Support of NDTs for the Gridification of Internet

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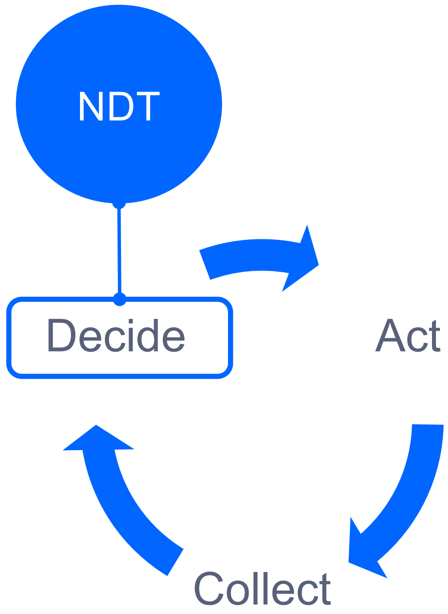
Gridification of the Internet

? How has the Internet **been impacted** by carbon awareness & accountability, renewables & energy storage, microgrid build-out, grid balance through elastic “computing” loads, capacity planning, AI / Data Centers?

- Different impacting dimensions
  - Architecture and network design
  - Aggregation of metrics and indicators
  - Optimization decision and algorithms
  - Incentivization mechanisms
  - Etc
- Two cases for this presentation (there are others, of course)
  - Decisions based on indicators from regulators (and enablers being developed for that)
  - The grid to be considered as part of the network from the point of view of critical infrastructure



BEREC* - Sustainability Indicators for Electronic Communications Networks and Services

Source: BEREC Report on Sustainability Indicators for Electronic Communications Networks and Services, BoR (23) 166, October 2023.

GROUP A

* Collected by at least one NRA

*High or medium support from companies

Name of the indicator	Collection by NRAs in BEREC	Level of support from the surveyed companies	Number of companies collecting this indicator	Relevant scope	Examples of data already collected
Energy consumption	Yes (FR, BE, ES, FI)	HIGH	61	Networks, data centres, company-wide	Energy consumption of different parts of the network (BE, FI, FR) Data centres and IT equipment energy consumption (BE, ES, FR)
Carbon emissions - Direct emissions	Yes (FR, BE, ES)	HIGH	52	Company-wide	Scope 1 emissions (FR, BE, ES)
Carbon emissions - Energy indirect emissions	Yes (FR, BE, ES)	HIGH	52	Company-wide (location based, and market based)	Scope 2 emissions (FR, BE, ES)
Carbon emissions - Other indirect emissions	Yes (FR, BE, ES)	HIGH	40	Company-wide	Scope 3 emissions (FR, BE, ES)
Energy efficiency	Yes (BE, ES)	HIGH	50	Networks, data centres	Consumption in function of data/clients/revenue (BE, ES) PUE (BE)
Use of renewable energy (rate)	Yes (BE, FI)	HIGH	51	Company-wide	Production and use of renewable energy (BE, FI)
Distribution or utilisation of recycled/refurbished/ reused products	Yes (FR, BE)	HIGH	26	Devices, equipment	Number of items recycled/refurbished (BE) Number of items collected in order to recycle or repackage them (FR) Number of items sold repackaged (FR)
Expected lifetime	Yes (FR)	MEDIUM	10	Devices, equipment	Devices duration of use by year of commercialisation (FR) Number of items sold each year (FR)
Water usage/consumption	Yes (FR, BE)	MEDIUM	35	Data centres and other infrastructures element	Water consumption by types of water (BE, FR) Water cooling systems used (FR) Reuse of water (BE) Water discharge areas and conditions (BE, FR)
Raw materials depletion (mineral)	Yes (FR)	MEDIUM	6	Devices, equipment manufacturing	Use of rare earths and precious metals (FR)

