Getting Ready for Energy-Efficient Networking
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Use Cases for Energy Efficiency Management
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Abstract

This document groups use cases for Energy efficiency Management of network devices.

Discussion Venues

Source of this draft and an issue tracker can be found at https://github.com/emile22/draft-ietf-green-use-cases

About This Document

This note is to be removed before publishing as an RFC.

The latest revision of this draft can be found at https://emile22.github.io/draft-ietf-green-use-cases/draft-ietf-green-use-cases.html. Status information for this document may be found at https://datatracker.ietf.org/doc/draft-ietf-green-use-cases/.

Discussion of this document takes place on the Getting Ready for Energy-Efficient Networking Working Group mailing list (mailto:green@ietf.org), which is archived at https://mailarchive.ietf.org/arch/browse/green/. Subscribe at https://www.ietf.org/mailman/listinfo/green/.

Source for this draft and an issue tracker can be found at https://github.com/emile22/draft-ietf-green-use-cases.

Status of This Memo

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1. Introduction

This document groups use cases collected from operators and from discussions since the GREEN WG preparations.

It provides a set of use cases for Energy efficiency Management of network devices. The scope is devices like switches, routers, servers and storage devices having an IP address providing a management interface. It includes their built-in components that receive and provide electrical energy.

In annex we recall the framework where the use cases can be put in situation.

2. Use Cases

This section describes a number of relevant use cases with the purpose of elicit requirements for Energy Efficiency Management. This is a work in progress and additional use cases will be documented in next versions of this document. Use cases which are not tied enough to the current GREEN chater will be moved to the GREEN WG wiki pages or to other WGs or RGs.

2.1. Incremental Application of the GREEN Framework

2.1.1. Use Case Description

This section describes an incremental example [legacy-path] of usage showing how a product, a service and a network can use the framework in different settings.

This use case is the less trendy of all the use cases by far as its ambitious is limited to migration and coexistence, as usual. Nevertheless from a telco perspective, it is the centrality for 2 main reasons:

* to start immediatly the move to energy efficiency using legacy devices;

* to account the gain of energy efficiency during incremental deployment of energy efficient network components;

Legacy routers, equipped with traditional Ethernet ports and optical interfaces will continue to operate within the network. As part of broader sustainability and energy efficiency goals, there is interest in exploring the incremental integration of such devices into energy efficiency framework deployments.

Two directions are considered:

* Improving energy efficiency of legacy devices through targeted upgrades such as replacing line cards, optimizing firmware behavior, or reconfiguring interface usage based on operational demand.

* Including legacy devices in early phases of energy-aware system deployment, ensuring that improvements are not limited only to new hardware generations.

Legacy devices can still contribute to reducing overall power consumption and lowering resource usage and associated environmental impact. Supporting these incremental improvements helps bridge the gap between existing infrastructure and modern energy-aware network strategies.

Device moving gradually to GREEN energy efficiency supports:

* step 1 "baseline" : establishing a reference point of typical energy usage, which is crucial for identifying inefficiencies and measuring improvements over time. At this step the controler use only the (c) part of the framework. It is collected from the datasheet.

By establishing a baseline and using benchmarking, you can determine if your networking equipment is performing normally or if it is "off" from expected performance, guiding you in making necessary improvements.

The initial measurement of your networking equipment’s energy efficiency and performance, aka Baselining, needs to be in coordination with the vendor specifications and industry standards to understand what is considered normal or optimal performance. example: Baseline: Your switches operate at 5 Gbps per watt. Benchmarking: Vendor specification is 8 Gbps per watt; industry standard is 10 Gbps per watt. Action: Implement energy-saving measures and upgrades. Tracking: Measure again to see if efficiency improves towards 8-10 Gbps per watt.

* step 2 "component": part of the device hw or sw migrated to support GREEN framework elements.

* step 3 "device controleur"

* step 4 "network level"

2.1.2. GREEN WG Charter Specifics

This use case demonstrates how Energy Efficiency can be incrementally applied and measured in legacy networks.

2.1.3. The Need for Energy Efficiency

Ensures that energy efficiency can be deployed, operated and measured per components, without waiting for full infrastructure upgrades.

2.1.4. Requirements for GREEN WG

* Baseline Measurement: Ability to establish reference energy usage per device (from datasheets or monitoring).

* Component-Level Upgradability: Support partial migration of device subsystems to GREEN-aware models.

* Legacy Compatibility: Ensure the framework can include legacy equipment alongside GREEN-enabled devices.

* Energy Saving Validation: Mechanisms to measure and verify actual energy savings over time.

* Protection from Overuse: Avoid frequent power cycling that may damage sensitive components like lasers or connectors.

2.2. Selective reduction of energy consumption in network parts proportional to traffic levels

2.2.1. Use Case Description

Traffic levels in a network follow patterns reflecting the behavior of consumers. Those patterns show periodicity in the terms of the traffic delivered, that can range from daily (from 00:00 to 23:59) to seasonal (e.g., winter to summer), showing peaks and valleys that could be exploited to reduce the consumption of energy in the network proportionally, in case the underlying network elements incorporate such capabilities. The reduction of energy consumption could be performed by leveraging on sleep modes in components up to more extreme actions such as switching off network components or modules. Such decisions are expected to no impact on the service delivered to customers, and could be accompanied by traffic relocation and / or concentration in the network.

