北京 2019
遨游“视”界 做你所想
Explore World, Do What You Want

机器学习在ABR算法中的应用

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出品：LiveVideoStack 音视频技术社区 CSDN

深圳 2019

遨游“视”界 做你所想
Explore World, Do What You Want

LiveVideoStackCon 2019 深圳

2019.12.13-14

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出品：LiveVideoStack 音视频技术社区

关于我

- 王莫为
- 本科：2013级 北京邮电大学 通信工程专业
- 研究生：2017级 清华大学计算机系网络所 博士生
- 导师：崔勇教授
- 研究方向：数据驱动网络和流媒体传输优化

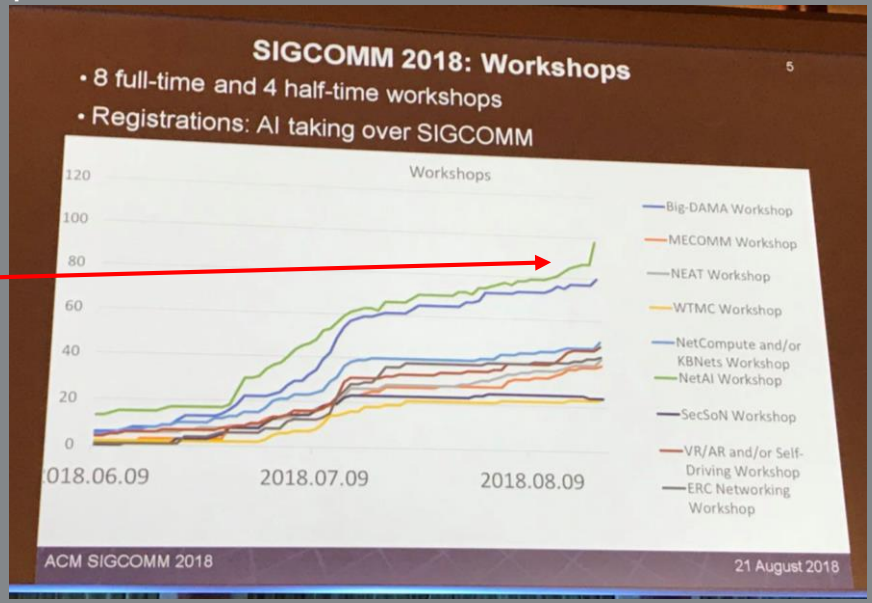
ML Applications in Networking Area [IEEE NETWORK'17]

Machine Learning

- Classification
  - Traffic classification: [TON'15][CCS'16 AISec][KDD'17]
  - Network security: [S&P'10]
- Prediction
  - Measurement inference: [CoNEXT'17] [Sigcomm'18 NetAI]
  - Performance prediction: [Sigcomm'16]
  - Performance extrapolation: [Sigcomm'08]
- Decision making
  - Routing: [HotNets'17][Sigcomm'18 Big-DAMA]
  - Traffic optimization: [Infocom'17][Sigcomm'18]
  - Congestion control: [Sigcomm'13&14][ATC'18][NDSI'15&18]
  - Video streaming QoE optimization: [NSDI'17][Sigcomm'17]
  - Topology configuration: [Sigmetrics'18][Sigcomm'18 NetAI]

AI接管SIGCOMM

- Sigcomm 2018主会
  - AuTO: Scaling Deep Reinforcement Learning to Enable Datacenter-Scale Automatic Traffic Optimization [HKUST]
  - SketchLearn: Relieving User Burdens in Approximate Measurement with Automated Statistical Inference [CAS]
  - RF-Based 3D Skeletons [MIT]
- Workshop
  - NetAI：12篇
    - SIGCOMM历史上首次人数破百
  - Big-DAMA：8篇
  - SelfDN：2+篇
- Posters and Demos：4+篇



SIGCOMM 2019

SIGCOMM 2019 BEIJING

- Main conference:
  - Learning: packet clas… …reinforcement learning
  - Video: live, uploadin… …on, QoE fairness
- Workshop and poster …
  - Learning: CC, cellular… …ability, verification, modeling

