Challenges and Opportunities in Green Networking

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Analyze challenges in green (sustainable, energy-efficient, carbon-neutral) networking

- Reducing carbon footprint to “Net Zero” is one of mankind’s “grand challenges”
- This challenge also extends to network technology

List resulting research problems and opportunities according to a systemic structure
Updates since IETF 117

• Posted -01 (23 October)
• Editorial improvements throughout
• Addressed comments from Kiran Makhijani on the list
• Clearer explanation of interrelated terms: green vs sustainable, greenhouse gas emissions vs carbon footprint vs energy efficiency etc
• Additional references to related work in IoT
Next steps for this Draft

• Document appears fairly complete at this point...
• ... but it would benefit from more reviews and discussion
  • Most sustainability discussion is on e-impact, not nmr – how can we bring them into the fold?
  • Consider moving to WGLC as a way to get more NMRG feedback?
Next steps beyond this Draft

• Considerable discussion on e-impact – informal mailer and IAB program

• Potential topics for further study include:
  • Visibility and instrumentation, metrics & metrics Framework
    • Currently a draft in opsawg, but still with open-ended questions early for standardization, eg
    • Metrics beyond the device: flows and paths; virtual energy, conversion factors, ...
  • Network optimization for sustainability
    • Minimizing energy, carbon emissions through network operations
    • Under the constraint of meeting service level, resilience, elasticity goals
    • Holistic perspective – taking into account also compute, service placement, various tradeoffs
    • Include cost versus benefit of optimization themselves (e.g. AI has a carbon cost)
  • Green Intent and control knobs to navigate tradeoffs
    • Carbon Accounting and Incentive Schemes, pollution-aware traffic steering, ...

• Joint workshop of NMRG and E-Impact on this topic?
Backup
Recap

Provide visibility as foundational problem:
- **Assess usage, validate effectiveness**
- **Enable control loops** for energy/sustainability optimization schemes
- Requires **Instrumentation for energy metrics**
- Companion draft: Green Networking Metrics (draft-cx-green-metrics; https://datatracker.ietf.org/doc/draft-cx-opsawg-green-metrics/)
- Selected challenges+opportunities
  - Certification and compliance assessment methods
  - Virtualized energy and pollution metrics
  - Accounting for energy mix, energy sources
  - Fair carbon footprint attribution to flows & paths
Recap

- Network optimization
  - Energy/carbon/pollution-aware routing & path configuration
  - Deployment / placement of VNFs
  - Optimize carbon footprint while maintaining other goals
  - AI and ML methods
  - Applicability of game-theoretic approaches
  - “Control knobs” for intent-based tradeoffs

- Energy-related control protocol extensions
  - Energy as a cost factor – in IGP, SDN controllers
  - Assess carbon intensity of paths, optimize networks to minimize overall footprint

- Carbon-aware traffic steering
to steer traffic along greener paths

- Green abstractions
taking into account memory, processing, transmission
Recap

- Protocol enablers for network energy saving mechanisms
  - Blur mgmt. and control – taking resources on/offline on short time scales requires mechanisms for fast discovery, fast state reconvergence
  - Role of autonotics? of IBN?
- Protocol optimization
  - Traffic adaptation (e.g. bursty vs smoothened transmission to maximize efficiency; control knobs for carbon-aware traffic pacing)
  - Data volume reduction (e.g. codings, efficient retransmissions)
- Network addressing and deployment (e.g. smaller tables to maintain)
- Instrumentation (again)
  e.g. energy telemetry at flow & path level
Recap

- **Facilitate organization of networking applications** to minimize energy consumption
- **Holistic carbon impact assessment methods** for alternative approaches
- **Examples**: retrieval of content, computation placement (compare CDN/ICN/COIN but from energy perspective)
THANK YOU!

Comments? Questions? Please contact us
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