PANEL on ICNS/ENERGY

Topic: Energy Constraints and Systems/Networks Design Methodologies

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Moderator

Eugen Borcoci, University "Politehnica"of Bucharest (UPB), Romania

Panelists

Eugene Feinberg, Stony Brook University, USA
Ravish Kumar, ABB GISL, India
Petre Dini, Concordia University, Canada || China Space Agency Center, China
Eugen Borcoci, University Politehnica Bucharest, Romania

Panel ICNS/ENERGY

- **Energy**
  - **Production, distribution, consumption, failure recovery, …- major problems of the society**
    - Optimization of the above processes – main area- for huge effort - both in research and real life deployments
  - **Communication technologies and systems**
    - Energy awareness in comm. systems→ energy saving/consumption optimization → "Green" systems - Internet, Data centres, WANs, …
    - **Intelligent/adaptive Management and Control support for electric power systems (smart grids)**
      - **Similarity to communication networking:**
        Data Plane – Power distribution system
        M&C Plane – Communication network supporting the first

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- **Possible question for this panel:**
- ***What are the most important and still open areas of research in the domains***
  - ***Energy systems +***
  - ***ICT and Networking systems***
- ***in the perspective of Horizon 2020 ?***
- **Thanks !**
- **Floor for the speakers…..**

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Energy Constraints and Systems/Networks Design Methodologies

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Topic: Wireless technologies – supporting Smart Grids

- **Smart grid:** intelligent power network characterized by its two-way flows of electricity and information
- **Integrated communication infrastructure-** essential subsystem for smart grids to manage the operation of all connected components aiming to reliable and sustainable electricity supplies
- Several advanced **wired/wireless communication technologies have been used or candidate** to be used in different domains of smart grid networks.

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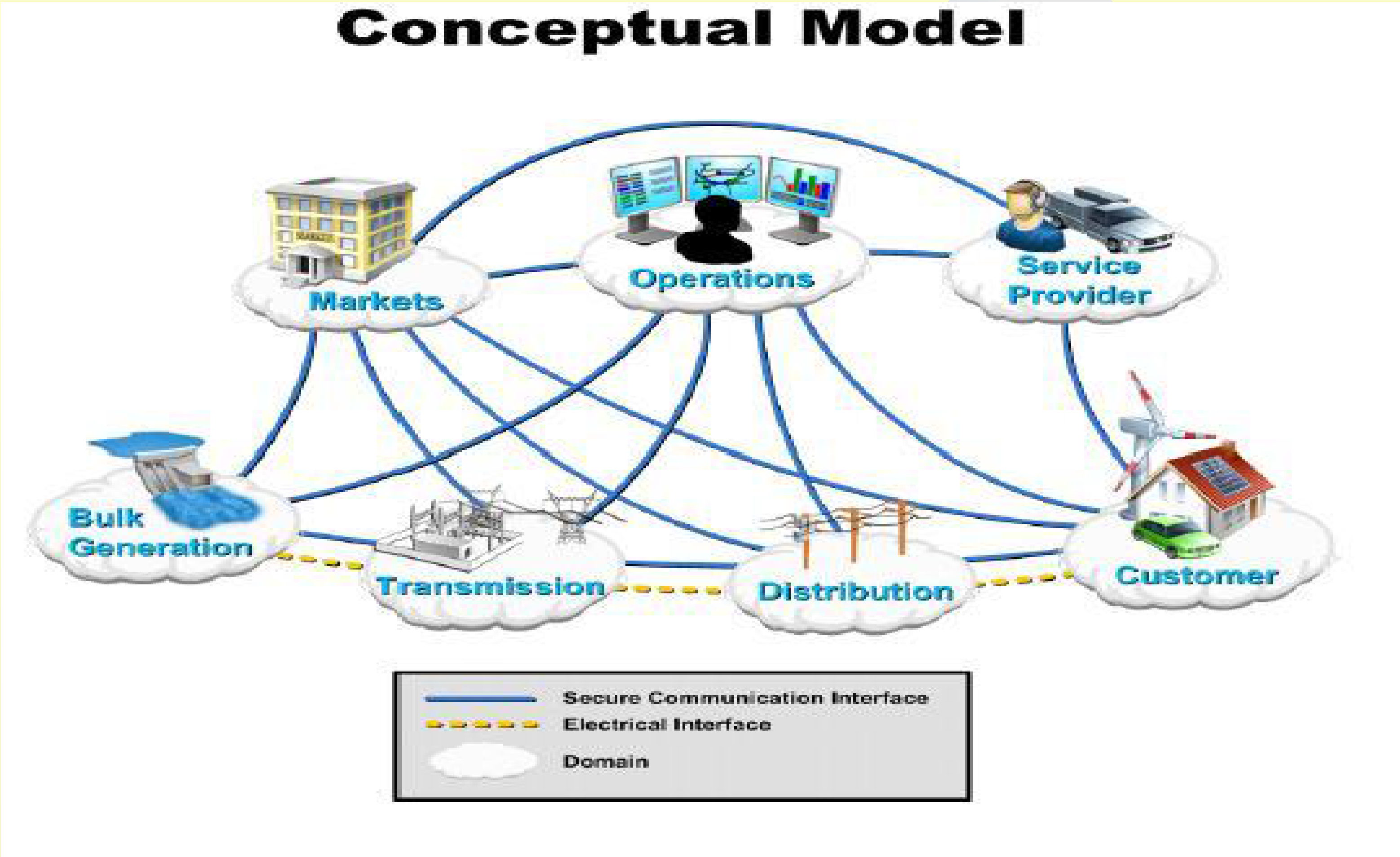
- NIST Smart Grid Conceptual model



