Hybrid Congestion Control with Variable Monitoring Time Period

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INTRODUCTION

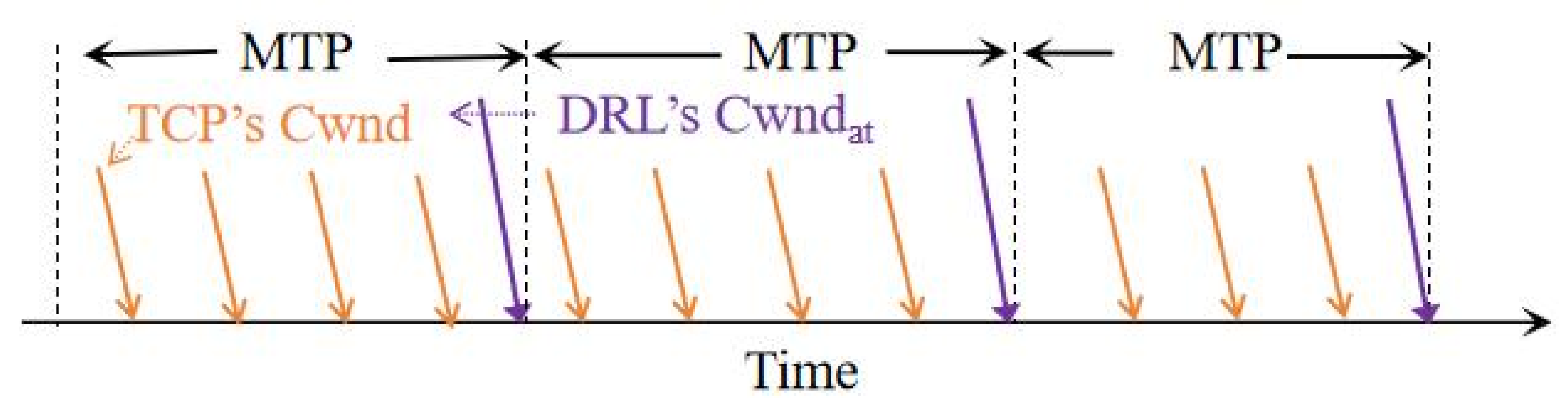
Congestion control algorithms(CCAs) are divided into three classes:

- Heuristic methods
  - Cubic
  - BBR
- Learning-based methods
  - Aurora (ICML 2019)
  - Sage (SIGCOMM 2023)
- Hybrid methods
  - Orca (SIGCOMM 2020)
  - Spine (CONEXT 2022)

INTRODUCTION

Drawbacks of Fixed MTP Hybrid CCAs

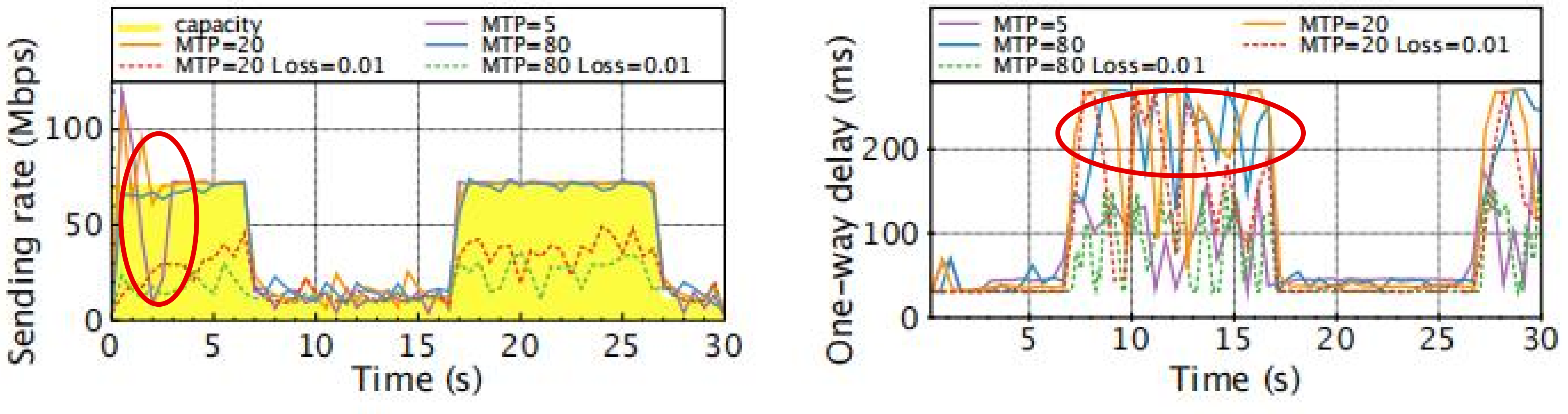
- Fixed MTP is suboptimal
- Large MTP will cause an increase in latency.
- Small MTP will cause an increase in CPU utilization.
- Lack of adaptability across network conditions.



