BitTorrent: An Extensible Heterogeneous Model

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Outline

- BT Model
  - Basic Model
  - More Realistic Model
- Model Validation Using Simulation
  - Experiment 1: Two Leecher Classes
  - Experiment 2: Three Leecher Classes
  - Experiment 3: Free-Riders
  - Experiment 4: Peer Set Size

BT Model

- Basic Model:
  - Assumptions
    - Perfect Clustering
    - Unbiased Optimistic Unchokes
  - Sources of download rates
    - Regular Unchokes
    - Optimistic Unchokes
    - Seed Unchokes
  - Free-Riders’ download rates

BT Model

- Basic Model

Regular Unchokes: $$d^i_{reg} = \frac{N^i_l u^i \frac{x_r}{x}}{N^i_l} = u^i \frac{x_r}{x}.$$

Optimistic Unchokes: $$d^i_{opt} = \frac{\sum_{j=1}^{h} N^j_l u^j \frac{x_o}{x}}{N_l}.$$

Seed Unchokes: $$d^i_{seed} = \frac{\sum_{j=1}^{h} N^j_s u^j}{N_l}.$$

BT Model

- Basic Model

Class i node's download rate:

$$d^i = d^i_{reg} + d^i_{opt} + d^i_{seed}$$

$$d^i \;=\; u^i \frac{x_r}{x} + \frac{\sum_{j=1}^{h} N_l^j w^j \frac{x_o}{x}}{N_l} + \frac{\sum_{j=1}^{h} N_s^j w^j}{N_l}$$

With Little's Results, we obtain:

$$N^i = \lambda^i T^i, N_l^i = \lambda^i T_l^i,$$
$$N_s^i = N^i - N_l^i = \lambda^i (T^i - T_l^i) = \lambda^i T_s^i.$$

And $T_l^i = \frac{m}{d^i}$, $\lambda^i = p^i \lambda$

BT Model

- Basic Model

We get the equations for class i’s node download rate:

$$
\begin{aligned}
d^i &= u^i \frac{x_r}{x} + \frac{\sum_{j=1}^{h} p^j \lambda \frac{m}{d^j} w^j \frac{x_o}{x}}{\sum_{j=1}^{h} p^j \lambda \frac{m}{d^j}} + \frac{\sum_{j=1}^{h} p^j \lambda T_s^j w^j}{\sum_{j=1}^{h} p^j \lambda \frac{m}{d^j}} \\
&= u^i \frac{x_r}{x} + \frac{\sum_{j=1}^{h} \frac{p^j w^j x_o}{d^j x}}{\sum_{j=1}^{h} \frac{p^j}{d^j}} + \frac{\sum_{j=1}^{h} p^j T_s^j w^j}{\sum_{j=1}^{h} \frac{p^j m}{d^j}}.
\end{aligned}
$$

BT Model

- Basic Model

Free-Rider's download rate:

The download rate for free-riders is:

$$d^h = \frac{\sum_{j=1}^{h} \frac{p^j w^j x_o}{d^j x}}{\sum_{j=1}^{h} \frac{p^j}{d^j}} + \frac{\sum_{j=1}^{h} p^j T_s^j w^j}{\sum_{j=1}^{h} \frac{p^j m}{d^j}}$$

BT Model

- More Realistic Model:
  - Characteristics of real BT systems
    - Imperfect clustering
    - Biased Optimistic Unchoking
  - The download rate
  - Determining Imperfect Clustering Fraction and Unbiased Optimistic Unchoking Fraction

BT Model

- More Realistic Model:

Characteristics of real BT systems:

- Imperfect clustering:

  A fraction of regular unchokes will go to nodes in other classes. Define $q_{i,j}$ to be the fraction of regular unchokes from class i that will go to class j.

- Biased Optimistic Unchoking:

  Optimistic unchokes of a node are not distributed evenly to all leechers. Define $o_{i,j}$ to be the fraction of optimistic unchokes from class i that will go to class j.