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- **SMART GRID attributes/requirements**
  - meet increased consumer demand without adding infrastructure
  - accept energy from virtually any fuel source (coal, natural gas solar, wind, etc.)
  - integrate any and all better ideas and technologies (e.g., energy storage technologies, for example)
  - enable real-time communication between the consumer and utility
    - consumers can tailor their energy consumption based on individual preferences
  - create new opportunities and markets (able to capitalize on plug-and-play innovation)
  - deliver necessary power quality: no sags, spikes, disturbances, and interruptions
  - resistant to attack and natural disasters (more decentralized and reinforced with smart grid security protocols)
  - green—reduce the impact on global climate change

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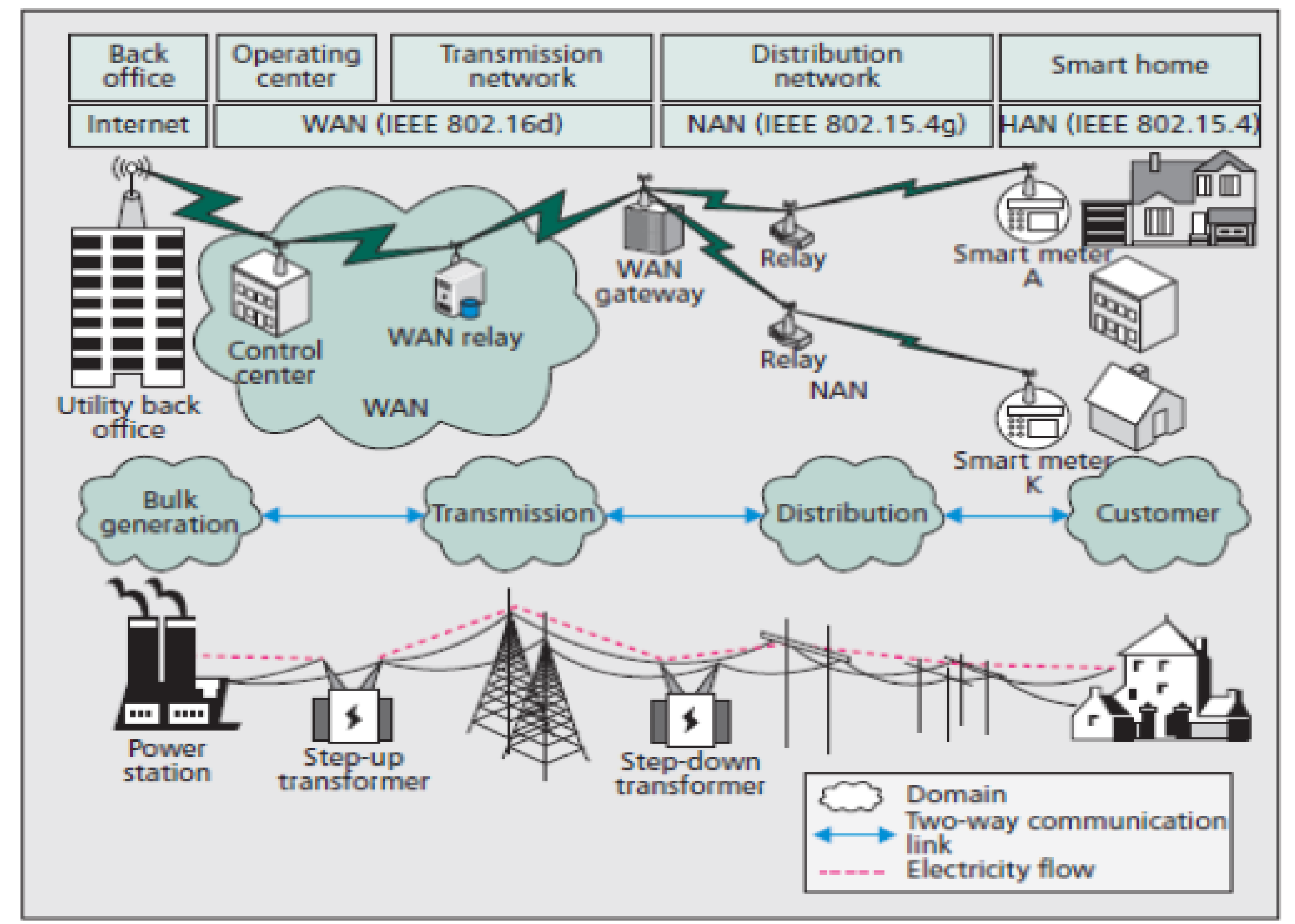
- **Example of a conceptual model for a M&C Plane of a Smart Grid**



