Traffic Patterns in Peer-to-Peer-Networking

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joint work with
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to be presented at ITA

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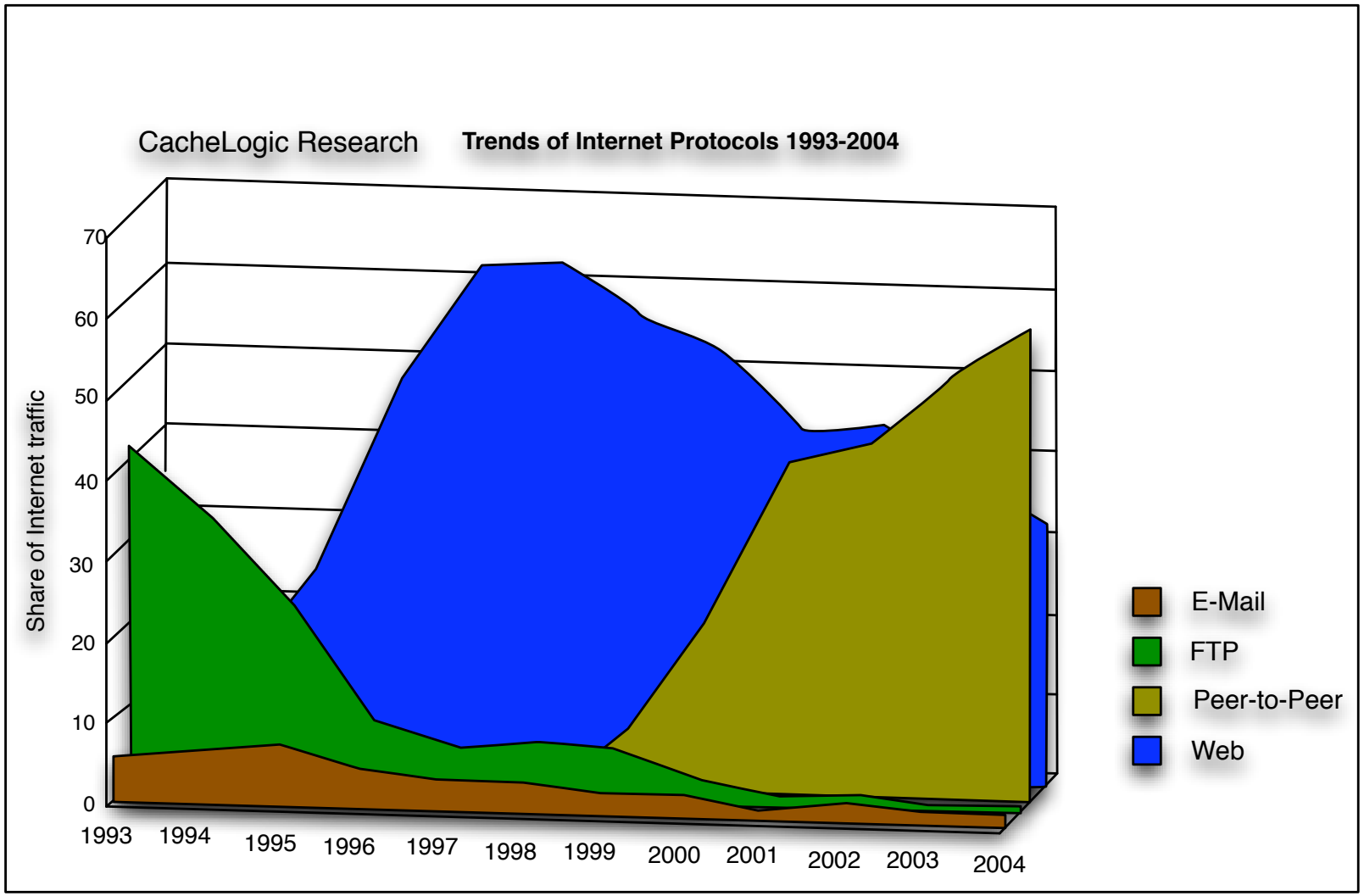
Global Internet Traffic Shares 1993-2004



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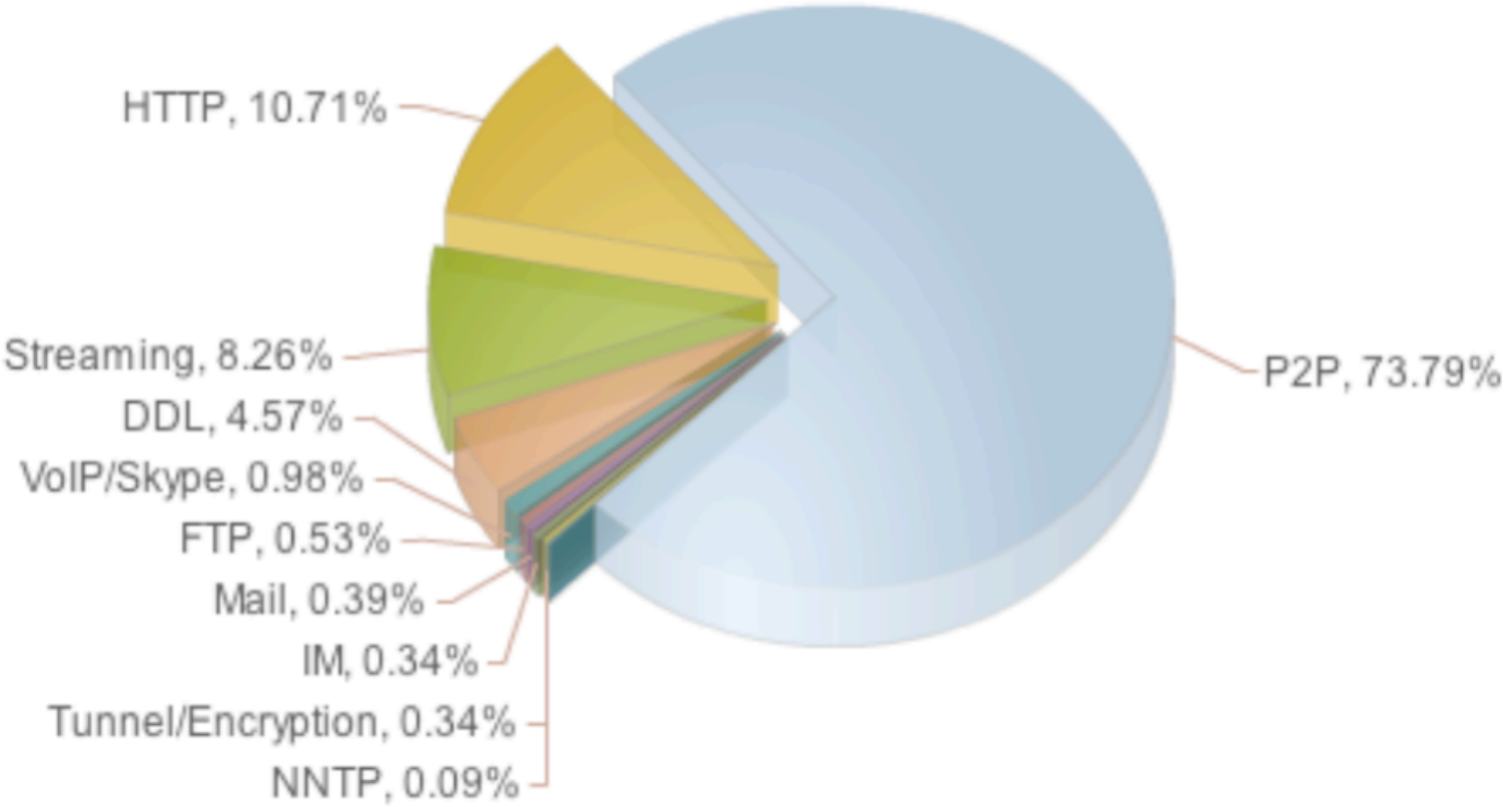
P2P Share Germany 2007



Quelle: Ipoque 2007

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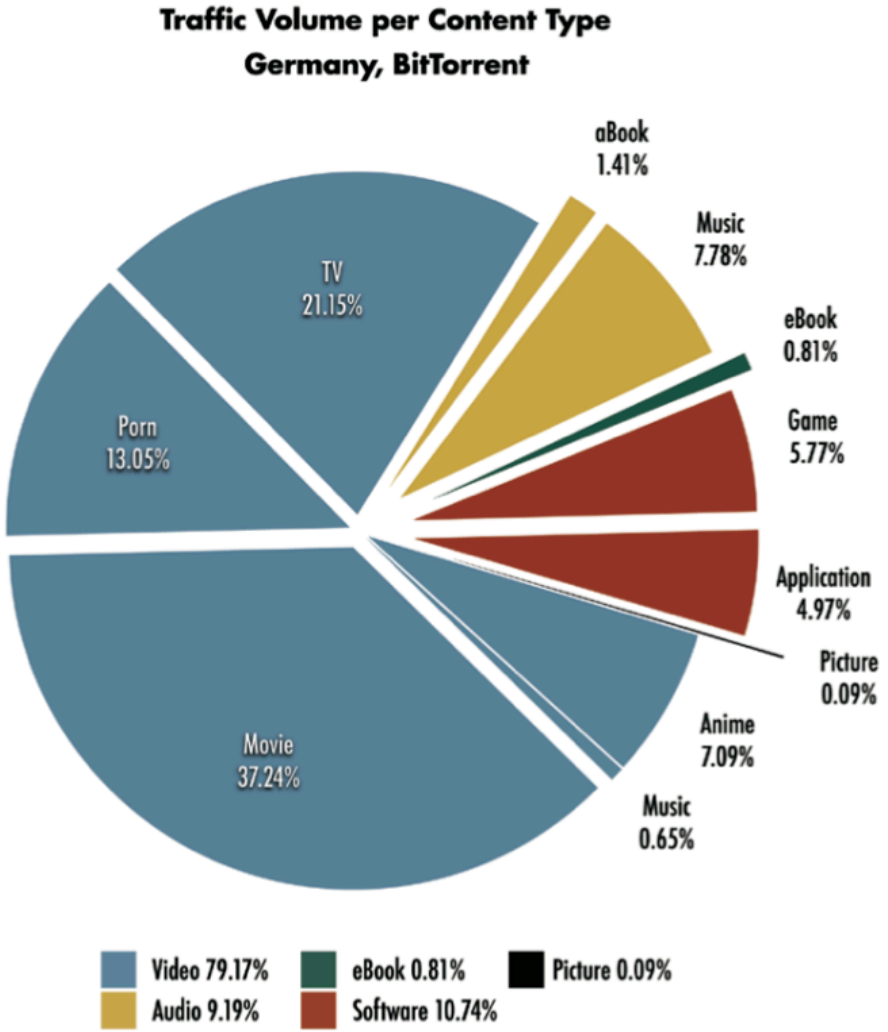
What Germans Download 2007 by Volume



Quelle: Ipoque 2007

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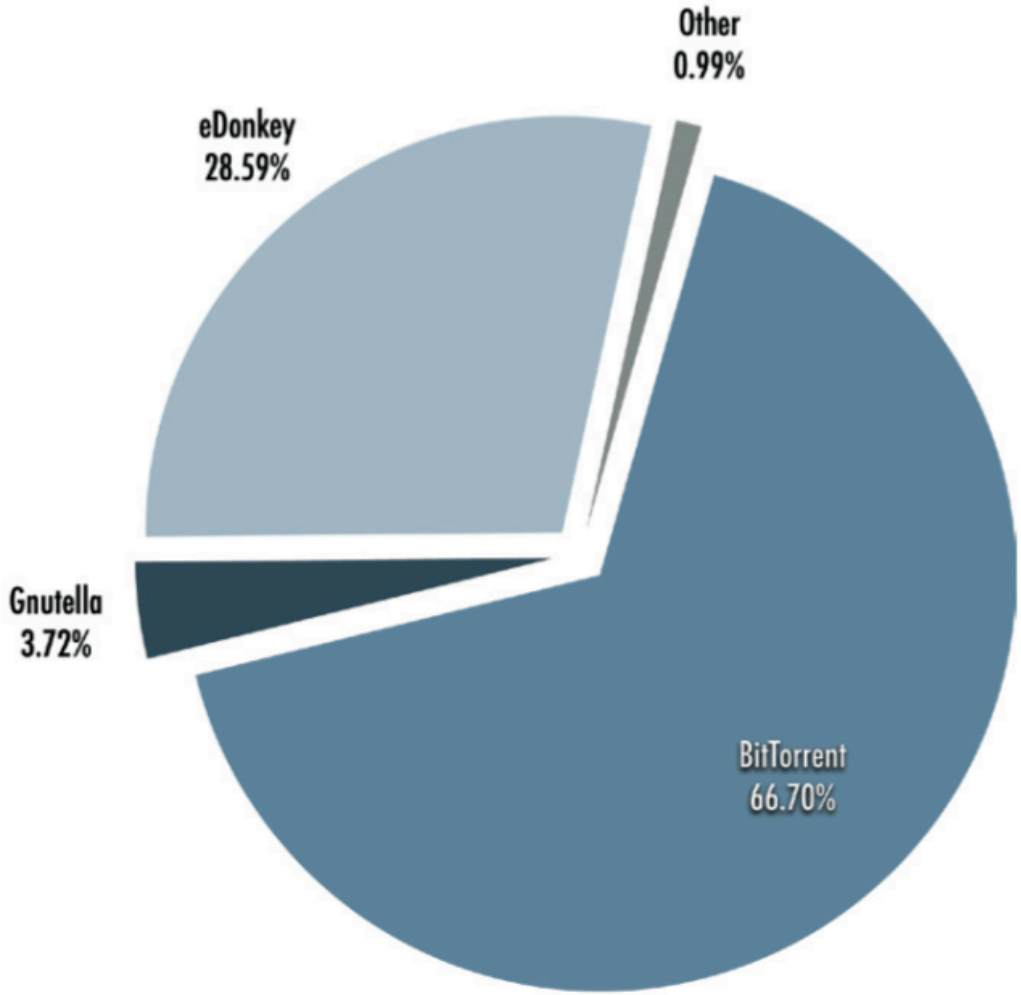
P2P Systems Germany 2007 by Volume



Quelle: Ipoque 2007

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Motivation

- Peer-to-Peer-Networks
  - Quality depends on user behavior
  - High churn rates
  - Egoistic users
- Only a small number of independent studies of Internet traffic
- We analyze the complete traffic of 20,000 users in August 2009 of a German digital cable TV based Internet provider.
  - Traffic was centrally monitored
  - Type classification by deep packet inspection
  - Looked at BitTorrent traffic

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Network Monitoring

- Network monitoring systems
  - installed in recent years
  - allow to monitor the behavior of each user.
- Motivation
  - new governmental regulations
  - detection and prevention of
    - Internet fraud
    - denial-of-service attacks
    - spam mailers
    - phishing attacks,
    - criminal conspiracies,
    - forbidden contents
    - copyright violations.
- ISPs are (usually) not the juridical target
  - are required to uphold an infrastructure, which allows law enforcement to take action in such cases.