2.2.2. GREEN WG Charter Specifics

This use case fits within the GREEN WG’s objectives by emphasizing energy-aware operational adjustments across network infrastructure that optimize energy use based on traffic loads and the intelligent activation/deactivation of resources.

2.2.3. The Need for Energy Efficiency

Reducing energy usage during during low-demand periods can lower operational costs and carbon emissions while also prolonging equipment lifespan.

2.2.4. Requirements for GREEN WG

* Support for device and component-level sleep, standby, and hibernation modes.

* Component-level control (e.g., ports, modules).

2.3. Reporting on Lifecycle Management

2.3.1. Use Case Description

Lifecycle information related to manufacturing energy costs, transport, recyclability, and end-of-life disposal impacts is part of what is called "embedded carbon." This information is considered to be an estimated value, which might not be implemented today in the network devices. It might be part of the vendor information, and to be collected from datasheets or databases. In accordance with ISO 14040/44, this information should be considered as part of the sustainable strategy related to energy efficiency. Also, refer to the ecodesign framework [(EU) 2024/1781] published in June by the European Commission.

2.3.2. Carbon Reporting

To report on carbon equivalents for global reporting, it is important to correlate the location where the specific entity/network element is operating with the corresponding carbon factor. Refer to the world emission factor from the International Energy Agency (IEA), electricity maps applications that reflect the carbon intensity of the electricity consumed, etc.

2.3.3. Energy Mix

Energy efficiency is not limited to reducing the energy consumption, it is common to include carbon free, solar energy, wind energy, cogeneration in the efficiency.

The type of the sources of energy of the power is one criteria of efficiency.

There are other dimensions that must visible: As many telecom locations include battery or additionnally several backups levels (as example battery, standby generator ...) there is a requirement to known exactly when a backup power is in used and which one is.

2.3.4. GREEN WG Charter Specifics

Capture lifecycle energy data and integrate it with operational metrics.

2.3.5. The Need for Energy Efficiency

Considering energy from production to disposal supports the broader goal of reducing total environmental impact.

2.3.6. Requirements for GREEN WG

* Awareness of backup systems (e.g., batteries, generators).

* Data ingestion from vendor databases or datasheets.

2.4. Real-time Energy Metering of Virtualised or Cloud-native Network Functions

2.4.1. Use Case Description

Cloud-native and virtualized functions require precise real-time energy measurements to manage their dynamic workloads and infrastructure efficiently. Effective metering of virtualized network infrastructure is critical for the efficient management and operation of next-generation mobile networks [GREEN_NGNM].

2.4.2. GREEN WG Charter Specifics

Meter and manage energy at both hardware and software layers.

2.4.3. The Need for Energy Efficiency

Granular and real-time insights into energy use enable optimization of virtualized workloads, leading to reduced energy footprints.

2.4.4. Requirements for GREEN WG

// TODO.

2.5. Indirect Energy Monitoring and control

2.5.1. Use Case Description

There are cases where Energy Management for some devices need to report on other entities. There are two major reasons for this.

- For monitoring energy consumption of a particular entity, it is not always sufficient to communicate only with that entity. When the entity has no instrumentation for determining power, it might still be possible to obtain power values for the entity via communication with other entities in its power distribution tree. A simple example of this would be the retrieval of power values from a power meter at the power line into the entity. A Power Distribution Unit (PDU) and a Power over Ethernet (PoE) switch are common examples. Both supply power to other entities at sockets or ports, respectively, and are often instrumented to measure power per socket or port. Also it could be considered to obtain power values for the entity via communication with other entities outside of the power distribution tree, like for example external databases or even data sheets.

- Similar considerations apply to controlling the power supply of an entity that often needs direct or indirect communications with another entity upstream in the power distribution tree. Again, a PDU and a PoE switch are common examples, if they have the capability to switch power on or off at their sockets or ports, respectively.

2.5.2. GREEN WG Charter Specifics

inclusion of legacy or non-instrumented devices.

2.5.3. The Need for Energy Efficiency

Energy monitoring across the network, even for devices that lack built-in sensors.

2.5.4. Requirements for GREEN WG

* Indirect control mechanisms.

* Integration with external databases or datasheets.

2.6. Consideration of other domains for obtention of end-to-end metrics

2.6.1. Use Case Description

The technologies under the scope of IETF provide the necessary connectivity to other technological domains. For the obtention of metrics end-to-end it would be required to combine or compose the metrics per each of those domains.

An exemplary case is the one of a network slice service. The concept of network slice was initially defined by 3GPP [TS23.501], and it has been further extended to the concerns of IETF [RFC9543].

