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Transport Network Level Use Cases
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Abstract

With the continuous growth of business volume, the transmission rate and number of network elements have increased sharply, and energy consumption of transport network has increased accordingly. Rising power costs due to significant energy consumption in transport networks necessitate energy-saving measures. To address this, adjusting energy consumption strategies according to different service requirements to optimize efficiency, ensuring quality while eliminating waste. Furthermore, regular network optimization and energy efficiency assessments enhance equipment performance and extend lifespan, thereby controlling long-term operational costs. Integrating energy-saving concepts into transport network operations proactively supports sustainable development.

This document presents two transport network level GREEN use cases, aiming to facilitate discussions within the GREEN Working Group on the potential benefits, challenges, and requirements. The use cases follow a structured template that is proposed for all GREEN use cases, ensuring consistency and comparability across different scenarios.

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1. Introduction

The transport network consists of numerous transport network elements, whose architecture directly affects energy consumption and network performance. Meanwhile, different traffic patterns lead to varying network element loads. The traffic model guides dynamic adjustments of network element operations to optimize energy utilization, ensuring that energy consumption scales proportionally with actual traffic demands, thereby achieving efficient energy saving.

On the one hand, regularly network optimization and conducting energy efficiency assessments and optimization can enhance equipment performance and extend their lifespan, thereby effectively controlling costs in long-term operations. Against the backdrop of increasingly tight energy resources and stricter environmental requirements, integrating energy-saving concepts into the operation of transport network is not only a factor in reducing operating costs but also a proactive response to the sustainable development.

On the other hand, as services continue to be assured in the transport network, the energy consumption of equipment accumulates over time, which significantly impacts operating costs in the long run. Through refined energy-saving strategies, energy efficiency can be optimized without compromising service quality. By employing intelligent traffic management to dynamically adjust the energy consumption of equipment based on dynamic service demands, not only can the efficient transport services be assured, but unnecessary energy waste can also be avoided.

This document presents two use cases related to transport network, aiming to facilitate discussions within the GREEN Working Group on the potential benefits, challenges, and requirements. The use cases follow a structured template that is proposed for all GREEN use cases [I-D.stephan-green-use-cases], ensuring consistency and comparability across different scenarios.

2. Transport Network Level Energy Optimization

2.1. Use case description

The transport network consists of numerous devices, and its planning directly affects energy consumption and network performance. Different traffic patterns lead to differences in device loads, and from the perspective of the entire network, traffic is unevenly distributed. Therefore, it’s crucial to develop a comprehensive network-level energy optimization strategy in view of dynamic traffic patterns and device capabilities in transport network.

This use case focuses on mid-to-long-term, strategic network energy efficiency optimization for operators. That is, through traffic prediction, traffic model optimization, traffic scheduling, and adjustment of device operating status, and energy consumption is positively correlated with actual traffic demand, thereby achieving load balancing and resource utilization optimization, improving the energy-saving potential of network elements, and achieving efficient energy saving.

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     |                 Transport Network Controller                    |
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     |   Traffic Prediction  -> Network Optimization -> Evaluation   |
     +-----------------------------------------------------------------+
                    ^                                   |
                    |                                   |
                Monitoring                Energy-Saving Strategy
                    |                                   |
                    |                                   v
     +-----------------------------------------------------------------+
     |                                                                 |
     |                   Transport Network Element                     |
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Figure 1: Network-level GREEN framework for transport network

As shown in the figure above, network-level GREEN is located on the controller for centralized policy generation and global scheduling, and the network elements perform specific energy-saving operations at the local.

First, network-level traffic prediction is performed based on historical traffic data obtained from the network. The transport network elements process the original per-second measurement data and aggregates it into 15-minute time intervals to report to the controller.

Secondly, based on the traffic monitoring from network elements, the controller captures the long-term regularity and short-term burst characteristics of network-level traffic through the neural network model in advance. The traffic prediction model embedded in the controller generates updated predictions to achieve near real-time perception. Based on the traffic load prediction results, the controller identifies high-load network elements (NEs) and idle NEs. The controller then formulates energy-saving traffic migration network optimization strategies.