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Background of the Study

- Our study
  - limited access to anonymized user data
  - gathered by a network monitoring systems using deep packet inspection (DPI)
- Main product of „our“ ISP: digital cable TV
  - thousands of German households
  - byproduct they also offer telephone and Internet service
- German households are connected via DSL
  - rural area the bandwidth is rather low
  - urban areas high data rates
- Mobile phone carriers providing GPRS, EDGE and HSDPA gain in traffic.
- Digital TV cable is a stable market
  - Installation of the necessary infrastructure is expensive
  - Television is still important media of Germans
  - No open market for digital cable TV.
  - Cable TV users extend their contracts to include Internet service because of low prices and high bandwidth rates.

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Internet over Digital TV Cable

- Each user needs a digital cable modem
  - encodes and decodes the data traffic
- Throughput rates range from 32-100 MBit/s download
  - DSL traffic: 2 to 16 kBit/s
  - HSDPA ending at 7.2 MBit/s
- No network bottleneck
  - measured traffic behavior directly reflects the users wishes.
- Ideal opportunity
  - What do Internet users want?
  - How long are users online?
  - How much data do users download or upload?
  - What are the network services they use?

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BitTorrent and „Friends“

- BitTorrent
  - most successful peer-to-peer network protocol
  - BitTorrent encourages to upload data using incentives
- Several BitTorrent clients deviate from the original protocol
  - BitTyrant
    - achieves a download gain up to 70 percent
    - strategic selection of peers in the swarm
  - BitThief
    - free riding client
    - allows downloading without any upload
    - achieve higher download rates than the official client.

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Bittorrent

- Bram Cohen
- Bittorrent is a real (very successful) peer-to-peer network
  - concentrates on download
  - uses (implicitly) multicast trees for the distribution of the parts of a file
- Protocol is peer oriented and not data oriented
- Goals
  - efficient download of a file using the uploads of all participating peers
  - efficient usage of upload
    - usually upload is the bottleneck
    - e.g. asymmetric protocols like ISDN or DSL
  - fairness among peers
    - seeders against leeches
  - usage of several sources

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Bittorrent: Coordination

- Central coordination
  - by tracker host
  - for each file the tracker outputs a set of random peers from the set of participating peers
    - in addition hash-code of the file contents and other control information
  - tracker hosts to not store files
    - yet, providing a tracker file on a tracker host can have legal consequences
  - Is often replaced with a decentralized peer-to-peer network
- File
  - is partitions in smaller pieces
    - as describec in tracker file
  - every participating peer can redistribute downloaded parts as soon as he received it
  - Bittorrent aims at the Split-Stream idea
- Interaction between the peers
  - two peers exchange their information about existing parts
  - according to the policy of Bittorrent outstanding parts are transmitted to the other peer

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Bittorrent
Part Selection

- Problem
  - The Coupon-Collector-Problem is the reason for a uneven distribution of parts
    - if a completely random choice is used
- Measures
  - Rarest First
    - Every peer tries to download the parts which are rarest
      - density is deduced from the comunication with other peers (or tracker host)
    - in case the source is not available this increases the chances the peers can complete the download
  - Random First (exception for new peers)
    - When peer starts it asks for a random part
    - Then the demand for seldom peers is reduced
      - especially when peers only shortly join
  - Endgame Mode
    - if nearly all parts have been loaded the downloading peers asks more connected peers for the missing parts
    - then a slow peer can not stall the last download

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Bittorrent Policy

- Goal
  - self organizing system
  - good (uploading, seeding) peers are rewarded
  - bad (downloading, leeching) peers are penalized
- Reward
  - good download speed
  - un-choking
- Penalty
  - Choking of the bandwidth
- Evaluation
  - Every peers Peers evaluates his environment from his past experiences

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Bittorrent Choking

- Every peer has a choke list
  - requests of choked peers are not served for some time
  - peers can be unchoked after some time
- Adding to the choke list
  - Each peer has a fixed minimum amount of choked peers (e.g. 4)
  - Peers with the worst upload are added to the choke list
    - and replace better peers
- Optimistic Unchoking
  - Arbitrarily a candidate is removed from the list of choking candidates
    - the prevents maltreating a peer with a bad bandwidth

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Deep Packet Inspection

- Internet Service Provider
  - deep packet inspection system for analyzing the type of traffic
- Using heuristics
  - Analyze the first few packets to identify a protocol
    - Assumption further data exchange over the connection (IP socket) belongs to the same protocol.
  - Only protocol headers of the first few packet are inspected
  - Applications without encryption can be identified this way
- Encrypted protocols
  - can only identified by version numbers and other unencrypted information
  - Up to 20 packets have to be inspected
  - User data cannot be processed

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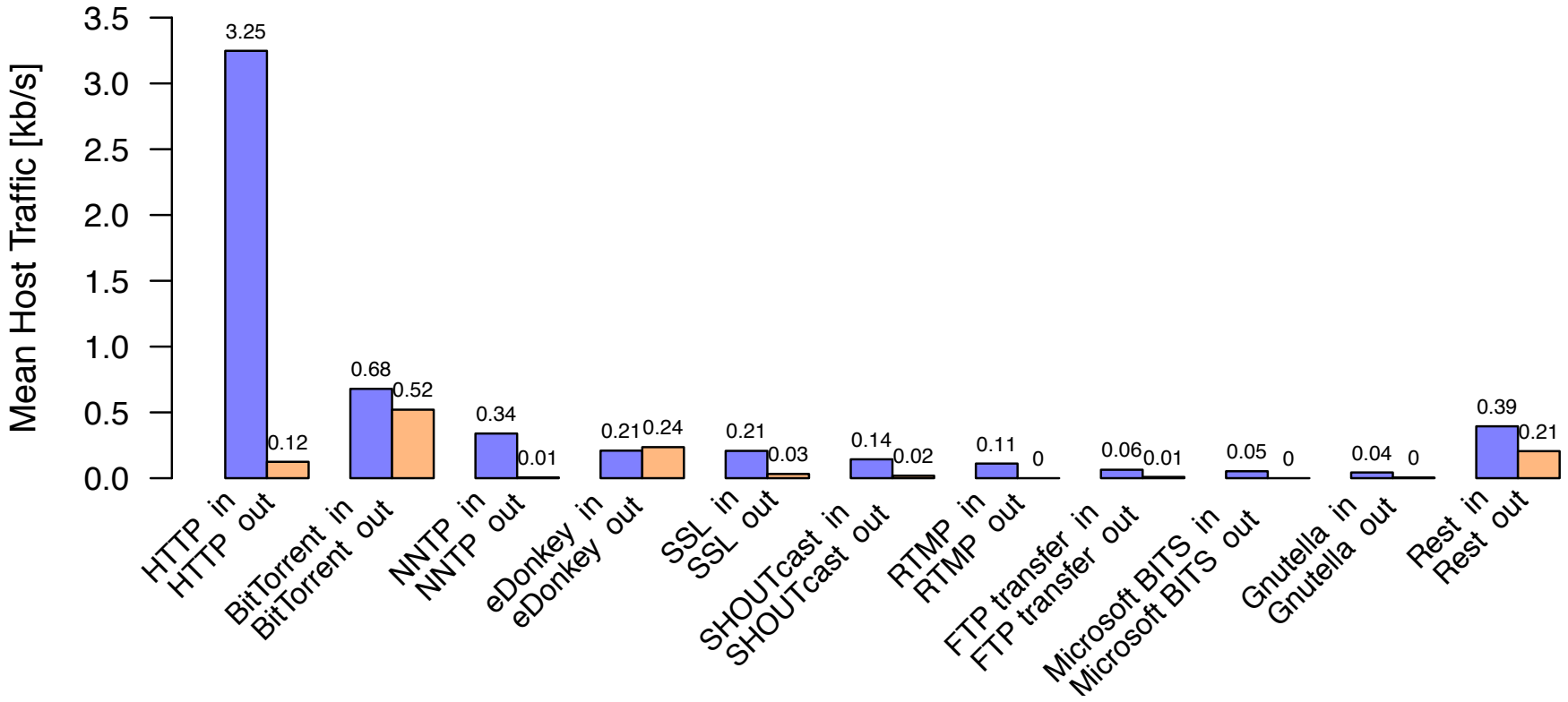
Traffic Types



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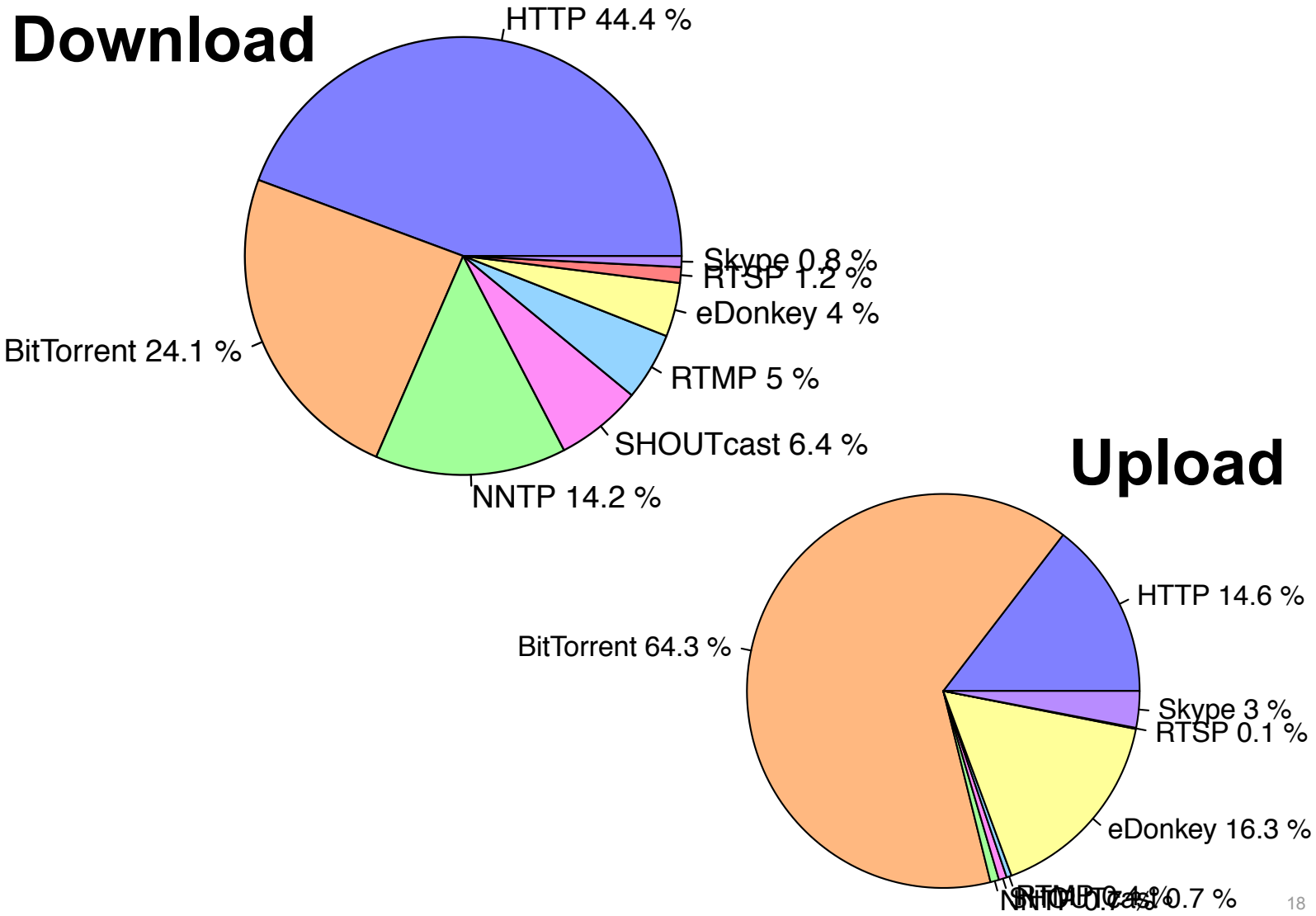
Internet Traffic of a Geman ISP August 2009



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Our Data Source

- After 15 minutes the DPI systems
  - reports the number of incoming and outgoing bytes for each protocol for each user.
  - rollected in log files.
  - We have received the data without IP addresses
    - replaced by anonymized IDs integer
- For each interval of 15 minutes over a month
  - we know for each anonymized user the number of open connections
  - the incoming and outgoing overall traffic
  - the incoming and outgoing unencrypted BitTorrent traffic
  - the sum of HTTP traffic of all users.
- We have received the sum of overall traffic in this month for each host for each service type.

