



## Towards Energy Efficient Home Networks

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Stanford University

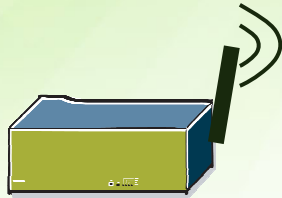
(3)  Inria

# Outline

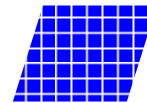
- Why ?
- Power consumption for Home Networks
- Short term approaches for greening the home network
  - Sleep mode
- Long term approaches
  - Virtual home gateway
  - Quasi-passive CPE
  - Virtualization of other home devices
- Conclusions

# Why lower power Home Networks ?

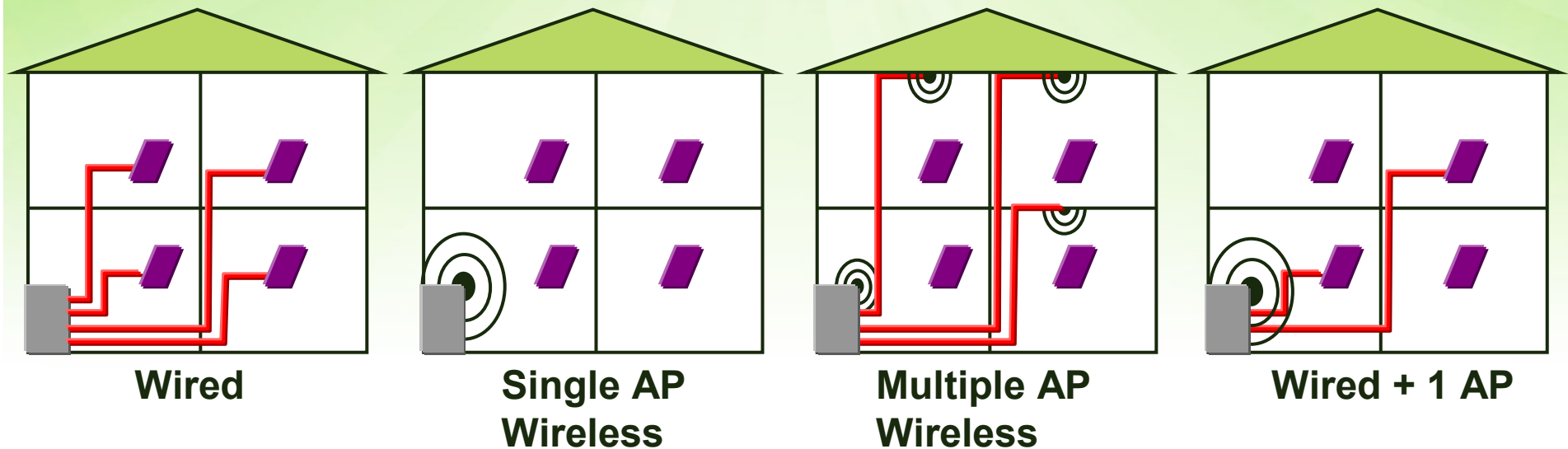
- 24 h always-on connectivity service
  - 10W of Home Network for 24 h similar to 80 W of TV for 3 h



