No Boundaries

ITU

AI/ML in 5G Global Challenge

Applying machine learning in network extension optimization

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2019 CMCC Independent Development Competition Bronze Award
2020 CMCC Maker Marathon First Prize

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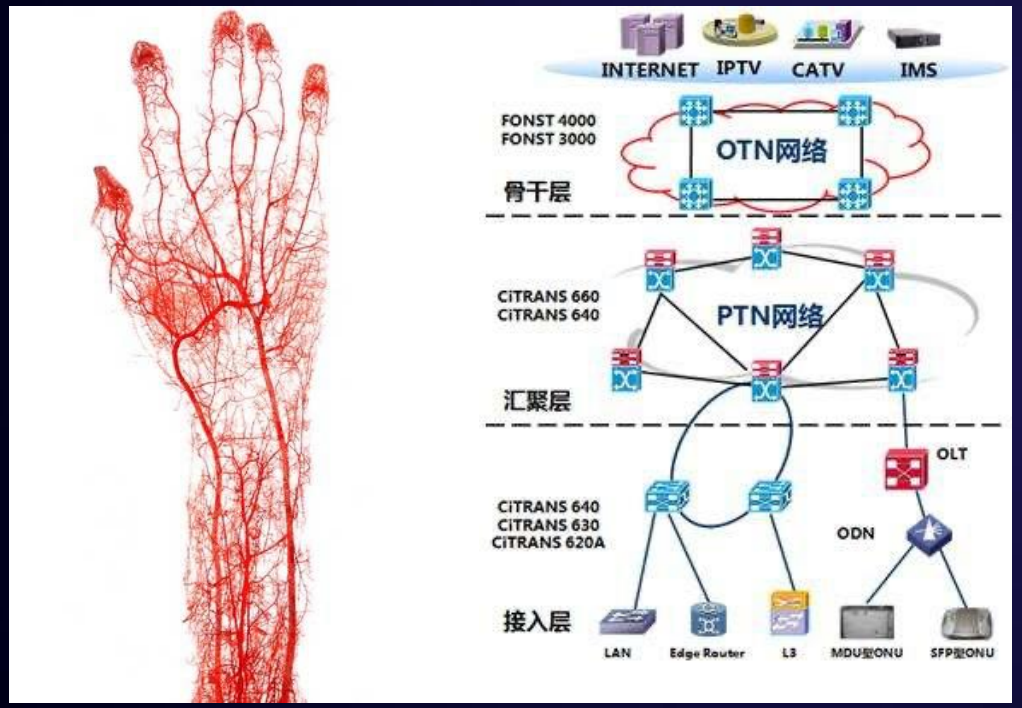
3 Evolution

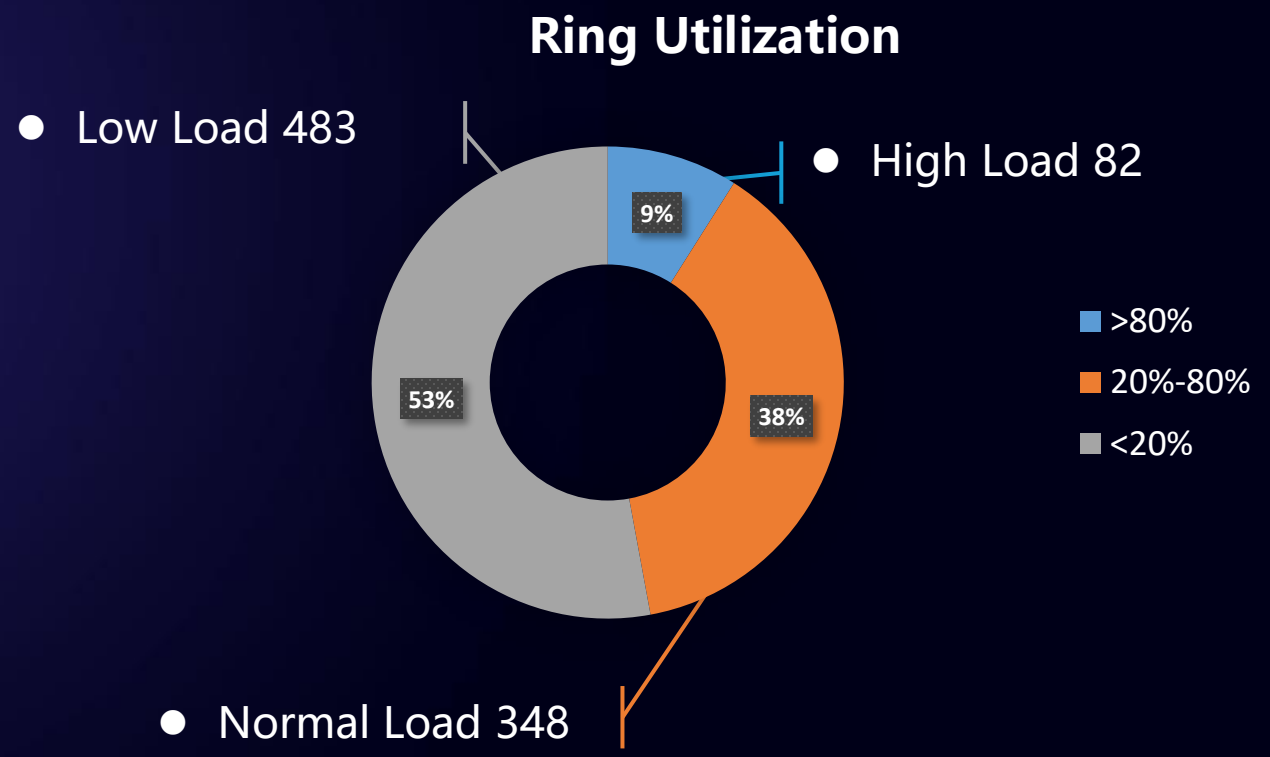
4 Outlook

Background——Problem Introduction

Transmission is the vessel of Telecommunication. To construct a highly efficient network, each node should be used efficiently to form the transmission network. While the actual situation is not the case.



Ex: Kaili PTN network consists of 3191 nodes, 913 rings



Note: Kaili is one of the ten cities in Guizhou Province.

Background——Optimization problem

As the network becomes more complex, topology optimization cannot be fully completed. Only local adjustment or node expansion can be used to solve the high-load ring problem and avoid affecting the business.

Possible Topologies=Nodes* Links

Ex: Kaili local network consists of 3191 nodes, 913 rings

Possible Topology	9 Nodes	19 Nodes	29 Nodes	……
3 Links	27	57	87	……
6 Links	54	114	174	……
9 Links	81	171	261	……
……	……	……	……	……

Possible Transmission Network Number =3191*913=

2,913,383！！！

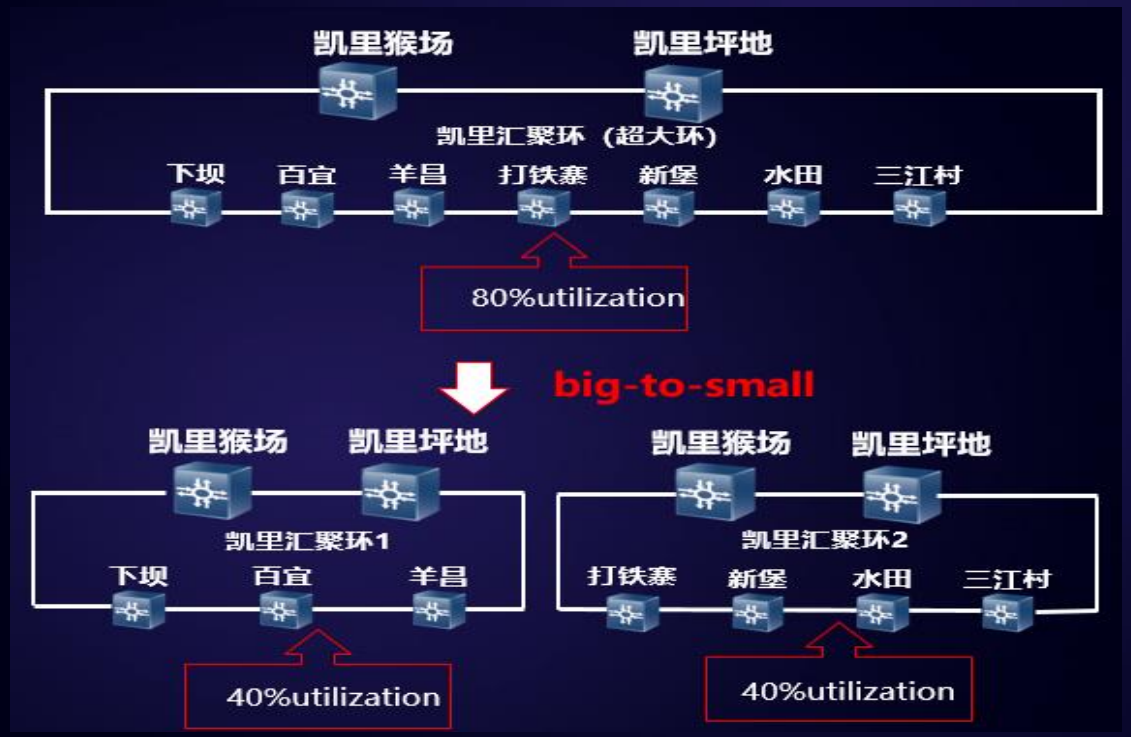
Impossible to fully analyze and optimize the network topology

Background——Optimization problem

As the network becomes more complex, topology optimization cannot be fully completed. Only local adjustment or node expansion can be used to solve the high-load ring problem and avoid affecting the business.

