A Modeling Framework to Understand the Tussle between ISPs and Peer-to-Peer File Sharing Users

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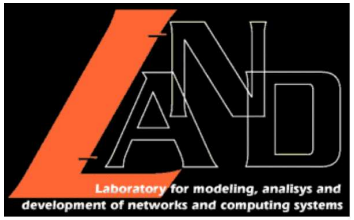
IFIP Performance 2007

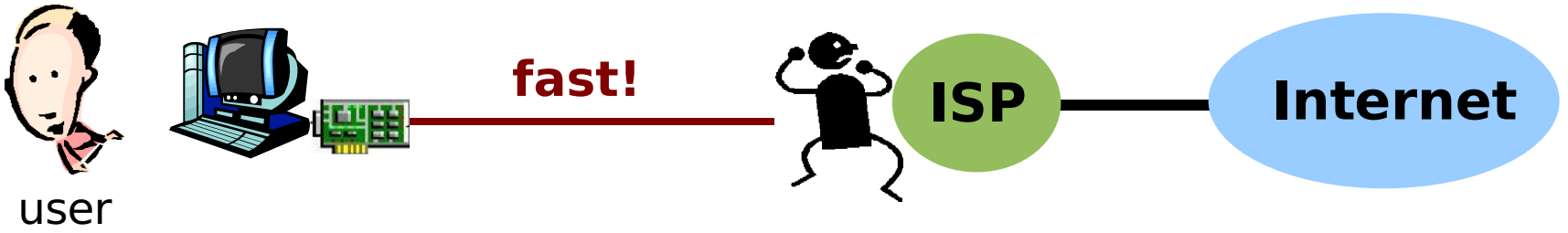


An Internet Tale

- Once upon a time...

  - user unhappy (“world wide wait”)
  - ISP unhappy (little revenue)

- Then came broadband access...

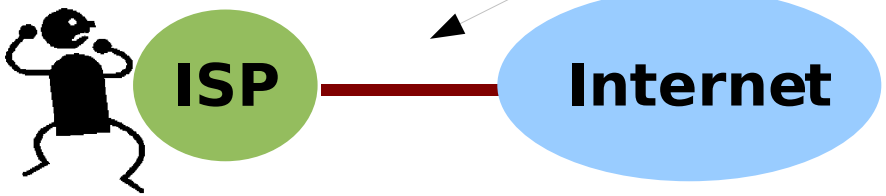


- And they lived happily ever after...

The Villain Arrives

- P2P file sharing application (Kazza, Bittorrent, Emule, etc)

- **users love it!**
- good and free content, overnight downloads



- **ISPs hate it!**
- users using their link
- Internet link utilization gone wild
- degrades all subscribers
- more bandwidth costs money!

Taking Care of The Villain

- **Mafia style!**

- seriously threaten application developers!
- doesn't seem to work (Napster story)

Is it Really a Villain?

user

- Users love it!
- Driving force for broadband adoption
- Increased revenue for ISPs

