Toward Carbon-Aware Networking

Noa Zilberman, Eve Schooler, Uri Cummings, Rajit Manohar, Dawn Nafus, Robert Soulé and Rick Taylor

March 2023
What is the carbon footprint of a networked application?
The network is negligible

- Amazon (2020): 24TWh
- Google (2021): 15.4TWh
- Telefonica (2021): 6.1TWh
- Vodafone (2021): 5.8TWh
- BT (2021): 3.3TWh
The network is negligible

- Amazon (2020): 24TWh
- Google (2021): 15.4TWh
- Telefonica (2021): 6.1TWh
- Vodafone (2021): 5.8TWh
- BT (2021): 3.3TWh

All ISPs
Carbon Reporting Metrics: Policy

- Use standard metrics
- Use standard evaluation environments
- Provide carbon efficiency under different loads
- Provide measured results.
- Avoid double counting
- Trustworthy reporting
- Real time observability
Carbon Reporting Metrics: Technical Challenges

- Across multiple domains
- Multiple types of devices
- Mixed with other services
- Sensitive to load

- Real time reporting of:
  - Electricity consumption
  - Carbon intensity
  - Tie back to the application
  - React in real time
Carbon Aware Networking
How to find the most carbon efficient route?

Route A-B-E or Route A-C-D-E?
How to find the most carbon efficient route?

Route A-B-E or Route A-C-D-E?

Use energy rating
How to find the most carbon efficient route?

Route A-B-E or Route A-C-D-E?

Route A-C-D-E uses only A rated devices

Use In-Network telemetry to collect information
How to find the most carbon efficient route?

Route A-B-E or Route A-C-D-E?
Is 2x A better than 1x B?

Use energy rating

[Diagram with nodes A, B, C, D, E and arrows connecting them.]

© N. Zilberman 2023
How to find the most carbon efficient route?

Route A-B-E or Route A-C-D-E?
Is 2x A better than 1x B?

Use weighted energy rating

A
B
C
D
E
F
G

© N. Zilberman 2023
How to find the most carbon efficient route?

Route A-B-E or Route A-C-D-E?

Need to consider:
- Congestion
- Load
- Carbon-efficiency gradient
- Multi-route optimization
- …..
Carbon Intelligent Networking
Carbon Aware & Intelligent Routing

• Carbon aware routing
  • knowing the carbon emissions and minimizing them while applying standard routing practices

• Carbon intelligent routing
  • knowing the carbon emissions and minimizing them while taking different approaches to routing and scheduling of data-transfer
Carbon Aware Routing

- What is the best route from A to B?
- “Best route” – Minimum carbon emissions
- Standard routing protocols
  - Slight modifications

Source: electricitymaps.com
Carbon Intelligent Routing

- Set metrics (e.g., delay) thresholds and carbon-footprint budget

- Use for route optimization

- Examples:
  - Delay tolerant carbon-bounded routing
  - Content distribution optimizing for carbon-efficiency
Carbon Intelligent Network Telemetry

- Collect information from network devices along the route, such as:
  - Energy rating (static)
  - Using renewable energy? Yes/No (dynamic)
  - Carbon intensity (dynamic)
  - Platform power consumption (dynamic)
How to find the most carbon efficient route?

Use in-network telemetry to collect real-time carbon intensity
Schedule / buffer message at nodes until carbon-intensity is low
How to find the most carbon efficient route?

Use in-network telemetry to collect real-time carbon intensity
Schedule / buffer message at nodes until carbon-intensity is low
How to find the most carbon efficient route?

Use in-network telemetry to collect real-time carbon intensity
Schedule / buffer message at nodes until carbon-intensity is low
Summary & A Call to Action

• Networking needs to be carbon-efficient!
• Need more visibility: application, stack, platforms, ...
• Need standard metrics
  • ... and standards!
• Carbon-intelligent routing is the next big challenge
We can make networking GREEN