Location based

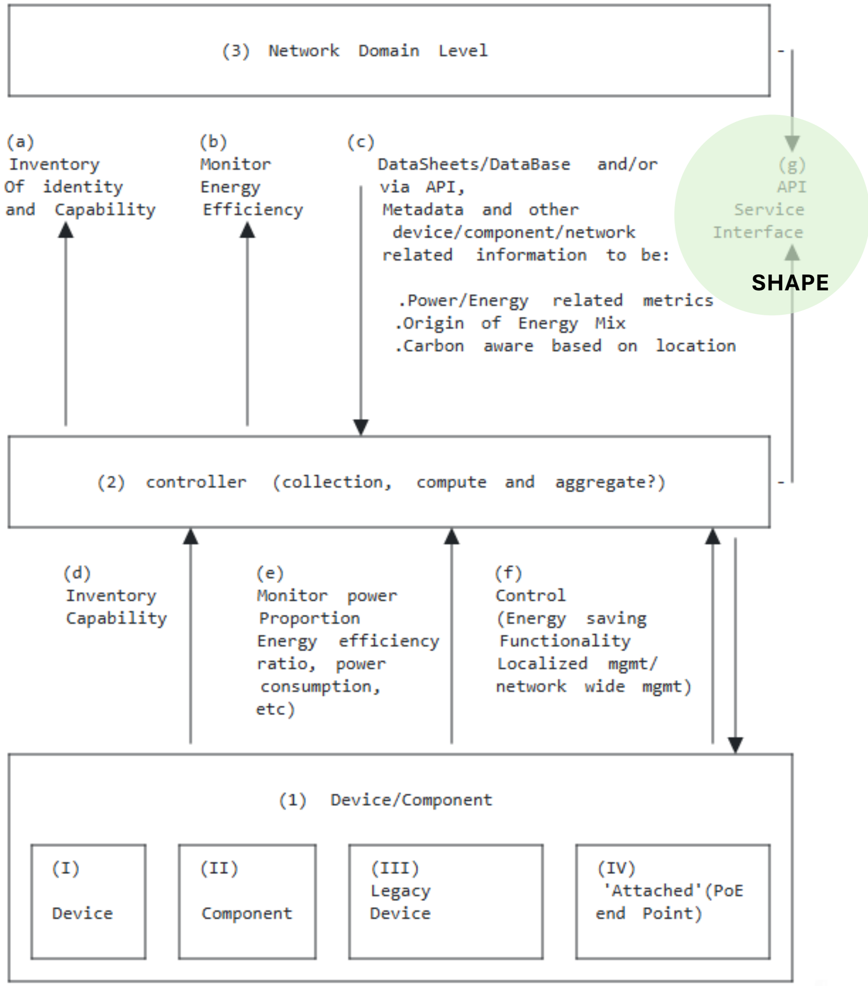
*BEREC (Body of European Regulators for Electronic Communications)

Sustainability holistic API for Path Energy Evaluation (SHAPE) *draft-amalj-sustain-shape-02*

Some examples parameters to consider

- Energy Mix (%): Indicates the share of energy from each source (solar, wind, biomass, nuclear, fossil) used along the path.
- Greenness Degree (%): Measures the total percentage of renewable energy consumed along the path.
- Temporal Carbon Variability (TCV): Quantifies how much the carbon intensity of the electricity powering the path fluctuates over a given period.
- Sleep-mode Availability (%): Indicates how often devices along the path support or enter low-power sleep modes.
- Sustainability Stability Index (SSI) (0–1): Measures the temporal stability of sustainability metrics such as carbon intensity or greenness.