BT Model

- More Realistic Model:
  - Given these adjustments, the download rate a class i node receives from regular unchokes from all nodes is:

$$d_{reg}^{i'} = \frac{\sum_{j=1}^{h} q_{j,i} N_l^j u^j \frac{x_r}{x}}{N_l^i}.$$

  - Download rate received from optimistic unchokes is:

$$d_{opt}^{i'} = \frac{\sum_{j=1}^{h} o_{j,i} N_l^j u^j \frac{x_o}{x}}{N_l^i}.$$

BT Model

- More Realistic Model:
  - We get the total download rate of a class i node,

$$d^{i'} = d^{i'}_{reg} + d^{i'}_{opt} + d^{i}_{seed}$$

$$\begin{aligned} d^{i'} &= \frac{\sum_{j=1}^{h} q_{j,i} N_l^j u^j \frac{x_r}{x}}{N_l^i} + \frac{\sum_{j=1}^{h} o_{j,i} N_l^j u^j \frac{x_o}{x}}{N_l^i} \\ &\quad + \frac{\sum_{j=1}^{h} N_s^j u^j}{N_l} \\ &= \frac{d^{i'}}{p^i} \sum_{j=1}^{h} \frac{(q_{j,i} x_r + o_{j,i} x_o) p^j u^j}{d^{j'} x} + \frac{\sum_{j=1}^{h} p^j T_s^j u^j}{\sum_{j=1}^{h} \frac{p^j m}{d^{j'}}} \end{aligned}$$

BT Model

- More Realistic Model:
  - Determine $q_{i,j}$
    - When a fast node optimistically unchokes a slow node, the slow node reciprocates with a regular unchoke.
    - First focus on a two class scenario: fast nodes are perfectly clustered ($q_{fast, fast} = 1$, $q_{fast,slow} = 0$). Imperfect clustering of slow nodes is determined by the timing of regular and optimistic unchokes
    - As a fast node realizes that it unchoked a slow node, it discards the slow node, then the slow node stops the regular unchoke of the fast node.

BT Model

- More Realistic Model:
  - Determine $q_{i,j}$

    the fraction of the regular unchoking capacity of a slow node that is spent on a fast node due to a fast node's optimistic unchoke is:

$$f_{opt} = \frac{\frac{1}{2}\left((t_{opt} - t_{reg} + t_{win}) + (t_{opt} + t_{win})\right)}{x_r t_{opt}}.$$

$$q_{slow,fast} = min(g_{opt} f_{opt}, 1)$$

$$g_{opt} = s\frac{N_l^{fast}}{N_l} x_o O_{fast,slow} \frac{1}{s\frac{N_l^{slow}}{N_l}} = \frac{N_l^{fast}}{N_l^{slow}} x_o O_{fast,slow}$$

    g_{opt} is the average number of optimistic unchokes that a slow node is receiving from fast nodes.

BT Model

- More Realistic Model:
  - Determine $q_{i,j}$

    Extend this to more than two classes. Assume the class indices are in descending order of their uploading capacities

$$q_{i,j} = min\left(min(g_{i,j} f_{opt}, 1), 1 - \sum_{k=1}^{j-1} q_{i,k}\right)$$

$$g_{i,j} = s\frac{N_l^j}{N_l} x_o o_{j,i} \frac{1}{s\frac{N_l^i}{N_l}} = \frac{N_l^j}{N_l^i} x_o o_{j,i}$$

BT Model

- More Realistic Model:
  - Determine $o_{i,j}$

    optimistic unchokes are in fact biased in the real world due to the reason that optimistic unchokes are only performed on peers that are not currently unchoked through regular unchokes:

$$o_{i,j} = \frac{s\frac{N_i^j}{N_i} - x_r q_{i,j}}{\sum_{k=1}^{h}\left(s\frac{N_i^k}{N_i} - x_r q_{i,k}\right)}.$$

    s is one node's peer list size.