1. 自适应码率（ABR）算法

2. 机器学习驱动的ABR算法

3. AITrans竞赛与直播场景下的ABR算法

视频，视频，还是视频！

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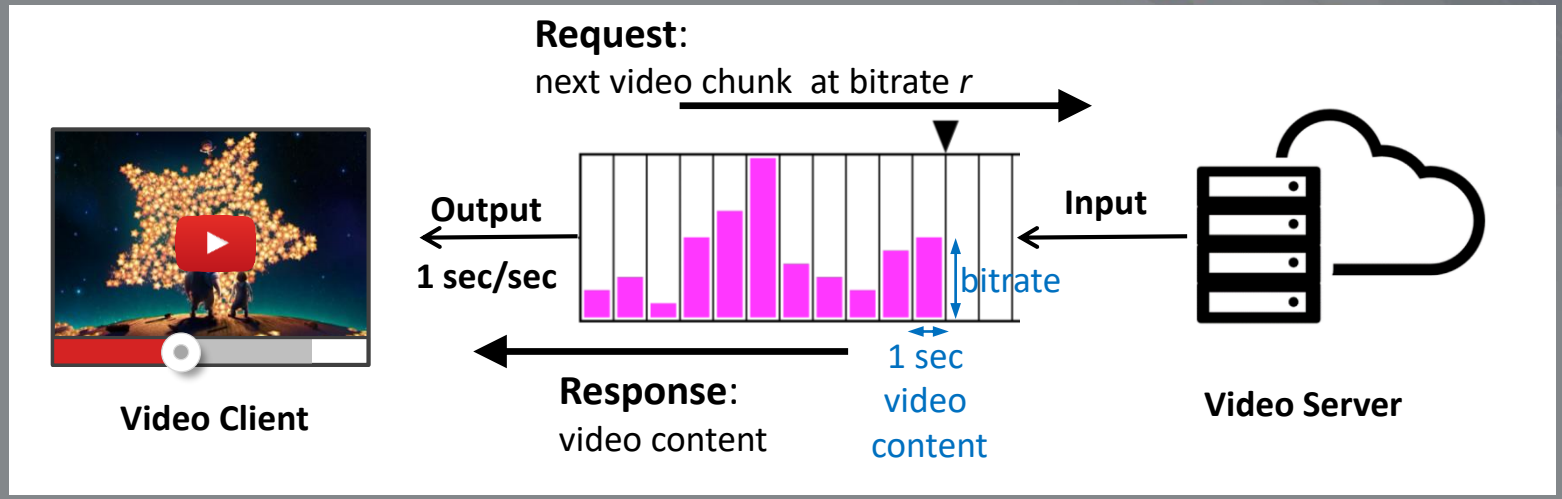
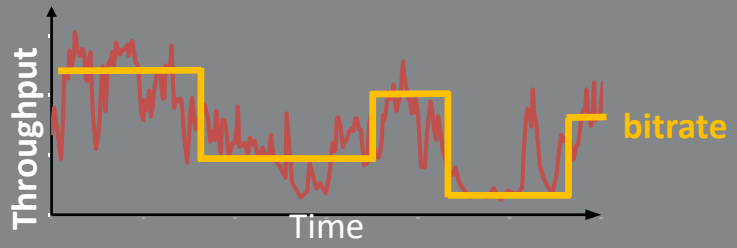
画质
1080p50 HD
720p50 HD
480p
360p
240p
144p
自动
0:07 / 2:10
滚动浏览详情

