Energy Saving for Future Networks

Second Study Group 13 Regional Workshop for Africa on "Future Networks: Cloud Computing, Energy Saving, Security and Virtualization"

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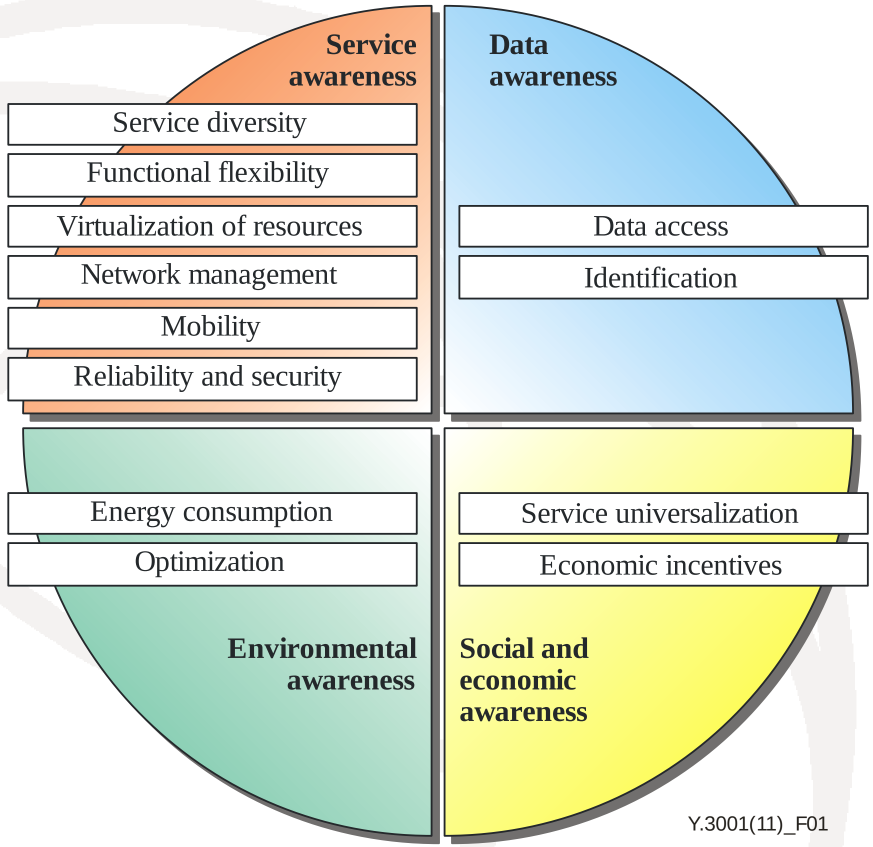
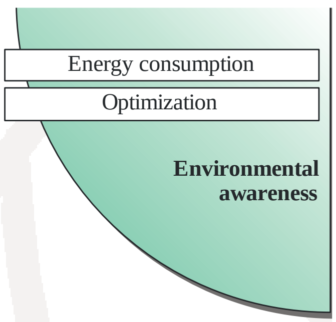
Objectives and design goals for Future Networks



- **Environmental awareness** one out of four objectives for Future Networks recommended by Y.3001
- **Energy consumption/ optimization** stated as design goal for Future Networks

Environmental aspects of Future Networks



Green by FN

Environmental load reduction achieved by FN

Green FN

Environmental load caused by FN

Positive issues:

- New way of working (communicating instead of commuting)
- Reduction of movement and transportation
- Reduction of greenhouse gas

Negative issues:

- Energy consumption
- Consumption of natural resources
- Generation of waste

Focus on green FN: energy saving within the networks themselves

Methods for energy saving

technical

static, dynamic methods

non-technical

Regulation by law

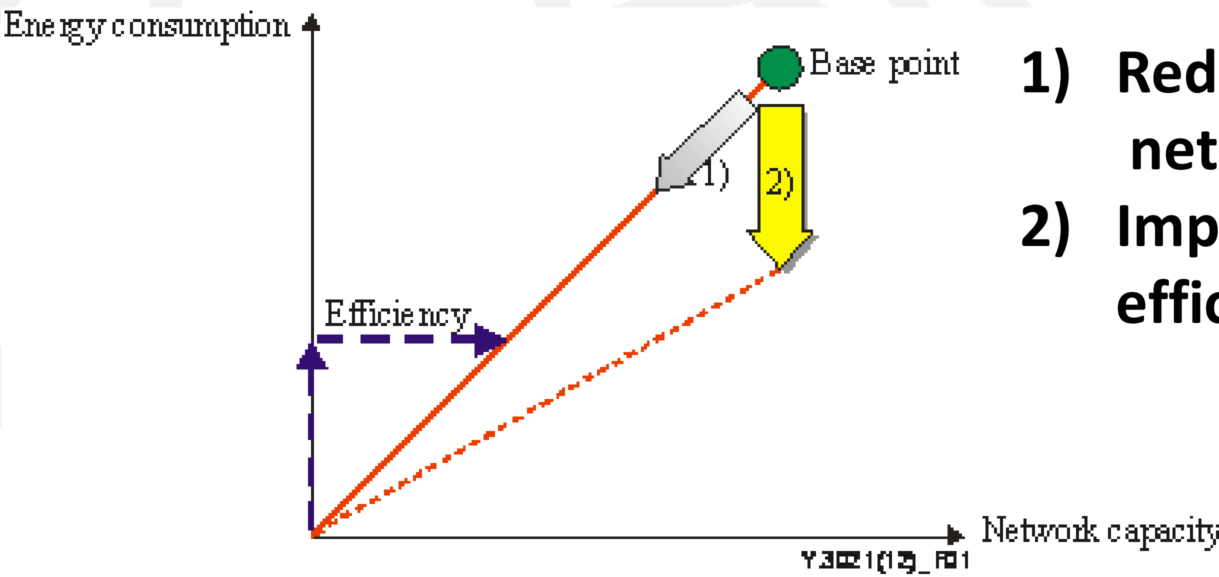
SG13 is working on technical methods for energy saving

SG13 work on green Future Networks

- Y.3021 Framework of energy saving for future networks **(published)**
- Y.3022 Measuring energy in networks **(published)**
- Y.energy ECN Energy efficiency class of networks (consent planned 2015, **active participation in Q16/13 welcome**)

ITU and climate change

Approaches to energy saving



1) **Reduction of required network capacity**
2) **Improvement of energy efficiency**

$$\text{network energy efficiency} := \frac{\text{Throughput of the network}}{\text{consumed power}} \left(\frac{\text{bps}}{\text{W}}\right)$$

Lifecycle stages

For reduction the analysis of energy consumption at each stage of the lifecycle is important.

ITU-T L.1400

Focus on NW operation stage:

- **energy consumption for "always-on" equipment**
- **control of energy consumption by network architecture, capabilities and operation**

Considered levels for energy saving technologies in Y.3021

- **Device-level**

Technologies which are applied to electronic devices, such as large scale integration (LSI) and memory.

- **Equipment-level**

Technologies which are applied to one piece of equipment (a set of devices) such as a router or switch.

- **Network-level**

Technologies which are applied to equipment within the whole network (e.g. a routing protocol applied to multiple routers).