In regards energy efficiency, 3GPP defines a number of energy-related key performance indicators (KPI) in [TS28.554], specifically Energy Efficiency (EE) and Energy Consumption (EC) KPIs. There are KPIs particular for a slice supporting a specific kind of service (e.g., Mobile Broadband or MBB), or generic ones, like Generic Network Slice EE or Network Slice EC. Assuming these as the KPIs of interest, the motivation of this use case is the obtention of the equivalent KPIs at IETF level, that is, for the network slice service as defined in [RFC9543].

Note that according to [TS28.554], the Generic Network Slice EE is the performance of the network slice divided by the Network Slice EC. Same approach can be followed at IETF level. Note that for avoiding double counting the energy at IETF level in the calculation of the end-to-end metric, the 3GPP metric should only consider the efficiency and consumption of the 3GPP-related technologies.

2.6.2. GREEN WG Charter Specifics

cross-domain measurement alignment.

2.6.3. The Need for Energy Efficiency

Cross-domain energy visibility is essential for services spanning multiple infrastructure providers and technologies.

2.6.4. Requirements for GREEN WG

* Avoidance of double accounting.

* Metric mapping and transformation.

2.7. Dynamic adjustment of network element throughput according to traffic levels in wireless transport networks

2.7.1. Use Case Description

Radio base stations are typically connected to the backbone network by means of fiber or wireless transport (e.g., microwave) technologies. In the specific case of wireless transport, automation frameworks have been defined [ONF-MW][RFC8432][mWT025] for their control and management.

One of the parameters subject of automated control is the power of the radio links. The relevance of that capability is that the power can be adjusted accordingly to the traffic observed. Wireless transport networks are typically planned to support the maximum traffic capacity in their area of aggregation, that is, the traffic peak. With that input, the number of radio links in the network element and the corresponding power per radio link (for supporting a given modulation and link length in the worst weather conditions) are configured. This is done to avoid any kind of traffic loss in the worst operational situation. However, such operational needs are sporadic, giving room for optimization during normal operational circumstances and/or low traffic periods.

Power-related parameters are for instance defined in [RFC8561]. Those power parameters can be dynamically configured to adjust the power to the observed traffic levels with some coarse granularity, but pursuing certain degrees of proportionality.

2.7.2. GREEN WG Charter Specifics

This aligns with the GREEN WG goals of enabling dynamic and context-aware energy optimization at the transport layer.

2.7.3. The Need for Energy Efficiency

Wireless links configured for peak traffic are often underutilized, wasting energy. Adjusting power to match demand can substantially reduce consumption.

2.7.4. Requirements for GREEN WG

* Adapt energy consumption to traffic change.

* Dynamic energy efficiency control and optimization.

2.8. Video streaming use case

2.8.1. Use Case Description

Video streaming is nowadays the major source of traffic observed in ISP networks, in a propotion of 70% or even higher. Over-the-top distribution of streaming traffic is typically done by delivering a unicast flow per end user for the content of its interest.In consequence, during the hours of higher demand, the total traffic in the network is proportional to the concurrence of users consuming the video streaming service. The amount of traffic is also dependent of the resolution of the encoded video (the higher the resolution, the higher the bit rate per video flow), which tends to be higher as long as the users devices support such higher resolutions.

The consequence of both the growth in the number of flows to be supported simultaneously, and the higher bit rate per flow, is that the nework elements in the path between the source of the video and the user have to be dimensioned accordingly. This implies the continuous upgrade of those network elements in terms of capacity, with the need of deploying high-capacity network elements and components. Apart from the fact that this process is shortening the lifetime of network elements, the need of high capacity interfaces also increase the energy consumption (despite the effort of manufacturers in creating more efficient network element platforms). Note that nowadays there is no actual possibility of activating energy consumption proportionality (in regards the delivered traffic) to such network elements.

As a mean of slowing down this cycle of continuos renewal, and reduce the need og higher bit rate interfaces / line cards, it seems convenient to explore mechanisms that could reduce the volume of traffic without impacting the user service expectations. Variants of multicast or different service delivery strategies can help to improve the energy efficiency associated to the video streaming service. It should be noted that another front for optimization is the one related to the deployment of cache servers in the network.

2.8.2. GREEN WG Charter Specifics

Video streaming represents a large portion of network traffic. Multicast techniques, adaptive streaming, and strategic caching can reduce traffic duplication and improve energy efficiency.

2.8.3. The Need for Energy Efficiency

Reducing redundant unicast traffic and improving caching strategies reduces backbone and access network energy consumption.

2.8.4. Requirements for GREEN WG

* Support for multicast-aware energy metrics.

* Cache server placement optimization.

2.9. WLAN Network Energy Saving

2.9.1. Use Case Description

In a WLAN network, Access Points(APs) are typically powered by Power over Ethernet (PoE) switches and represent a substantial portion of the energy consumed by edge network devices due to their high density and round-the-clock operation.

