Environmental Impacts of Internet Technology (e-impact) Program

Interim Meeting 15 February 2024

Map/survey of e-impact drafts

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Motivation

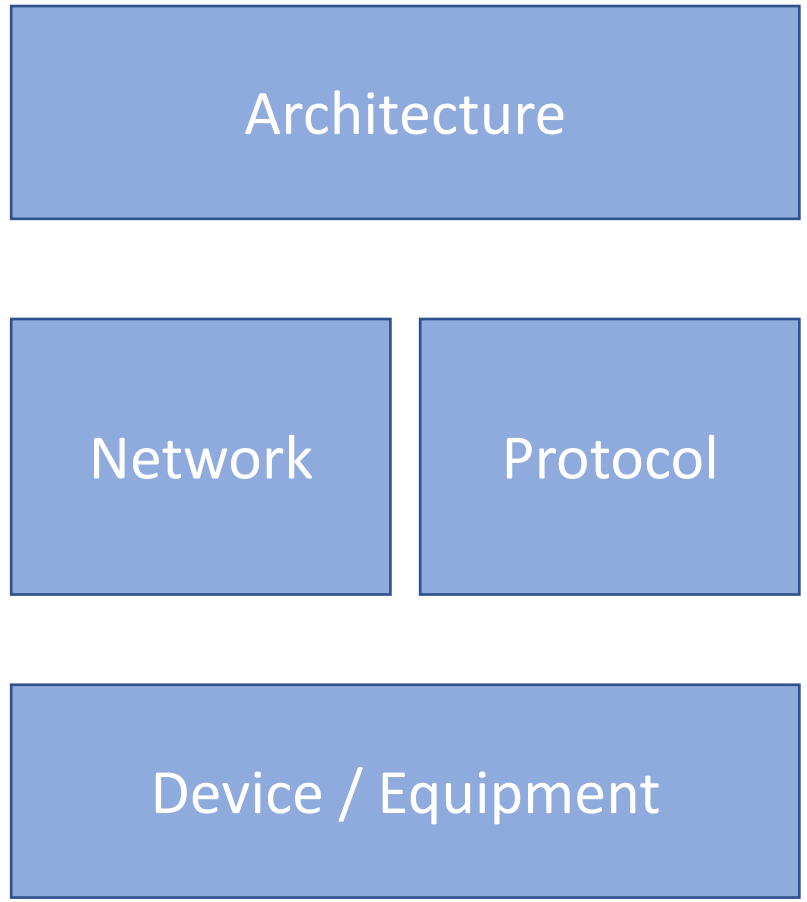
- Overview of current E-Impact-related Drafts
  - Obtain a view of current “inventory”
  - Brief synopsis
    (some briefer than others as covered further in later agenda items)
- First attempt at drafting a map of overall landscape

