实时音视频场景下拥塞控制算法的探索与实践

—声网 庄泽森 2020-10-31

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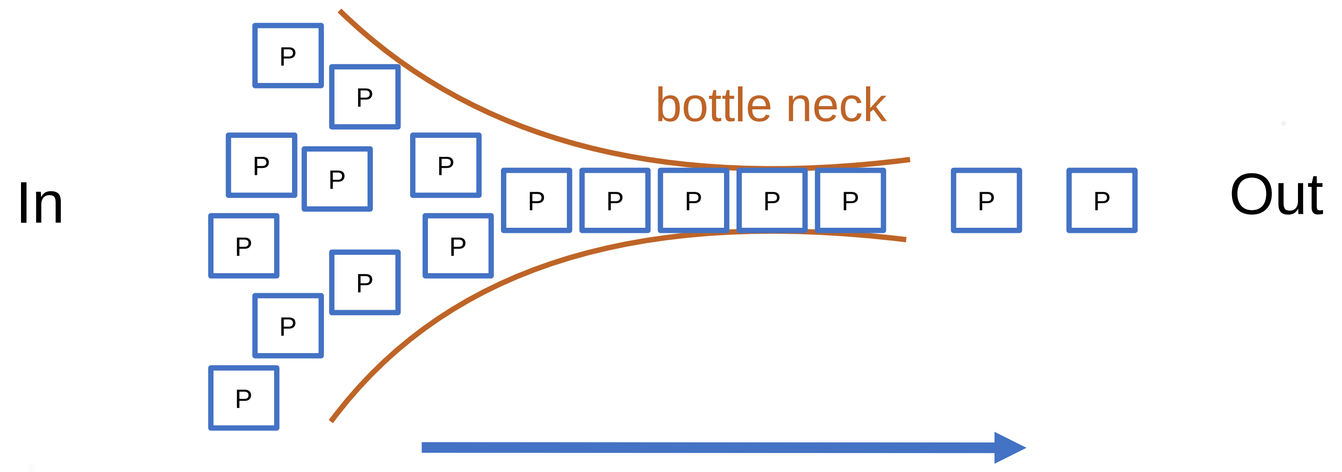
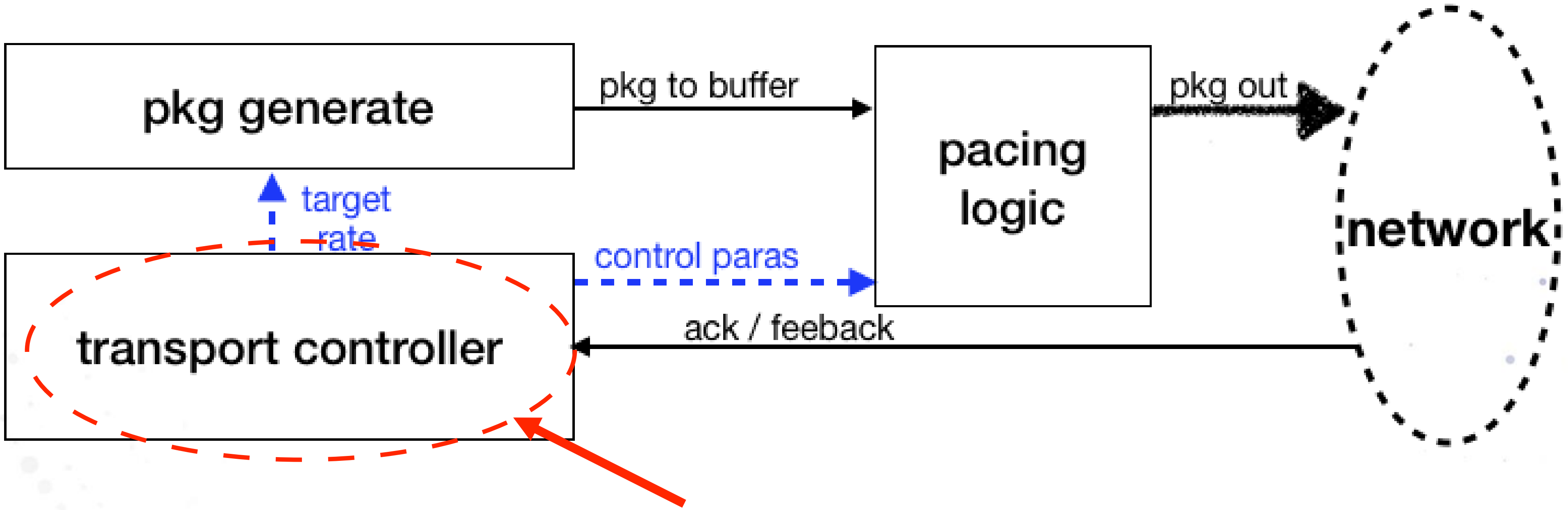
拥塞控制与传输 - Overview

