# 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



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

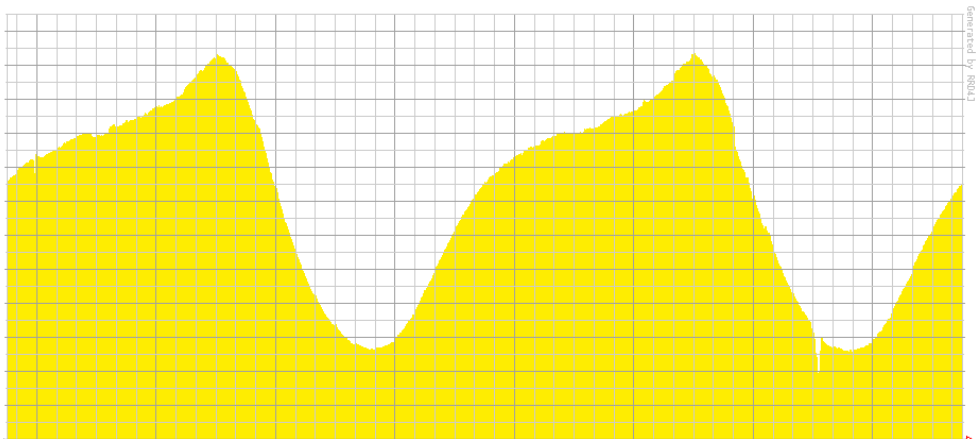
2012 share of ICT equipment: **4.7%**[1] of worldwide electrical energy

~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]



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

Source: DE-CIX Traffic Statistics,
© 2013 DE-CIX Management GmbH

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

# Motivation

*Reduction of Power Consumption in Core Networks*

## Energy Consumption in Networks

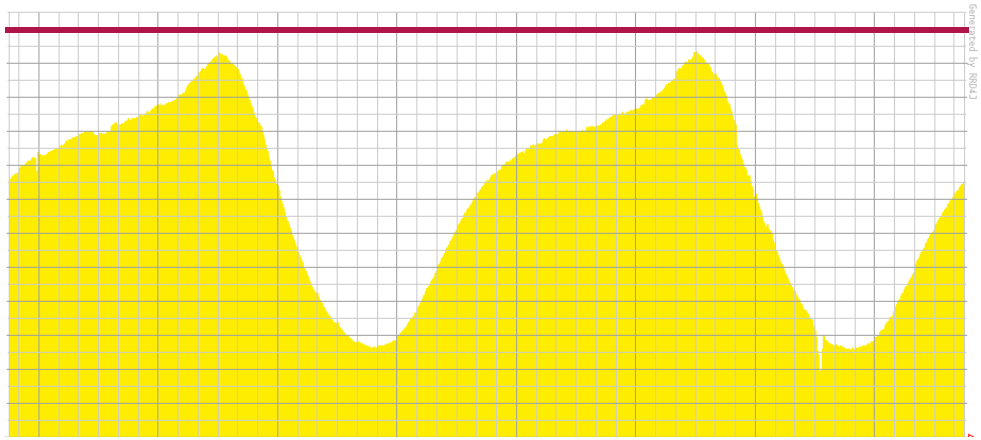
2012 share of ICT equipment: **4.7%**[1] of worldwide electrical energy

~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]



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

Source: DE-CIX Traffic Statistics,
© 2013 DE-CIX Management GmbH

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

# 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

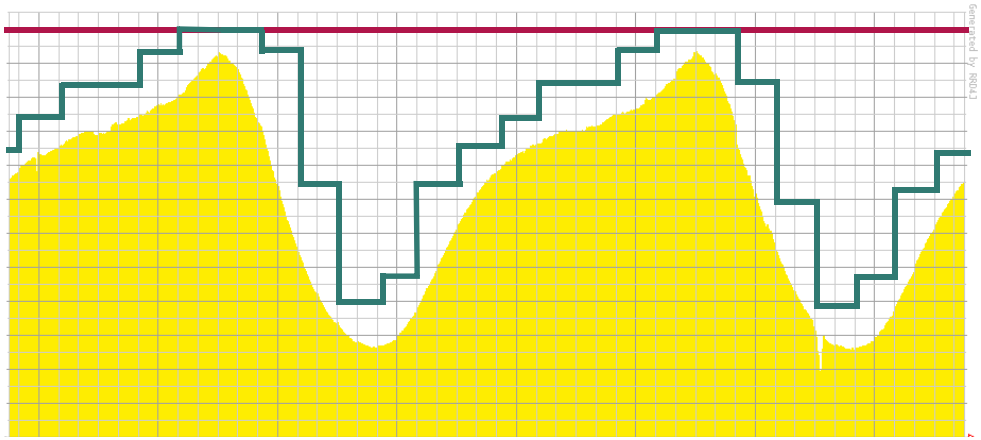
## Focus on Core Networks

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

Source: DE-CIX Traffic Statistics,
© 2013 DE-CIX Management GmbH

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

# 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

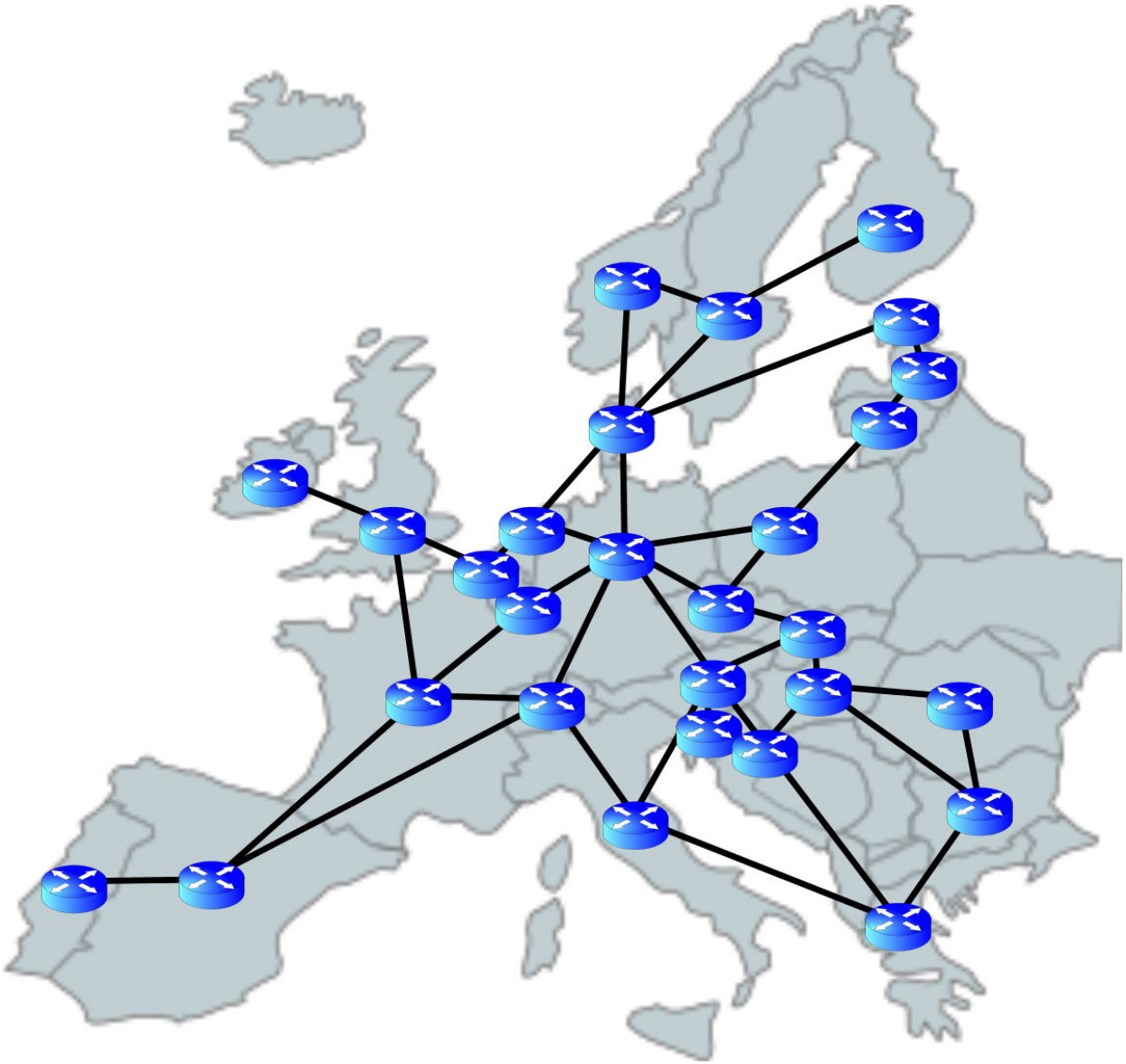
- Adaptable components
- Applicable power saving schemes
- Effectiveness