List of E-Impact Internet Drafts as of 2/14/2024 *anything missing?*

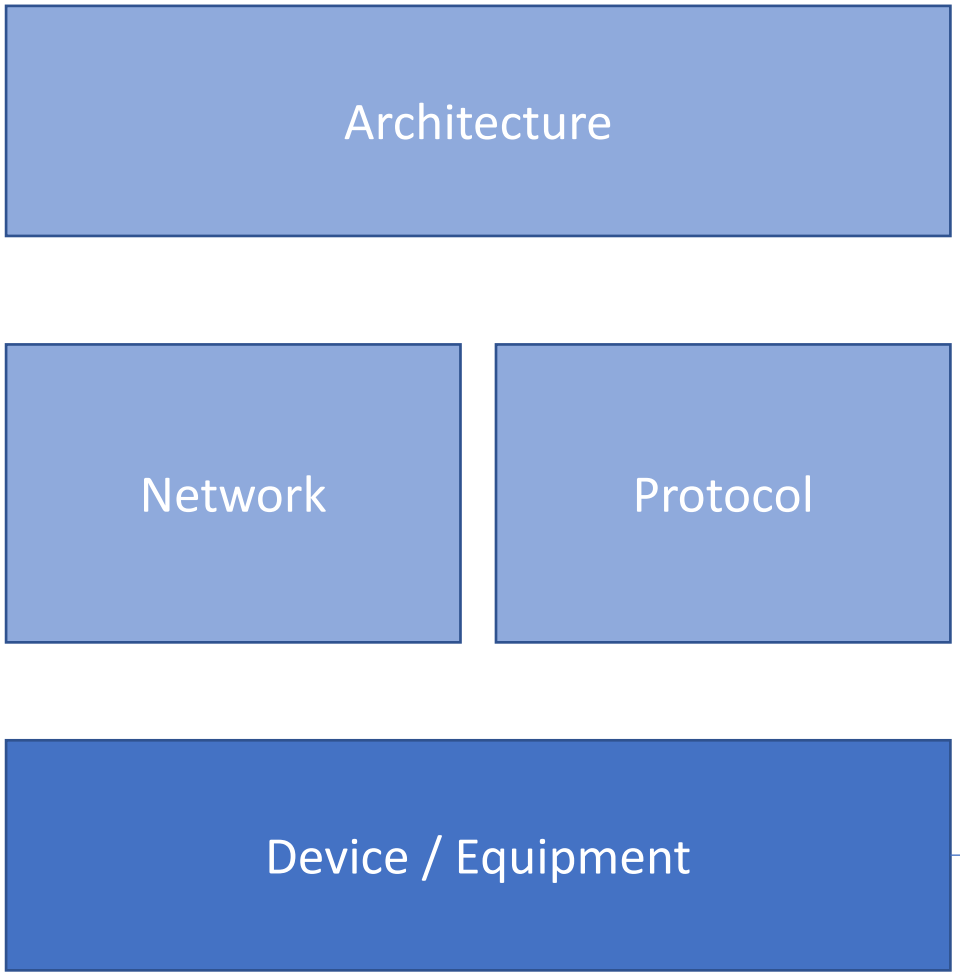
Identifier	Title	Authors (3+)	WG
draft-irtf-nmrg-green-ps	Challenges and Opportunities in Management for Green Networking	Clemm, Westphal, Tantsura, Ciavaglia, Pignataro, Odini	NMRG
draft-cparsk-eimpact-sustainability-considerations	Sustainability Considerations for Internetworking	Pignataro, Rezaki, Krishnan, ElBakoury, Clemm	
draft-almprs-sustainability-insights	Sustainability Insights	Andersson, Lindblad, Mitrovic, Palmero, Roure, Salgueiro, Emile	
draft-cx-opsawg-green-metrics	Green Networking Metrics	Clemm, Dong, Mirsky, Ciavaglia, Tantsura, Odini, Schooler, Rezaki, Pignataro	OPSAWG
draft-opsawg-poweff	Power and Energy Efficiency	Lindblad, Mitrovic, Palmero, Salgueiro	OPSAWG
draft-li-ivy-power	A YANG model for Power Management	Li, Bonica	IVY
draft-petra-path-energy-api	Path Energy Traffic Ratio API (PETRA)	Rodriguez-Natal, Contreras, Muniz, Palmero, Munoz	
draft-pignataro-eimpact-icmp	ICMP Extensions for Environmental Impact	Pignataro, Parikh, Bonica	
draft-eckert-ietf-and-energy-overview	An Overview of Energy-related Effort within the IETF	Eckert, Boucadair, Thubert, Tantsura, Pignataro	Indepdt stream

Challenges and Opportunities in Management for Green Networking

- https://datatracker.ietf.org/doc/html/draft-irtf-nmrg-green-ps-01
- Analyze challenges in green (sustainable, energy-efficient, carbon-neutral) networking
- List resulting research problems and opportunities according to a systemic structure
- Most are management-related, but non-management related aspects are also mentioned
- Most actionable opportunities with greatest immediate impact concern visibility: data models and instrumentation
  ("You can't manage/optimize what you can't measure")