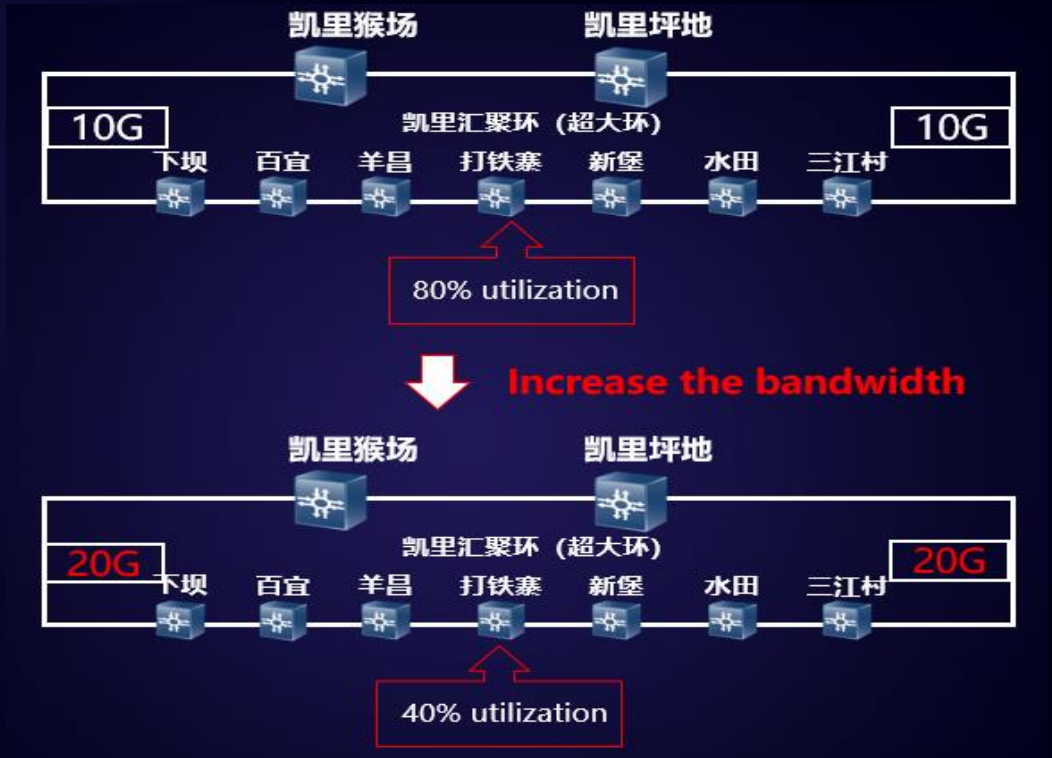
Solution1:Local（Ring）Adjustment

Targeted "big-to-small" optimization for some links, reducing the number of nodes and load.



Solution2:Node Expansion

Increase the bandwidth of the link by upgrading hardware, and reduce link utilization.



Background——Solution

Existing technologies and solutions cannot effectively solve the problem of network topology optimization. But it is enlightened that artificial intelligence can be used to complete topology optimization schemes.

SDN

1.《Unveiling the potential of Graph Neural Networks》

Wireless Network

1.《flexible adjustments between energy and capacity for topology control in hetreogeneous wireless multi-hop network》

2.《A DBN-Based Independent Set Learning Algorithm for Capacity Optimization in Wireless Networks》

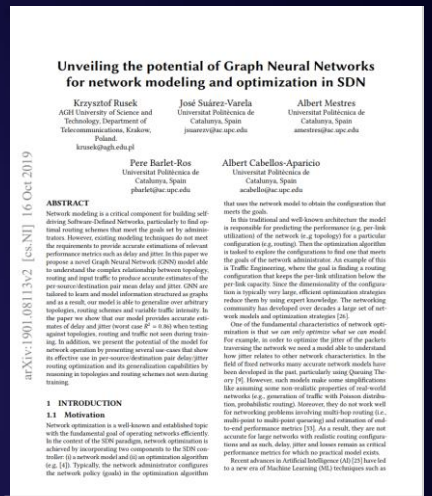
Data Center Network

1.《ElasticTree_Saving_Energy_in_Data_Center_Networks》

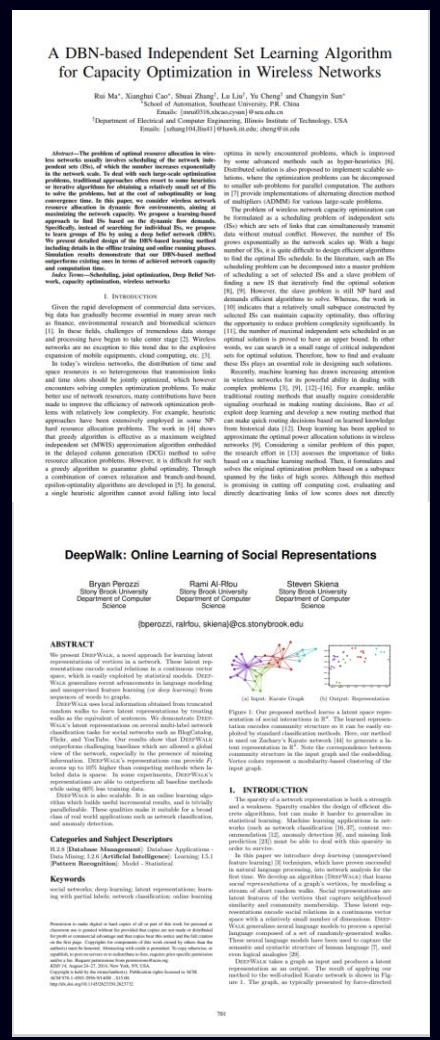
2.《Understanding and Mitigating Packet Corruption in data center networks》

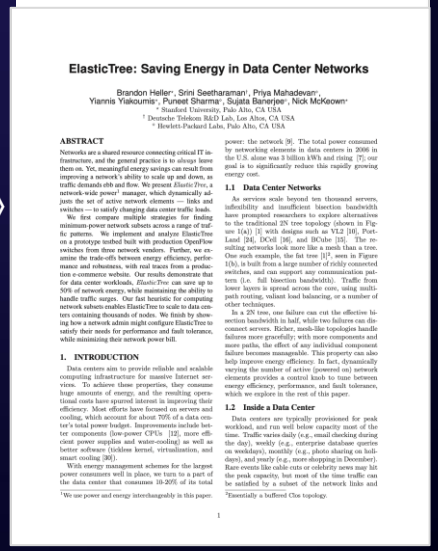
Internet

1.《DeepWalk: Online Learning of Social Representations》


Unveiling the potential of Graph Neural Networks for network modeling and optimization in SDN


Flexible Adjustments Between Energy and Capacity for Topology Control in Heterogeneous Wireless Multi-hop Networks


A DBN-based Independent Set Learning Algorithm for Capacity Optimization in Wireless Networks


ElasticTree: Saving Energy in Data Center Networks


Understanding and Mitigating Packet Corruption in Data Center Networks

DeepWalk: Online Learning of Social Representations

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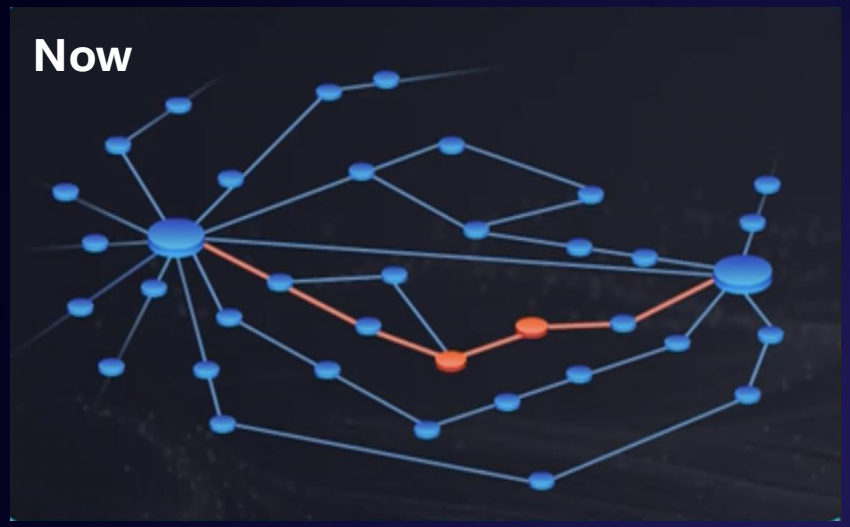
Ideas——Problem Analysis

The problem is based on real data on the live network, allowing developers to simulate and automatically optimize the network topology.



