Analysis of Adaptive Streaming for CDN/P2P Live Video Systems

Presenter: Xuanjia Qiu

Nov. 30, 2011

Introduction

- Author: A. Mansy and M. Ammar, from Georgia Institute of Technology.
- Pushlied at ICNP 2011(October 17-20)
- Significance: Existing researches explore Adaptive streaming and Hybrid(CND/P2P) streaming system respectively, but not yet explore the combination of the two.
- Highlight: Build the model with existing models as building blocks.

Definition and problem

- Adaptive streaming:
- Hybrid CDN/P2P:
- Questions:
  - How to find a way to switch the operation of the system between the CDN and P2P modes
  - How to find the best bitrate adaption strategy
  - Is a hybrid adaptive system better than a classic CDN adaptive system? (of course, because peers contribute upload bandwidth) How much better will it be? (can not answer withouth a quantitative model)

System Architecture

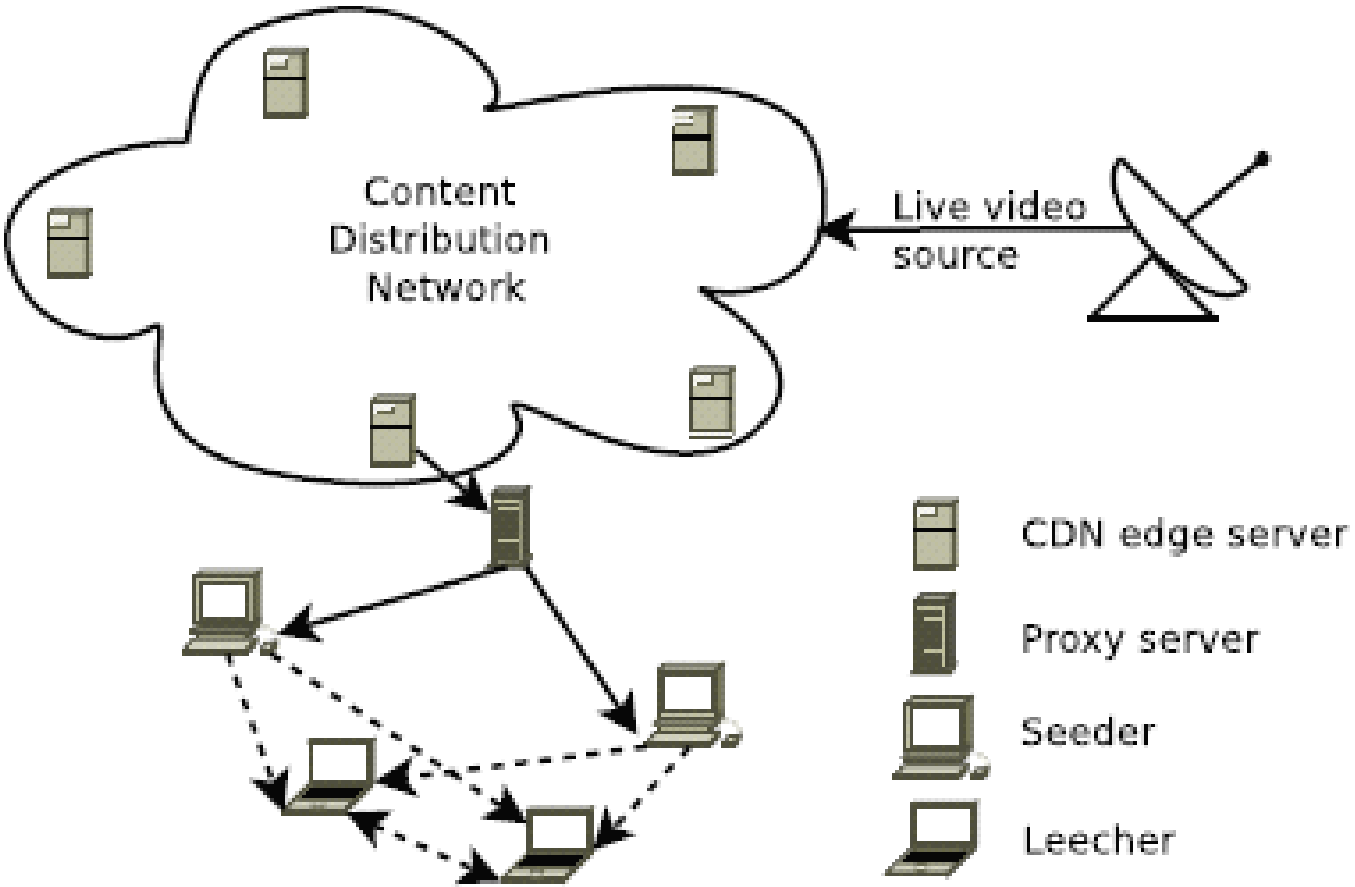


Fig. 1: System architecture

Approach

- Hybrid system model with single rate
  - **Unconstrained churnless system (fluid model)**
  - **Unconstrained system with churn(M/G/∞ queueing model)**
  - Constrained churnless system
  - Constrained system with churn
- Adaptive hybrid system model
  - ..... (similar as the previous part)
- CDN adaptive model

- churn:
  - model as simple queueing model M/G/infinity, get the function: prob.=F(queueing length<x)
  - give a confidence level
  - give a interval

Single rate, unconstrained, churnless

- Relationship between streaming rate, # of seeders, # of leechers, bw. of seedrs, bw. of leechers

$$r \leq \frac{n_s u_s + n_l u_l}{n_l}$$

Single rate, unconstrained, with churn