自适应码率 Adaptive Bitrate (ABR) Algorithms



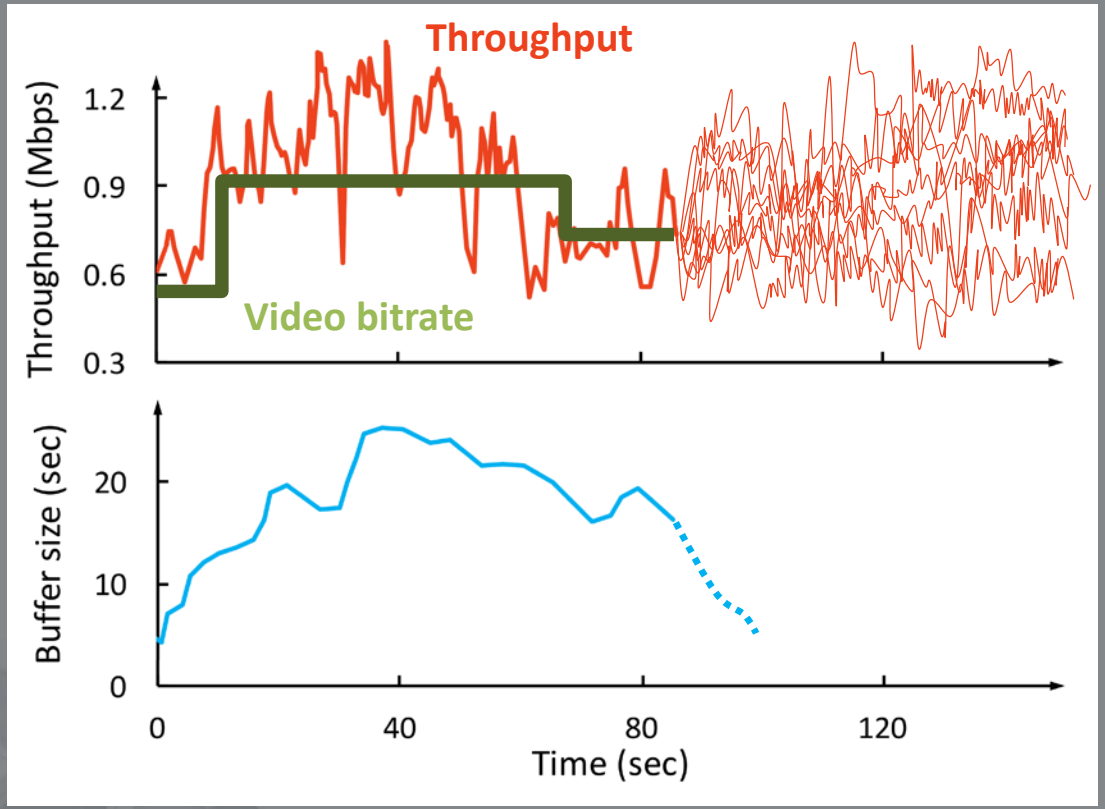
ABR的优化目标

- 提升用户的体验质量 Quality of Experience (QoE)
- 指标：视频质量，卡顿时间，码率抖动等



Animation borrowed from Te-Yuan Huang (SIGCOMM '14) http://conferences.sigcomm.org/sigcomm/2014/doc/slides/38.pdf

为什么ABR是一个挑战?



网络带宽变化&难以预测

QoE指标之间相互冲突

- 高视频质量
- 低卡顿
- 视频质量平滑切换

码率决策具有级联效应

Animation borrowed from pensieve's slides.

相关工作

- 传统 ABR 算法
  - Rate-based: 基于估计的throughput进行码率决策[FESTIVE CoNEXT'12]
  - Buffer-based:基于buffer占用量进行码率决策[BBA SIGCOMM'14]
  - Hybrid [...] GCOMM'15]
    - 基
- 基于机器
  - Throug [...] S2P SIGCOMM'16]
  - End-to- [...] SIGCOMM'17]

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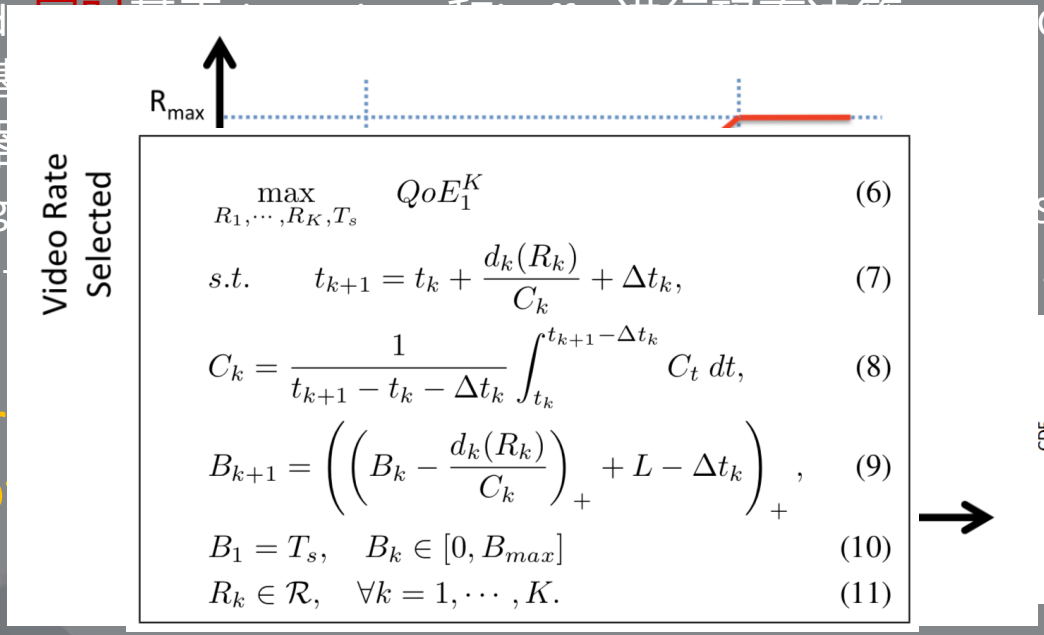