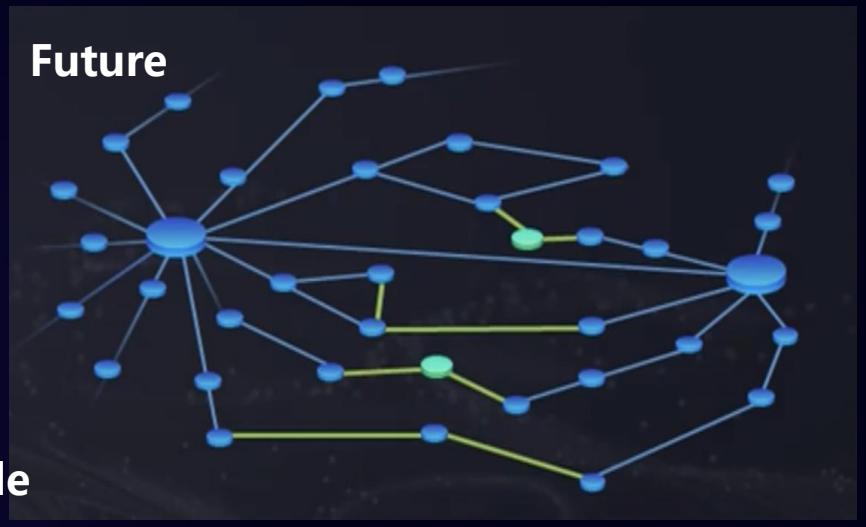
optimize

2000 Nodes

Previous Traffic

Topology

Latitude and Longitude



Choose Recommendation ITU-T Y.3172

ML Pipeline Subsystem

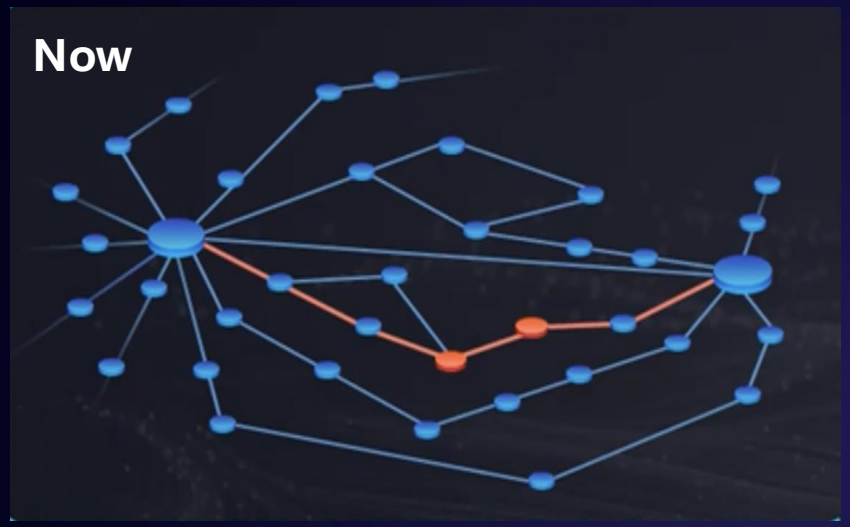
ML Management Subsystem

ML Sandbox Subsystem

Adopt

Ideas——Problem Analysis

The problem is based on real data on the live network, allowing developers to simulate and automatically optimize the network topology.



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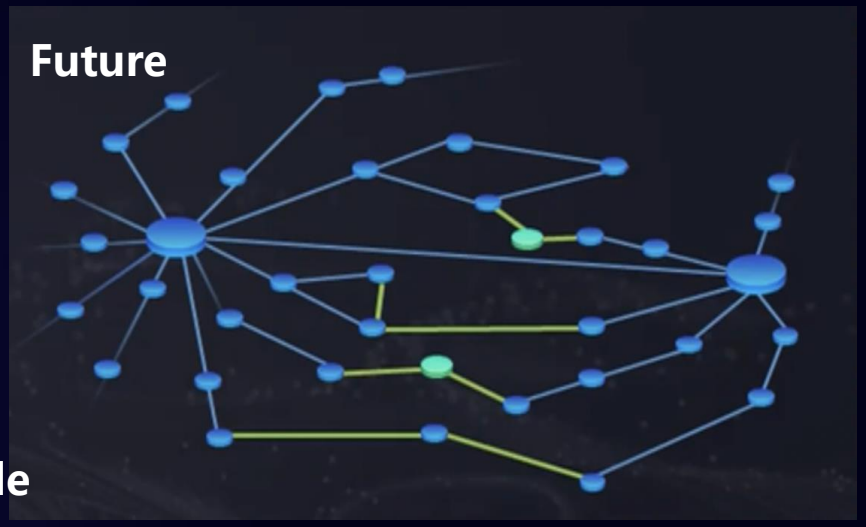

Choose Recommendation ITU-T Y.3172

ML Pipeline Subsystem

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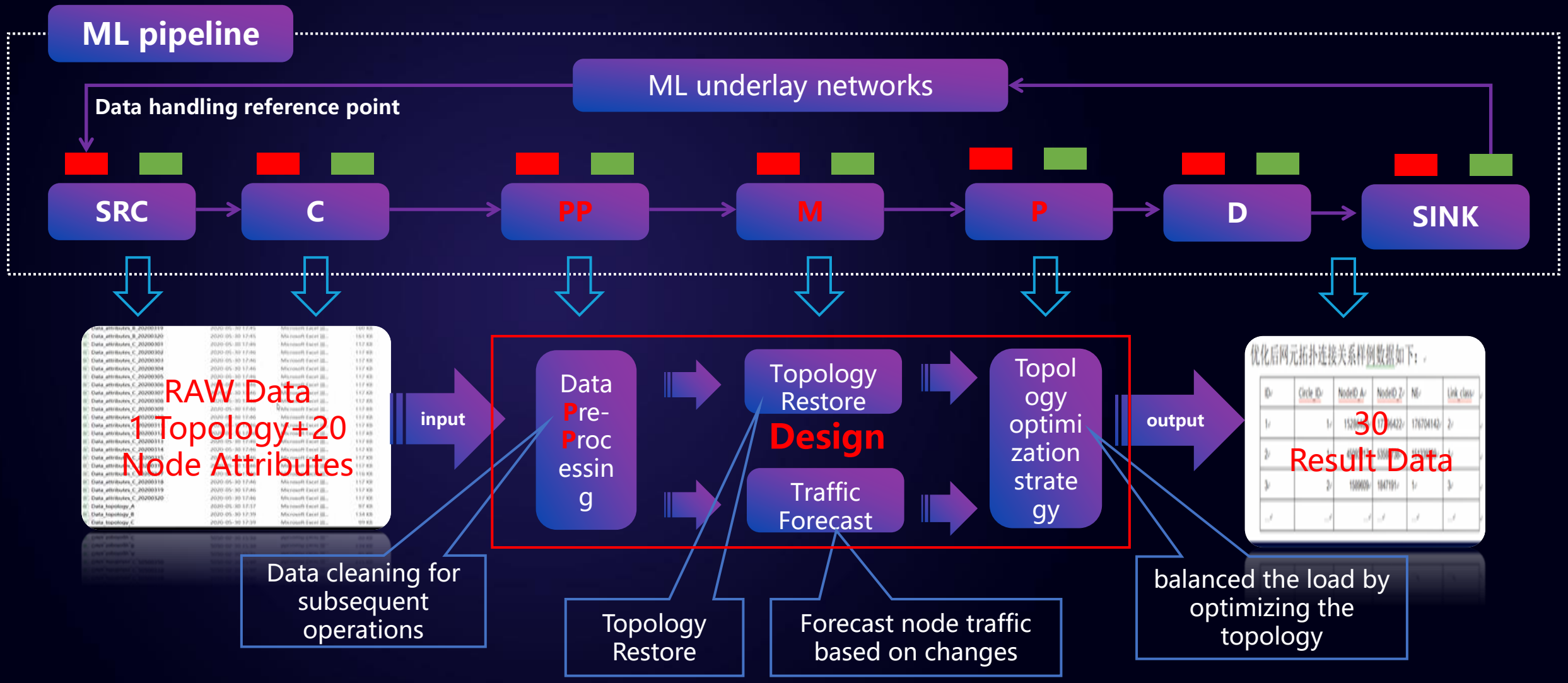
Adopt

Development——Architecture Design

The design result mainly includes three parts: preprocessing, model and strategy.

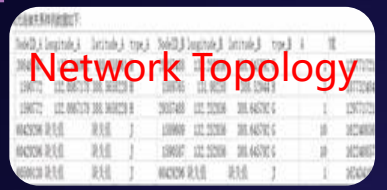


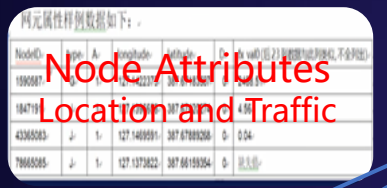
Development——Achievement Exhibition

Preprocessing, model and strategy, with unique advantages.