Smart Grid

"M&C Plane"

NAN= Neighborhood Area Network

HAN= Home Area Network

Source: W.Meng et.al., Smart Grid Neighborhood Area Networks: A Survey, IEEE Networks, Jan 2014

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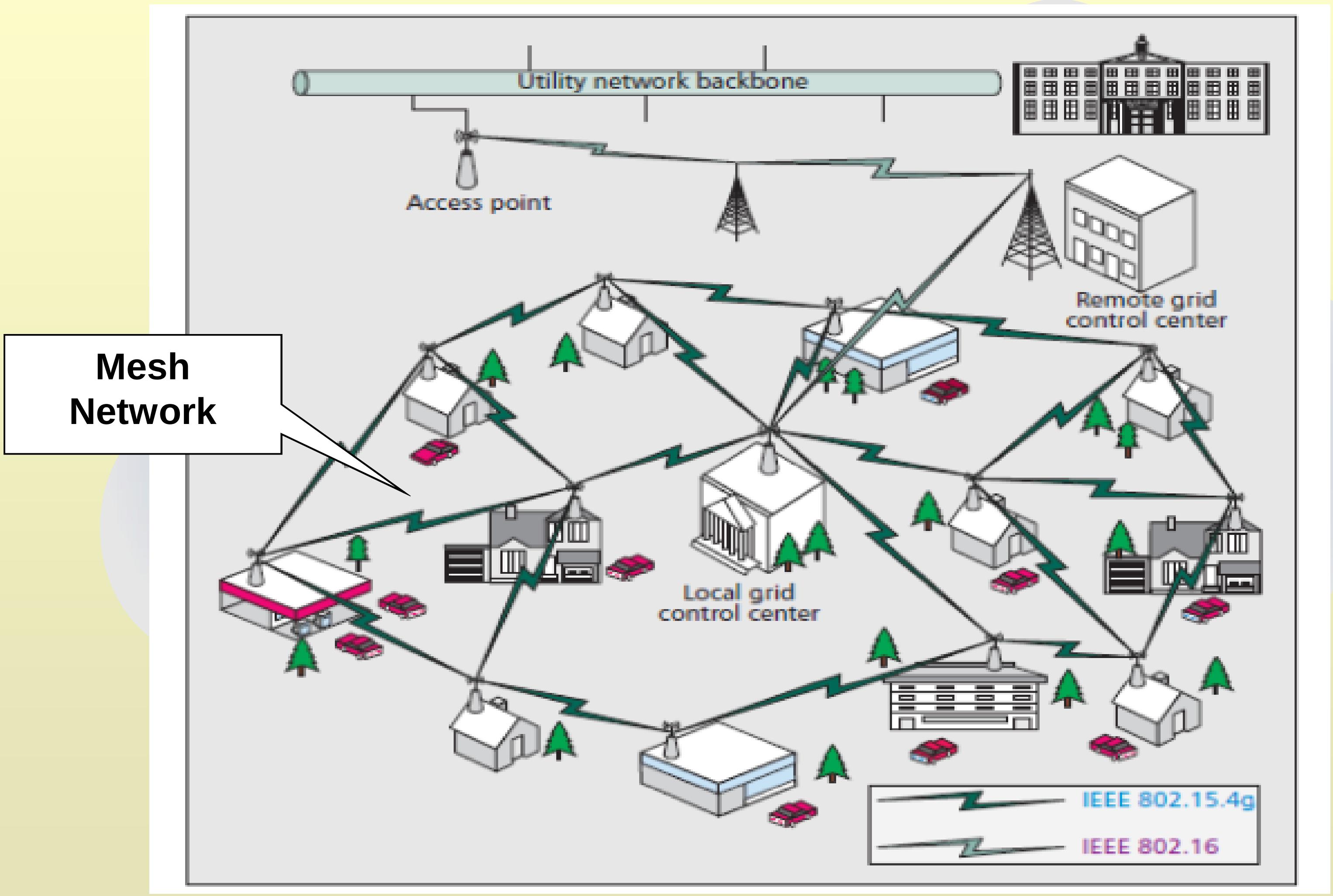
- **Hybrid M&C Plane- Cooperation example : IEEE 802.16d + IEEE802.15g**