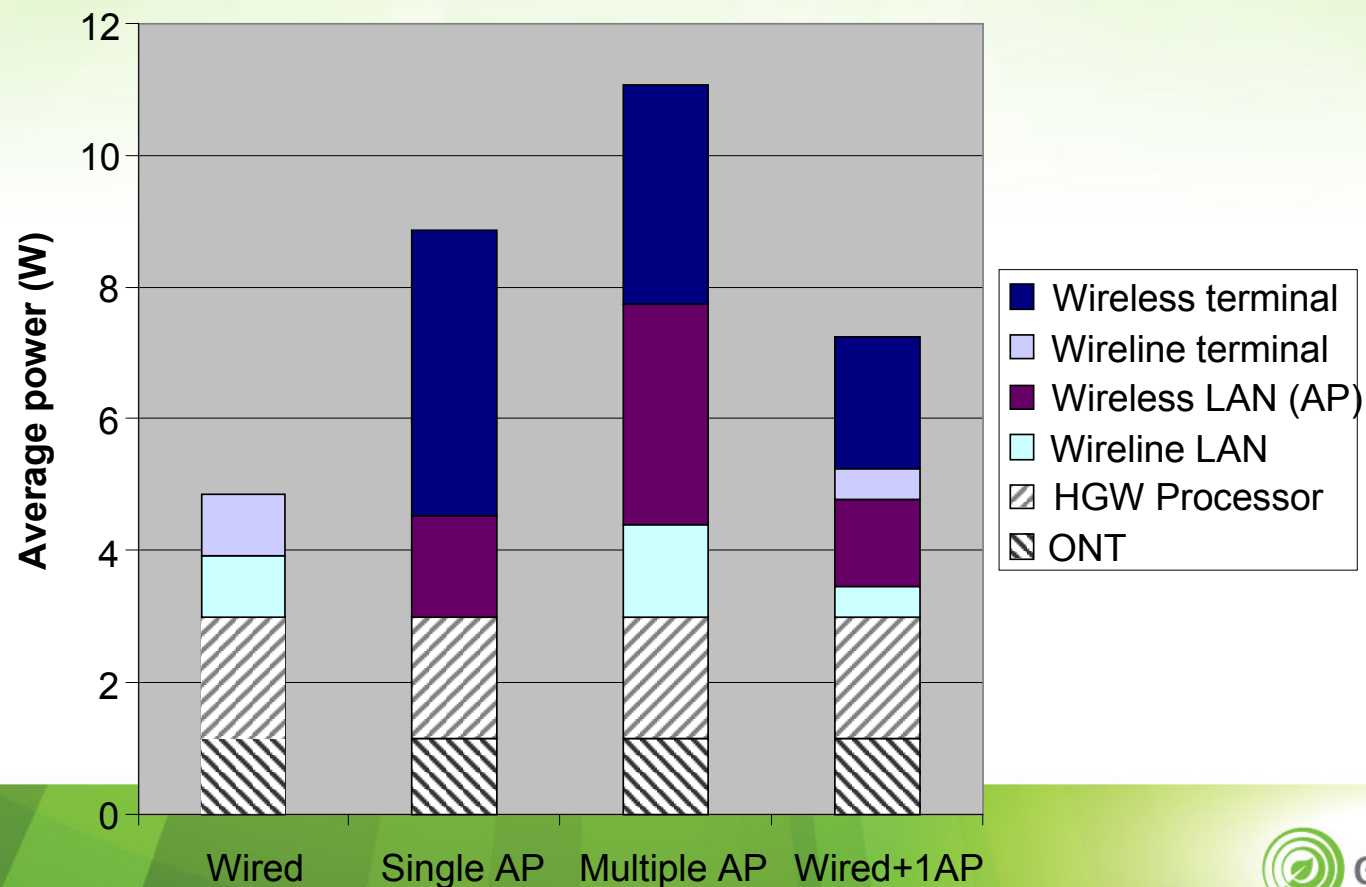
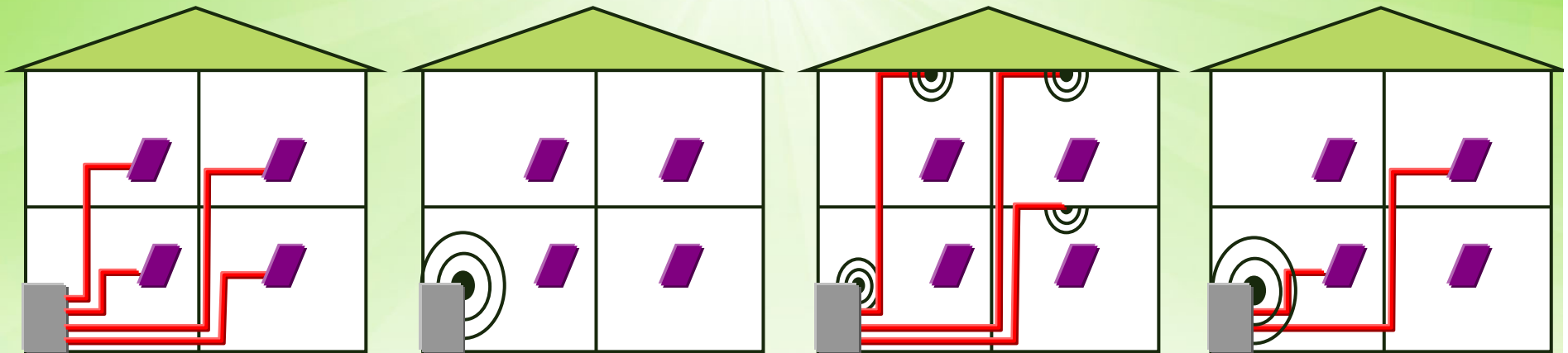
- Battery lifetime or energy scavenging for HN elements and devices
  - Back-up for voice during power outages
  - No need for AC-power supply => installation flexibility