MOTIVATION

Limitations of hybrid CCAs with fixed MTP

- Limitations on Performance
  - Small MTP : the sending rates exhibit fluctuations during the initial phase.
  - Large MTP : the delay of CCA is higher.



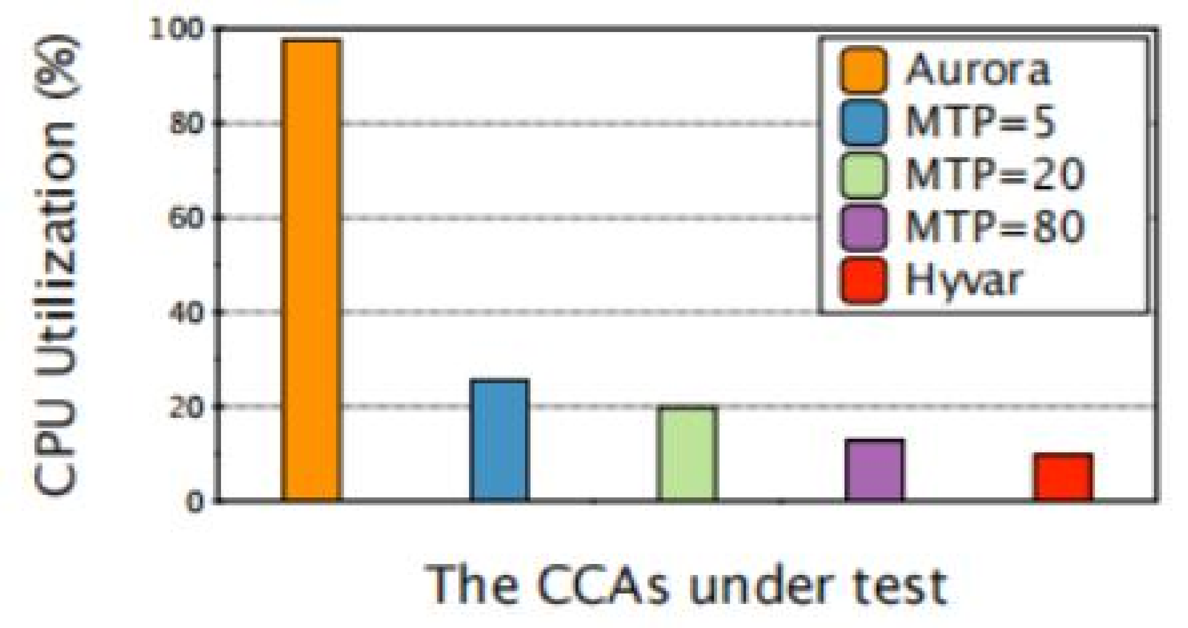
(a) Sending rate (b) Delay

MOTIVATION

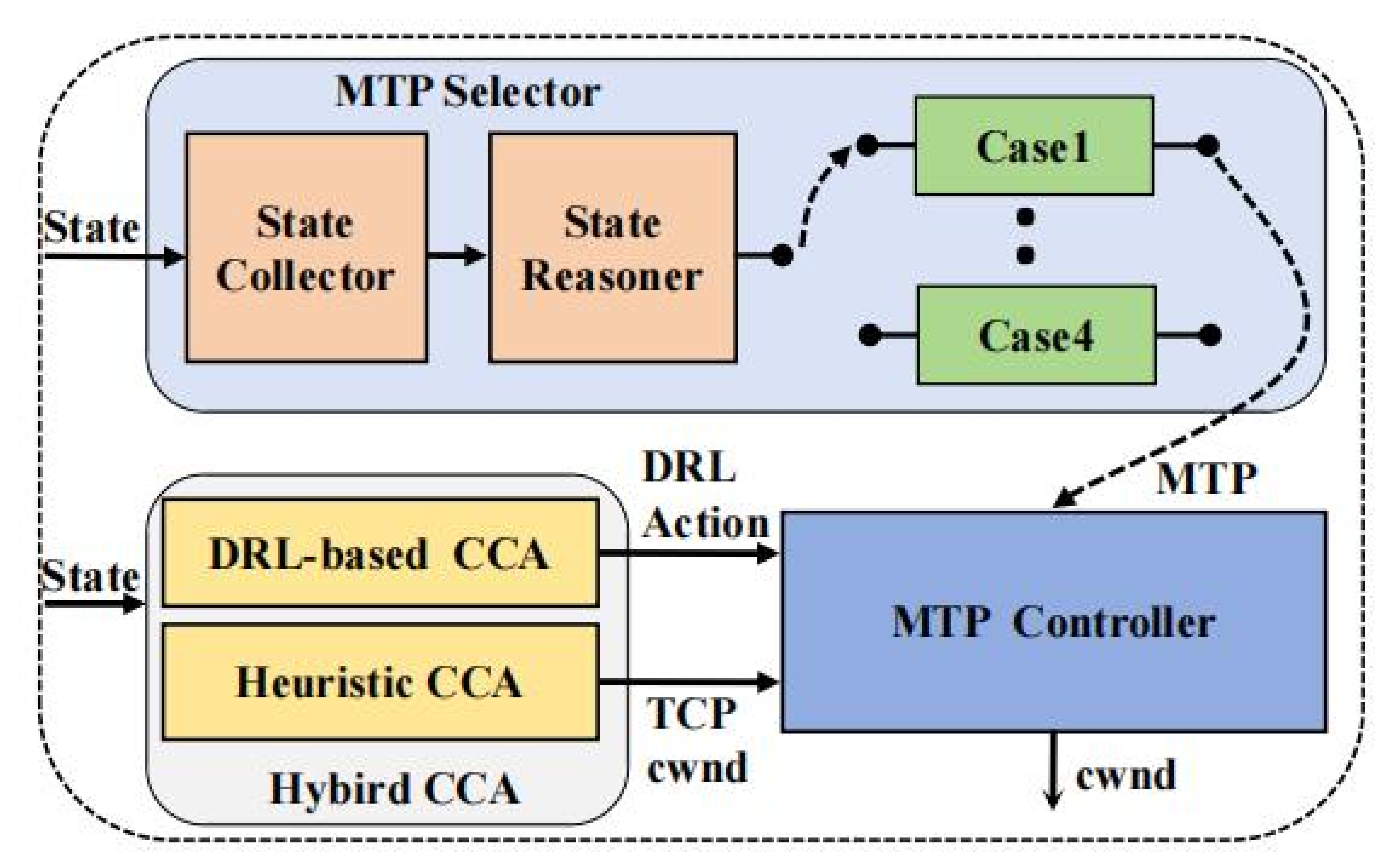
Limitations of hybrid CCAs with fixed MTP

➢ Limitations on Practicality

- The CPU utilization of hybrid CCAs is lower than that of pure deep DRL-based CCAs.
- A smaller MTP increases the CPU utilization.



DESIGN


MTP Selector
State
State Collector
State Reasoner
Case1
Case4
DRL
Action
MTP
State
DRL-based CCA
Heuristic CCA
Hybird CCA
TCP
cwnd
MTP Controller
cwnd

➢MTP Selector

- State Collector :inputs network states,The outputs are consecutive and normalized network states.

- State Reasoner :Update MTP by selecting the appropriate calculation formula based on the state reasoner.

- The four cases :

$$Case1: \widehat{RTT}_t \le \alpha \ and \ \nabla\widehat{RTT}_t < 0 \ and \ Loss_t < \delta, \ MTP_n \leftarrow MTP_{n-1} \times 2^{S(x)}$$

$$Case2: \widehat{RTT}_t \le \alpha \ and \ \nabla\widehat{RTT}_t \ge 0 \ and \ Loss_t < \delta, \ MTP_n \leftarrow MTP_{n-1} \times e^{-\frac{\nabla\widehat{RTT}_t}{\alpha}}$$

