Dynamic Resource Operation and Power Model for IP-over-WSON Networks

EUNICE 2013, Chemnitz

Uwe Bauknecht, Frank Feller
{uwe.bauknecht,frank.feller}@ikr.uni-stuttgart.de
2013-08-28

Universität Stuttgart
Institute of Communication Networks and Computer Engineering (IKR)
Prof. Dr.-Ing. Andreas Kirstädter
Table of Contents

Motivation
IP-over-WSON\textsuperscript{1} Networks
Line Card Model
Conclusion

1. Internet Protocol over Wavelength Switched Optical Network
Motivation

Reduction of Power Consumption in Core Networks

Energy Consumption in Networks

2012 share of ICT equipment: 4.7%\(^1\) of worldwide electrical energy

\(~1/3\) end user equipment, \(1/3\) data centers, \(1/3\) communication networks

1. Not contained: smart phones, networked TVs, game consoles etc. Data from EINS Deliverable 8.1.
Motivation

Reduction of Power Consumption in Core Networks

Energy Consumption in Networks

2012 share of ICT equipment: 4.7%\(^1\) of worldwide electrical energy

~1/3 end user equipment, 1/3 data centers, 1/3 communication networks

Focus on Core Networks

Present situation

- Mode of operation: always on
- No explicit power saving features
- Load dependency: <10%\(^2\)

1. Not contained: smart phones, networked TVs, game consoles etc. Data from EINS Deliverable 8.1.

DE-CIX 2-day graph: average traffic in bit/s
Motivation

Reduction of Power Consumption in Core Networks

Energy Consumption in Networks

2012 share of ICT equipment: 4.7%¹ of worldwide electrical energy
~1/3 end user equipment, 1/3 data centers, 1/3 communication networks

Focus on Core Networks

Present situation
• Mode of operation: always on
• No explicit power saving features
• Load dependency: <10%²

¹ Not contained: smart phones, networked TVs, game consoles etc. Data from EINS Deliverable 8.1.
² Cf. "Power Awareness in Network Design and Routing", Chabarek et al., 2008

DE-CIX 2-day graph: average traffic in bit/s
Source: DE-CIX Traffic Statistics,
© 2013 DE-CIX Management GmbH
Motivation

Reduction of Power Consumption in Core Networks

Energy Consumption in Networks

2012 share of ICT equipment: 4.7%\(^1\) of worldwide electrical energy
~1/3 end user equipment, 1/3 data centers, 1/3 communication networks

Focus on Core Networks

Present situation
- Mode of operation: always on
- No explicit power saving features
- Load dependency: <10%\(^2\)

Envisioned future
- Mode of operation: dynamic
- Deactivation of resources
- Power follows load more closely

DE-CIX 2-day graph: average traffic in bit/s

---

1. Not contained: smart phones, networked TVs, game consoles etc. Data from EINS Deliverable 8.1.
Motivation

Formulation of Detailed Models

Quantify potential Savings

- Percentage of energy saved through deactivation?
- Absolute amount of energy savings?
- How much is achievable in a particular network?

Dynamic Resource Operation

- Adaptable components
- Applicable power saving schemes
- Effectiveness

Power Consumption

- Primary contributors
- Component power values
IP-over-WSON Networks

Core Network Example
IP-over-WSON Networks

Basic Multi-Layer Structure

IP / Electrical Layer
IP-over-WSON Networks

Basic Multi-Layer Structure

IP / Electrical Layer

WSON / Optical Layer
IP-over-WSON Networks

Basic Multi-Layer Structure
IP-over-WSON Networks

Basic Multi-Layer Structure

IP / Electrical Layer

WSON / Optical Layer
IP-over-WSON Networks

Basic Multi-Layer Structure
IP-over-WSON Networks

Logical Node Structure

Core Router

Routing Engine

IF #1

IF #2

IF #3

IF #4

IF #5

IF #6

Access

WSON-Node

Power Consumption

100%

50%

0%

100%

50%

0%
IP-over-WSON Networks

Logical Node Structure

Core Router
Routing Engine

IF #1
IF #3
IF #5

IF #2
IF #4

WSON-Node

Access

Power Consumption

100% 50% 0%

100% 50% 0%
IP-over-WSON Networks

Logical Node Structure

Core Router

IF #1
IF #3
IF #5

Routing Engine

IF #2
IF #4

WSON-Node

Power Consumption

Access

© 2013 Universität Stuttgart • IKR
U. Bauknecht, F. Feller – EUNICE 2013
IP-over-WSON Networks

Logical Node Structure

Core Router

Routing Engine

IF #1

IF #2

IF #3

IF #4

IF #5

IF #6

WSON-Node

Access

Power Consumption

100%

50%

0%

100%

50%

0%
IP-over-WSON Networks

Component-Based Model
IP-over-WSON Networks

Component-Based Model
Line Card

Components and Power Consumption

Functionality

- Provide network interfaces
- Classify packets
- Store and forward packets
- Connect to switch fabric
Line Card

Components and Power Consumption

Functionality
- Provide network interfaces
- Classify packets
- Store and forward packets
- Connect to switch fabric

Components
- Forwarding Engine
- Port Card with Transceivers

Diagram:
- Forwarding Engine
- Port Card
- to Switch Fabric
- to WSON Node

Power Consumption:
- 446 W
- 209 W
Line Card

Components and Power Consumption

Functionality
- Provide network interfaces
- Classify packets
- Store and forward packets
- Connect to switch fabric