$$\max_{R_1,\cdots,R_K,T_s} \quad QoE_1^K \tag{6}$$

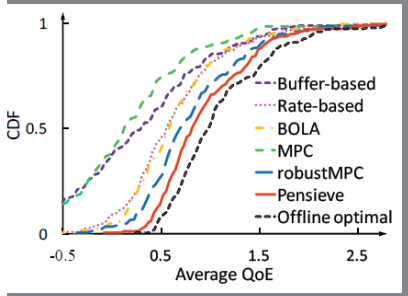
$$s.t. \quad t_{k+1} = t_k + \frac{d_k(R_k)}{C_k} + \Delta t_k, \tag{7}$$

$$C_k = \frac{1}{t_{k+1} - t_k - \Delta t_k} \int_{t_k}^{t_{k+1}-\Delta t_k} C_t \, dt, \tag{8}$$

$$B_{k+1} = \left(\left(B_k - \frac{d_k(R_k)}{C_k} \right)_+ + L - \Delta t_k \right)_+, \tag{9}$$

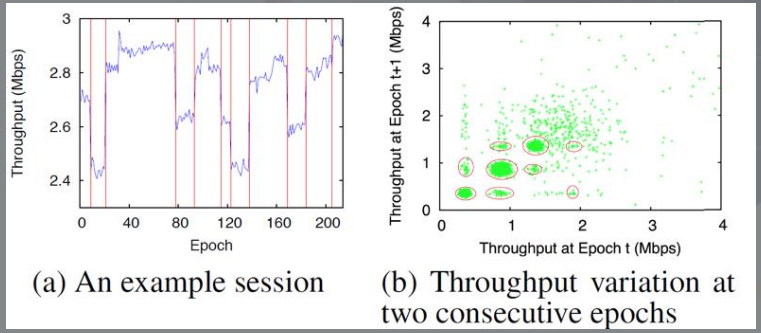
$$B_1 = T_s, \quad B_k \in [0, B_{max}] \tag{10}$$

$$R_k \in \mathcal{R}, \quad \forall k = 1, \cdots, K. \tag{11}$$

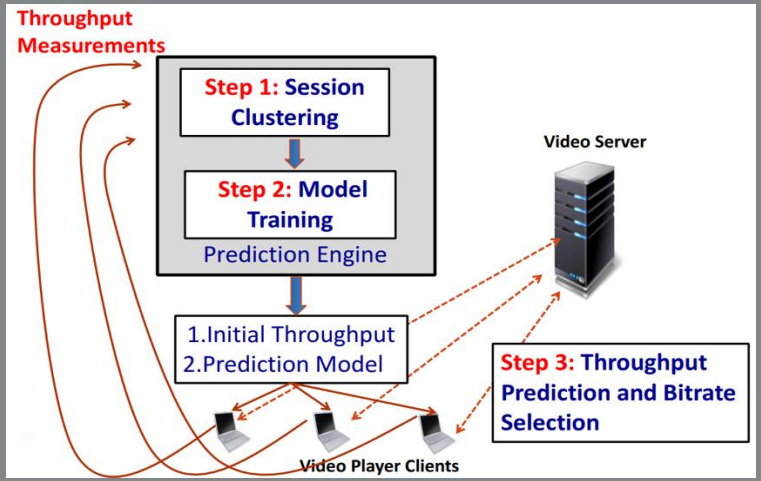


CS2P [ICT/CAS Sigcomm'16]

