Hybrid Energy Saving Mechanism for Transport Network

draft-chen-green-transport-energy-saving-00

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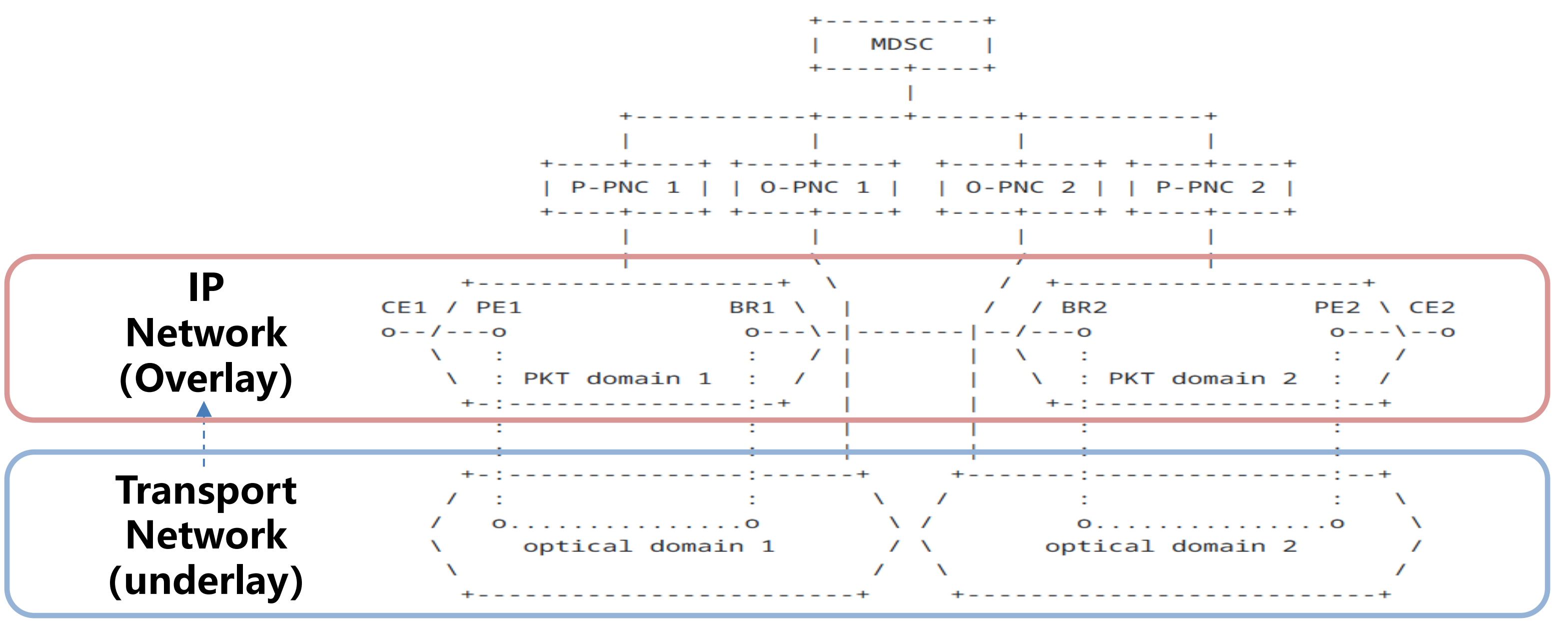
Introduction

- Transport network is the underlay compared to IP router's overlay role, designed for guaranteed connectivity with relatively rigid resource allocation.
- The use case draft now incorporates "Network-level cross-layer energy saving" of the transport network, thanks to the collaborative revisions with Emile Stephan and Qin Wu.
- Our Goal: Define a hybrid approach for GREEN that combines fast local response with coordinated holistic network-wide optimization, all while maintaining SLA guarantees, supported by power-related monitoring, policy configurations and YANG models.



Hybrid Mechanism Overview

- **Device-Centric:**

  Local & Fast

- Real-time, localized energy adjustments by individual network elements.