Device level technologies

Higher integration, smaller chip size:

Reduction of power consumption ~ (driving voltage reduction)^2

Multi-core CPU

Energy consumption ~ (clock frequency)^3

Usage of lower clocked multiple CPU cores in a single processor instead of a single high clocked CPU

Clock-gating

Reduction of power consumption by suspension of clock supply to circuits in case of they are not busy

Digital pre-distortion

Reduction of power consumption by improve the linearity of power amplifiers PA (cancellation of distortion by input of an inversely distortion)

Equipment level technologies

Optical network node

All-optical packet switching can reduce power consumption by traffic aggregation and by the avoidance of optical to electric and electric to optical translation

Sleep mode control

Power saving by the deactivation of components and/or functions of e.g. a router/ switch when they are not used. The effect of energy saving depends on traffic dynamics

Adaptive link rate (ALR) and dynamic voltage scaling (DVS)

ALR: power saving by bit rate control of the interface according to the processed traffic amount

DVS: power saving by driving voltage control of the CPU, hard disc, NIC, etc. according to the to the processed traffic amount

Thermal design

Power saving by avoidance of cooling system due to thermal design of nodes

Network level technologies

Burst switching

Aggregation of packets into data bursts at routers can save energy consumption (reduction of header computation)

Energy consumption based routing

Traffic distribution into multiple routes so that each node treats the minimum traffic and makes limits link rate or driving voltage to the adequate level so that unnecessary energy can be saved, precond.: ALR/DVS (similar sleeping mode)

Transmission scheduling

Saving energy by operation with fewer buffers at the nodes: control of the amount and the timing of packet transmission

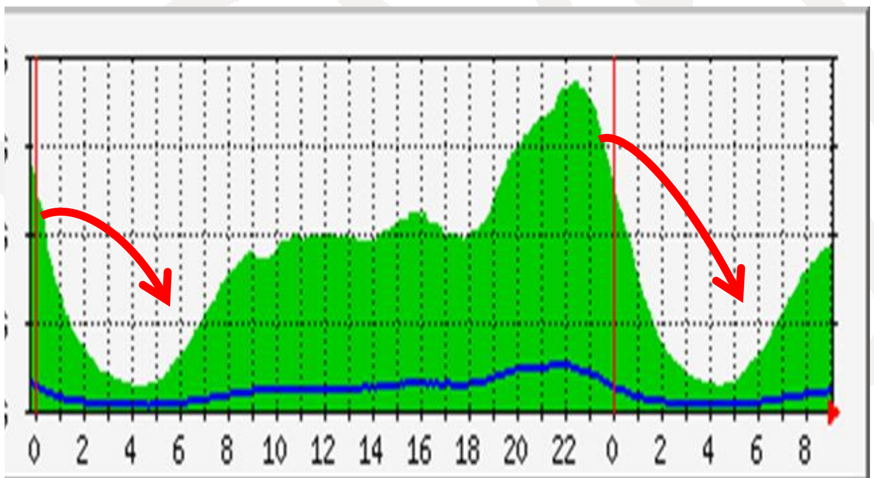
Content delivery network (CDN)

CDN save bw/ energy by access a server nearer than the original one

Network level technologies (cont.)

Traffic peak shifting

Reduction of power consumption by reduction of the maximum traffic to be accommodated by shifting the transmission of the traffic peak as much as possible onto the time axis (e.g. cache servers)



Source: Mobitel Data

Energy consumption-aware network planning

Inclusion of energy efficiency and the reduction of the environmental impact (e.g. energy consumption reports) in addition to performance and reliability aspects into the network planning process

Layout for less traffic

Problems & limitations of technologies

Examples

- **LSI:** increased leakage current

- **Clock gating:** too frequently transition between ON and OFF states of the clock requires additional energy

- **Optical network node:** difficulties regarding realization on a large and practical scale

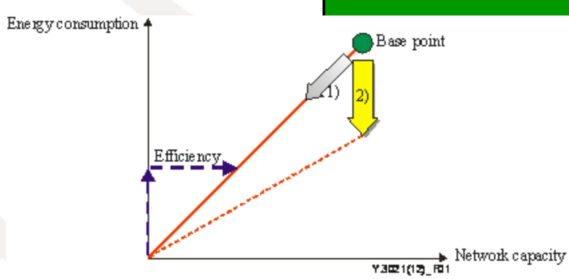
- **Sleep mode control:** control traffic handling

- **ALR/ DVS:** Treatment of burst traffic (quick response time, efficient frequent change)