This use case introduces a multi-mode approach for AP energy saving: The working status of the AP can be break down into 3 modes as follows: PoE power-off mode: In this mode, the PoE switch shuts down the port and stops supplying power to the AP. The AP does not consume power at all. When the AP wakes up, the port provides power again. In this mode, it usually takes a few minutes for the AP to recover. Hibernation mode: Only low power consumption is used to protect key hardware such as the CPU, and other components are shut down. Low power consumption mode: Compared with the hibernation mode, the low power consumption mode maintains a certain communication capability. For example, the AP retains only the 2.4 GHz band and disables other radio bands.

* PoE Power-Off Mode: The PoE switch disables the port, completely cutting power to the AP. No energy is consumed, though recovery takes several minutes when power is restored.

* Hibernation Mode: The AP powers down most components, preserving minimal CPU functionality to allow faster reactivation.

* Low Power Mode: The AP disables some radios (e.g., 5GHz), retaining minimal operation (e.g., 2.4GHz) for reduced but persistent service.

To maintain coverage and service quality, surrounding APs dynamically adjust their transmit power when some APs enter energy-saving states. Energy-saving schedules may be time-based (e.g., during off-hours) or traffic-aware (low utilization periods).

Grouping APs by location enables coordinated energy-saving plans, minimizing disruption while maximizing cumulative energy reduction.

```
      /---\
     |     +-----+
     | AP  |     |
      \---/      |      +------------+
                 |      |            |
                 |------+     PoE    |
      /---\      |      |   Switch   |
     |     |     |      +------------+
     | AP  +-----+
      \---/
```

Figure 1: PoE Power Off Mode

```
                    4                         4
    +----------+   \|/        +----------+   \|/
    |          |    |         |          |    |
    |   +----+ |    |         |   +----+ |    |
    |   |5GHz+-+----+         |   |5GHz+-+-X--+
    |   | RF | |    2         |   | RF | |    2
    |   +----+ |   \|/    \   |   +----+ |   \|/
    |   +----+ |    |   ---\  |   +----+ |    |
    |  2.4GHz| |    |       \ |  2.4GHz| |    |
    |   | RF +-+----+       / |   | RF +-+-X--+
    |   +----+ |    2   ---/  |   +----+ |    2
    |   +----+ |   \|/    /   |   +----+ |   \|/
    |  2.4GHz| |    |         |  2.4GHz| |    |
    |   | RF |-+----+         |   | RF +-+----+
    |   +----+ |              |   +----+ |
    +----------+              +----------+
```

Figure 2: Low Power Consumption Mode

```
        +--+  +--+    +--+
        |AP|--|AP|--- |AP|      ------------------------------
        +--+  +--+   \+--+      Grouping  Recommended
        /               \        Area     Energy Saving Period
     +--+     +--+      +--+    ------------------------------
     |AP|     |AP|      |AP|    XED01-1  01:00:00,06:30:00
     +--+     +--+      +--+
       |                 |      ------------------------------
        +--+          +--+
        |AP|  +--+   /|AP|      XED01-2  01:30:00,06:30:00
        +--+--|AP|--- +--+     --------------------------------
              +--+
```

Figure 3: Wireless Resource Management on APs

2.9.2. GREEN WG Charter Specifics

This use case aligns with the GREEN WG’s charter by:

* Illustrating real-world scenarios where energy efficiency mechanisms (discovery, monitoring, control) apply to IP-managed devices.

* Providing a localized but scalable use case that fits into broader energy-aware network management frameworks.

-Addressing interoperability and observability across energy states and reporting mechanisms, including energy mix awareness.

2.9.3. The Need for Energy Efficiency

Given the number of deployed APs in enterprise and campus networks, their continuous operation contributes significantly to energy consumption. Many of these environments experience well-defined periods of inactivity (e.g., nighttime, weekends), during which full AP operation is unnecessary.

Reducing AP energy consumption during these periods, while maintaining sufficient coverage and quality of service, presents an effective opportunity for energy savings. Applying coordinated power-state transitions across AP groups enables measurable improvements with minimal operational impact.

2.9.4. Requirements for GREEN WG

To support WLAN Network Energy Saving, the GREEN WG should consider:

* Defining power state transition models and standard energy mode nomenclature for APs (e.g., OFF, HIBERNATE, LOW-POWER, ACTIVE).

* Specifying APIs or YANG models for monitoring and controlling AP power modes via PoE switches or WLAN controllers.

* Enabling reporting of per-mode energy consumption, transitions over time, and cumulative energy savings.

* Ensuring support for scheduled and dynamic (traffic-aware) control policies.

* Allowing integration with broader network monitoring frameworks for energy efficiency analysis at the local and network-wide level.

* Considering implications for resiliency, coverage trade-offs, and restart delays in power-off scenarios.

Enable measuring and reporting of energy usage through metrics and attributes and allow operators to optimize energy usage.

2.9.5. The Need for Energy Efficiency

AP nodes as network devices with the largest number consume large amount of energy.