- Local data collection and pre-configured policies.

- Enables fast response to transient traffic fluctuations.

- Maintains autonomous operation even when DCN is unavailable.

- **Controller-Centric:**

  Global & Strategic

- Centralized, holistic view across the entire network domain.

- Performs cross-layer analytics and long-term traffic prediction.

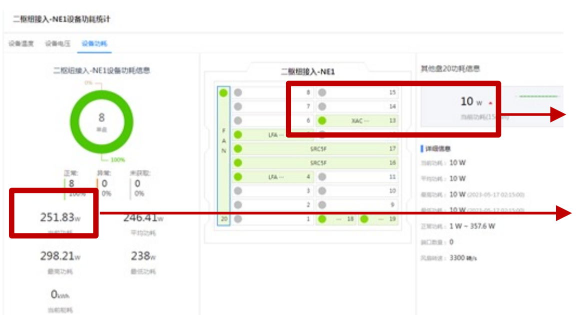
- Formulates strategic policies and assesses network-level risks.

- Offers northbound interfaces for intuitive energy management.

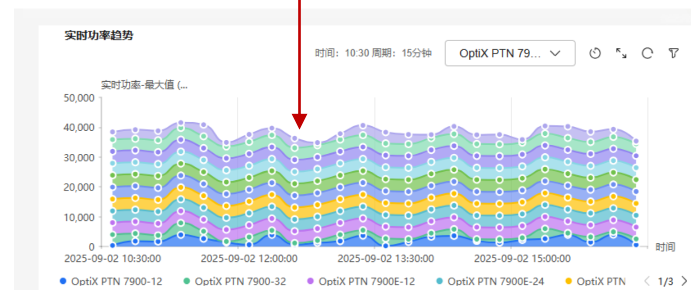
A Hybrid Approach for Immediate Reaction and Global optimization

Power-related Data Monitoring

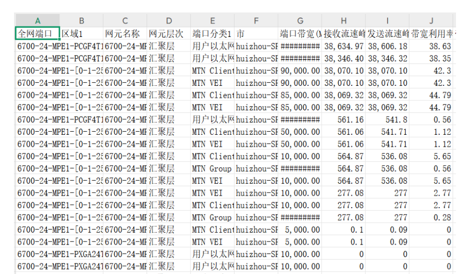
- **Power Monitoring:**
- Component-level: boards, fans, PSU
- Device-level: chassis
- Period: s, 15min



Power variation verse time

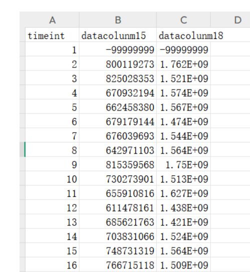


- **Traffic Monitoring:**
- Port traffic, tunnel traffic
- Period: ms, 15min, day, week, month



