Energy Efficient BitTorrent for Green P2P File Sharing

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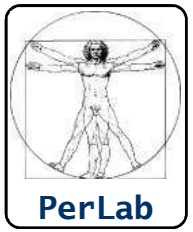


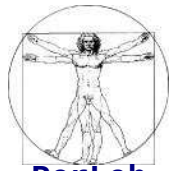
Dept. of Computing, Hong Kong Polytechnic University, April 1, 2011

Acknowledgments

- ICT Action IC0804
  - Energy Efficiency in Large-Scale Distributed Systems
  - Starting date : 23/01/2009
  - End of action : 04/05/2013
  - Additional info at

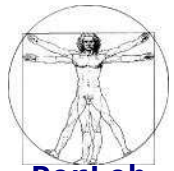
http://www.irit.fr/cost804/

Overview



- Introduction
- Motivations for
  - Energy Efficient Internet
  - Energy Efficient P2P File Sharing
- EE-BitTorrent
- Experimental Analysis
  - Real testbed
- Conclusions

The Energy Problem



- Dramatic increase in the global energy consumption
  - Energy: not renewable and limited resource
  - Environmental pollution and planetary overheating

- Energy consumption of Internet
  - 74TWh/year in US (equivalent to $ 6 billions)
  - 2-3% of the total energy consumption in US
  - About 1/3 of this energy could be saved by simple power management techniques

(Source: Lawrence Berkeley National Laboratory, USA, 2006)

Where Energy is consumed

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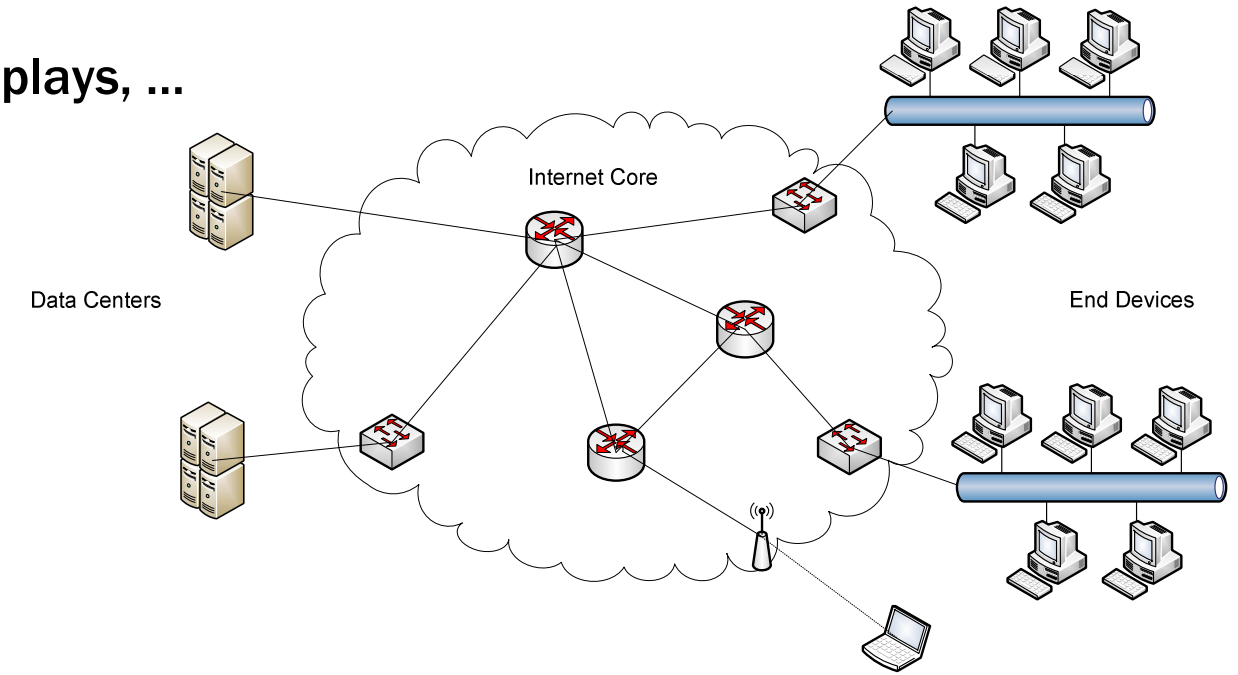
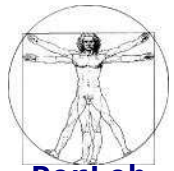
- Internet Core
  - Routers , Switches, Access Points, Links
- Data Centers
  - Servers
- User Devices
  - PCs, Printers, Displays, ...



