Nankai University

Predicting the Impact of Parameter Adjustments on Cellular Networks

Yongqian Sun[1], Qingliang Zhang[1], Yu Luo[1], Mingjie Li[2*], Shenglin Zhang[1], Xiaolei Hua[2], Renkai Yu[2], Xinwen Fan[2], Lin Zhu[2], Junlan Feng[2], Dan Pei[3]

[1]Nankai University [2]China Mobile Research Institute [3]Tsinghua University

中国移动
China Mobile

Content

Background

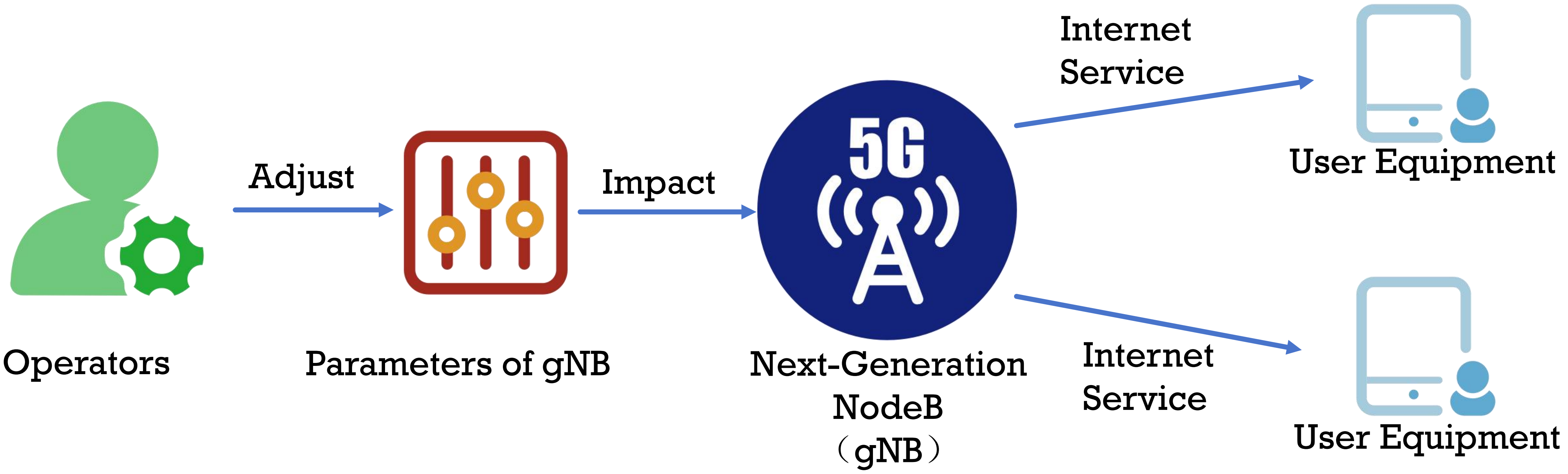
Challenges

Approach

Evaluation

Conclusion

Ensuring 5G Service Quality for Better User Experience

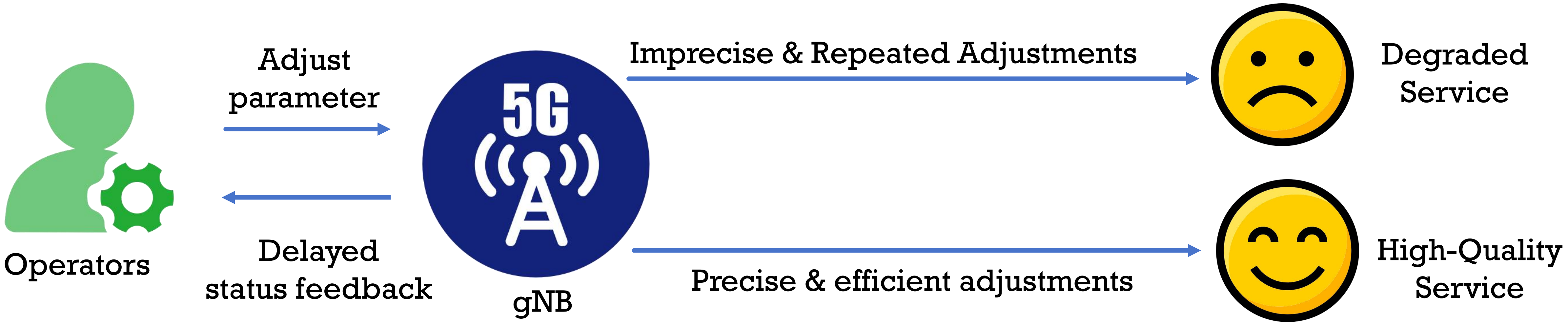


- Cellular networks are the backbone of internet access
- The gNBs provide connectivity to user equipments
- Operators typically adjust gNB parameters to optimize network performance
- Network stability and service quality are essential