2.9.6. Requirements for GREEN WG

* Energy saving mode switching based on network condition changes

* Allow network devices shutdown to save energy

* Allow working network devices transmit more power to increase the coverage of the entire area

2.10. Fixed Network Energy Saving

2.10.1. Use Case Description

In many fixed networks, particularly those at metro or backbone level, traffic patterns follow a predictable tidal cycle - with clearly defined high-traffic and low-traffic periods. These fluctuations provide opportunities for dynamic energy-saving mechanisms. During low-traffic periods, certain network components can be deactivated or put into sleep mode. Additionally, routers equipped with interfaces of varying speeds (e.g., from 1G to 400G) can dynamically adjust interface speeds, deactivate unused ports, or scale down internal resources such as processor cores, chipset clock frequencies, or SerDes lanes, depending on traffic demand.

2.10.2. GREEN WG Charter Specifics

The GREEN working group can contribute by defining standard mechanisms and protocols to: - Monitor traffic load in a standardized and interoperable manner. - Communicate energy-saving intents across network elements (e.g., turning off links or reducing interface speeds). - Signal state transitions (e.g., from active to low-power states) reliably, taking into account the need for fast reactivation during traffic bursts. - Ensure compatibility with QoS and network availability requirements.

2.10.3. The Need for Energy Efficiency

Network devices at metro or backbone network consume large amount of energy.

2.10.4. Requirements for GREEN WG

* Standardized definitions and telemetry models for identifying tidal traffic patterns and low-utilization windows.

* Protocol support for energy-aware dynamic reconfiguration (e.g., speed adjustment, core deactivation).

* Trade-offs between energy savings and network latency/performance.

* Mechanisms to synchronize energy-saving decisions across multiple devices (e.g., coordinated interface downshifts).

* Fail-safe or fallback procedures to ensure robustness in case of unexpected traffic surges.

2.11. Energy Efficiency Network Management

2.11.1. Use Case Description

Modern network operators need comprehensive visibility into the energy consumption and efficiency of their infrastructure. This includes real-time and historical statistics of power usage per device, identification of devices participating in energy-saving modes, differentiation between energy-optimized and legacy devices, and aggregated views of energy trends across the entire network. Such visibility enables more informed decisions about network adjustments and optimizations that align with energy efficiency goals.

2.11.2. GREEN WG Charter Specifics

The GREEN WG has a role in developing interoperable models and mechanisms for: - Real-time telemetry and historical analysis of energy metrics. - Mapping energy efficiency indicators to network topology and traffic load. - Identifying energy-saving capabilities of devices (e.g., support for interface power scaling, sleep modes). - Integration with existing network management and orchestration systems. - Encouraging adoption of GREEN-compliant energy observability in vendor equipment.

2.11.3. The Need for Energy Efficiency

// TODO.

2.11.4. Requirements for GREEN WG

* Standardized YANG models or data formats for energy metrics and efficiency reporting.

* Methods to correlate energy usage with traffic load and service demands.

* Interfaces for exposing energy capabilities and statuses of devices in a vendor-neutral way.

* Security and privacy implications of exposing energy-related telemetry.

* Guidelines for presenting energy insights to operators in a way that supports actionable decisions.

2.12. ISAC-enabled Energy-Aware Smart City Traffic Management

2.12.1. Use case description

Integrated Sensing and Communications (ISAC) is emerging as a key enabler for next-generation wireless networks, integrating sensing and communication functionalities within a unified system. By leveraging the same spectral, hardware, and computational resources, ISAC enhances network efficiency while enabling new capabilities such as high-resolution environment perception, object detection, and situational awareness. This paradigm shift is particularly relevant for applications requiring both reliable connectivity and precise sensing, such as autonomous vehicles, industrial automation, and smart city deployments. Given its strategic importance, ISAC has gained significant traction in standardization efforts. The ETSI Industry Specification Group (ISG) on ISAC has been established to explore technical requirements and use cases, while 3GPP has initiated discussions on ISAC-related features within its ongoing research on future 6G systems. Furthermore, research initiatives within the IEEE and IETF are investigating how ISAC can be integrated into network architectures, spectrum management, and protocol design, making it a critical area of development in the evolution of wireless networks.

This use case involves deploying ISAC systems in a smart city to monitor and optimize vehicles' traffic flows while minimizing energy consumption of the mobile network. The system integrates sensing technologies, such as radar and LIDAR, with communication networks to detect vehicle density, monitor road conditions, and communicate with autonomous vehicles or traffic lights. By using ISAC, the system minimizes redundant infrastructure (e.g., separate sensors and communication equipment), thus reducing the overall carbon and energy footprint.

On the other hand, such an infrastructure will have to adapt its energy optimization policies to sensing applications: critical functions (e.g., threat detection) must run continuously, while others should activate depending on the context.

2.12.2. GREEN WG Specifics

Energy Consumption Monitoring: Each ISAC component (e.g., roadside units, integrated sensors, and communication transceivers) is capable of reporting its energy consumption in real time to the centralized or distributed energy management system.

Reconfiguration for Energy Efficiency: The system can dynamically switch between high-resolution sensing modes (e.g., during peak hours) and low-power modes (e.g., during low traffic periods). The network can reconfigure traffic communication paths to prioritize routes or nodes that consume less power, leveraging energy-efficient communication protocols.