# Power consumption of in-house networks

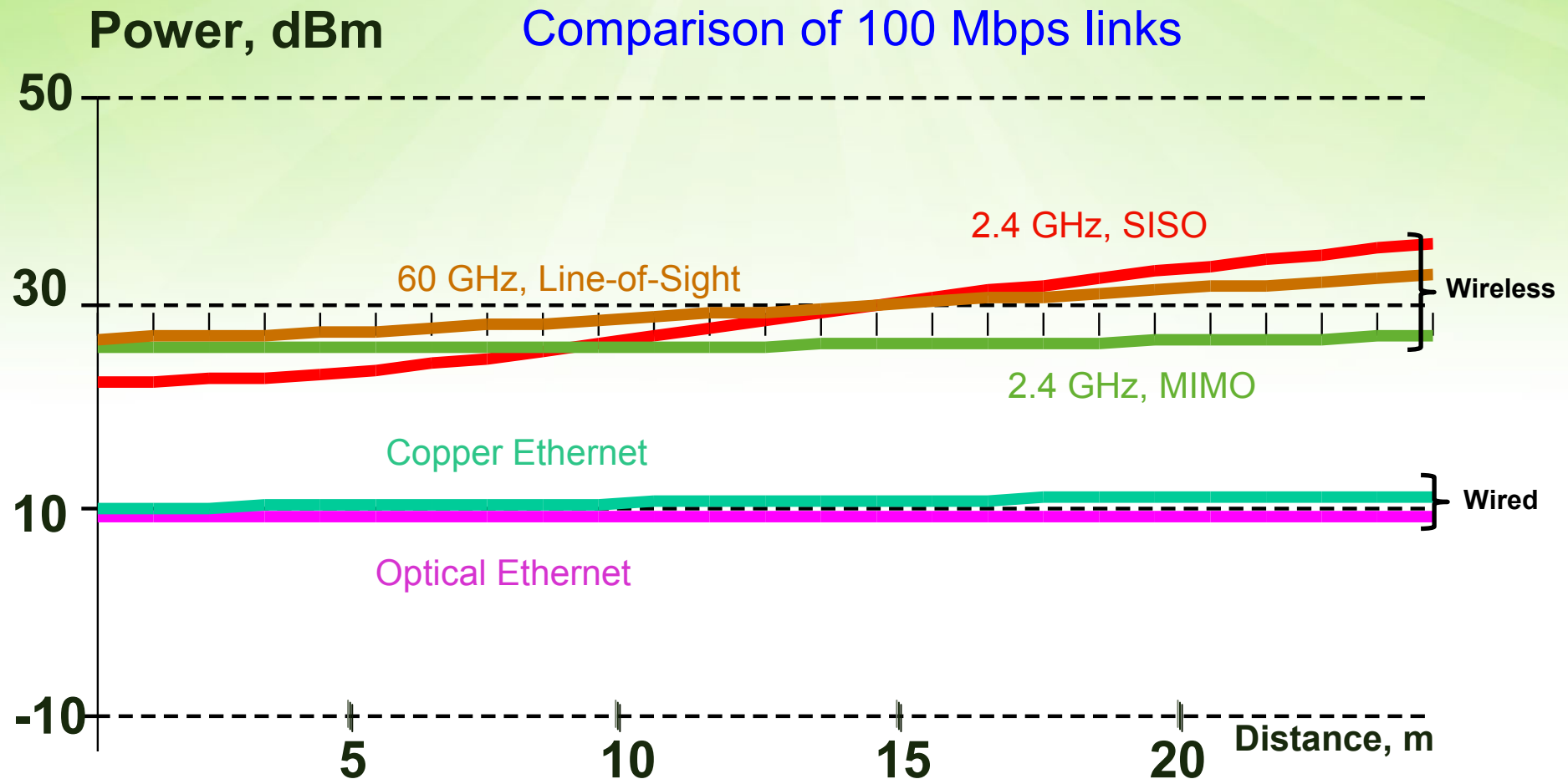


- Model assumptions:
  - Wireline Fast Ethernet
  - Single AP: 802.11n (EIRP 30 dBm - across house)
  - Multiple AP: Wireline FE + 802.11g (EIRP 23 dBm - in single room)
  - Average: 8 h active state, 16 h idle state, activity in 2 rooms
  - 4 terminals connected
  - Values EU CoC v4, Tier 2013-2014
  - Proportional power supply inefficiency included



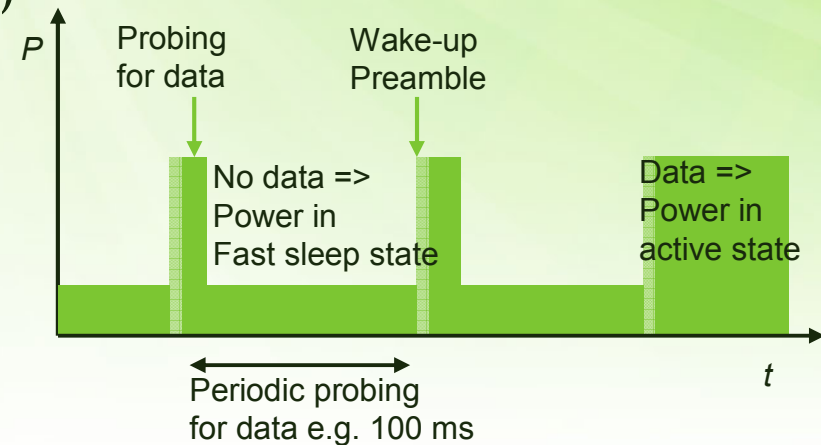
Note: Includes state of the art power during idle when not in active