全网端口	区域1	网元名称	网元层次	端口分类1	市	端口带宽(M	接收流速峰	发送流速峰	带宽利用率
6700-24-MPE1-PCGF4T1		6700-24-M	汇聚层	用户以太网	huizhou-S	#########	38,634.97	38,606.18	38.63
6700-24-MPE1-PCGF4T1		6700-24-M	汇聚层	用户以太网	huizhou-S	#########	38,346.40	38,346.32	38.35
6700-24-MPE1-[0-1-2		6700-24-M	汇聚层	MTN Client	huizhou-S	90,000.00	38,070.10	38,070.10	42.3
6700-24-MPE1-[0-1-2		6700-24-M	汇聚层	MTN VEI	huizhou-S	90,000.00	38,070.10	38,070.10	42.3
6700-24-MPE1-[0-1-2		6700-24-M	汇聚层	MTN Client	huizhou-S	85,000.00	38,069.32	38,069.32	44.79
6700-24-MPE1-[0-1-2		6700-24-M	汇聚层	MTN VEI	huizhou-S	85,000.00	38,069.32	38,069.32	44.79
6700-24-MPE1-PCGF4T1		6700-24-M	汇聚层	用户以太网	huizhou-S	#########	561.16	541.8	0.56
6700-24-MPE1-[0-1-2		6700-24-M	汇聚层	MTN Client	huizhou-S	50,000.00	561.06	541.71	1.12
6700-24-MPE1-[0-1-2		6700-24-M	汇聚层	MTN VEI	huizhou-S	50,000.00	561.06	541.71	1.12
6700-24-MPE1-[0-1-2		6700-24-M	汇聚层	MTN Client	huizhou-S	10,000.00	564.87	536.08	5.65
6700-24-MPE1-[0-1-2		6700-24-M	汇聚层	MTN Group	huizhou-S	#########	564.87	536.08	0.56
6700-24-MPE1-[0-1-2		6700-24-M	汇聚层	MTN VEI	huizhou-S	10,000.00	564.87	536.08	5.65
6700-24-MPE1-[0-1-2		6700-24-M	汇聚层	MTN VEI	huizhou-S	10,000.00	277.08	277	2.77
6700-24-MPE1-[0-1-2		6700-24-M	汇聚层	MTN Client	huizhou-S	10,000.00	277.08	277	2.77
6700-24-MPE1-[0-1-2		6700-24-M	汇聚层	MTN Group	huizhou-S	#########	277.08	277	0.28
6700-24-MPE1-[0-1-2		6700-24-M	汇聚层	MTN Client	huizhou-S	5,000.00	0.1	0.09	0
6700-24-MPE1-[0-1-2		6700-24-M	汇聚层	MTN VEI	huizhou-S	5,000.00	0.1	0.09	0
6700-24-MPE1-PXGA24T		6700-24-M	汇聚层	用户以太网	huizhou-S	10,000.00	0	0	0
6700-24-MPE1-PXGA24T		6700-24-M	汇聚层	用户以太网	huizhou-S	10,000.00	0	0	0
6700-24-MPE1-PXGB24T		6700-24-M	汇聚层	用户以太网	huizhou-S	10,000.00	0	0	0

Port traffic



timeint	datacolunm15	datacolunm18
1	-99999999	-99999999
2	800119273	1.762E+09
3	825028353	1.521E+09
4	670932194	1.574E+09
5	662458380	1.567E+09
6	679179144	1.474E+09
7	676039693	1.544E+09
8	642971103	1.564E+09
9	815359568	1.75E+09
10	730273901	1.513E+09
11	655910816	1.627E+09
12	611478161	1.438E+09
13	685621763	1.421E+09
14	703831066	1.524E+09
15	748731319	1.564E+09
16	766715118	1.509E+09

Tunnel traffic

- **Topology Monitoring**
- Cross-layer visibility across transport and IP layers
- Capture protection relationships and service mappings

Working path

Protection path

Device-Centric and Controller-Centric Operations

Controller

Data Collection
- Captures protection paths and routing adjacencies
- Builds holistic model spanning transport (L0/L1/L2) and IP (L3) layers

Analysis
- AI/ML engines perform long-term traffic forecasting
- Cross-layer correlation identifies optimization opportunities
- Simulates strategy impact before deployment

Control & Execution
- Computes optimal paths for traffic migration and service consolidation
- Instructs idle devices to enter appropriate low-power states
- Coordinates cross-layer actions to ensure service continuity

Device

Data Collection
- Continuous sensing of power, temperature, and traffic load, at finer granularity.
- Real-time metrics from chips, ports, boards, fans, and chassis

Analysis
- Lightweight algorithms model load-power relationships
- Short-term traffic prediction and strategy evaluation
- Assessment against configured policies for energy efficiency and service reliability

Control & Execution
- Dynamic power state switching: deep sleep, light sleep, normal, power-off

Information flows

- Controller to Users:

Northbound interfaces for configuring objectives and viewing results

- Controller to Devices:

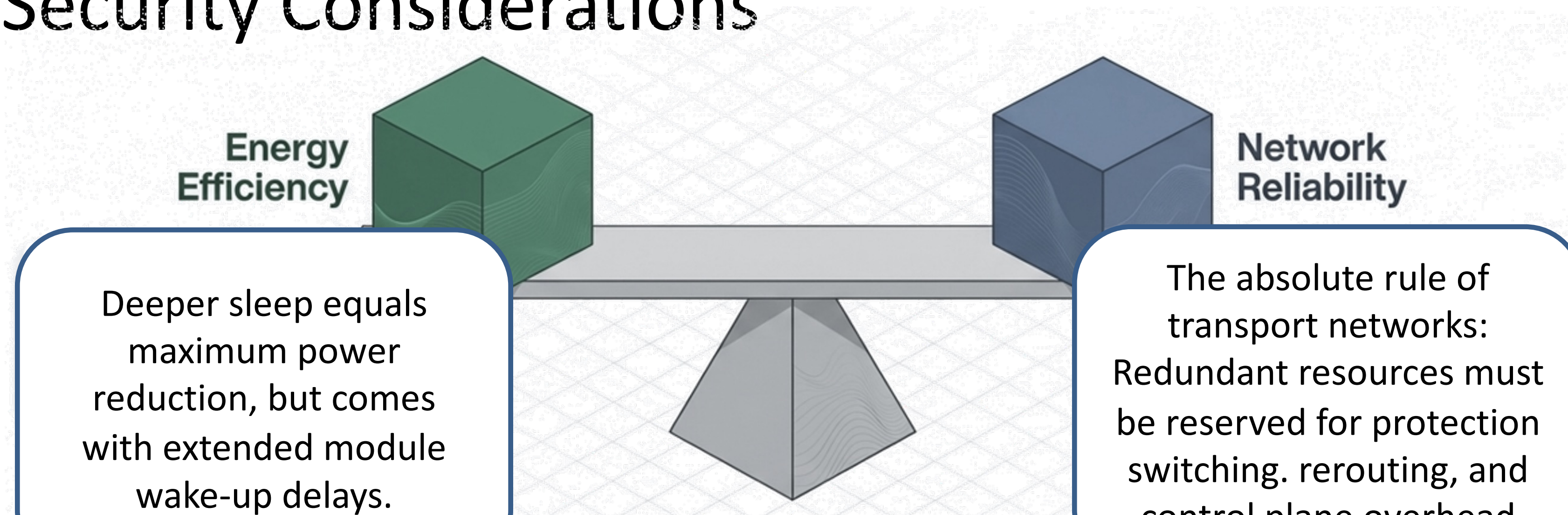
Southbound interfaces for policy distribution, telemetry, and commands

- Device to Device:

Peer interactions for local energy saving coordination and capability advertisement

```
                             User
                              ^
                              |
                              |
                              v
+--------------------------------------------------------------+
|                                                              |
|                Transport Network Controller                  |
|                                                              |
+--------------------------------------------------------------+
              ^                                 ^
              |                                 |
YANG model    Monitoring          Energy-Saving Strategy    YANG model
              |                                 |
              v                                 v
+--------------------------+        +--------------------------+
|                          |        |                          |
|  Transport Network Element |<------>| Transport Network Element |
|                          |        |                          |
+--------------------------+        +--------------------------+
                            Protocols
```

Security Considerations



Deeper sleep equals maximum power reduction, but comes with extended module wake-up delays.

The absolute rule of transport networks: Redundant resources must be reserved for protection switching. rerouting, and control plane overhead

- **Service-Aware Power States:**

Power state alignment with service tolerance and network idle/busy cycles.