- Throughput预测
  - Cross-Session Stateful Prediction
  - 准确的吞吐量预测->更好的码率选择
- 测量与分析
  - 吞吐量具有状态特性
  - 关键特征相同的会话吞吐量特性相似
- 解决方案
  - 利用关键特征对会话进行聚类
  - 针对每个类别训练隐马尔可夫模型
  - 多个小模型效果优于一个大模型



(a) An example session (b) Throughput variation at two consecutive epochs



CS2P, Sun et al. Sigcomm'16

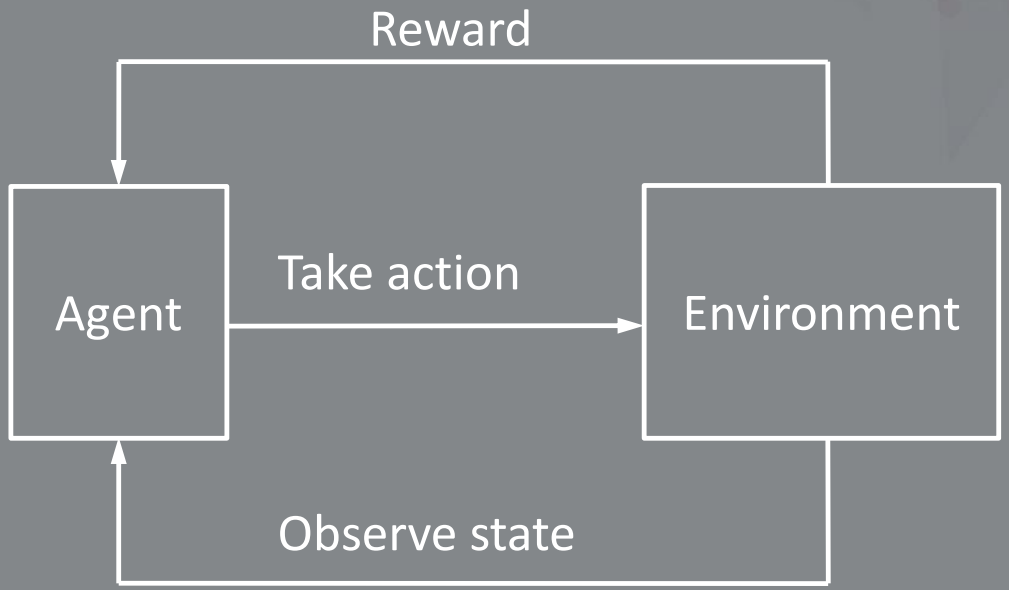
Pensieve [MIT Sigcomm'17]

- *“Algorithms suffer from a key limitations: they use fixed control rules based on simplified or inaccurate models of the deployment environment. As a result, existing schemes inevitably fail to achieve optimal performance across a broad set of network conditions.”*

  ——Pensieve

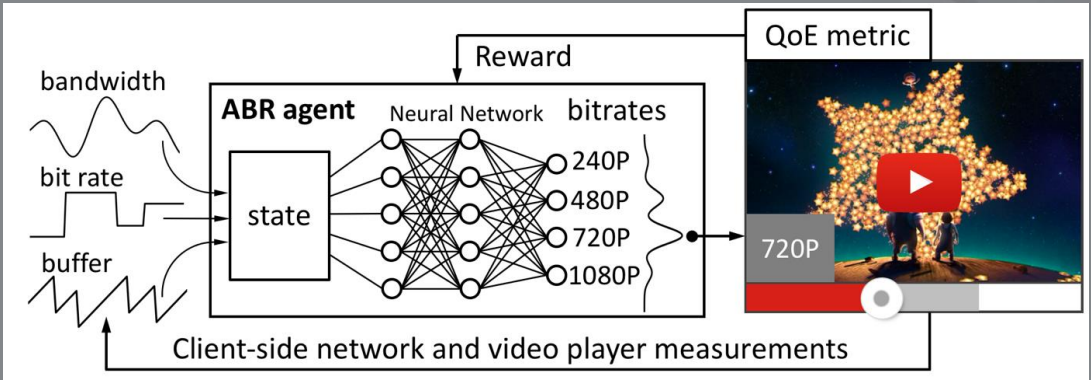
- 基于深度强化学习端到端进行码率决策
  - 强化学习适配序列决策
  - 深度神经网络处理多维输入信号
  - 交互式学习去除过多模型假设
  - 奖励函数支持多种优化目标