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- **Technologies for NAN**

- **IEEE 802.15.4g** - standard making a PHY + MAC amendment and modifications to WPAN IEEE 802.15.4, aiming to
  - outdoor low data rate and wireless smart metering utility network (SUN) requirements.

  - SUN was designed to operate in a
    - distributed mode
    - over shared network resources
    - to enable the monitoring and control of utility systems.

  - SUN devices operate in a very large scale and low-power wireless application environment

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- **Technologies for NAN**
- IEEE 802.11s-derived from IEEE 802.11 family

- Goals
  - to to extend IEEE 802.11 MAC protocol for Wireless Mesh Networks
  - A significant feature : support frame delivery and route selection at MAC layer through radio-aware metrics.

- Topology of an IEEE 802.11s WMN
  - a central gateway is designated and deployed for data transmission to
  - mesh stations.
    - Mesh APs
      - offer the access I/Fs to the end users in either static or dynamic state,
      - transmit aggregated information to gateways via multi-hop paths.

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- **Technologies for WAN connectivity**
- IEEE 802.16 (d)
  - can be used for WANs connectivity
  - and relay signals from IEEE 802.15.4g back to utility backbone.

  - **Conclusions**
  - Wireless technologies can be successfully used for Smar Grid M&C Plane
    - IEEE 802.16x
    - IEEE 802.15.x
    - IEEE 802.11x
    - Topologies: p-mp, mesh, hybrid, etc.
  - However requirements need to to be fulfilled and adapted to Smart Grids needs: reliability, scalability, real-time capabilities, throughput, security, cost efficiency, ..

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- Thank you !

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- **References**

1. W.Meng et.al., “Smart Grid Neighborhood Area Networks: A Survey”, IEEE Networks, Jan 2014
2. M. E. El-hawary, “The Smart Grid—State-of-the-art and Future Trends” http://www.tandfonline.com/loi/uemp20
3. Z. Fan *et al.*, “The New Frontier of Communications Research: Smart Grid and Smart Metering,” *e-Energy*, 2010, pp. 115–18
4. Y.Yan, Y.Qian, H.Sharif, and D.Tipper, “A Survey on Smart Grid Communication Infrastructures: Motivations, Requirements and Challenges”, IEEE COMM. Surveys & Tutorials, VOL. 15, NO. 1, Q1, 2013

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- Backup slides

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- **IEEE 802.15.4g**
- The role of IEEE 802.15 Smart Utility Networks (SUN) Task Group 4g
- is to create a PHY amendment to 802.15.4 to provide a global standard that facilitates very large scale process control applications such as the utility smart-grid network
- capable of supporting large, geographically diverse networks with minimal infrastructure, with potentially millions of fixed endpoints.

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- **IEEE 802.15.4g**
- Operation in any of the regionally available license exempt frequency bands, such as 700MHz to 1GHz, and the 2.4 GHz band
-
- Data rate of at least 40 kbits/s but not more than 1000 kbits per second
- Achieve the optimal energy efficient link margin given the environmental conditions encountered in Smart Metering deployments
- Principally outdoor communications
- PHY frame sizes up to a minimum of 1500 octets
- Simultaneous operation for at least 3 co-located orthogonal networks
- Connectivity to at least one thousand direct neighbors characteristic of dense urban deployment

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- **IEEE 802.15.4g**

- Provides mechanisms that enable coexistence with other systems in the same band(s) including
  - IEEE 802.11, 802.15 and 802.16 systems
  - In early stage of standardization, IEEE 802.15.4 amendment was considered.

- However, the communication range, robustness, and coexistence characteristics required for SUN application have not been met with existing 802 standards including IEEE 802.15.4.