Provided Data

RAW Data
Topology
+
20 Node
Attributes





Python+pandas+Tensorflow

Data pre-processing

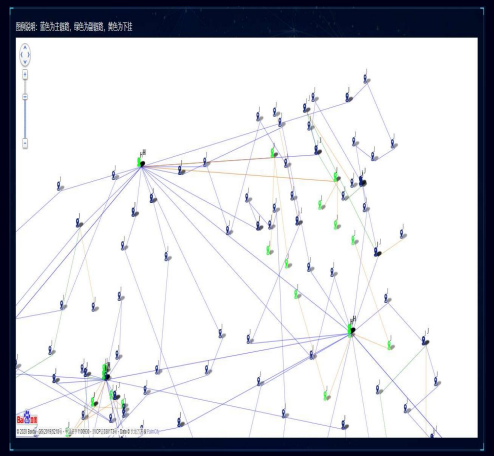
Topology Restore

Design

Traffic Forecast

Topology optimization strategy

Topology diagram by Qunee



1、Adopt adjacency matrix to store node connection relations
2、Use pandas to fill in missing traffic data
3、 Mark nodes with missing latitude and longitude

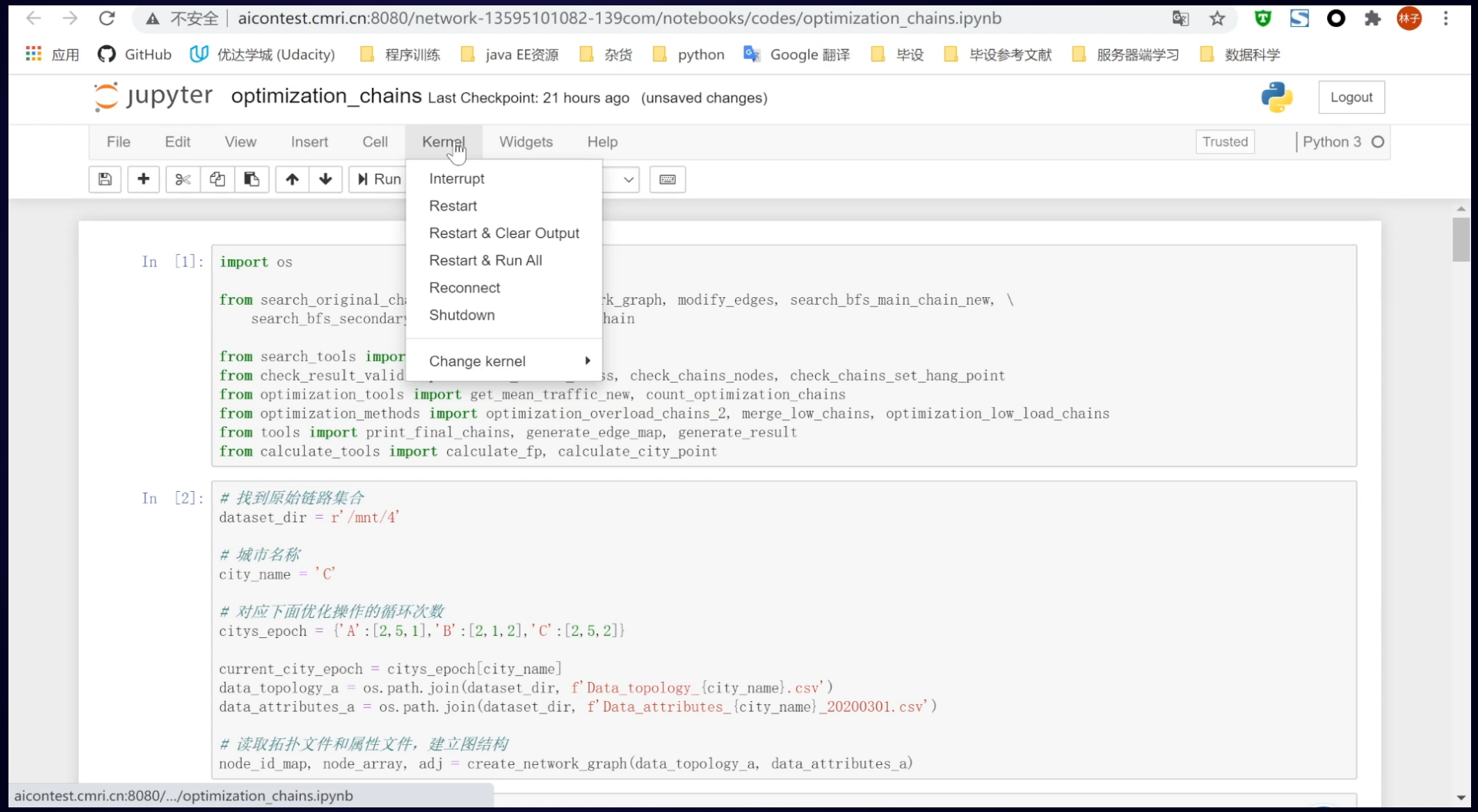
1、Adopt adjacency matrix to query node connection relationship for higher efficiency
2、Use BFS to search topology for faster searching speed
Innovation:
The BFS search node can be accessed repeatedly to adapt the search of the link set

Modeling with LSTM
Innovation:
1、Model each node and make predictions separately
2、 Each neuron carries 24 traffic data

1、optimize overloaded links
2、optimize low-load links
3、 aggregate low-load links
Innovation:
Aggregate low-load links with the same head and tail nodes