Integration of Local and Global Energy Goals: The system can operate both locally (e.g., turning off specific roadside units in low-traffic areas) and globally (e.g., modifying traffic patterns across the city) to achieve defined energy consumption goals.

2.12.3. Requirements for GREEN WG

1. Measurement Granularity:

* Ability to measure energy consumption per ISAC component (e.g., roadside unit, sensor, transceiver).

* Granular reporting per communication link or sensing mode (e.g., high-power radar mode vs. low-power mode).

1. Power Control Mechanisms:

* Ability to switch components on/off or place them in sleep/standby mode when not in use.

* Support for dynamic adjustment of sensing resolution or communication bandwidth to balance energy savings and system performance.

1. Reconfiguration and Adaptability:

* Support for hardware reconfiguration (e.g., adaptive sensing modes, transceiver settings) to optimize energy use.

* Mechanisms to steer traffic or adjust network routing based on global or local energy-saving objectives.

1. Global Coordination:

* Capabilities for cross-domain coordination to enable global optimization (e.g., city-wide traffic rerouting or dynamic resource allocation across different regions).

* Ability to aggregate and analyze energy consumption data from all ISAC components to inform high-level decision-making.

1. Energy-Aware Standards and Protocols:

    * Communication protocols that minimize power usage while maintaining reliability.

    * Interoperability standards for energy-aware reconfiguration across heterogeneous ISAC components and systems.

2.13. Double Accounting Open issue

2.13.1. Use case description

Energy consumption monitoring often includes metering at both upstream and downstream levels of power distribution. While this can provide granular visibility, it may also lead to double accounting if not carefully managed.

A common case arises when energy is measured at the input of a Power Delivery Unit (PDU), and individually at each device powered by that PDU (e.g., servers, switches). Since the PDU input already reflects the downstream consumption, summing the per-device values with the PDU input results in redundant reporting. A similar issue occurs with Power over Ethernet (PoE) infrastructures when a network switch supply power directly to devices. If the total power consumption measured encompasses both the power delivered to the PoE switch and to the powered devices, this again results in double accounting.

These 2 cases distort energy dashboards and indicators such as Power Usage Effectiveness (PUE).

2.13.2. GREEN WG Charter Specifics

Unlike most of the WGs, the GREEN WG purpose sums the constraints of data networks and grid/off-grid networks, independantly of the location of the network domain in the architecture (aka edge, core...): - include the grid network picture in networks operation

2.13.3. The Need for Energy Efficiency

// TODO.

2.13.4. Requirements for GREEN WG

The monitoring must not count twice the power that passthru devices and components monitored, including legacy elements.

2.14. Energy Efficiency Under Power Shortage

2.14.1. Use case description

This use case focuses on network devices (e.g., routers, switches, access points) that must maintain essential connectivity during power shortages. Telecom locations use different power backups levels (as example battery, standby generator ...). Devices may have access to one or more backup power sources such as onboard batteries, PoE fallback, or centralized UPS systems. When a power shortage occurs, the network device transitions from grid power to available backup sources and must prioritize operational resilience over typical energy optimization strategies. Unlike behavior in a normally powered state, the focus here is not on minimizing energy consumption per se, but on sustaining essential operation with limited energy and prepare to worse situations and more constrained powered state fallbacks. These behaviors increase the device’s ability to operate longer under backup power, ensuring availability of essential services during outages.

Data networks and grid networks resiliency are closely interleaved during power shortage. It is a race between the speed of the operations to restore the grid network and the availability of mobile connectivity for power grid repair teams because of the impairment of operational visibility and response coordination.

Network constraints differ in sparse or dense situations but shortage impacts change accordingly. This is becoming crucial and not limited to sparse environments where stable power supply is well known to not be guaranteed: it applies to dense cities’ utilities which operations are coupled to the simoultaneous availability of both power and persistent data communication and compute at the edge.

2.14.2. GREEN WG Charter Specifics

Unlike most of the WGs, the GREEN WG purpose sums the constraints of data networks and grid/off-grid networks, independantly of the location of the network domain in the architecture (aka edge, core...): - Improved networks resiliency by making energy constraints an input into the network’s operations.

2.14.3. The Need for Energy Efficiency

Energy efficiency under power shortage conditions is fundamentally different from routine energy optimization. In this context, energy is a finite and rapidly depleting resource, not just an environmental concern or cost factor: - Optimize backup power usage for resilience - Maintain critical networking capabilities during power shortage events - Maximize operational uptime using fallback power sources

2.14.4. Requirements for GREEN WG

* Awareness of backup systems (e.g., batteries, generators).

* Awareness of hierarchical fallback to more constrained powered state.

2.15. Energy-Efficient Management of Distributed AI Training Workloads

2.15.1. Use Case Description

Training large AI models requires distributed computing across multiple servers or GPUs. This distributed training generates significant East-West traffic as data is exchanged between nodes. This use case focuses on managing the energy consumption of distributed AI training workloads by optimizing data placement, communication patterns, and compute resource allocation. Strategies include scheduling training jobs to run during periods of lower energy prices, using compression techniques to reduce data transfer volume, and dynamically adjusting the number of active nodes based on training progress. It is also critical to have a cross-domain view of the end to end flow to address power consumption holistically.