- 网络拥塞的简单图示
- 为什么是拥塞控制？ —> 传输栈的核心模块和算法，避免拥塞，提升传输效率
- 传输栈的大脑：感知网络，控制发送，处理丢包



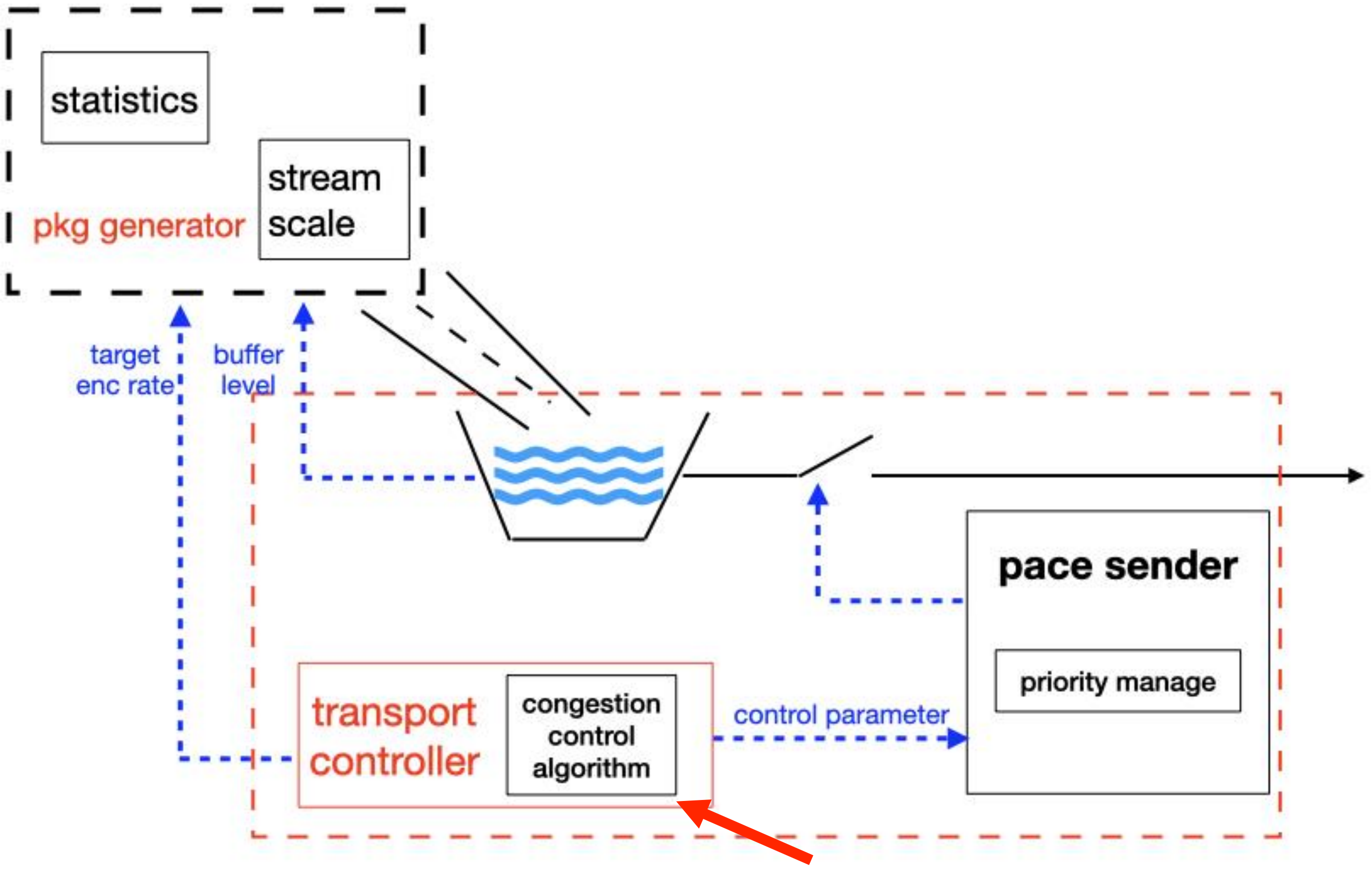
拥塞控制与传输 - Overview

- 在传输栈中的位置
  - pkg gennerator, transport controller, pacing logic

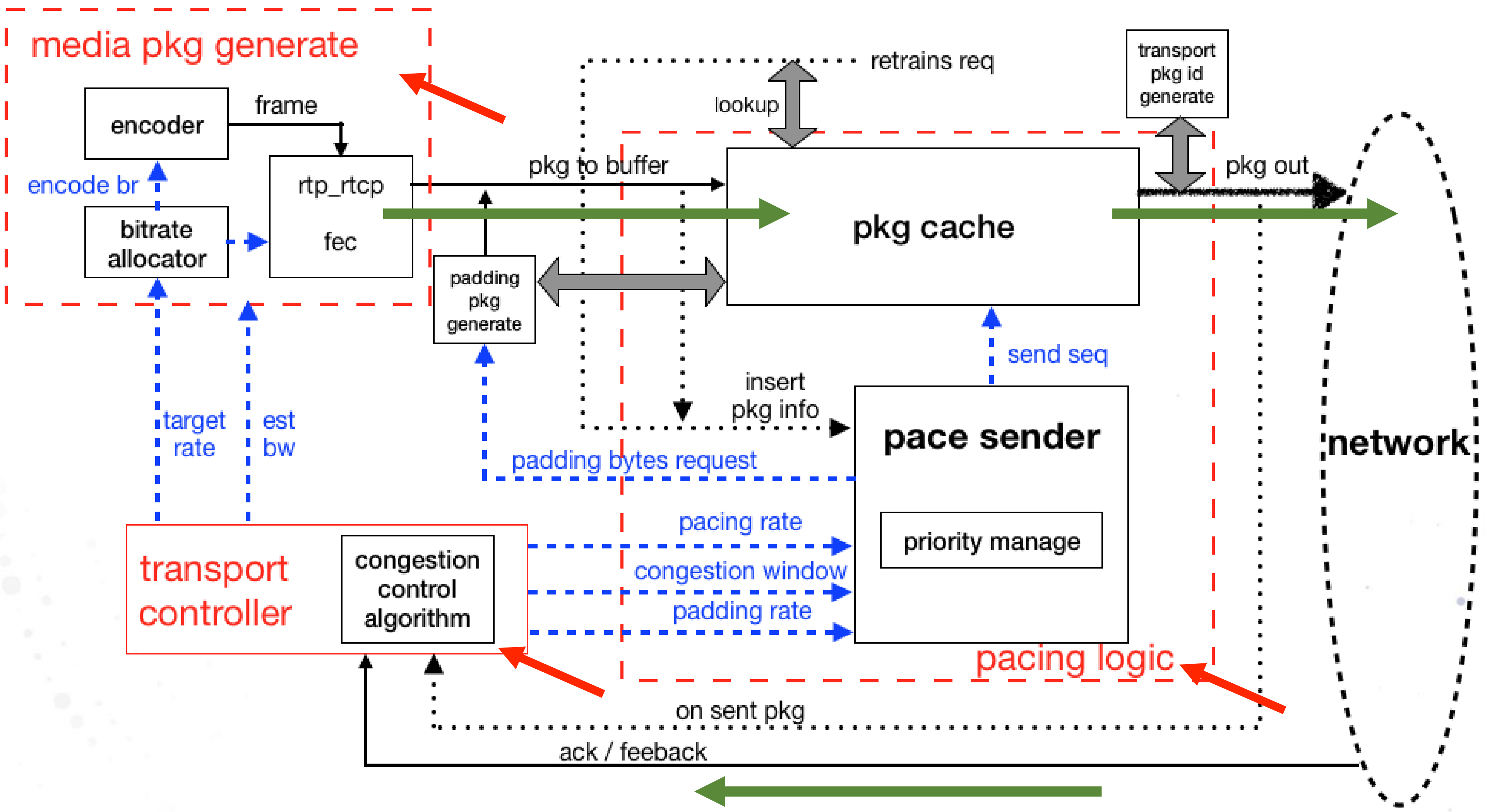


拥塞控制与传输 - Overview

• 传输栈与上层媒体及业务的关系

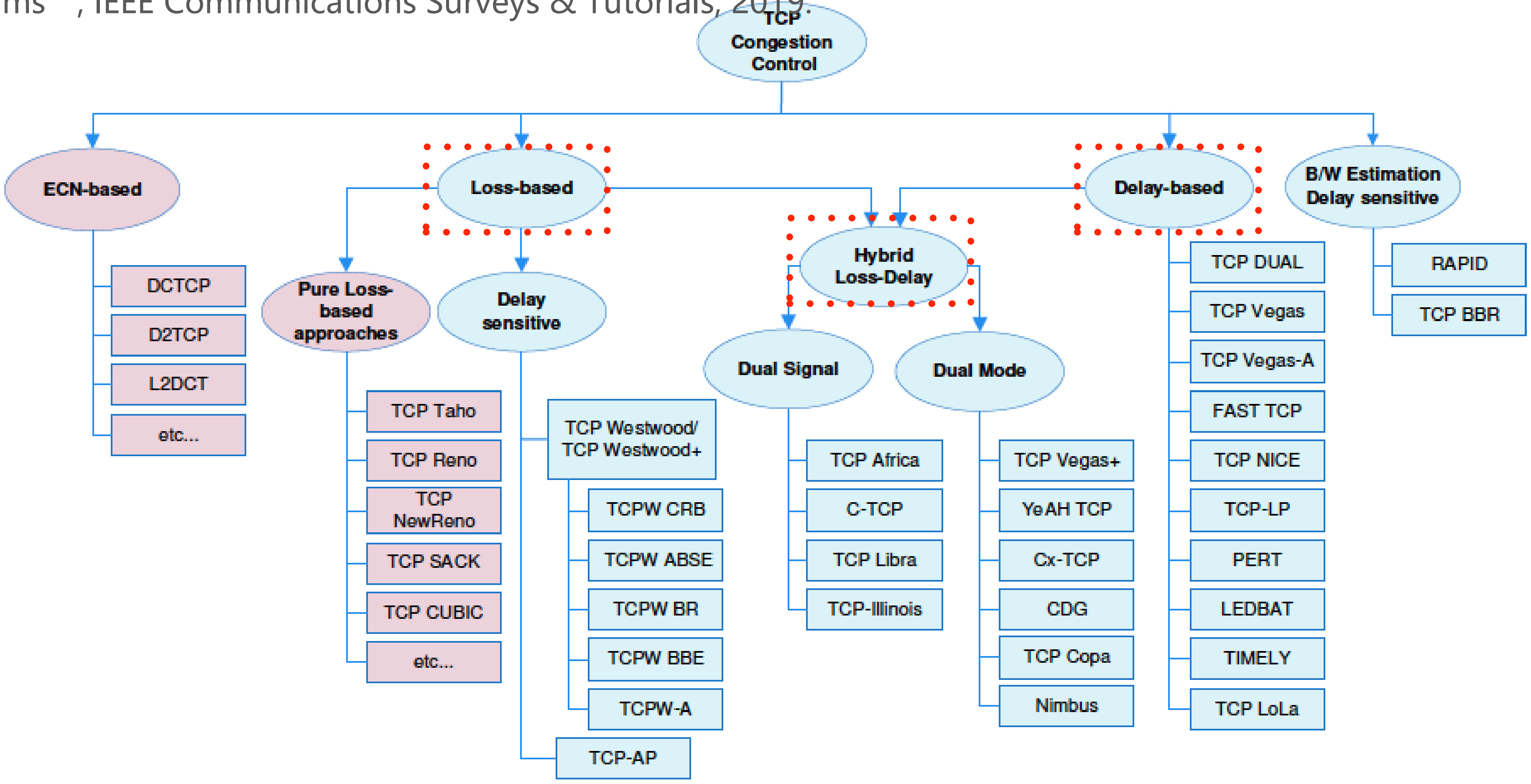


拥塞控制与传输 - WebRTC Example



主流算法 - Overview

- Fig from Rasool Al-Saadi, Grenville Armitage et al. “A Survey of Delay-Based and Hybrid TCP Congestion Control Algorithms”, IEEE Communications Surveys & Tutorials, 2019.