# Power Consumption of Wired and Wireless Links



# Sleep Mode in Home Network

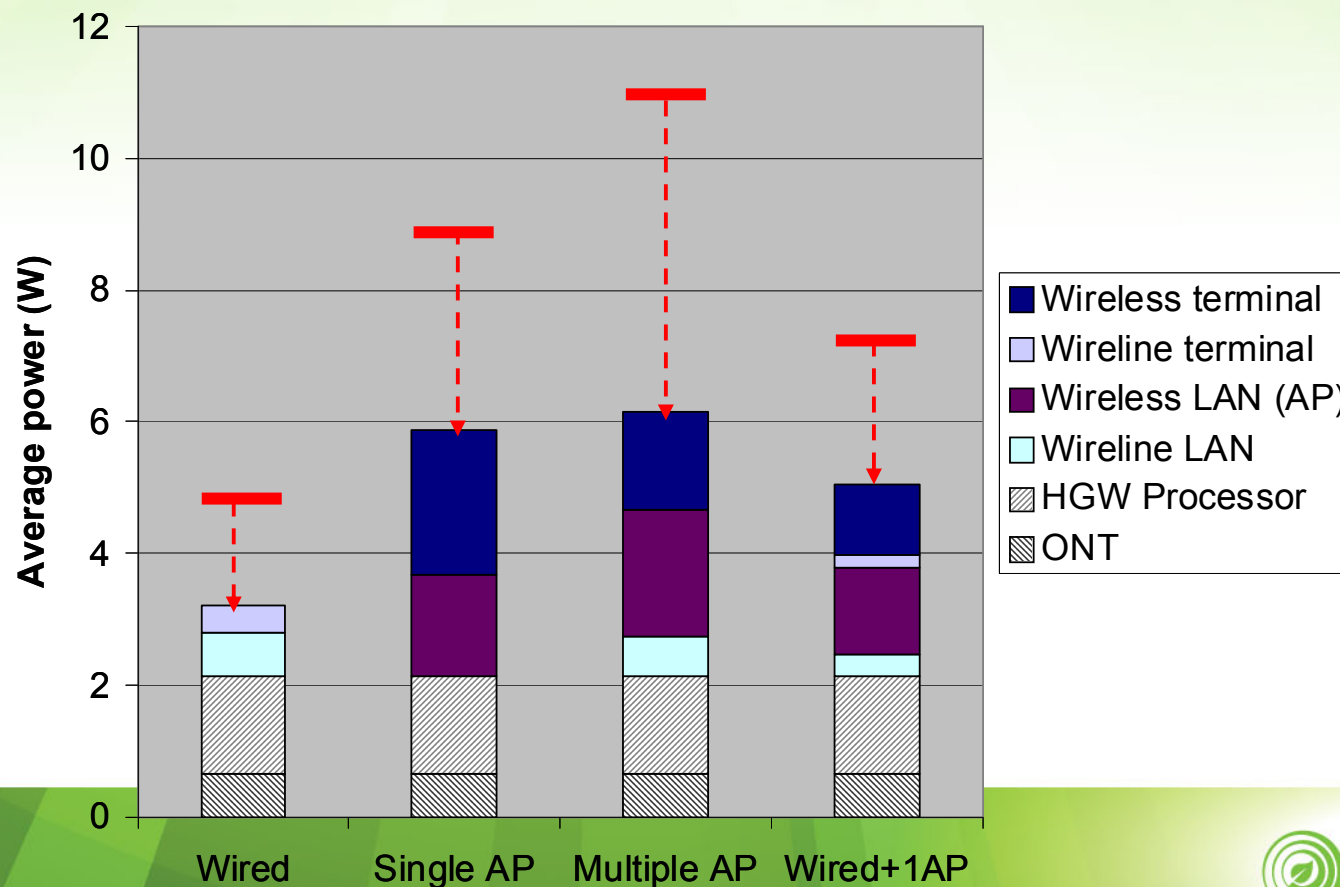
- Sleepmode on Wireline 802.3az (“EEE”)
  - Defined for Cu cable and Backplane, however also suited for fiber links
  - Turn off front-end
  - Periodic probing for activity detection
- Wireless power management in 802.11



- Savings in sleep state are trade-off with required wake up time
  - Typical wake-up times of electronic functionality:
    - 1-10  $\mu$ s to activate front-end circuit
    - 1-10 ms to activate processor logic
    - 1-10 s to establish context on processor
  - Home gateway timing requirements (HGI RD-009-R3):
    - 1s for activation of voice services
    - 3s for activation of Ethernet services
    - 10s deactivation of services