- Therefore, New PHY for SUN application was requested in IEEE 802.15.4g SUN.

Some of the Lessons Learned from Long Island Smart Energy Demonstration Project Funded by US Department of Energy

(February 2010 – February 2015)

Eugene A. Feinberg

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Long Island and Route 110 Corridor

- Long Island is a part of New York State that is significant in terms of economic importance.
- Route 110 corridor, located in the middle of Long Island, is a highly developed area that includes a large number of commercial, industrial and residential customers.
- State University of New York (SUNY) at Stony Brook, Long Island Power Authority ("LIPA"), and SUNY Farmingdale State College proposed the Smart Grid Demonstration Project along Route 110 corridor.
- The project was awarded by the US Department of Energy in November 2009.
- Project spans 2010 through 2015.

Key Stony Brook University Tasks

- Enhanced load modeling and forecasting
- Integration of renewable generation
- Phase balancing
- Voltage control
- Visualization tools for customer interaction
- Cybersecurity
- Curriculum development and public outreach

Smart Grid Optimization

- Optimization models were built and solved for the following problems:
  - Distribution feeder reconfiguration with the presence of renewable generation
  - Phase balancing
  - Voltage control combining both transformer tap changer and capacitor banks.

Efficiency Enhancement

- AMI provides 15-interval data on currents, voltage, real and reactive power of individual customers.
- We used these data to improve load modeling in the distribution network, which improves the accuracy of power flow analysis.
- We implemented this distributed load model in CYMDIST – a distribution network analysis software.

Power Quality Improvement

- We used AMI data to examine the power factor and voltage level at individual customers.
- Customer accounts with low power factors were identified and reported to the utility
- We discovered that the system in the corridor area was run at the upper end of the voltage level, which potentially increased the energy consumption.

Customer Concerns

- Customers have (often unjustified) health, security and privacy concerns about Smart Grid.
- Health concern: Radio Frequency (RF) exposure.
- Security concern: cyber attacks using smart meter as the access point, data being stolen or manipulated during transmission.
- Privacy concern: metered data may be used to reveal private information about the residents.
- Sufficient customer interaction is needed to address and clarify these concerns.

WWW.IARIA.ORG

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Energy Constraints and Systems/Networks Design Methodologies

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Systems/Networks Requirements

- **Operational requirements**
  - **→ as defined by the customers /operations//functions//…**
- **Non-operational requirements**
  - **→ Performance**
  - **→ Security**
  - **→ Fault-tolerance**
- **Lifecycle requirements**
  - **→ Maintainability**
  - **→ Testability**
  - **→ Scalability**
  - **→ Accessibility**
- **Environmental requirements**
  - **→ Energy /consumption, recycling, etc. /**
  - **→ Pollution /radiation, noise, etc. /**
  - **→ Urbanistic /trespassing limitations, citizen accessibility, etc./**

Energy

- From chip, to laptop, to data centers

- Energy saving
- Consumption optimization
- Energy saving awareness
- Energy saving incentives

- Energy control

    → computation
    → communication
    → cooling/heating

- Energy consideration levels

    → chip-level
    → data centers
    → sources

Reducing energy consumption (Green Computing)

Graphical Parallel Units [GPU]

Techniques for reducing the GPU power consumption are classified into five categories:
- **dynamic voltage/frequency scaling (DVFS)**
- **CPU-GPU workload division-based techniques**
- **architectural techniques**
- **techniques that exploit workload variation to dynamically allocate resources and**
- **programming-level techniques**

The common code patterns that lead to inefficient use of GPU hardware and increase the power consumption:
These code segments are grouped into following categories:
- **Global memory data types and access patterns**
- **The thread block dimensions**
- **Portability across different GPUs**
- **The use of constant and texture memory**
- **Floating-point number computations**

http://www4.ncsu.edu/~yyang14/icpp2012.pdf
Yi Yang et al.
Fixing Performance Bugs: An Empirical Study of Open-Source GPGPU Programs

Green Communication (Green protocols)

Green communication: **Energy-aware protocols**

Traffic-based decision

#1

IP routers are able to power off some network links during low traffic periods

a three-phases algorithm:

- **first phase: some routers are elected as "exporter" of their own Shortest Path Trees (SPTs);**
- **second one: the neighbors of these routers perform a modified Dijkstra algorithm to detect links to power off;**
- **last one: new network paths on a modified network topology are computed.**

Performance study shows that, in an actual IP network, even more than the 60% of links can be switched off.