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Overvie of all Traffic in August 2009

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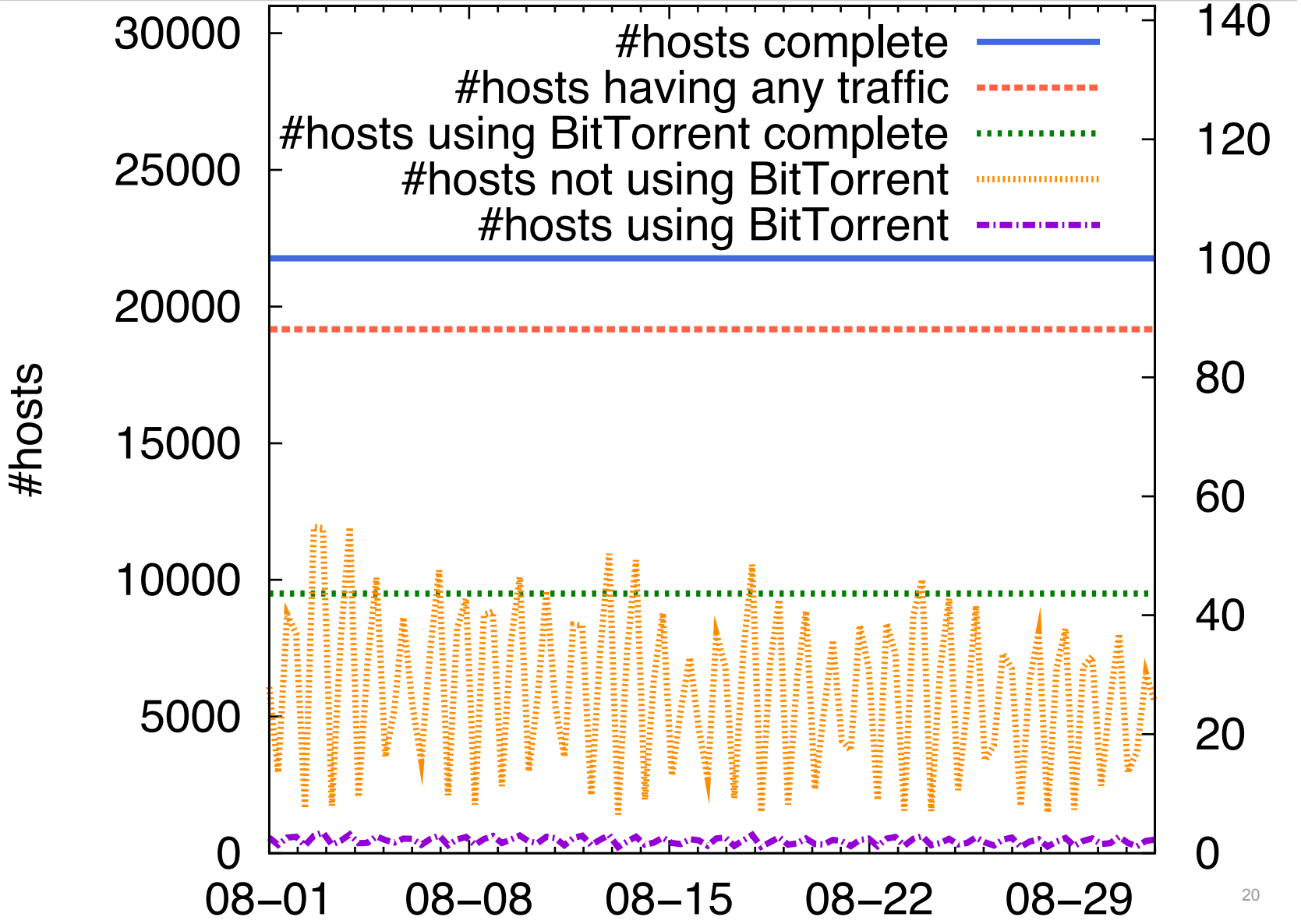

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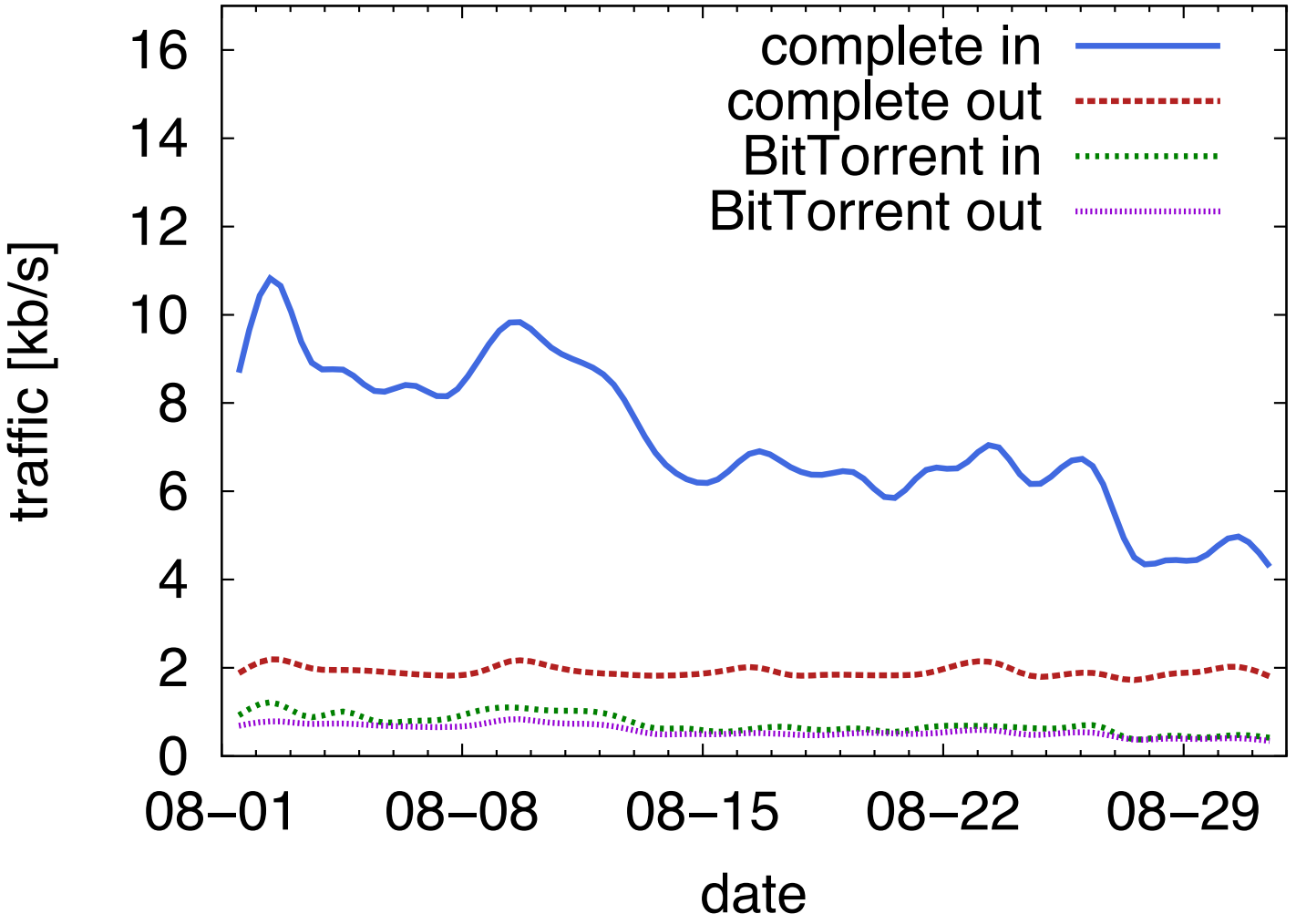
Overall Traffic Devolopent in August averaged over days 2009



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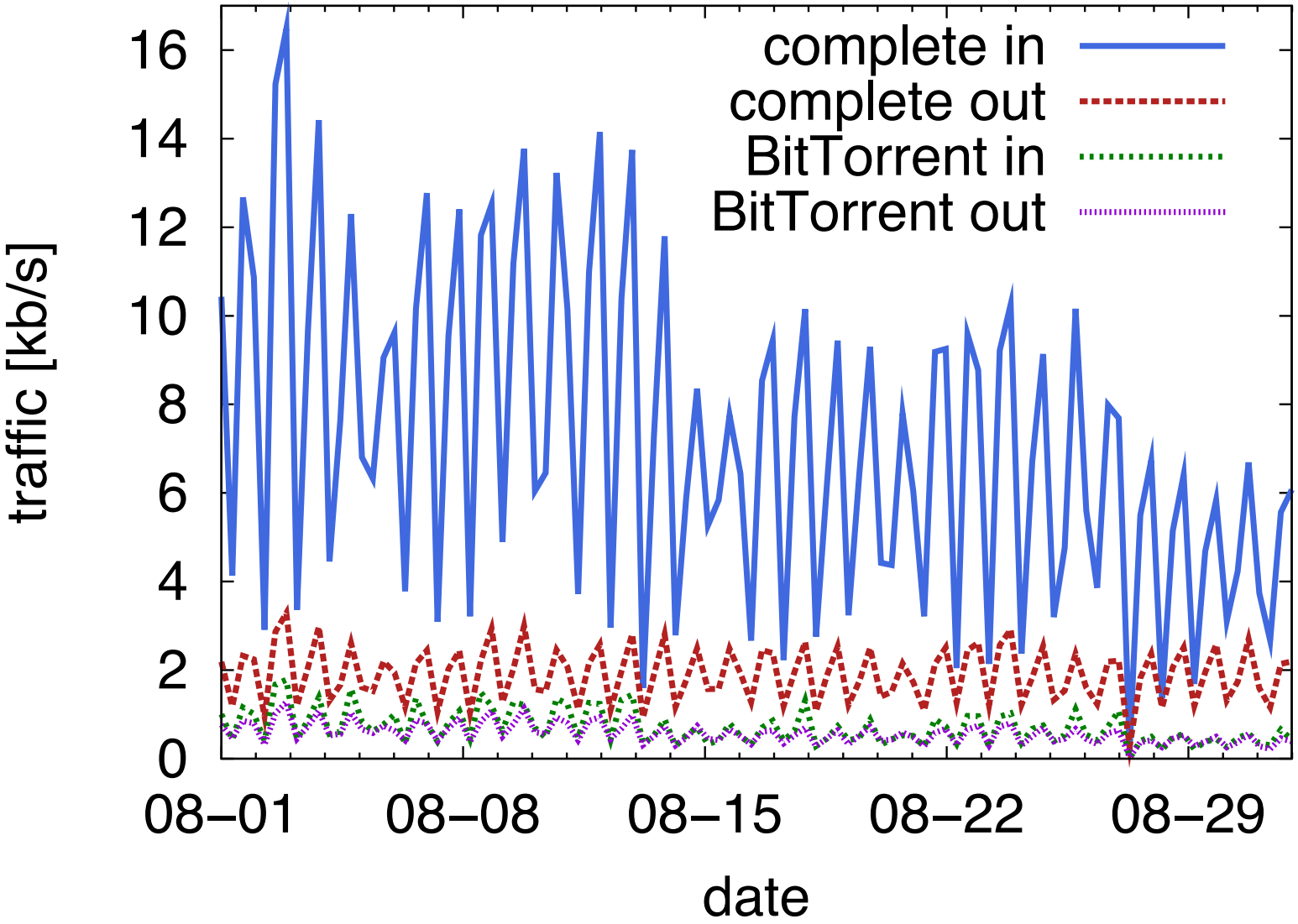
Measured Traffic



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Shortcomings of Data Set

- Identification of each user by the IPv4 address is not completely reliable
- No reconnection every 24 hours
  - unlike other ISPs
  - IPv4 address of a network user remains the same until the modem is rebooted
- Possible reasons for a modem reboot are
  - hardware reset
  - disconnecting of the modem
  - power outage.
- Error types
  - user occurs under several IP addresses
    - leads to an overestimation of users.
  - different user might reuse a free IP address
    - ISP assured us that IPv4 addresses are rarely reused
- Look at the intervals when an IP address is used and count the number of such simultaneous time intervals.
  - This number gives us a lower bound of the number of distinct users

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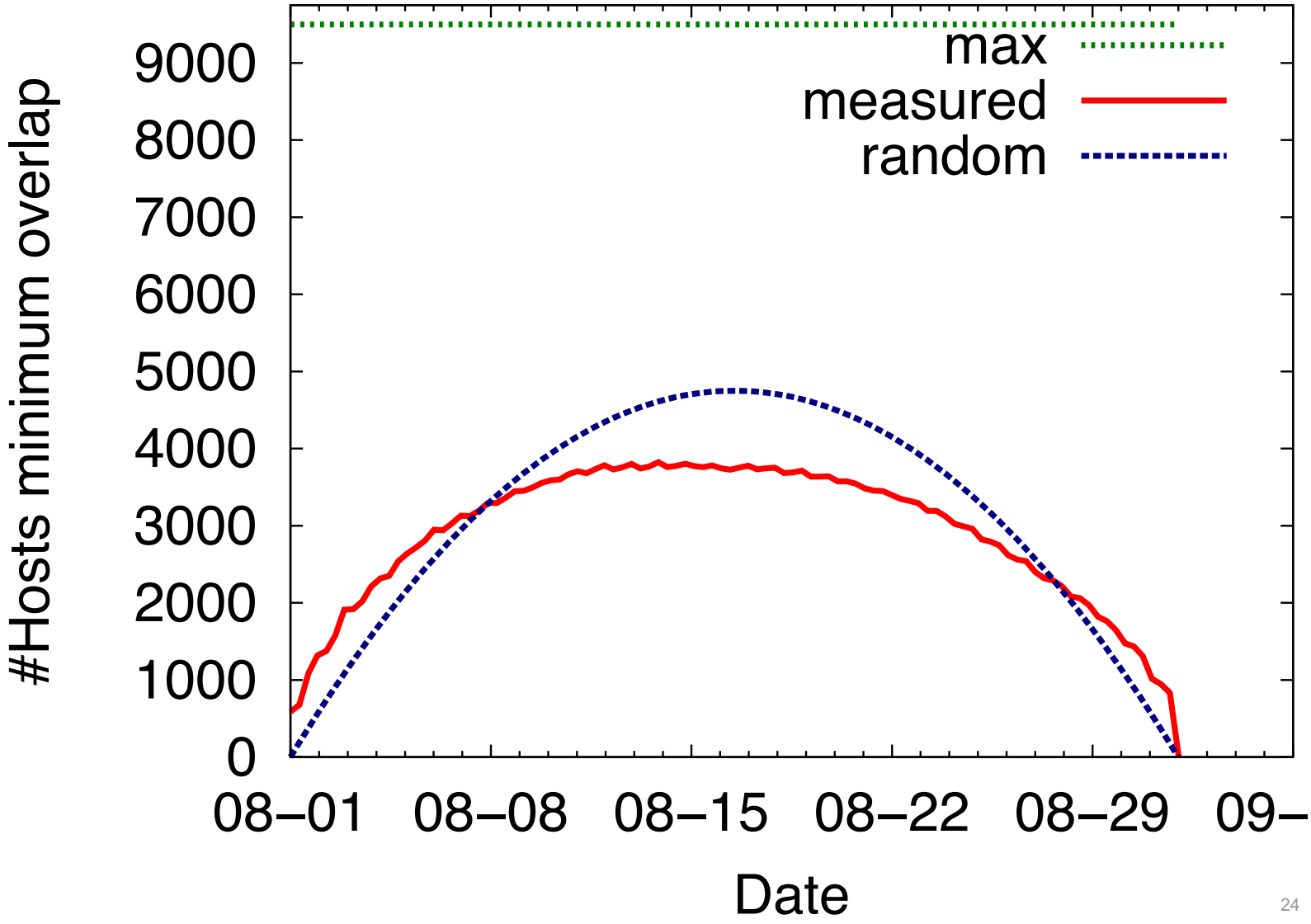
Overlapping Technique
BitTorrent Traffic only