Model Validation Using Simulation

Experiment settings:

Filesize (m)	500 MB (2000 Chunks, 256 KB each)
Avg node inter-arrival ($\frac{1}{\lambda}$)	1 min
Peer Set Size (s)	80
# Leecher Unchokes	4 Reg. (x_t) + 2 Opt. (x_o)
# Seed Unchokes	6
Unchoke Re-eval. Interval	Reg. (t_{reg}): 5 sec; Opt. (t_{opt}): 30 sec
Re-eval. History (t_{win})	20 sec

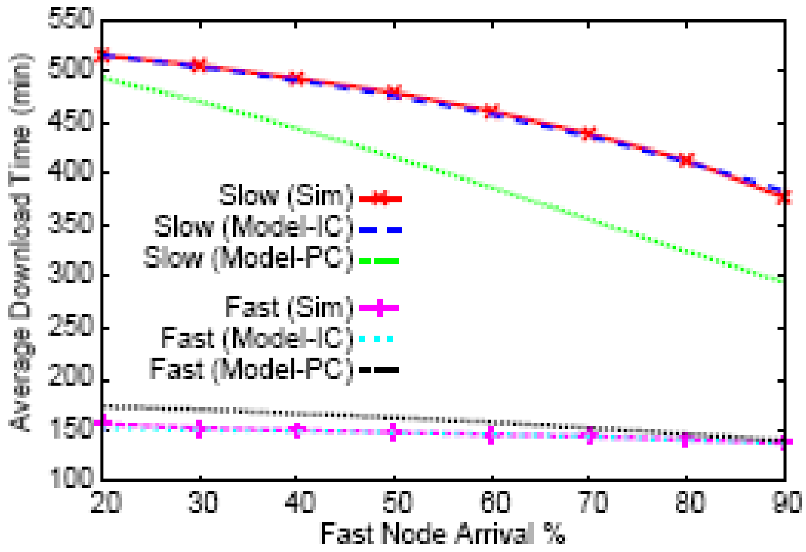
Model Validation Using Simulation

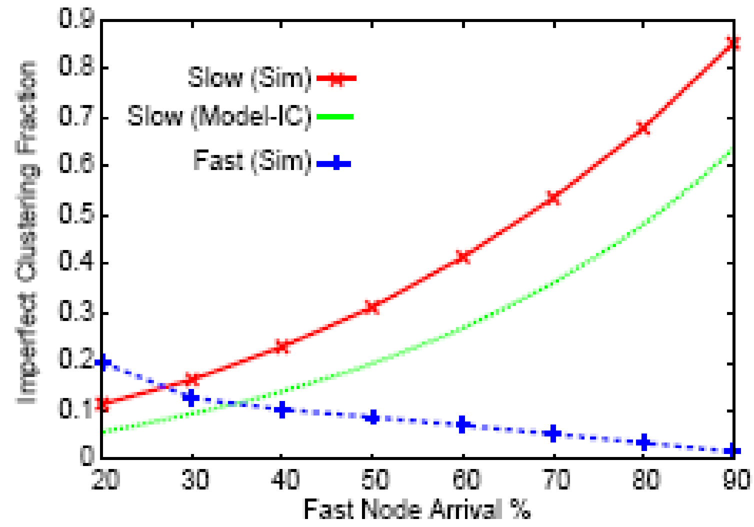
Experiment 1: Two Leecher Classes

Fast: download: 5000kbps, upload: 512kbps;

Slow: download: 5000kbps, upload: 128kbps.