## Power Consumption

- Primary contributers
- Component power values

# IP-over-WSON Networks

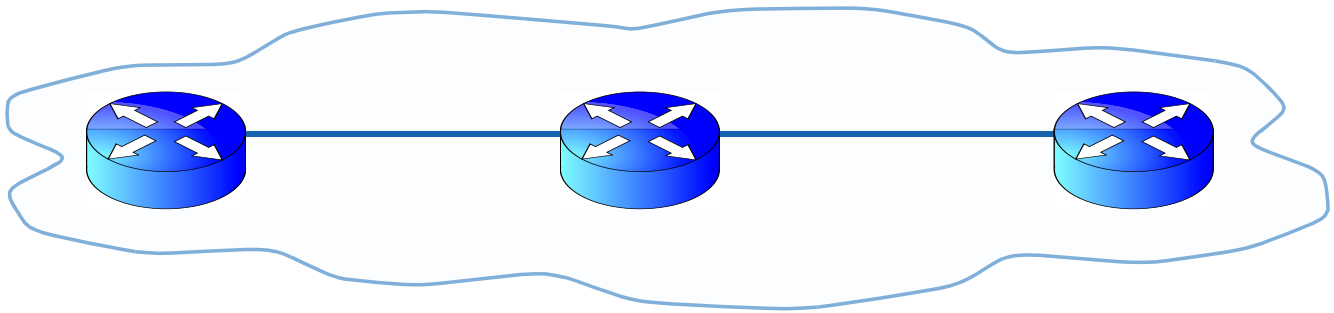
*Core Network Example*



# IP-over-WSON Networks

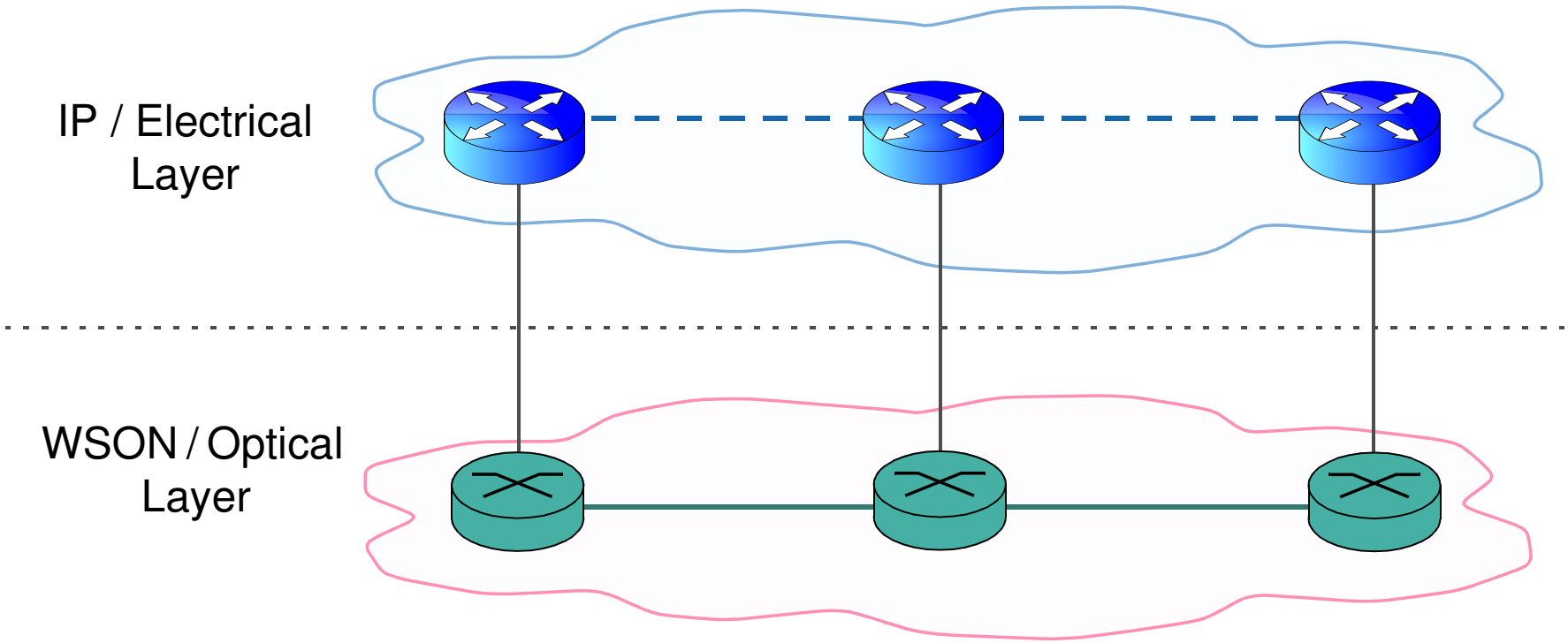
*Basic Multi-Layer Structure*

IP / Electrical Layer



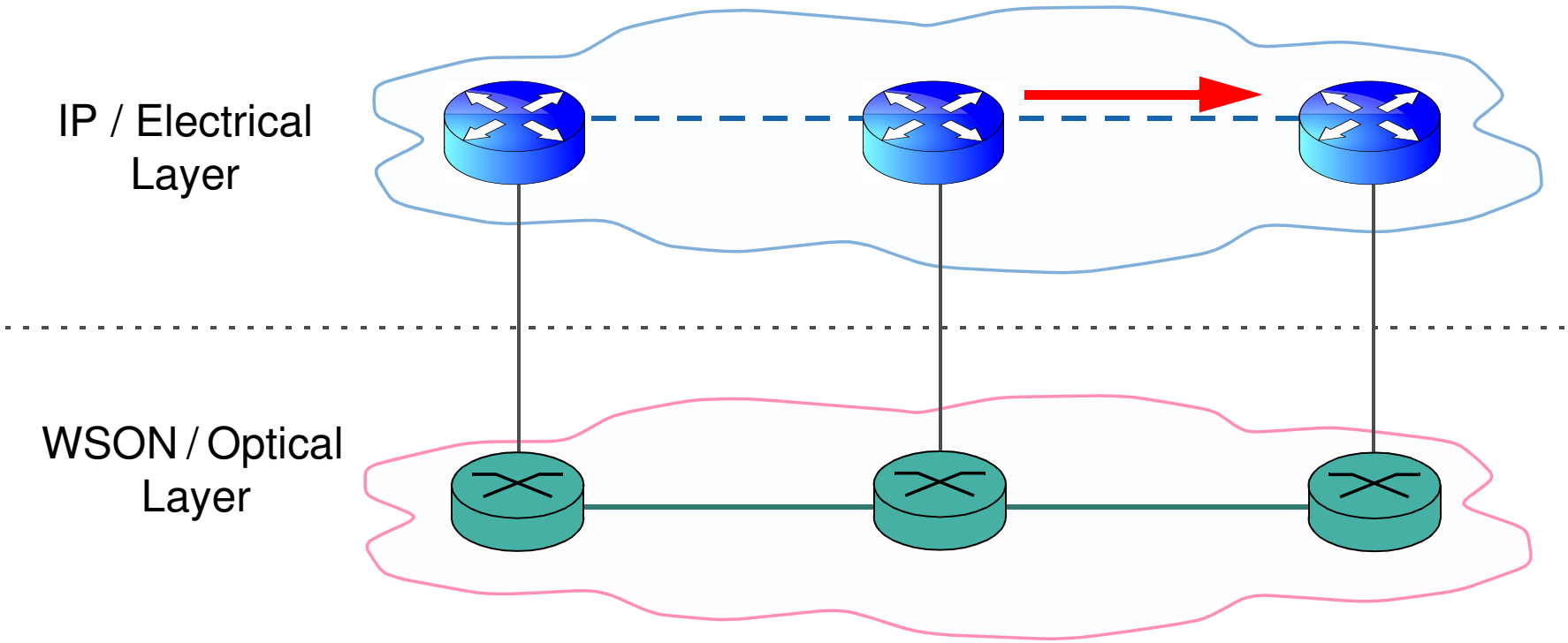
# IP-over-WSON Networks

*Basic Multi-Layer Structure*



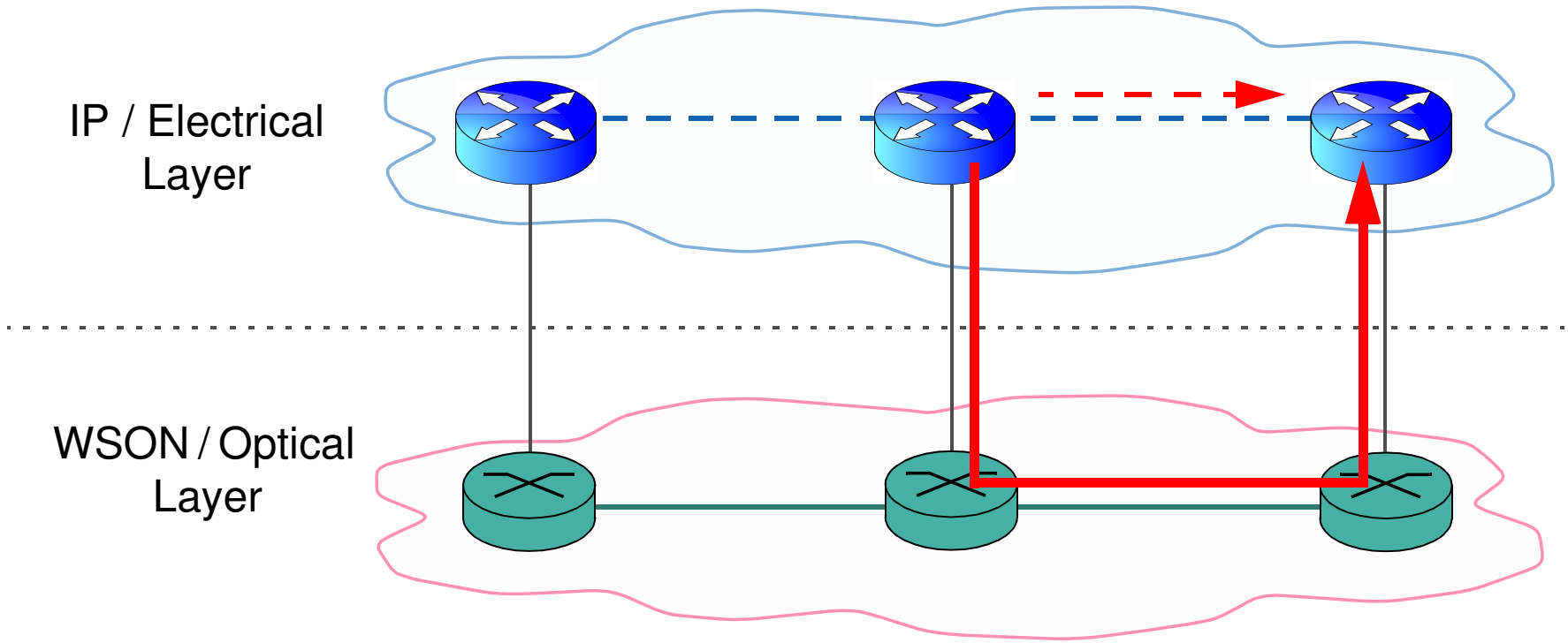
# IP-over-WSON Networks

*Basic Multi-Layer Structure*



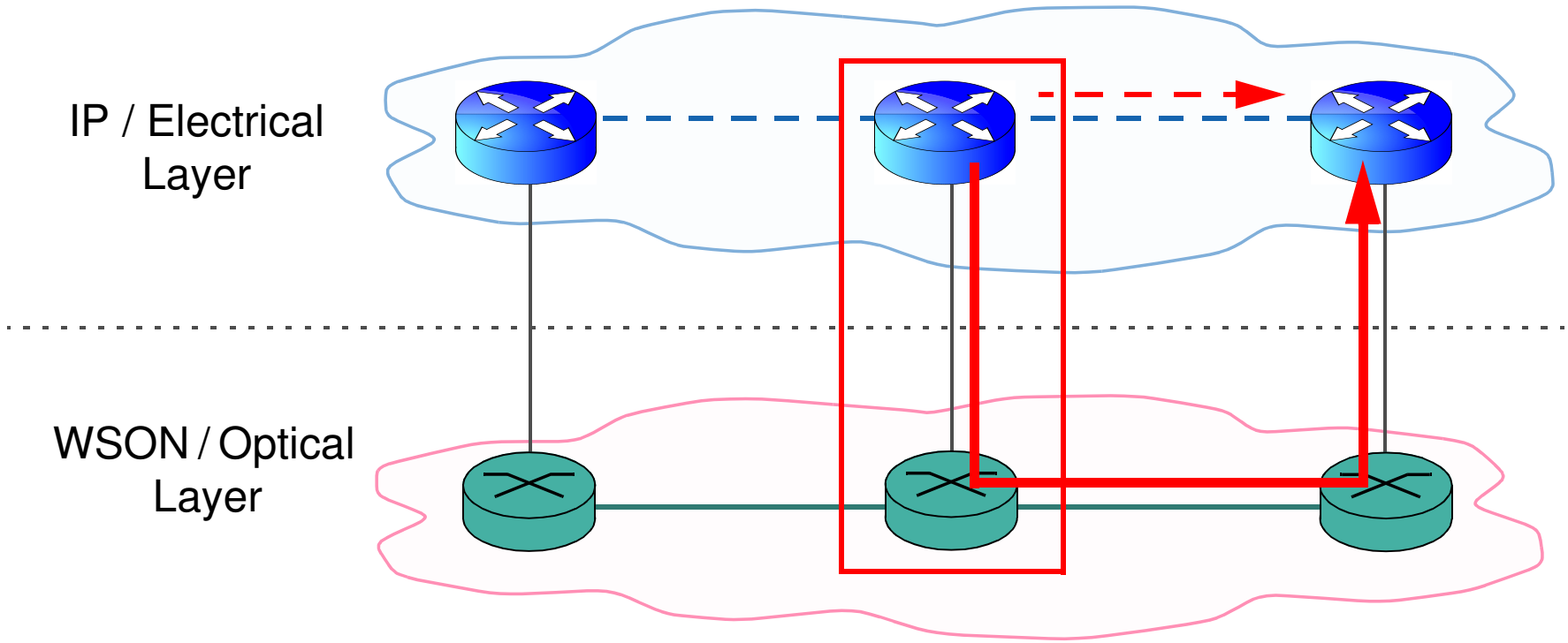
# IP-over-WSON Networks

*Basic Multi-Layer Structure*



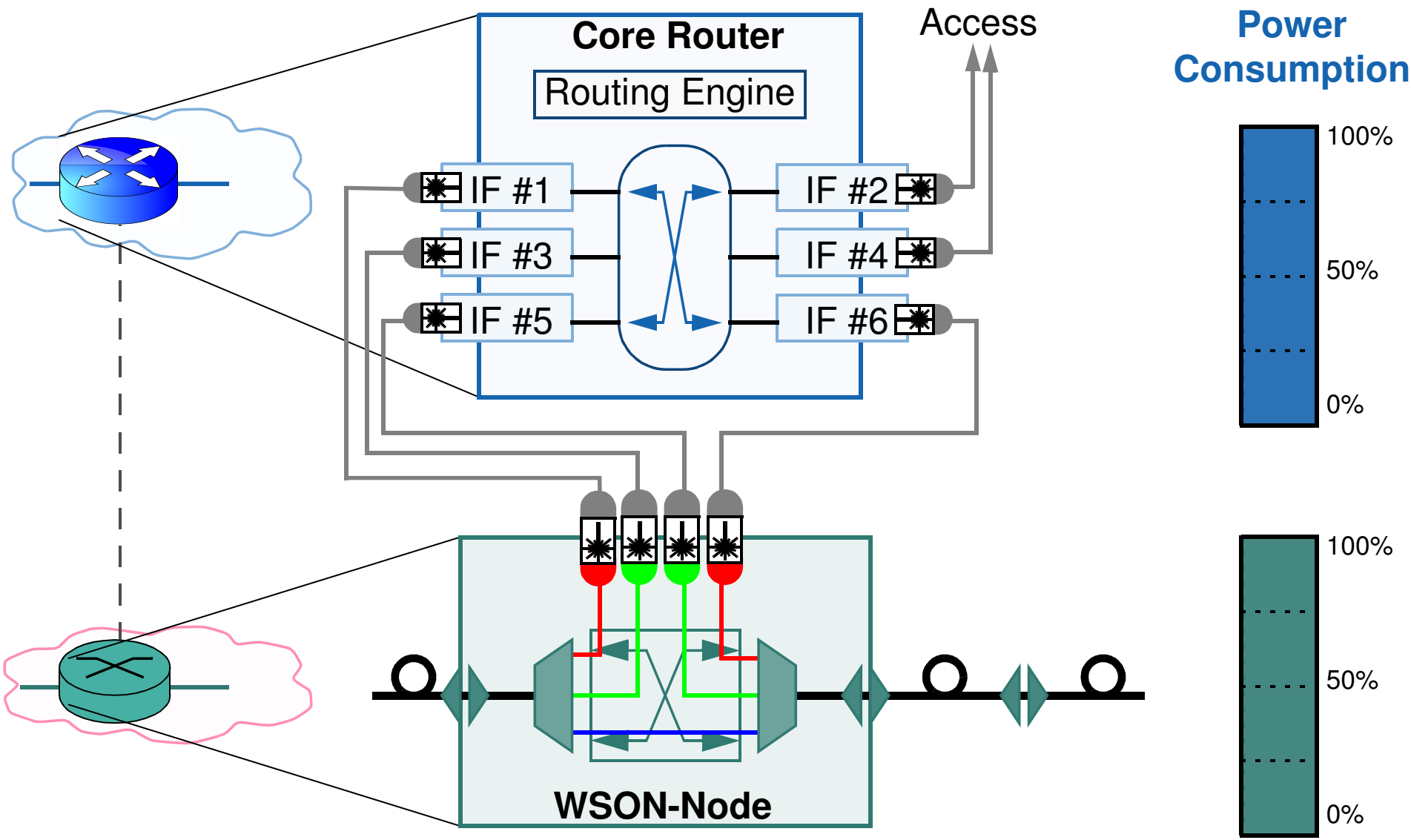
# IP-over-WSON Networks

*Basic Multi-Layer Structure*