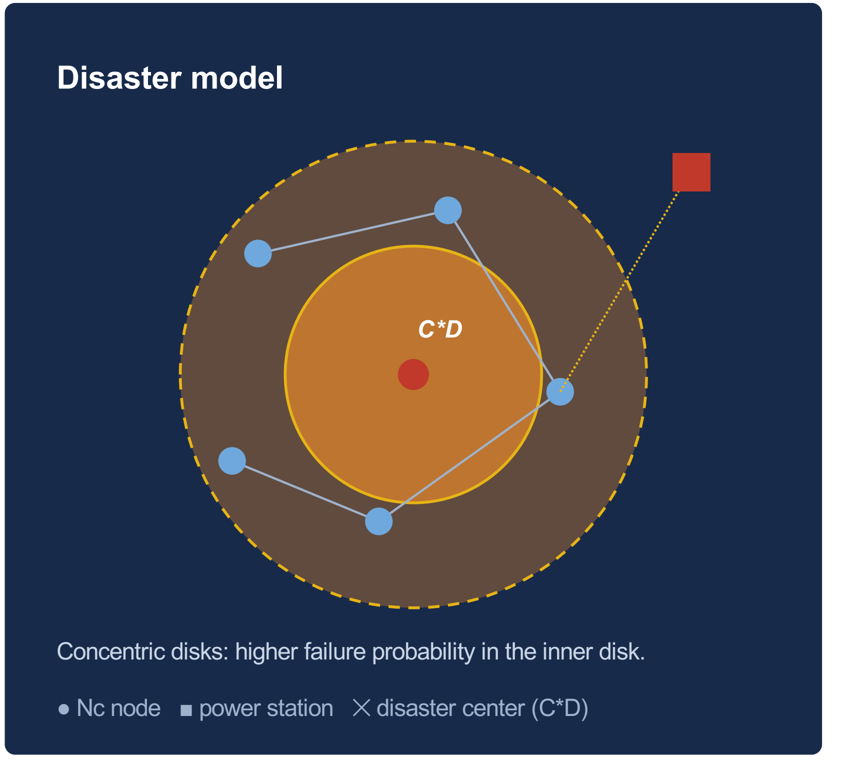
```
module: irtf-shape
  +--imports ietf-petra

  augment /petra:energy/petra:query/petra:input:
    +---w measurement-interval?    uint32
    +---w recursive?               boolean

  augment /petra:energy/petra:query/petra:output/petra:result/petra:success:
    +--ro shape-metrics
       +--ro carbon-intensity?                uint32
       +--ro energy-mix*                      -> list of sources and percentages
       +--ro greenness-degree?                decimal64
       +--ro sustainability-score?            decimal64
       +--ro pue?                             decimal64
       +--ro transmission-loss?               decimal64
       +--ro idle-watts?                      decimal64
       +--ro temporal-carbon-variability?     decimal64
       +--ro sleep-mode-availability?         decimal64
       +--ro sustainability-stability-index?  decimal64
       +--ro trustworthiness-score?           decimal64
       +--ro variance-energy-consumption?     decimal64
       +--ro anomaly-factor?                  decimal64
       +--ro cooling-energy-ratio?            decimal64
```



Critical location of communications networks and the power grid

- Disasters threaten an increasingly critical infrastructure
  - Network infrastructure is increasingly important
  - The “most critical” location can be a power-grid location rather than a telecom location
- Service goes down even when the facilities survive
  - The electricity supply is not restored within the battery's lifetime.
  - Fuel runs out, with the fuel transport is not resumed before the generator empties its tank.
- Therefore, to properly assess a disaster's damage, the power grid that feeds the communications network must be taken into account.
- Communications network Nc powered by the power grid Np.
  - Each node in Nc needs a working route in Np to an electric power distribution station.
- Need of evaluating worst-case scenario of future disasters and strengthening network survivability (re-routing, reinforcements).
  - The critical location could sit on a distribution station, disconnecting many supply routes, and with them, many links.

Example



Source: Hiroshi Saito, “Critical Location of Communications Network with Power Grid Power Supply”, IEICE Trans. Commun., Vol. E106-B, No. 2, Feb. 2023

What is a Network Digital Twin (NDT)?

A **real-time virtual representation of the network** that continuously mirrors status, topology, traffic, services and resources - combining telemetry, simulation/emulation and AI to predict, validate and optimize operations before acting on the live network.

1 - Virtual replica

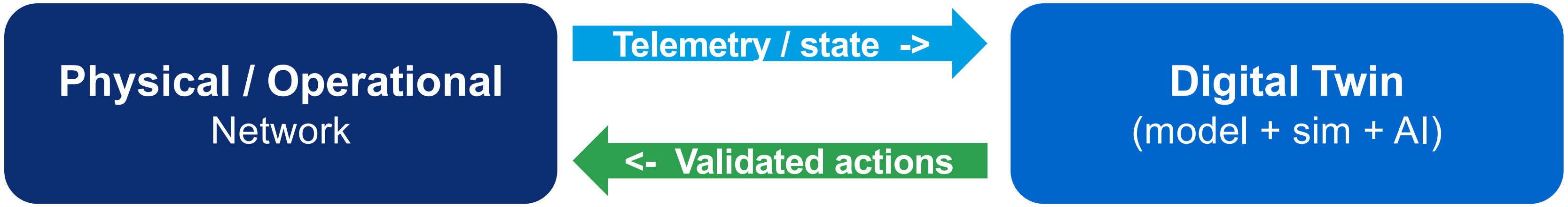
Mirrors the real network's structure & behavior at the needed level of fidelity

