Sustainability considerations for networking equipment

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Background:

Over the past decade, there has been increased awareness of the environmental impact produced by the widespread adoption of Internet technologies. While the impact of Internet technologies has an overwhelmingly positive component in this regard over the past years (providing alternatives to travel, enabling remote/hybrid work, enabling technology-based endangered species conservation, etc.) there are also negative implications and, most importantly, a lot of room remains for us to improve going forward. Looking from the networking industry perspective there has been increased awareness and a worldwide push for ESG regulations, and this has made the environmental concerns visible to the leadership of companies and an associated push for improvements. While this is a welcome turn of events, as it pertains to global warming and a product's carbon footprint, many of the improvements have been focused on what the GHG Protocol standard classifies as **Scope 1** and **Scope 2** greenhouse gas emissions that are owned and controlled by the companies (directly and indirectly, respectively). This is the case because these emissions are easier to measure and control.

Scope 3 emissions are caused by the activities of the company but do not occur from sources that are owned/controlled by the company. These are harder to measure and, in most cases, have not been mandated in reporting. In our industry the size of the Scope 3 emissions can be very significant, and it is not uncommon that by measurements and models, **Scope 3 emissions are several times larger than Scope1+2 emissions put together**. We believe that it should be our goal as an industry to help consumers of our technologies measure and understand their Scope 3 emissions impact, specifically as a consequence of energy usage, and help consumers reduce these impacts.

During most of their existence, networks have been engineered to optimize business metrics, and as such broadly prioritize along the axes of performance, utilization, and availability. This has been changing recently and there have been notable advances in network elements and sub-elements that aim to optimize metrics related to technology sustainability and environmental impact (e.g., improvements in power efficiency).

Many of those optimizations are typically local in nature, and widely sprinkled across different pieces of the network architecture. An opportunity for maximizing the positive environmental impact of these technologies calls for a more flexible view that spans the complete product lifecycle for hardware and software. Currently protocols and network equipment are designed in a tightly optimized manner for a very specific use case and context. This does not take into account that the same equipment and protocols could be reused in a different context in the

near future. It is very likely that extending the life of such equipment with higher flexibility could provide a better environmental benefit than micro-optimizing for today. E.g., Consider a core router of today that becomes more usable as an edge/access router of the future due to need for higher throughput in the core. Other opportunities include product design, packaging, consumption and reuse/repurpose/recycling of hardware (circular design principles) as well as related consumption issues such as consideration of the nature of power sources. As with every transition, there are phases, as well as prioritization of said improvements.

First, we would like to focus on what is necessary for us to do in the near term as pertaining to the sustainable use of networking protocols and the Internet. We believe a phased strategy would work best and consists of the following three phases:

Phase 1: Visibility (collecting and organizing data in a standard vendor agnostic manner)

Paraphrasing the words of the legendary Peter Drucker "You can't improve what you don't measure.", we believe the first step in improving our environmental impact is to actually measure it. The IETF, IRTF and the IAB have a long history of work in this field, and this has greatly helped with the instrumentation of network equipment in collecting metrics for network management, performance, and troubleshooting. On the environmental-impact side though, there has been a proliferation of a wide variety of vendor extensions based on our standards. Without a common definition of metrics across the industry and widespread adoption we will be left with ill-defined, potentially redundant, proprietary, or even contradicting metrics.

Phase 2: Provide insights and Recommendations

Once the metrics have been collected, categorized, and aggregated in a common format, it would be straightforward to visualize these metrics and allow consumers to draw insights into their GHG and energy impact. The visualizations would take the form of high-level dashboards that provide aggregate metrics and potentially some form of maturity continuum. We think this can be accomplished using reference implementations of the standards developed in phase 1. We do expect vendors and other open projects to customize this and incorporate specific features. This will allow identifying sources of environmental impact and address any potential issues through operational changes, creation of best-practices, and changes towards a greener, more environmentally friendly equipment, software, platforms, applications, and protocols.

Phase 3: Enable Self-optimization and Automation

Manually making changes as mentioned in Phase 2 works for changes needed on large timescales but does not scale to improvements on smaller scales (i.e., it is impractical in many levels for an operator to be looking at a dashboard monitoring usage and making changes in real-time 24x7). There is a need to provision some amount of self-awareness into the network itself, at various layers, so that it can recognize opportunities for improvement and make those changes and measure the effects by closing the loop. The goals of the consumers can be stated

in a declarative fashion, and the networks can continually use mechanisms such as ML/DL/AI with an additional goal to optimize for improvements in the environmental impact. These include, for example:

- Discovery and advertisement of networking characteristics that have either direct or indirect environmental impact,
- greener networking protocols that can move traffic on to more energy efficient paths, directing topological graphs to optimize environmental impacts, and
- protocols that can instruct equipment to move under-utilized links and devices into low-energy modes

This positive environmental-impact goal is an additional goal added to existing ones mentioned in the introduction (e.g., performance, resiliency), creating a multi-objective optimization problem space. Further, there also must be awareness in the Internet Engineering community to build robustness and recoverability into protocols – an aspect in which we have mostly done great over the years – instead of trying to over-engineer unnecessary redundancy. E.g., we can use an alternate multi-hop path with a slightly worse latency instead of fully redundant links If that is sufficient to meet SLAs.

We also envision that on top of minimizing the environmental impact of our technologies and helping consumers identify and reduce the environmental impact of their use, we can also make a positive impact on other less-traditionally and non-Internet technologies as well as non-technologies. E.g., use our technologies to choose greener and more efficient sources of power, control HVAC systems efficiently, etc. We are extremely inspired and motivated for us to positively impact the environment using Internet technologies and protocols, and we look forward to discussing and learning from other interested parties in this space.