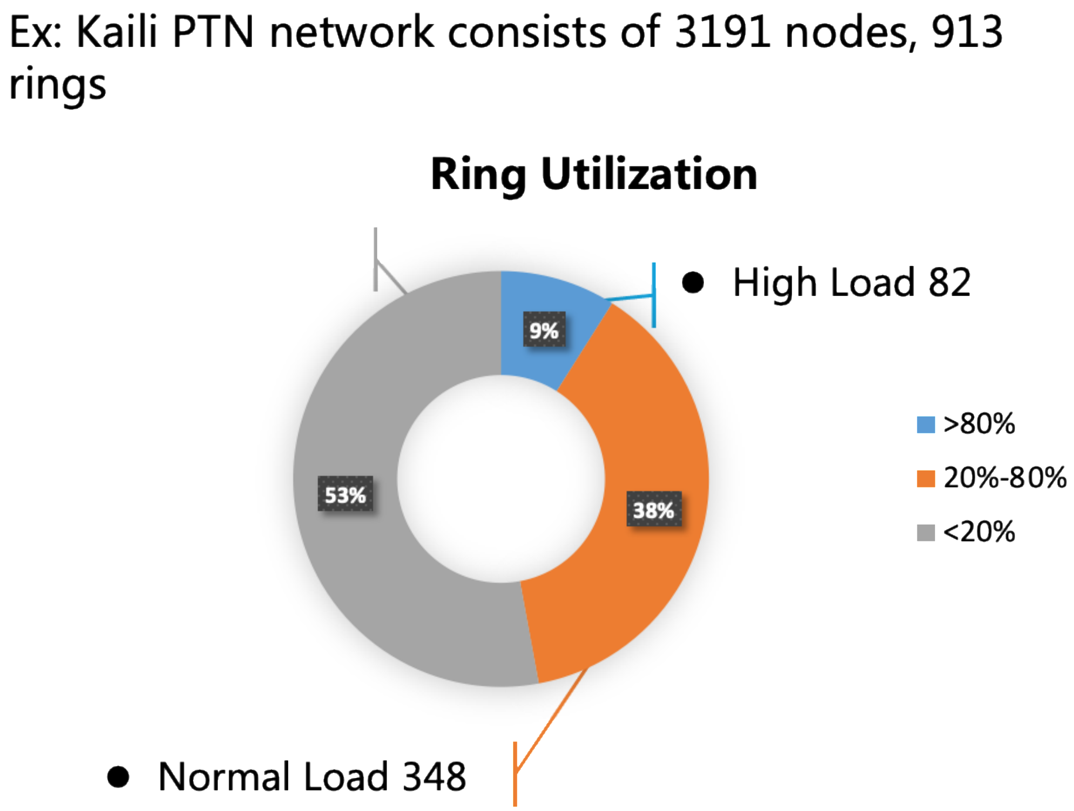
Report for transmission net topology optimization

Team: No Boundaries

A. Background

Transmission network is the vessel of network. 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.

Take the Kaili PTN network as an example. Among the 913 links in the entire network, 82 are high-load links, accounting for 9%, and the highest proportion is low-load links, reaching 53%. Faced with such a low utilization, operations staff needs to optimize the network topology.



However, the topology is composed of transmission nodes, possible topologies can be calculated with the nodes and links.