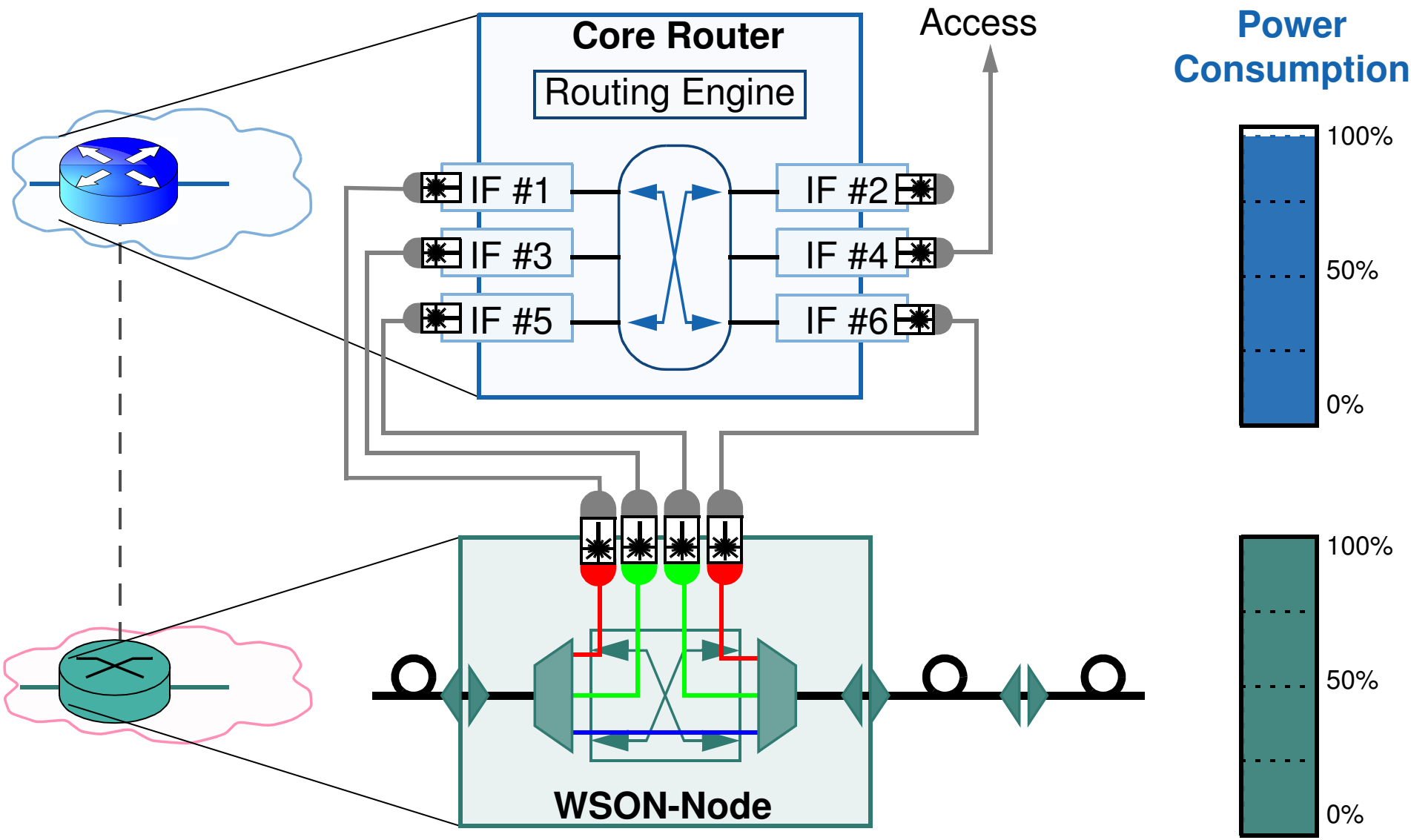
# IP-over-WSON Networks

*Logical Node Structure*



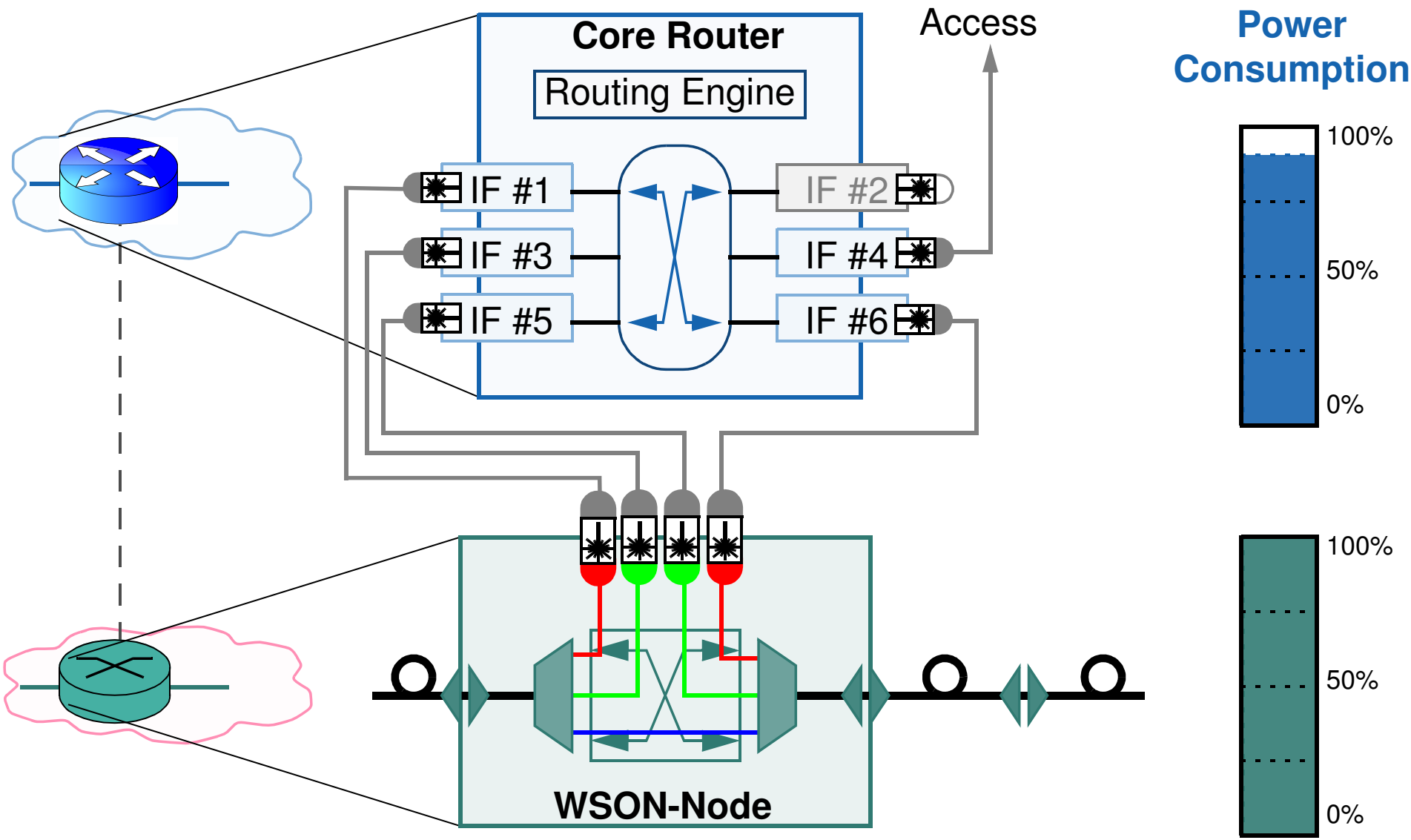
# IP-over-WSON Networks

*Logical Node Structure*



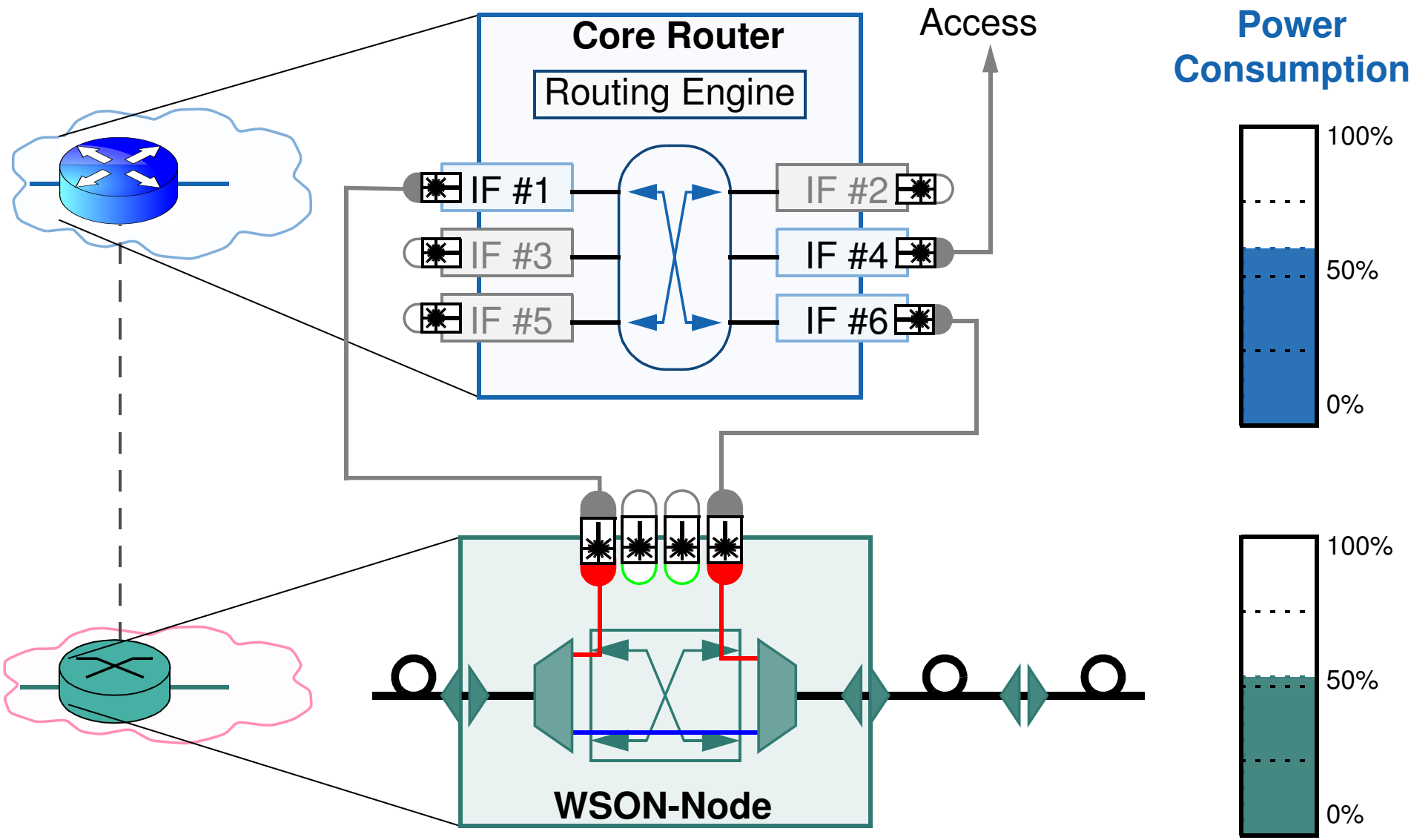
# IP-over-WSON Networks

*Logical Node Structure*



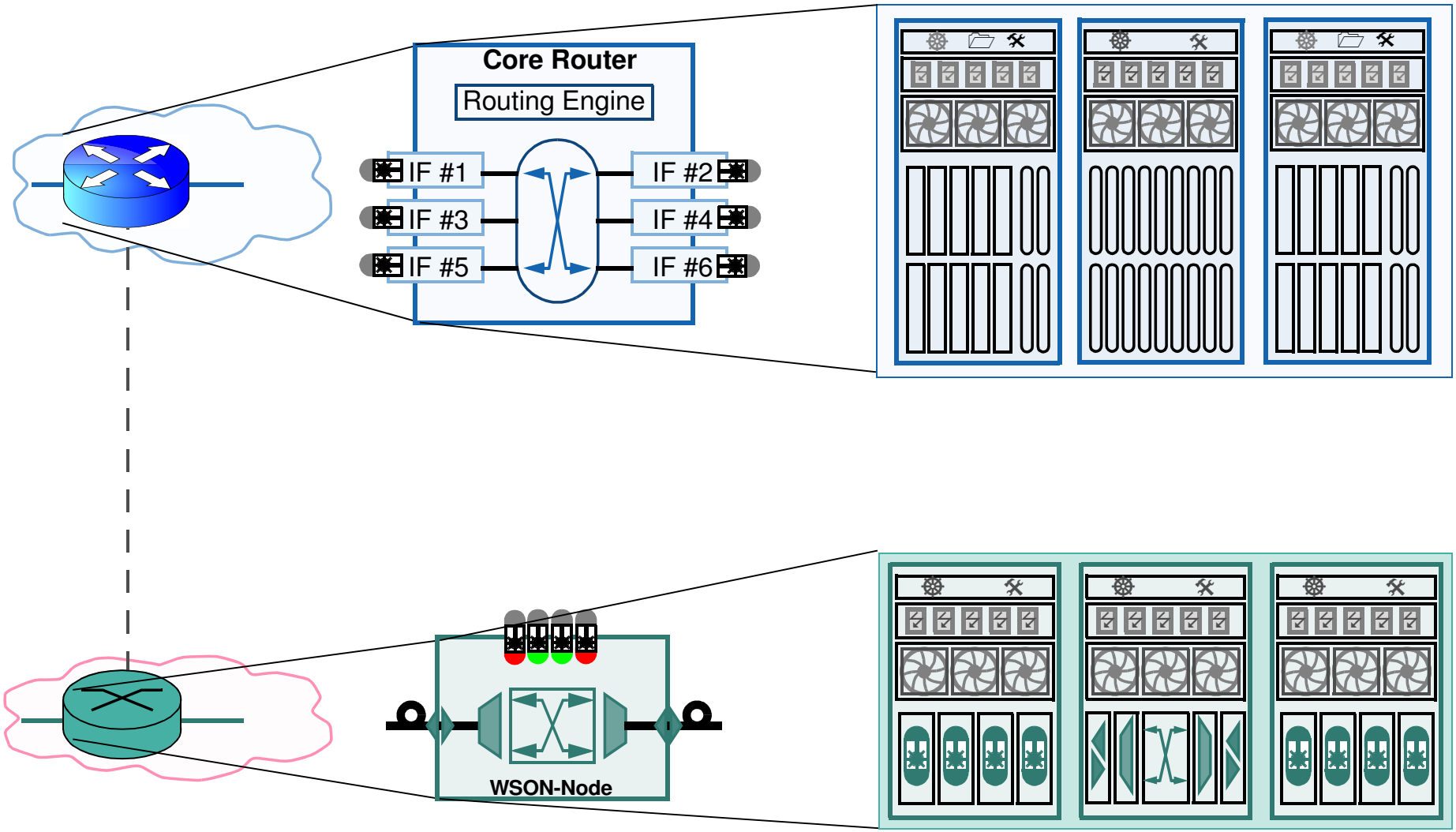
# IP-over-WSON Networks

*Logical Node Structure*



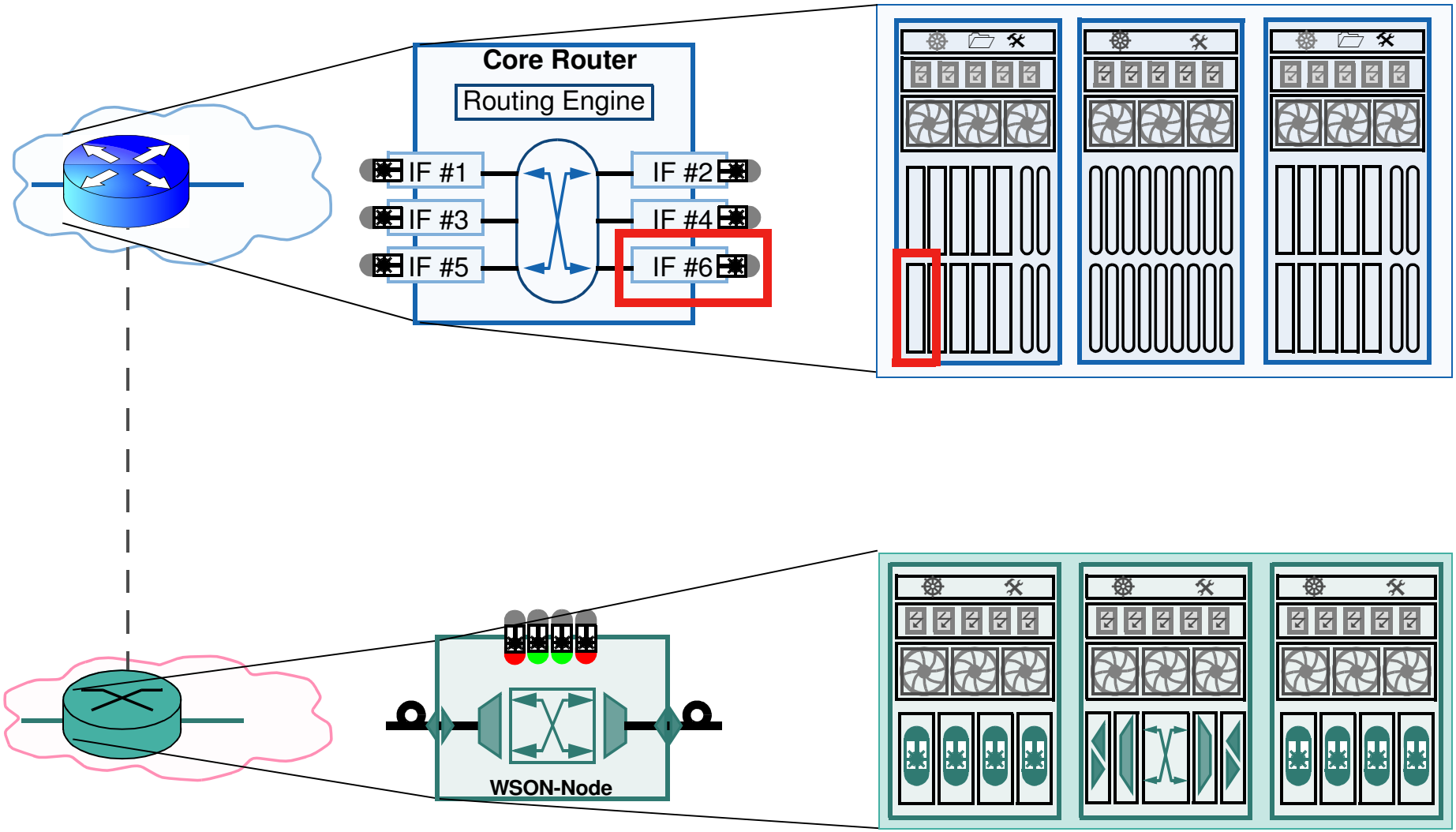
# IP-over-WSON Networks

*Component-Based Model*



# IP-over-WSON Networks

*Component-Based Model*

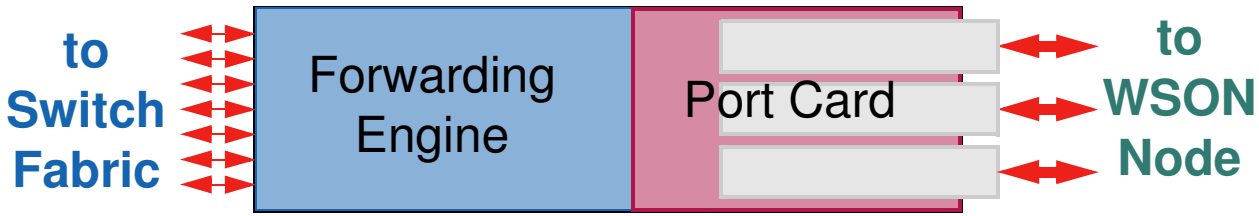


# Line Card

*Components and Power Consumption*