#2

coordinating how core routers go into power saving mode without degrading quality of service and network connectivity during non-peak hours.

on top of any existing distributed routing protocols in the Internet without any compatibility problems. Numerical results showed that the protocol can save up to 47.5% of the power used in a core router

Logistics

Sleep mode-based green strategies

Failure rates depends on the operational temperature versus the reference temperature (recommended)

Arrhenius law; if the operating temperature of a device is reduced, its failure rate becomes smaller

Coffin-Manson model: there is a material fatigue due to temperature variations, especially in a cyclic way

This happens when the device passes from full power to sleep mode and vice versa

Sleep-mode affects the lifetime via temperature variations (isolated device)

Additional reparations costs are exceeding any energy saving benefits (for some)

SM parameters

Lifetime depends on energy-efficient algorithms, network topology, traffic variations

Is Green Networking Beneficial in terms of Device Lifetime

Luca Chiaraviglio et al.

IEEE Communications Magazine, May 2015, vol. 53, no. 5

Forecast: almost here, or soon to come

- **Technical aspects (a few)**
  - → **Soggy Computing**
  - → **Virtualization (Data centers)**
  - → **Energy harvesting**

- **Social aspects**
  - → **Energy-saving awareness**
  - → **Energy-saving incentives**
  - → **Planning for energy consumption: domestic/industrial**

Soggy Computing

Soggy Computing

Stuart Parkin, IBM/Stanford

No motherboards, memory chips, transistors

But a brain-inspired box full of liquid-driven circuitry that swells and shrinks (liquid gates)

No more ‘go smaller, go faster’ go faster costs a lot of energy

Candidate:

Vanadium dioxide (metal oxides), capable of switching from an insulating state to a conductive one (metallic)

- → **very low-power switches that retain their states even when no power is supplied to them**
- → **frequency on the order of tens of hertz**
- → **everything at the room temperature**
- → **redesigning the transistor: includes thin film of vanadium dioxide, topped by a gate that consists if a duplet of ionic liquid….**

Ramanathan, Harvard

Candidate:

Nikellate- based materials (switch from insulator to metal above 100C)

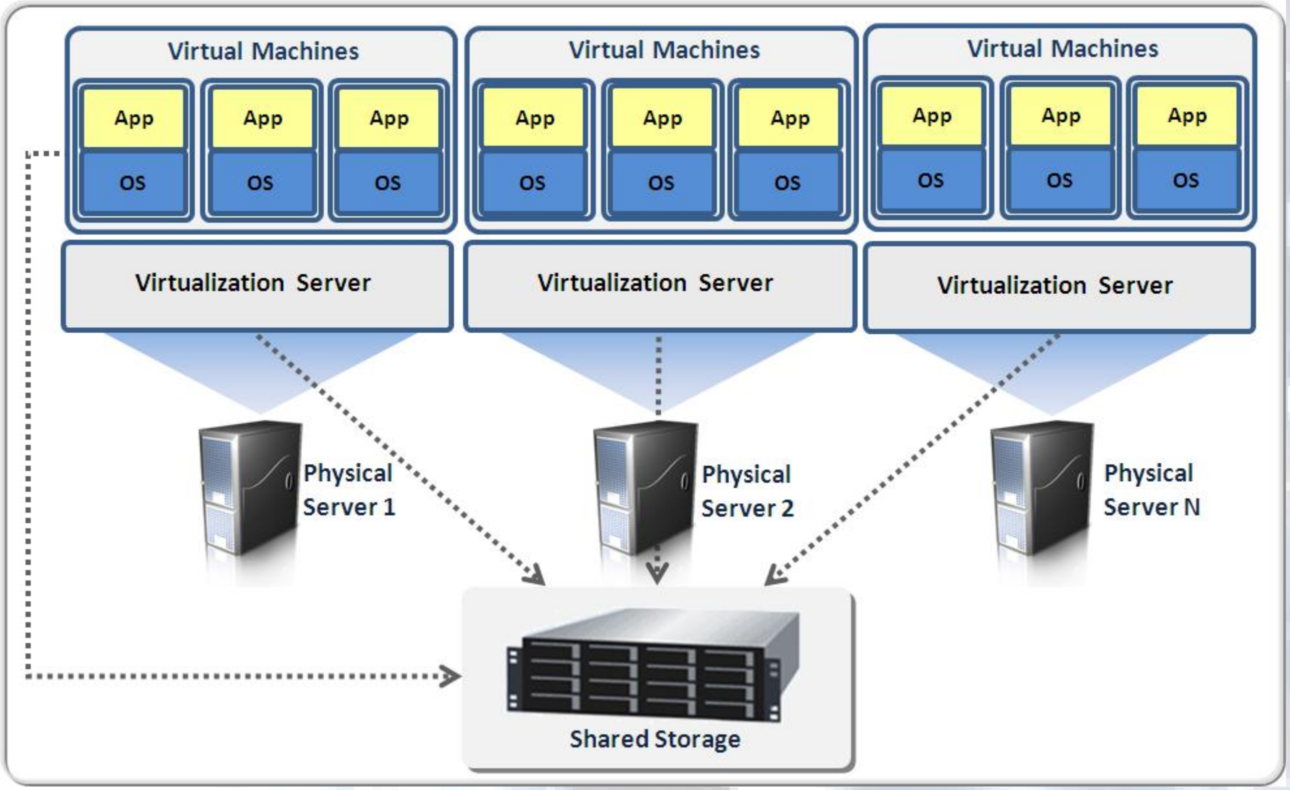
- → **Solid gate to apply a voltage to samarium/nickel/oxygen → pumping protons in/out**
- → **1oo million-fold change in resistance**