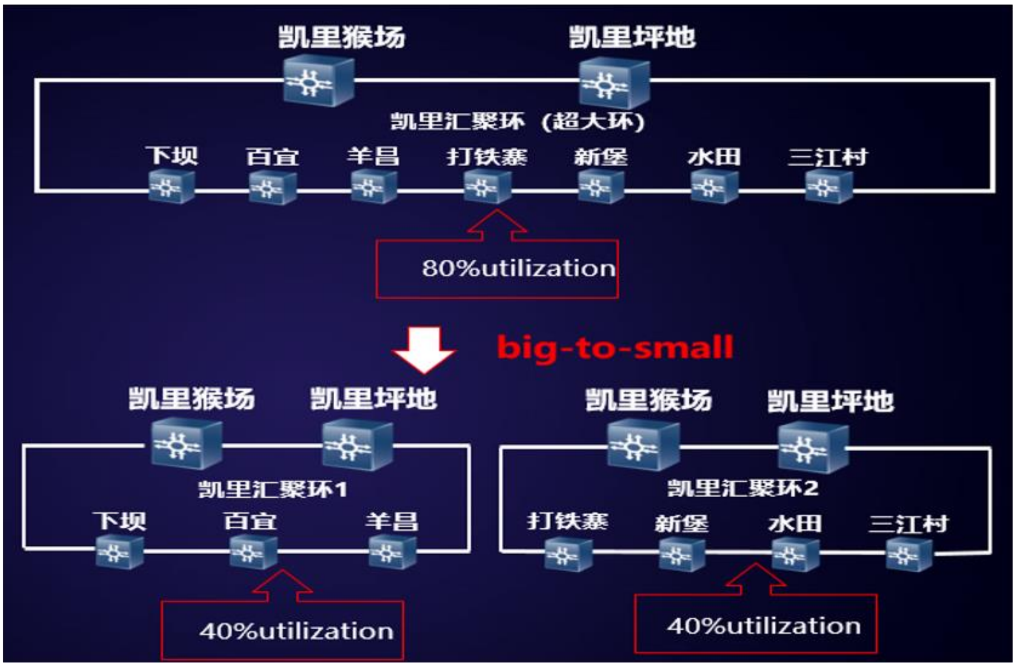
Possible Topologies=Nodes*Links

When the network is simple, you can rely on the experience of experts for analysis. However, as the network becomes increasingly complex, it is no longer possible to achieve comprehensive optimization by relying on manual labor. Taking Kaili as an example, the possibility of all topologies exceeds 2.9 million, which is far beyond the scope of human analysis.

The first solution is Local (Ring) Adjustment, Targeted "big-to-small" optimization for some links, reducing the number of nodes and load. Another is to Increase the bandwidth of the link by upgrading hardware, and reduce link utilization which cause imbalance of transmission nodes.

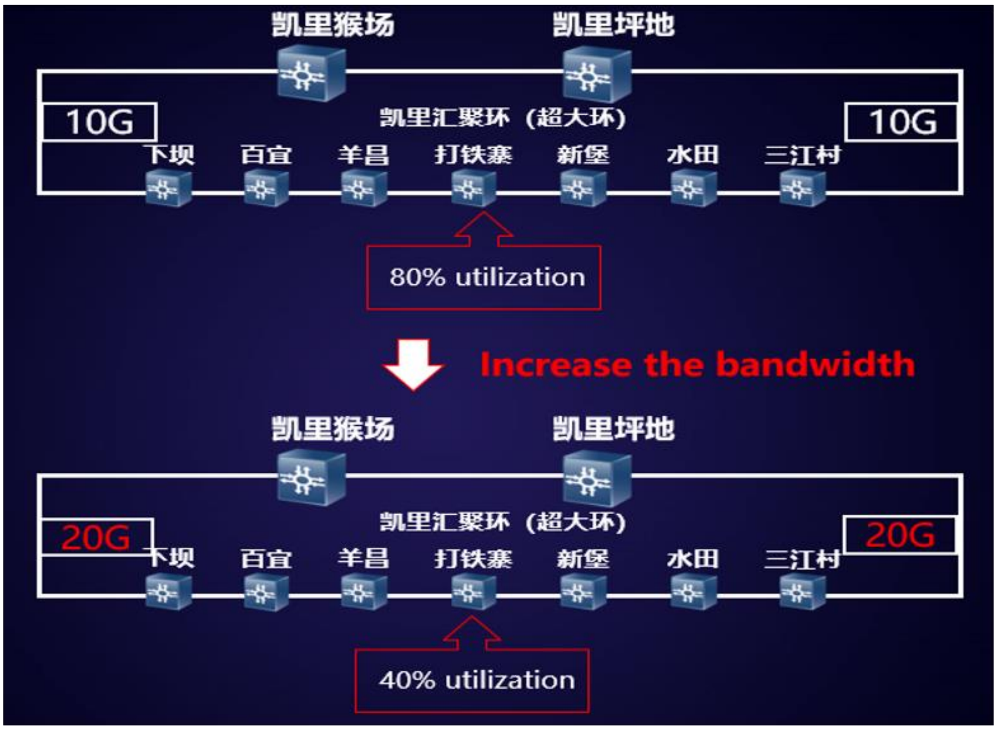
Solution1:Local (Ring) Adjustment

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.



In order to solve this problem more effectively, we have read a lot of literature, but there is no mature solution. SDN technology mainly solves the problems of delay and local optimization. The wireless device is the network end-point, which is different from the nature of the transmission network. The number of nodes in the data center and Internet scenarios is far less than that of the transmission network and cannot be applied.