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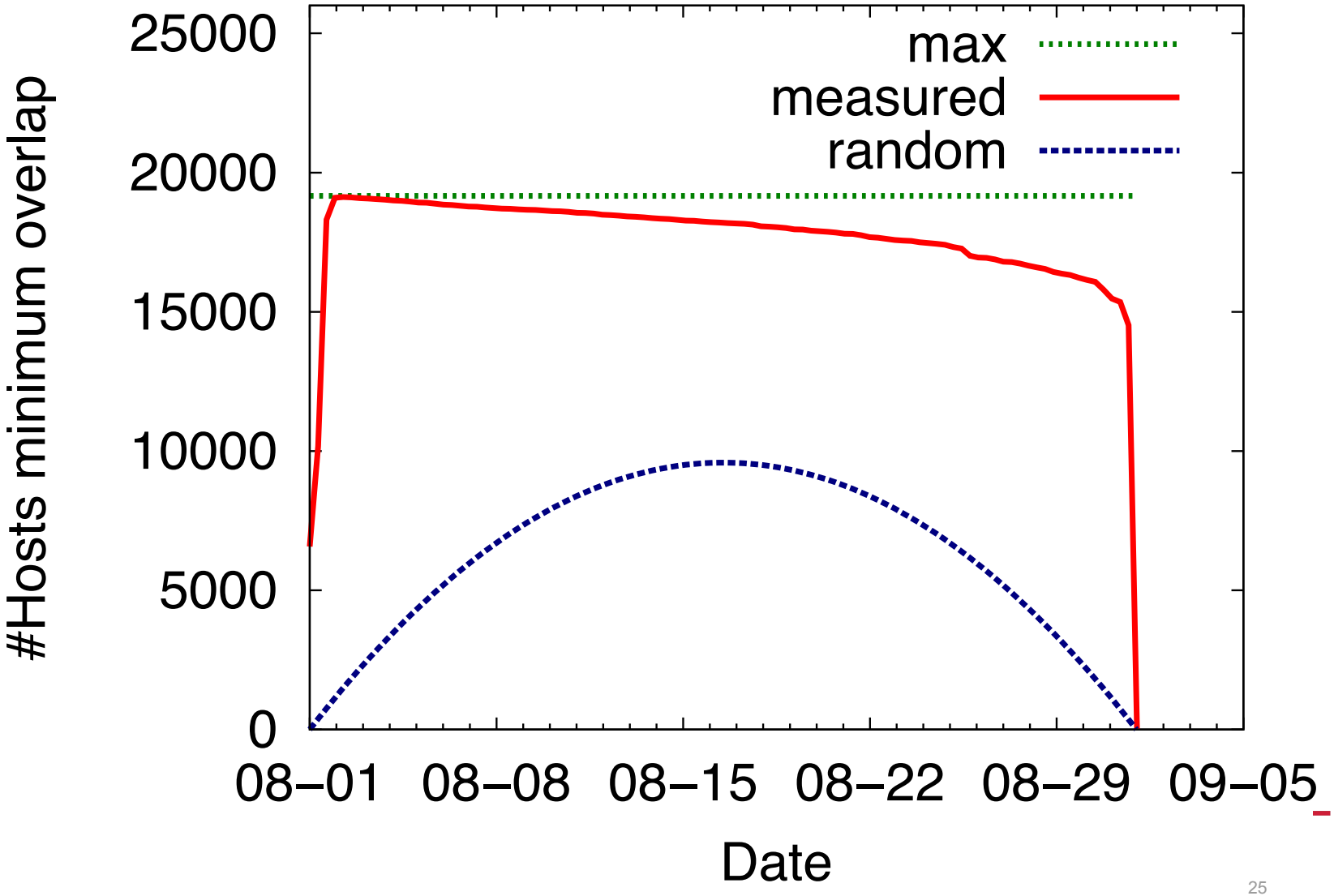
Overlap with Internet Traffic



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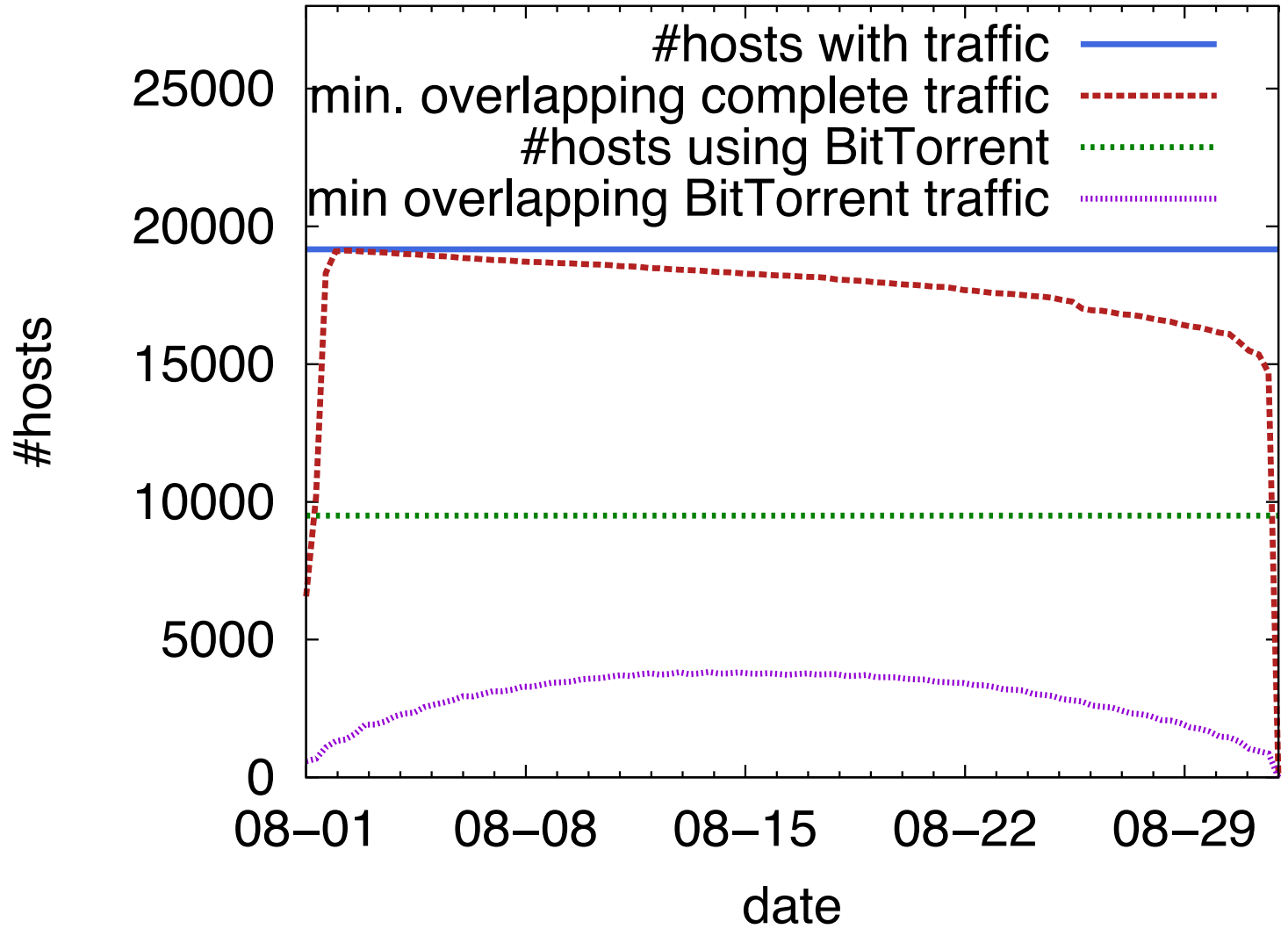
Comparison



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BitTorrent Traffic

- Scatterplots for Up/Download Traffic
- BitTorrent and other traffic not related
- Remember: correlation coefficient

$$\rho_{X,Y} = \frac{\operatorname{cov}(X,Y)}{\sigma_X \sigma_Y} = \frac{E[(X-\mu_X)(Y-\mu_Y)]}{\sigma_X \sigma_Y},$$

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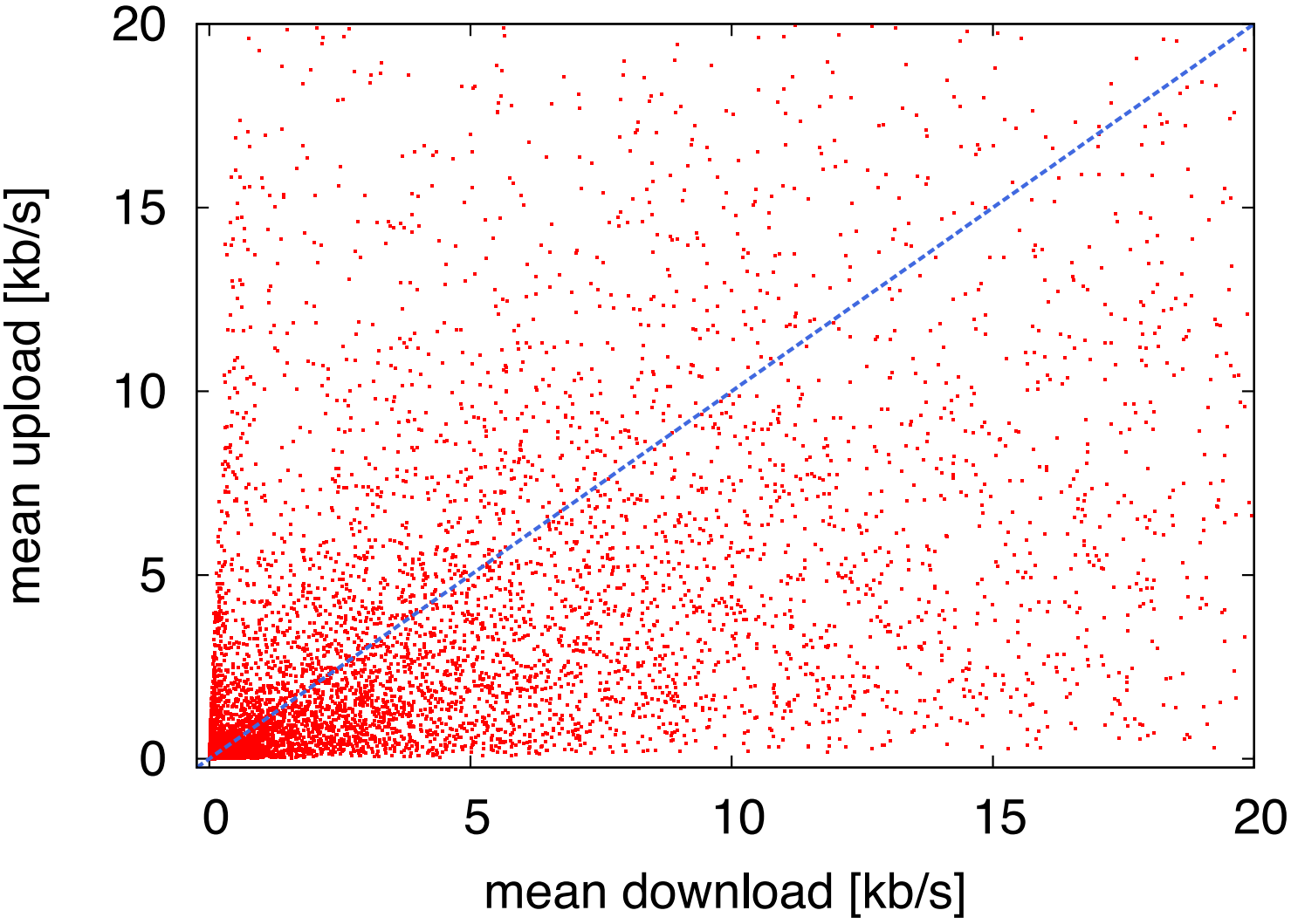
Scatterplott - BitTorrent Traffic

- correlation coefficient: 0.58



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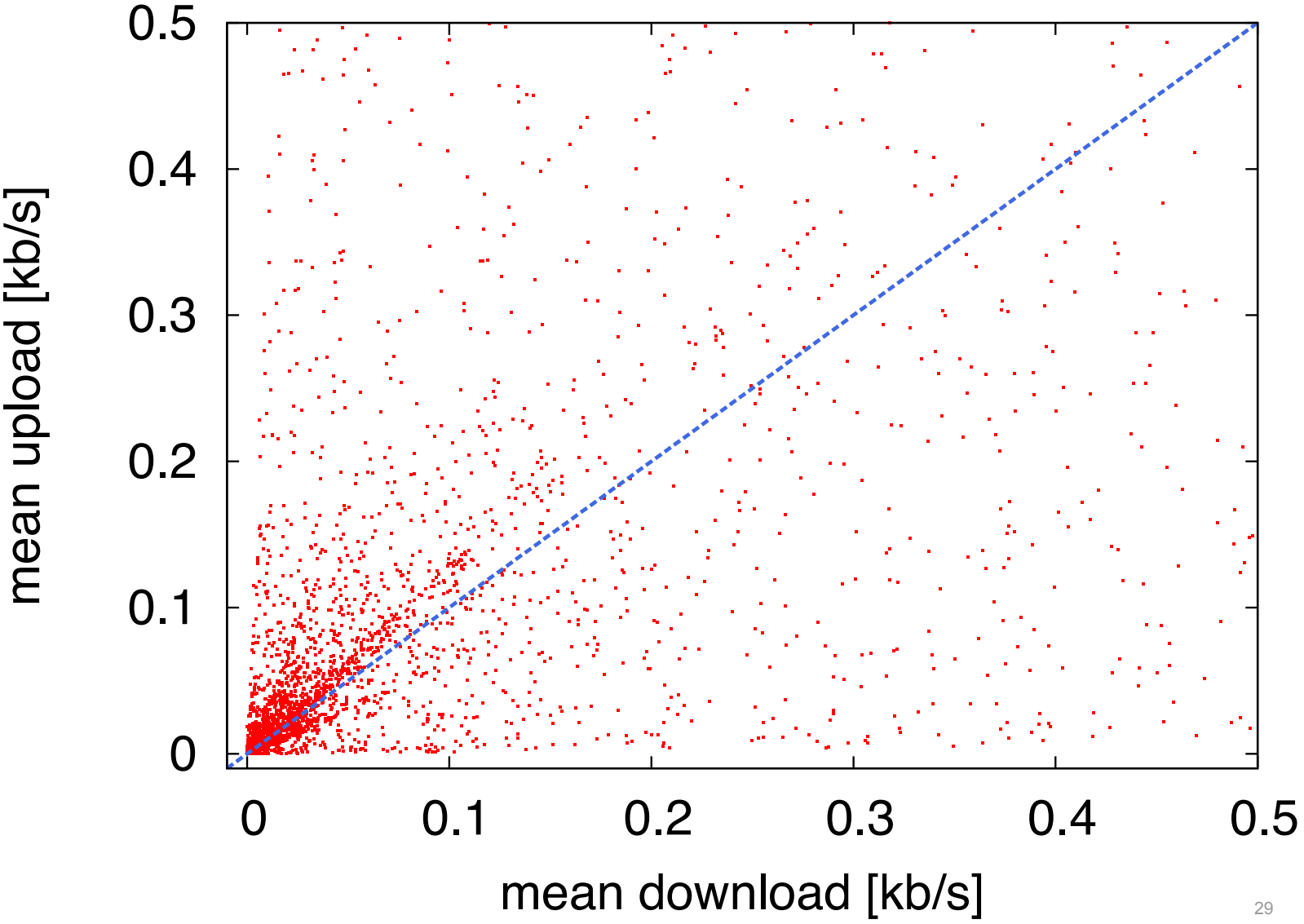
Scatterplott - BitTorrent Traffic (Zoom in)