# Power consumption with sleep mode

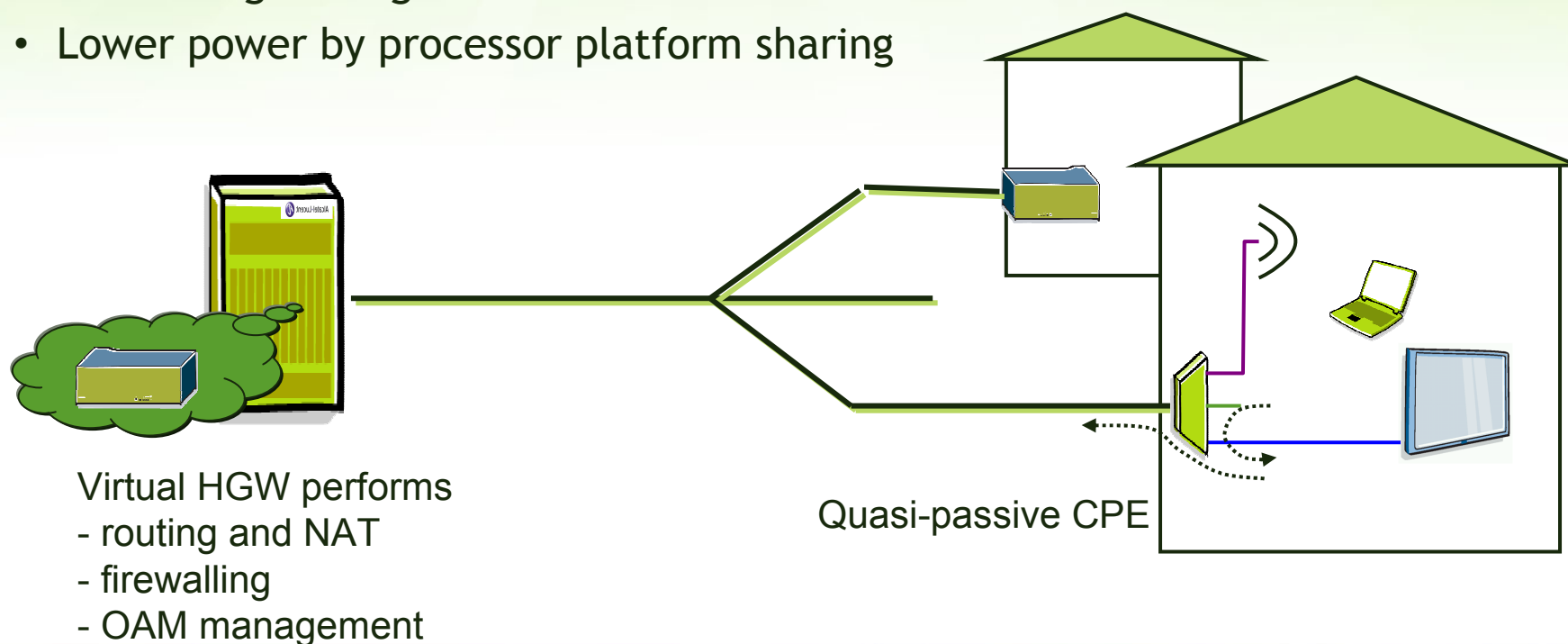
- About 30-50% saving
  - ONT and home network in fast sleep state to allow service in 1-3s



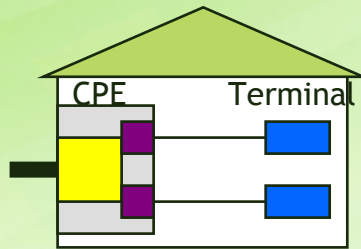


# Virtual Home Gateway / Quasi-passive CPE

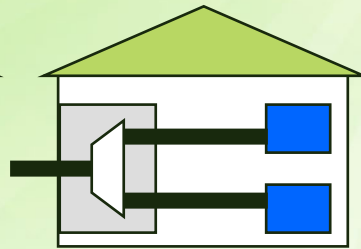
- Transparent CPE providing connectivity in-house and to network
  - Functions of current CPE moved to virtual HGW in network
  - Low power connectivity (“quasi-passive”) or transparent (“passive”) CPE
- Savings:
  - Cut-through of high bitrate services to terminal: LAN interfaces on CPE
  - Lower power by processor platform sharing



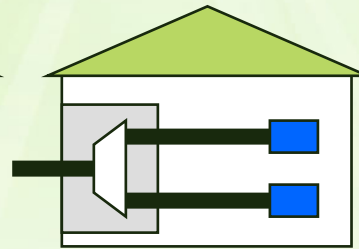
# Transparent CPE options



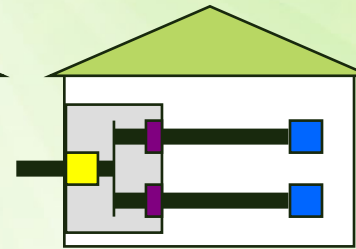
A. Reference:  
Conventional  
access and HN