Key Parameters and Cell Status Metrics

- Key Parameters:
  - Transmission Power (TP): TP controls the received signal strength
  - Cell Individual Offset (CIO): CIO controls handovers and achieve proper load balancing
- Key Cell Status Metrics:
  - Workload: The number and behaviors of served UEs
  - Quality of Service(Qos) : Quality of Service measurements
  - Interference : The strength of irrelevant electromagnetic waves

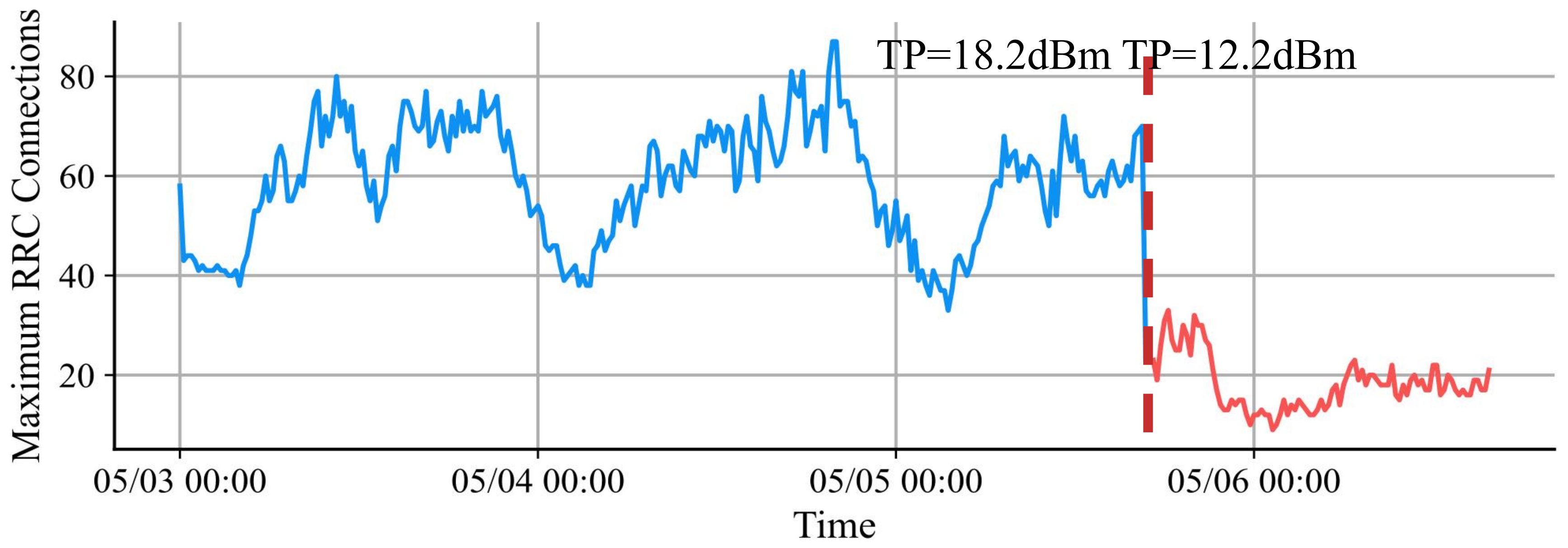
Adjusting GNB Parameters to Optimize Performance



- Correct gNB parameter adjustments are vital for user experience
- Status feedback can be delayed by hours
- Imprecise adjustments slow optimization and harm user experience

Problem Statement

南開大學 Nankai University



Example of a cell parameter adjustment

Our goal is to develop a method that can
model the effects of parameter adjustments before they are applied,
enabling proactive and accurate network performance predictions

Content

Background

Challenges

Approach

Evaluation

Conclusion

Limited Data for Parameter Adjustments

Nankai University

- Challenge 1: Limited data for parameter adjustments
  - Limited historical data hinders learning generalizable impact patterns
  - Even TP and CIO yield over 18,000 combinations, far beyond available data
  - This vast space far exceeds availabledata coverage
- Challenge 2: Complex, dynamic dependencies among multiple metrics
  - Modeling metric dependencies under cell parameter adjustments is challenging
  - 17 key metrics from China Mobile, grouped into 3 clusters
  - Dependencies are dynamic, nonlinear, and context-sensitive

PIPCell

Predictive framework
that models the effect of cell parameter adjustments
on key metrics

