A Case for Taxation in Peer-to-Peer Streaming Broadcast

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Outline

- Introduction
- P2P Stream Broadcast
  - Bit-for-Bit model
  - Taxation model
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Introduction

- In p2p streaming, the bottleneck resource is the bandwidth capacity.
- The Bit-for-Bit model limits the amount of bandwidth that resource-poor peers can receive.

Bit-for-Bit Model

- *Bit-for-Bit* model, these resource-poor peers would only receive lower video bitrate, even though they have enough capacity to receive a much higher bitrate.

- The net result is that these resource-poor peers would *not* participate in the broadcast due to the poor quality.

Taxation

- In the taxation model, resource-rich peers contribute more bandwidth to the system, and subsidize for the resource-poor peers.

Model of P2P Streaming

- We model the bandwidth capacity of a peer *i* with two parameters:
  - forward capacity (*Fi*)
  - receive capacity (*Ri*)
- We denote the actual bandwidth a peer contributes and receives as *fi* and *ri*.

Model of P2P Streaming

- A peer gains benefit b_i when it receives bandwidth from the broadcast system, and incurs cost c_i when it contributes bandwidth to the system.

- $u_i(r_i, f_i, F_i) = b_i(r_i) - c_i(f_i, F_i)$

Model of P2P Streaming

- The benefit function (b_i) captures the user-perceived video quality.
  - $b_i(r_i)=\sqrt{r_i}$
- The cost function (c_i) captures the cost of forwarding data.
  - $c_i(f_i, F_i) = \alpha * \sqrt{F_i} * p_i(f_i, F_i)$
  - $p_i(f_i, F_i) = \beta * (f_i/F_i) + (1-\beta) * (f_i/F_i)^4$

Taxation in P2P Streaming

- *Asymmetry of roles and power*
- *Public and fixed tax schedule*
- *Fair*
  - Horizontal Fairness
  - Vertical Fairness
- *Budget balanced*

Linear Tax Schedule

- We choose a linear tax schedule, which takes on two parameters:
  - t → marginal tax rate
  - G → lump sum grant, also known as demogrant.

- f = max(t*(r-G), 0)

Linear Tax Schedule

- When $t = 1$, the tax schedule becomes *Bit-for-Bit* and $G = 0$.
  - This is because when $fi = ri$, there is no extra tax expenditure for demogrant.
- When $t > 1$, the demogrant G may be greater than 0.
  - If a peer contributes more than it receives ($fi > ri$), the bandwidth difference goes to a *demogrant pool*.

Example of Tax Schedules

Linear taxation
t=2, G=1

f	r
0	1
2	2
4	3

Linear taxation
t=2, G=2

f	r
0	2
2	3
4	4
6	5
8	6

Bit-for-Bit

f	r
0	0
1	1
2	2
3	3

tax schedule

f	r
0	1
2	2
4	3

outcome

	F	R	f	r	U
Peer A	10	3+	4	3	1.45
Peer B	4	3+	2	2	1.16
Peer C	1	3+	0	1	1.0

(a) Linear taxation with t=2.0, G=1: **S=1.20**

tax schedule

f	r
0	0
1	1
2	2
3	3

outcome

	F	R	f	r	U
Peer A	10	3+	3	3	1.54
Peer B	4	3+	2	2	1.16
Peer C	1	3+	1	1	0.25

(b) Bit-for-Bit with t=1.0, G=0: **S=0.98**

An example illustrating the two tax schedules and their impact on the strategy and utility of the three peers.

