IEEE Sustainable Network Standards

Jaafar Elmirghani,
University of Leeds, UK, j.m.h.elmirghani@leeds.ac.uk
Outline

- Introduction, ICT carbon footprint, traffic trends
- The IEEE Green ICT Initiative
- Standards for green backhaul, core and content distribution networks, and virtualisation
  - IEEE P1927.1 Standard for Services Provided by the Energy-efficient Orchestration and Management of Virtualized Distributed Data Centers Interconnected by a Virtualized Network.
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Introduction, ICT carbon footprint, traffic trends

The IEEE Green ICT Initiative

• Standards for green backhaul, core and content distribution networks, and virtualisation
  • IEEE P1927.1 Standard for Services Provided by the Energy-efficient Orchestration and Management of Virtualized Distributed Data Centers Interconnected by a Virtualized Network.
  • IEEE P1929.1 An Architectural Framework for Energy Efficient Content Distribution.
Energy Supply and Consumption: Most Energy is Lost

Estimated U.S. Energy Consumption in 2019: 100.2 Quads

Source: LLNL March 2020. Data is based on DOE/EIA M6 (2019). If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Distributed electricity represents only retail electricity sales and does not include self-generation. EIA reports consumption of renewable resources (i.e., hydro, wind, geothermal and solar) for electricity in BTU-equivalent values by assuming a typical fossil fuel plant heat rate. The efficiency of electricity production is calculated as the total retail electricity delivered divided by the primary energy input to electricity generation. End use efficiency is estimated as 69% for the residential sector, 63% for the commercial sector, 21% for the transportation sector and 44% for the industrial sector, which was updated in 2017 to reflect DOE’s analysis of manufacturing. Totals may not equal sum of components due to independent rounding. LLNL-MT-61057
and more energy efficient end-user devices is particularly important, as nearly half the sector's emissions, in the scope of this analysis, comes from "end-user devices", rather than from networks or data centers (see figure below).

Figure 7: Environment - ICT emissions footprint (2030)

Comparing ICT's own footprint of 1.25Gt CO₂e in 2030 with the 12Gt CO₂e of emissions avoided through the use of ICT solutions demonstrates that ICT delivers a benefit 9.7 times higher. In other words, for each ton of CO₂e used to power ICT, users can on average realize almost 10 tons of CO₂e savings in 2030. In our previous report, SMARTer2020, we found that ICT could cut CO₂e by 9.1Gt in 2020 and create an enablement factor of 7.2. Our first report, SMART2020, published in 2008, had estimated the enablement factor of ICT at 5.5 times ICT's own footprint (see Figure 8).

Our preliminary analysis of ICT's enablement factor in 2015 leads us to conclude that the ICT sector currently abates roughly 1.5 times that of its own emissions.

*Accenture has included, where feasible, scope 1 (direct), scope 2 (indirect from consumption of energy), and scope 3 emissions (all others related). Baseline fixed at 63.5 GtCO₂eq ICT emissions*
Internet Traffic Growth Rate

• Courtesy Thierry Klein, Alcatel-Lucent Bell Labs, Sources: RHK, 2004; McKinsey, JPMorgan, A1&1, 2001; MINTS, 2009; Arbor, 2009
Exponential traffic growth

Doubling every 2 years
- 40% per year
- 30x in 10 years
- 1000x in 20 years

Mix of services is important from energy perspective:
- Mobile less efficient than fiber optics

Data from: RHK, McKinsey-JPMorgan, AT&T, MINTS, Arbor, ALU, and Bell Labs Analysis: Linear regression on log(traffic growth rate) versus log(time) with Bayesian learning to compute uncertainty.
GreenTouch: Improving Energy Efficiency by a factor of 1000
## Green Meter Results for Core Networks