Content

Background

Challenges

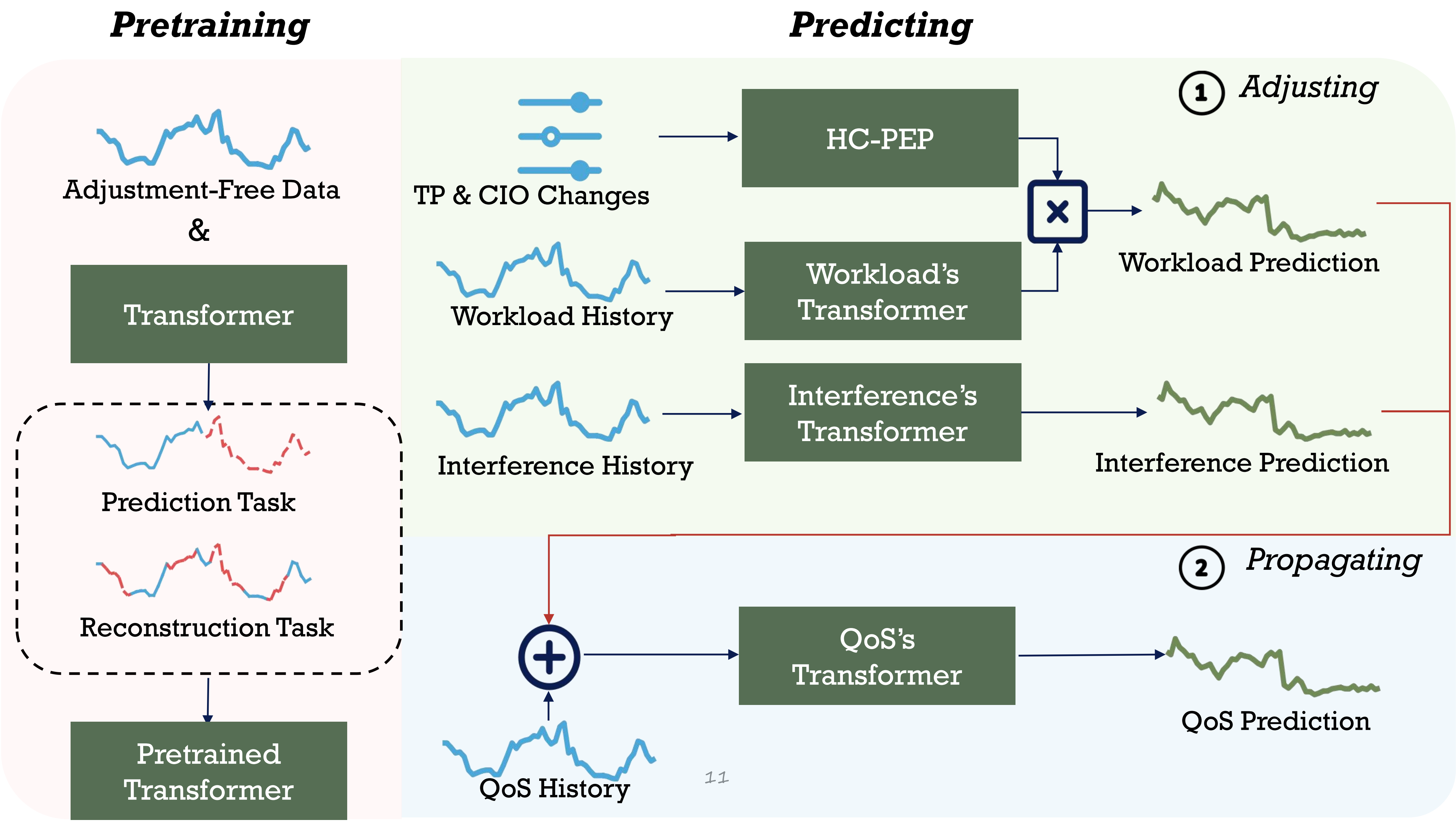
Approach

Evaluation

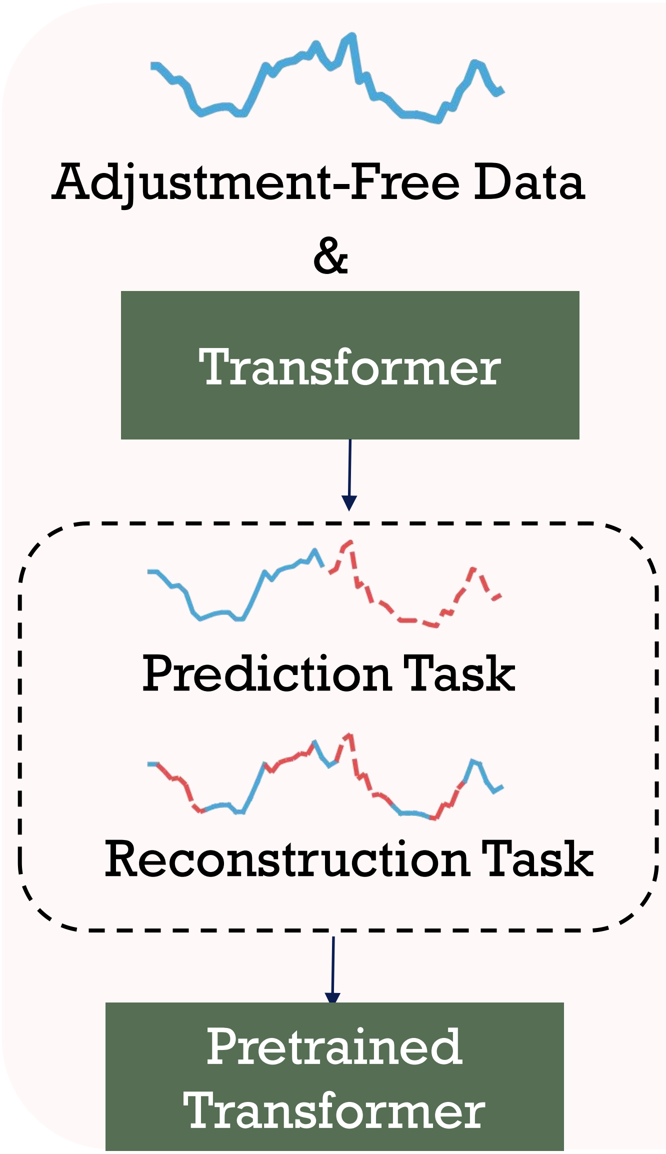
Conclusion

Overview

Nankai University



Pretraining



Transformer Pretraining:

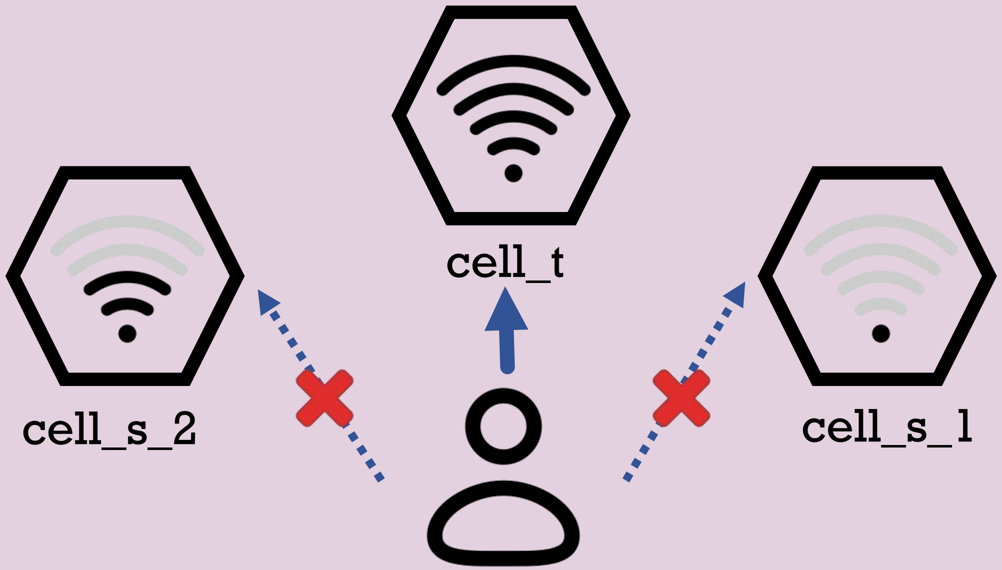
- Handles long-range dependencies in multivariate time series
- Pretrained per metric cluster on adjustment-free data
- Trained with two tasks: forecasting and masked reconstruction
- Loss: average squared error, ignoring missing data

$$loss = \frac{\sum_{i=1}^{N}\sum_{j=1}^{S}\sum_{k=1}^{d}(x_{i,j,k} - \tilde{x}_{i,j,k})^2\omega_{i,j,k}}{\sum_{i=1}^{N}\sum_{j=1}^{S}\sum_{k=1}^{d}\omega_{i,j,k}}$$

N: number of samples
S: sequence length
d: number of metrics
$x_{i,j,k}$ – true value (sample i, timestep j, metric k)
$\tilde{x}_{i,j,k}$ – predicted or reconstructed value
$\omega_{i,j,k}$ – availability mask (1 if valid, 0 if missing)