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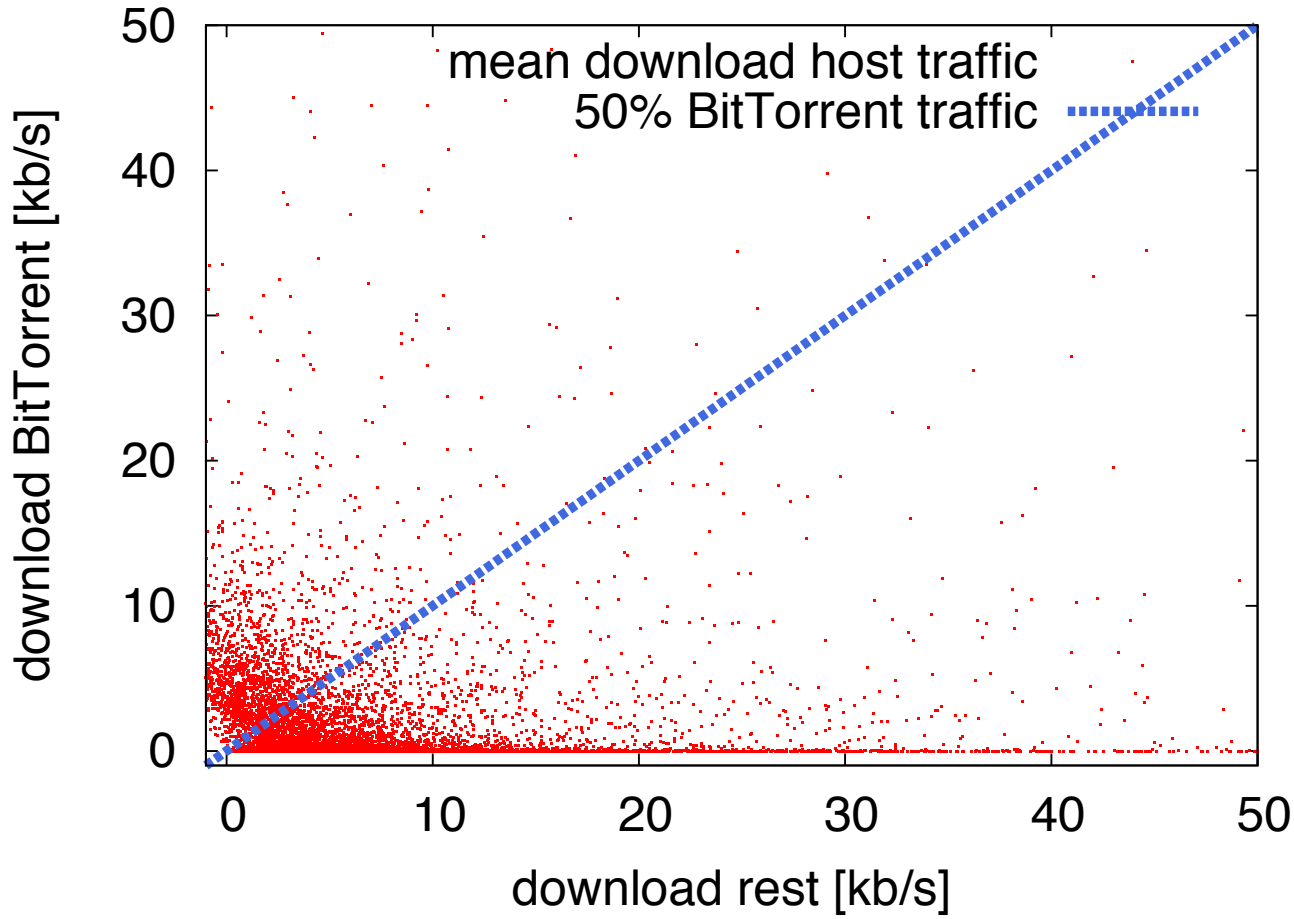
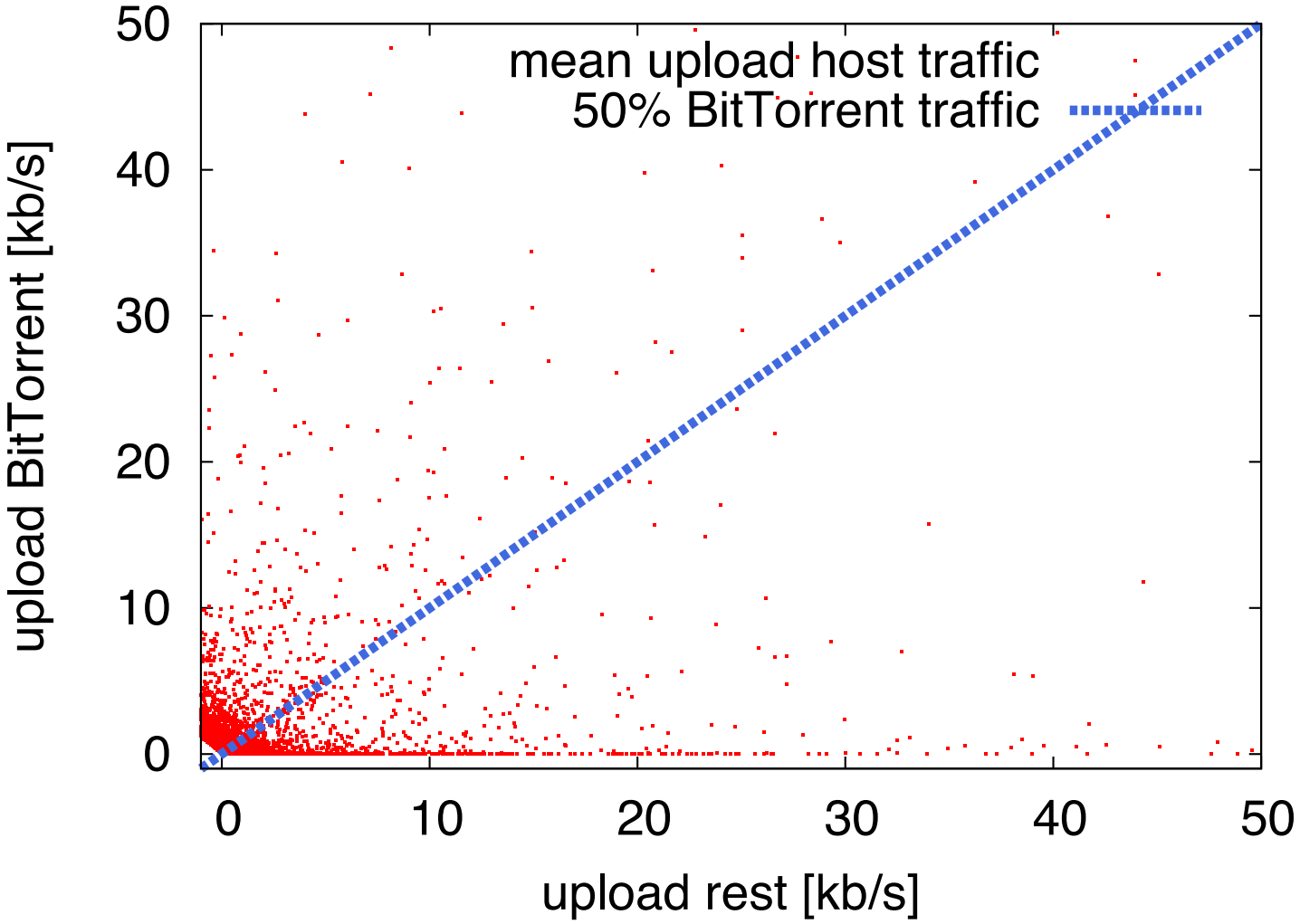
BitTorrent Traffic versus Other Traffic Downstream

- correlation coefficient: −0.38.



Upload BitTorrent versus Other Traffic Upload

- correlation coefficient −0.53



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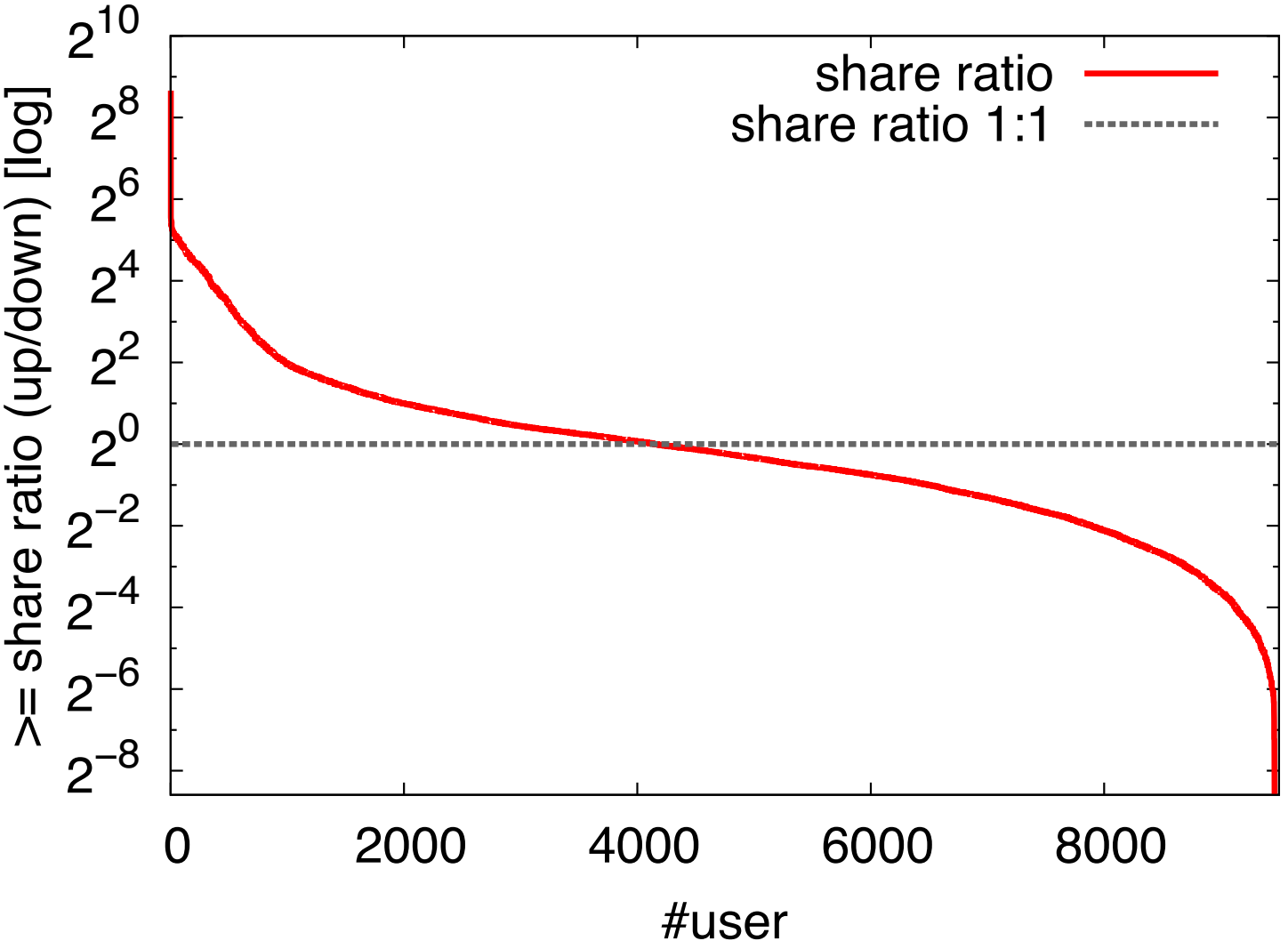
Upload / Download Distribution