2.15.2. GREEN WG Charter Specifics

This use case contributes to the GREEN WG's goals by addressing the energy efficiency of emerging workloads and exploring the use of dynamic resource allocation to minimize energy consumption. It calls for energy-aware scheduling and optimization techniques.

2.15.3. The Need for Energy Efficiency

AI training is a computationally intensive task that consumes a significant amount of energy. Optimizing the energy efficiency of distributed AI training workloads can reduce costs, improve sustainability, and enable more widespread adoption of AI technologies. There is an impact not only for the network consumption, rather than the compute consumption.

2.15.4. Requirements for GREEN WG

* East-West Traffic Monitoring: Standardized mechanisms for monitoring the volume, type, and characteristics of East-West traffic.

* Workload Characterization: Standardized methods for characterizing the energy consumption profile of AI training workloads.

* Energy-Aware Scheduling: APIs for scheduling training jobs based on energy prices, grid conditions, and other energy-related factors.

* Data Compression and Optimization: Techniques for reducing the volume of data transferred during distributed training.

* Dynamic Resource Allocation: Mechanisms for dynamically adjusting the number of active nodes based on training progress and energy availability.

* Resource co-location, so the data used for processing can be as close as possible to the data crunching machines.

3. Security Considerations

Energy efficiency management comes with numerous security considerations :

Controlling Power State and power supply of entities are considered highly sensitive actions, since they can significantly affect the operation of directly and indirectly connected devices. Therefore, all control actions must be sufficiently protected through authentication, authorization, and integrity protection mechanisms.

Entities that are not sufficiently secure to operate directly on the public Internet do exist and can be a significant cause of risk, for example, if the remote control functions can be exercised on those devices from anywhere on the Internet.

The monitoring of energy-related quantities of an entity as addressed can be used to derive more information than just the received and provided energy; therefore, monitored data requires protection. This protection includes authentication and authorization of entities requesting access to monitored data as well as confidentiality protection during transmission of monitored data. Privacy of stored data in an entity must be taken into account. Monitored data may be used as input to control, accounting, and other actions, so integrity of transmitted information and authentication of the origin may be needed.

4. IANA Considerations

This document has no IANA actions.

5. Acknowledgments

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6. Use Cases Living List

Consider 5g vs network slicing: 3GPP spec describing energy efficiency KPIs. 3GPP TS 28.554. Reference:https://datatracker.ietf.org/doc/rfc9543/ Connectivity from radio side (trying to control the traffic/related work to CCAMP) Marisol to add one use case: drift from data specifications... (somehow link to the above) Energy Metric in E2E view

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8. Appendix I: Template preparation

This appendix should be removed when the template will be stable.

It is based on the example from https://datatracker.ietf.org/doc/rfc9450/.

8.1. Use Case Description

General description of the use case.

8.2. GREEN WG Charter Specifics

(if there are no GREEN specific aspects, then it is not a UC to be documented) For example, the use case involves components that can report on energy consumption and that might be reconfigured (on a local or global scale) to operate based on energy goals/limitations.

8.2.1. The Need for Energy Efficiency

8.3. Requirements for GREEN

Examples (can be split into different categories to facilitate a summary at the end of the document):

* Granularity of measurements should be per component, per line, per port.

* Ability to switch on/off, put on sleep mode’ components.

* Ability to reconfigure hardware mode based on power savings (e.g., reduce reliability or speed).

* Ability to operate globally (not constrained to just one device) based on power savings/goals (e.g., steer traffic using a different path that consumes less energy).

```
(a)              (b)              (c)
Inventory        Monitor       +- DataSheets/DataBase and/or via API
Of identity      Energy        |  Metadata and other device/component
and Capability   Efficiency    |  /network related information:
     ^               ^         |
     |               |         |  .Power/Energy related metrics
     |               |         |  .information
     |               |         |  .origin of Energy Mix
     |               |         |  .carbon aware based on location
     |               |         |
     |               |         |
     |               |         |
     |               |         v
+--------------------------------------------------------------------+
|                   *                                                |
|     (2) controller   (collection, compute and aggregate?)          |
|                                                                    |
+--------------------------------------------------------------------+
             ^              ^                   ^ |
  (d)        |  (e)         |  (f)              | |(g)
  Inventory  |  Monitor     |  GREEN WG:        | |GREEN WG: Control
  Capability |  Traffic     |  Monitor power    | |(Energy saving
             |  & power     |  Proportion,      | |Functionality
             |  consumption |  Energy efficiency| |Localized mgmt/
             |              |  ratio, etc)      | |network wide mgmt)
             |              |                   | |
             |              |                   | |
             |              |                   | v
+--------------------------------------------------------------------+
|                                            *                       |
|                  (1) Device/Component Level                        |
|                                                                    |
| +---------+  +-----------+  +----------------+  +----------------+ |
| | (I)     |  | (II)      |  | (III)          |  | (IV)           | |
| | Network |  | Device    |  | Legacy Network |  | ’Attached’(PoE | |
| | Device  |  | Component |  | Device         |  | kind) Device   | |
| |         |  |           |  |                |  |                | |
| +---------+  +-----------+  +----------------+  +----------------+ |
+--------------------------------------------------------------------+

(*) Energy Efficiency Management Function is implemented inside the
device or in a controller
```