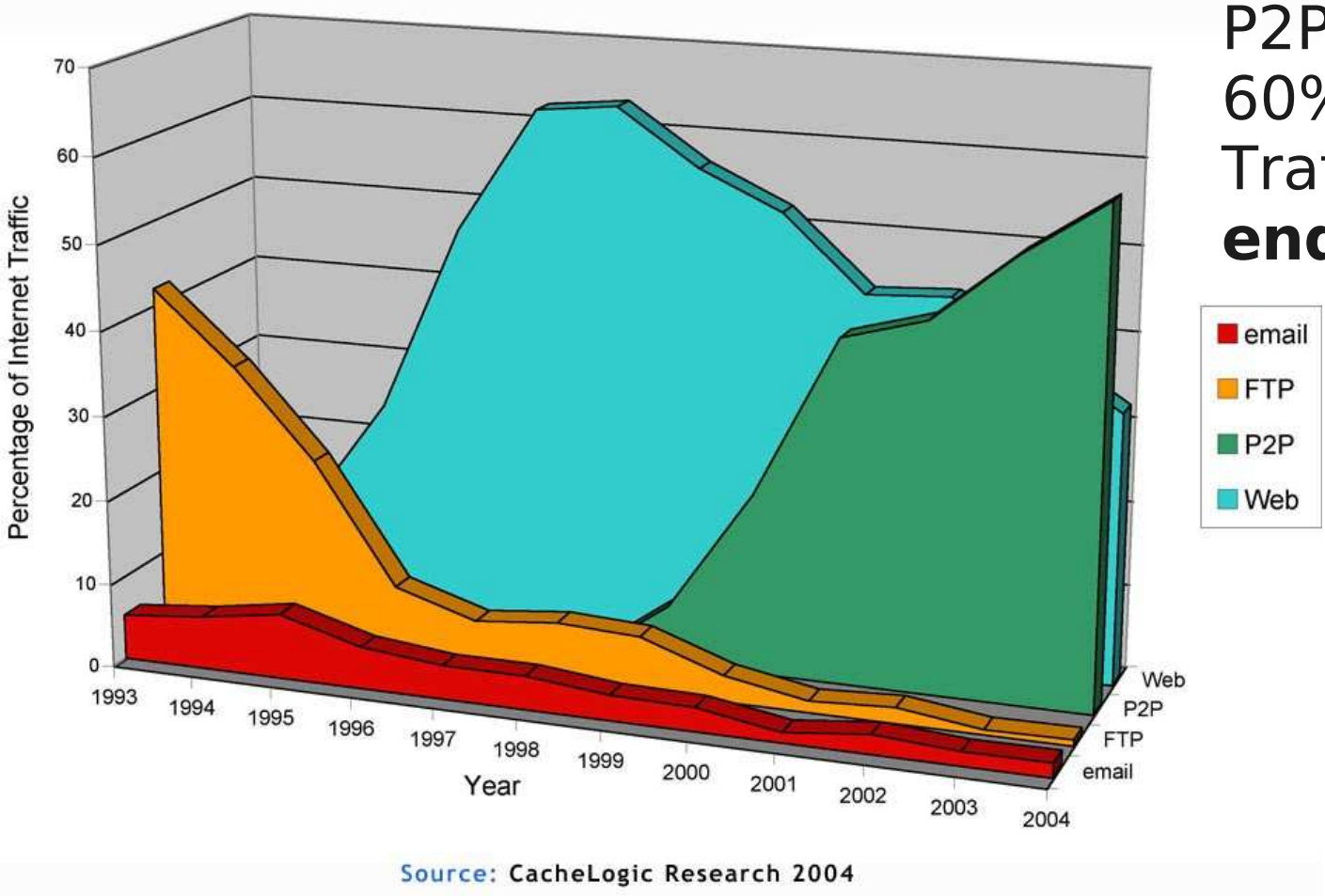
Some Other Options

- User **unfriendly** ideas
  - increase subscription cost
  - volume based pricing
  - block / shape P2P traffic
- User **friendly** ideas
  - acquire more bandwidth
  - network caching
  - application-layer redirection


user

What should the ISP do?

The Real Thing (Data)



P2P represented 60% of Internet Traffic at the **end of 2004!**

Our contribution

- Modeling framework to analyze interactions between P2P file sharing users (their traffic) and ISP
  - economic + performance models
- Basic insights about system dynamics
- Used to evaluate different strategies to manage P2P traffic

Meet the Players

user

- generates queries
- quality of service expectations
- what's hot, what's not

- P2P application
- locates object

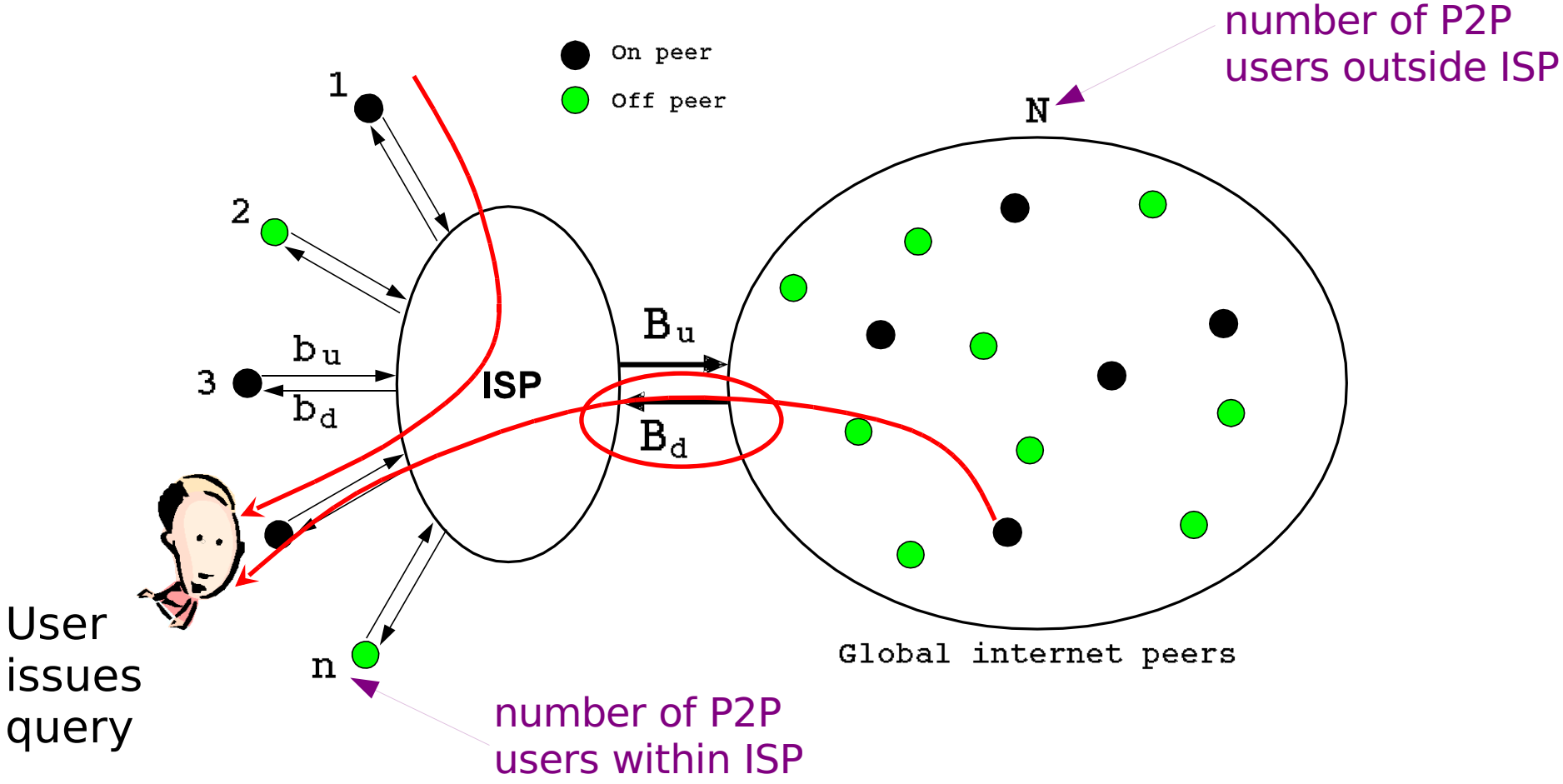
ISP

- **goal**: to make money!
- sets subscription price
- controls bandwidth
- influences P2P app. behavior