(1)e.g. Low-traffic periods (night): Deep sleep for maximum savings

Peak hours (daytime): Light sleep for faster wake-up

(2)e.g. High-reliability premium services: Light sleep for instant wake-up

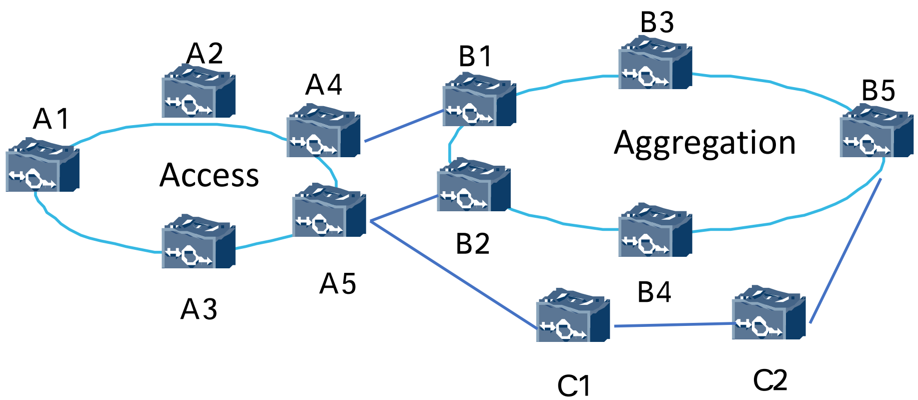
Low-priority services: Deep sleep for maximizing savings

- **Risk-Controlled Energy Saving:**

e.g. Protection paths may carry extra traffic normally, but must be instantly available for failover scenarios. Risk assessment is mandatory before sleep.

Deployment Considerations

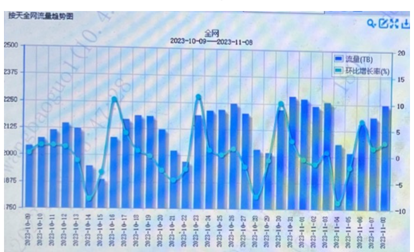
- **Demo demonstration:**



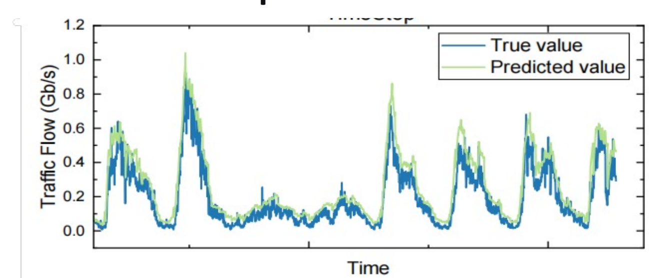
The hybrid mechanism is being deployed in China Mobile's commercial network , spanning over 10,000 nodes. It enables cross-layer energy saving that extends energy-aware optimization from Layer 3 (network layer) down to Layer 1 (physical layer).

- **Data monitoring, acquisition and analysis:**

✓ **Controller-side：Collected traffic data @ day-level for long-term trend analysis**



✓ **Device-side: Collected traffic data @ ms-level for burst trend prediction**

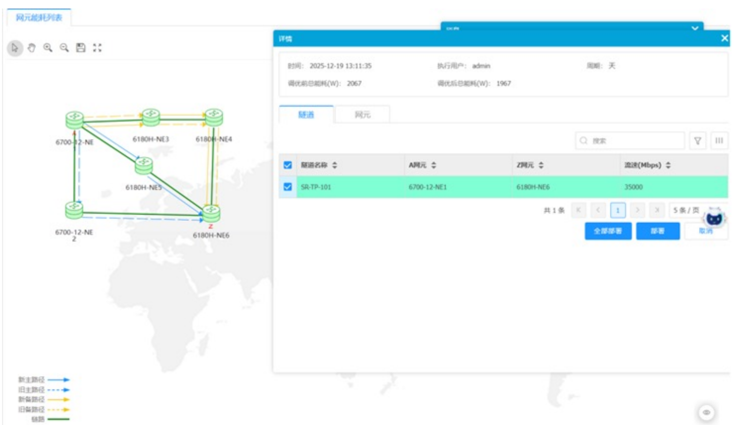


✓ **Controller-side：power monitoring @ 15min-level**

14.88% Energy Savings Achieved in 24-Hour
Live Demo: Saving 34.33 kWh across all devices.

Deployment Considerations (Cont.)

