Valuing the greenness of NRENs

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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_2-emission [g.CO_2/kWh]

  (depends on energy type supplied:

  anthracite 870 g.CO_2/kWh, wind turbines 10 g.CO_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.

- Luxembourgh 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

$$z_i = 1/3(P_p/P_i + PUE_p/PUE_i + X_p/X_i) * (u_i/u_p) =$$

$$z_{i\_inputs} * z_{i\_outputs}$$

z_i is relative input efficiency times relative output efficiency

Reference node *p* is network node with the best z_{i_inputs} and best $z_{i\_outputs}$ of all nodes in the network → $z_i < z_p = 1$

Example

3 SURFnet paths from demo
construct matrix
$R(o,j) = 1/3(P_o/P_j + PUE_o/PUE_j + X_p/X_i) * (u_j/u_o)$

R(o,j)	j=0	j=1	j=2	
o=0	1	0.57	0.21	(Delft)
o=1	1.68	1	0.38	(Groningen)
o=2	4.66	2.70	1	(Maastricht)

Choose node 0 as reference node →
$Z_1 = 0.21$, $Z_2 = 0.57$, $Z_0 = 1$

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 $z_{path(i)}$ increases from 0.21 -> 0.38
is a better investment than one into *path(j)* where
$z_{path(j)}$ 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

$$Dev = 1/N \sum (1 - z_i) = 1 - Q$$

$$Q = 1/N \sum z_i$$

Dispersion measures on NRENs

Example:

http://green3.lab.uvalight.net/Surfnet/power_demo/powergui.html

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, z_Gron = 0.57, z_Mstr = 0.21, Q=0.59

Delft has less nodes in path and higher traffic.

Traffic patterns ‘fixed’

Improve PUE Maastricht - > 1.2

z_Delft = 1, z_Gron = 0.57, z_Mstr = 0.31, Q=0.63

powergui.html

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: -> Rel Eff.

z_Delft = 1, z_Gron = 0.57, z_Mstr = 0.70, Q=0.76

default:

z_Delft = 1, z_Gron = 0.57, z_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.