Network

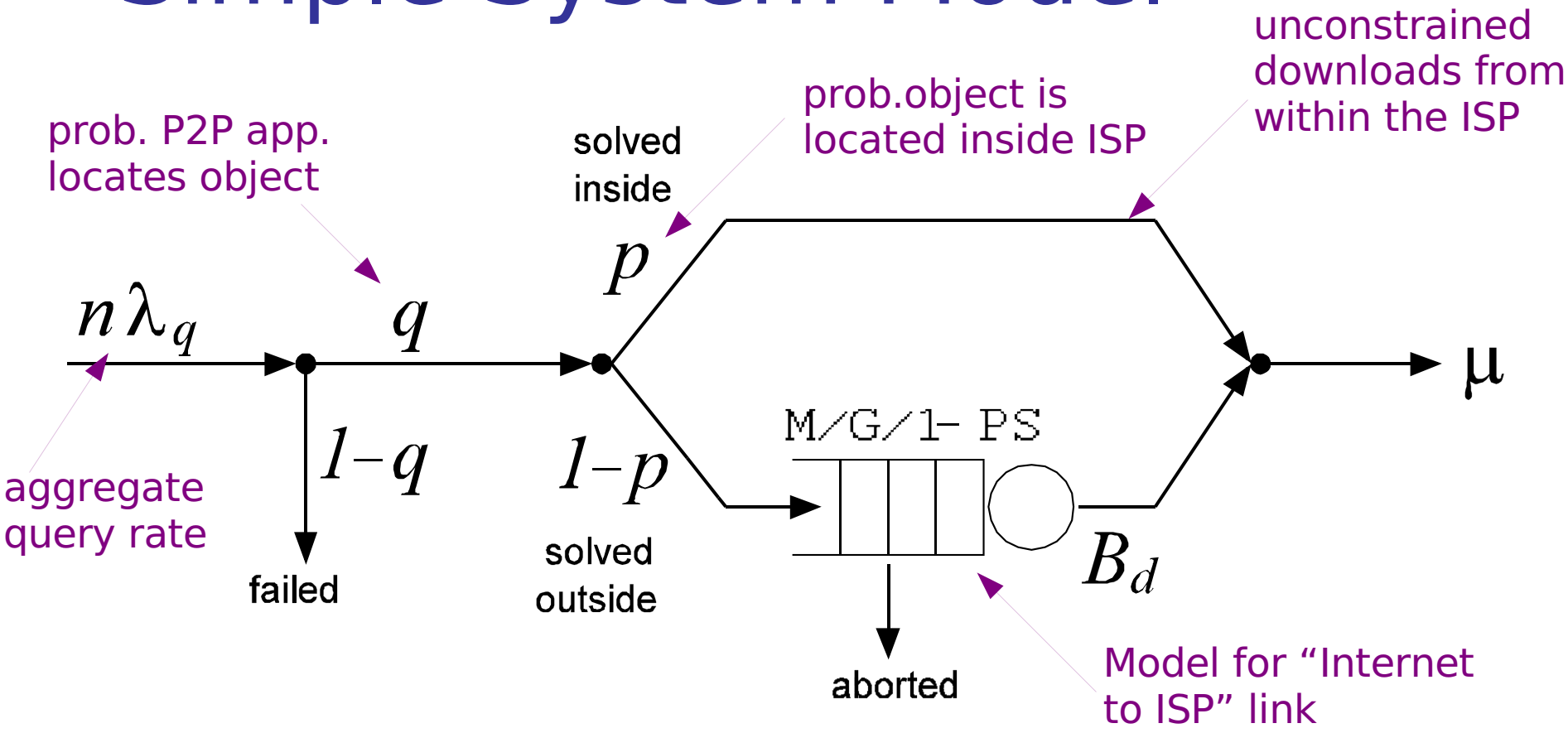
- network architecture
- protocols

System Setting



- B_d → constrained resource for ISP
- Outside download consumes B_d

Simple System Model



object retrieval probability: $\sigma = \dfrac{\mu}{n\lambda_q}$

User Utility Function

- Satisfaction model for user i

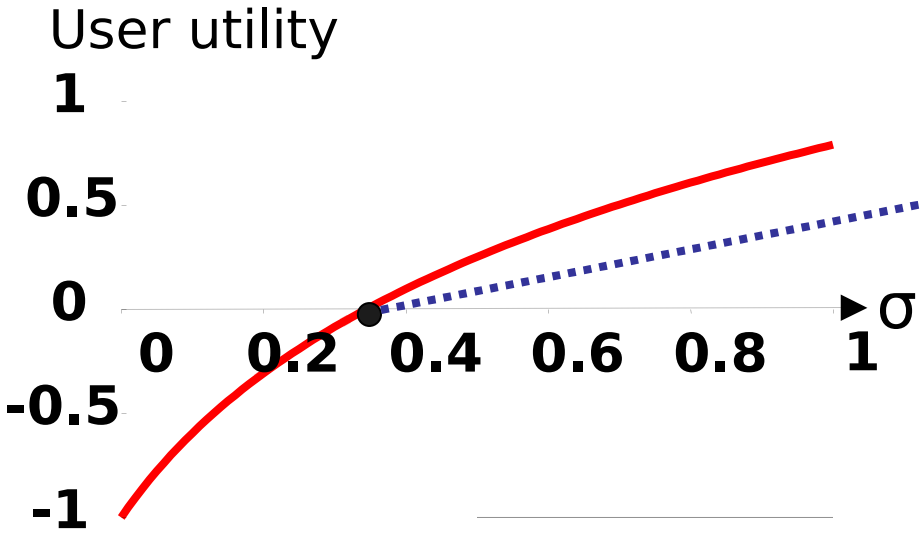
user

$$U_i(\sigma, c) = \log(\alpha_i \sigma + 1) - c$$

shape parameter

probability of successful object retrieval

subscription cost



$\sigma \min_i$

Minimum service level for user i

ISP Utility Function

- Profit for ISP (revenue - costs)