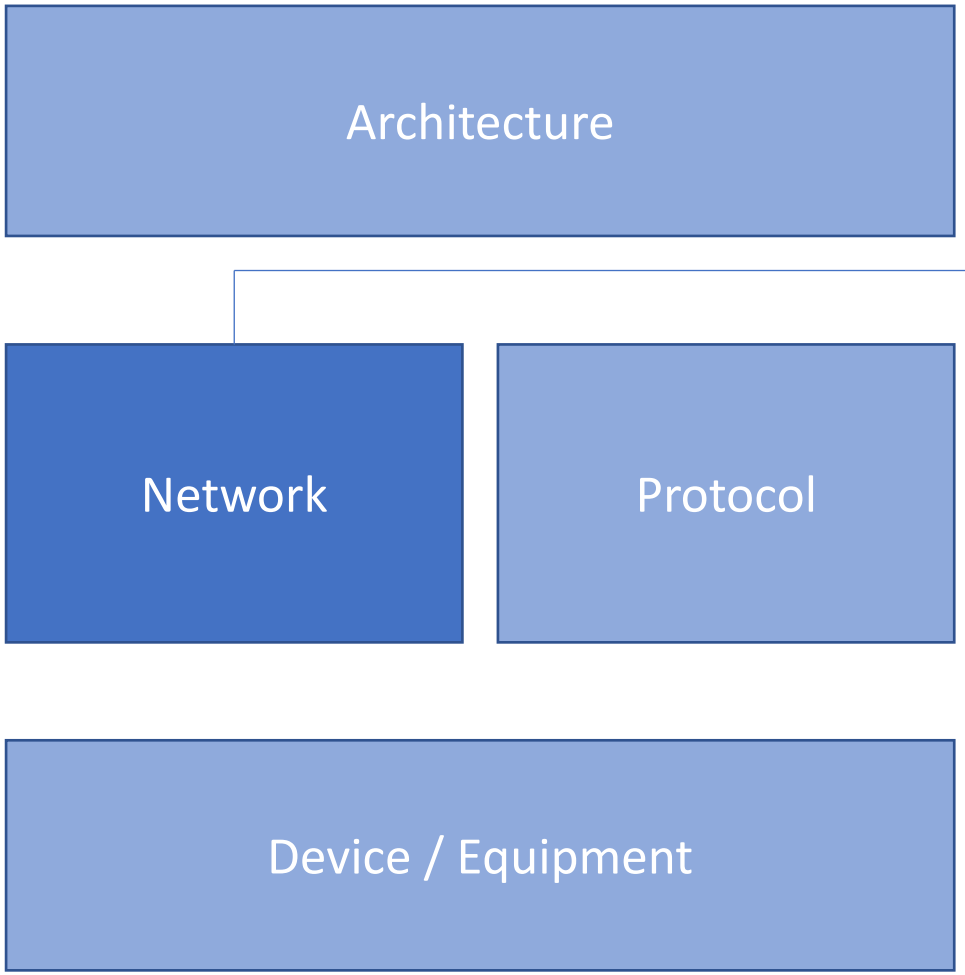
Challenges and Opportunities in Management for Green Networking



Provide visibility as foundational problem:

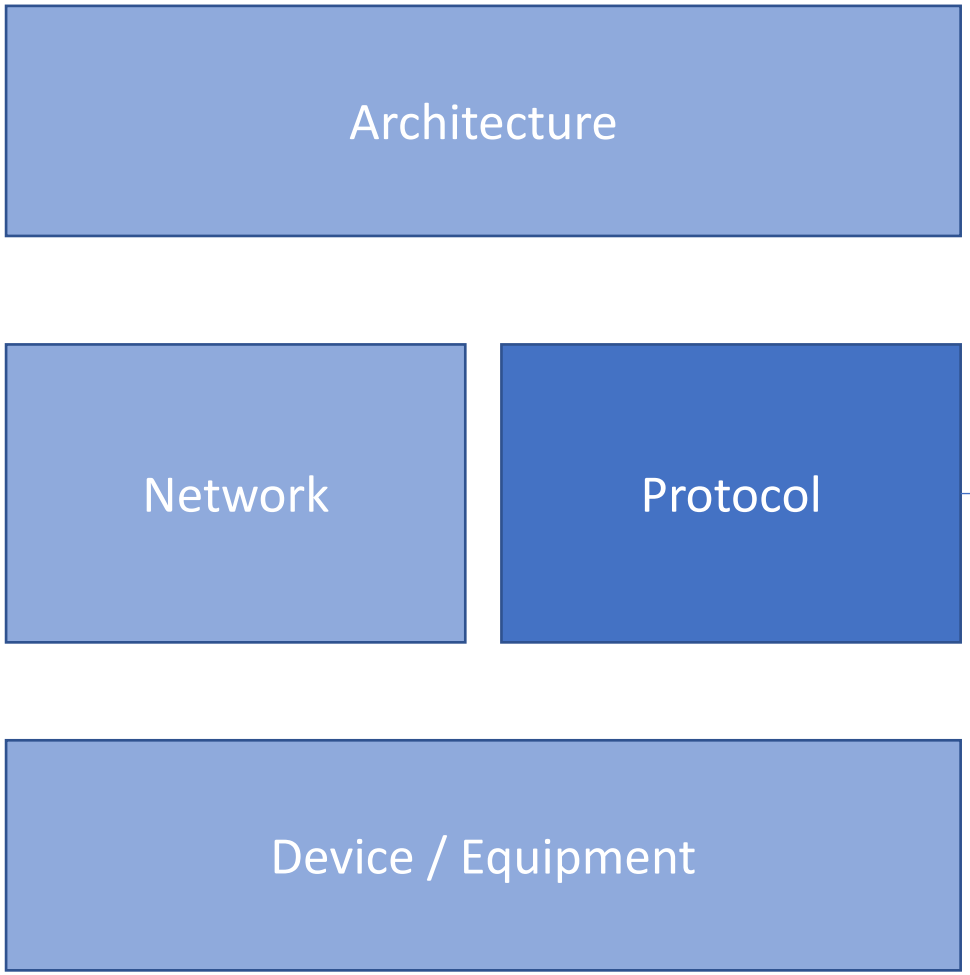
- **Assess usage, validate effectiveness**
- **Enable control loops** for energy/sustainability optimization schemes
- Requires **Instrumentation for energy metrics**
- Companion draft: Green Networking Metrics (draft-cx-green-metrics; https://datatracker.ietf.org/doc/draft-cx-opsawg-green-metrics/)
- 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