No seeding time





Model Validation Using Simulation

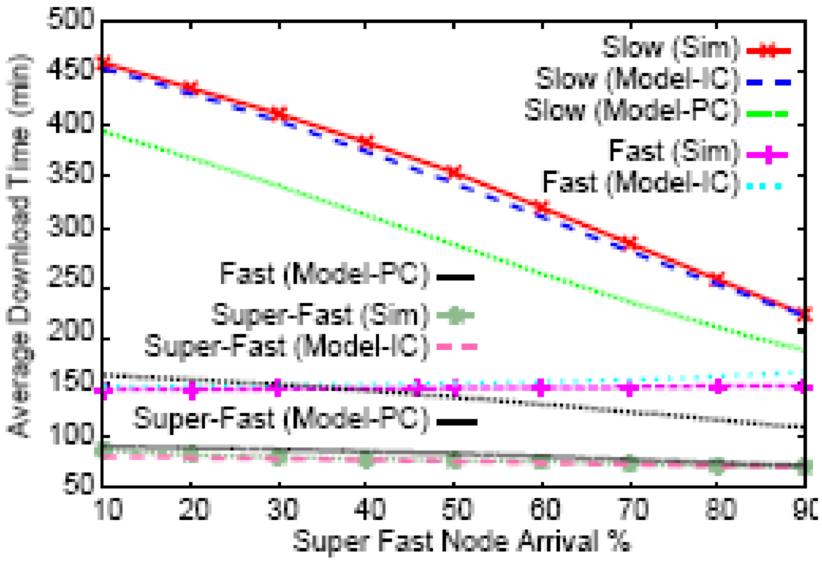
Experiment 2: three Leecher Classes

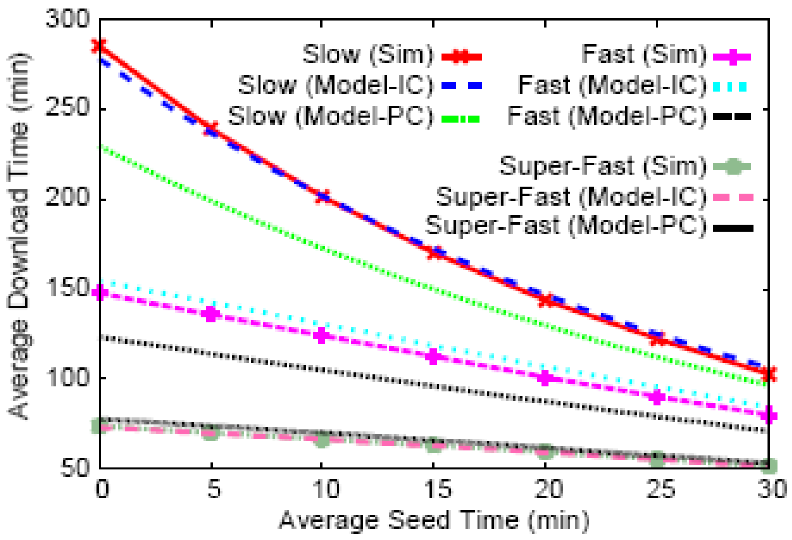
Superfast: download: 5000kbps, upload: 1000kbps;

Fast: download: 5000kbps, upload: 512kbps;

Slow: download: 5000kbps, upload: 128kbps.