- The key is to find the probablity relating to peer population
- M/G/∞

$$
\begin{aligned}
P(\text{support bitrate } r) &= P(r \leq \frac{n_s u_s + N u_l}{N}) \\
&= P(N \leq \frac{n_s u_s}{r - u_l}) = F(\frac{n_s u_s}{r - u_l})
\end{aligned}
$$

- Relationship between streaming rate, # of seeders, # of leechers, bw. of seedrs, bw. of leechers

$$
n_s \geq \frac{(\phi_{1-\alpha}\sqrt{\rho} + \rho)(r - u_l)}{u_s}
$$

Single rate, constrained, churnless

- Avg. download bw. of leechers

$$
\begin{aligned}
d &= \sum_x E[d|\text{leecher is connected to } x \text{ seeders}] \times Pr\{x\} \\
&= \sum_x \left(\frac{x u_s}{S_{in}} + \frac{(Y_{out} - x)\eta u_l}{Y_{in}} \right) \times Pr\{x\} \\
&= \frac{Y_{out}\eta u_l}{Y_{in}} + \left(\frac{u_s}{S_{in}} - \frac{\eta u_l}{Y_{in}} \right) \sum_x x Pr\{x\} \qquad (4)
\end{aligned}
$$

$$
d = \frac{n_s u_s + \eta n_l u_l}{n_l}
$$

Adaptive, unconstrained, churnless

- Mininze peers' dissatisfaction under capacity constraints.

$$\min \sum_{i=1}^{R} \sum_{j=i}^{R} x_{ij} n_{l_i} (r_i - r_j) \tag{7}$$

subject to: $\sum_{j=i}^{R} x_{ij} = 1$, $0 \leq x_{ij} \leq 1$ for $i = 1, \ldots, R$

$$n_{s_i} u_s \geq \left(n_{l_i} x_{ii} + \sum_{k=1}^{i-1} n_{l_k} x_{ki} - n_{s_i} \right) (r_i - u_l) \tag{8}$$

$$\sum_{i=1}^{R} n_{s_i} r_i \leq C_{proxy} \tag{9}$$

Adaptive, unconstrained, with churn

- Relationship between streaming rate, # of seeders, # of leechers, bw. of seedrs, bw. of leechers

$$n_{s_i} u_s \geq (\phi_{1-\alpha}\sqrt{\hat{\rho}_i} + \hat{\rho}_i)(r_i - u_l)$$

where $\hat{\rho}_i = \rho_i x_{ii} + \sum_{k=1}^{i-1} \rho_k x_{ki}$

CDN adaptive

- Mininze peers' dissatisfaction under capacity constraints.