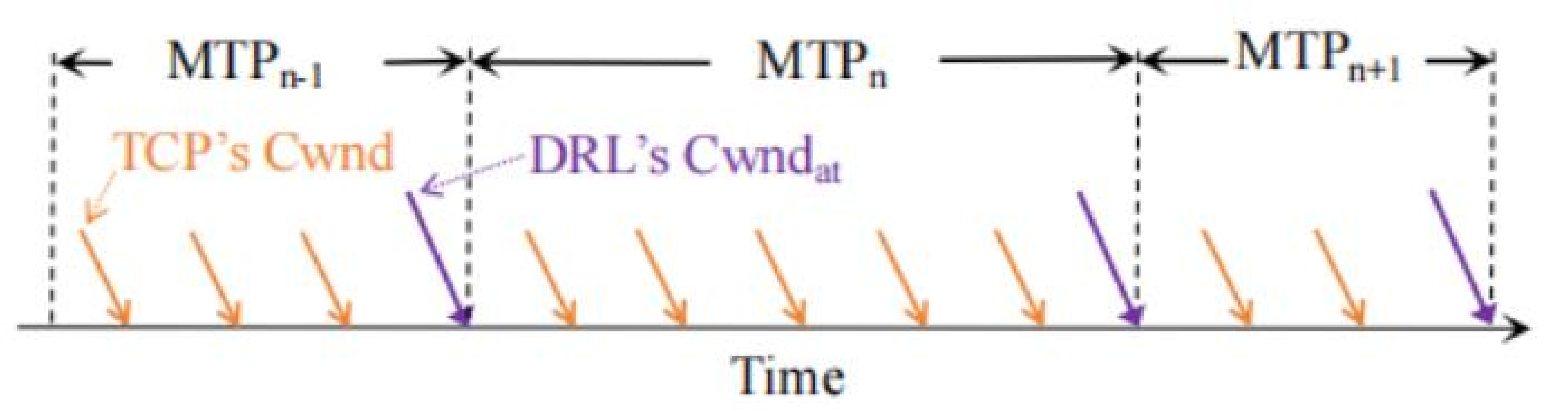
$$Case3: \widehat{RTT}_t \le \alpha \ and \ Loss_t < \delta, \ switch \ to \ learning \ baed \ CCA$$

$$Case4: \widehat{RTT}_t > \alpha, \ MTPn \leftarrow MTPn - 1 \times e^{-\frac{\widehat{RTT}_t}{\alpha}}.$$

DESIGN

➢MTP Controller

Based on the current MTP value from the selector,The MTP Controller in Hyvar selects the optimal cwnd by dynamically switching between heuristic and learning-based approaches.



DESIGN

- Hybird CCA

  Heuristic CCA : Cubic

  Learning-based CCA :

Rewad: $R = (\frac{thr - \varepsilon \times loss}{RTT})/(\frac{thr_{max}}{RTT_{min}})$

State:

Paremeter	Description
thr	The average throughput.
thrmax	The maximum throughput of the flow so far.
RTT	The average RTT.
RTTmin	The minimum RTT of the flow so far.
loss	The average packet loss rate.
cwnd	The current congestion control window
sRTT	The smooth RTT of packets so far.

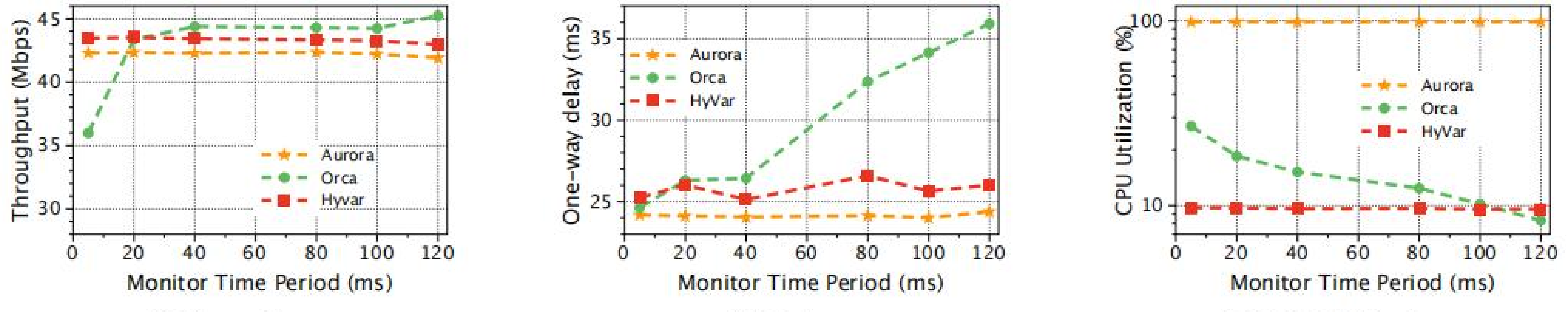
Action: $cwnd_{at} = 2^{at} \times cwnd_{at-1}$

EVALUATION

➢ MTP Insensitivity

Bandwidth is 48 Mbps,RTT is 30 ms,Buffer size is 1 BDP.