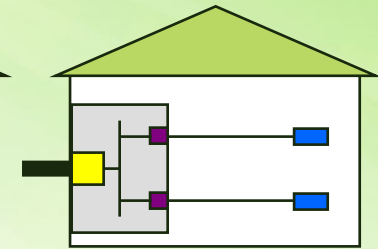
B. Passive:  
standard PON  
protocol



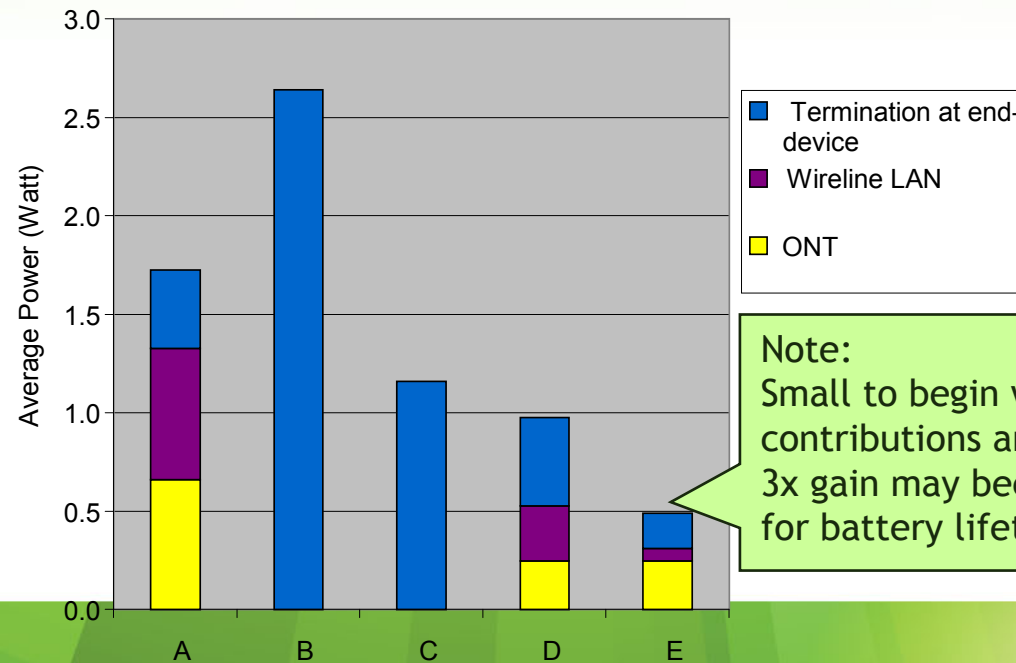
C. Passive:  
new Bi-PON  
protocol



D. Quasi-passive:  
OEO - full rate in  
home



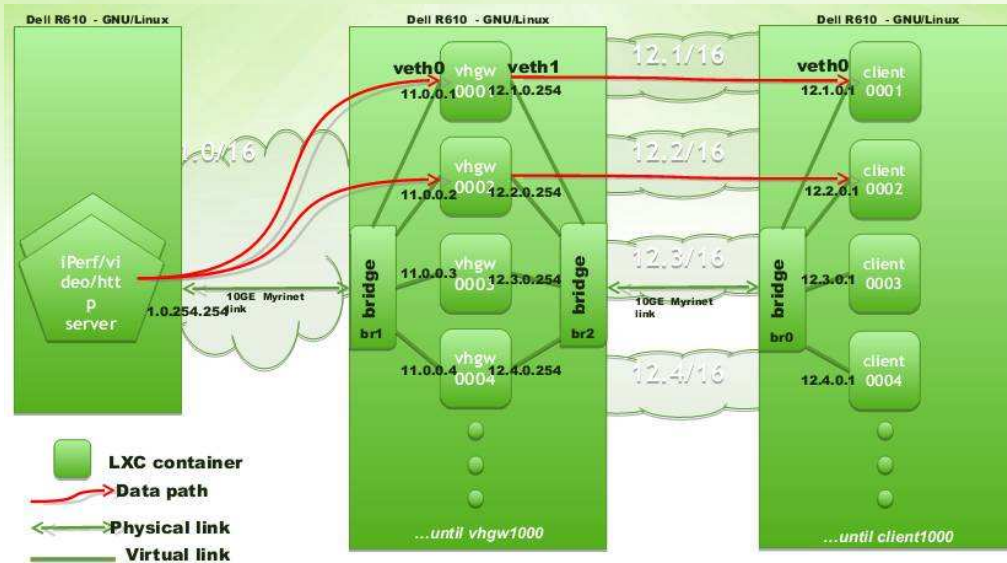
E. Quasi-passive:  
OEO - reduced  
rate in home



Note:  
Small to begin with - other power  
contributions are currently higher priority.  
3x gain may become useful in long term e.g.  
for battery lifetime optimization.