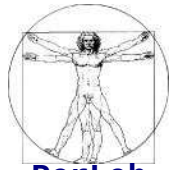
Energy Efficiency in the Internet Core



- **Re-Engineering**
  - More energy-efficient network devices through
    - ⇨ Energy-Efficient Silicon
    - ⇨ Complexity Reduction
- **Dynamic Adaptation**
  - The capacity of network elements id dynamically modulated so as to meet actual traffic loads
    - ⇨ Performance Scaling
    - ⇨ Idle Logic
- **Sleeping/Standby**
  - Unused network/device portions are put in low-power mode

R. Bolla, R. Bruschi, F. Davoli, F. Cucchietti, **Energy Efficiency in the Future Internet: A Survey of Existing Approaches and Trends in Energy-Aware Fixed Network Infrastructures**, *IEEE Communications Surveys and Tutorials*, To appear. Available at http://tnt.reti.dist.unige.it/index.php/en/publications

Edge Devices



- Overall Energy Consumption
  - Data Centers: 2 TWh per year
  - User Devices: 16 TWh per year
    - ⇨ User devices are widespread and very numerous
    - ⇨ User devices are often left powered on even if idle
    - ⇨ People typically do not pay attention to energy issues

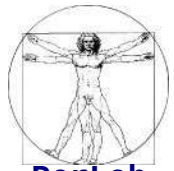
(Source: Lawrence Berkeley National Laboratory, USA, 2006)

Edge devices (cont'd)

- Some statistics about people behavior
  - 43,5% of UK population uses PC at work and
    - ⇨ 18% *never* powers it off
    - ⇨ 16% *sometimes* powers it off
  - Energy wastage corresponding to
    - ⇨ 153 millions of €
    - ⇨ 700.000 tons of CO2
- Motivations for not powering off
  - It is no so important
  - It takes some time and I am always in a hurry
  - I simply forget to power off
  - I don't want to lose my work
  - Nobody else turns PC off , so …
  - ….

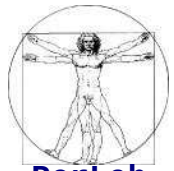
(Source: National Energy Foundation, UK, 2007)

Causes for energy wastes



- PCs left on for
  - ⇨ Laziness, Omissions, …
- PCs intentionally left on for maintaining connectivity
  - ⇨ Remote login
  - ⇨ Automatic software upgrades
- PCs intentionally left on for
  - ⇨ P2P file sharing applications

Possible Solutions

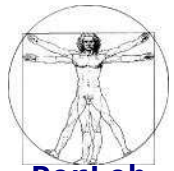


- Centralized Shutdown
  - Already used in data centers and labs
  - No flexibility

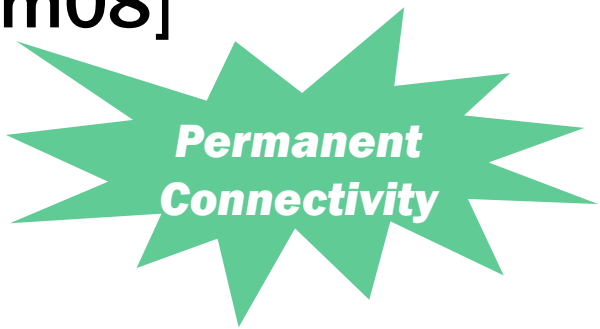
- Power Manager [Chi10]
  - Better flexibility
  - Luca Chiaraviglio, Marco Mellia, PoliSave: Efficient Power Management of Campus PCs, IEEE SoftCOM - 18th *International Conference on Software, Telecommunications and Computer Networks*, Bol, Croatia, September 2010

- Context-aware Power Management [Har05]
  - Uses low-power sensors/devices to predict the user's intention to use/not use the PC
  - [Har05] C. Harris, V. Cahill, Power Management for Stationary Machines in a Pervasive Computing Environment, *Proc. 38th Hawaii International Conference on System Sciences*, 2005.