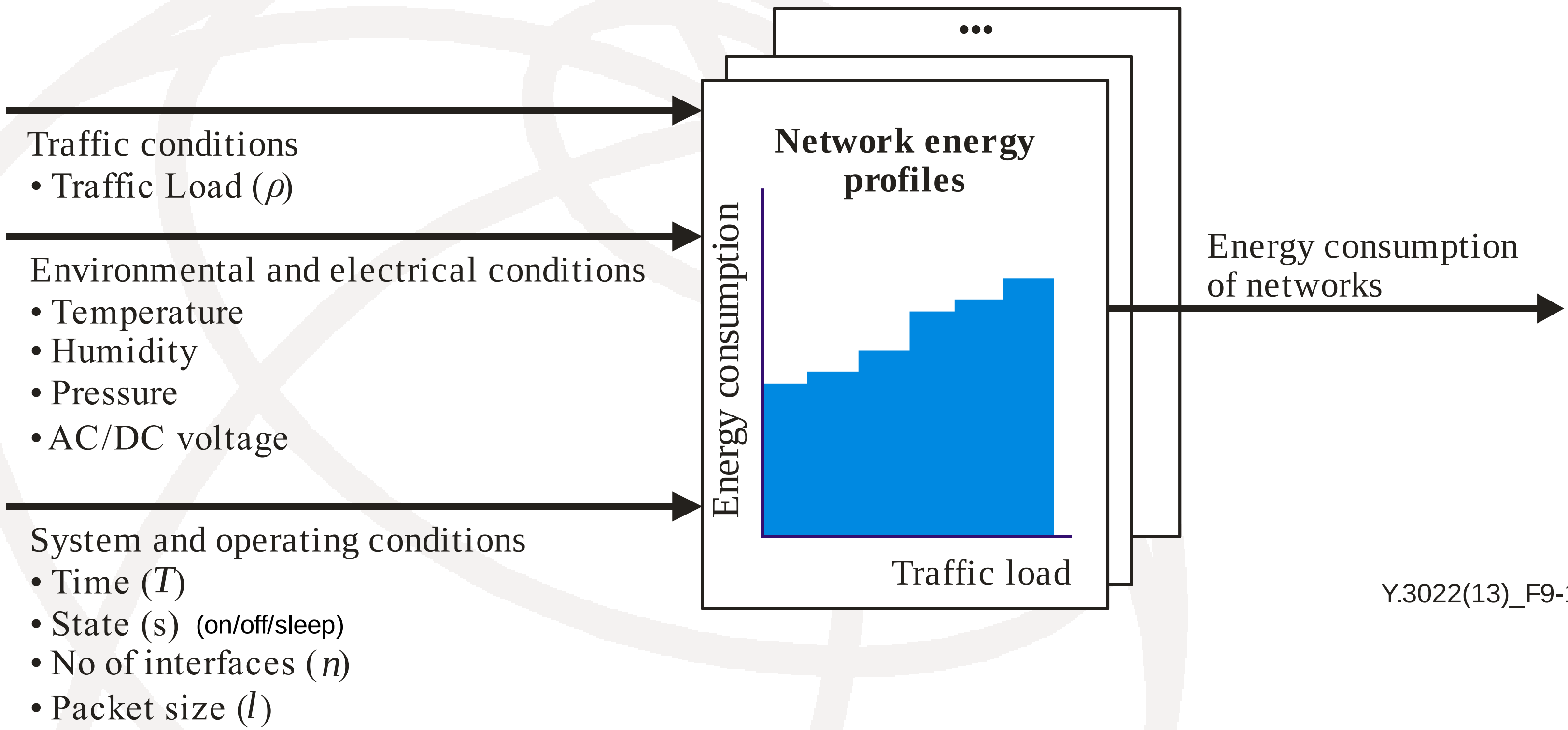
- **CDN/ cache server:** inefficient in case of small hit rate

