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X. Chen  
CMCC  
J. Zhou  
J. Yan  
ZTE  
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Hybrid Energy Saving Mechanism for Transport Network  
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Abstract

This document continues the transport network energy saving that harmonizes device-level autonomy with network-wide coordination. By implementing control at hybrid both the device and network controller coordination, it enables dynamic, SLA-aware, and multi-layer energy optimization.

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## 1. Introduction

This document presents transport network energy saving management framework that harmonizes device-level autonomy with network-wide coordination. The framework is grounded in [I-D.belmq-green-framework] 's reference model and addresses the specific requirements identified in [I-D.ietf-green-use-cases] through practical mechanisms for multi-layer energy optimization.

The framework is organized into two functionally distinct yet complementary layers that work in concert to achieve coordinated energy optimization:

- \* Device-Centric Energy Saving: The device-centric management encompasses individual network elements that execute real-time, localized energy adjustments based on local data collection and policies received from the network controller. Device-centric management enables fast response to transient traffic conditions and maintains autonomous operation.
- \* Controller-Centric Energy Saving: The controller-level energy management provides centralized visibility, cross-layer analysis, and strategic policy formulation across the entire network domain. Controller-centric management performs long-term traffic prediction, assesses network-level risks, and provides a northbound interface to users for intuitive evaluation of energy-saving effects.

## 2. Monitoring

Transport networks requires comprehensive, real-time, and granular measurements spanning physical, logical, and environmental domains to enable cross-layer correlation and coordinated optimization.

- \* **Power Monitoring:** Power monitoring is the foundation for understanding energy consumption patterns and identifying optimization opportunities. Power monitoring encompasses measurements at multiple hierarchical levels within network elements, from component-level including boards, fans, and PSU to device-level chassis power.
- \* **Traffic Monitoring:** Traffic monitoring extends the framework to address transport network-specific requirements. Understanding traffic characteristics across multiple layers is essential for correlating energy consumption with network utilization and for identifying temporal patterns that enable predictive optimization. This enables both real-time response to transient traffic changes and long-term trend analysis for strategic planning.
- \* **Topology Monitoring:** Topology monitoring provides the cross-layer visibility necessary for coordinated energy optimization. Transport networks span multiple protocol layers with complex interdependencies; understanding these relationships is critical for making energy-saving decisions that respect service requirements and network constraints. Topology monitoring across both transport and IP layers should be used to capture relevant logical relationships, such as protection relationships, resource aggregation, and service-to-infrastructure mappings that support the formulation of energy optimization strategies.

## 3. Hybrid Both Device and Controller Coordination

Section 6.1 of [I-D.belmq-green-framework] discuss the implementation focus and where intelligence resides. The transport network uses the hybrid approach which need device capabilities and controller coordination.

Transport network device must independently manage its energy saving no matter DCN is available for local real-time process. It needs local algorithms, minimal controller dependency, autonomous operation. Secondly, the device-centric performs traffic prediction, quickly responds to short-term traffic changes, formulates strategies, and executes actions.

On the other side, the controller-centric energy saving performs long-term traffic prediction based on network topology resources, assesses network-level risks, provides a northbound interface to users, and enables visualized and intuitive evaluation of energy-saving effects.

Depending on the scenario, inference time, accuracy, and other factors, different intelligent algorithms are deployed on the controller and device to intelligently predict long and short cycles and burst traffic. This allows the controller to accurately predict long-term changes in services and devices to accurately predict short-term burst traffic, thereby adjusting the equipment operating status in advance and avoiding service disruption.

### 3.1. Device-Centric Energy Saving

This allows devices to make local decisions on resource scheduling based on real-time, node-local data/information collection, enabling faster reaction to transient traffic conditions through on-device analysis.

#### 1. Data collection

- \* Sensors continuously gather real-time power and energy-related metrics, including chip, port, board, fan, and chassis power consumption, as well as device zone temperature and instantaneous traffic load.

#### 2. Analysis

- \* An embedded processing unit applies lightweight algorithms to model the relationship between local load and power consumption. It performs short-term traffic trend prediction, evaluates energy-saving strategies through simulation, and supports cross-layer command coordination. Conditions are continuously assessed against configured energy-saving policies.

#### 3. Simulation and Verification

- \* The simulation model describes the relationships between parameters of device and relationships between devices themselves. It uses the data from scenario and energy-saving scheme to simulate and verify the consumption information after executing energy-saving scheme. Based on the power consumption information, the feasibility of energy-saving scheme is tested and determined.

#### 4. Control and Execution

- \* Devices dynamically switch the power state of the components (e.g., ports, line cards, switch cards, chassis) based on local traffic load, in accordance with policies received from the device controller. For instance, when predicted traffic falls below a predefined threshold, the system sequentially initiates energy-saving actions, such as placing boards into sleep mode and intelligently adjusting fan speeds.
- \* Supported power states include deep sleep, light sleep, normal operation, and power-off. Deep sleep maintains only essential core links, substantially reducing energy consumption during idle periods. Light sleep can satisfy hitless wake-up from sleep modes to ensure zero service impact, particularly for high-priority services.

### 3.2. Controller-Centric Energy Saving

This network-level energy management operates from a network controller platform, providing a holistic view and strategic control. Unlike device-local management, its role is primarily one of coordination, optimization, and assurance across the multi-layer network.