$$U_{\text{ISP}}(B_d, c) = \sum_{i=1}^{n} c\mathbb{1}_{(U_i(\sigma,c)\geq 0)} - (\beta_2 B_d + \beta_1)$$

revenue from subscribers' fee

cost per unit of external bandwidth

fixed charge

- The ISP starts service only if

$$U_{\text{ISP}}(B_d, c) > 0$$

Modeling Traffic Locality

- Probability there exist at least one internal replica of object replicated r times in the system

Number of internal copies

$$1 - \left(1 - \frac{f}{F}\right)^r \sim r\frac{f}{F} \qquad (f \ll F)$$

Number of external copies

- Probability to download from internal replica

$$p \sim \gamma r f / F$$

locality parameter

Analytical Results

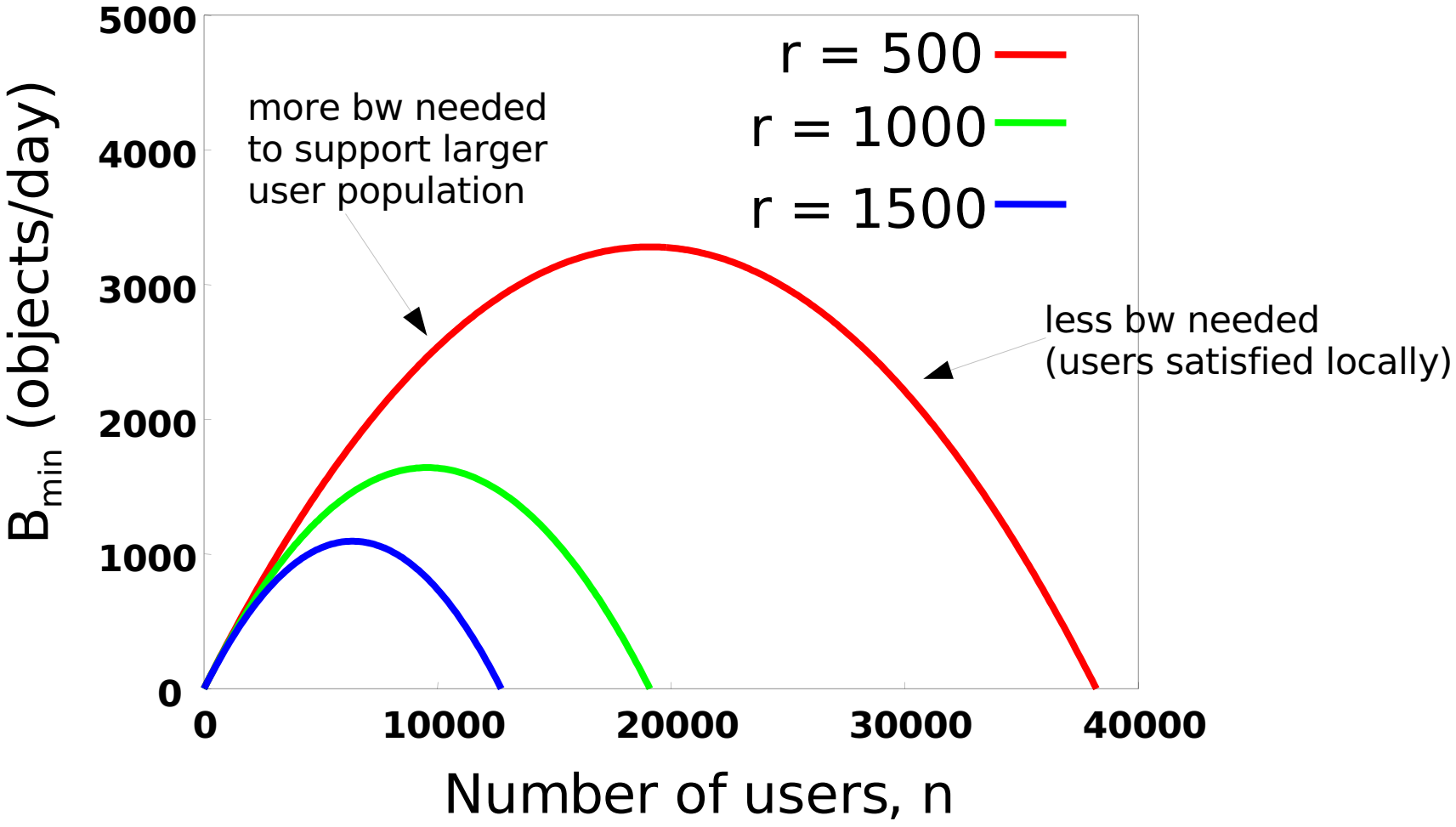
- How much bandwidth should the ISP buy to minimally satisfy the users?