Soggy computing, page 18

IEEE Spectrum, May 2015

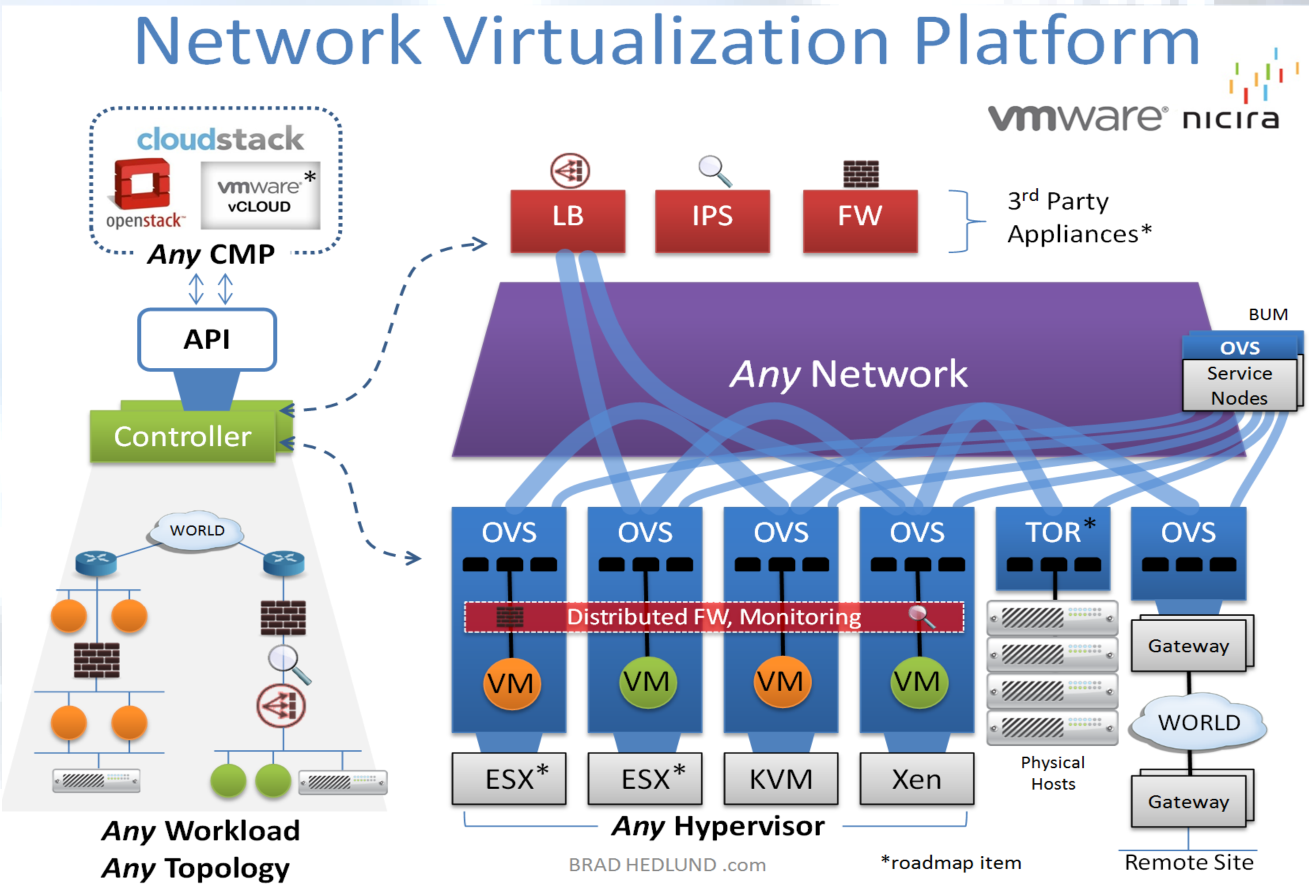
Virtualization (Server)

