GreenTouch Wireline Access
50x reduction power per user / 500x efficiency gain

Un-cooled tunable lasers
Low power OFDM in optical access

Virtual HGW

Bell Labs
Novel PON protocols; Low power electronics

Transparent CPE

Also: TNO, ZTE, KAIST

Min. energy access architectures
Sleep modes; Hybrid PON

INRIA
University of Cambridge
Swisscom

CEET
Centre for energy-efficient telecommunications

IBBT

AIT
Centre of Excellence for Research and Education

Oberth" as Optimus

GreenTouch
Why is energy reduction of fixed broadband important?

- Fixed Broadband is an important part of the total carbon footprint of ICT
- Lower power reduces cost
  - Reduces OPEX
  - Allows for higher density, hence reduced floorspace
  - 2x for additional consumption (supply, cooling)
  - Reduces back-up battery
  - Alternative supplies in remotes (e.g. reverse power feed via DSL)

GESI: Smart2020: Enabling the low carbon economy in the information age

49 MtCO$_2$e
Dissipation in Current Fixed Access

- GPON OLT: 0.35 W/user (1:32 split)
- 13 W/ONU (GPON + Gateway)
- Optical feeder: 0.2 W/user
- VDSL: 1.8 W/port
- Remote
- ADSL: 1.2 W/port
- 9.1 W/CPE (ADSL2 + Gateway)
- 10.3 W/CPE (VDSL2 + Gateway)

(Upper bound values from EU CoC – CPE includes 4xFE, WiFi, and voice)

Focus of this presentation
GPON Improvements - GreenTouch roadmap

Ref (2010): GPON (w/o WLAN) = 7.4 W

- Power shedding
- Sleepmode
- EE HW design
- Sleepmode 2
- Virtual HGW
- Long reach
- Transparent CPE
- BI PON
- Low power Optics
- Low power electronics

Wireless LAN
OLT (per user)
HGW processor
Wireline LAN (Eth.)
PON digital
OE PON

>50x per subscriber
Energy Saving Techniques

- **Short term**
  - Sleep modes
  - Energy Efficient Hardware design

- **Medium term**
  - Sleep modes 2
  - Virtual Home Gateway
  - Long reach access

- **Long term**
  - Bit-Interleaving PON
  - Transparent CPE
  - Low power electronics and optics
Fast Sleep Mode

- Aim for awake time ONU proportional to useful payload
- Challenges
  - Schedule probing cycles and awake time with minimum impact on QoE
  - Minimize power during sleep state
  - Minimize fast wake-up

![Diagram showing power consumption in Fast Sleep Mode](image)

- Probing for data (e.g., 1ms)
- Wake-up Preamble (~us)
- No data Power in Fast sleep state
- Data Power in active state
- Periodic probing for data e.g., <20 ms
Special functionality may be required for some system concepts and may not be for others.

TDMA: Time Division Multiple Access; DSP: Digital Signal Processing; Mod: Modulator; OA: Optical Amplification; DC: Dispersion Compensation; SoC: System on Chip; SLIC: Subscriber Line Interface Circuit; GbE: Gigabit Ethernet; MoCA: Multimedia over Coaxial Alliance
ONU Power Consumption Model (Power Shedding)

Special Functionality
- TDMA
- DSP
- Mod
- OA
- DC

Core Functionality
- Digital Optics
- SoC
  - Memory = 30 mW/MB
  - Miscellaneous losses = 5%
  - Power Conversion efficiency = 80%

Service Interface
- Dual SLIC
- GbE
- Analog Optics
- MoCA

: Component not used
: Low activity (in SLICs due to no on-hook transmission; SoC: due to reduced processing speed)

Digital Optics
Memory = 30 mW/MB
Miscellaneous losses = 5%
Power Conversion efficiency = 80%

MoCA
GbE
Analog Optics
Dual SLIC
ONU Power Consumption Model (Doze state)

Special Functionality:
- TDMA
- DSP
- Mod
- OA
- DC

Core Functionality:
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- SoC
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Service Interface:
- Dual SLIC
- GbE
- Analog Optics
- MoCA

: Component not used
: Low activity (in SLICs due to no on-hook transmission; SoC: due to reduced processing speed)
: 50% power savings
ONU Power Consumption Model (Sleep state)

- **Core Functionality**
  - **Digital Optics**
  - **SoC**
    - Memory = 30 mW/MB
    - Miscellaneous losses = 5%
    - Power Conversion efficiency = 80%

- **Service Interface**
  - Digital SLIC
  - GbE
  - Analog Optics
  - MoCA

- **Special Functionality**
  - TDMA
  - DSP
  - Mod
  - OA
  - DC

Note that the SoC power consumption will further reduce compared to doze state due to even reduced processing:

- Component not used:
- Low activity (in SLICs due to no on-hook transmission; SoC: due to reduced processing speed)
- 50% power savings

Component not used:
- Low activity (in SLICs due to no on-hook transmission; SoC: due to reduced processing speed)
- 50% power savings
ONU Power Consumption in Different States

The diagram shows the ONU power consumption (mW) for various states: Active, Power Shedding, Doze State, and Sleep State. Each category is represented by different colors:

- **Active**: Red
- **Power Shedding**: Purple
- **Doze State**: Yellow
- **Sleep State**: Green

The categories represented are:
- GPON
- HB-TDMA
- WDM-TL
- WDM-RSOA
- Passive-TWDM
- SemiPassive-TWDM
- AON
- Pt-t-Pt

The graph illustrates the power consumption levels for each category across different ONU types.
Wireline access PON improvements

- Power shedding
- Sleepmode

- Short Term
- Medium Term
- Long Term

Legend:
- Wireless LAN
- OLT (per user)
- HGW processor
- Wireline LAN (Eth.)
- PON digital
- OE PON

GreenTouch
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Virtual Home Gateway / Quasi-passive CPE

- Transparent CPE providing connectivity in-house and to network
  - Functions of current CPE moved to virtual HGW in network
  - Low power connectivity (“quasi-passive”) or transparent (“passive”) CPE

- Savings:
  - Cut-through of high bitrate services to terminal: LAN interfaces on CPE
  - Lower power by processor platform sharing
    - >5x reduction per subscriber demonstrated
Energy Saving Techniques

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Standard XG-PON

10 Gb/s

~10 Mb/s
Bit-Interleaving PON

10 Gb/s ~ 10 Mb/s
Demonstrator

More than order of magnitude better efficiency of MAC electronics for Bi-PON than XG-PON in cyclic sleep mode!

Link to video about the press release and demo http://www.greentouch.org/index.php?page=Bi-PON
Wireline Access Improvements

Average Power/Subscriber (Watt)

Wireless LAN
OLT (per user)
HGW processor
Wireline LAN (Eth.)
PON digital
OE PON

Short Term
Medium Term
Long Term
Conclusion: Wireline Access Energy efficiency

- Low power electronics
- BI PON
- Transparent CPE
- Long reach
- Virtual HGW
- Sleepmode 2
- EE HW design
- Sleepmode
- Power shedding

500x Efficiency gain (Energy per useful bit)
Thanks for your Attention..
Any Questions?

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