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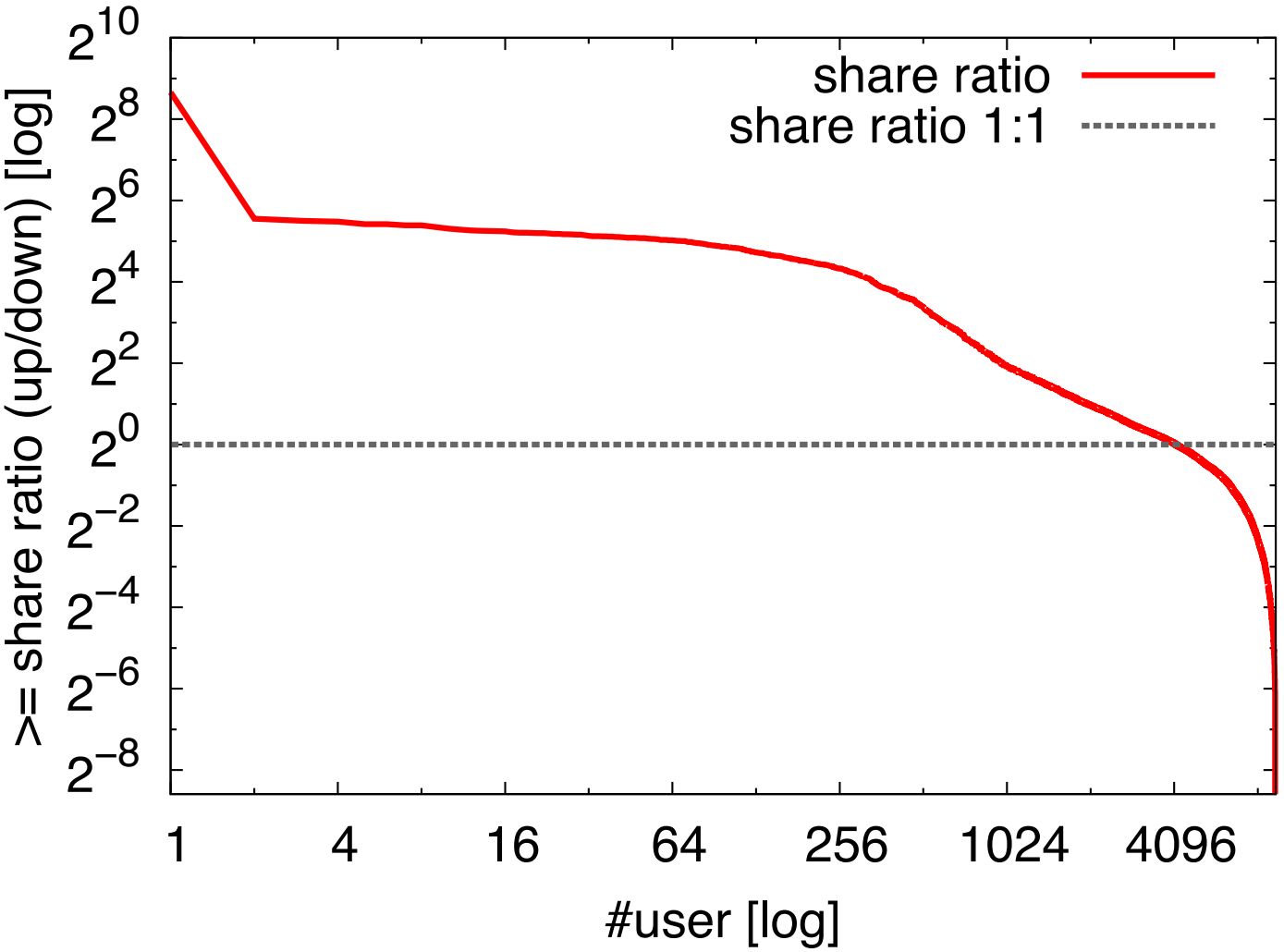
Upload / Download Distribution (Log-Log-Plot)



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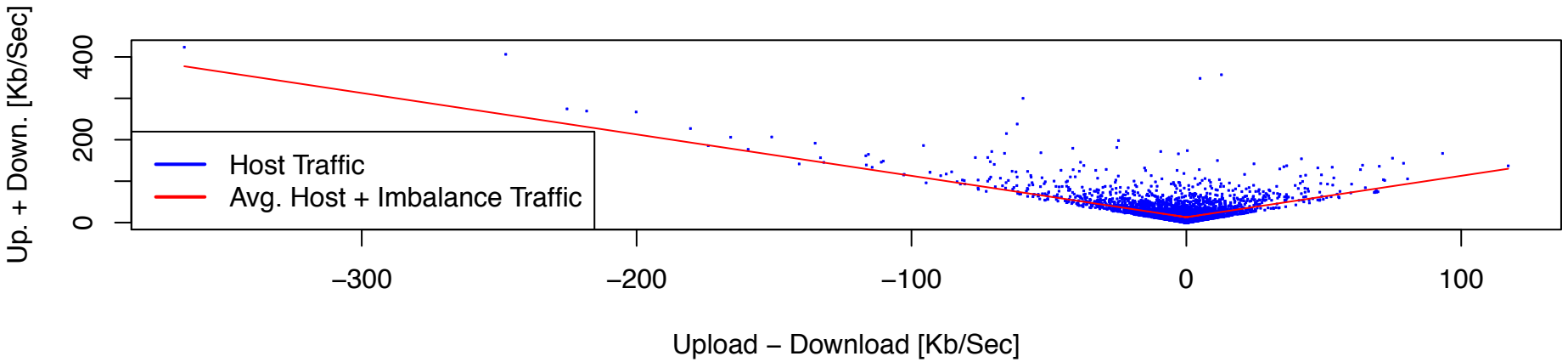
Traffic Difference versus Traffic Sum



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Share Difference of Torrent Traffic

- From scatterplot: no sharp distribution for BitTorrent traffic.
- Difference of download and upload traffic is a piecewise power law (Pareto) distribution

$$P_{d-u}\left[\text{share-difference } x\right] \approx \begin{cases} 0.68 \cdot (x + 1.1)^{-2.04} & \text{for } x \geq 0, \ (\sigma = 0.0008) \\ 4.33 \cdot (3.07 - x)^{-2.33} & \text{for } x < 0 \ (\sigma = 0.0006) \end{cases}$$

- Explanation: maybe the power law distribution of the overall BitTorrent upload and download?

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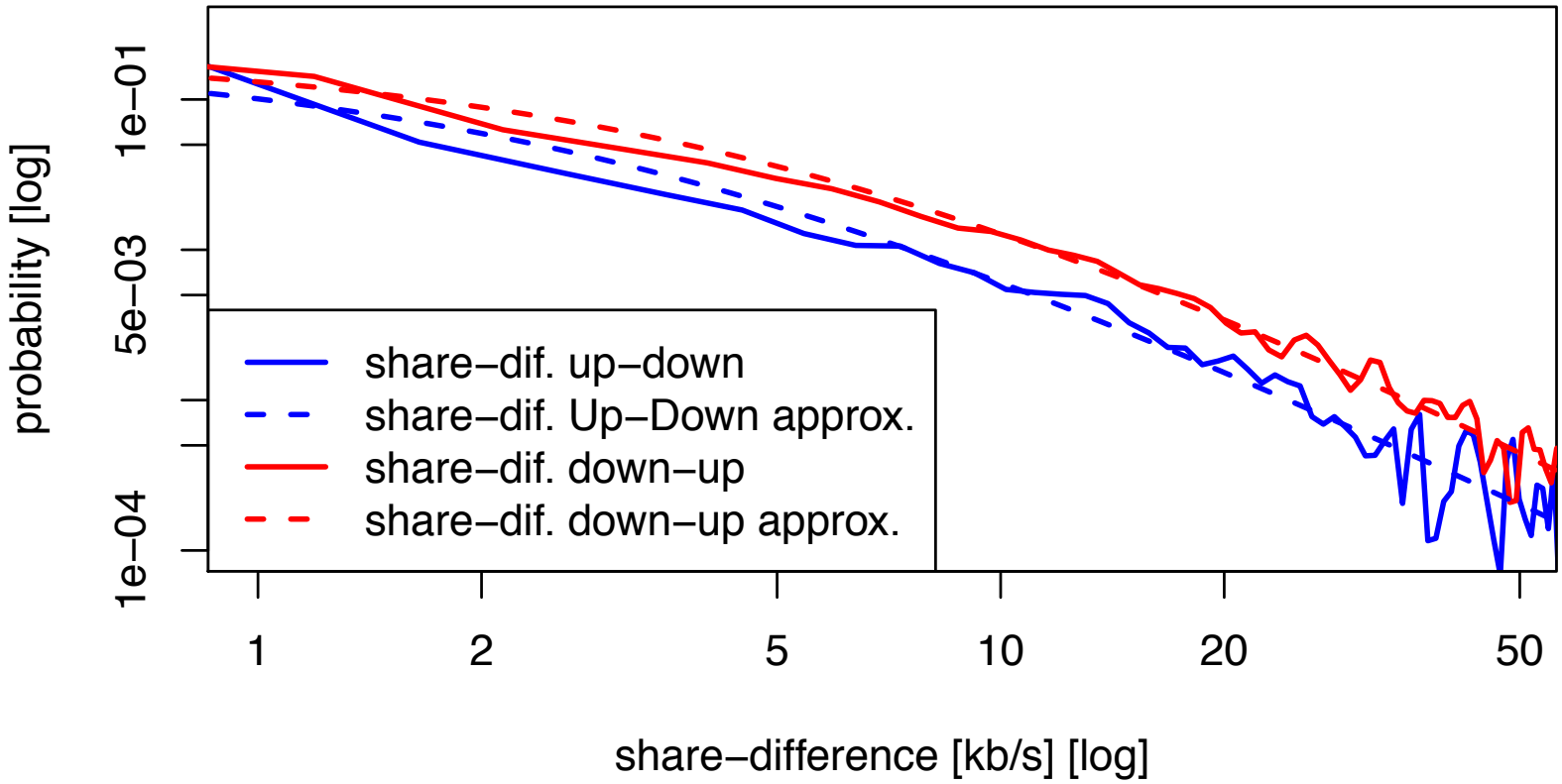
Share Difference of Torrent Traffic



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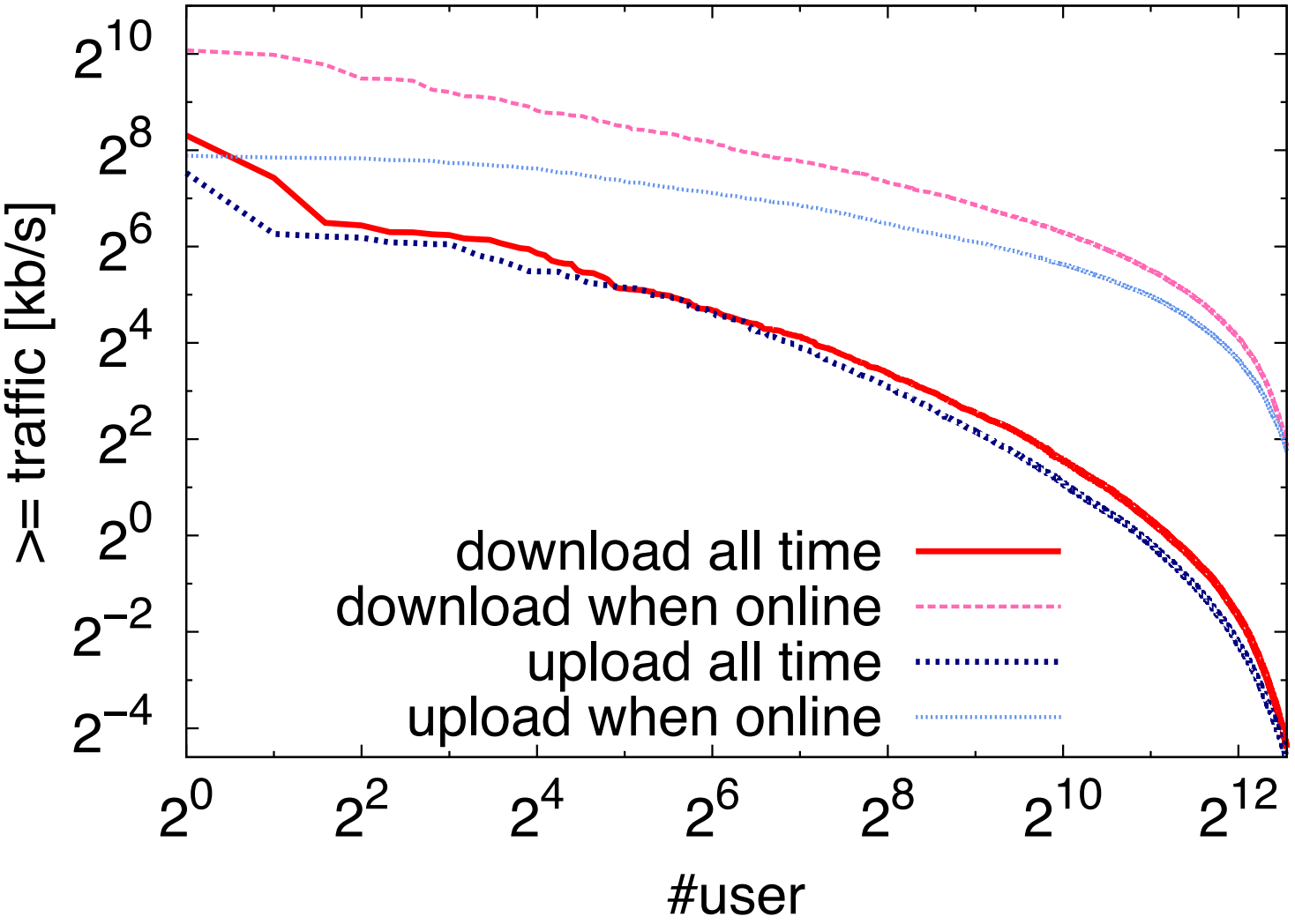
Overall Traffic Distribution



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Periodicity

- Obviously there is a perodicity in the data
- New idea:
  - Look at Fourier Transformation
  - And normalized by frequency to receive the „energy“ level
  - and verify with averaged plots