主流算法 - Overview

- **Popular CC algorithms (industrial & academic)**
  - Cubic
  - BBR
  - PCC Vivace
  - Copa
  - Verus
  - Sprout
  - Vegas
  - LEDBAT
  - ...

loss based

delay based

model based

hybrid

learning based

data driven

主流算法 - Cubic

- Cubic原理
- from BIC to Cubic

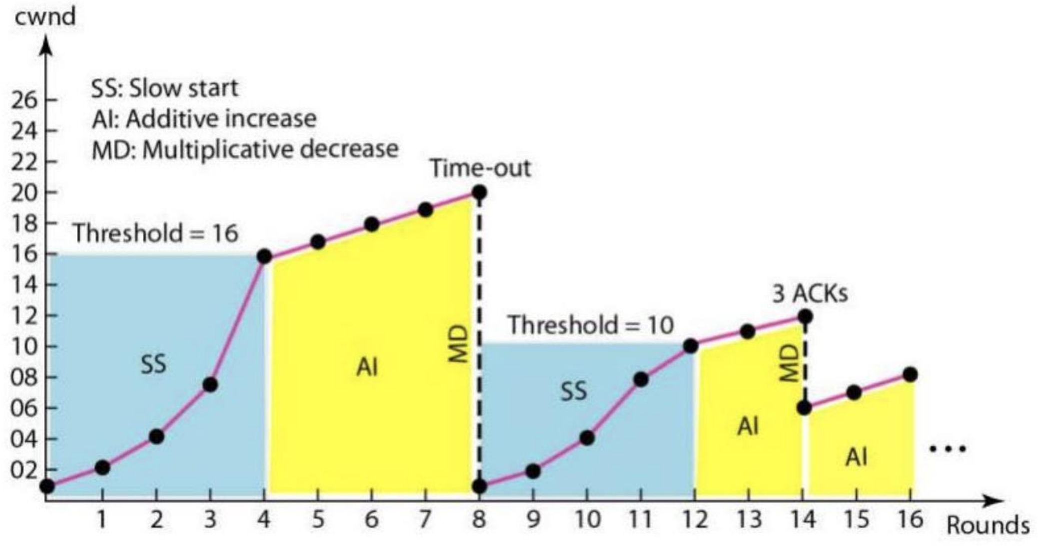


Fig from:The NewReno Modification to TCP's Fast Recovery Algorithm, by A. Gurtov etc..

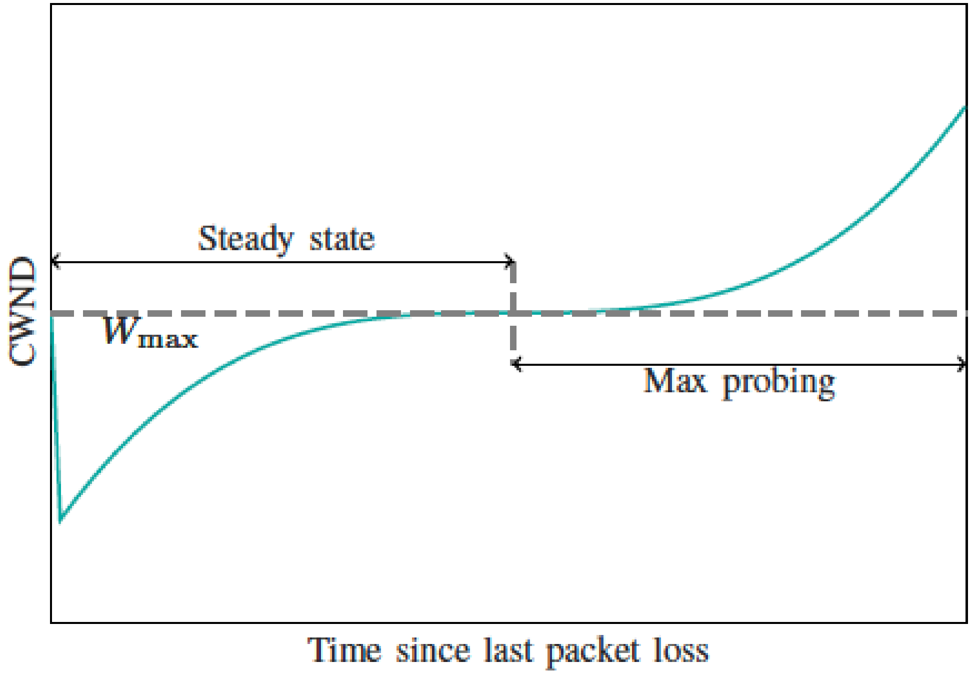
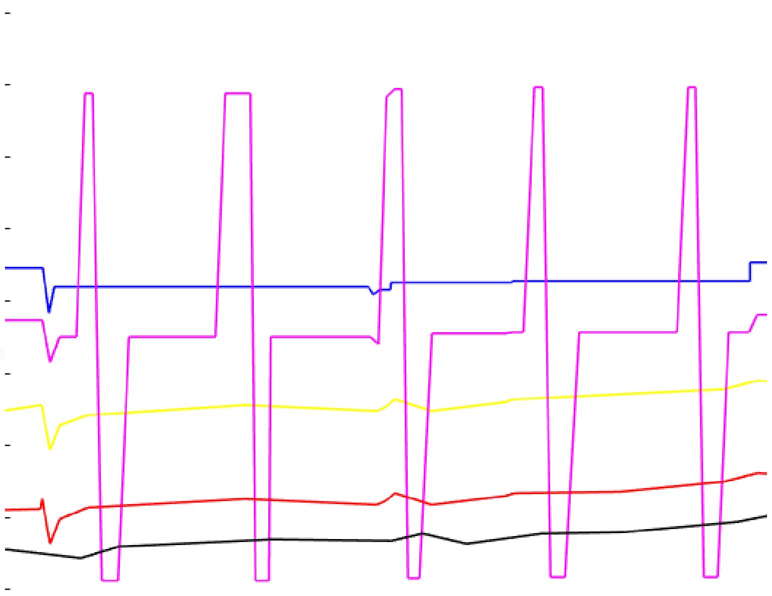


Fig from: A Survey on Recent Advances in Transport Layer Protocolsl. by Michele Polese etc.