$$B_{min} = max[0, n\lambda_q(\sigma_{min} - q\gamma r n/N)]$$

  - identical users and n >> N

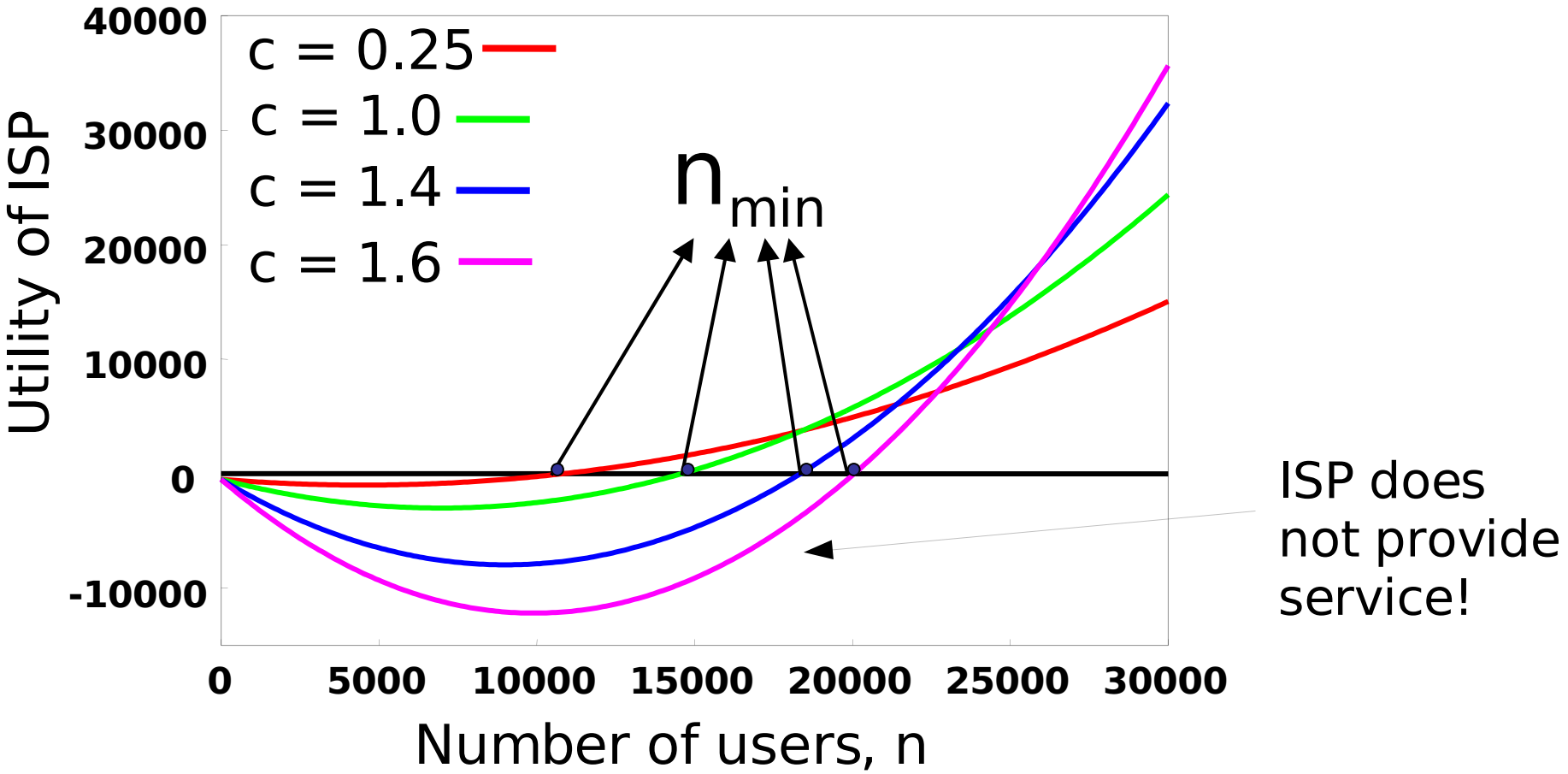
- Non-linear behavior (on *n*)
  - more users, more locality, less BW needed
  - can be zero if *n* large enough
- May not yield profit
  - too few users, too costly to satisfy them
- Dependent on multiple parameters

Impact of Object Replication (r)