Although we have not found a mature solution, we have learned that we can use ML instead of humans for topology optimization.

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》

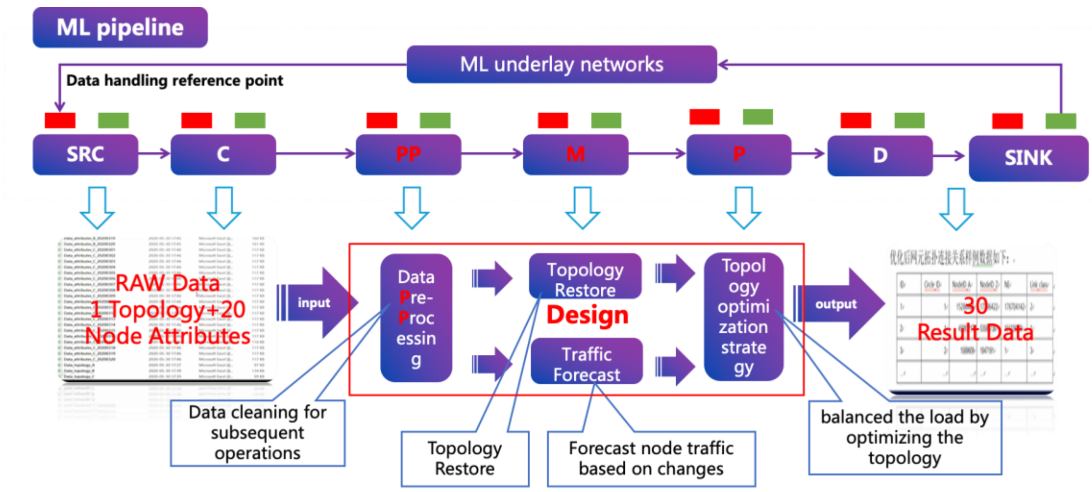
Internet

1. 《DeepWalk: Online Learning of Social Representations》

B. Solution

The data for this competition all come from the actual network, using the connection relationship of 2000 nodes, the latitude and longitude, and the traffic in the past 20 days to optimize network topology for the next 10 days based on the rules. The machine learning architecture framework in the future network mainly contains three components, ML sandbox system, ML pipeline subsystem and Management subsystem. Through analysis, we believe that the ML pipeline subsystem meets the needs of this competition.

The ML pipeline subsystem consists of 7 parts, but the data has been provided for this competition, and the optimization results are given in the form of a table. Therefore, SRC, C, D, and SINK are not designed in the development of the competition results. It mainly consists of three parts: PP, M, and P. The preprocessing of data cleaning according to analysis needs, the restoration of the topology according to the connection relationship, the two models of predicting future traffic according to the past traffic, and the optimization of the topology according to optimization rules and predicted traffic Strategy.



In order to achieve better results, we chose the mainstream technology in the industry.

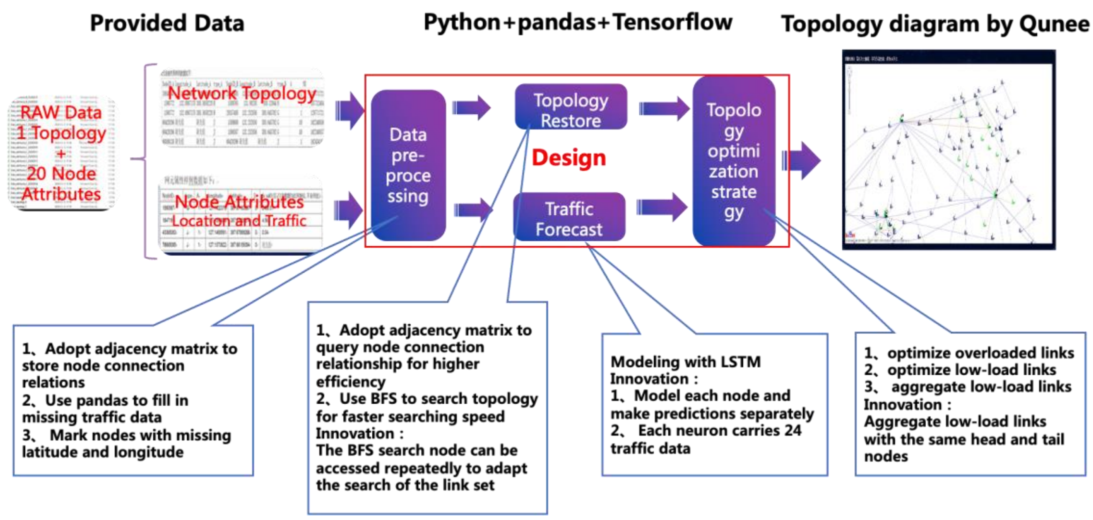
In preprocessing, the adjacency matrix is used to store node connection relationships, and pandas is used to fill in missing traffic data.