## Functionality

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

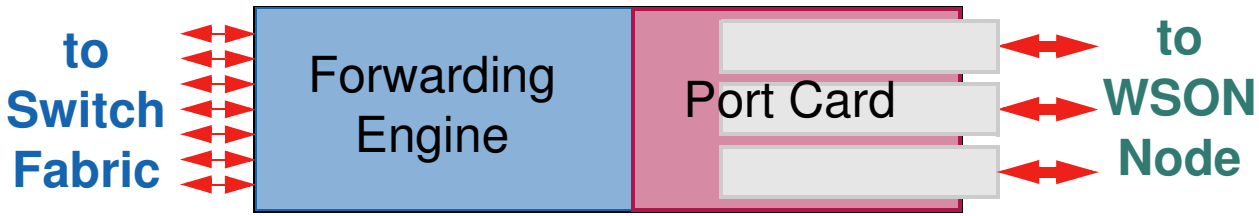


# Line Card

*Components and Power Consumption*

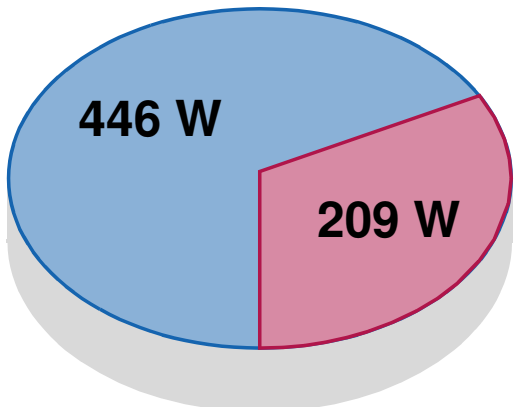
## Functionality

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




## Components

- Forwarding Engine
- Port Card with Transceivers

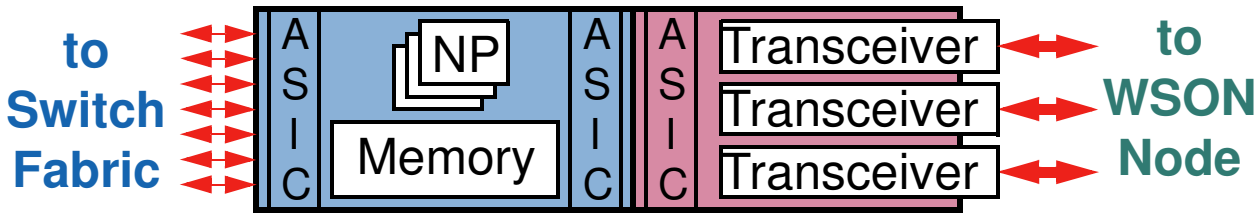


# Line Card

*Components and Power Consumption*

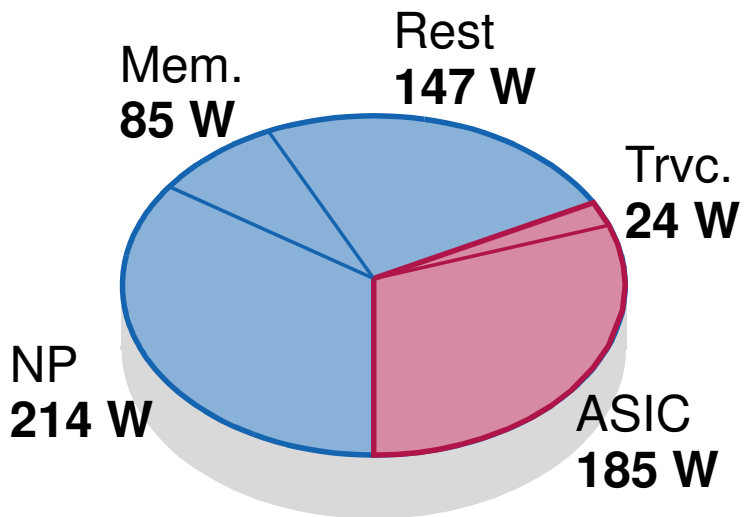
## Functionality

- 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



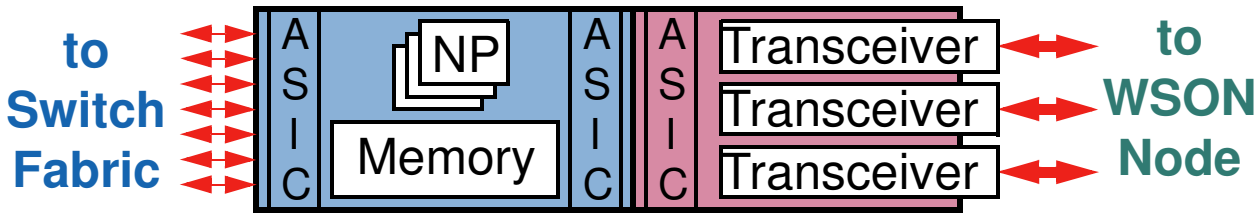
# Line Card

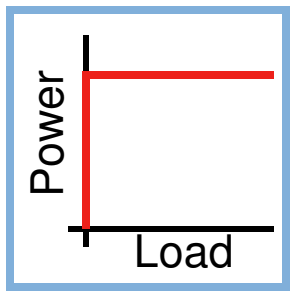
*Dynamic Operation*