Virtualization



source: vmware

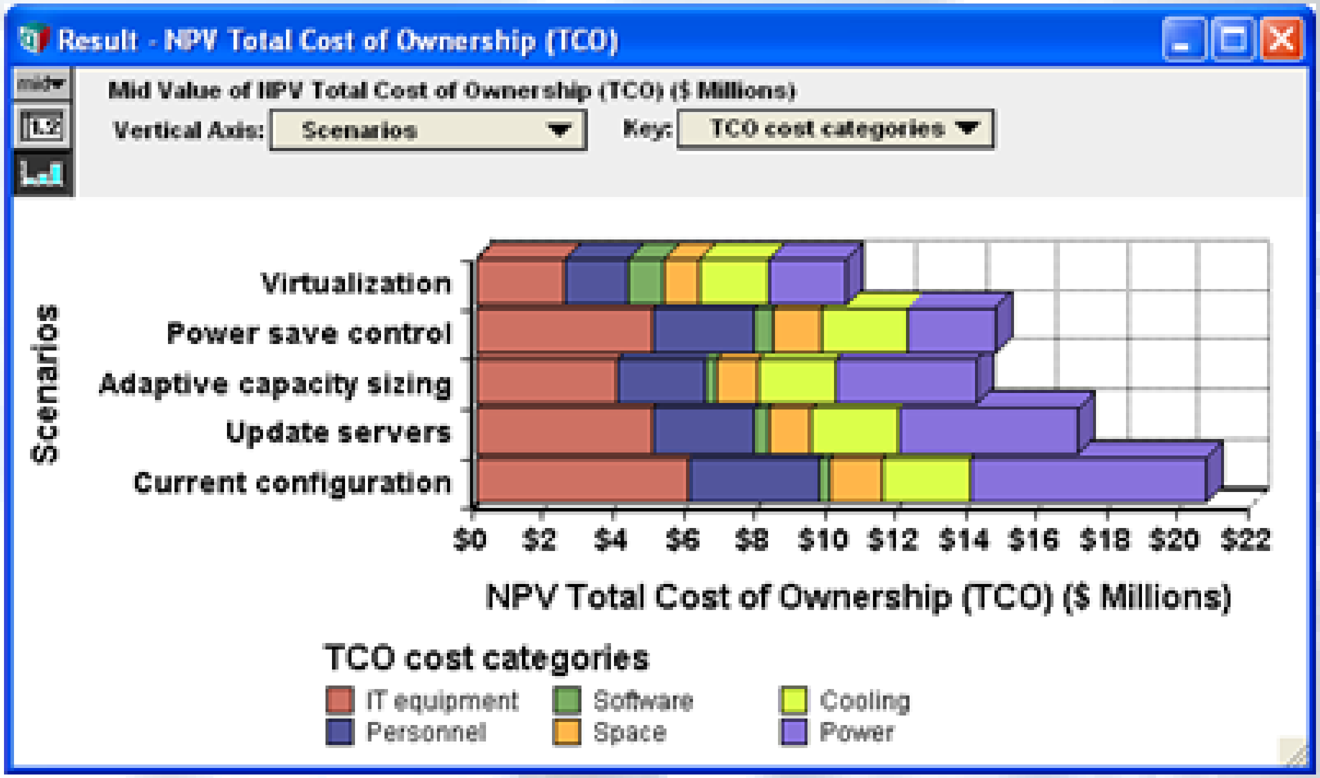
Virtualization (Network)



source: vmware

also: http://bradhedlund.com/2013/01/28/network-virtualization-a-next-generation-modular-platform-for-the-virtual-network/

Virtualization (Power and Cooling)



source: vmware

Energy harvesting

Energy harvesting

For low-cost devices, in energy-constrained networks, by scavenging energy from the ambient environment to power up

Wireless: ultra-low power: wireless sensor networks, hard-to-reach areas, no batteries

Cellular networks: powering base stations by wind or solar power

RF energy harvesting: RF energy is currently broadcasted from billions of radio transmitters

- → Optimal relay placement
- → Data transfer scheduling
- → Cross-layer design

Energy harvesting communications

Special issue

IEEE Communications Magazine, April 2015, vol. 53, no. 4

Thanks!

Qs & As

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