Valuing the greenness of NRENs

Paola Grosso
Arie Taal
Daniel Romão

System and Network Engineering research group

University of Amsterdam
Greenness: trade of between end-user’s and network owner’s interests

Multiple diverse network aspects:

- Latency [s]
- Service costs, write-off costs [Euro,$]
- Power dissipation [W]
- Utilization of a network device [%]
- Power Usage Efficiency (PUE) of equipment housing
- CO\textsubscript{2}-emission [g.CO\textsubscript{2}/kWh]
  (depends on energy type supplied: anthracite 870 g.CO\textsubscript{2}/kWh, wind turbines 10 g.CO\textsubscript{2}/kWh)
Search for a quality measure able to take diverse network aspects into account.

Requirements quality measure:
• Should behave according to expectations
• Every aspect, regardless its value, should have the same importance, e.g.:
  CO$_2$-emission of 800 [g.CO$_2$/kWh] has same importance as
  PUE of 1.6
  has same importance as
  Latency of 3 ms.
Valuing the effect of a single aspect

Single aspect dispersion measures available:
e.g. Variance,
Gini-coefficient from economics

Gini-coefficient in economics measures the degree of inequality in the distribution of family income in a country.

- Luxembourg 0.26 (2005)
- Netherlands 0.309 (2007)
- Panama 0.519 (2010)

The lower the value of the Gini-coefficient the more equality in the distribution (not enough information)

Network node ← people
Utilized capacity ← income
Multi aspect quality measure needed

Relative efficiency of a node

Define Inputs and Outputs for a node
Inputs are ‘negative’ aspects (to be as low as possible)
Outputs are ‘positive’ aspects (to be as high as possible)

Compare Inputs/Outputs of each device with corresponding Inputs/Outputs of a device with highest efficiency, so Watts are compared to Watts, and Euros are compared to Euros.
Relative efficiency of a network node

Example. 4 aspects of network node $i$:

- $P_i$ (power) [W]
- $u_i$ (utilization max. capacity)
- $PUE_i$ (Power Usage Efficiency)
- $X_i$ (emission cost) [g. CO$_2$/kWh]

1. Design method to determine a reference node $p$ with which all other nodes are compared.
2. Compare each node $i$ with node $p$ according to

$$z_i = 1/3 \left( \frac{P_p}{P_i} + \frac{PUE_p}{PUE_i} + \frac{X_p}{X_i} \right) * \left( \frac{u_i}{u_p} \right) = z_{i_{\text{inputs}}} * z_{i_{\text{outputs}}}$$

$z_i$ is relative input efficiency times relative output efficiency.

Reference node $p$ is network node with the best $z_{i_{\text{inputs}}}$ and best $z_{i_{\text{outputs}}}$ of all nodes in the network $\Rightarrow z_i < z_p = 1$
Example

3 SURFnet paths from demo
construct matrix

\[ R(o,j) = \frac{1}{3} \left( \frac{P_o}{P_j} + \frac{PUE_o}{PUE_j} + \frac{X_p}{X_i} \right) \times \left( \frac{u_j}{u_o} \right) \]

<table>
<thead>
<tr>
<th>R(o,j)</th>
<th>j=0</th>
<th>j=1</th>
<th>j=2</th>
</tr>
</thead>
<tbody>
<tr>
<td>o=0</td>
<td>1</td>
<td>0.57</td>
<td>0.21</td>
</tr>
<tr>
<td>o=1</td>
<td>1.68</td>
<td>1</td>
<td>0.38</td>
</tr>
<tr>
<td>o=2</td>
<td>4.66</td>
<td>2.70</td>
<td>1</td>
</tr>
</tbody>
</table>

Choose node 0 as reference node \( \rightarrow \)

\[ Z_1 = 0.21, \ Z_2 = 0.57, \ Z_0 = 1 \]
Relative efficiency for a network node

Gives an ordering on nodes of a network for multiple diverse aspects:

\[ 0 \leq \ldots \leq z_i \leq z_{i+1} \leq \ldots \leq z_p \leq 1 \]

Ordering can also be used to decide where investments are most effective.

Investment into a better PUE of a path(i) of nodes such that \( z_{\text{path}(i)} \) increases from 0.21 -> 0.38 is a better investment than one into path(j) where \( z_{\text{path}(j)} \) increases from 0.85 -> 0.857, if both investment costs are comparable.
Relative efficiency for a network node

Quality measure from rel. efficiency

How far off are the rel. efficiencies from 1

\[ \text{Dev} = \frac{1}{N} \sum (1 - z_i) = 1 - Q \]

\[ Q = \frac{1}{N} \sum z_i \]
Dispersion measures on NRENs

Example:

http://green3.lab.uvalight.net/Surfnet/power_demo/powergui.html
Scenario 1: Default settings 3 paths
Traffic according workday stats
Energy type the same (400)
PUE the same (2.4)
Calculate: -> Rel Eff.
\[ z_{Delft} = 1, \quad z_{Gron} = 0.57, \quad z_{Mstr} = 0.21, \quad Q=0.59 \]

Delft has less nodes in path and higher traffic.
Traffic patterns ‘fixed’
Improve PUE Maastricht - > 1.2
\[ z_{Delft} = 1, \quad z_{Gron} = 0.57, \quad z_{Mstr} = 0.31, \quad Q=0.63 \]
Scenario 2: PUE improvement expensive, try better energy type for Maastricht path
Traffic according workday stats
Energy type the same (400, 400, 40)
PUE the same (2.4)
Calculate: \( \rightarrow \text{Rel Eff.} \)
\[ z_{\text{Delft}} = 1, \ z_{\text{Gron}} = 0.57, \ z_{\text{Mstr}} = 0.70, \ Q=0.76 \]
default:
\[ z_{\text{Delft}} = 1, \ z_{\text{Gron}} = 0.57, \ z_{\text{Mstr}} = 0.21, \ Q=0.59 \]
single aspect dispersion measures

Variance and Gini-coefficient, of the utilization of max. capacity, only change if the traffic over a path changes.