$$\min \sum_{i=1}^{R} \sum_{j=i}^{R} x_{ij} n_i (r_i - r_j)$$

-

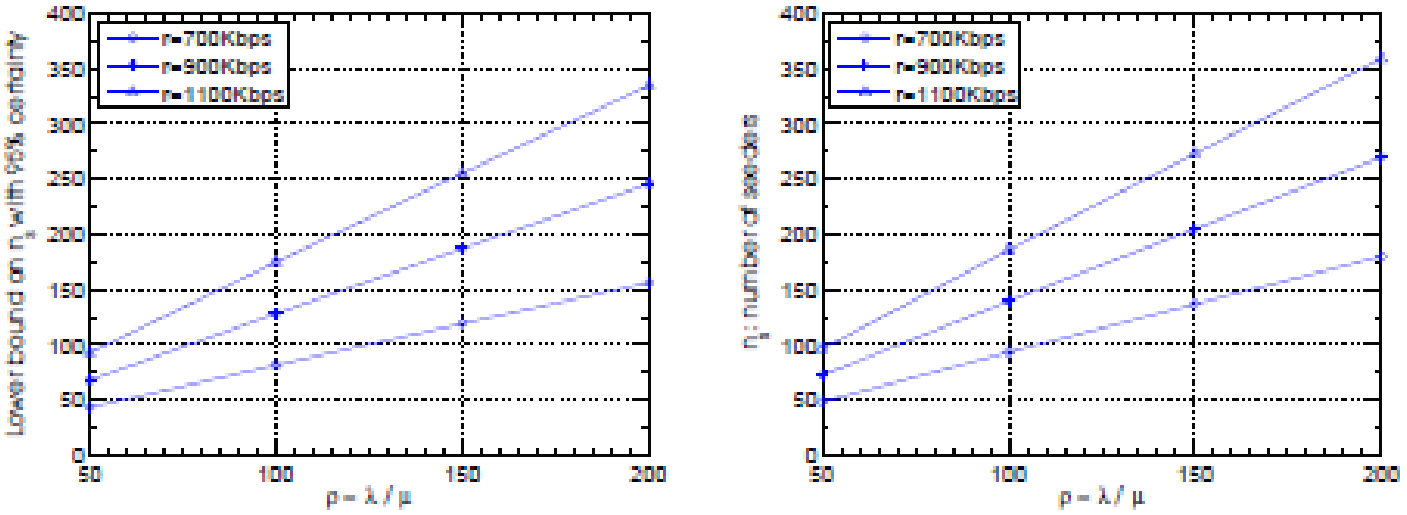
$$\text{subject to: } \sum_{j=i}^{R} x_{ij} = 1 \ , \ 0 \leq x_{ij} \leq 1 \text{ for } i = 1, \ldots, R$$

$$\sum_{i=1}^{R} r_i \left(n_i x_{ii} + \sum_{k=1}^{i-1} n_k x_{ki} \right) \leq C_e \qquad (12)$$

Validation

- 1. Validate single-rate model (show gap between fluid model and reality. Fluid model is the corestone of the whole model)
- 2. Validate the CDN adaptive model
- 3. Fix bandwidth capacity and compare QoS
- 4. Fix QoS and compare bandwidth saving