2 - Continuous sync

Kept aligned with reality via telemetry, alarms, OSS & control interfaces

3 - Bidirectional loop

Experiments in the twin can drive changes back onto the physical network

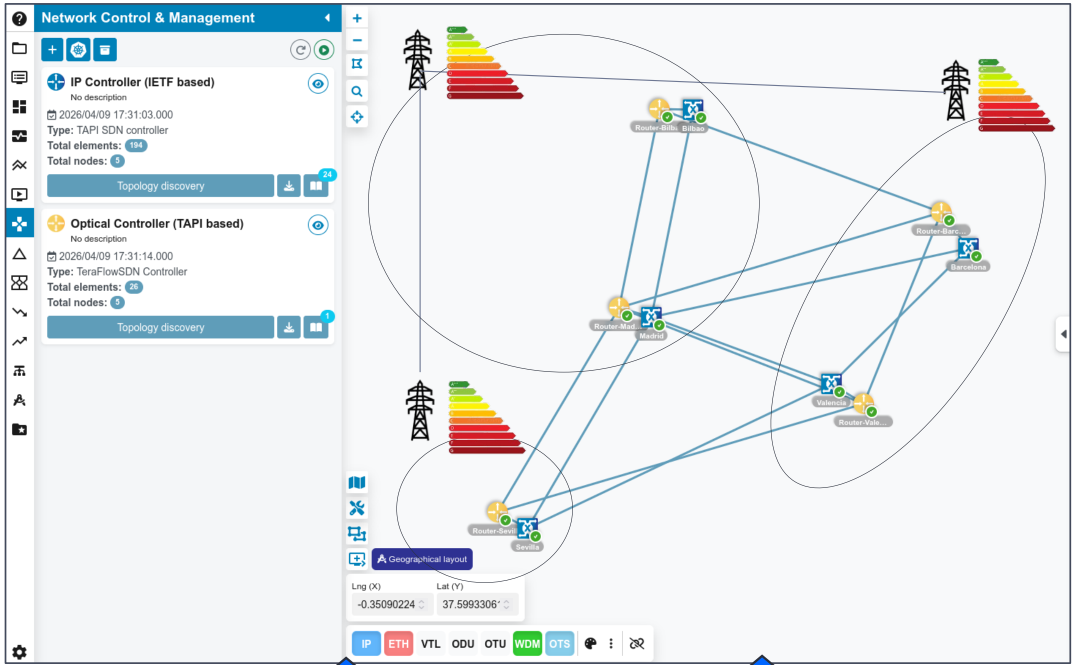


The bidirectional sync loop is what makes it a twin - not just a static model or a one-off simulation.

Standards anchors: IETF/IRTF NMRG (NDT reference architecture), ITU, TM Forum (autonomous networks)

SUPPORT OF NDTS FOR THE GRIDIFICATION OF INTERNET

Collect / Decide / Act ↔ NDT



Network Data
(Topology, Metrics, …)

Grid Data
(Topology, Indicators, …)

NDT → enabling decisions

Optimize usage of renewable energy → take decisions on network considering info from the grid according to indicators

Design a robust network → combine in the analysis grid + network

Peak vs off-peak → activate or deactivate specific connectivity paths / workloads to optimize energy.

Enabled Use Cases

UC1 — Before a disaster: resilience planning

UC2 — During a disaster: impact awareness

UC3 — After a disaster: recovery optimization

UC4 — Normal operation: green optimization

UC5 — Carbon-aware operation

etc

Conclusion

- A number of problems depend on the same missing visibility: how the network interacts with power grid
  - Apart from optimization and critical infrastructure analysis there are others like
    - Communication network architecture (re-)design due to new DCs close to energy sources
    - How to handle criticality of different kinds of communication services in case of issues with the energy supply
    - Impacts on energy and network paths of workloads migration / consolidation, etc …
- Tools are needed for decision
  - E.g., a Network Digital Twin for energy-aware resilience and carbon-aware operation
- But the same tool can serve different purposes (i.e., running different algorithms), for instance

Crisis mode	Normal mode
Maximise service continuity	Minimise energy/carbon footprint
Prioritise survival	Prioritise efficiency
Power dependency as risk	Power dependency as optimisation lever

- **The missing layer: energy dependency and survivability context**
  - **The big challenge is how to automatically collect this information and how to feed it in the NDT**

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