## Sleep States

Transceiver inactive ⇨ sleep

All Transceivers asleep
⇨ Line Card to sleep



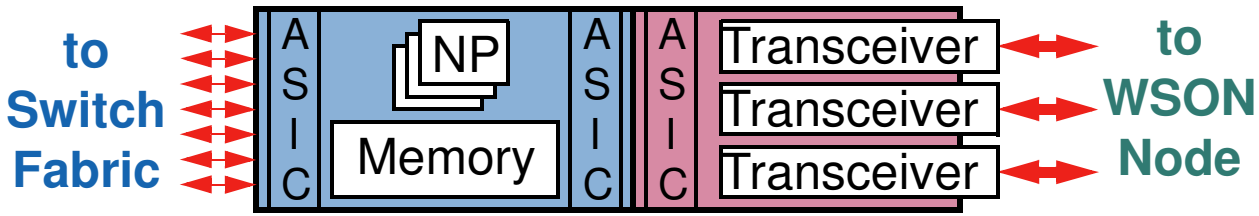
# Line Card

*Dynamic Operation*

## Sleep States

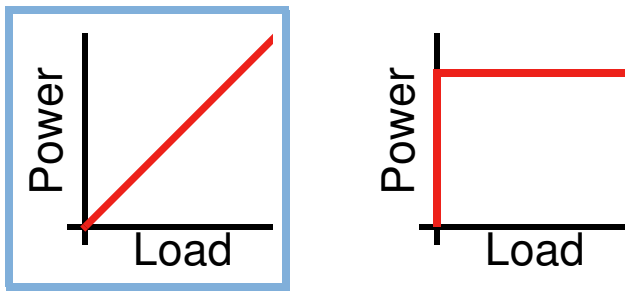
Transceiver inactive ⇨ sleep

All Transceivers asleep
⇨ Line Card to sleep




## Power/Load Dependency

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



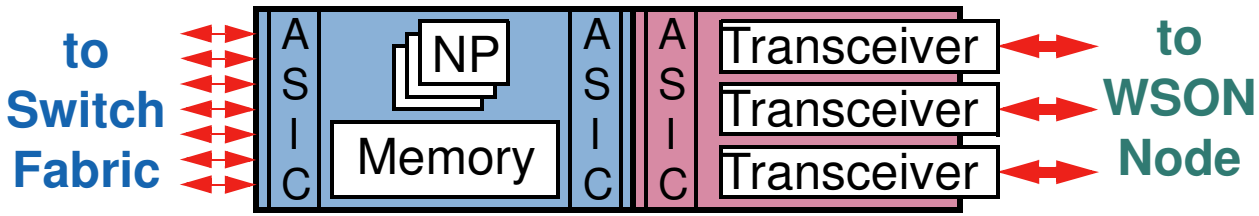
# Line Card

*Dynamic Operation*

## Sleep States

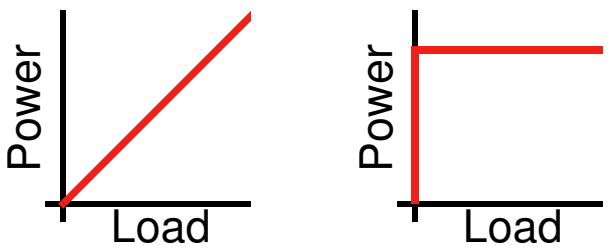
Transceiver inactive ⇨ sleep

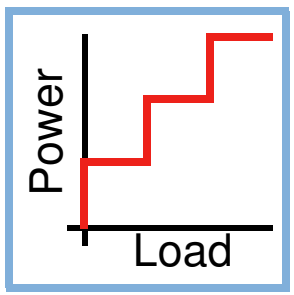
All Transceivers asleep
⇨ Line Card to sleep