主流算法 - BBR

- BBR原理
- 目标为控制 BDP (bandwidth-delay product)
- bandwidth probing



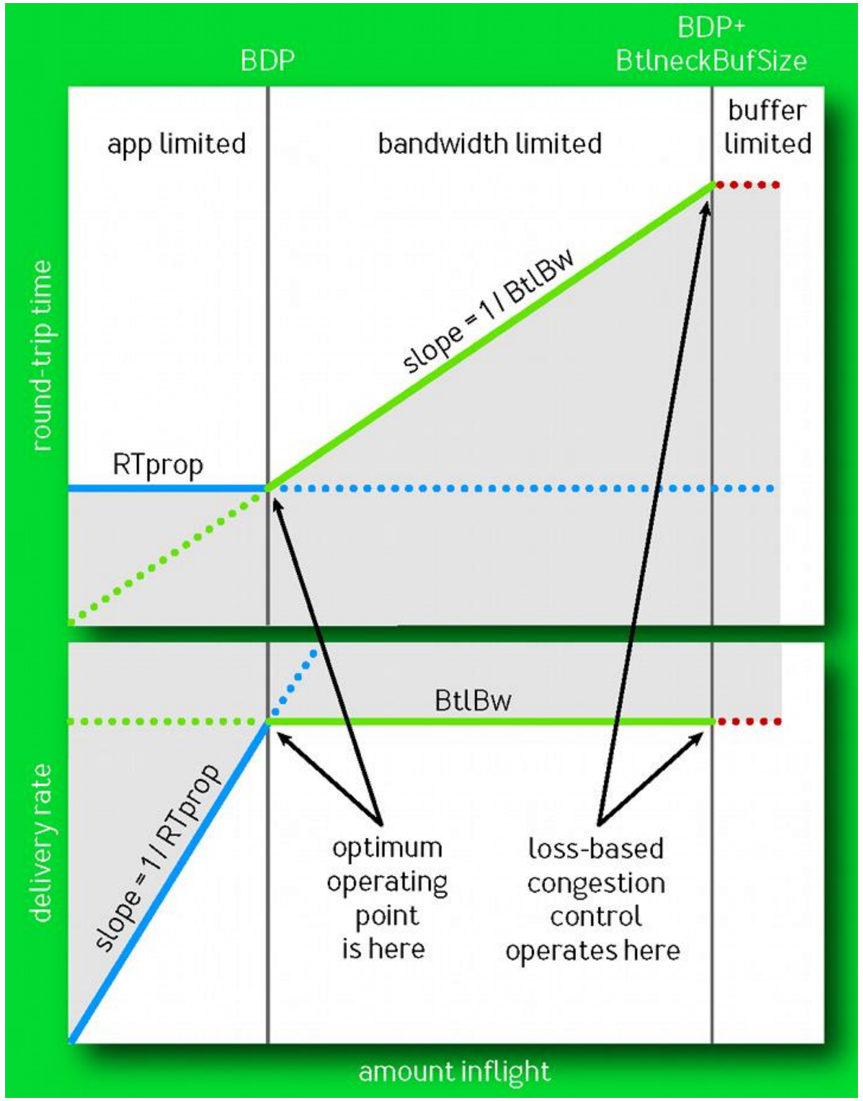


Fig from: BBR: Congestion-Based Congestion Control. by Neal Cardwell etc.

主流算法 - PCC Vivace

- PCC原理
- 优化 utility 函数，或者说reward
- online learning，根据相邻MI的utility函数结果做梯度下降

$$u_P(x_i) = x_i^t - b \cdot x_i \cdot max\left\{0, \frac{d(RTT_i)}{dt}\right\} - c \cdot x_i \cdot L \ ,$$

主流算法 - Vegas & LEDBAT etc

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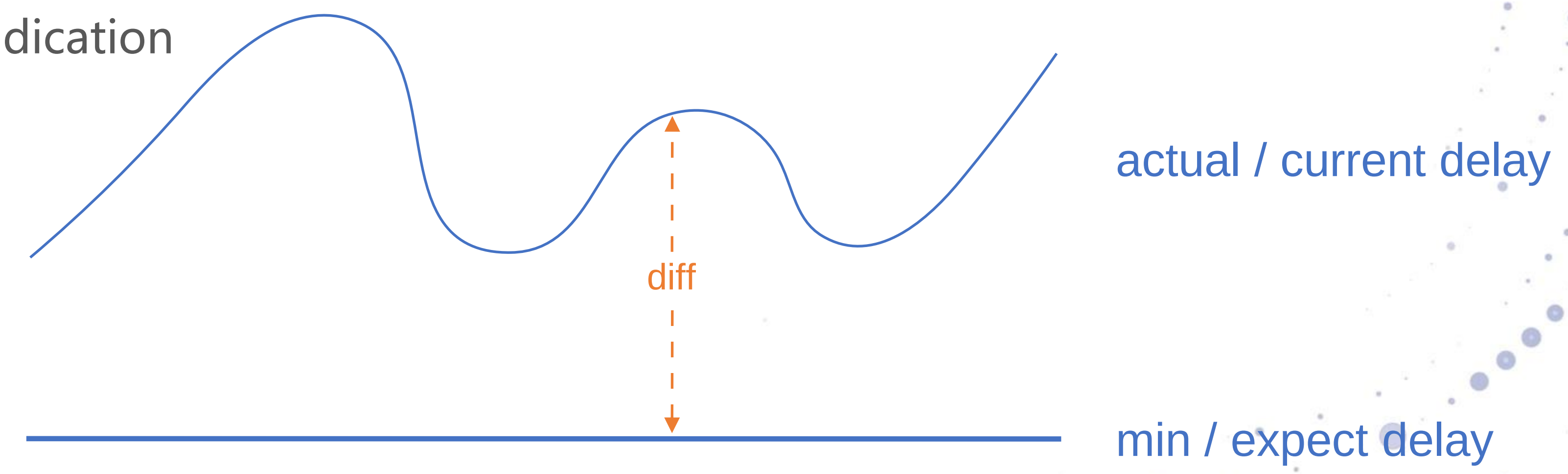
- delay-based
  - delay based, rtt 变化 - > queuing的估计
  - queuing estimate as congestion indication
- others
  - sprout etc.



$$P(X=k)=\frac{\lambda^k}{k!}e^{-\lambda}, k=0,1,\cdots$$

主流算法 - Lab弱网测试

good
acceptable
not good
bad
LT low throughput
HT over estimate

	BBR	CUBIC	Vegas	LEDBAT	PCC Vivace	Copa	Sprout	Verus	Indigo
2M		HT			LT	HT		HT	
600k		HT			HT	HT	LT		
2M -> 500k -> 1.5M		HT			HT	HT		HT	
5M loss 8%		LT	LT	LT	LT			LT	
5M loss 20%		LT	LT	LT	LT				
5M loss 30%	LT	LT	LT	LT	LT		LT		
500k loss 20%		LT	LT	LT	HT		LT		
5M 20ms -> 120ms			LT				LT	HT	LT
1M 20ms -> 300ms		HT	LT	LT	HT	HT	LT		LT
2M & cubic			LT	LT			LT	HT	LT

主流算法 - Summary

- 各个算法各有优缺点，适用的网络或者业务场景不同
- TCP类拥塞控制算法和传输栈，针对可靠传输应用

还没有哪一个cc算法，适用于所有业务场景所有网络

不适合应用于实时音视频场景

应用于实时场景和实际网络 - 实时场景

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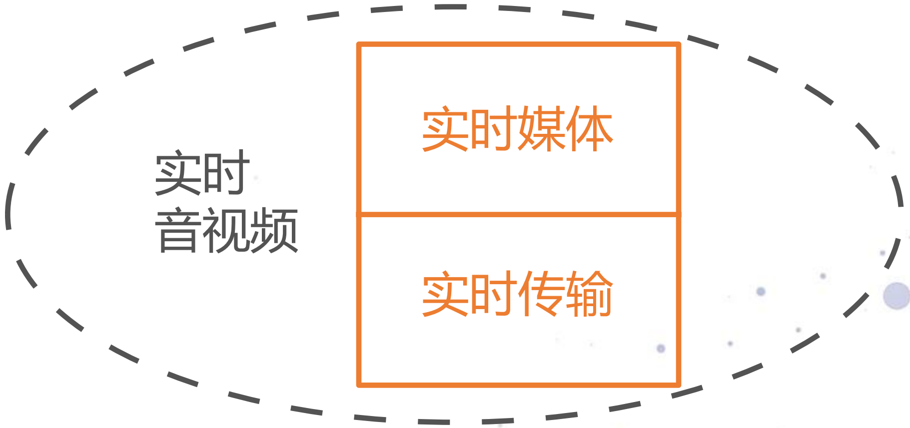
- 什么是实时音视频场景
  - 对延时有高要求，并且总体音视频体验要好
  - 例子：网络电话、会议，云游戏、直播连麦、远程医疗/操控等等
- 实时音视频方案
  - 实时媒体 + 实时传输
  - 实时媒体：如服务于实时场景的编解码算法
  - 实时传输：鲁棒高效的传输栈，服务于实时场景的cc算法
  - SDN的设计，如声网的SD-RTN