Multiple Tree Protocol

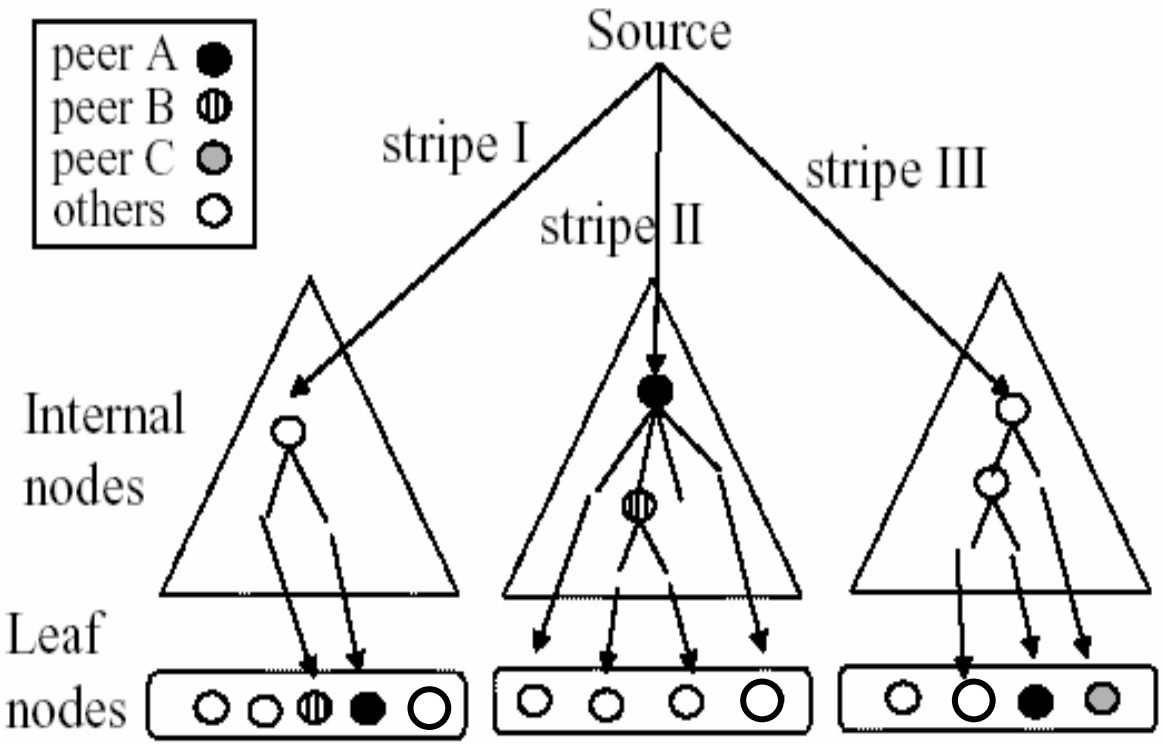
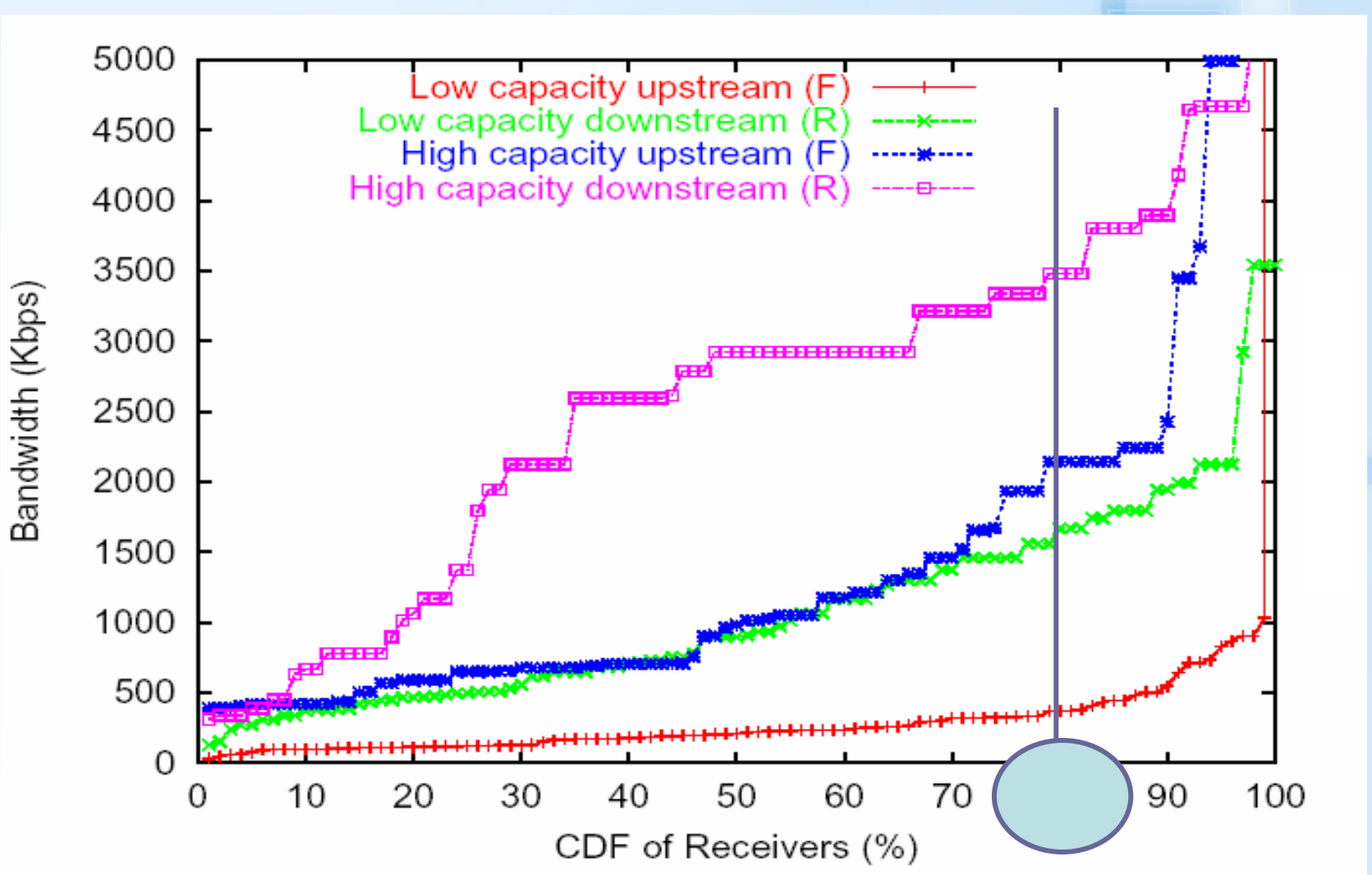