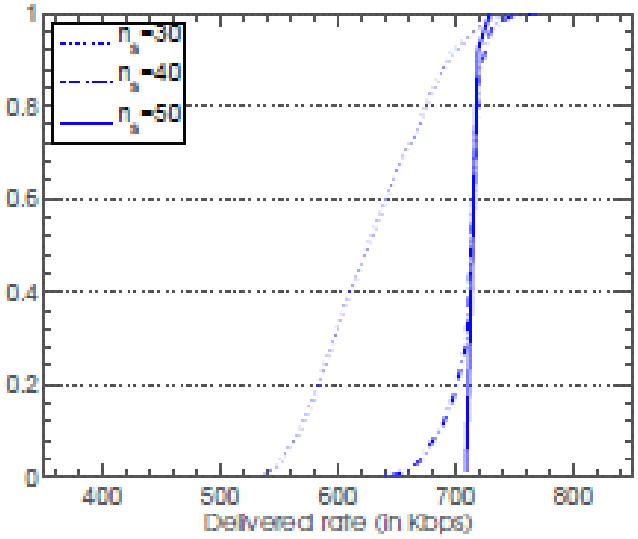
Numerical results of single-rate model



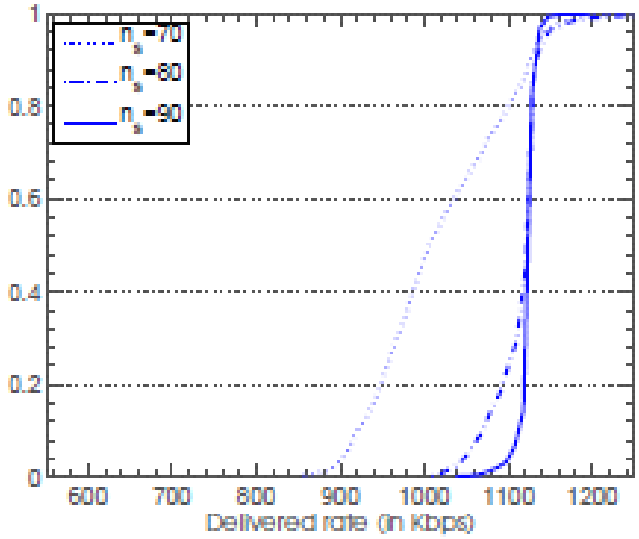
(a) Unconstrained system (b) Constrained system

Fig. 2: n_s vs ρ for different video bitrates for systems with churn, $\alpha = 0.05$