应用于实时场景和实际网络 - 实时传输

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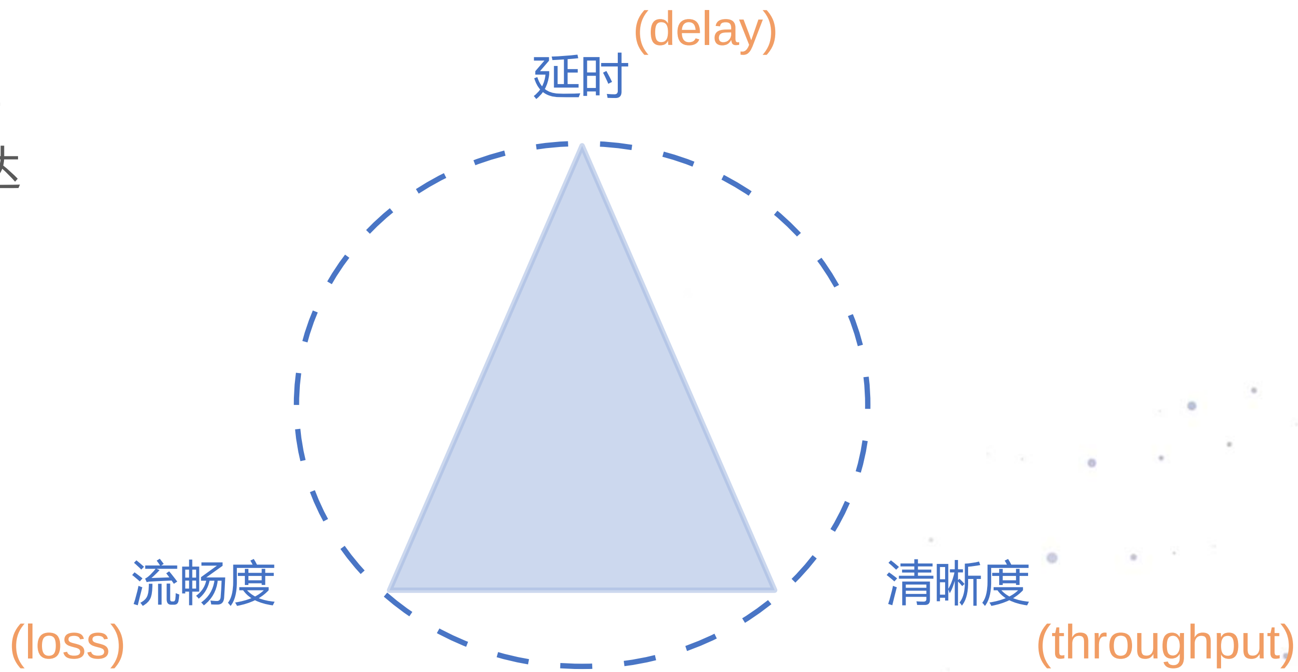
- tcp拥塞控制方案更多是为非实时传输服务
  - 应用于实时场景的问题，如bufferbloat
- 实时传输 vs 非实时传输
  - 非可靠传输 vs 可靠传输 -> 对丢包的处理
  - 延时 -> 包不仅要到达，还要“及时”到达
- 拥塞控制算法于实时场景的评估与挑战
  - 体验三角形
  - 不是简单降低编码码率和发送码率



应用于实时场景和实际网络 - 实际网络

- 实际网络的多样性、复杂性、随机性
  - 网络模型和网络条件多样性, example, deep buffer / shallow buffer model
  - 网络的随机性，突发性
  - 地区和运营商的不同
  - wifi与路由器行为多样
  - lastmile vs. backbond
- 端设备的多样性，处理能力的不同，最终也会反应到传输上

应用于实时场景和实际网络 - 实际网络

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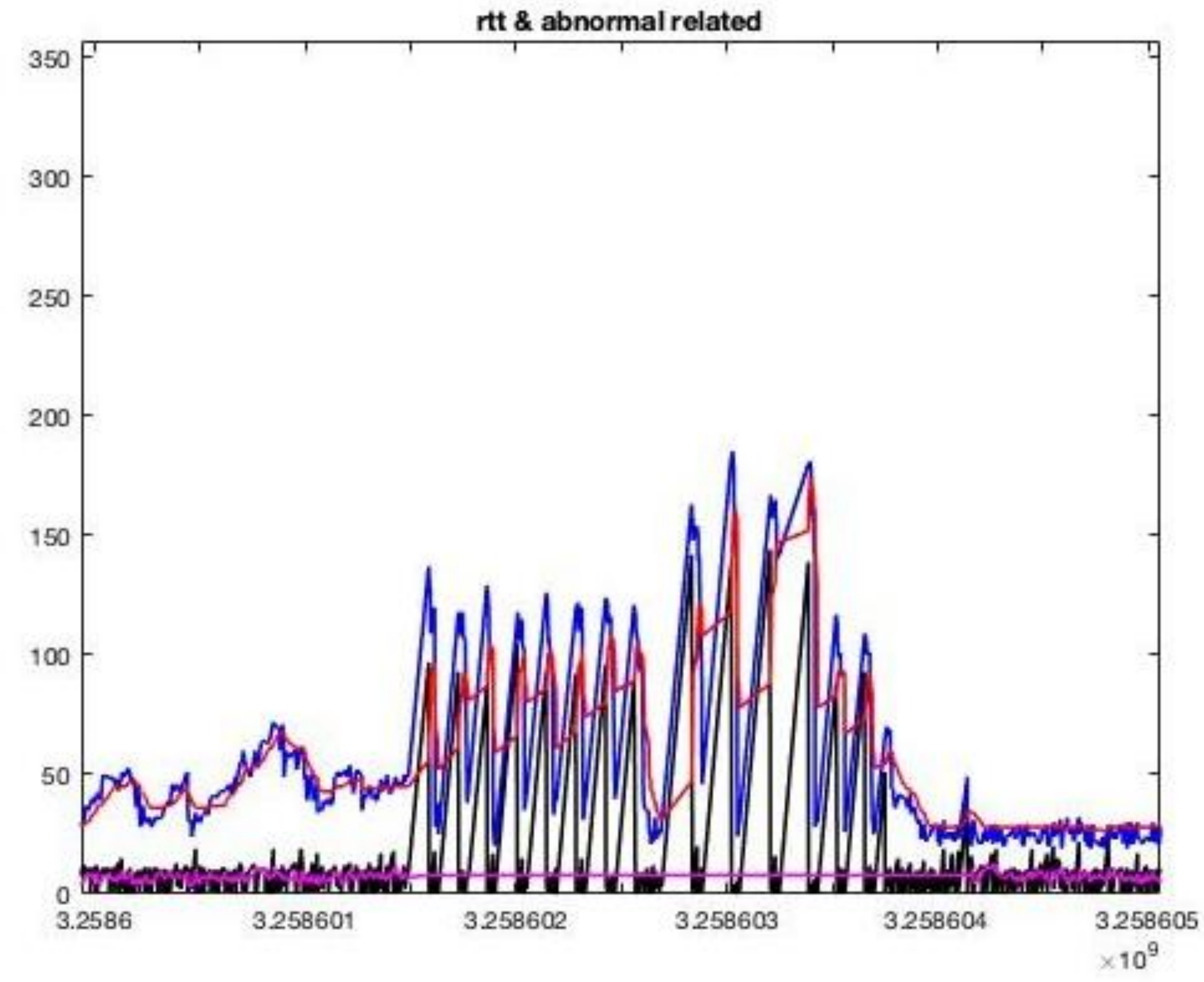
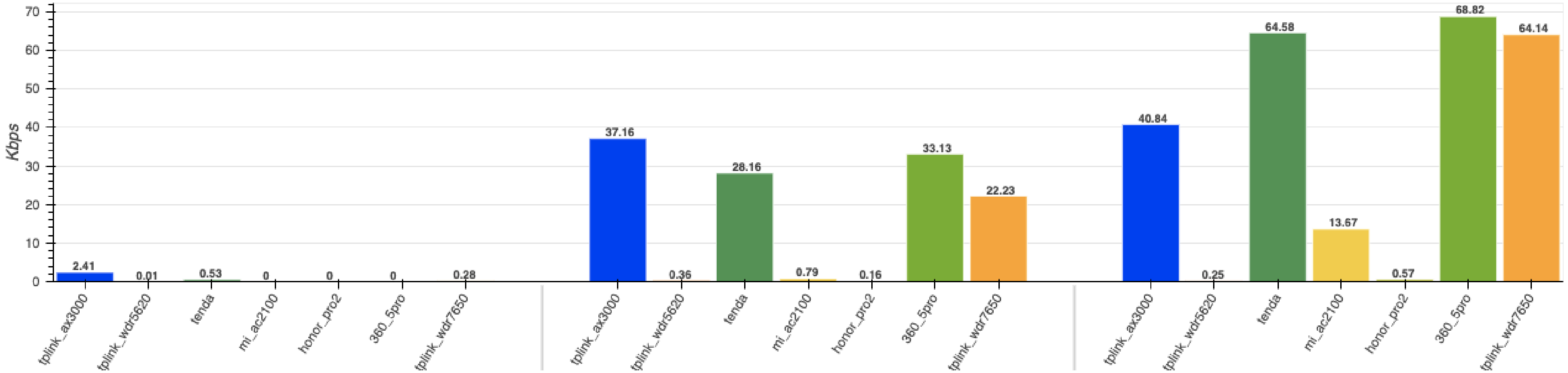
- abnormal network behaviour
  - wifi abnormal pattern