Reinforcement Learning



Goal: maximize the cumulative reward

Pensieve



- State：吞吐量，下载时间，块大小，buffer大小，剩余chunk数，上次决策
- Action：码率档位
- Policy：神经网络
- Reward：单步QoE函数
- Training：A3C算法快速异步更新
- Environment：仿真器模拟客户端下载行为，高加速比
- Dataset：真实trace or 人工合成trace

$$\mathrm{QoE} = \alpha \sum_{n=1}^{N} q(R_n) - \beta \sum_{n=1}^{N} T_n - \gamma \sum_{n=1}^{N-1} |q(R_{n+1}) - q(R_n)|$$

质量 卡顿 切换

Pensieve, Mao et al. Sigcomm’17

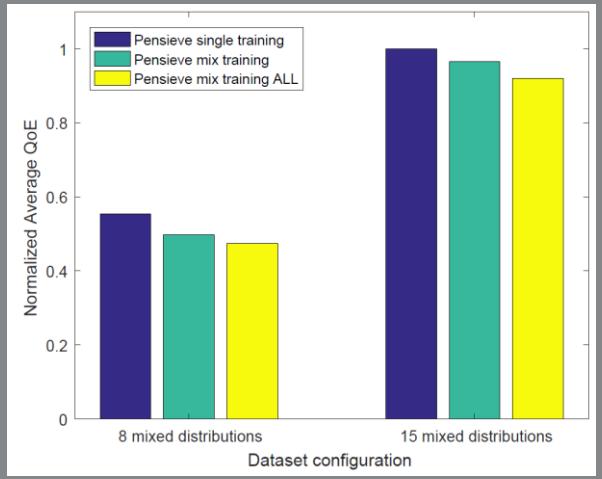
机遇与挑战

- QoE模型 (优化目标)
  - 用户偏好，业务需求?
  - 主观模型：MOS
  - 训练完成后，不可调整，多目标强化学习?

$$\mathrm{QoE} = \alpha \sum_{n=1}^{N} q(R_n) - \beta \sum_{n=1}^{N} T_n - \gamma \sum_{n=1}^{N-1} |q(R_{n+1}) - q(R_n)|$$

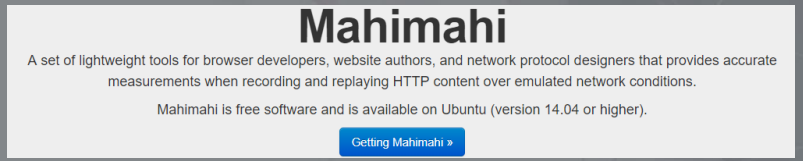
质量 卡顿 切换

- 泛化
  - 网络场景：
    - In-distribution: 多分布混合训练，性能下降
    - Out-of-distribution: 没有训练过的场景
  - 视频源：内容特性，编码器设置
  - 在线学习? Meta-learning



机遇与挑战

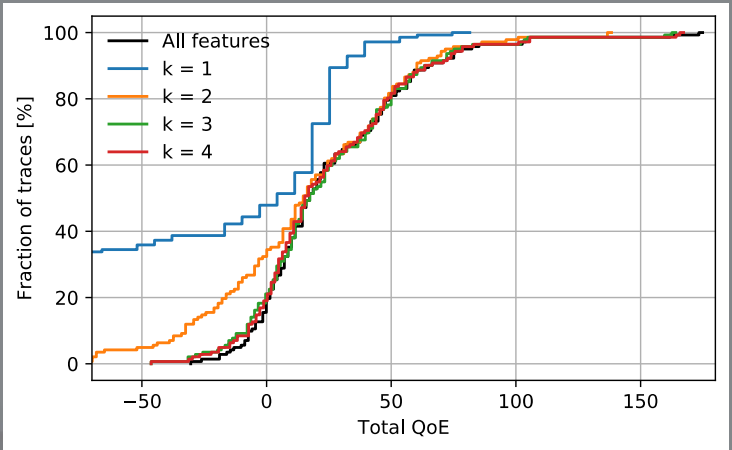
- 仿真器与真实网络环境
  - 传输层信息（e.g. RTT）与反馈
  - 多用户带宽竞争与QoE公平 [Minerva SIGCOMM19]
  - Throughput trace与带宽
  - 跨层优化?