- **Energy-awareness routing policy:**



Energy-awareness path optimization analysis at the controller-side

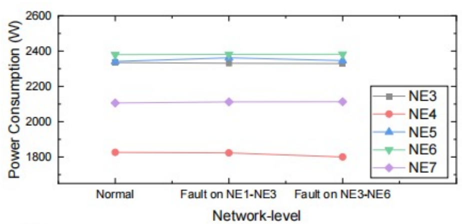
Confirm tunnel rerouting

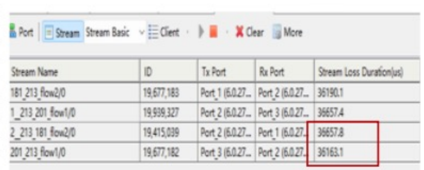
Deployment and Optimized tunnel changed

Device-side line card powered off

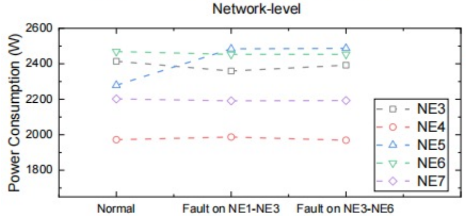
2.3% network-wide energy-saving profit

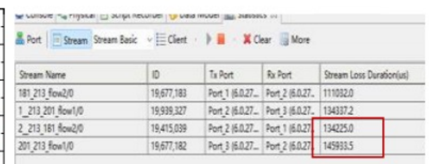
- **Protection switching & traffic burst reliability test**



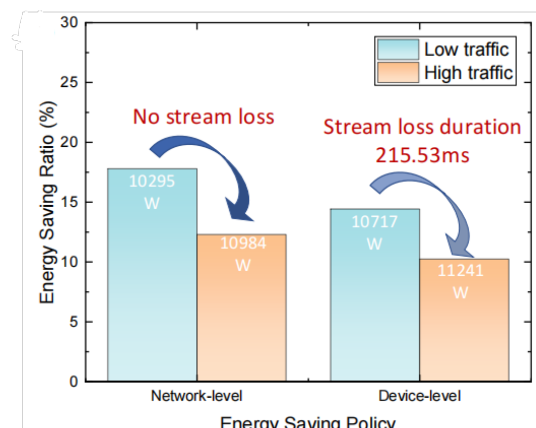


Stream Name	ID	Tx Port	Rx Port	Stream Loss Duration(us)
181_213_flow2/0	19,677,183	Port_1 (6.0.27...	Port_2 (6.0.27...	36190.1
1_213_201_flow1/0	19,939,327	Port_2 (6.0.27...	Port_3 (6.0.27...	36657.4
2_213_181_flow2/0	19,415,039	Port_2 (6.0.27...	Port_1 (6.0.27...	36657.8
201_213_flow1/0	19,677,182	Port_3 (6.0.27...	Port_2 (6.0.27...	36163.1





Stream Name	ID	Tx Port	Rx Port	Stream Loss Duration(us)
181_213_flow2/0	19,677,183	Port_1 (6.0.27...	Port_2 (6.0.27...	111032.0
1_213_201_flow1/0	19,939,327	Port_2 (6.0.27...	Port_3 (6.0.27...	134337.2
2_213_181_flow2/0	19,415,039	Port_2 (6.0.27...	Port_1 (6.0.27...	134225.0
201_213_flow1/0	19,677,182	Port_3 (6.0.27...	Port_2 (6.0.27...	145933.5



Next Step

- Are the scenarios and motivations clear?
- This draft establishes the foundation. Looking ahead, we see several potential extensions within GREEN:

- Interface & Data Models: Cross-layer energy status exchange? Device power state negotiation? What is the required granularity?
- How to facilitate mutual understanding of power/energy-saving states among related devices to enable collaborative energy optimization?
- What monitoring dimensions are essential to guarantee SLAs during energy-saving modes?
- The specific extentions will continue to apply in the future.

- Comments welcome.

Thank you!

Datatracker :https://datatracker.ietf.org/doc/draft-chen-green-transport-energy-saving/

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