In the topology restoration model, the adjacency matrix is used to query the connection relationship of nodes, which has high query efficiency.

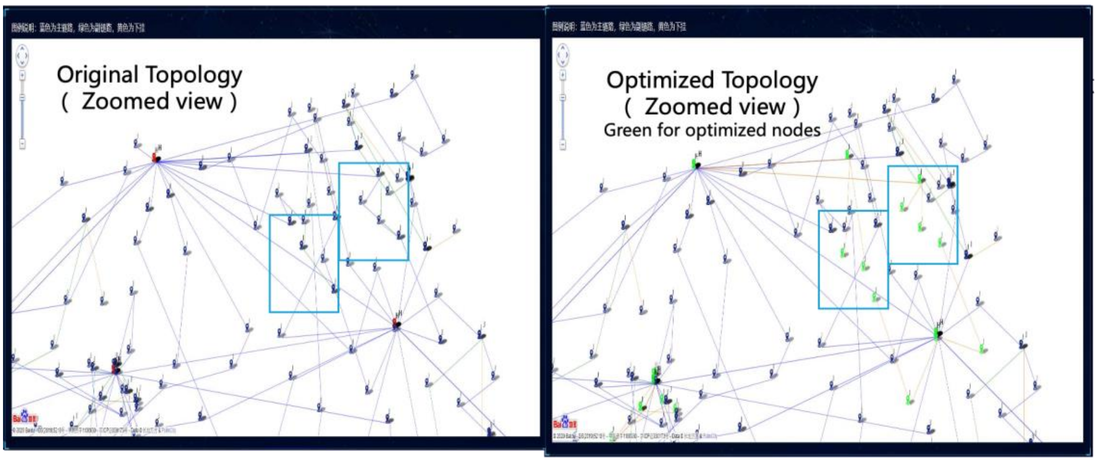
The BFS search topology is adopted, the search efficiency is fast, and the BFS is modified to allow repeated access when searching for nodes.

We use LSTM to build a traffic prediction model, each node has its own prediction model, and the number of neurons carrying traffic information is increased from 1 to 24 to improve the accuracy of prediction.

In terms of optimization strategy, we adopted a three-step optimization strategy of first optimizing overloaded links, then optimizing low-load links, and finally aggregate low-load links, and realized the selection of low-load links with the same head and tail nodes for aggregation.



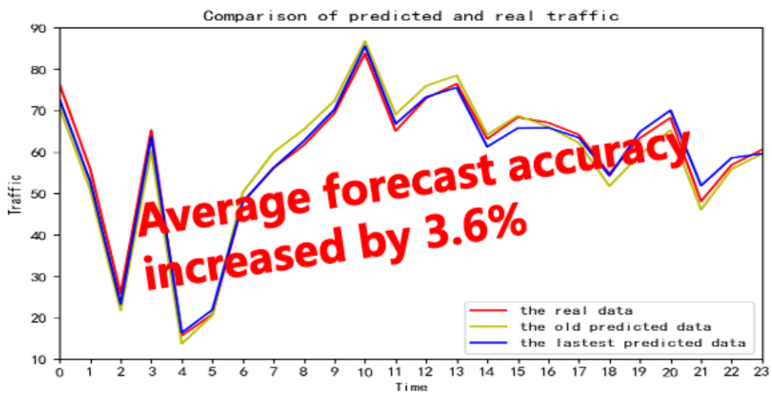
Through this technology, the algorithm only needs 10 minutes to complete the topology optimization solution and obtain an evaluation score of 44.55. The left picture below is the original topology of City C, and the right picture is the optimized topology. The green color indicates the adjusted node.



In the final defense, the 6 judges all gave high evaluations and some suggestions, and the results won the first prize in the final. We integrated the judges' suggestions into 4 points, improved the optimization algorithm, added peripheral features to improve the traffic prediction model, used docker technology to package and promote it quickly, and then put it into actual production to verify the effect.