Homogeneous Cell Modeling

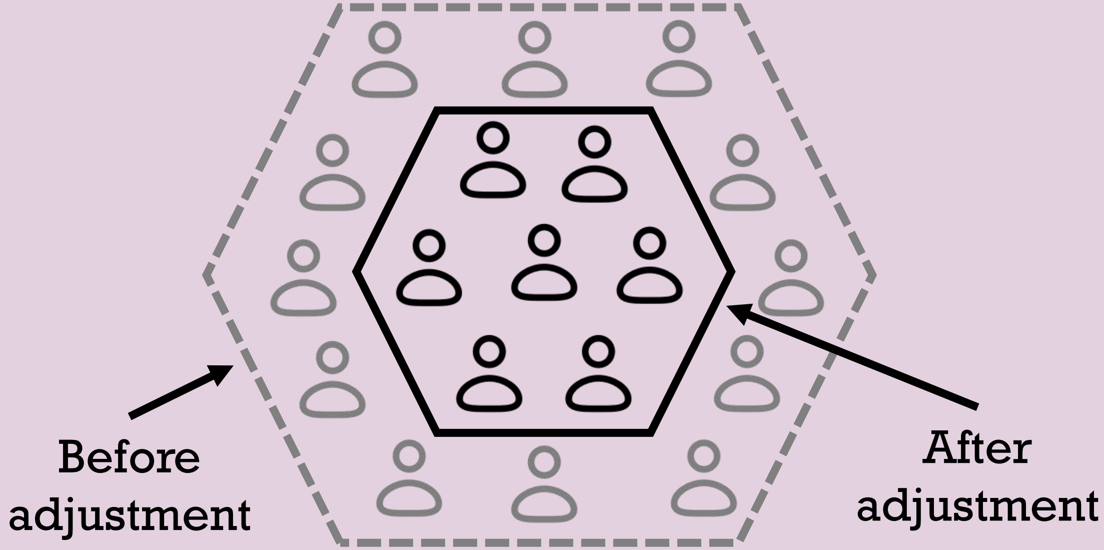
Strongest RSRP+CIO



$$RSRP_t + CIO_{t\rightarrow s} > RSRP_s + CIO_{s\rightarrow t}$$

- Transmission power (TP) directly affects the received signal strength(RSRP)
- Cell Individual Offset (CIO) is used for load balancing
- A User equipment chooses serving cell with strongest weighted signal