## 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



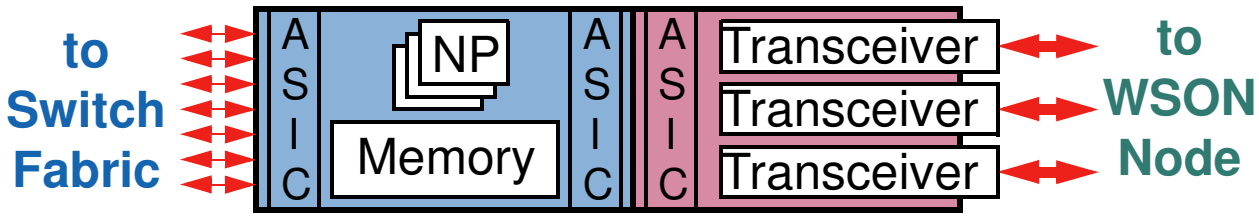
# Line Card

*Dynamic Operation*

## Sleep States

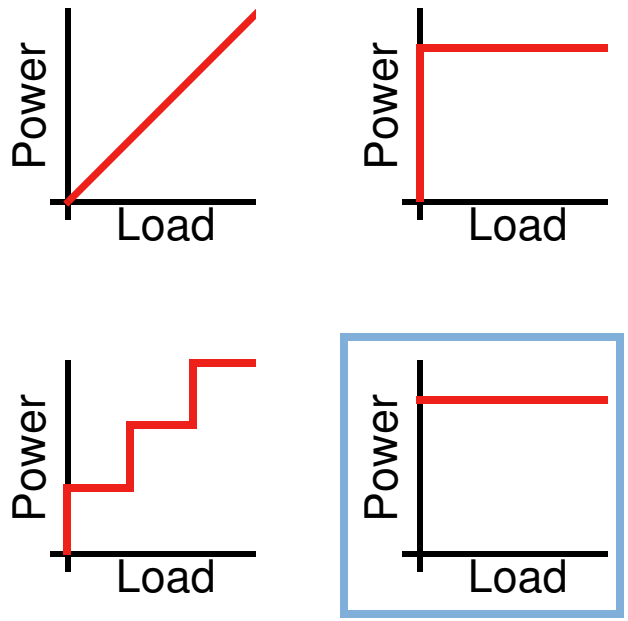
Transceiver inactive ⇨ sleep

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



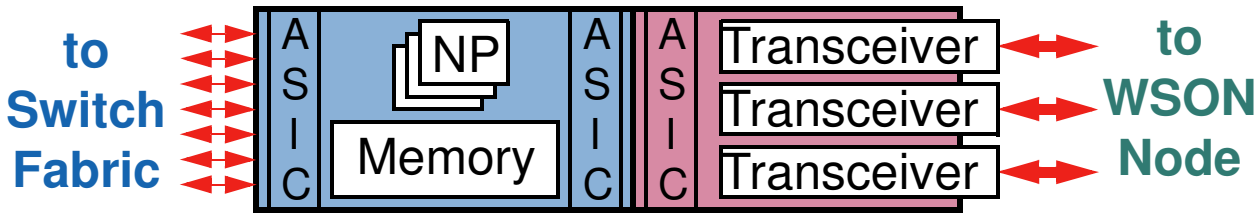
# Line Card

*Dynamic Operation*

## Sleep States

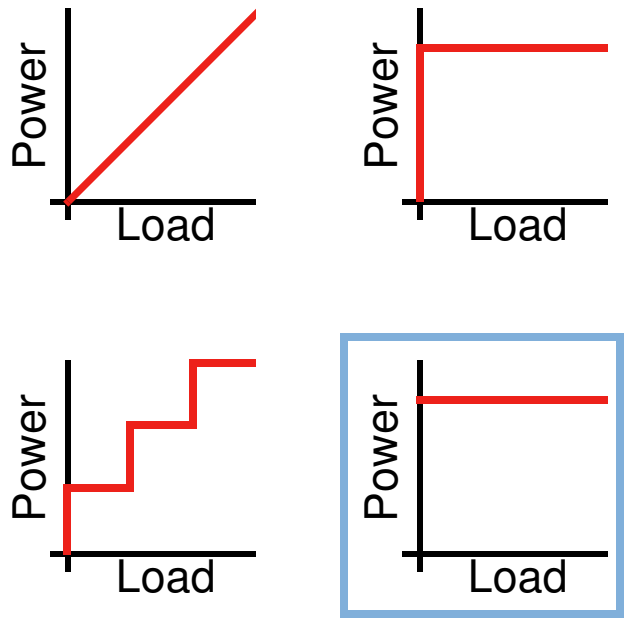
Transceiver inactive ⇨ sleep

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

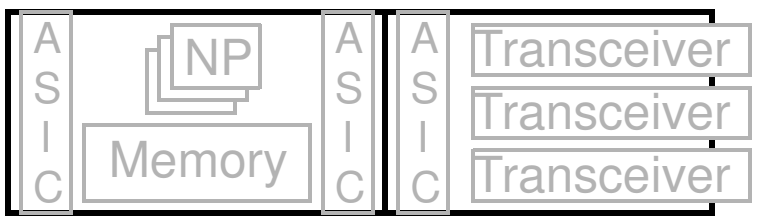