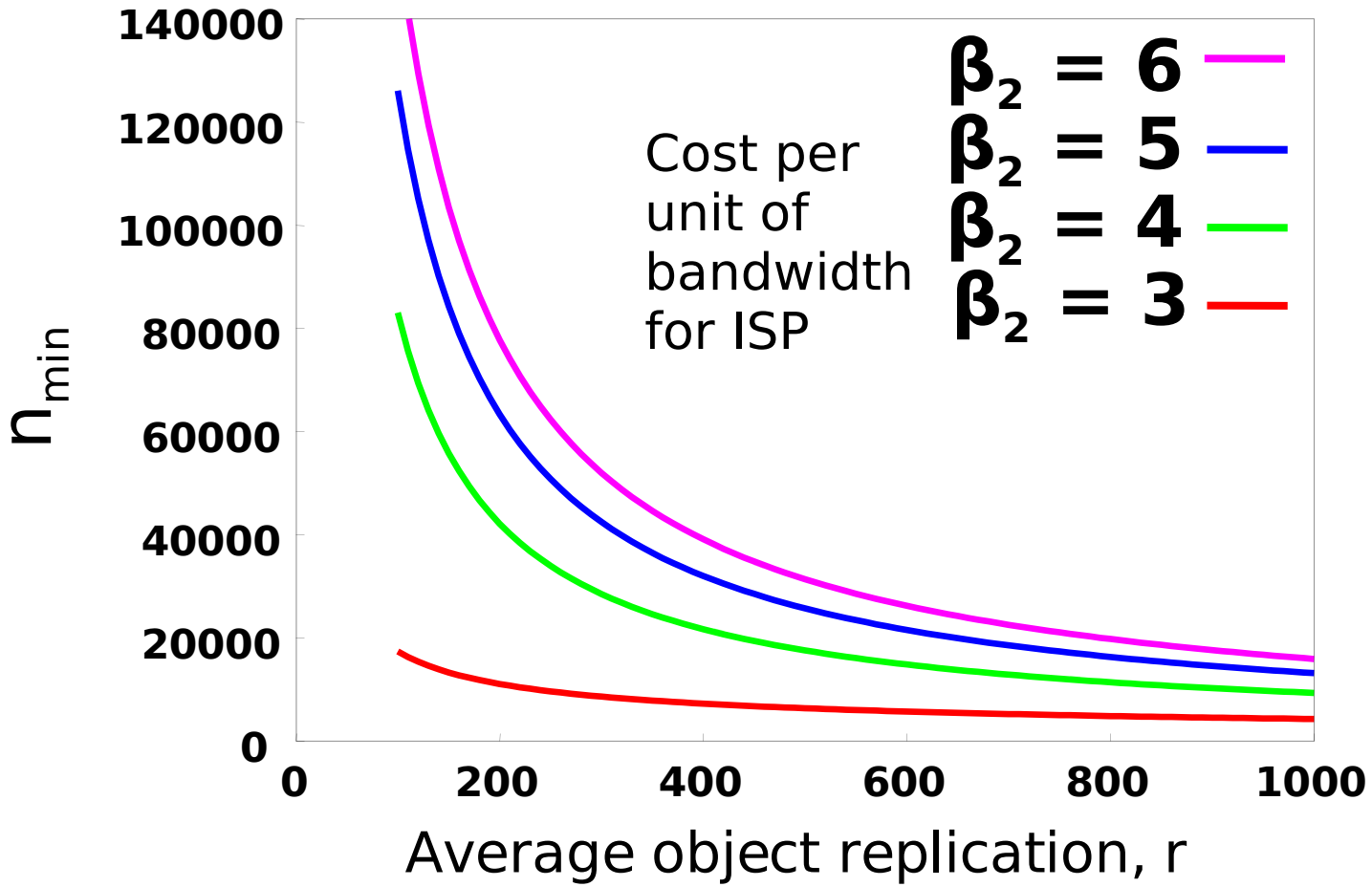
- more replicas, better locality, lower B_{min}

Impact of Subscription Cost (c)



- critical mass of users, n_{min}
- lower cost, more profit earlier, less profit later

Critical Mass of Users, n_{min}



- higher bw cost for ISP, higher critical mass
- large influence of number of replicas

Model Refinements

- Simple model
  - users' access bandwidth are unconstrained
  - object replication is a parameter
  - all objects are identical (no popularity)
  - users availability identical
- Refined model relax these assumptions
  - propose object popularity and replication model

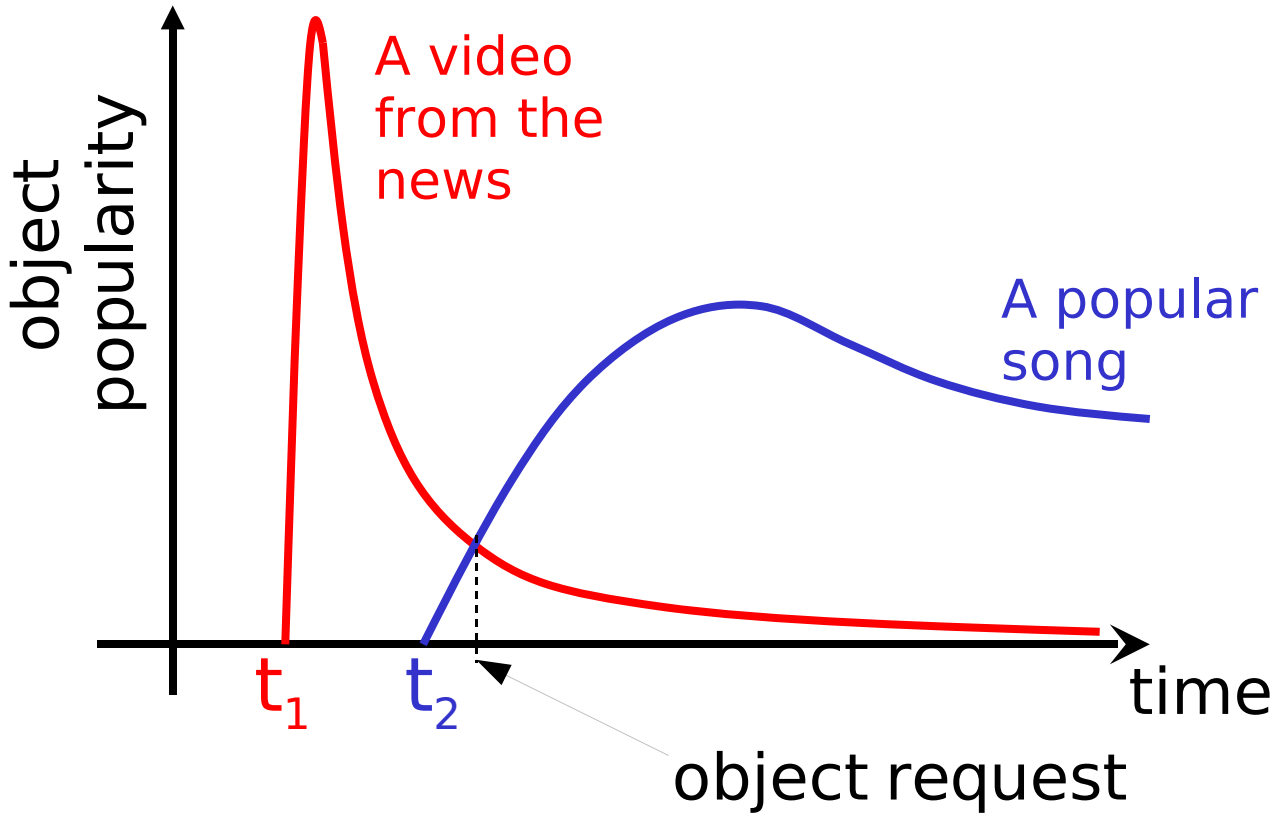
Object Popularity and Replication Model

- Temporal evolution of object popularity
- Objects' popularities evolve differently
- Objects continuously introduced and removed by users

Number of replicas of an object at time t?