# GreenTouch VHG demo

- Prototype Dell server <150 W with #1000 VHG
- LXC Containers in Linux optimized for power

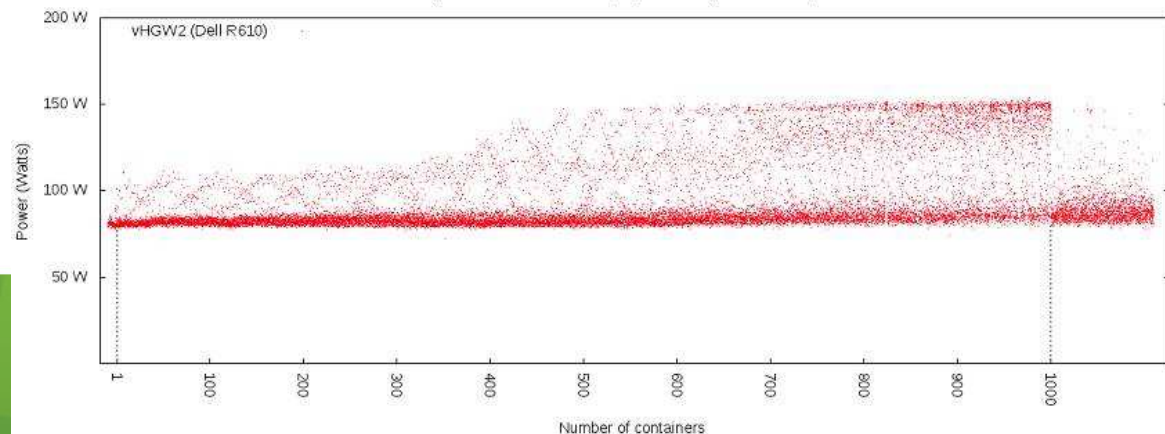


## TIA Exhibition Dallas June 2012



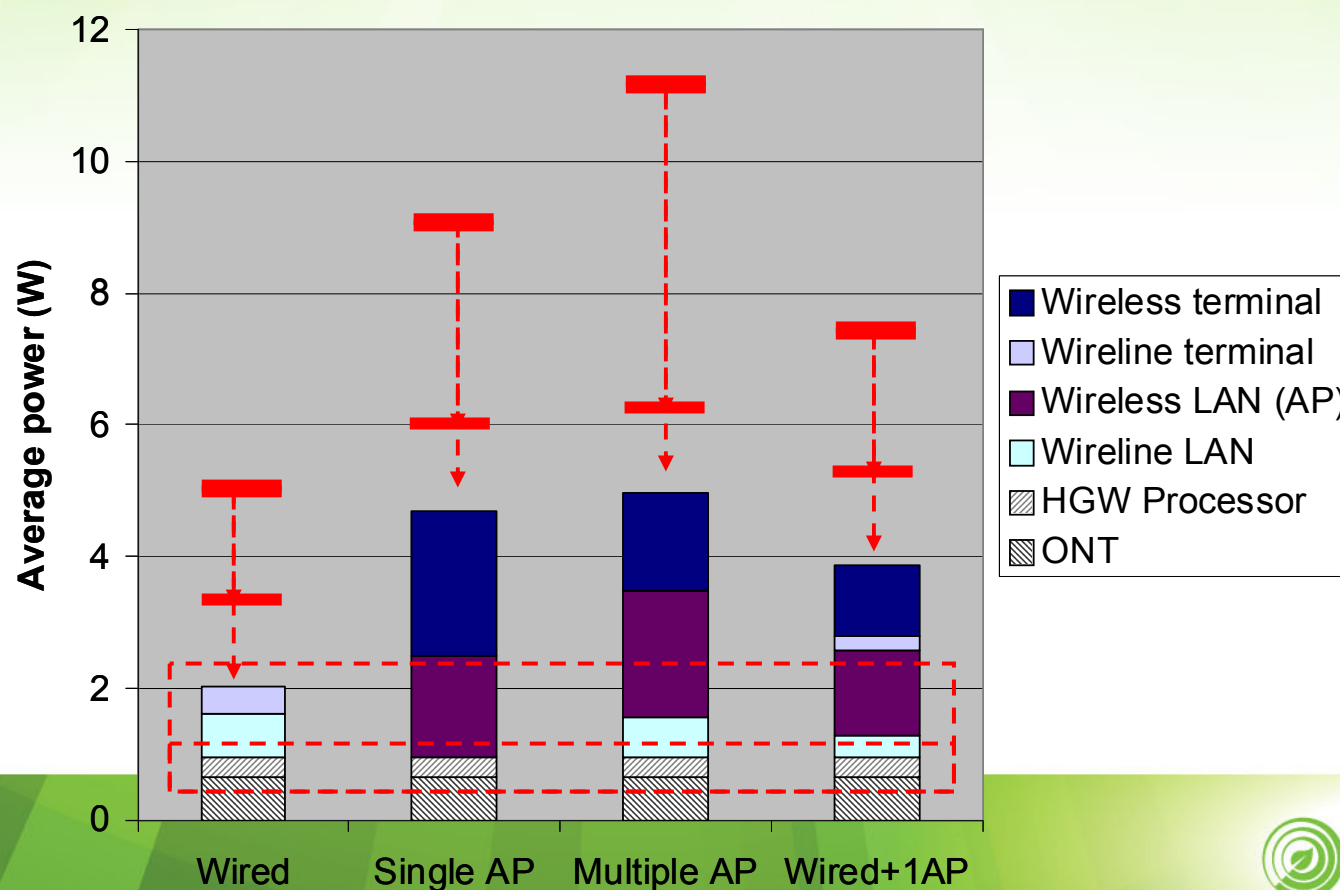
L. Lefevre, J.P. Gelas, T. Assefa.  
**"Virtualizing Home Gateways for large  
 scale energy reduction in networks",**  
 Electronic Goes Green 2012 (EGG)  
 Conference, Berlin, Germany, Sept. 2012