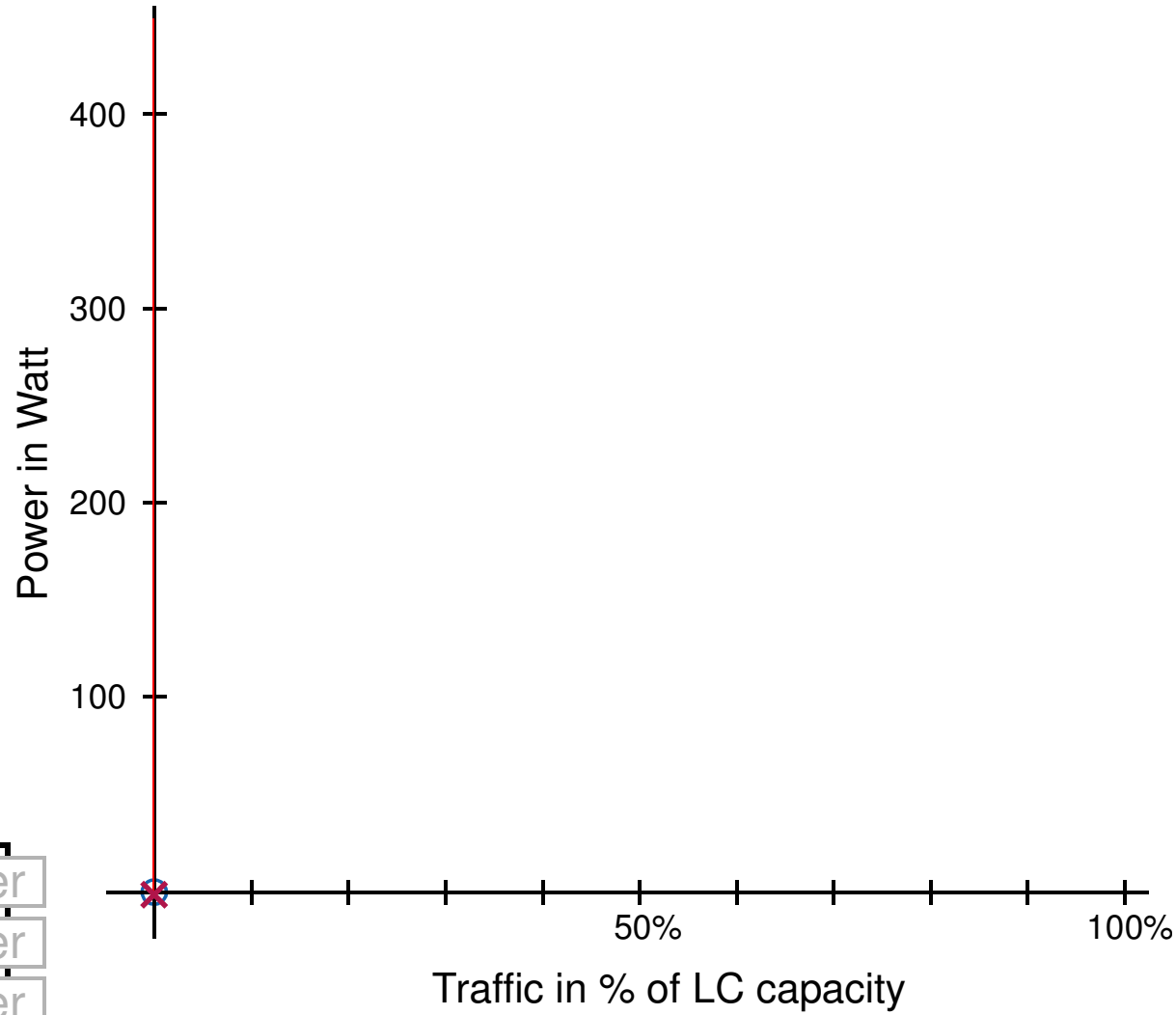
# Line Card

## *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 |



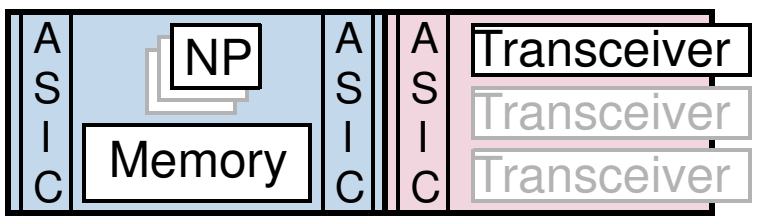



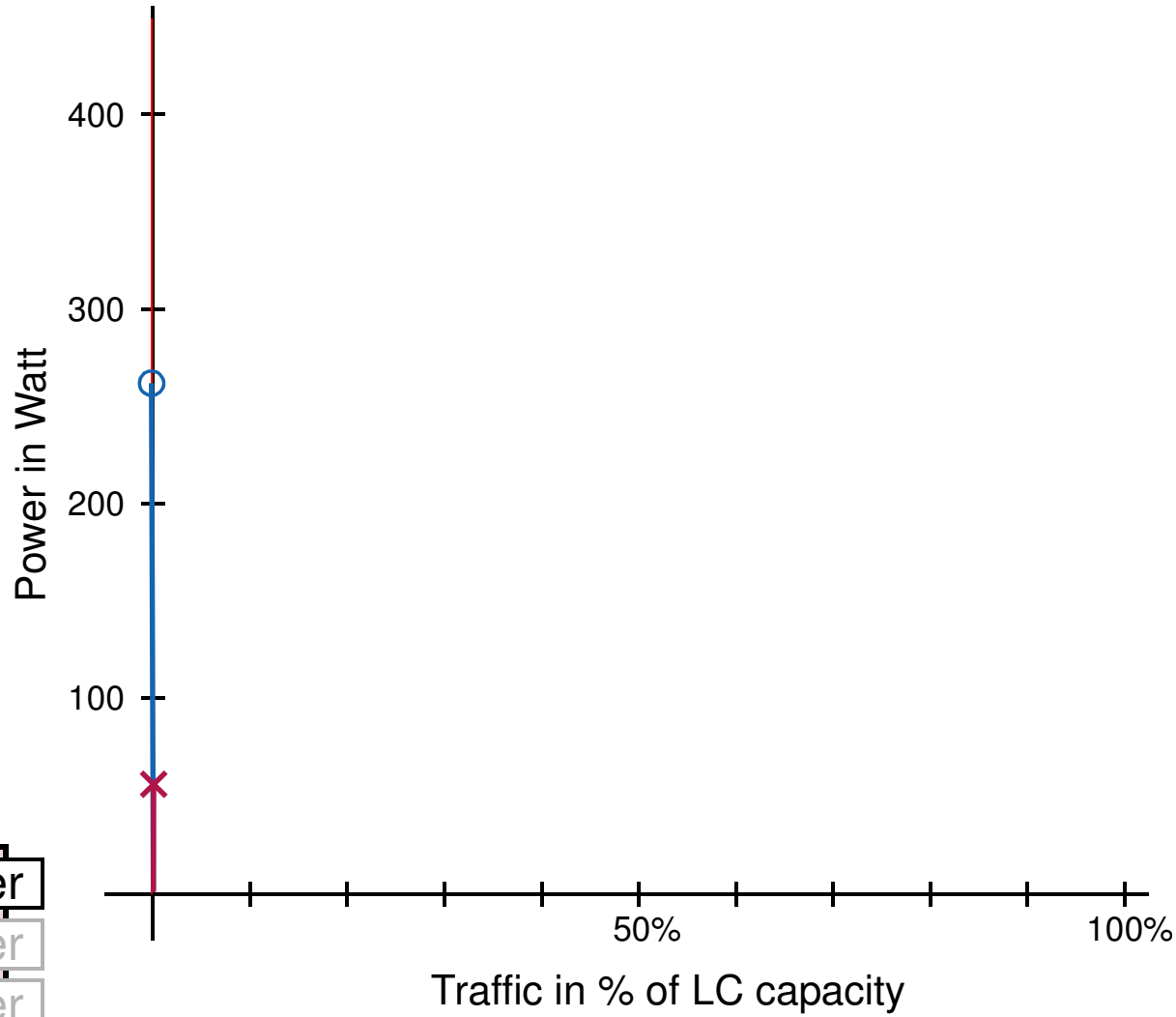
# Line Card

## *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 |



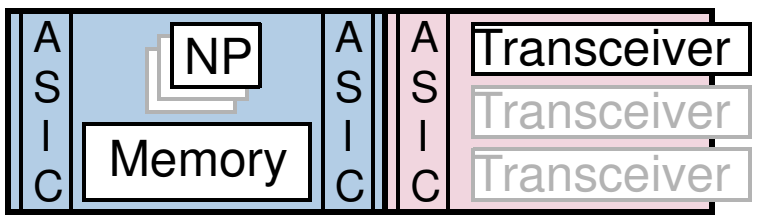



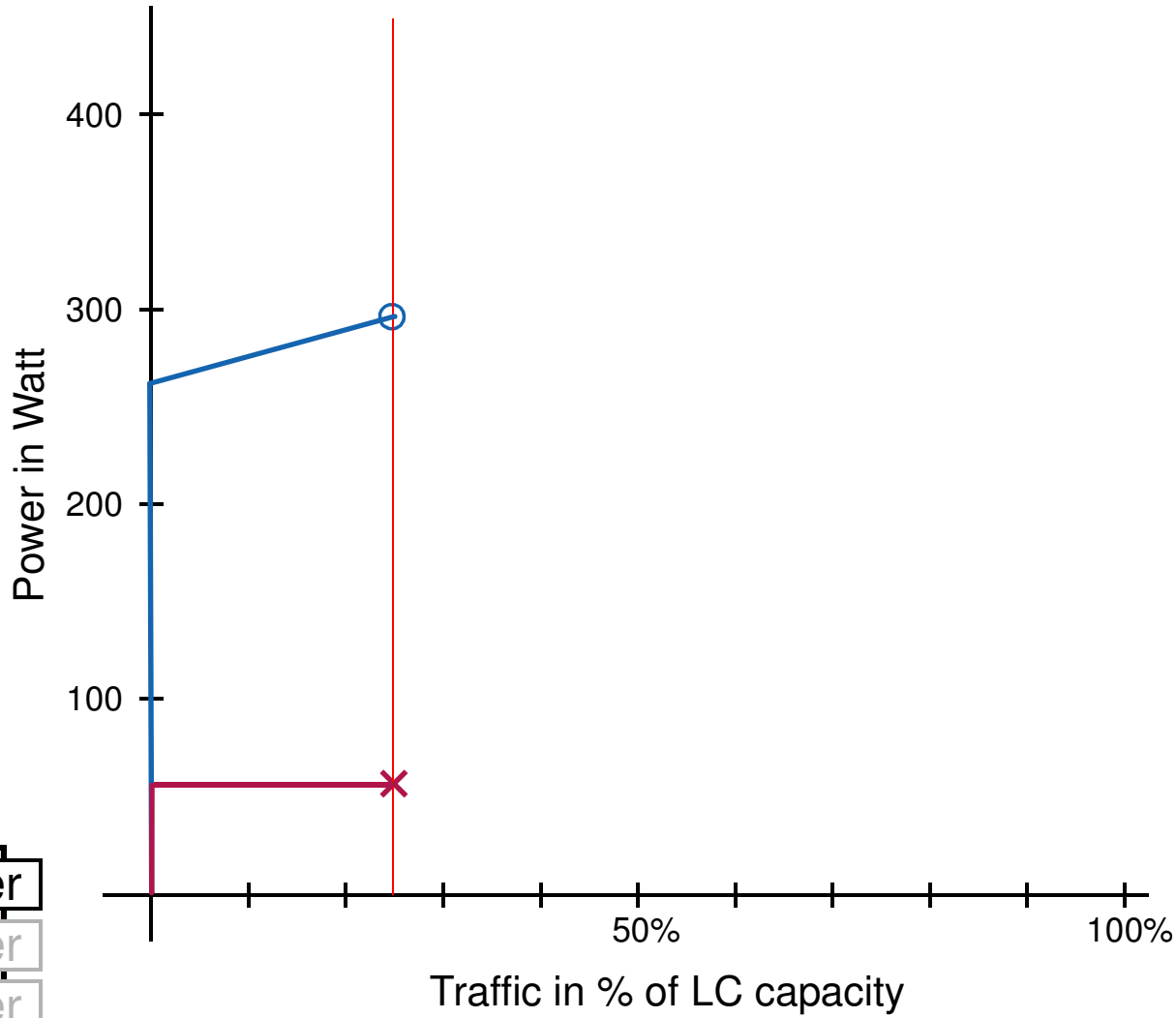
# Line Card

## *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 |



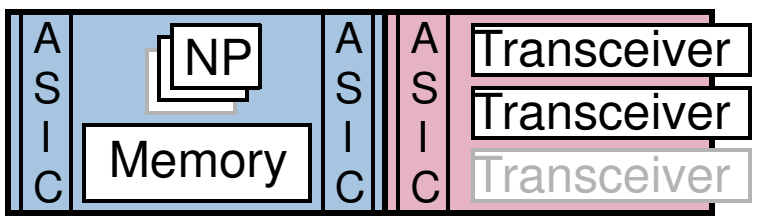



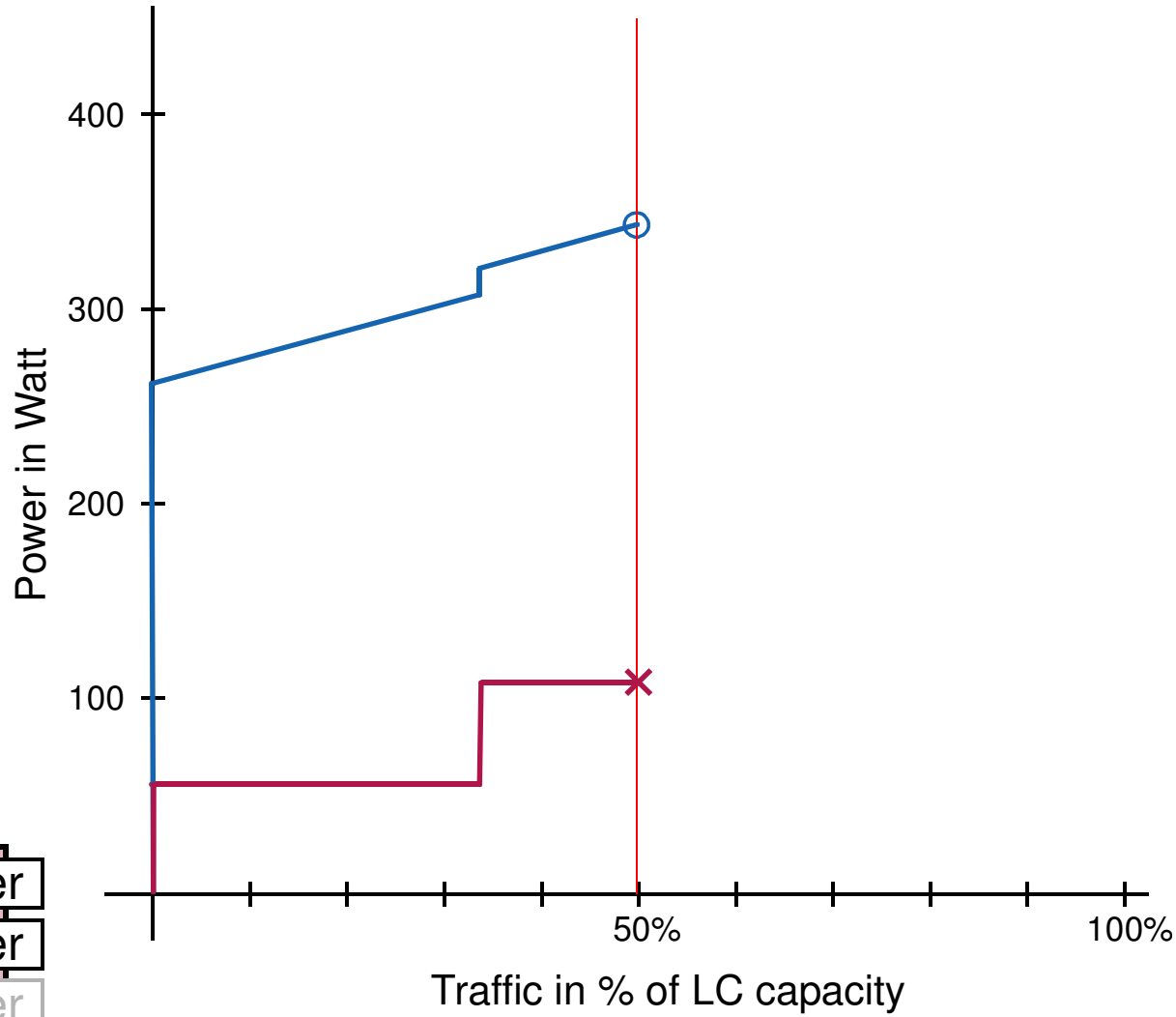