Result

a) Based on 4 suggestions from the judges, we improved our results. For the traffic prediction model, we added two types of features: time and space. In terms of time, we added two features of the day’s weather and weekends, and spatially added adjacent traffic at a certain distance as features. The final prediction increased by 3.6%.

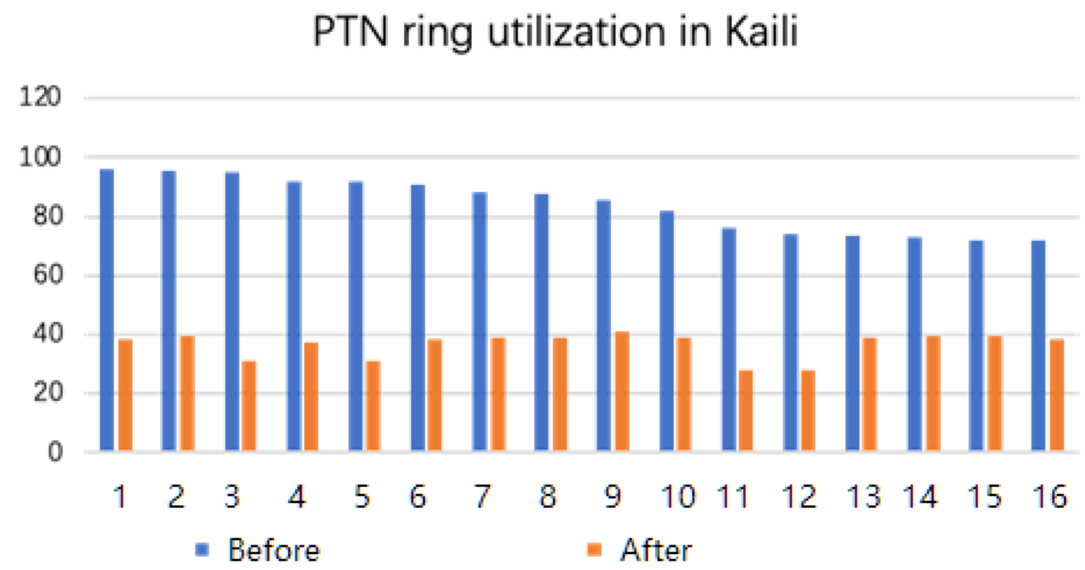


b) For the optimization strategy, we introduced a greedy algorithm, based on the highest evaluation index score as a criterion, to evaluate the priority of node movement and finally select the best solution, the link optimization ratio increased by 0.4.

c) In order to meet the requirements of rapid replication and promotion, we use kubernetes and docker technology to encapsulate capabilities according to ITU specifications. According to the test, MLFO can shorten development time by 70%, reduce storage consumption by 50% for data sharing, and realize service self-healing when failure occurs. It can reduce the impact duration by 80%.

C. Result

We introduced the results into Kaili City, with 913 chains composed of 3191 network elements, and an AI optimization solution that restores 16 high-load rings to normal load.



Our AI plan reduces construction cost by 2.6 Million RMB, human input by 17 Man-Day, capacity by 79T.

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

Our results are evaluated in accordance with ITU specifications. Analysis, Decision, and Demand mapping reach L3, and Data collection reach L2. Due to the need for manual deployment of new links in transmission topology optimization, Action implementation only reaches L1 while there is a lot of room for improvement.

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

Finally, we believe that the results of this time have positive significance in three aspects:

a) The communication network before 5G mainly communicates between people, and the three typical scenarios in the 5G standard reflect that 5G has increased the communication between people and things, and things and things. Therefore, the complexity of 5G networks will far exceed the previous networks. The results of this combination of communication operation and maintenance and AI can greatly reduce the operation and maintenance costs of 5G networks and accelerate the promotion of 5G.

b) In China Mobile, an intelligent operation and maintenance ecosystem of developers + platform + standards has been formed. After operators have screened and promoted, an ever-growing ecosystem has been formed. Relying on this ecosystem, China Mobile has incubated many intelligent operation and maintenance achievements, supporting the rapid and large-scale construction and use of China Mobile's 5G network, and realizing efficient operation and maintenance of complex networks.

c) Most of the current AI development is the toC mode that focuses on serving users, based on user needs, and conforms to users' living habits. Based on the ITU specifications, this project has achieved the integration of the communications industry and AI. This is an exploration of the toB model of AI development serving the industry. It is developed based on industry needs and meets industry development specifications. This research will provide an example of AItoB model.