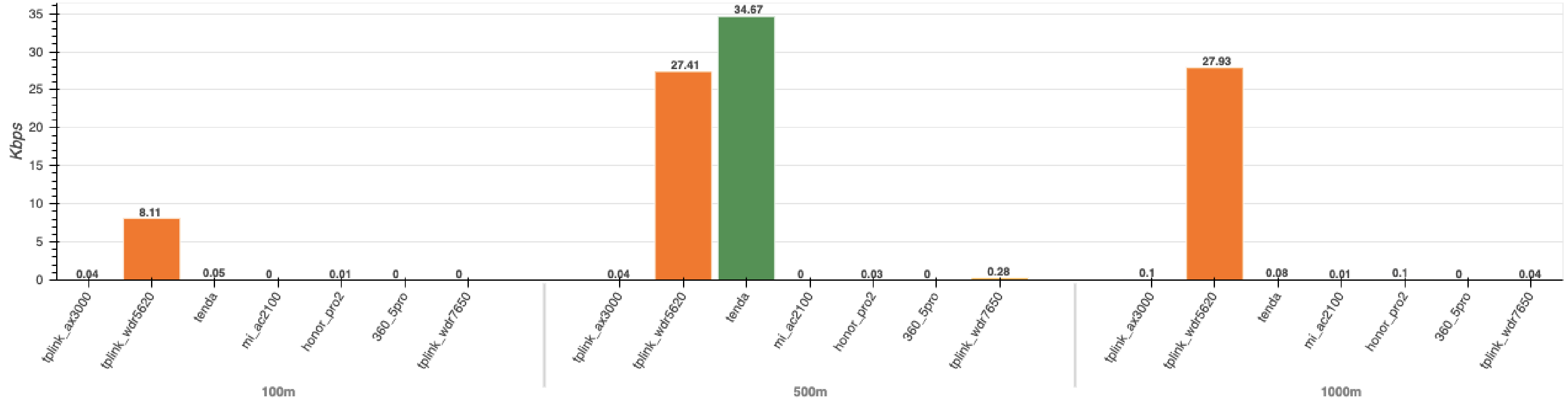
应用于实时场景和实际网络 - 实际网络

- 一些主流路由器在有背景流量，频带竞争，距离较远等场景下的行为：背景流量

Background Downlink 5G Downlink Loss-Rate

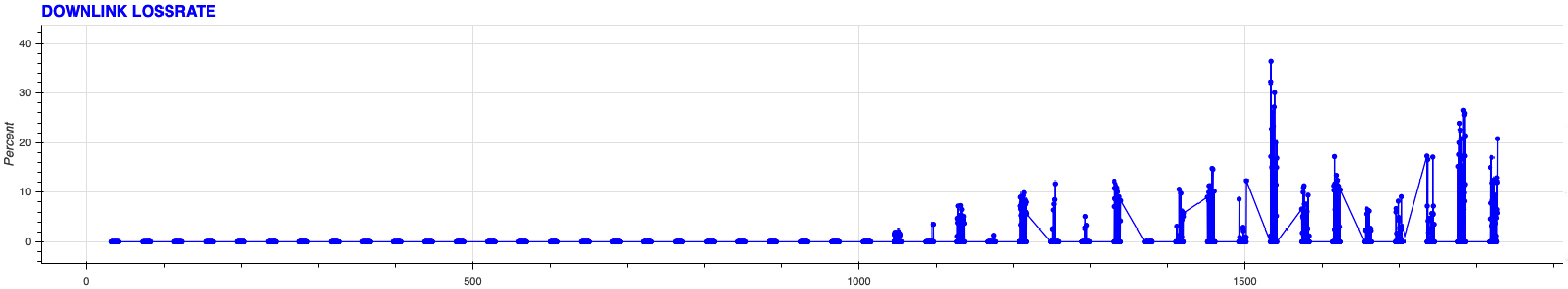


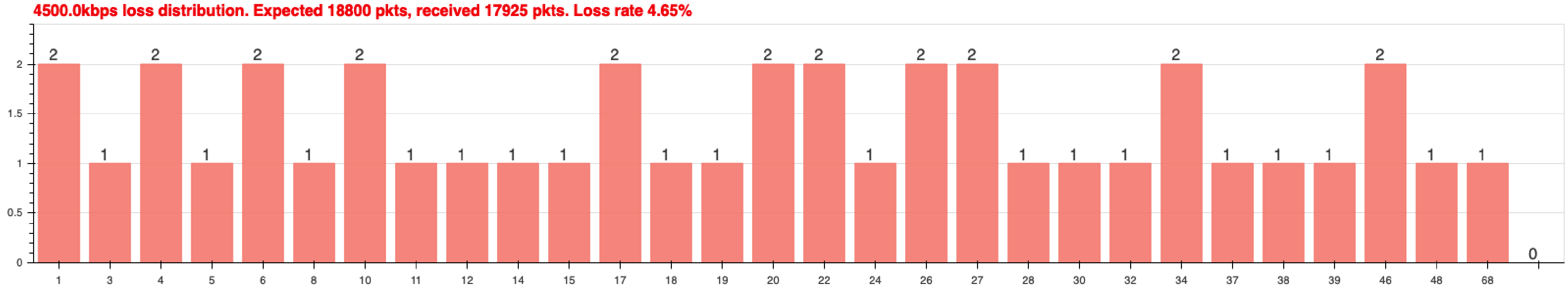
Background Uplink 5G Uplink Loss-Rate



应用于实时场景和实际网络 - 实际网络

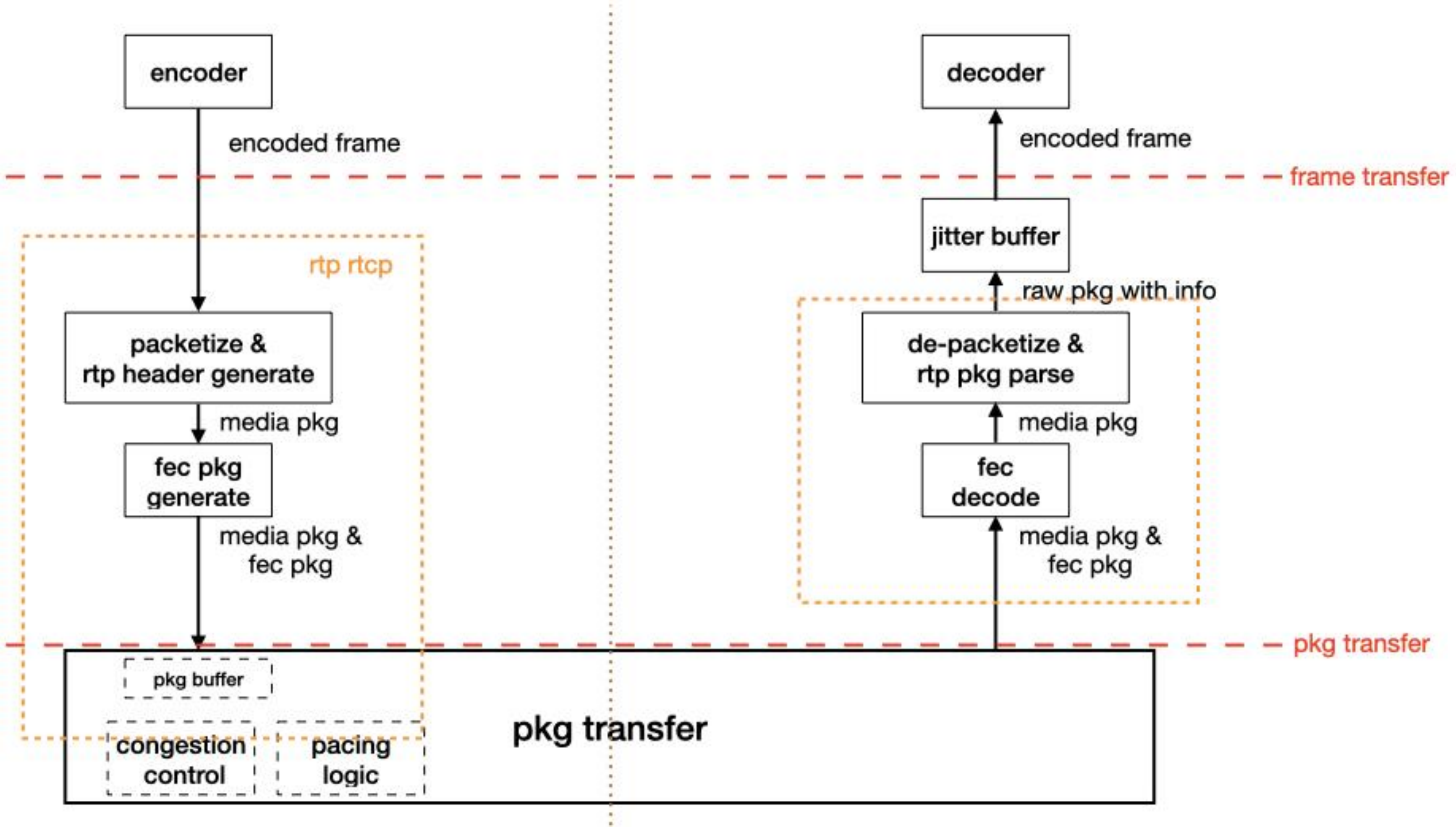
- 场测，电信营业厅4G/5G网络，探测码率 100kbps -> 4.5Mbps





我们的方法和结果 - 分层

- 做好模块化和分层架构
- 媒体层和传输层
- 例子



我们的方法和结果 - 传输栈的设计

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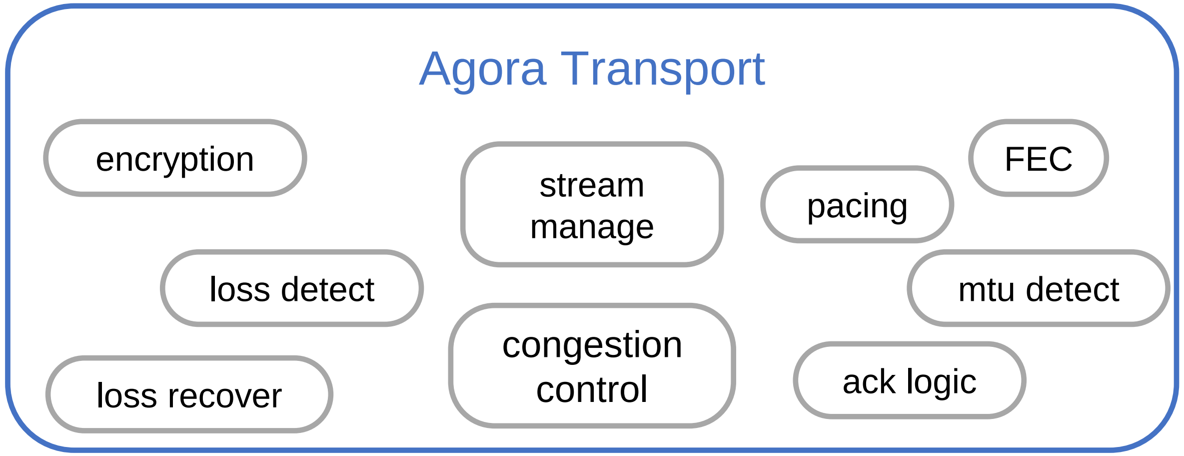
- 自研传输栈和传输协议
- 解耦业务和传输，专注更准确的网络感知和更鲁棒的传输算法
- fec算法方案
- 可配置，支撑各种媒体业务和场景的需求
- 考虑数据安全问题



我们的方法和结果 - 算法改进

- learning-based method
- abnormal detection
- improve track speed
- cope with loss

online learning

loss differentiator

abnormal detector

我们的方法和结果 - Some Results

- 极端弱网下的实时连麦 demo
- 测试条件：带宽 300k，丢包率 65%
- 对比测试结果视频:

Ref **New**

我们的方法和结果 - Some Results

- Lab 弱网测试覆盖
- 测试实例：

	带宽限制 (Kbps)	丢包率 (%)	延迟 (ms)
xx37	128	0	15
xx38	256	0	15
xx39	256	8	15
xx40	256	20	15
xx41	300	30	15
xx42	512	0	15
xx43	512	8	15
xx44	512	20	15
xx45	512	30	15
xx46	512	40	15
xx47	800	0	15
xx48	800	8	15
xx49	800	20	15
xx50	800	30	15
xx51	800	40	15
xx52	1024	0	15
xx53	1024	8	15
xx54	1024	20	15
xx55	1024	30	15
xx56	1024	40	15
xx57	unlimited	50	15
xx58	(512,0,15)=>(256,8,15)=>(512,8,15)		
xx59	(unlimited,0,15)=>(512,20,15)=>(800,8,15)		
x207	unlimited	64	15