Validate single-rate model



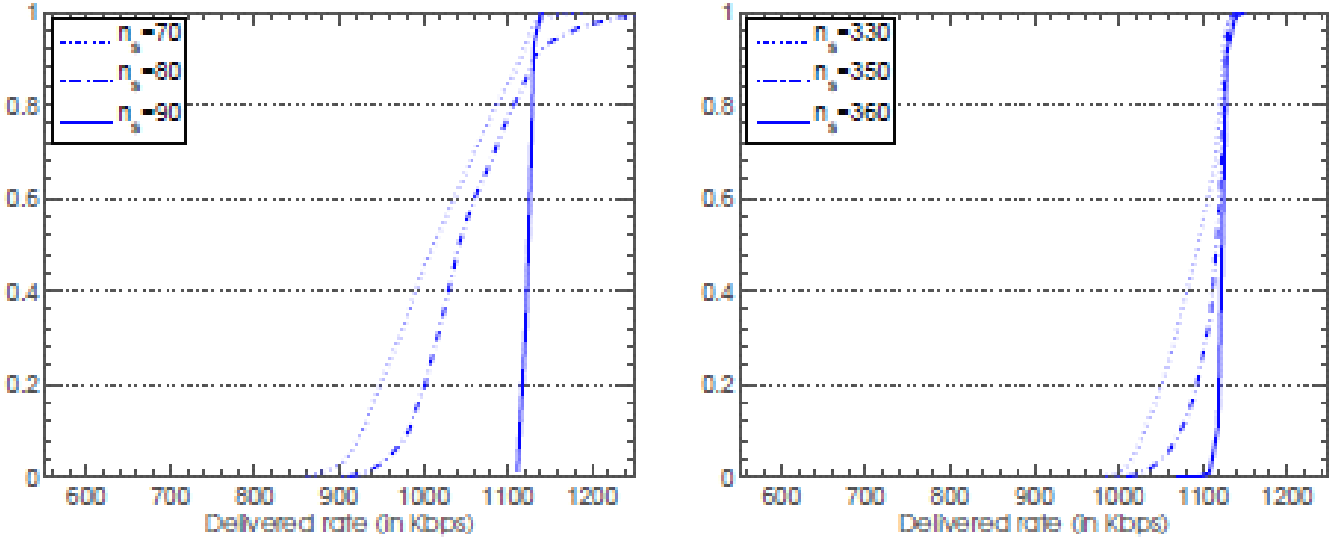
(a) $r = 700Kbps, \rho = 50$



(b) $r = 1100Kbps, \rho = 50$

Fig. 3: CDF of average delivered rate for unconstrained system with churn

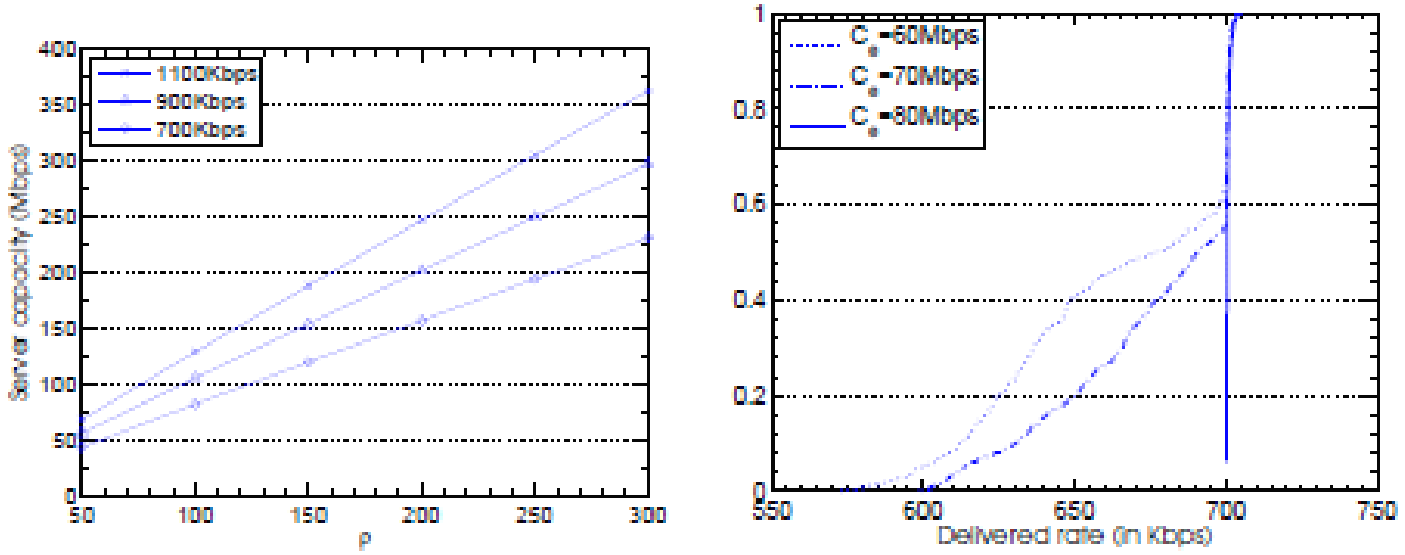
Validate single-rate model



(a) $\rho = 50$ (b) $\rho = 200$

Fig. 4: CDF of average delivered rate for constrained system with churn, $r = 1100Kbps$