<table>
<thead>
<tr>
<th>Portfolio of 2020 Technologies</th>
<th>Efficiency Gains</th>
</tr>
</thead>
<tbody>
<tr>
<td>Business as Usual (Moore’s Law Improvement)</td>
<td>4.23x</td>
</tr>
<tr>
<td>GreenTouch Equipment Innovations</td>
<td></td>
</tr>
<tr>
<td>- Optical Interconnects</td>
<td></td>
</tr>
<tr>
<td>- Optimized Packet Processing</td>
<td>4.73x</td>
</tr>
<tr>
<td>- Link-Optimized Signal Processing in Transponders</td>
<td></td>
</tr>
<tr>
<td>Deployment and Management of Protection Equipment</td>
<td>1.96x</td>
</tr>
<tr>
<td>Router Bypass &amp; Sleep Modes During Off-Peak</td>
<td>2.13x</td>
</tr>
<tr>
<td>Dynamically Allocated Line Rates (40G, 100G, 400G, 1T)</td>
<td>1.21x</td>
</tr>
<tr>
<td>Optimized Network Direct Path Topology</td>
<td>1.43x</td>
</tr>
<tr>
<td>Optimized Distributed Cloud and Virtualisation</td>
<td>2.19x</td>
</tr>
</tbody>
</table>

Enabling a 96% Decrease in Net Energy Consumption in Future Core Networks

2010
360 nJ/bit

315 x gain

2020
1.14 nJ/bit
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    • IEEE P1929.1 An Architectural Framework for Energy Efficient Content Distribution.
IEEE P1927.1 Standard for Services Provided by the Energy-efficient Orchestration and Management of Virtualized Distributed Data Centers Interconnected by a Virtualized Network.

- **Scope**
  This standard specifies an architecture for a service composed of distributed data centers interconnected by a network. It specifies the interfaces and the dynamic orchestration and management mechanisms for energy-efficient allocation of resources from data centers and network.

- **Purpose**
  The purpose of this standard is to provide an energy efficient networked data center service through joint network and data center virtualization.

- **Need**
  The need is to reduce the energy consumption of virtualized, interconnected data centers. This standard also fills the need for enabling independent network and data center operators to cooperate in the provisioning of energy-efficient networking and processing services.
• Enterprise clients requests for network resources
• A resource allocation framework (RAF) assigns these resources
• Optimization is on the RAF to achieve energy and cost efficiencies
Case study 2: Joint core network and cloud virtualisation

- Solution to the current ossifying forces of the Internet
- Allows the existence of several heterogeneous networks in one physical network
- Enabler of Energy Savings through resource consolidation

Case study 3: VM placement and migration


Network virtualisation, energy efficiency


• **Scope**
  This standard specifies an algorithm for energy-efficient virtual machine placement strategies considering network and computational power consumption. It also considers the geographic distribution of user demand.

• **Purpose**
  The purpose of this standard is to enable energy efficient processing of information considering processing requirements and network power consumption.

• **Need**
  Information processing is becoming more centralized in large data centers that are distributed across geographic areas. Therefore, there is a need to establish mechanisms for energy efficient virtual machine placement.
Virtual Machine (VM) Placement for Energy Efficiency

We develop an MILP model to optimize cloud VM service delivery in IP/WDM networks. Two kinds of decision variables are optimized for the cloud service model:

- **External decision variables:**
  - Number of clouds
  - Location of clouds
- **Internal decision variables:**
  - Number of servers
  - Number of switches
  - Number of routers

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Total Savings</th>
<th>Network Saving</th>
</tr>
</thead>
<tbody>
<tr>
<td>Migrate</td>
<td>5%</td>
<td>23.5%</td>
</tr>
<tr>
<td>Replicate</td>
<td>6%</td>
<td>26%</td>
</tr>
<tr>
<td>Slice</td>
<td>27.5</td>
<td>86%</td>
</tr>
</tbody>
</table>

The saving are compared to single cloud at node 6.
Purpose
The purpose of this standard is to create a framework for design of energy-efficient content distribution mechanisms for various service and networking scenarios.

Need
It is needed for designing content distribution networks with energy efficiency as a primary goal. Content (primarily video) currently represents about 90% of the traffic on the network and therefore improving energy efficiency of the network requires energy efficient content delivery.

Stakeholder
Content providers, network operators, Content Distribution Network (CDN) operators, equipment suppliers, and regulators.
DEER: Distributed Energy Efficient Resources

We develop a MILP model for cloud content delivery in IP/WDM networks to answer whether centralised or distributed content delivery is the most energy efficient solution. Two kinds of decision variables are optimized for the cloud service model:

- **External decision variables:**
  - Number of clouds
  - Location of clouds
- **Internal decision variables:**
  - Number of servers
  - Number of switches
  - Number of routers
  - Storage capacity

![Zipf Distribution](image)

- **Scope**
  This standard specifies a functional architecture that supports the energy-efficient transmission and processing of large volumes of data, starting at processing nodes close to the data source, with significant processing resources provided at centralized data centers.