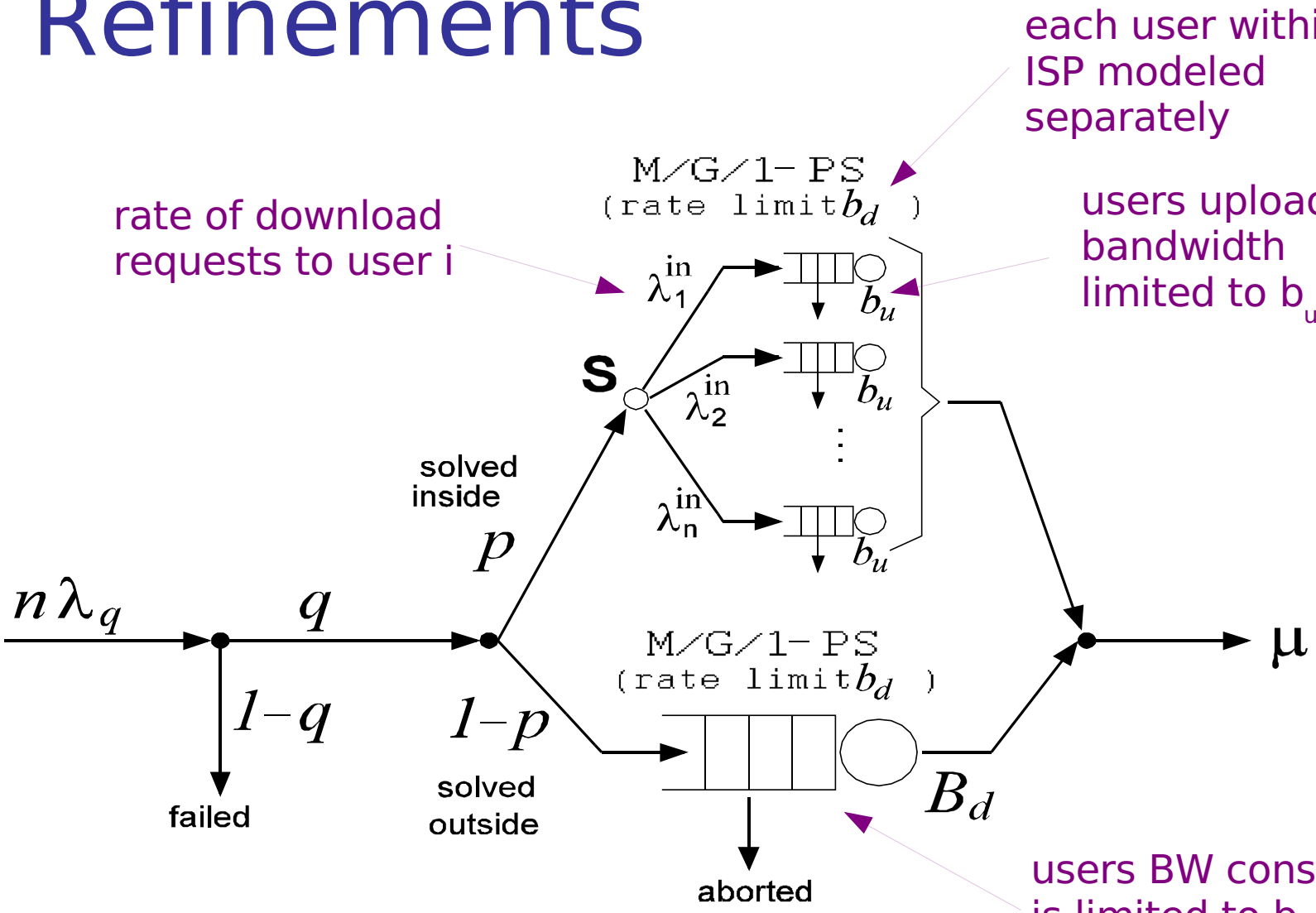
- Analytical technique based on Poisson shot noise process