# Line Card

## *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 |



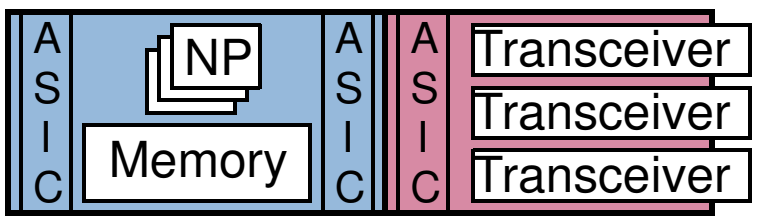



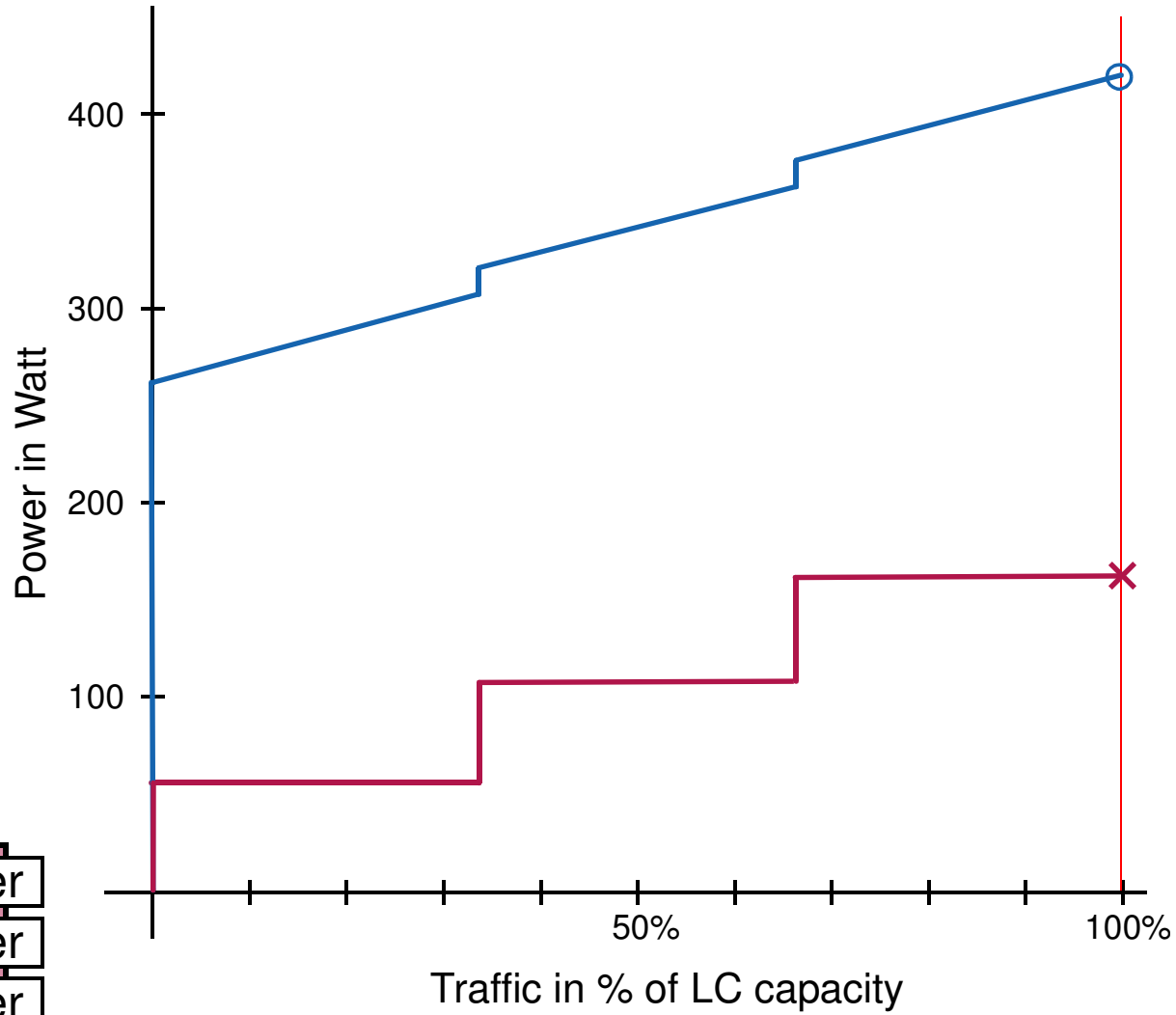
# Line Card

## *Dynamic Operation*

Current traffic demand: 100%

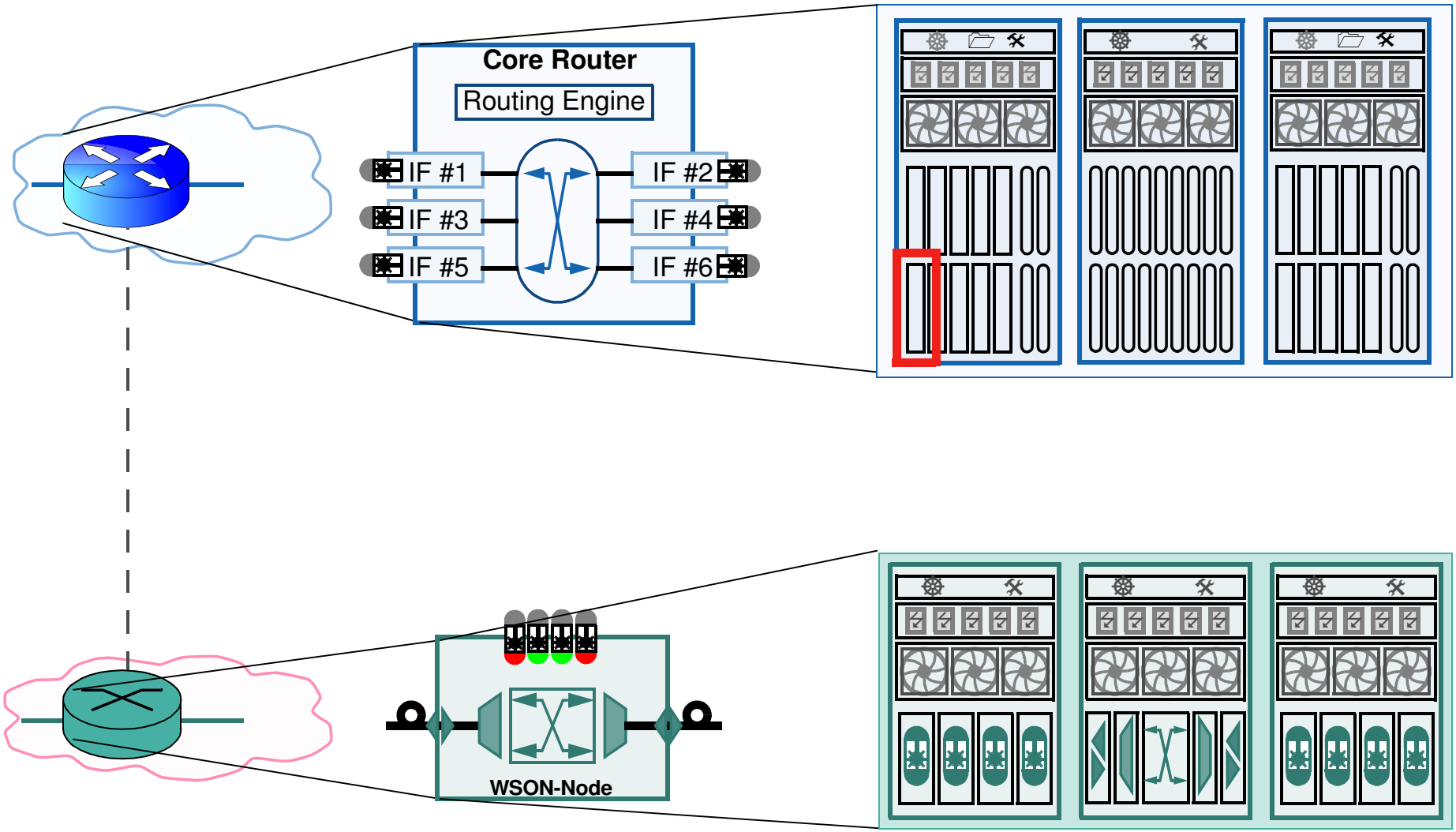
| | |
|---|---|
| **Forwarding Engine** | |
| Base | 147 W |
| NP | 193 W |
| Mem | 79 W |
| **Port Card** | |
| ASIC | 139 W |
| Transceiver #1 | 8 W |
| Transceiver #2 | 8 W |
| Transceiver #3 | 8 W |



# 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!**