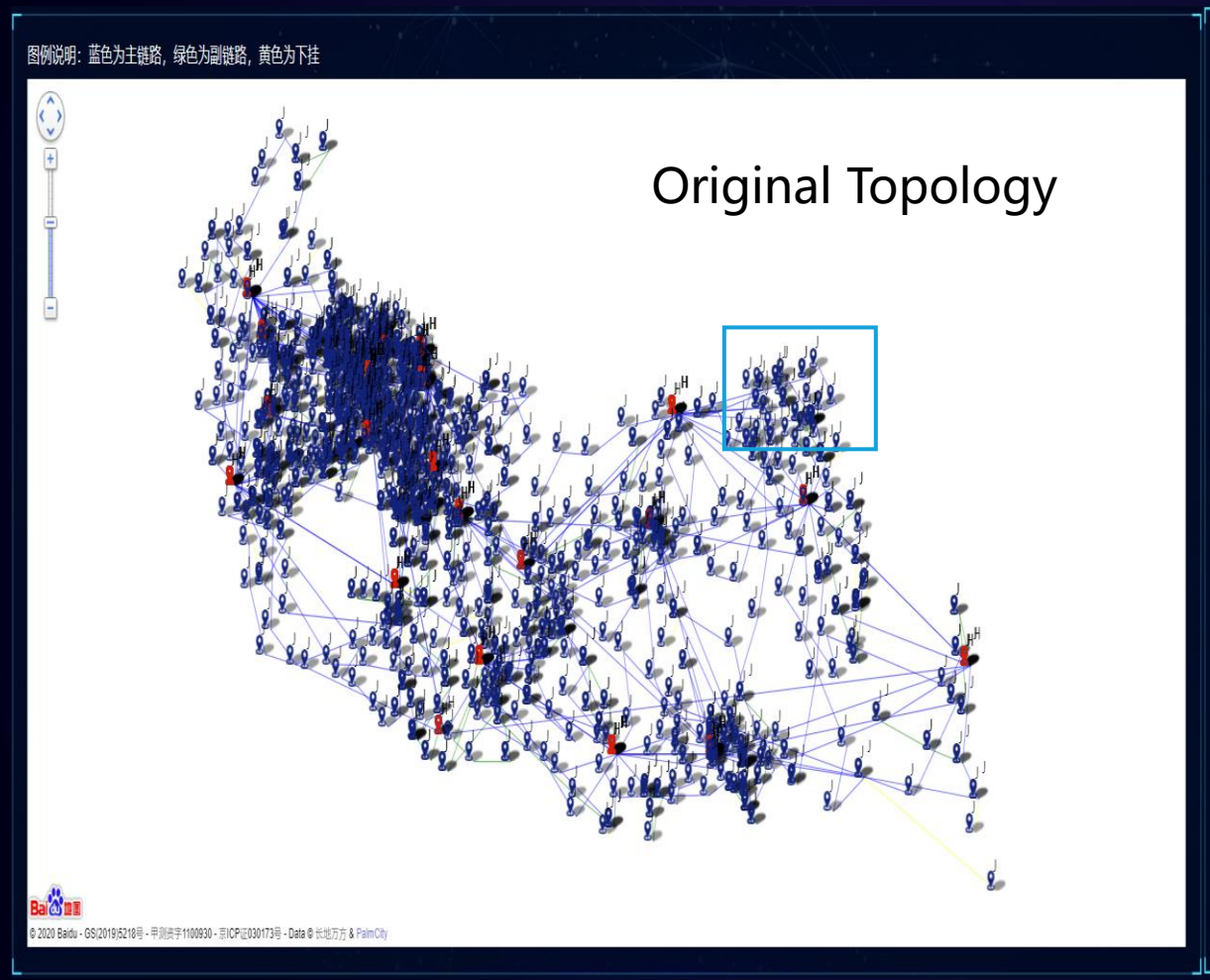
Results——Video Demo

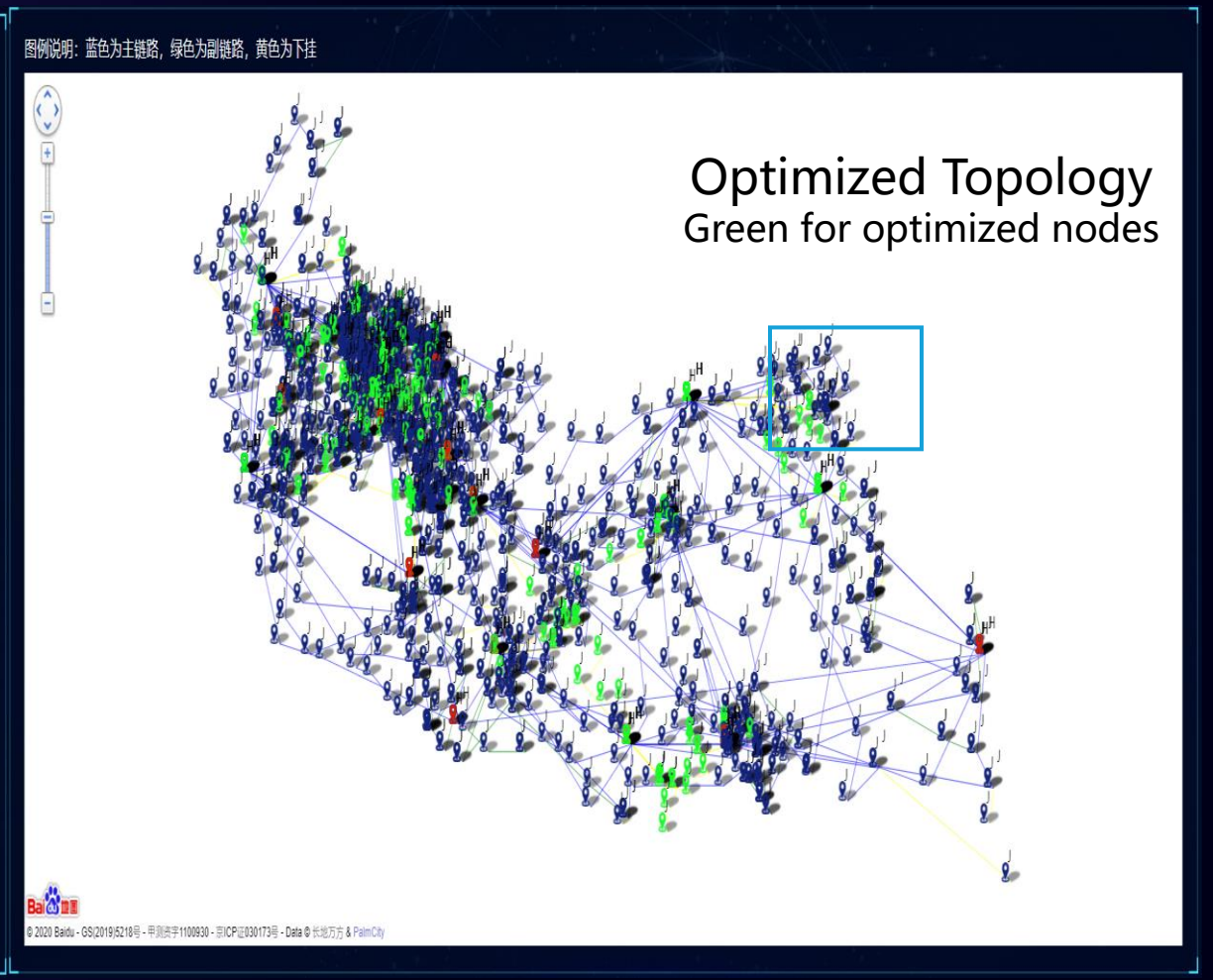
A video demo for our project.



Results——Achievement Exhibition

The Algorithm automatically completed the topology optimization plan of City C in 10 minutes and obtained 44.55 points





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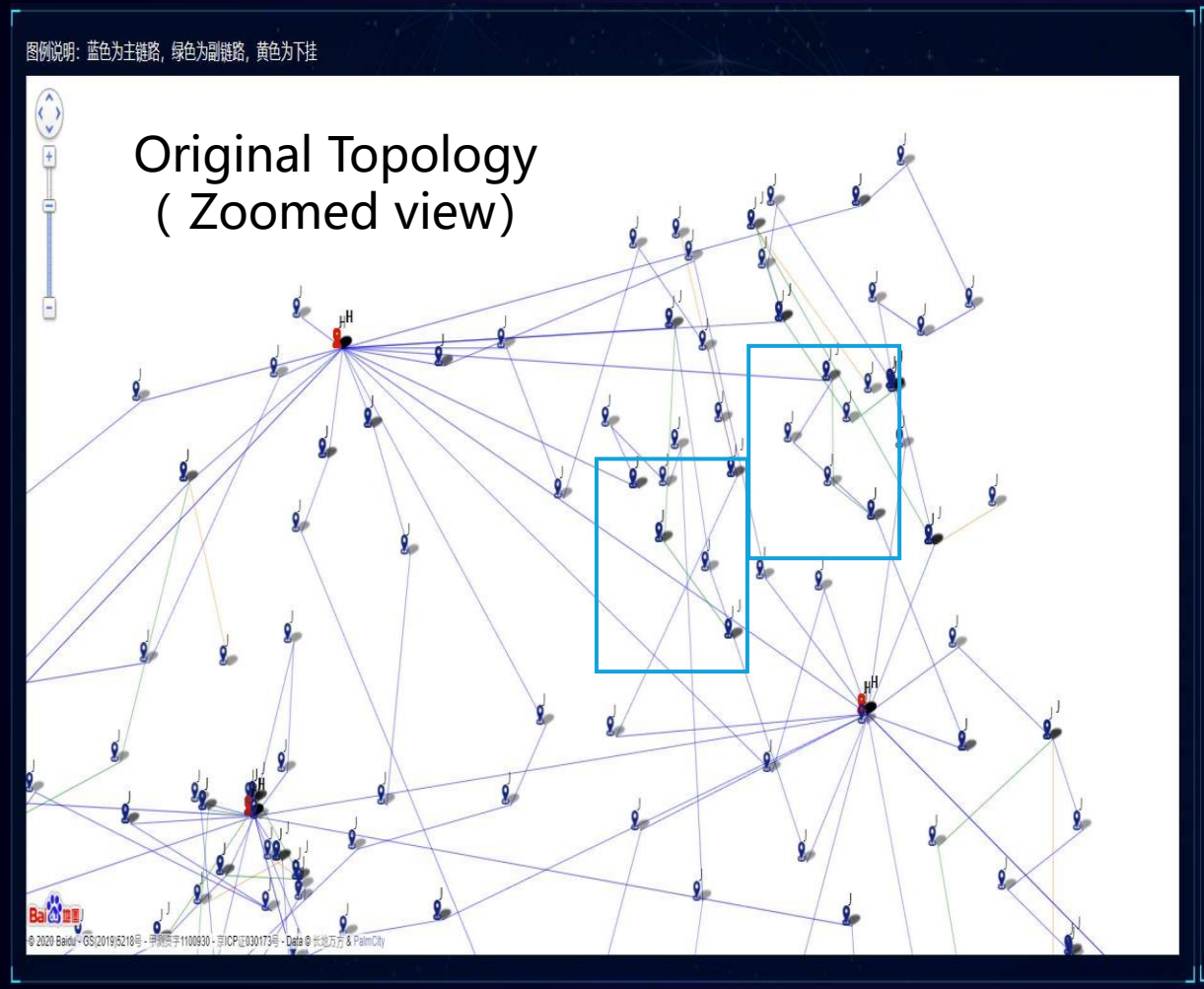