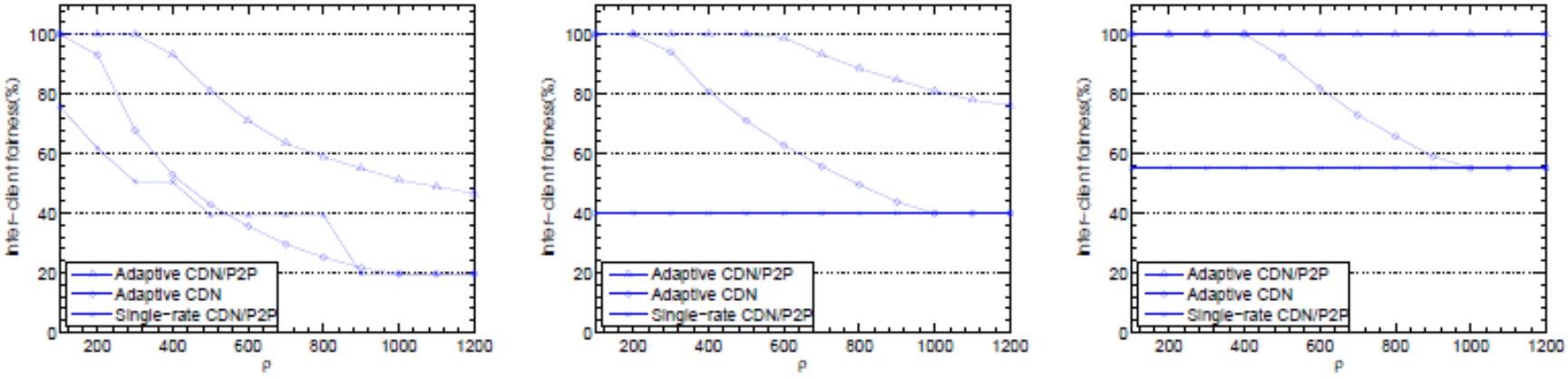
Validate the CDN adaptive model



(a) Server capacity (C_e) vs ρ (b) $\rho = 100, r = 700$Kbps

Fig. 5: CDN system with churn

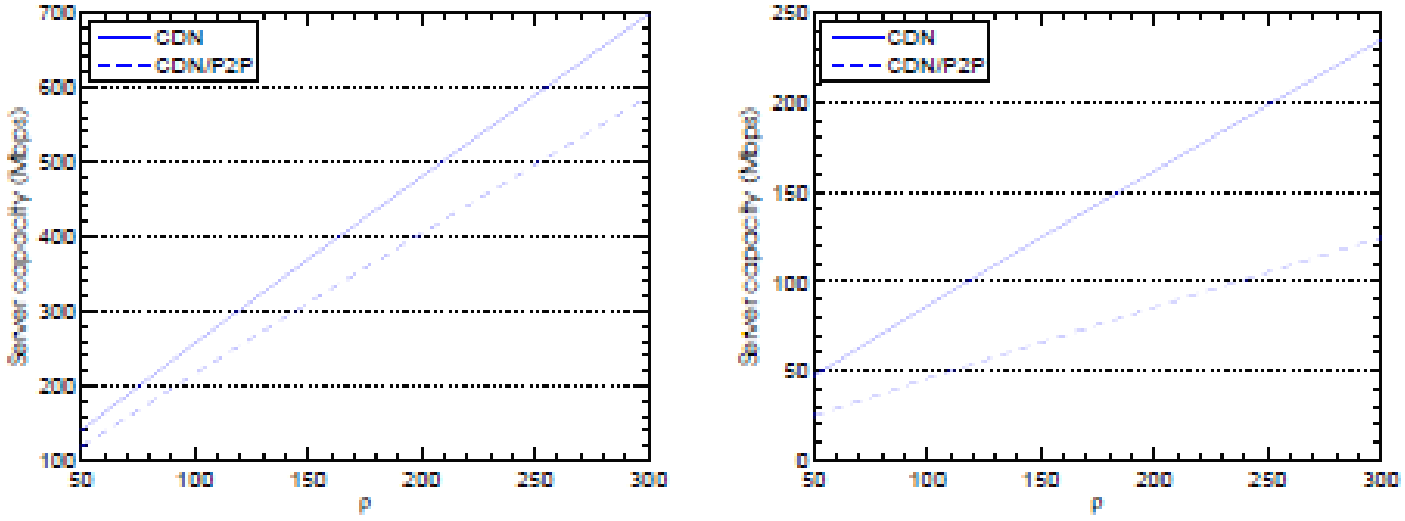
Fix bandwidth capacity and compare QoS



(a) High bitrate bias (b) Uniform distribution over bitrates (c) Low bitrate bias

Fig. 6: Inter-client fairness for systems with churn

Fix QoS and compare bandwidth saving



(a) High bitrate bias (b) Low bitrate bias

Fig. 7: Required server capacity for CDN/P2P and CDN systems with churn

Q & A

Thank you!