Network Power Measurement at ESnet

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Outline

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Why measure network power utilization?

- Green computing means all parts of the infrastructure
- Without actual data there is only about guessing what is happening
- Develop an understanding of how much power is needed to get useful work done on the network
- Prove or disprove the widely held assumption that power utilization is not proportional
- Provide a baseline for comparison of future devices and networks
Project Goals

- Collect data from as many devices as possible at both the routed and optical layer
- Automate the collection of data (some data was collected by hand previously)
- Develop a summary metrics describing power consumption as it relates to the network
- Develop models for both routed and optical layer
- Provide a baseline for future work
The anatomy of a Sentry PDU

Tower A

- Inlet A
  - Outlet 1
  - Outlet n
  - AA1
  - AAn

- Inlet B
  - Outlet 1
  - Outlet n
  - AB1
  - ABn

Tower B (optional)

- Inlet A
  - Outlet 1
  - Outlet n
  - BA1
  - BAn

- Inlet B
  - Outlet 1
  - Outlet n
  - BB1
  - BBn
What data is collected

Data
Currently collected:
- Amps per outlet (outletLoadValue)
- Temperature (from 0, 1 or 2 sensors, tempHumidSensorTempValue)
- Humidity (from 0, 1, or 2 sensors, tempHumidSensorHumidValue)
- I2/ESnet optical footprint
- ESnet routed network (mostly)

All data is collected via SNMP from Sentry PDUs once per minute

Metadata
Outlet to device mapping
- Create a stand alone mapping
- Use port name from PDU
  - eg. router-name_PEM0

Relationship of optical gear to layer 2/3 circuit
We observed only a 2% difference between power consumption at idle versus three 100G interfaces running full duplex at line rate.

This is 24 hours of throughput and power consumption data for for star-ani during acceptance testing on October 21-22, 2012 showing both full and idle load.
Network model for the summary metric: A unit of work

ESnet is a transit network:

• All traffic enters at one interface and exits at another interface
• We know what all the entrances and exits are
• ESnet infrastructure (web, mail, etc) is tagged as external
• This means the total traffic in is equal to the total traffic out†
• A unit of work is the delivery traffic accepted from one external interface to another external interface.

†Well almost, there is protocol overhead and incorrectly tagged interfaces, but we are ignoring these here.
Units for the summary metric: Joules per bit

How do we measure the amount of energy required to transfer data?
Joules per bit turns out to be a convenient unit:

\[ P = I \times V \]
\[ J = P \times s \]
\[ \frac{P}{\text{bits}} = P \times \frac{s}{\text{bits}} = \frac{P \times s}{\text{bits}} = \frac{J}{\text{bit}} \]

How much energy is a Joule?
- Lighting a 100 W light bulb for 0.01 second uses 1 J (360 KJ for 1 hour)
- Or put another way, a slice of pizza contains about 1.2 MJ (290 Kcal)

Why not Kilowatt Hours (kWh)?
- Network traffic is bits per second
- Joules is Watts per second
- Convenient alignment of units!
- But, you can have it your way: 1 kWh = 3.6 MJ
The Summary Metric: Joules per bit of transit traffic

Therefore, the power consumption for ESnet is (in Joules per bit):

\[ \left( \frac{J}{\text{bit}} \right)_{\text{ESnet}} = \frac{\sum P_{\text{Routers}}}{\sum T_{\text{External}}} \]

What the summary metric tells us:

• Coarse grain metric for the power required to do useful work
• Similar computation can be done for the optical layer
• Routed + optical could be combined to make a more complete picture
• Measures aggregate transit flow (no double counting)
Summary Metric on the MyESnet Portal

Network Power Consumption [BETA]

As part of the ANI project ESnet is measuring the power utilization of the entire prototype network. This visualization shows the power consumption of the ANI network both as the number of Joules consumed per bit and as the raw Watts (Joules/sec) consumed. This power utilization is measured for the five ANI testbed routers. This does not include the power consumed by the optical transport gear.

This visualization is in beta testing and is not fully production quality yet. There may be missing or incorrect data. Please report bugs to the ESnet Tools Team.

Joules per Bit

The summary metric was implemented for the ANI project. It currently does not work with ESnet 5 and needs to be updated.
Additional Models

Other models to consider
• per optical span/circuit
• per node
• per site
• per flow

Example:
Joules per optical span/circuit

- Power for the circuit $P_C$
- Power for node $P_x$
- Number of circuits at node $N_x$

$$P_C = \frac{P_A}{N_A} + \frac{P_Z}{N_Z}$$

- Could be extended to Joules per path but summing this for each circuit along a path
Additional Models: Joules per flow

For each time step:

\[ \sum_{n=1}^{hops} \frac{T(\text{flow})}{T(rtr_n)} \times P(rtr_n) \times \text{step} \]

Fraction of utilization due to flow
Total power utilized by device
Time step in seconds

Offline or “near real time” analysis possible
Implementation & Lessons Learned

Implementation
ESxSNMP
  • Data collection
  • REST API for data access
Visualizations using d3.js
Ad-hoc data analysis done in Python

Lessons (Re)-Learned
The devil is in the details!
  • Keeping track of outlets
  • Clean up of documentation and diagrams
  • Dealing with the physical world
Start your project (even) earlier than you think you need to
Planning, consensus and coordination take time
Future Directions

• What power measurements can the devices provide?
  • Per card?
  • Per port?
• Compare PDU measurements to device based measurements
• Develop more sophisticated models
• Develop experimental implementations of models
• Lots of room for exploration
Questions?

Thanks!

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