- 潜在方向
  - 新场景：直播，360全景视频，RTC
  - 基础设施：benchmark，仿真系统，开放数据集
    - Pantheon: TCP拥塞控制的训练场 [ATC18 Best paper]

机遇与挑战-可解释性

- **Cracking Open the Black Box: What Observations Can Tell Us About Reinforcement Learning Agents**
  - Arnaud Dethise, Marco Canini, Srikanth Kandula
  - SIGCOMM 2019 NetAI
- “Removing” some inputs



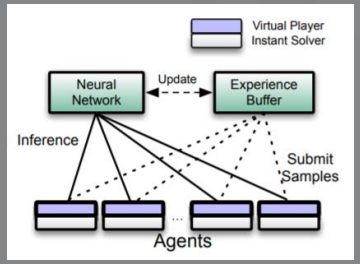
- Previous bit rate
- Buffer
- ThroughputT
- ThroughputT-1

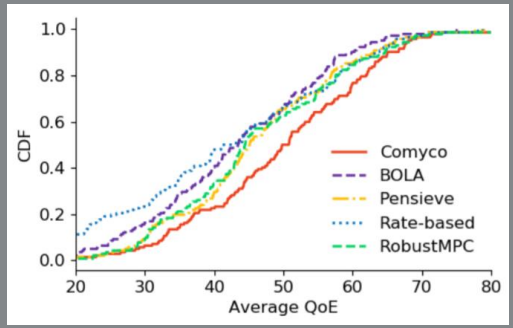
Even with incorrect inputs, pensieve achieve high performance

Borrowed from “Cracking Open the Black Box”’s slides.

后pensieve时代

- 基于模仿学习的质量感知ABR算法
  - Comyco: Quality-Aware Adaptive Video Streaming via Imitation Learning [ACM MM 2019]
  - Tianchi Huang, Chao Zhou, Rui-Xiao Zhang, Chenglei Wu, Xin Yao, Lifeng Sun
- 挑战
  - Model-free RL: 低效学习，收敛不佳
    - ✓ 通过模仿离线最优策略更新迭代自身
  - 未将画面质量考虑入QoE指标中
    - ✓ 更关注画面质量（VMAF），卡顿，平滑度与用户体验之间的关系
- 基于模仿学习
  - 快速高效生成ABR算法
  - 收敛时间加快16倍，QoE提升7.5%到16.7%。

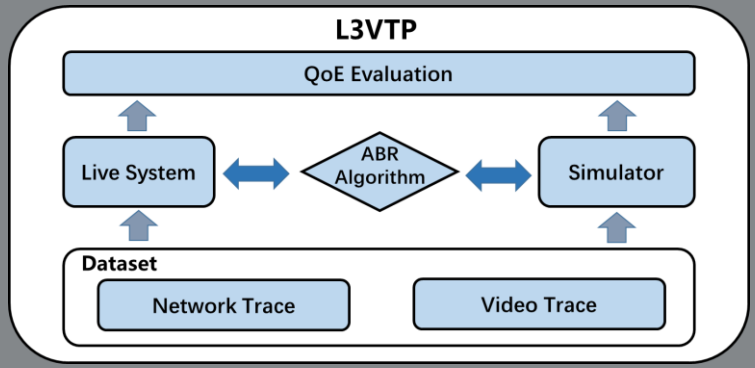




直播流媒体传输质量优化

- AITrans & ACM MM Grand Challenge
- 优化挑战
  - DASH以视频块为传输单位，延迟大
  - 直播内容实时产生，ABR算法可利用信息减少
  - 低延迟、高清、低卡顿、少切换的多目标QoE
- 解决方案
  - 帧级别基于Push的直播流媒体传输系统
  - 时延控制机制：快慢播、跳帧
  - 首个低时延直播传输仿真平台L3VTP
    - 数据集、仿真器、真实系统、在线评测