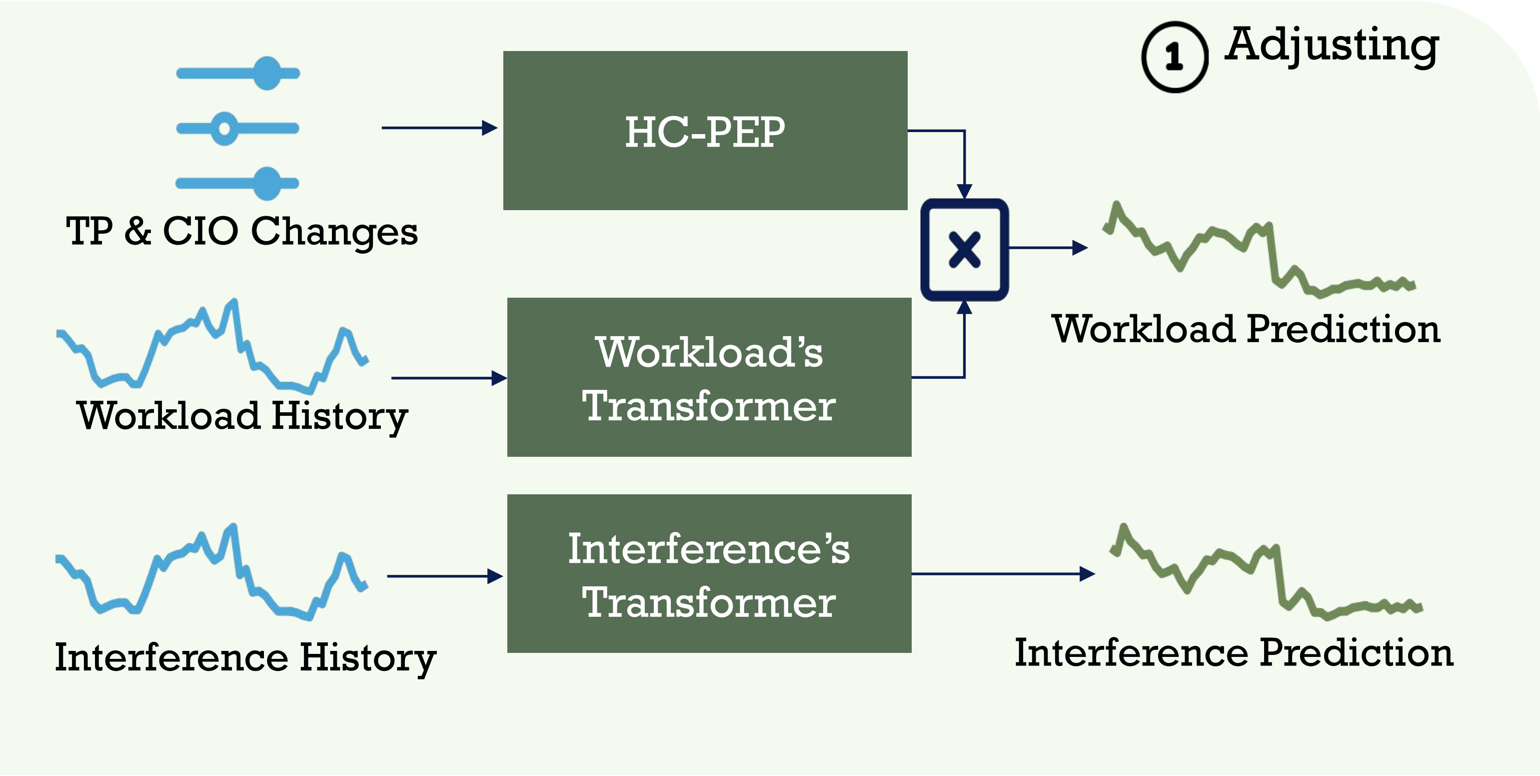
Workload before and after adjustment



(under uniform user density assumption)

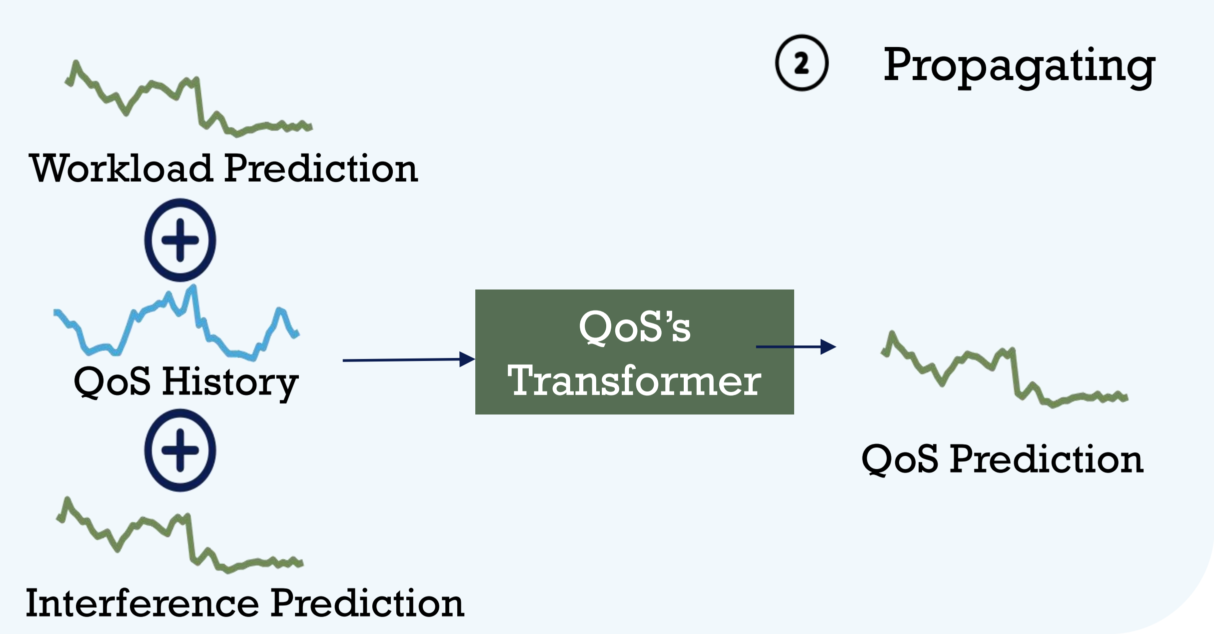
$$\text{Workload}' = \alpha \cdot \text{Workload}$$