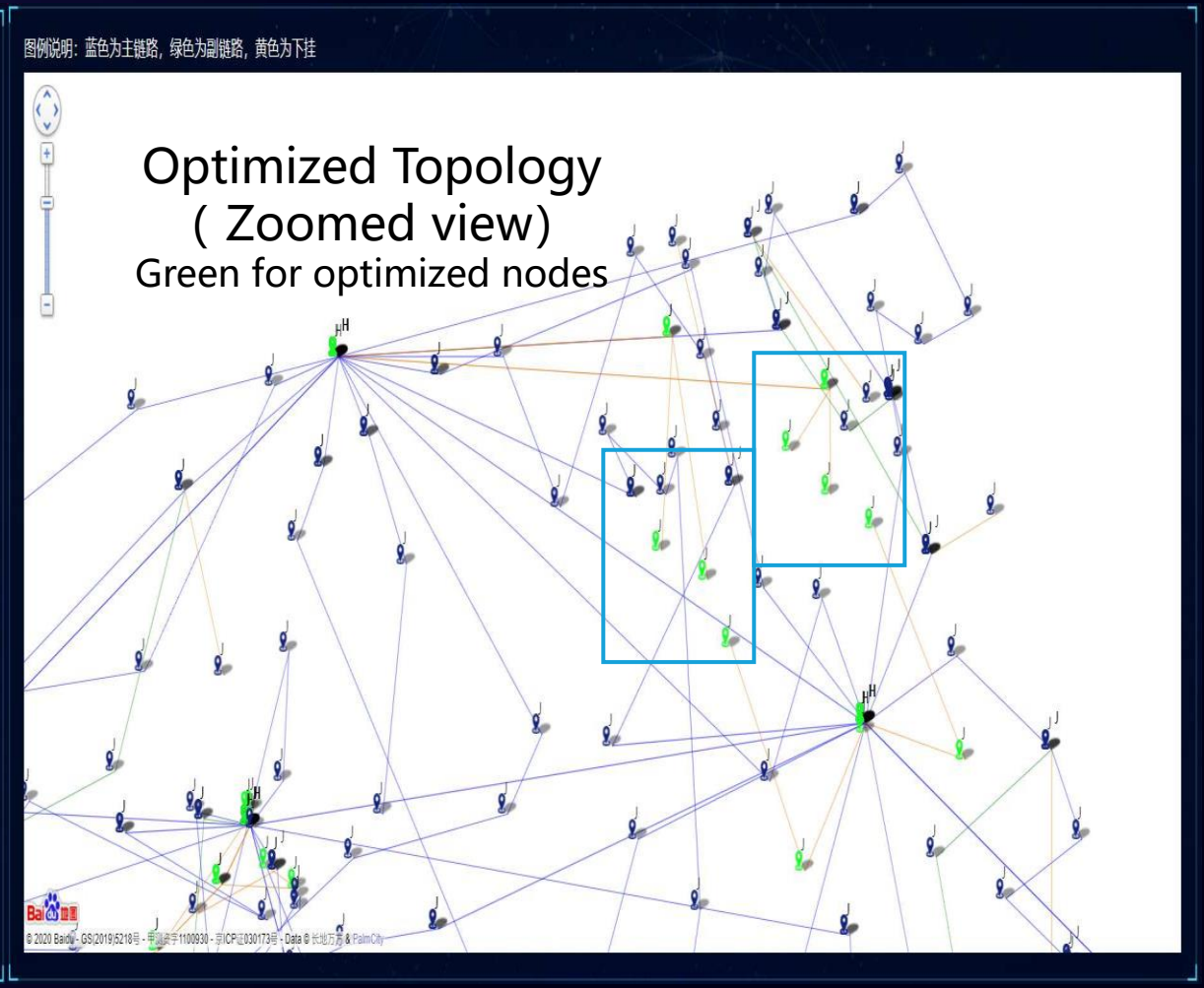

Results——Feedback

In the finals, the host highly affirmed the results and awarded us the first prize.

Advantage

1. Many special situations are considered in the traffic forecast, and the thinking is comprehensive。
2. Advantages in topology restoration, and a unique topology optimization strategy has been established.
3. For data preprocessing, adjacency matrix is applied to store the connection relationship for faster query speed. The idea of using the average value to complete the missing data solves the inconsistency between the actual and ideal.
4. Good model generalization, robustness and practicability.
5. Propose an innovative approach suitable for link set search.

Result

Verify the effect through pilot projects and confirm the actual effect of the results

Advice

1. Improve traffic forecast
2. Improve optimization strategy with Genetic algorithm
3. Docker Support for Peripheral features

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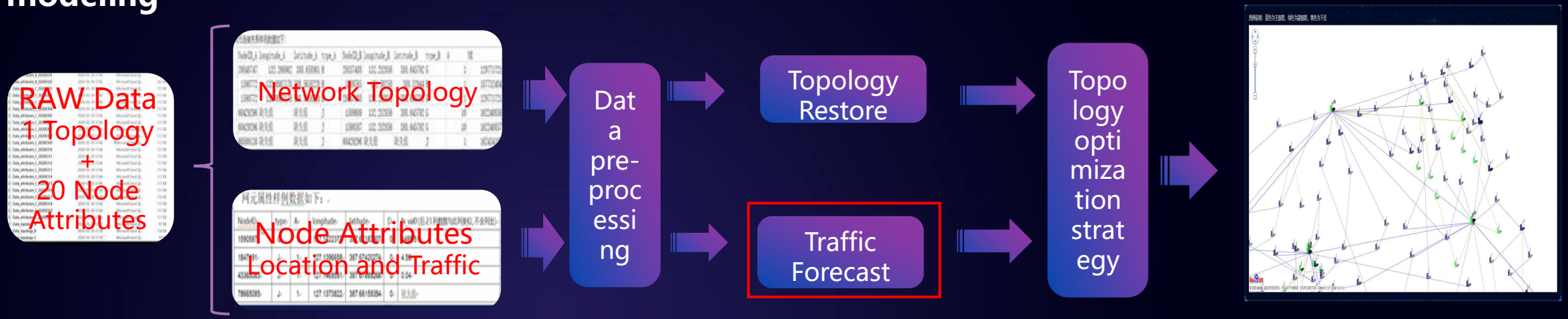
Improvement——Traffic Forecast

Feedback “try to add peripheral features to the traffic forecast and use multi-modal data modeling”



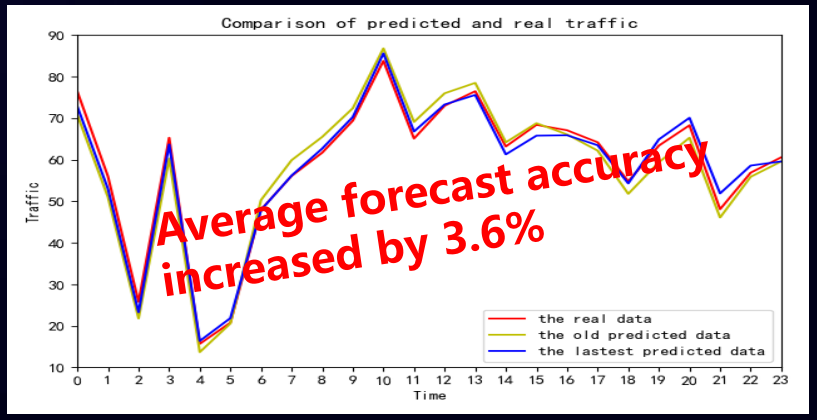
Solution

Three features are added when modeling, considering the influence of surrounding nodes:

1、Add features: add weather, weekends, so that it has characteristics of traffic, weather, and weekends;

2、Add surrounding nodes: It is assumed that nodes within a certain range (500 meters) have an impact on the node traffic of the current link.

Result



Improvement——Optimization Strategy

Feedback “The topology optimization strategy can be improved, and it is recommended to consider the use of genetic algorithm for improvement.”

Solution

The greedy algorithm is used to optimize the topology, and the node is moved based on the highest evaluation index score.

Result

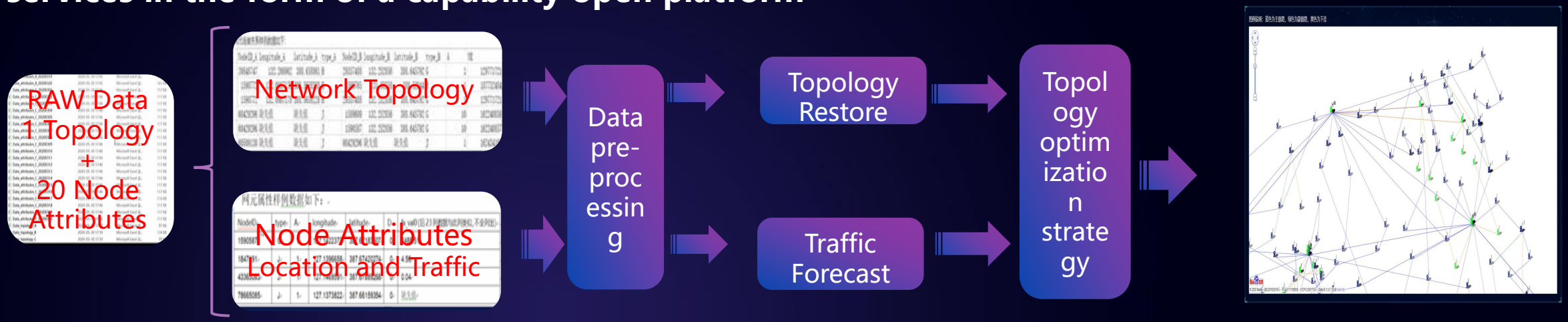
```
print(f'负载链路优化后指标得分为 {calculate_city_point(final_chains, node_array, predict_new_traffic, city_u)}')
链路优化比例均值为0.3616838487972509,负载均衡E值最小值为0.2795108078972847,均值为0.5082392657461345,最大值为0.6575346239310922,副链路和下挂点比例为0.009691560509679942
负载链路优化后指标得分为 -1.0932924092869405
```

The link optimization ratio increased from 0.36 to 0.4

```
print(f'负载链路优化后指标得分为 {calculate_city_point(final_chains, node_array, predict_new_traffic, city_u)}')
链路优化比例均值为0.4042096219931272,负载均衡E值最小值为0.27716028447990976,均值为0.5040147105332035,最大值为0.652556131218271,副链路和下挂点比例为0.009223653128836747
负载链路优化后指标得分为 -1.0387451573670938
```