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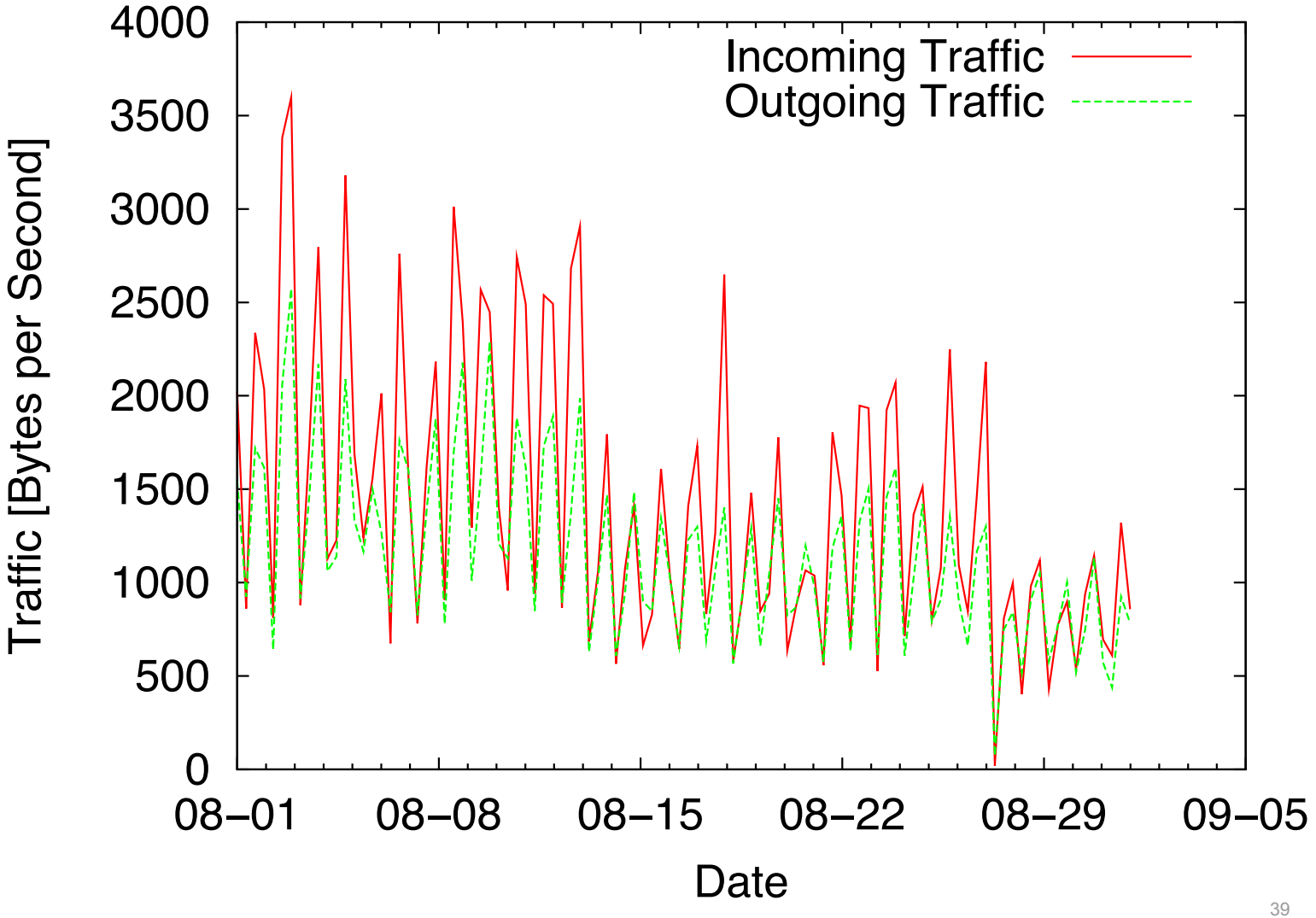
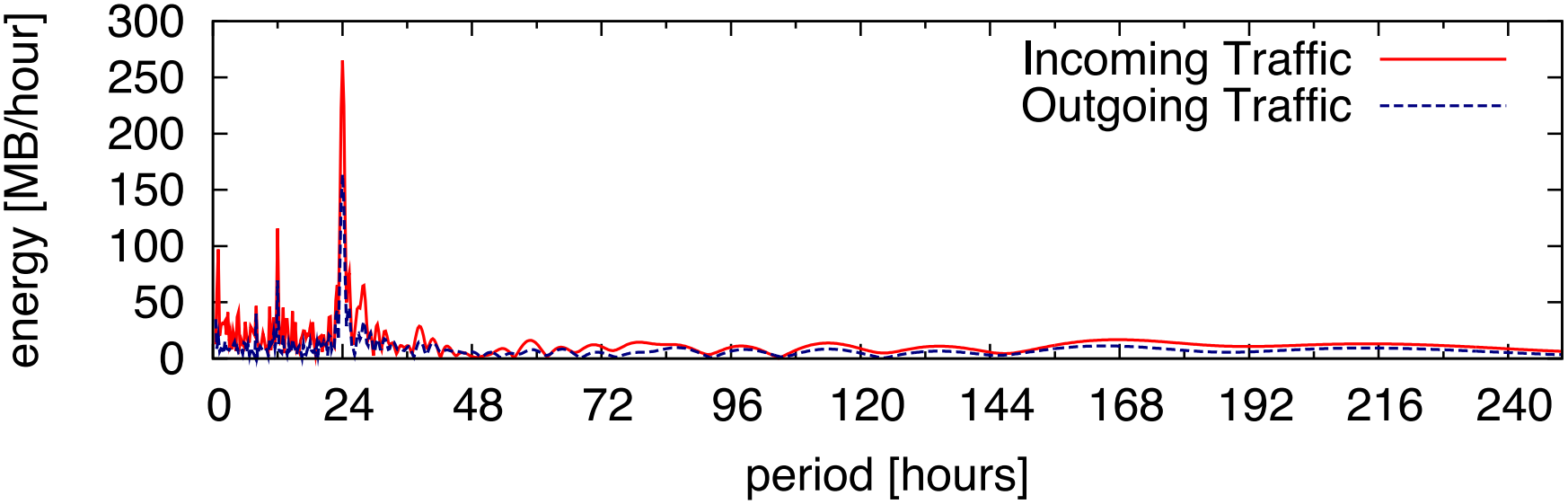
Average Traffic per Host



Fourier Transformation of Traffic Pattern



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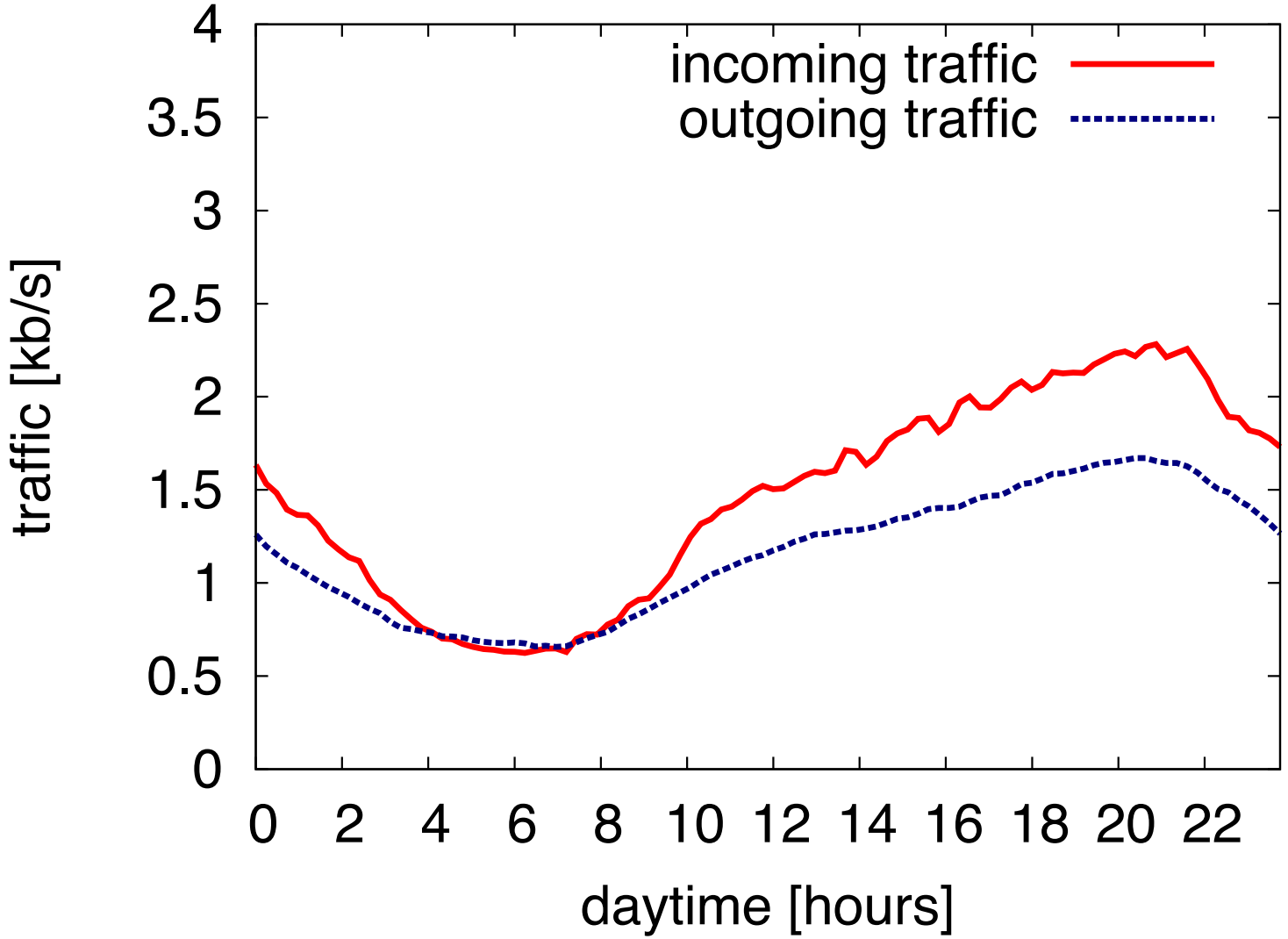
Traffic Average per Hour of the Day



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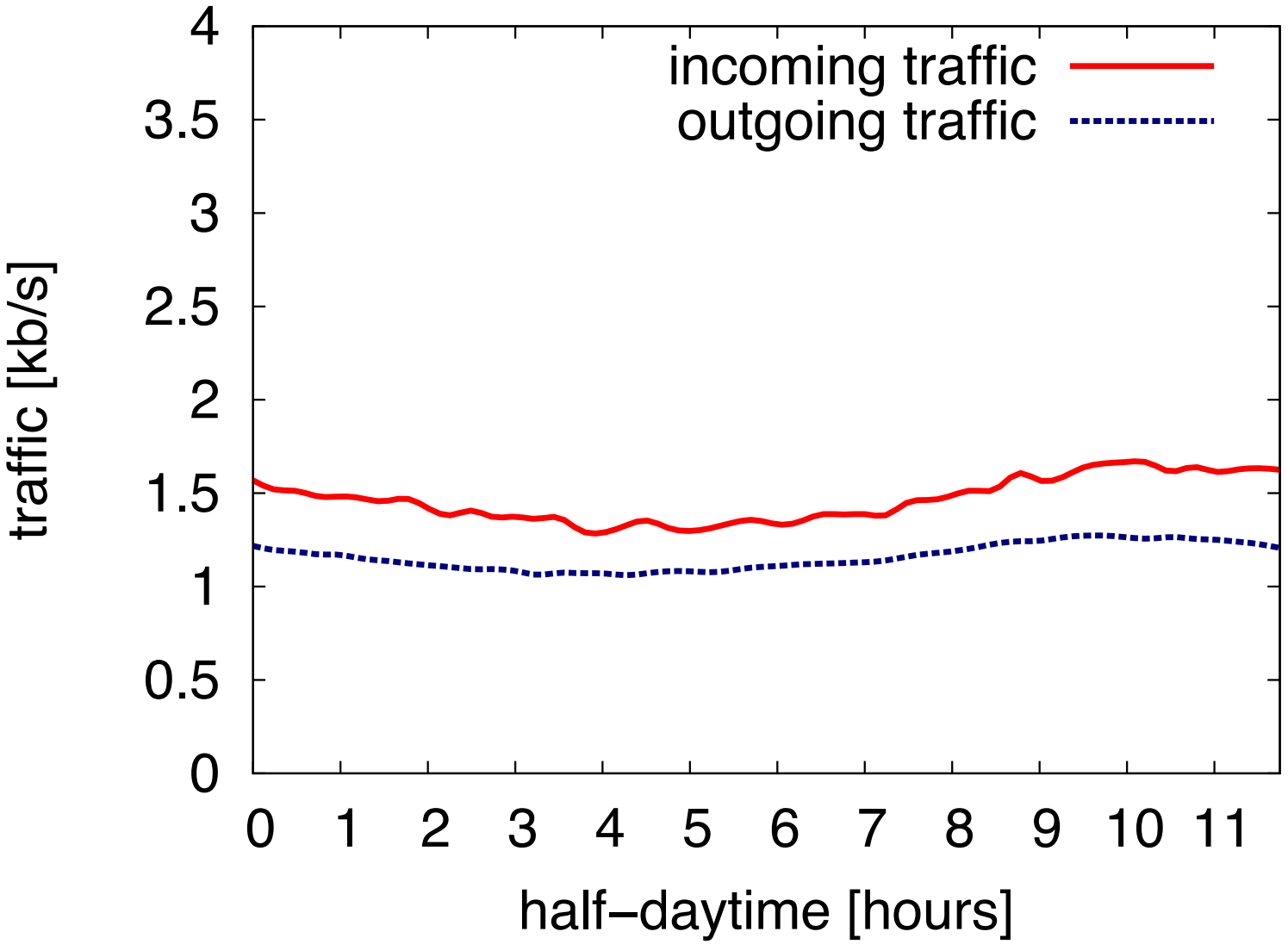
Is there a 12h Periodicity?