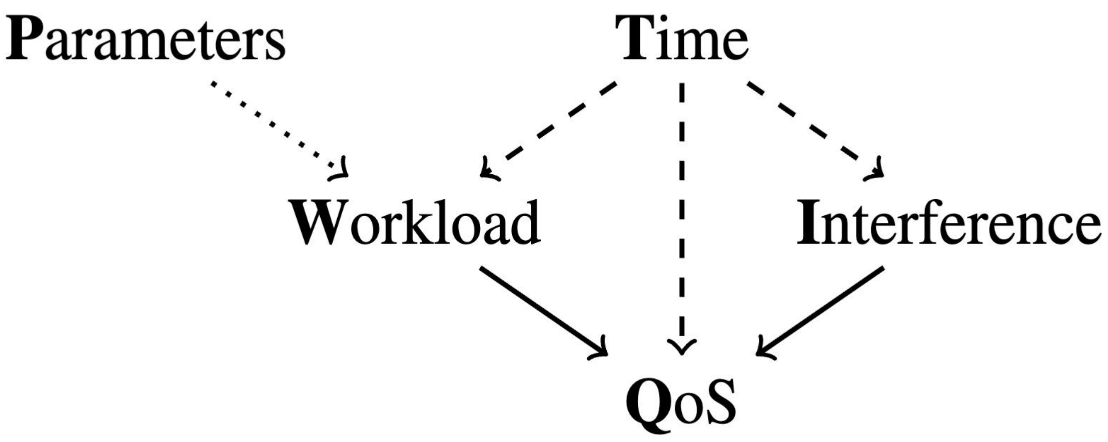
- Assume uniform user density across the cell
- TP and CIO adjustments change the cell coverage area
- Workload change is estimated by the area ratio before and after adjustment



- Transformer predicts workload and interference without parameter adjustments
- Homogeneous Cell Parameter Effect Predictor (HC-PEP) :
  - I ntegrates physical parameter effects (TP&CIO) into workload prediction
  - Acts as a multiplier on Transformer outputs
  - Adjusts workload based on area ratio derived from parameter changes
  - Eliminates the need for additional adjustment data

Propagating





- Parameter changes can indirectly affect multiple metrics, not just workload
- PIPCell arranges multiple Transformers according to a dependency graph
- Each Transformer predicts a metric cluster from its history and parent predictions
- Design captures complex dependencies while avoiding spurious correlations
- Example: interference is treated as independent from workload, enforced by the graph

Content

南開大學
Nankai University

Background

Challenges

Approach

Evaluation

Conclusion

Research Questions (RQs)

- RQ1: How does PIPCell perform compared to baselines?
- RQ2: How much does each component contribute?
- RQ3: How well does PIPCell generalize across regions?

Dataset

- Real-world dataset from China Mobile (Aug 11–30, 2022)
- 1,045 parameter adjustment cases
- 628 samples per case, sampled every 15 minutes
- 17 monitoring metrics across 3 clusters

Baseline Methods
- GBRT: Traditional machine learning model for time-series regression
- VCNet: Deep neural model for causal effect estimation
- β-Intact-VAE: Variational autoencoder capturing latent causal factors

Evaluation Metrics
- RMSE — Root Mean Squared Error
- sMAPE — Symmetric Mean Absolute Percentage Error
- Train/Test Split: 50% / 50%, repeated 10 times
- Prediction horizon: 1 day (96 time steps)

RQ1: How Does PIPCell Perform Compared to Baselines?

Nankai University

Method	Relative RMSE		Relative sMAPE	
	mean(std)	p-value	mean(std)	p-value
GBRT	1.347(0.80)	0.007*	2.440(2.69)	0.000*
VCNet	6.739(9.53)	0.000*	5.220(11.5)	0.000*
β-Intact-VAE	4.996(10.3)	0.002*	11.693(37.5)	0.000*
PIPCell	1.000(0.00)	/	1.000(0.00)	/

*Statistically significant as $p < 0.05$

PIPCell outperforms all baselines with significant accuracy gains and robust generalization across scenarios

RQ2: How Much Does Each Component Contribute?