Improvement——Model encapsulation

Feedback “using Docker for packaging, and referring to ITU specifications to try to provide services in the form of a capability open platform”



Solution

Capability scheduling、Self-healing、Horizontal Expansion and Data Sharing

Web Interface、Virtualization、CI/CD

Result

1. Instantiation time of N nodes = single node time
2. MLFO shortens development time by 70%
3. Data sharing reduces storage consumption by 50%
4. Service self-healing reduces failure to affect business by 80%

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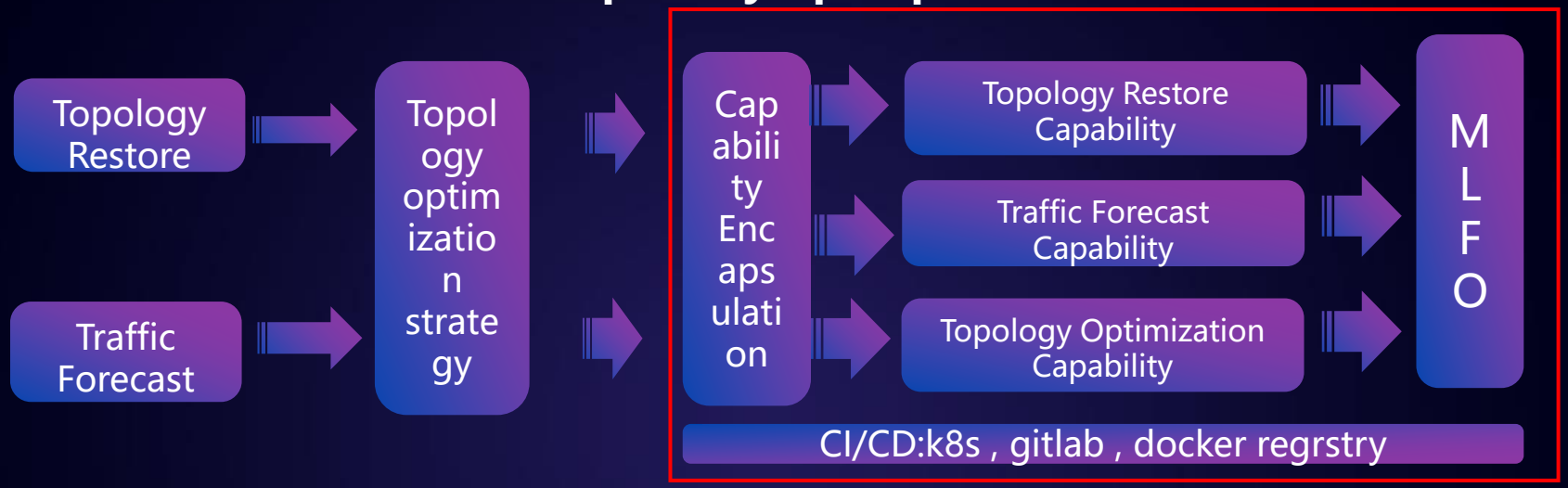

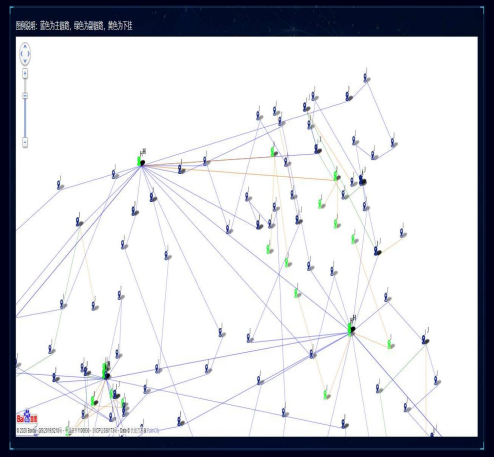

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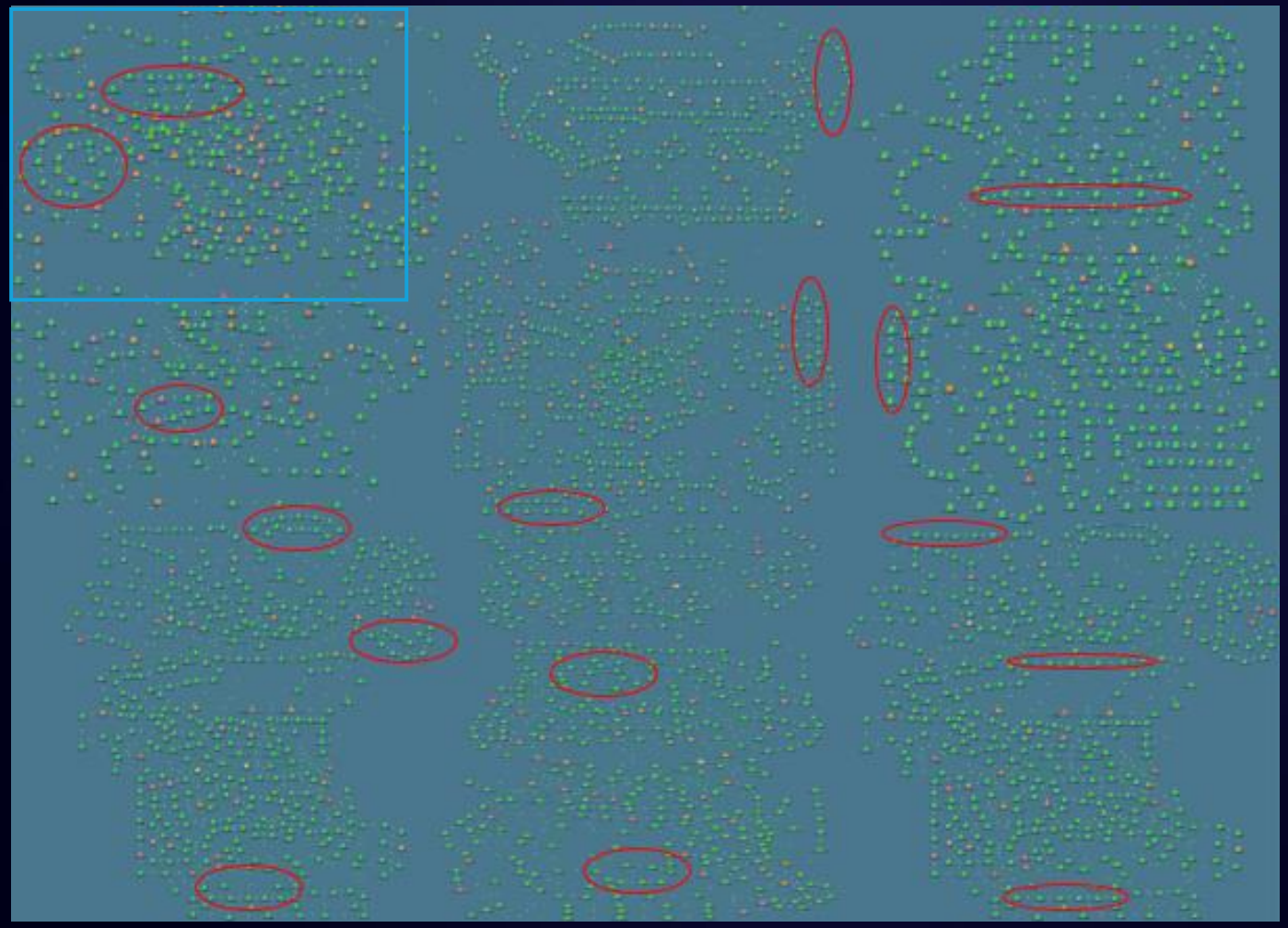
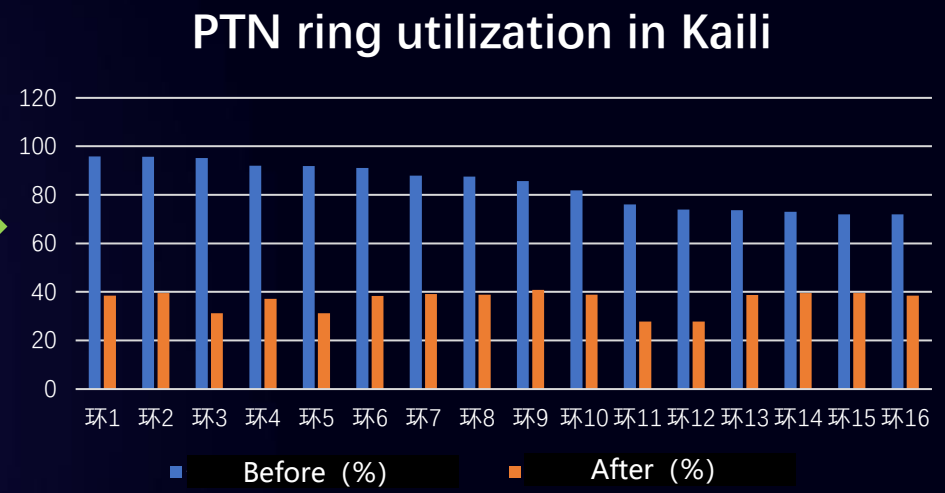
Improvement——Verify in Production

We chose Kaili City for the pilot city. We Solve 16 high-load ring with the help of this technology.