AITrans 智能网络传输竞赛

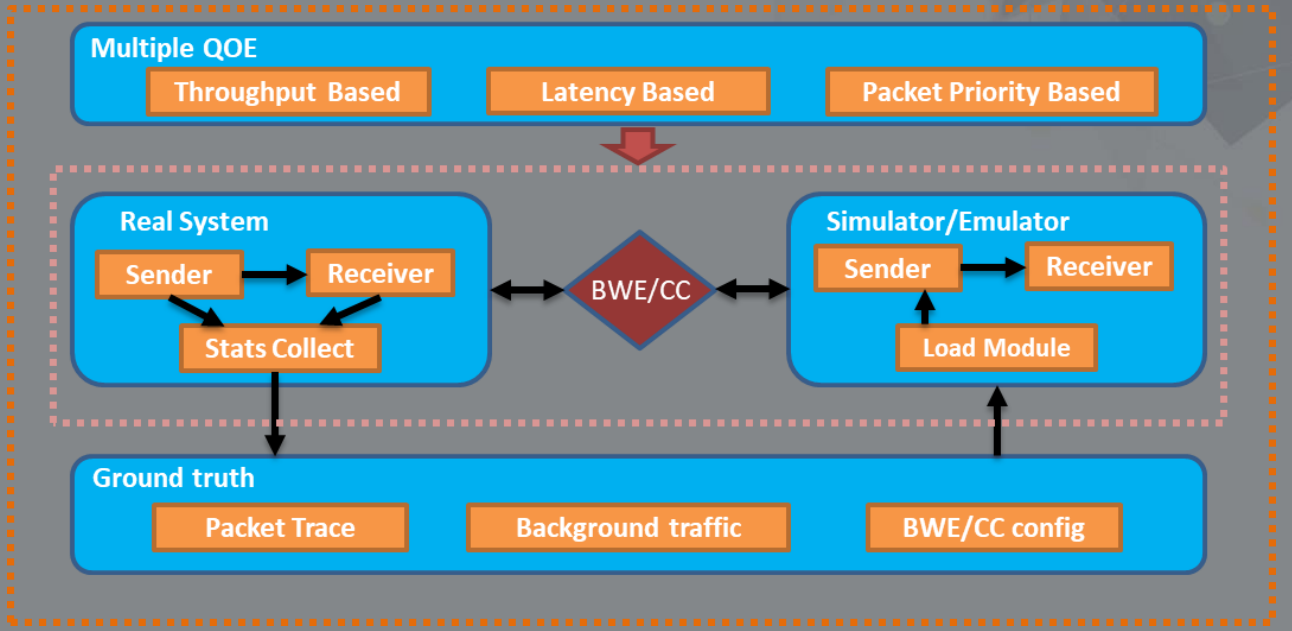


Lessons Learned

- 选手算法总结
  - BBA、MPC、pensieve算法变种
    - 多阈值BBA
    - MPC + Oboe [sigcomm’18]
    - Pensieve：输入，训练算法，神经网络结构
- 关键设计
  - 网络状态分类
  - 源端信息预测：I帧大小和间隔
  - 强化学习中的Reward对齐
- 教训
  - 不要过度依赖仿真器

The 2nd AITrans competition

- Topic: BWE/CC
- Components
  - Multiple QoE
  - Testbed
    - Real System
    - Sim/Emu
    - Algorithm
  - Ground Truth
    - Packet Trace
    - Traffic Trace
    - Config
- 2019.11 – 2020.5
- Detail info



Q&A

- AITrans 智能网络传输大赛
  - https://www.aitrans.online/
- ACM MM grand challenge 2019
  - https://www.aitrans.online/MMGC/
- L3VTP: Sigcomm 2019 poster
  - https://github.com/L3VTP/L3VTP
- AI for Networking:
  - Machine Learning for Networking: Workflow, Advances, and Opportunities [IEEE Network’17]

北京
2019

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Thank you

出品：LiveVideoStack 音视频技术社区 CSDN