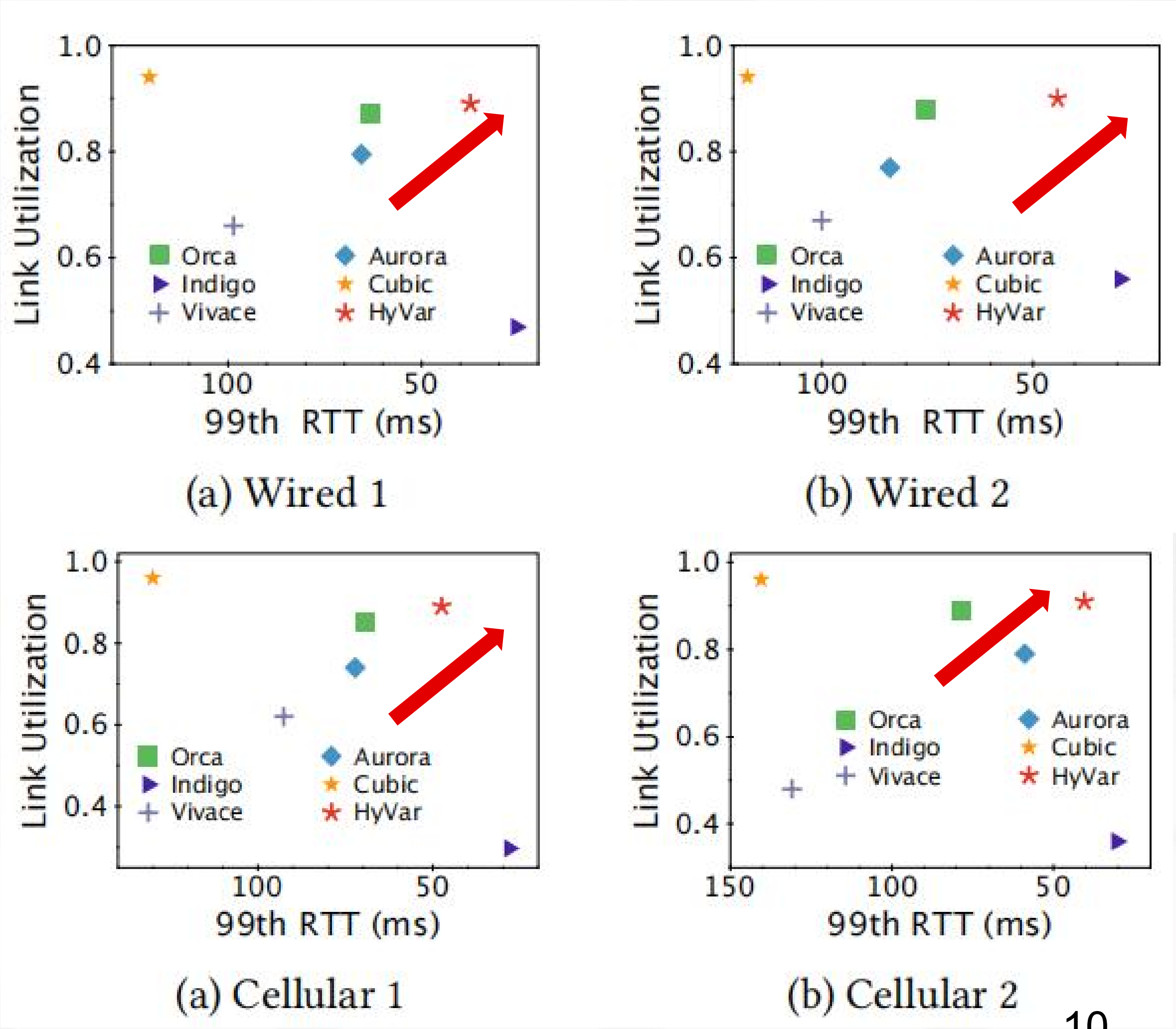
Hyvar maintains stable performance, achieving similar throughput and latency with up to 90% lower CPU usage



(a) Throughput (b) Delay (c) CPU Utilization

EVALUATION

➢ Consistent High Performance



(a) Wired 1 (b) Wired 2

(a) Cellular 1 (b) Cellular 2

Hyvar outperformed competitors in both wired and wireless tests, achieving higher throughput and lower latency consistently

CONCLUSION

- Fixed MTP in hybrid CCA can't adapt to changing network conditions, causing either high latency or excessive CPU usage.

- Hyvar introduces the dynamic MTP that automatically adjusts between heuristic and learning-based methods based on real-time network.

- In comprehensive tests, Hyvar reduced latency and CPU overhead and maintaining high throughput.

THANKS