No seeding time



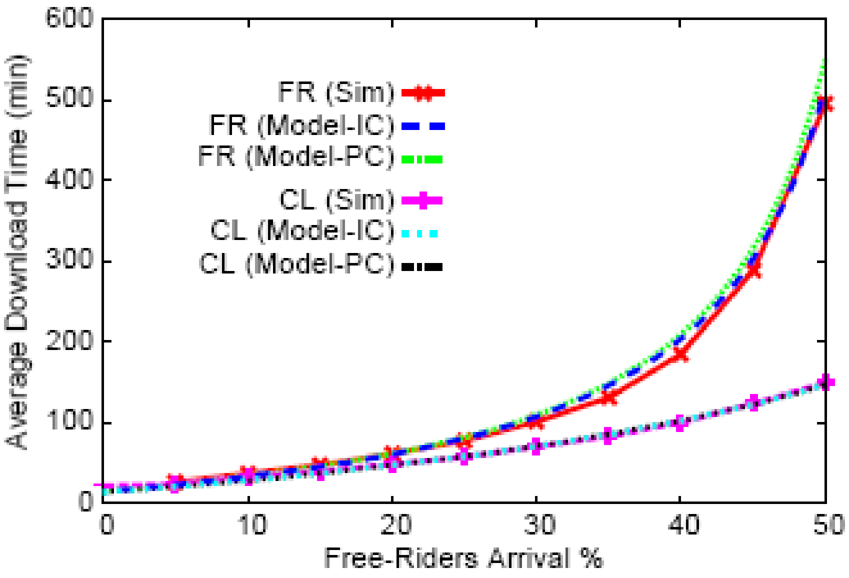


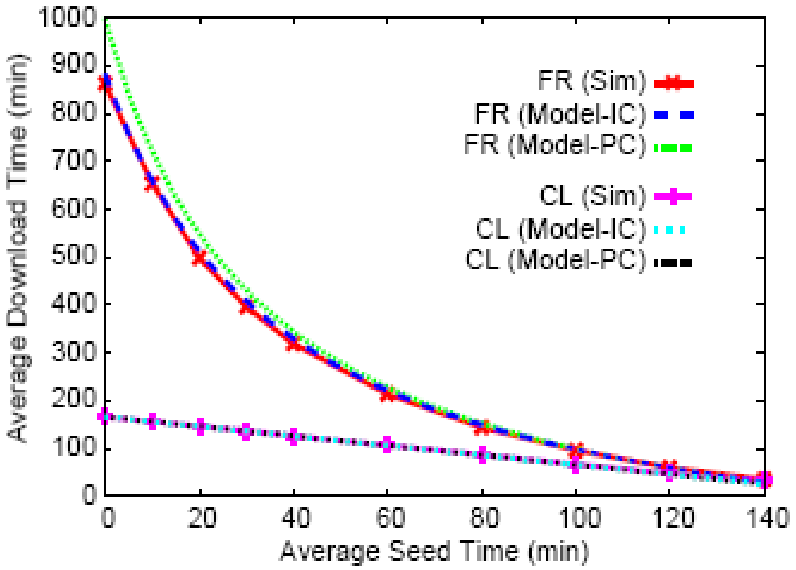
Model Validation Using Simulation

Experiment 3: Free-Riders

Contributing: download: 5000kbps, upload: 512kbps;

Free-Riders: download: 5000kbps, upload: 0kbps.



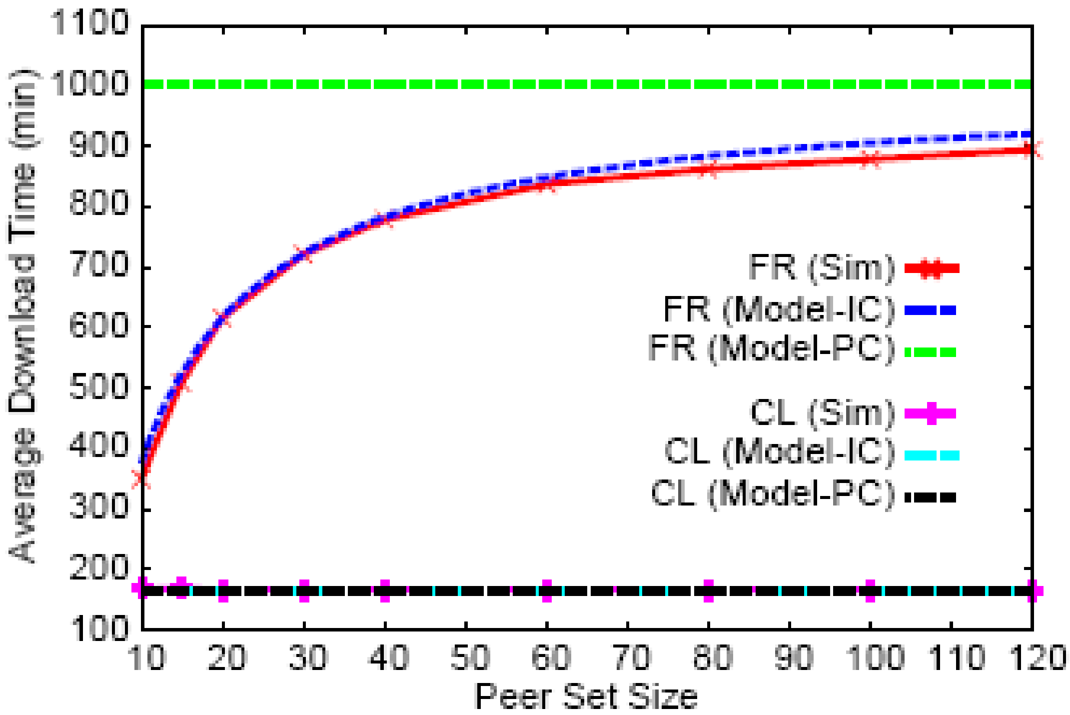


Model Validation Using Simulation

Experiment 4: Peer set Size

Contributing: download: 5000kbps, upload: 512kbps;

Free-Riders: download: 5000kbps, upload: 0kbps.



Thank You!