Figure 4: Framework discussed during the BoF

The main elements in the framework are as follows:

(a),(d) Discovery and Inventory

(b),(c) GREEN Metrics

(b),(f) Monitor energy efficiency

(e) Monitor power consumption and traffic (IPPM WG throughput, traffic load, etc)

(g) Control Energy Saving

9. Appendix II: Necessity and Impact of a Framework for Energy Efficiency Management

This appendix outlines the necessity of defining a framework for energy efficiency management within the GREEN Working Group’s current phase. Establishing a framework now is crucial for standardizing processes, optimizing energy usage, and ensuring interoperability across network devices. Immediate action enables the industry to achieve cost savings, meet regulatory requirements, and maintain competitiveness. By utilizing insights from existing use cases, the framework can deliver actionable metrics and support ongoing innovation, positioning the industry to effectively manage future energy challenges.

9.1. Framework Necessity

Analyzing use cases such as the "Incremental Application of the GREEN Framework" reveals the critical need for a structured approach to transitioning network devices towards energy-efficient operations. The framework is essential for:

* *Standardization*: Ensuring consistent practices across different devices and network segments to facilitate interoperability.

* *Efficient Energy Management*: Providing guidelines to identify inefficiencies and implement improvements.

* *Scalability*: Offering solutions that accommodate growing network demands and complexity.

* *Cost Reduction*: Optimizing energy usage to lower operational costs and extend equipment lifecycles.

* *Competitiveness*: Enabling organizations to maintain a competitive edge through enhanced sustainability.

* *Environmental Impact*: Supporting broader sustainability initiatives by reducing carbon footprints.

* *Simplified Implementation*: Streamlining the deployment of energy-efficient measures to minimize service disruptions.

* *Security*: Protecting sensitive operations related to power states and consumption.

9.2. Use Cases Calling for a Framework

Multiple use cases underscore the need for a framework, including:

* *Incremental Application of the GREEN Framework*

* *Selective Reduction of Energy Consumption in Network Parts*

* *Real-time Energy Metering of Virtualized or Cloud-native Network Functions*

* *Indirect Energy Monitoring and Control*

* *Consideration of Other Domains for Obtention of End-to-End Metrics*

* *Dynamic Adjustment of Network Element Throughput*

* *Video Streaming Use Case*

* *WLAN Network Energy Saving*

* *Fixed Network Energy Saving*

* *Energy Efficiency Network Management*

These use cases highlight diverse aspects of energy management that require a cohesive framework for effective implementation.

9.3. Impact on Energy Metrics

The framework will significantly enhance the creation of energy metrics with actionable insights by:

* *Standardizing Metrics*: Establishing consistent measurement protocols for energy consumption and efficiency.

* *Enhancing Data Collection*: Facilitating comprehensive monitoring and data aggregation across devices.

* *Supporting Real-time Monitoring*: Enabling dynamic tracking and immediate optimization of energy usage.

* *Integration Across Devices*: Ensuring interoperability for network-wide data analysis.

* *Providing Actionable Insights*: Translating raw data into meaningful information for decision-making.

9.4. Current Device Readiness

While many modern networking devices have basic energy monitoring capabilities, these are often proprietary. The framework will define requirements to enhance these capabilities, enabling standardized metric production and meaningful data contributions for energy management goals.

9.5. Why Now?

The decision to define the framework now, rather than later, is driven by:

* *Immediate Benefits*: Start realizing cost savings, reduced carbon footprints, and improved efficiencies.

* *Rapid Technological Advancements*: Aligning the framework with current technologies to prevent obsolescence.

* *Increasing Energy Demands*: Mitigating the impact of growing energy consumption on costs and sustainability.

* *Regulatory Pressure*: Preparing for compliance with existing and anticipated sustainability regulations.

* *Competitive Advantage*: Positioning organizations as leaders in sustainability and innovation.

* *Foundational Work Ready*: Building on the use cases and requirements established in Phase I.

* *Proactive Risk Management*: Minimizing risks associated with energy costs and environmental factors.

* *Facilitate Future Innovations*: Creating a platform for continuous improvements and adaptations.

* *Stakeholder Engagement*: Ensuring diverse perspectives are reflected for broader adoption.

In conclusion, establishing the framework for energy efficiency management now is strategic and timely, leveraging the current momentum of use cases and requirements to drive meaningful progress in energy efficiency management. Delaying its development could result in missed opportunities for immediate benefits, increased costs, and challenges in adapting to future technological and regulatory landscapes.

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