- **Purpose**
  The purpose of this standard is to improve the energy efficiency of data networks involved in the processing and transmission of big data. Dealing with the large data volumes generated by big data applications requires a mechanism to handle the tradeoffs between transmission and processing from an energy consumption viewpoint.

- **Need**
  This standard is needed because traditional design efforts have focused on how to process these vast volumes of data inside data centers, however the transmission of large data volumes to distant data centers results in increased network power consumption, increased delay and the transmission of potentially redundant data.
Case study 5: Big Data Networks

The average power saving is 76%.


IEEE P1925.1 Standard for Energy Efficient Dynamic Line Rate Transmission System

- **Scope**
  This standard specifies an energy-efficient rate-adaptive transmission system that can be used to deploy mixed line rates. It introduces the architecture and mechanisms needed to enable the use of an optimal combination of line rates to accommodate the traffic while reducing power consumption.

- **Purpose**
  The purpose of this standard is to create a new energy-efficient transmission system.

- **Need**
  Energy-efficient and cost-effective solutions are needed to meet the increasing demand for high capacity core, metropolitan, and access networking infrastructure.
Energy Efficient Elastic Optical Networks

Power Consumption of WDM Router Ports and Transponders

<table>
<thead>
<tr>
<th>Description</th>
<th>Power Consumption (W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power consumption of a WDM router port (40Gb/s)</td>
<td>1000</td>
</tr>
<tr>
<td>Power consumption of a WDM transponder (10Gb/s)</td>
<td>45</td>
</tr>
<tr>
<td>Power consumption of a WDM transponder (40Gb/s)</td>
<td>73</td>
</tr>
<tr>
<td>Power consumption of a WDM transponder (100Gb/s)</td>
<td>135</td>
</tr>
</tbody>
</table>

- Optical Orthogonal Frequency Division Multiplexing (OFDM) has been proposed as an enabling technique for elastic optical networks.
- In addition to the spectral efficiency, optical OFDM supports distance-adaptive spectrum allocation by adapting the modulation format according to the end-to-end physical conditions of the optical path.
Fog, cloud, access, core, IoT testbed


NetFPGA, 100 Gb/s
People With Things

Things (M2M)

RRH

Fog & Edge Compute

Private Cloud

Enterprise DC

Public Cloud

Key

Fiber optical network

Fog cell

PON

Wireless connection

Fiber Connection

NetFPGA based ONU

Access OLT and ONU

NetFPGA card

Fog cell
VM Orchestration in Test-bed

NetFPGA Fog, VM Orch.

Huawei ONU

IP over WDM nodes

Huawei OLTs

Fujitsu and HP servers, Edge Processing

3 IP over WDM nodes
Mission:

to build a holistic approach to sustainability through ICT by incorporating green metrics throughout IEEE technical domains.

Actions:

• Standards
• Conferences and events
• Publications
• Education

Interactions among multiple IEEE societies and initiatives to implement energy-sustainable:

• Metrics
• Hardware design Methods
• Energy-aware algorithms
• Power-proportional computing designs

Deliveries

• 9 standards, PARs approved 2017
  • 3 IEEE Comsoc, SA working groups
• Sustainable ICT Summit, 2017, 2019
• White papers
• Publications
  • IEEE Trans on Green Communications and Networking
  • IEEE Magazine “Sustainability and ICT”
• Education
  • 7 Short courses
9 New IEEE Standards, building on the work of the 50+ GreenTouch industrial and academic members

- IEEE P1922.1 Standard for a Method Calculating Anticipated Emissions Caused by Virtual Machine Migration and Placement
- *(Approved)* IEEE P1922.2 Standard for a Method to Calculate Near Real-time Emissions of Information and Communications Technology Infrastructure
- *(Ballot successful)* P1923.1 Standard for computation of energy efficiency upper bound for apparatus processing communication signal waveforms
- P1924.1 Recommended practice for developing energy efficient power-proportional digital architectures
- IEEE P1927.1 Standard for Services Provided by the Energy-efficient Orchestration and Management of Virtualized Distributed Data Centers Interconnected by a Virtualized Network.
Energy Efficiency Publications


Energy Efficiency Publications


Energy Efficiency Publications