Figure 1: An example of a multiple disjoint tree structure.

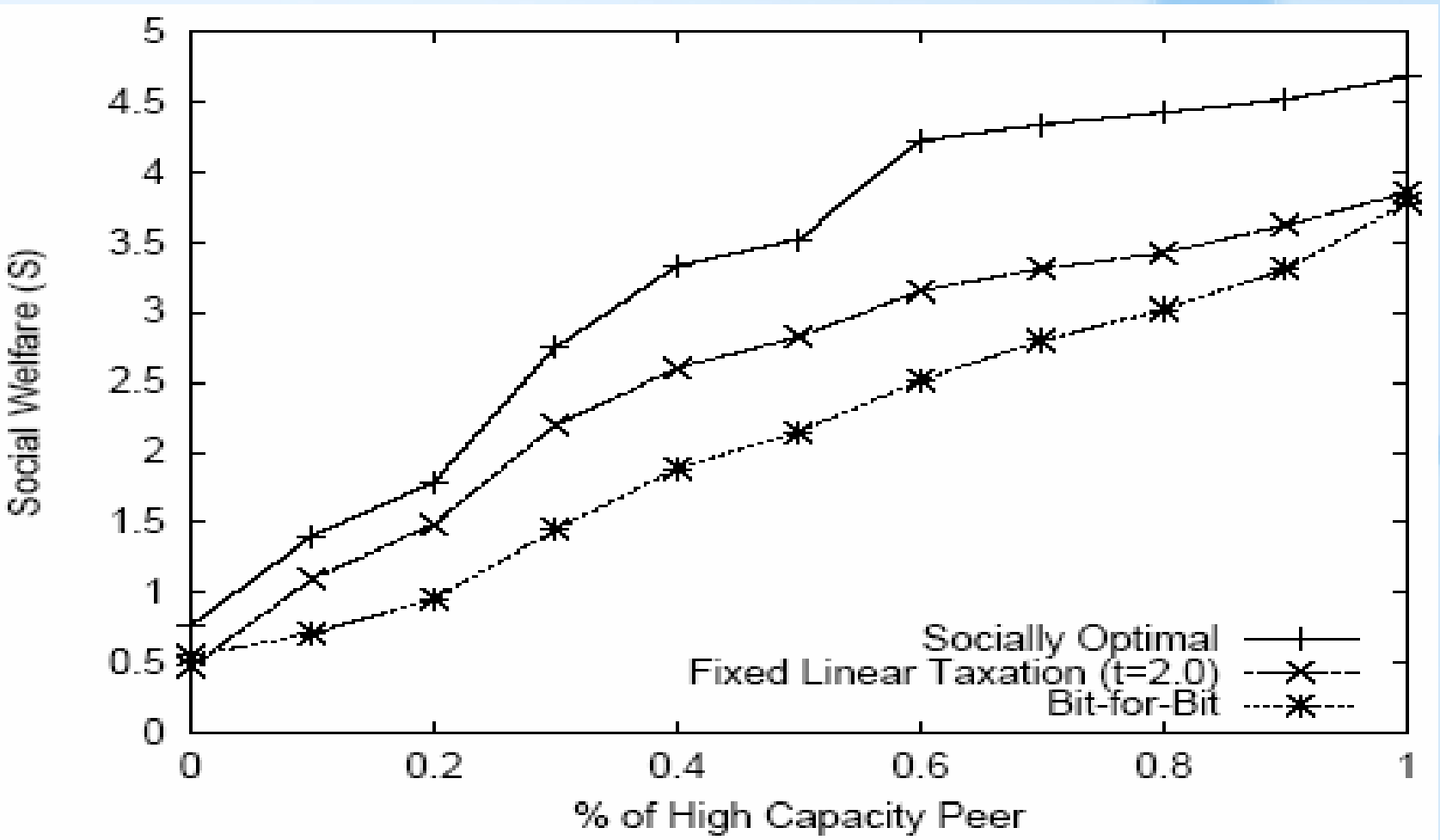
Evaluation

- Does taxation yield good social welfare outcome under various peer environment?
- What is the performance implication when incorporating taxation in a distributed streaming protocol?