我们的方法和结果 - Some Results

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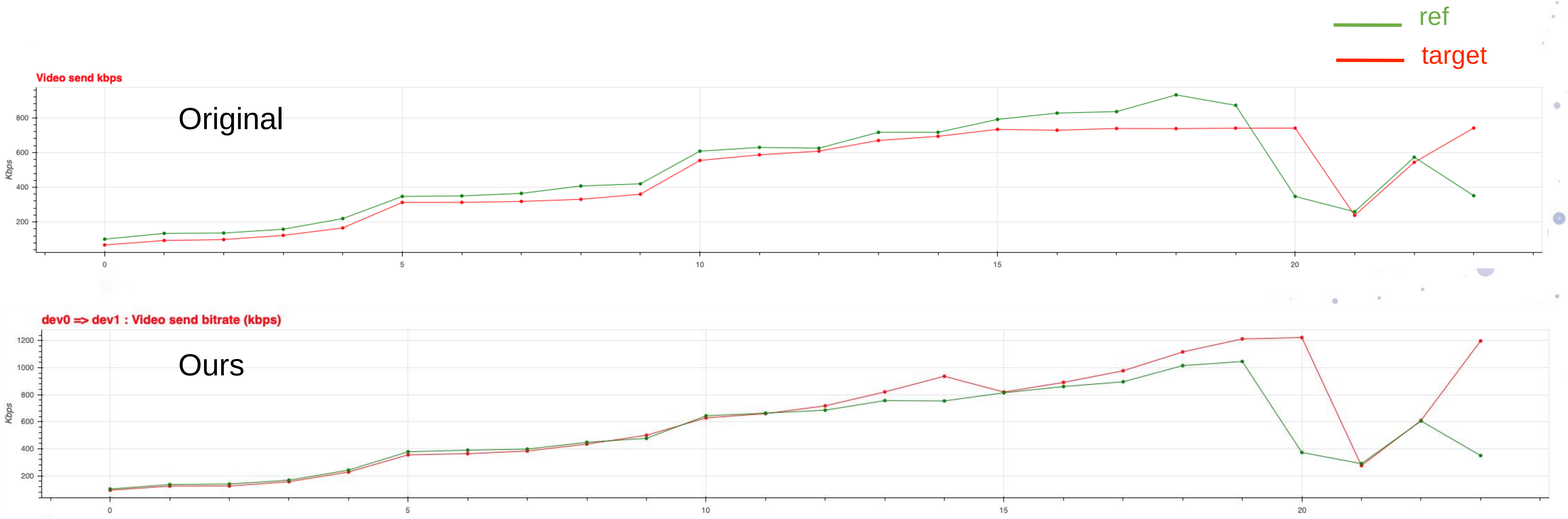
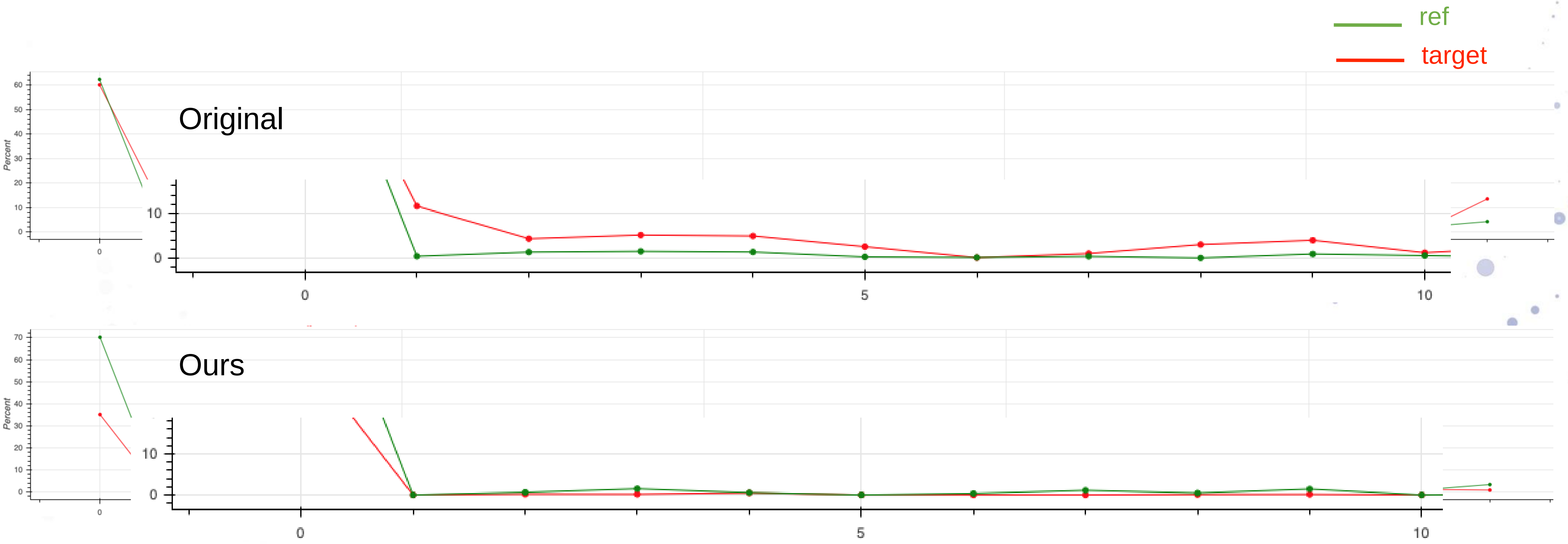
- 改进前后实验室弱网case对比 - 码率
- 改进后各种case码率提升明显



我们的方法和结果 - Some Results

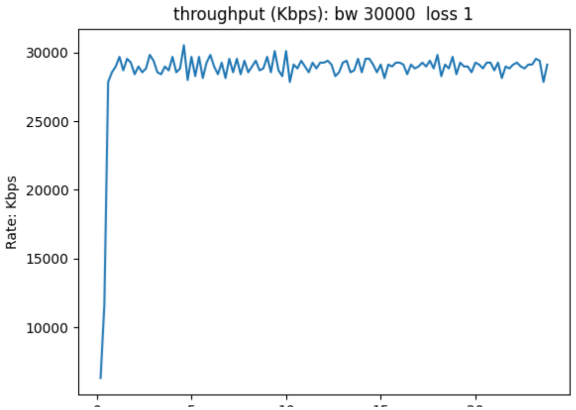
- 改进前后实验室弱网case对比 - 卡顿率
- 改进后各种case卡顿率体验指标下降明显

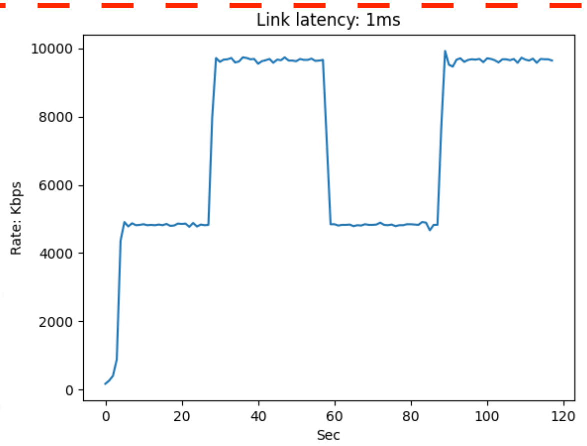


我们的方法和结果 - Some Results

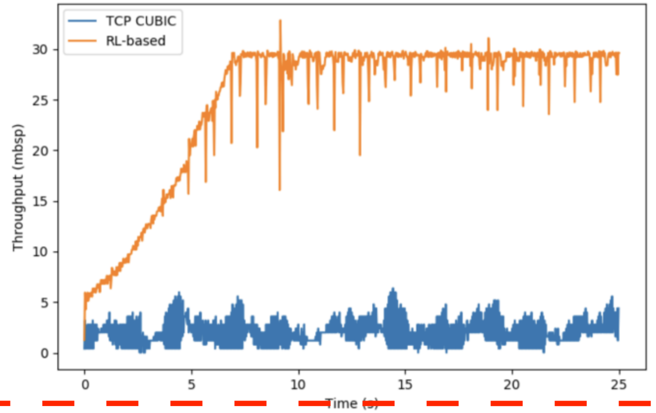
- 下一代算法探索 - > 基于机器学习的方法

our result

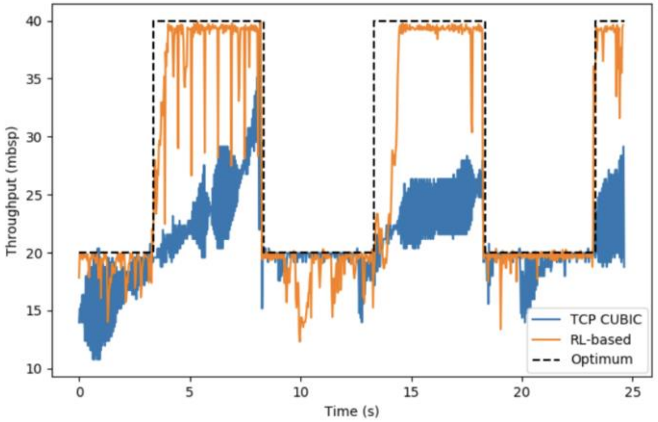




paper result



1% loss + 30Mbps



10Mbps <-> 40Mbps

Ref figures from Jay, Nathan, et al. "A deep reinforcement learning perspective on internet congestion control." *International Conference on Machine Learning*. 2019.

我们的方法和结果 - 下一步

- 持续进行实际网络的探索，实际场景的验证和分析
- 下一代cc算法，进一步提升指标和鲁棒性
  - —>open question：DRL? other data driven approach ?

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Thank you