Kaili PTN Network：3191 Nodes，913 Rings



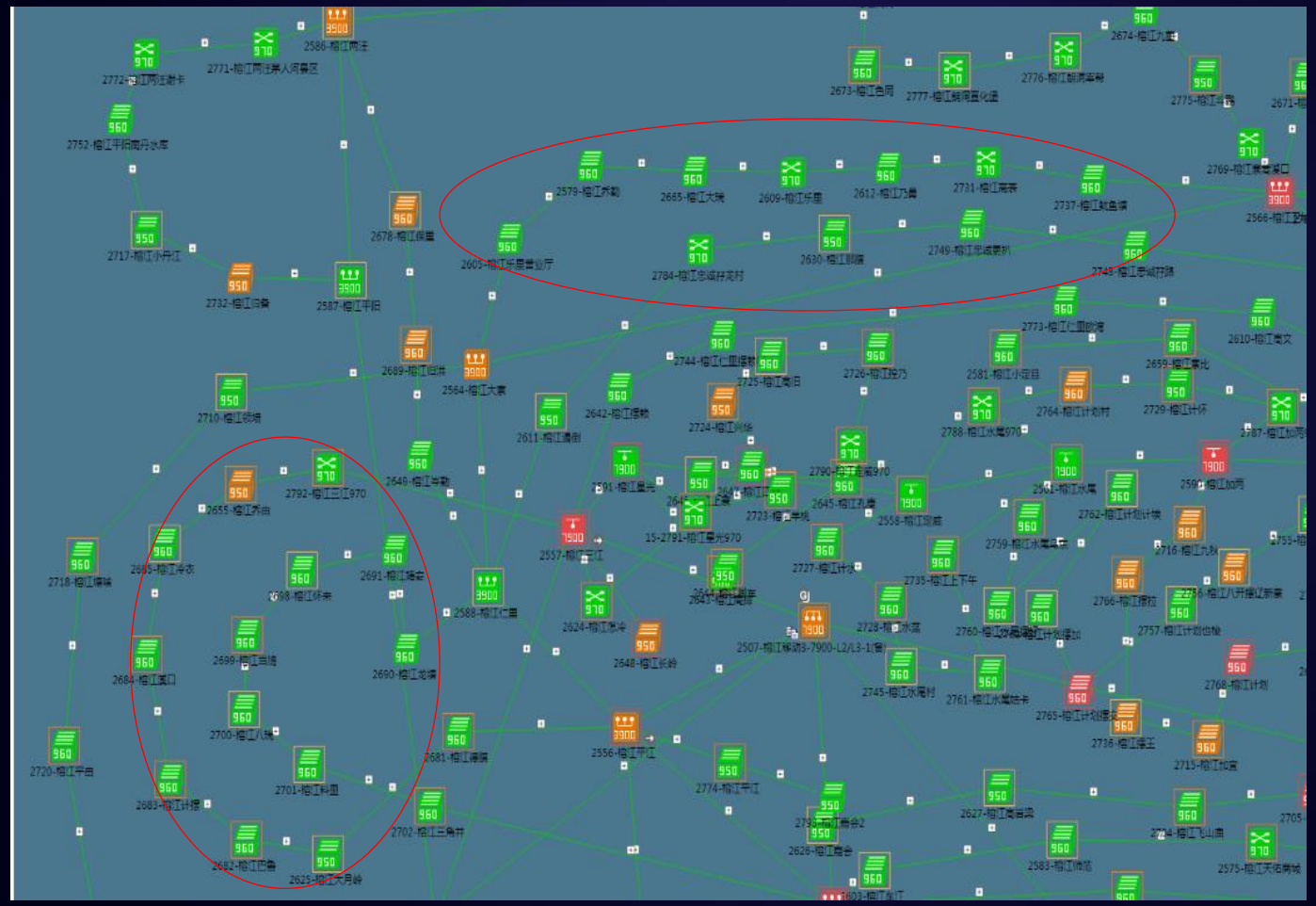


Plan	Traditional Plan	AI Plan
Construction Cost	￥3.05M	￥0.45M
Human Input	21 Man-Day	4 Man-Day
Low-load rings	40	3
Threshold crossing rings	5	0
Capacity (day)	102T	181T

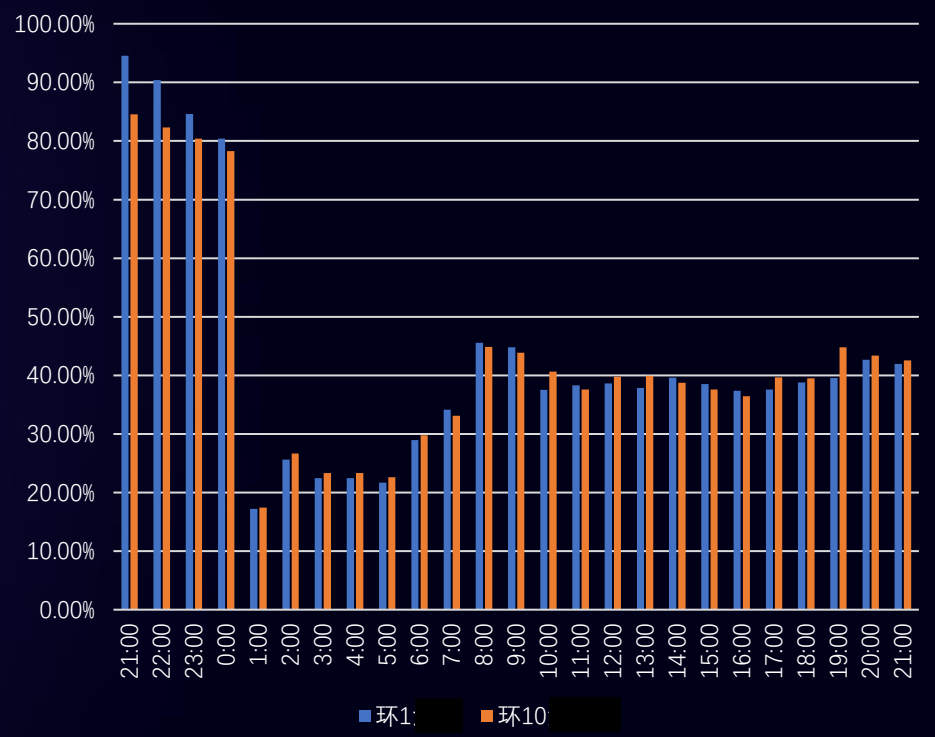
Improvement——Verify in Production

We chose Kaili City for the pilot city. We Solve 16 high-load ring with the help of this technology.

Ring 1 and Ring 10:



Ring 1 and Ring 10 optimization:



Note: 00:00-01:00 is time for optimization

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Outlook——Evaluation

Recommendation ITU-T Y.3173

Future network intelligence level assessment framework including IMT-2020

Network intelligence level	Dimensions				
	Action implementation	Data collection	Analysis	Decision	Demand mapping
L0	Human	Human	Human	Human	Human
L1	H&S	H&S	Human	Human	Human
L2	System	H&S	H&S	Human	Human
L3	System	System	H&S	H&S	Human
L4	System	System	System	System	H&S
L5	System	System	System	System	System

Basis of Evaluation： Y.3173 P12，Table 7-1

Demand mapping：
- Demand mappings are done by human, so the rating is Human.

Decision：
- The topology optimization scheme given by the system needs people to evaluate and verify, and then decide whether to implement it, so the rating is H&S.

Analysis：
- Data analysis requires people to choose specific analysis algorithms and analysis rules, and cannot be automatically selected and constructed by the system, so the rating is H&S.

Data collection：
- Data collection requires people to define fields and collection rules, and then the system automatically collects them, so the rating is H&S.

Action implementation：
- Transmission topology optimization involves optical cable splicing. In the case of link disconnection, it can be realized through system use cases. In the case of link establishment, it is a manual operation, so it is rated as H&S.

Dimensions					Overall network intelligence level
Action implementation	Data collection	Analysis	Decision	Demand mapping	
Human	Human&System	Human&System	Human&System	Human&System	
L1	L2	L3	L3	L3	L1

Outlook——5G、Ecosphere 、AItoB

5G

The combination of communication maintenance and AI can accelerate the promotion of complex 5G network.

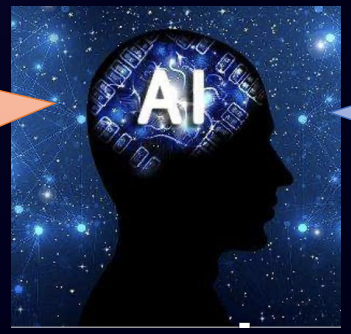
Ecosphere

In CMCC, an ecosystem of people + platform + standards has been formed.

AItoB

This study will provide an example for the AItoB model.

AItoC:
To meet people’ s needs and meet people’ s living and working habits.



AItoB:
To meet enterprises' needs with corporate standards and processes.

END

Thanks