Challenges and Opportunities in Management for Green Networking



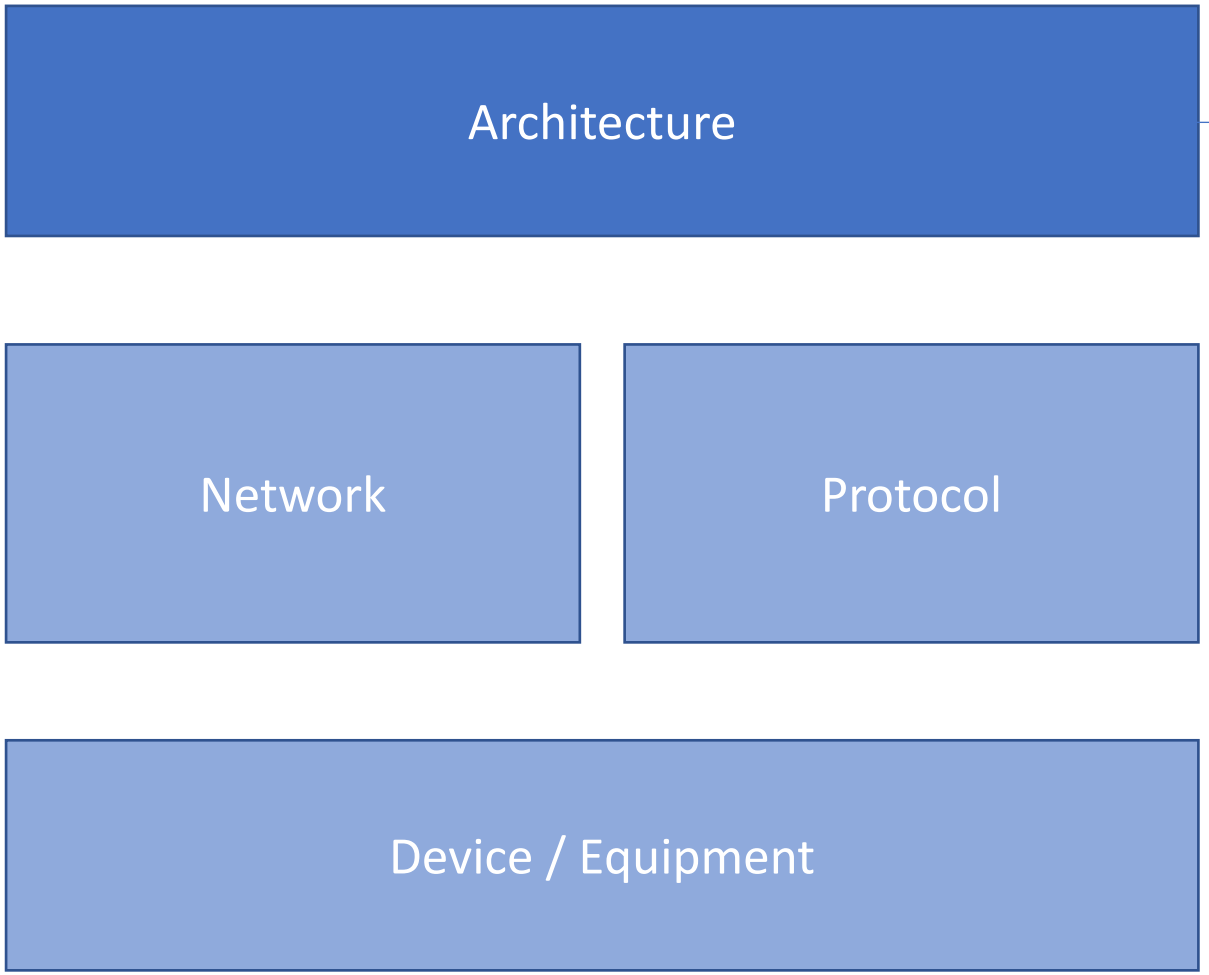
- **Network optimization**
  - Energy/carbon/pollution-aware routing & path configuration
  - Deployment / placement of VNFs
  - Optimize carbon footprint while maintaining other goals
  - AI and ML methods
  - Applicability of game-theoretic approaches
  - “Control knobs” for intent-based tradeoffs
- **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, pollution-aware routing** to steer traffic along greener paths
- **Green abstractions** taking into account memory, processing, transmission

Challenges and Opportunities in Management for Green Networking



- **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 autonomics? 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

Challenges and Opportunities in Management for Green Networking



- **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)

Green Networking Metrics

- https://datatracker.ietf.org/doc/html/draft-cx-opsawg-green-metrics-00
- Visibility and instrumentation are an important building block for sustainable networking solutions; this draft defines starter set of metrics
- Augment metrics with use cases / applications / motivation

Equipment/ Device	Attribute carbon footprint to the “root” Energy consumption, energy utilization efficiency Considerations for energy sources Sustainability factors, modifiers (e.g. adjust for energy mix) Conversion factors between “power” and “carbon” Virtualization considerations: virtual energy, virtual footprint Attributing carbon footprint incurred by hosting infrastructure to VNFs, etc Examples Power consumption absolute / normalized, per chassis/line card/port, etc Consumption ratings (datasheet stuff) sustainability ratings and factors

Green Networking Metrics (contd.)

Flows	Relate carbon footprint to flows and service instances Function of volume and duration Additional considerations for packet replication, loss, etc. Carbon flow statistics, enable carbon-based accounting Examples: Energy consumption / carbon footprint over duration of flow
Paths	Assess carbon intensity of paths and route alternatives Energy-/ Carbon-/ Pollution-Aware Networking Examples: Path energy/carbon ratings (function of carbon ratings of hops)
Network-at-large	Totality of the picture aggregated across network-at-large Examples: Total energy consumption (MWh), Network energy efficiency (MWh/PB)

Outside scope: Data Models, Methods for Measurement&Instrumentation

Sustainability drafts (separate agenda items)