Classification of technologies

Technology level	Reduction of capacity		Improvement of energy efficiency	
	Reduce traffic	**Peak-shift**	**Dynamic control**	**Less power**
Device			Multi-core CPU Clock gating	LSI fabrication Advanced power amplifier
Equipment	Cache server		Sleep mode control ALR/DVS	Optical node Thermal design
Network	CDN	Traffic peak shifting	Routing/traffic engineering Energy-aware network planning (dynamic)	Circuit/burst switching Light protocol Transmission scheduling Energy-aware network planning (static)



Calculation of network energy consumption



Network energy profile: Energy consumption of network elements versus offered traffic load (for each interface, node and server)

Calculation of network energy consumption (cont.)

$$E_{network} = \sum_i E_{node,i} + \sum_j E_{server,j} + E_{environment}$$

For further details see alsoc Y.3022

node,i : in case of a switch

$$E_{switch} = \sum_0^T \left(P_{common} + \sum_i P_{Module,i} \right)$$

$$P_{common} = P_{buffer} + P_{fan}$$

node,i : in case of a router

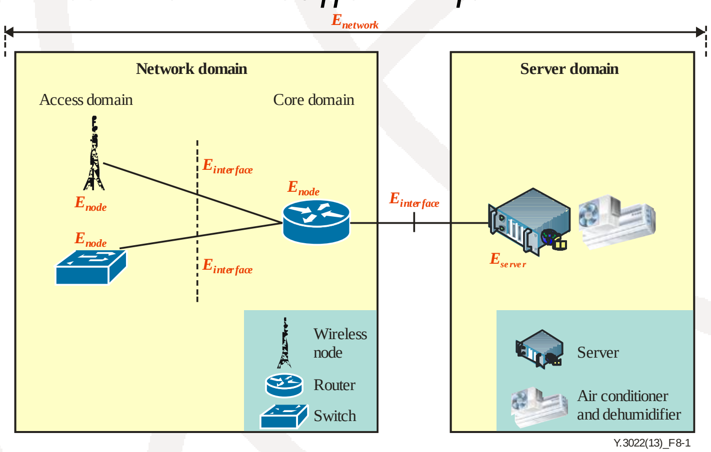
$$E_{router} = E_{common} + \sum_i E_{interface,i}$$

$$E_{common} = \sum_0^T P_{common}$$

$$P_{common} = P_{chassis} + \sum_i P_{routing\ engine,j} + \sum_k P_{power\ supply\ unit,k} + \sum_l P_{linecard,l}$$

$$E_{interface,i} = \sum_0^T P_{interface,i}(\rho, l, s, c)$$

$$P_{interface,i} = P_{HP,i} + P_{PT,i} = \left(E_{HP} \times \frac{\rho \times R_i}{l} \right) + \left(E_{PT} \times \rho \times R_i \right)$$



$$E_{server} = \sum_0^T P_{server} = \sum_0^T \left\{ P_{common} + \sum_i P_{interface,i} + (P_{environment}) \right\}.$$

$$P_{environment} = P_{chiller} + P_{dehumid}.$$

$$\sum_i P_{interface,i} = (P_{server_{Peak}} - P_{server_{Idle}}) \times u_{server}$$

Impacts of energy saving technologies

➢**Impacts on network performance**

Introduction of energy-saving technologies may alter the network performance

- increased delays,
- congestion,
- connection hang-ups (e.g. in case of too long status transition time)

➢**Impacts on service provisioning**

Mitigation of increased energy consumption because of new service provision

Energy-saving technologies have to be realized as the trade-off between energy saving and performance degradation

Ongoing work and future studies

Y.energyECN draft recommendation on "*Energy efficiency class of networks*": continues work of Y.3022 by the determination of energy efficiency classes that allow to compare networks by their energy consumption

Mandatory & options technologies for network energy saving

Overcome (at least to some extend) problems and difficulties implied in current technologies for network energy saving

Active participation in work very welcome

For further information do no hesitate to ask
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