Nankai University

Variant	Relative RMSE		Relative sMAPE	
	mean(std)	p-value	mean(std)	p-value
PIPCell	1.000(0.00)	/	1.000(0.00)	0.000*
A1	0.973(0.26)	0.189*	1.409(0.89)	0.000*
A2	1.621(0.99)	0.003*	2.005(1.34)	0.000*
B1	1.458(1.33)	0.013*	2.007(1.80)	0.000*
B2	5.219(13.7)	0.004*	13.400(44.9)	0.000*
B3	16.179(49.8)	0.001*	36.496(13.3)	0.000*

*Statistically significant as $p < 0.05$

Model Variants:

- HC-PEP Replacements: A1 – Multiplier | A2 – VCNet
- Transformer Replacements: B1 – GBRT | B2 – NLinear | B3 – Autoformer

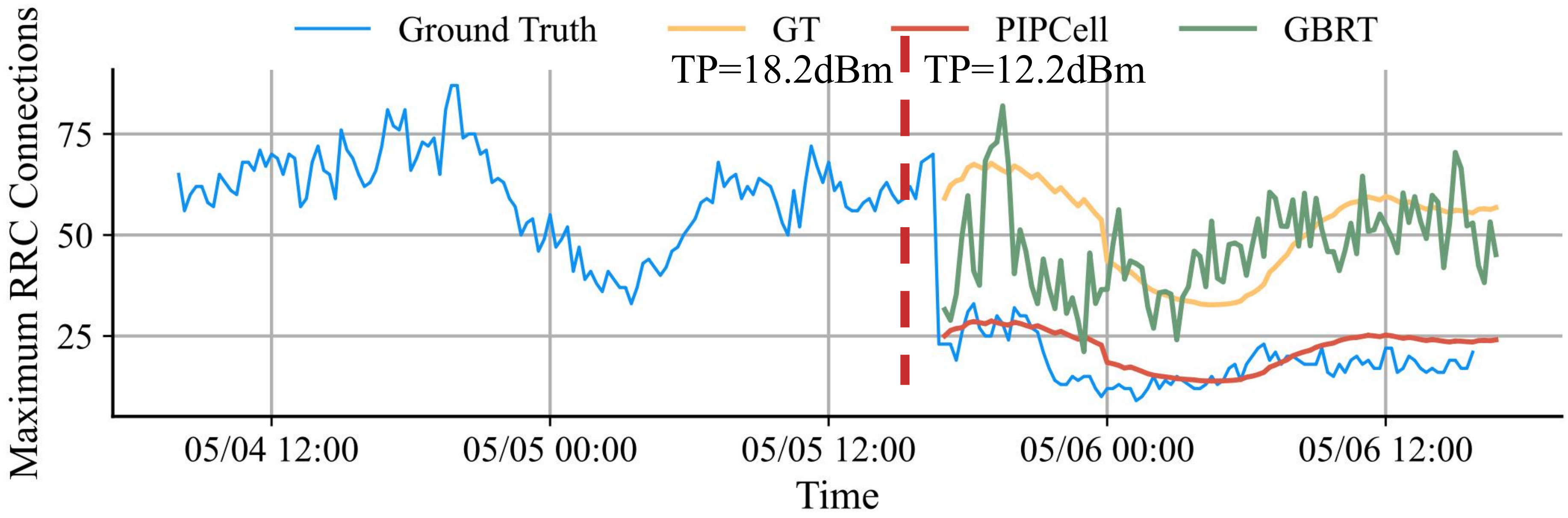
RQ3: How Well Does PIPCell Generalize Across Regions?

Method	Relative RMSE		Relative sMAPE	
	mean(std)	p-value	mean(std)	p-value
GBRT	1.665(0.76)	0.001*	3.294(7.88)	0.002*
VCNet	7.523(14.5)	0.000*	10.313(19.7)	0.000*
β-Intact-VAE	7.259(10.7)	0.000*	14.127(27.6)	0.000*
PIPCell	1.000(0.00)	/	1.000(0.00)	/

*Statistically significant as $p < 0.05$

PIPCell maintains high accuracy and robust performance across different regions

RQ3: How Well Does PIPCell Generalize Across Regions?



- TP reduced from 18.2 dBm to 12.2 dBm
- Graphical Transformer fails to capture impact after TP drop
- HC-PEP enables PIPCell to adapt dynamically and improve accuracy
- PIPCell outperforms best baseline GBRT, capturing real effects of parameter changes

Content

Background

Challenges

Approach

Evaluation

Conclusion

Conclusion

Nankai University

Predicting the Impact of Parameter Adjustments on Cellular Networks

Core innovation

Presents PIPCell, a framework designed to predict how changes in cell parameters impact key performance metrics over time

Design

Adjusting: HC-PEP refines workload by modeling TP and CIO effects

Propagating: Graphical Transforme propagate parameter impacts across metrics

Validated performance

Consistently outperforms baselines on real-world datasets from China Mobile , with experiments validating the effectiveness of each component

Thank you!

- This work was conducted at the **AIOps Laboratory, School of Software, Nankai University** (AIOps@NKU).
- Lab website: **https://nkcs.iops.ai/**
- Contact email: **cuitianyu@mail.nankai.edu.cn**

Please feel free to reach out with any questions or feedback!