#### 1. Data collection

The controller ingests and correlates telemetry from all managed devices, building a holistic network model that spans real time power consumption, topology, and traffic state.

- \* Transport Layer Topology: Logical link information and resource status from both the optical layer (L0) and electrical layer (L1/L2).
- \* IP Layer Topology: Logical links, protection relations and routing adjacencies from the IP layer (L3). For instance, protection paths may carry extra traffic under normal conditions but must be reserved for failover scenarios. This integrated view allows the network controller to assess risks, such as extended wake-up delays from deep sleep modes, that could impact service performance during protection switching or other reactive scenarios.

#### 2. Analysis

- \* Leveraging AI/ML and analytical engines, the controller performs predictive traffic and load forecasting. It identifies optimization opportunities through cross layer correlation. It also can simulate the potential impact of different energy management strategies before deployment.
- \* Cross-layer Coordination: The controller translates high-level strategies into specific, synchronized actions for both transport and IP layers to ensure service continuity. For example, before putting a transport node to sleep, it coordinates with the IP layer to reroute traffic away from that node.

### 3. Control and Execution

The central controller acts as the brain for network-level energy optimization. Its key functions include:

The controller analyzes historical and real-time traffic data to predict future load patterns. Based on these predictions and service SLAs, it generates holistic energy-saving strategies,

- \* Computing paths for traffic migration to consolidate services onto fewer network elements.
- \* Instructing idle or underutilized devices to enter low-power states (e.g., deep sleep for best-effort services, light sleep for premium services). These policies are then dispatched to devices.

### 4. YANGs Considerations

The implementation of the hybrid device-centric and controller-centric energy optimization requires standardized data models for representing energy-related information, policies, and control mechanisms. This section discusses the YANG data model considerations for this implementation.

The framework defines information flows between devices and controllers:

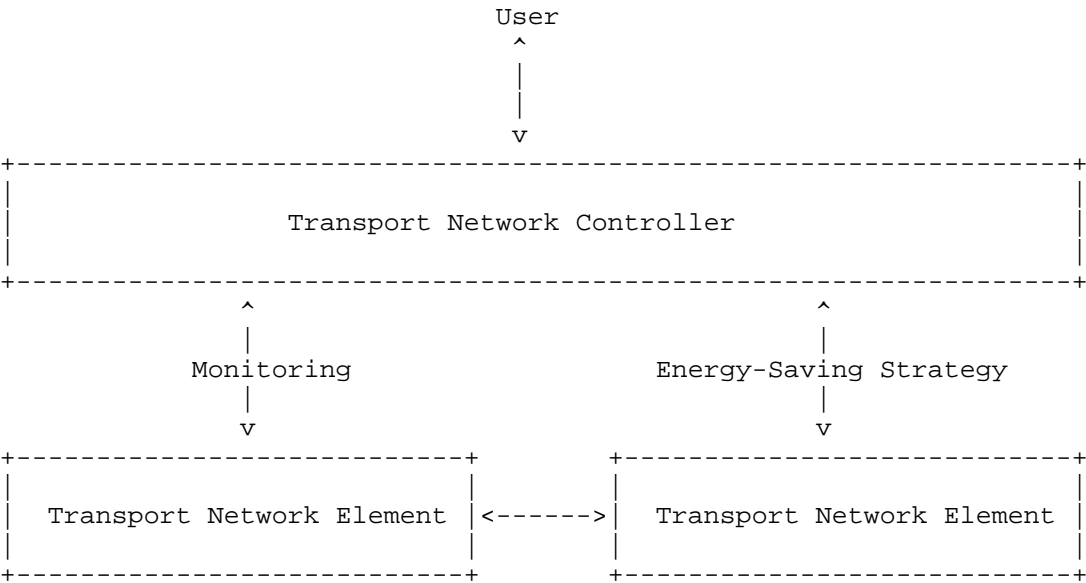


Figure 1: Transport Network Energy Saving Framework

Devices report operational data including power measurements, traffic characteristics, device status, and multi-granularity aggregated data to the controller. Controllers distribute energy-saving policies, SLA constraints, cross-layer control commands, and configuration updates to devices.

To address this hybrid coordination, the following YANG considerations should be evaluated:

1. Controller and Users: YANG models for northbound interfaces enabling users to configure energy-saving objectives, view optimization results, and monitor energy consumption.
2. Controller and Devices: YANG models for southbound interfaces enabling the controller to distribute policies, receive telemetry, and issue control commands to devices.
3. Device and Device: Peer-to-peer interactions between devices to support cross-layer coordination and local optimization. This may involve protocol or signaling extensions, such as capability advertisement, energy-saving status synchronization, or the notifications of energy-saving policies, which can guide other devices to perform operations or provide information to the other devices.

## 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 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. Informative References

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#### Authors' Addresses

Xinyu Chen  
China Mobile  
No.32 Xuanwumen west street  
Beijing  
100053  
China  
Email: chenxinyuyjy@chinamobile.com

Jin Zhou  
ZTE Corporation  
Email: zhou.jin6@zte.com.cn

Jinjie Yan  
ZTE Corporation  
Email: yan.jinjie@zte.com.cn