Measured TCP throughput of peers



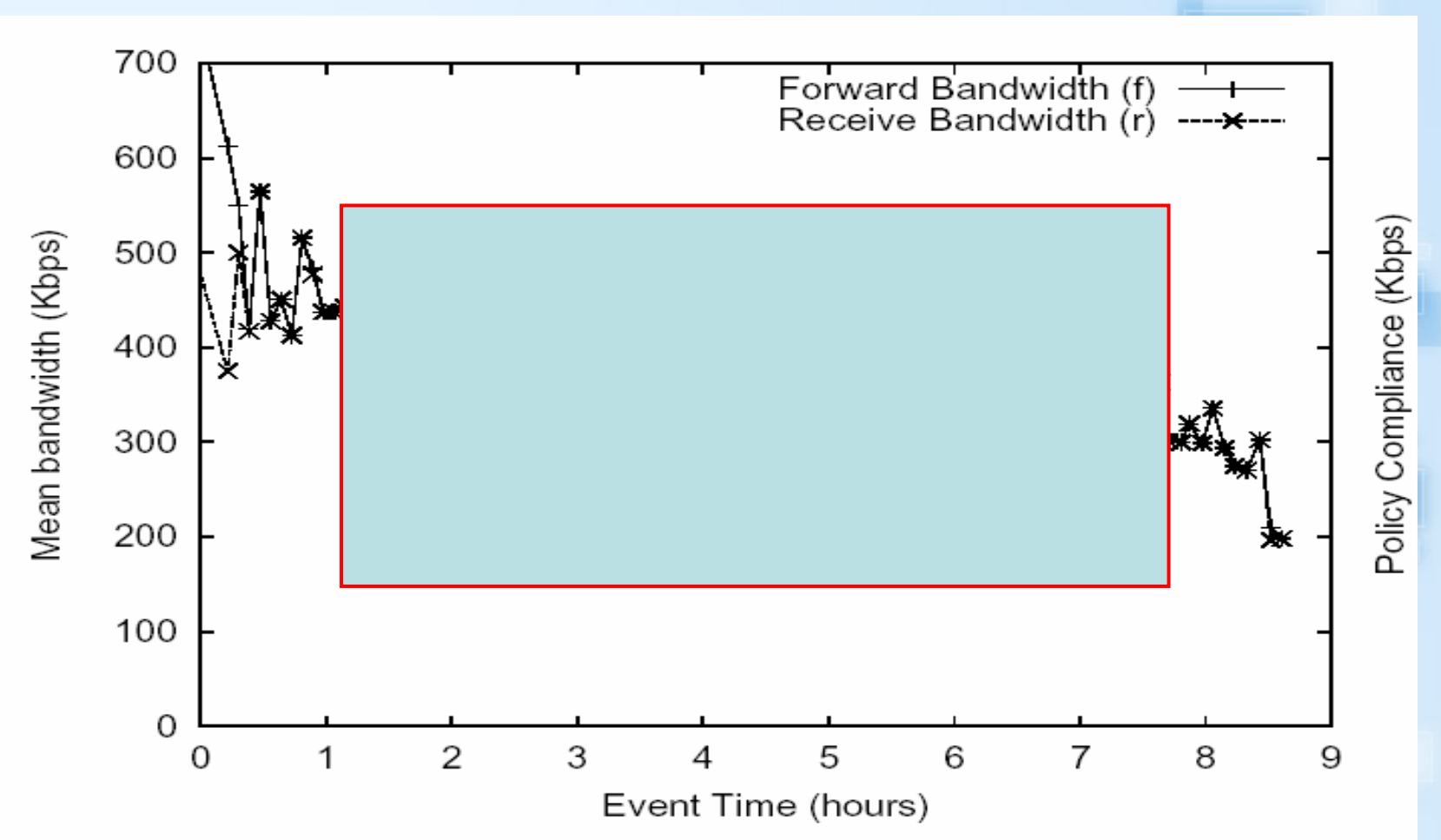
Social welfare as a function environment heterogeneity for the taxation scheme and the two benchmark schemes.



Effectiveness of Linear Taxation

- Best Linear Tax Scheme
  - The tax schedule is linear but the rate can be adjusted dynamically.
- Best (Non-Linear) Taxation Scheme
  - The tax schedule can be non-linear *and* the rate can be adjusted dynamically.

Linear & Non-Linear Tax Scheme



Summary

- We leverage the uniqueness of the p2p streaming context and propose *taxation* as an incentive mechanism to achieve a desirable outcome.
- We show that taxation is an effective means to maximize social welfare when peers are strategic in a heterogeneous p2p environment.
- We demonstrate that linear taxation can be implemented efficiently in a distributed streaming protocol with reasonable overhead.