- Sustainability Considerations for Internetworking, draft-cparsk-eimpact-sustainability-considerations
  - General considerations / guidelines in the design of networking protocols, e.g.:
    - Tradeoffs that affect (and maybe be affected by) sustainability – e.g. resilience, QoE
    - Consequences of energy linearity
    - Impact of properties such as chattiness on equipment sleep / power saving patterns
    - Enablers for power optimization schemes such as rapid discovery and reconvergence
- Sustainability Insights, draft-almprs-sustainability-insights
  - Collection of use cases (e.g. power optimization, scheduled switchoff, recycling/hw lifecycle) that will benefit from sustainability-related metrics, KPIs, data models
  - OSS framework for processing stages of network sustainability data: normalization, collection, aggregation, higher-level processing

Data model drafts (separate agenda items)

- Power and Energy Efficiency, draft-opsawg-poweff
  - Information model and accompanying YANG data models to quantify power and energy efficiency
  - Includes benchmarked data as per datasheets (poweff-static), real-time observations (poweff-traffic), groupings for power sensor management (poweff-sensors), etc.
  - YANG data models augment and tie in with asset lifecycle data models from the same authors
- A YANG model for Power Management, draft-li-ivy-power
  - YANG data model for basic power information and control: power drawn, power save capability, enable/disable power management
  - To tie in with IVY (network inventory)
- Both models are separate & independent efforts, potential alignment TBD

Programmability & Control

- Path Energy Traffic Ratio API (PETRA), draft-petra-path-energy-api
  - API definition to retrieve a specific metric that relates throughput between a source and destination with end-to-end energy consumption attributable to it (i.e. share of energy consumption as a part of traffic)
  - Does not define actual method to determine the metric (one such method is defined in Aggregation Trace Option for In-situ Operations, Administration, and Maintenance (IOAM): draft-cxx-ippm-ioamaggr-00, with a similar use case as a driver)
- ICMP Extensions for Environmental Impact, draft-pignataro-eimpact-icmp
  - ICMP extension that allows to request/return certain sustainability-related data parameters as part of ICMP messages, such as KW/Gbps or idle power

An attempt at categorization

Foundational

- Challenges and opportunities in management: draft-irtf-nmrg-green-ps
- Sustainability considerations: draft-cpars-eimpact-sustainability-considerations
- Sustainability insights: draft-almprs-sustainability-insights
- History: draft-eckert-ietf-and-energy

Instrumentation and visibility

- Green networking metrics: draft-cx-opsawg-green-metrics
- Power and energy efficiency: draft-opsawg-poweff
- A YANG model for Power Management: draft-li-ivy-power

Programmability & Control

- Path Energy Traffic Ratio API (PETRA): draft-petra-path-energy-api
- ICMP Extensions for Environmental Impact: draft-pignataro-eimpact-icmp

- Focus is on energy, not on other aspects of sustainability
- Notable omissions: Fulfillment, Accounting, Power Sources (in addition to consumption)

Other IETF efforts

- Past – out of scope here but honorable mention: EMAN – Energy Management
  - RFC 6988: Requirements for energy management (e.g. power states, batteries, power supply management)
  - RFC 7603: Energy Management Applicability Statement (including use cases)
  - RFC 7460/7460: Monitoring and Control MIB for Power and Energy + Context MIB

  Not so much concerned with sustainability per se, but relevant for data model work
- TVR – Time Variant Routing
  - Concerned with time-based scheduled changes to a network

  Generalization to Energy Variant Routing (for some sustainability use cases) is conceivable

Conclusions

- List of e-impact related drafts continues to grow
- One focus is on drafts that frame the problem and on metrics+data models
- A second focus is on data models and parameters related to energy and power consumption
- Drafts are somewhat scattered: ivy, opsawg, nmrg, independent stream; issue of proper landing spots for e-impact drafts
- Notable omissions (potentially in scope) at this point:
  - Aspects of sustainability beyond energy
  - Power supply vs consumption/demand
  - Fulfillment & configuration aspects
  - Carbon accounting
  - Presumably out of IETF scope: algorithms & applications

Thank you!