Example



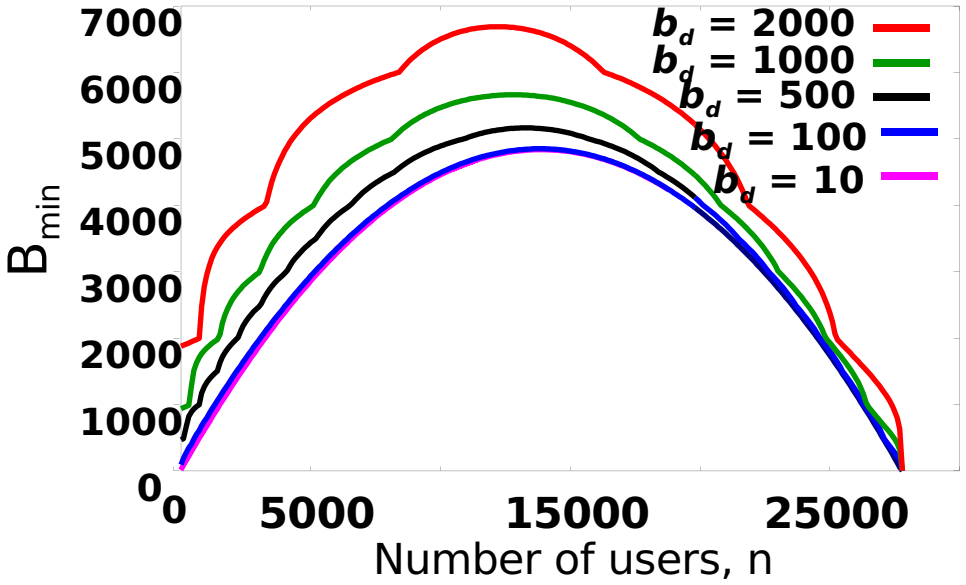
- at request time, both have same popularity, but news has more replicas

Limited Bandwidth Refinements



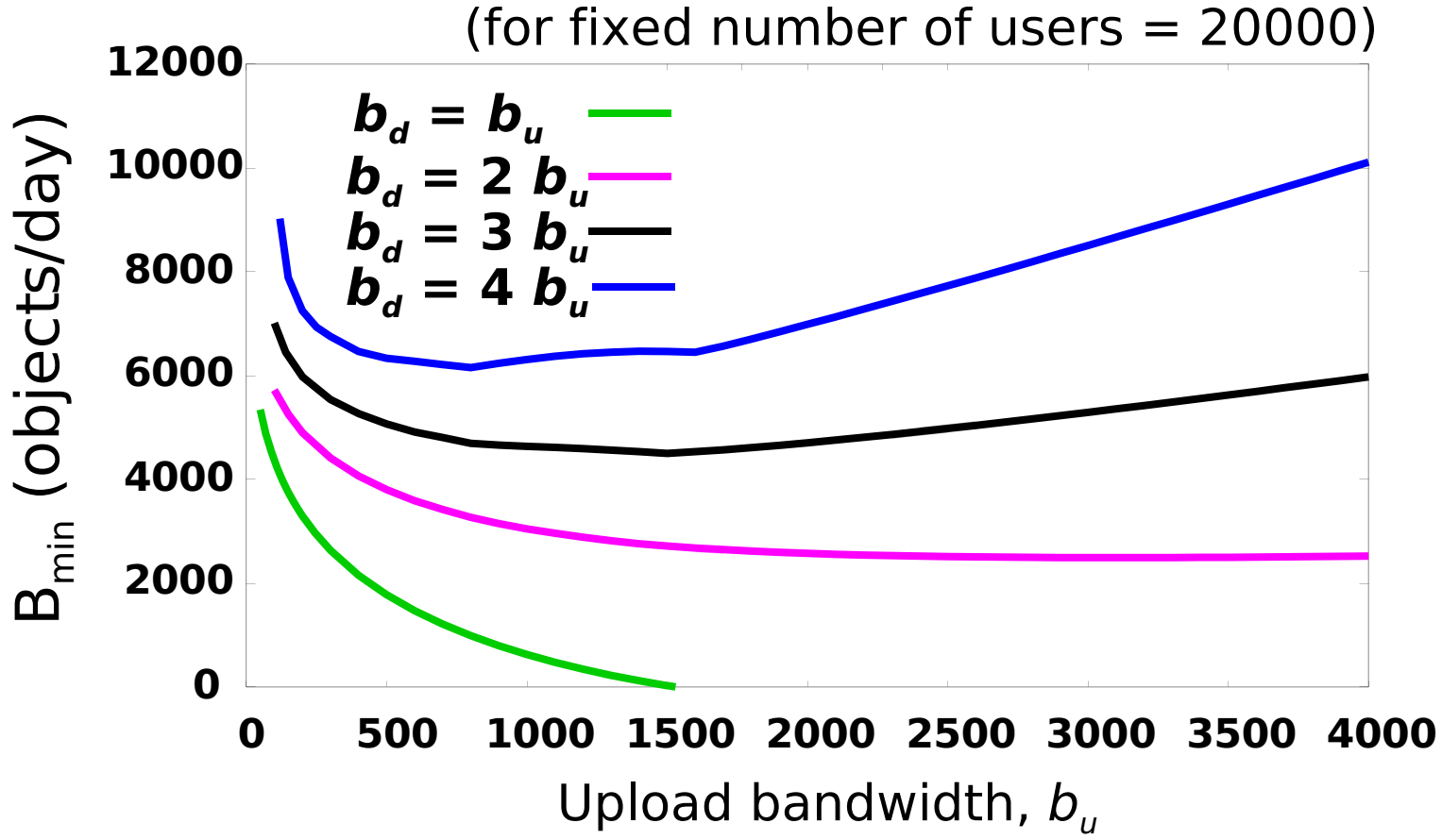
Results from Refined Model

- Degenerate to simple model
  - when parameters set appropriately



- Other interesting insights
  - influence of limited upload bandwidth
  - upload/download bandwidth asymmetry
  - object popularity and replication
  - influence of user impatience

Impact of asymmetric access bandwidths



- cost for ISP *increases* as ratio increases
- better if upload BW is *greater* than download

Conclusions

- Development of simple analytical model
  - economics + performance
  - interaction between P2P users (their traffic) and ISP
  - insights into strategy for ISP to manage its traffic
- Model for object popularity and replication
  - of independent interest
- Future work
  - Multiple ISPs competing with each other

THE END

- Thank you!
- Questions? Comments?