Components
- Forwarding Engine
  - Network Processors (NP) & ASIC
  - Memory
  - Power conversion, control and auxiliary logic
- Port Card with Transceivers
  - Transceivers
  - Port Card with ASIC

![Diagram showing components and power consumption]
Line Card

Dynamic Operation

Sleep States

Transceiver inactive ⇒ sleep

All Transceivers asleep ⇒ Line Card to sleep
Line Card

Dynamic Operation

Sleep States

Transceiver inactive $\Rightarrow$ sleep

All Transceivers asleep $\Rightarrow$ Line Card to sleep

Power/Load Dependency

- NP: >100 cores.
  - Idle power assumed at 30%
  - $\Rightarrow$ 70% scale linearly with IP-Traffic
Line Card

Dynamic Operation

Sleep States

Transceiver inactive \(\Rightarrow\) sleep

All Transceivers asleep
\(\Rightarrow\) Line Card to sleep

Power/Load Dependency

- NP: >100 cores.
  Idle power assumed at 30%
  \(\Rightarrow\) 70% scale linearly with IP-Traffic

- Memory: packet buffers
  Size related to bandwidth-delay product
  \(\Rightarrow\) 50% scale with capacity of active transceivers
Line Card

Dynamic Operation

Sleep States

Transceiver inactive $\Rightarrow$ sleep

All Transceivers asleep $\Rightarrow$ Line Card to sleep

Power/Load Dependency

- NP: $>100$ cores.
  - Idle power assumed at 30%
    $\Rightarrow$ 70% scale linearly with IP-Traffic

- Memory: packet buffers
  - Size related to bandwidth-delay product
    $\Rightarrow$ 50% scale with capacity of active transceivers

- Memory: routing information
  $\Rightarrow$ 50% assumed static
Line Card

Dynamic Operation

Sleep States

Transceiver inactive ⇒ sleep
All Transceivers asleep ⇒ Line Card to sleep

Power/Load Dependency

- NP: >100 cores.
  Idle power assumed at 30%
  ⇒ 70% scale linearly with IP-Traffic
- Memory: packet buffers
  Size related to bandwidth-delay product
  ⇒ 50% scale with capacity of active transceivers
- Memory: routing information
  ⇒ 50% assumed static
- Power conversion, control and auxiliary logic
  ⇒ Assumed static
Line Card

**Dynamic Operation**

Current traffic demand: 0%

*Forwarding Engine*
- Base: Sleep
- NP: Sleep
- Mem: Sleep

*Port Card*
- ASIC: Sleep
- Transceiver #1: Sleep
- Transceiver #2: Sleep
- Transceiver #3: Sleep

---

Power in Watt

Traffic in % of LC capacity
Line Card

Dynamic Operation

Current traffic demand: 0%

Forwarding Engine
- Base: 147 W
- NP: 64 W
- Mem: 53 W

Port Card
- ASIC: 47 W
- Transceiver #1: 8 W
- Transceiver #2: Sleep
- Transceiver #3: Sleep

Traffic in % of LC capacity: 0%

Power in Watt: 0
Line Card

Dynamic Operation

Current traffic demand: 25%

Forwarding Engine
- Base: 147 W
- NP: 96 W
- Mem: 53 W

Port Card
- ASIC: 47 W
- Transceiver #1: 8 W
- Transceiver #2: Sleep
- Transceiver #3: Sleep

![Diagram showing power consumption and traffic demand relation]
Line Card

Dynamic Operation

Current traffic demand: 50%

Forwarding Engine
- Base: 147 W
- NP: 128 W
- Mem: 66 W

Port Card
- ASIC: 93 W
- Transceiver #1: 8 W
- Transceiver #2: 8 W
- Transceiver #3: Sleep

Graph showing the relationship between traffic in % of LC capacity and power in Watt.

Traffic in % of LC capacity: 50%
Power in Watt: 100, 200, 300, 400

© 2013 Universität Stuttgart • IKR
Line Card

Dynamic Operation

Current traffic demand: 100%

Forwarding Engine
- Base: 147 W
- NP: 193 W
- Mem: 79 W

Port Card
- ASIC: 139 W
- Transceiver #1: 8 W
- Transceiver #2: 8 W
- Transceiver #3: 8 W

Traffic in % of LC capacity
Power in Watt

© 2013 Universität Stuttgart • IKR
U. Bauknecht, F. Feller – EUNICE 2013
Conclusion

Overview
Conclusion

Power Saving in IP-over-WSON Networks
• Large variations in traffic allow savings
• Dynamic Operation can save significant amounts of energy
• Exact savings are quantifiable through the models
• Model applicable in evaluation of network (re)configuration schemes

Future Work
• Extension to new optical technologies (Software-defined Transceivers, Flexgrid, etc.)
• Integration of more complex node structures
• Application in network (re)configuration scenarios
Conclusion

Power Saving in IP-over-WSON Networks

• Large variations in traffic allow savings
• Dynamic Operation can save significant amounts of energy
• Exact savings are quantifiable through the models
• Model applicable in evaluation of network (re)configuration schemes

Future Work

• Extension to new optical technologies (Software-defined Transceivers, Flexgrid, etc.)
• Integration of more complex node structures
• Application in network (re)configuration scenarios

Thank you!