Finally, by migrating traffic from high-load NEs to idle NEs, some switching resources of high-load NEs can be released to enter a dormant state, saving power consumption; while idle NEs can carry more traffic with the support of the existing switching matrix without increasing power consumption, thereby reducing the overall energy consumption of the transport network.

2.2. GREEN Specifics

1. Network Level Monitoring

   * The transport network elements process raw per-second traffic measurements, aggregating them into 15-minute intervals for reporting to the controller.

   * The controller performs network-level traffic prediction based on historical. This capability captures both long-term regular "tides" and the short-term "burst" characteristics. Based on traffic prediction results, energy-saving opportunities are able to be identified. (e.g. This capability allows for the detection of significant reductions in traffic within a specific time window, thereby enabling the devices to transition into a sleep/lower-power state).

2. Centralized Strategy Generation and Global Scheduling

   * The controller identifies high-load and idle network elements based on results of traffic prediction and historical data, and develops traffic migration and optimization strategies.

   * By migrating the traffic from high-load NEs to idle NEs, some fabric resources are freed to sleep for power saving, while the idle NEs can hold more traffic without power increasing supported by the existing switch fabrics at work.

2.3. Requirements for GREEN

* The controller has the ability to display energy consumption per transport network element at specified time granularity.

* The controller has the ability to perform accurate network-level traffic prediction, capturing both long-term regularities and short-term bursts, using historical traffic data.

* The controller has the capability to generate GREEN optimization strategies including the traffic migration methods based on traffic forecasts, operating on defined planning cycles.

3. Diversified Service Assurance with GREEN

3.1. Use case description

The transport network handles massive optical signals and fabric switching, which requires high bandwidth and low latency, and also incurs significant energy consumption. In order to efficiently manage the transport network, it’s necessary to integrate energy saving factors into service assurance. This use case aims to achieve differentiated energy saving without affecting the quality of service. Specifically, services with general service quality requirements try to use low-power devices and links; services with high service quality requirements use relatively safe energy-saving strategies to reduce power consumption while maintaining service requirements.

3.2. GREEN Specifics

* Service assurance with energy efficiency: Energy efficiency factors can be taken into account in processes during service provisioning, in combination with the client’s SLA and available underlying hard isolation resources. The transport network element reports its energy consumption. The controller evaluates the possible energy consumption during the service lifecycle.

* Control and Management: Local automatic energy saving can be processed on the network element, if enabled. It identifies power-consuming components that can be turned off or reduced based on configuration and traffic information. This may depend on the energy-saving object, such as the PHY, link, etc. If the link is considered, deactivate the link or reduce the bit rate supported by link during periods of low demand are possible approaches for energy saving. This may also needs the coordination between both the digital layers and the media layer.

3.3. Requirements for GREEN

* The transport network element has the ability to measure and report its energy consumption.

* The controller has the capability to consider energy efficiency factor in the multi-layer resource allocation during service assurance lifecycle.

* The network element capability interacted between controller and transport network element must be considered, especially the energy-saving object, and the energy-saving capability.

4. Deployment Considerations

In the field trial involving 1966 commercial network elements traffic data prediction, the network-level optimization strategy provides a power reduction of 7.7% for the whole network and up to 20.8% for the single network element node with service quality guaranteed. This document fully verifies the potential of network-level energy-saving technology, demonstrating an effective approach for sustainable large-scale transport network operations.

5. Security Considerations

A general principle is that the more significant the energy savings, the slower the module response time and the longer the wake-up delay, which may impact service performance.

To address this, the following items should be considered:

1. Power state configuration aligned with service tolerance: During low-traffic periods (e.g., nighttime), idle line cards/standby main control units can enter deep sleep mode for maximum energy savings. During peak hours (e.g., daytime), a light sleep mode should be adopted to enable faster wake-up and minimize service disruption.

2. Resource reservation for reliable energy efficiency: In the transport network, the total bandwidth utilization of a network network element is primarily determined by the aggregate traffic across its ports. However, in practice, the available capacity cannot be entirely assigned to user traffic, as a portion of the bandwidth must be reserved for protection switching, rerouting operations and control plane overhead. It ensures the network reliability during network anomalies or congestion events.

So redundant resources should be reserved to accommodate scenarios like protection switching at failure cases. This guarantees service reliability while maintaining energy-saving benefits.

6. Acknowledgments

TBD.

7. Informative References

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