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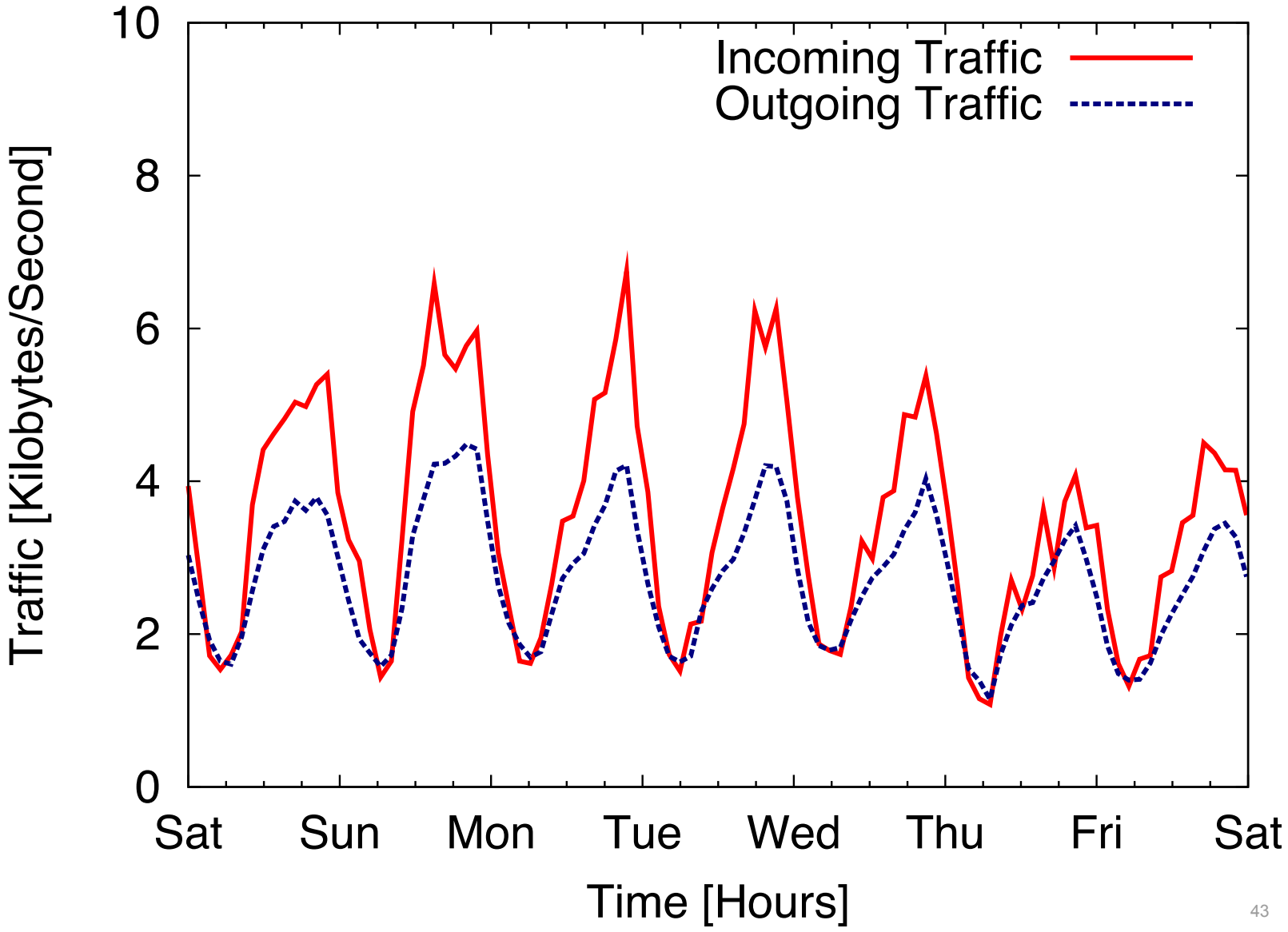
Traffic Averaged per Weekday



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How Long are Users Online

- Online period
  - continuous amount of time when users are using HTTP
- Online times
  - sum of periods over a day/week/month

$$P\left[\text{online period } t\right] \approx \begin{cases} 0.18 \cdot t^{-0.82} & \text{for } t \geq 16, \ (\sigma = 0.013) \\ 2782 \cdot t^{-4.40} & \text{for } 16 < t \leq 24, \ (\sigma = 0.00006) \\ 11 \cdot t^{-2.58} & \text{for } t > 24 \ (\sigma = 0.000015) \end{cases}$$

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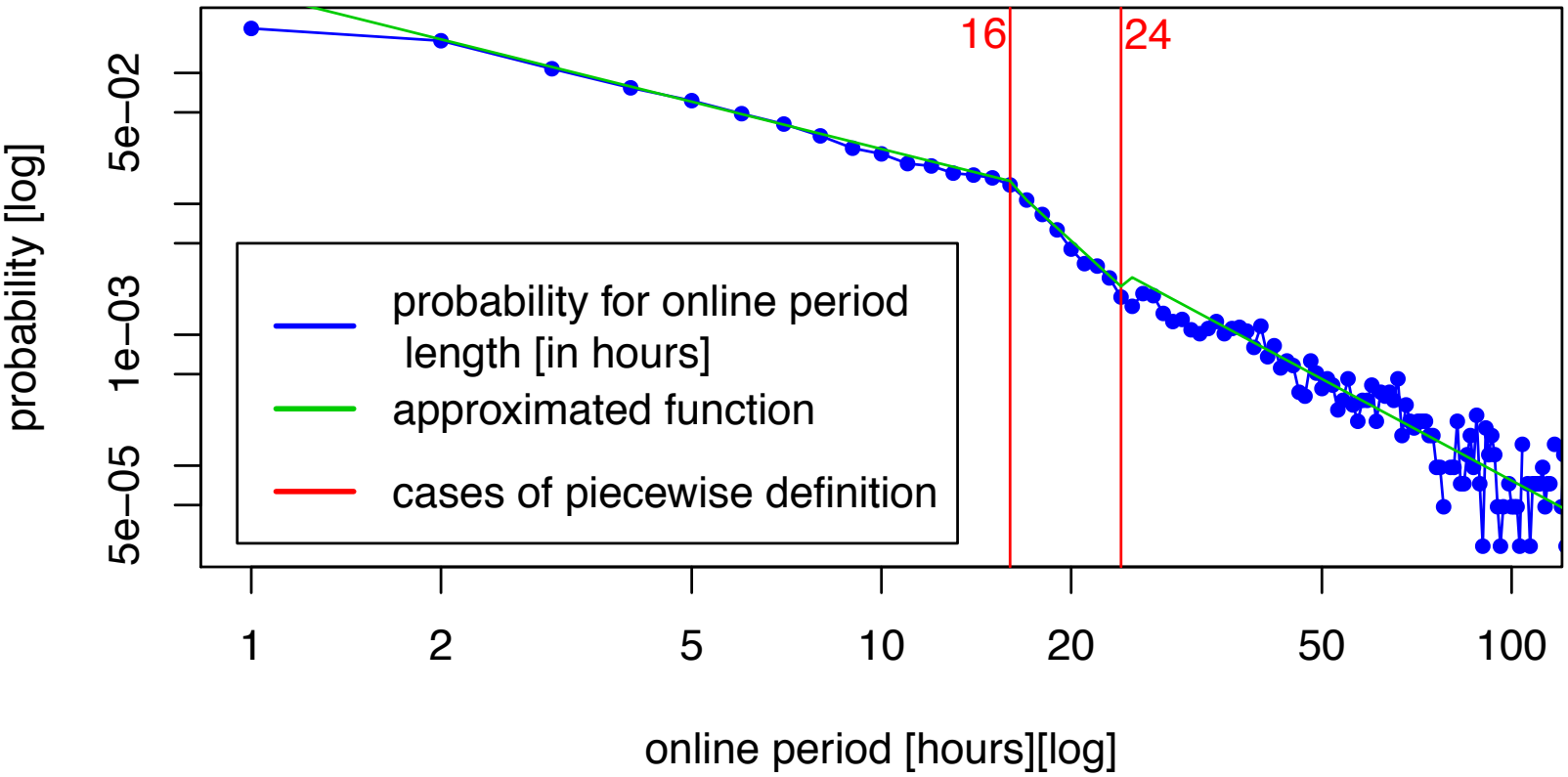
Distribution of Online Periods



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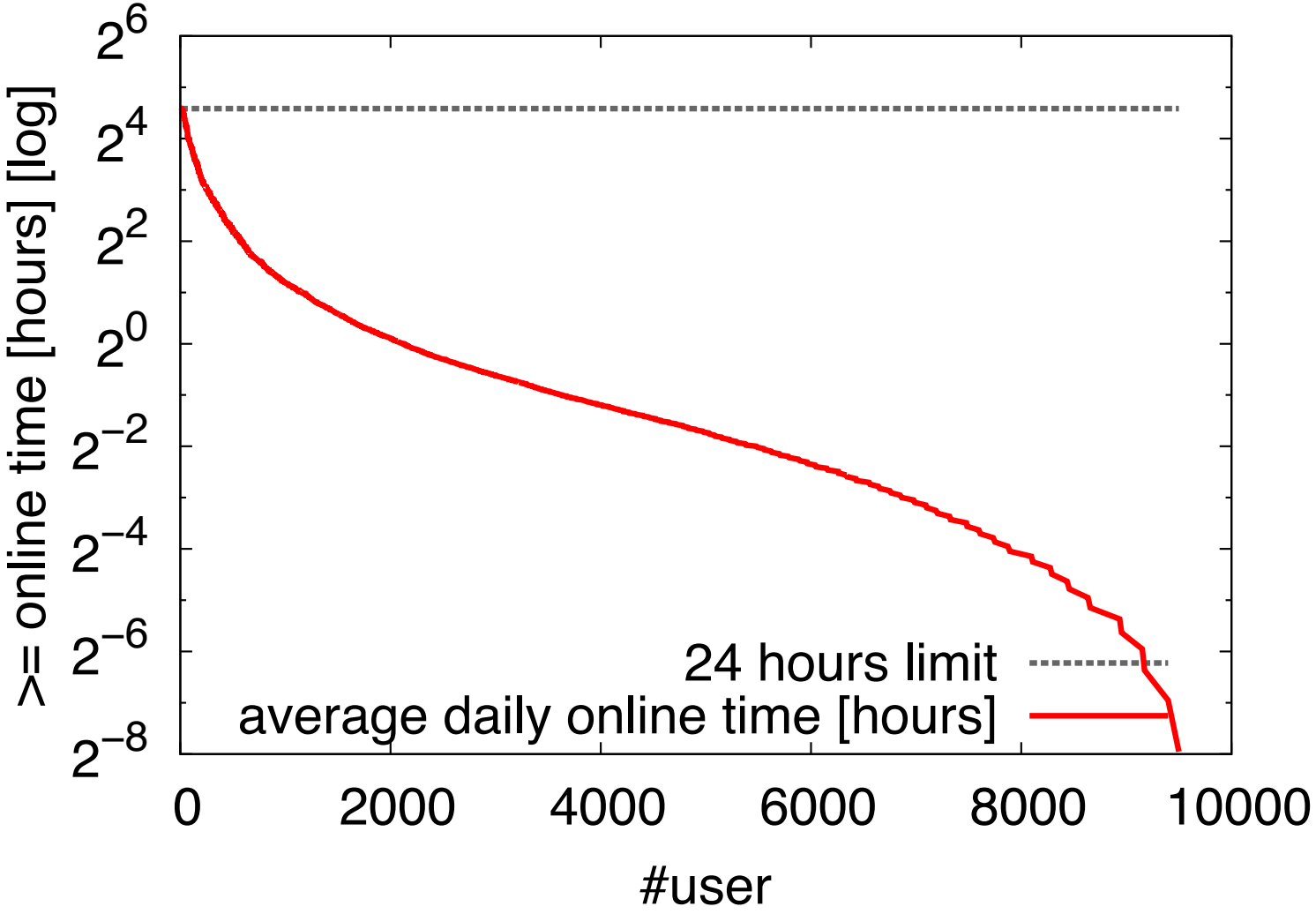
Online Times per Day (Lin-Log-Plot)



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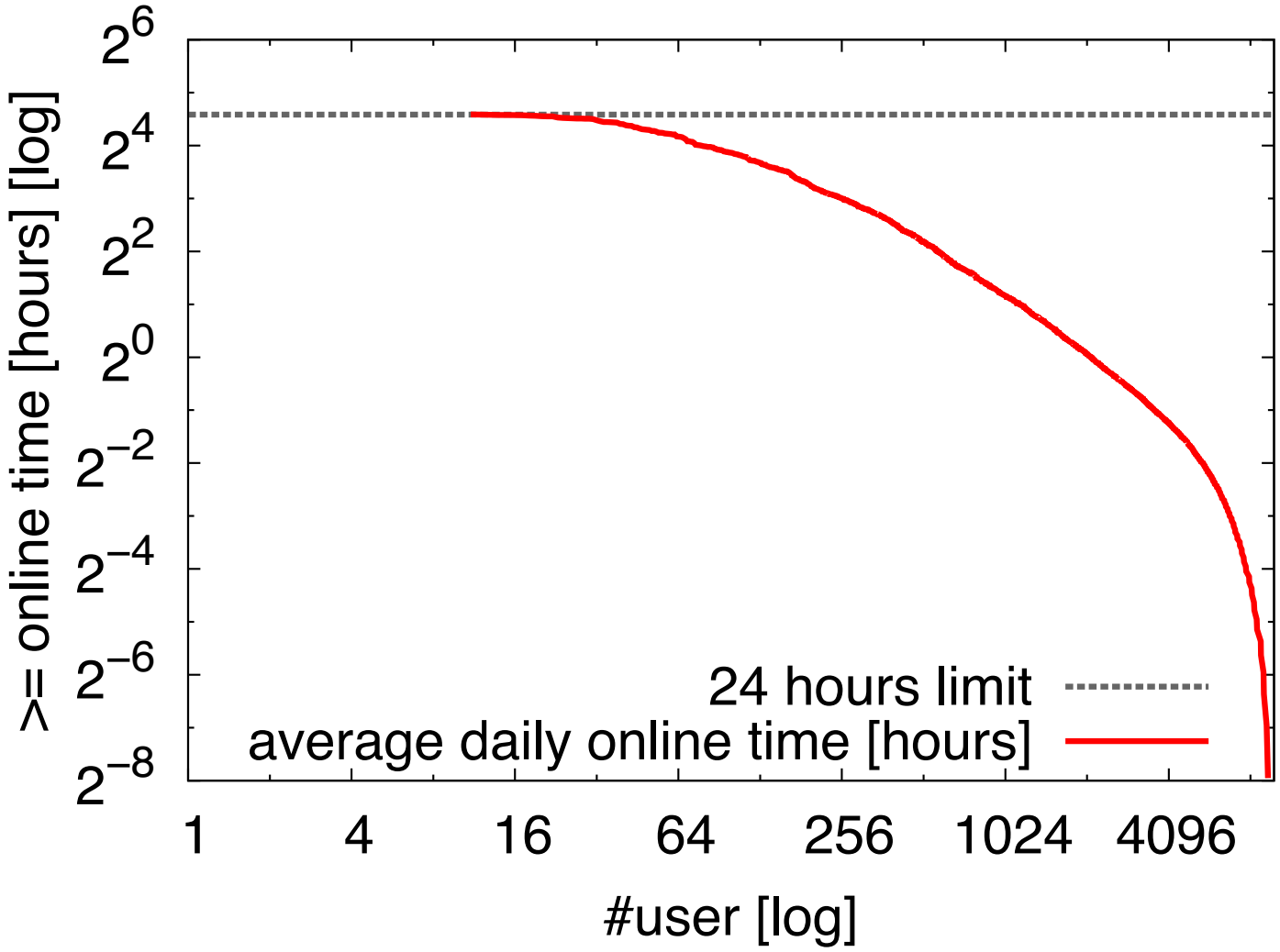
Online Times (log log Plot)



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Conclusions

- Analysis of web traffic of 21,766 hosts of an Internet service provider (ISP) in Germany
- Emphasis BitTorrent traffic August in 2009
- 50% used BitTorrent
- At most 40% of BitTorrent users online at the same time
- Many users participate in this peer-to-peer network only for some short time periods
- Most Internet traffic is HTTP

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