*Inria*



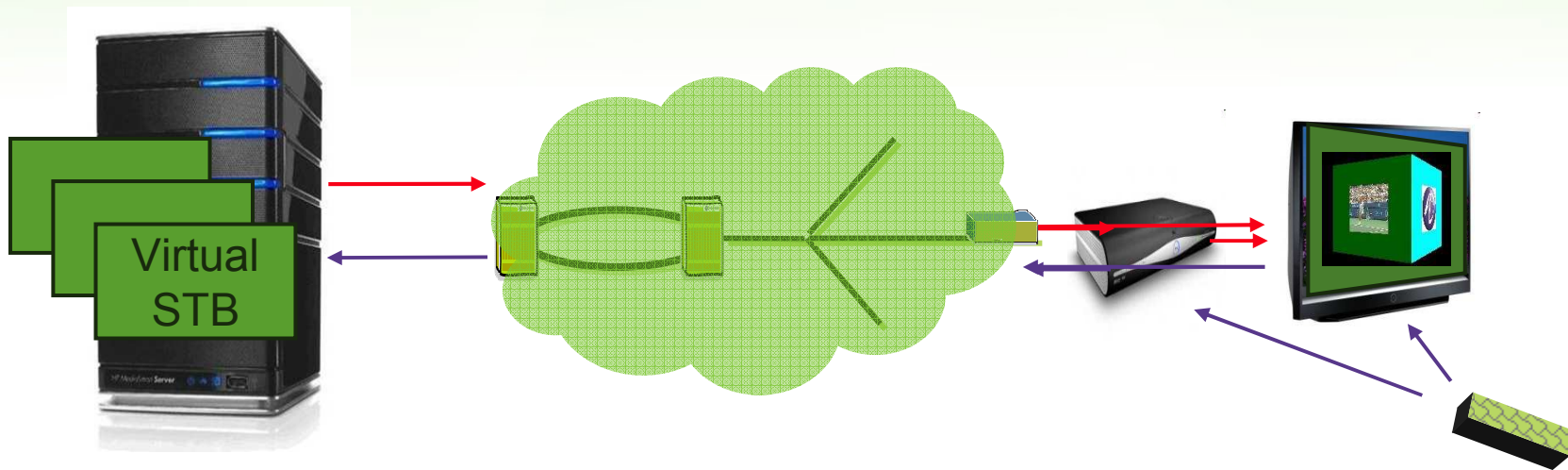
## Power consumption with VHG for CPU

- >5x reduction of HGW processor thanks to
  - Time multiplexing of shared processor on server
  - Single OS instantiated - VHG separated by containers



# Virtualization of other devices e.g. Set Top Box

- Move functions of STB from home to server in network
- Reduces overall power consumption
- Other benefits:
  - Enable new features without need for new HW (avoids OPEX and CAPEX for replacement)



- Virtualization of other devices: e.g. PC, Game Box

*Courtesy: Wim Acke, Bell Labs*



## Summary

- Wired HN is most energy efficient
  - Combination with single wireless AP desired for flexibility
  - Fiber HN slightly better than Cu, but not decisive
- Sleep modes provide 30-50% lower average power in HN
- VHG concept reduces consumption of processor by >5x
  - Virtualization also beneficial for other devices
  - Virtualization is mainly motivated by other benefits, but also improves energy efficiency