Possible Solutions



- Network Connectivity Proxy (NCP) [Jim08]
  - Based on proxying + Magic Packet
    - ⇨ Somniloquy [Aga09]
    - ⇨ Sleep Server [Aga10]



- [Jim08] M. Jimeno, K. Christensen, B. Nordman, **A Network Connection Proxy to Enable Hosts to Sleep and Save Energy**, *Proc. IEEE International Performance Computing and Communications Conference*, pp. 101-110, December 2008.
- [Aga09] Y. Agarwal, S. Hodges, J. Scott, R. Chandra, P. Bahl, R. Gupta, **Somniloquy: Augmenting Network Interfaces to Reduce PC Energy Usage**, Proceedings USENIX Symposium on Networked System Design and Implementation (NSDI, 2009), Boston, MA, USA, April 22-24, 2009.
- [Aga10] Y. Agarwal, S. Savage, and R. Gupta, **SleepServer: Energy Savings for Enterprise PCs by Allowing them to Sleep**, Proceedings of the USENIX Annual Technical Conference, June 2010.

- Energy-aware Applications and Protocols

P2P Applications

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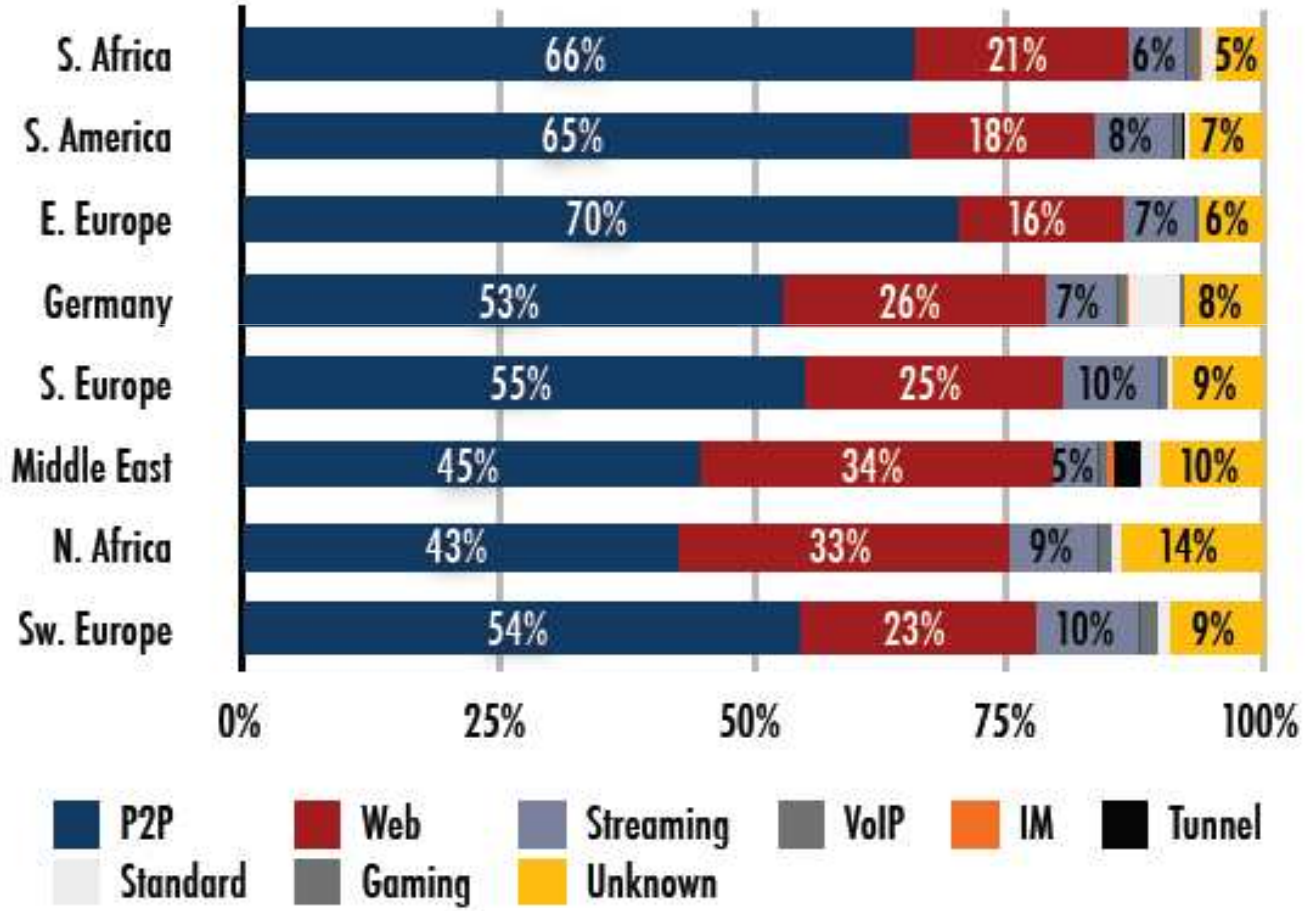
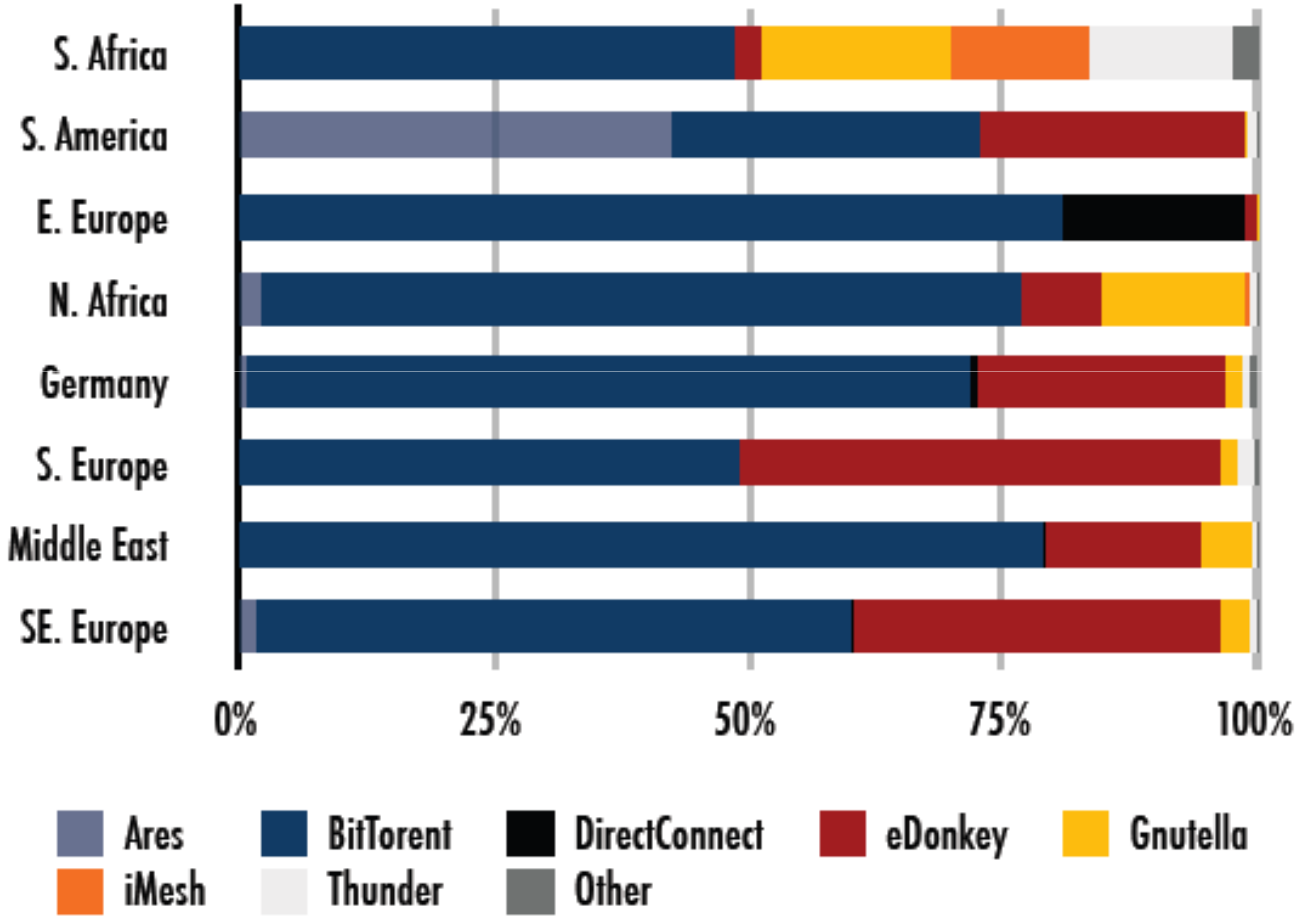
- Require permanent connectivity
- P2P Traffic in Internet



Source: Ipoque 2008 / 2009

P2P Applications (Cont'd)

- P2P Traffic originated by BitTorrent



Source: Ipoque 2008 / 2009

BitTorrent

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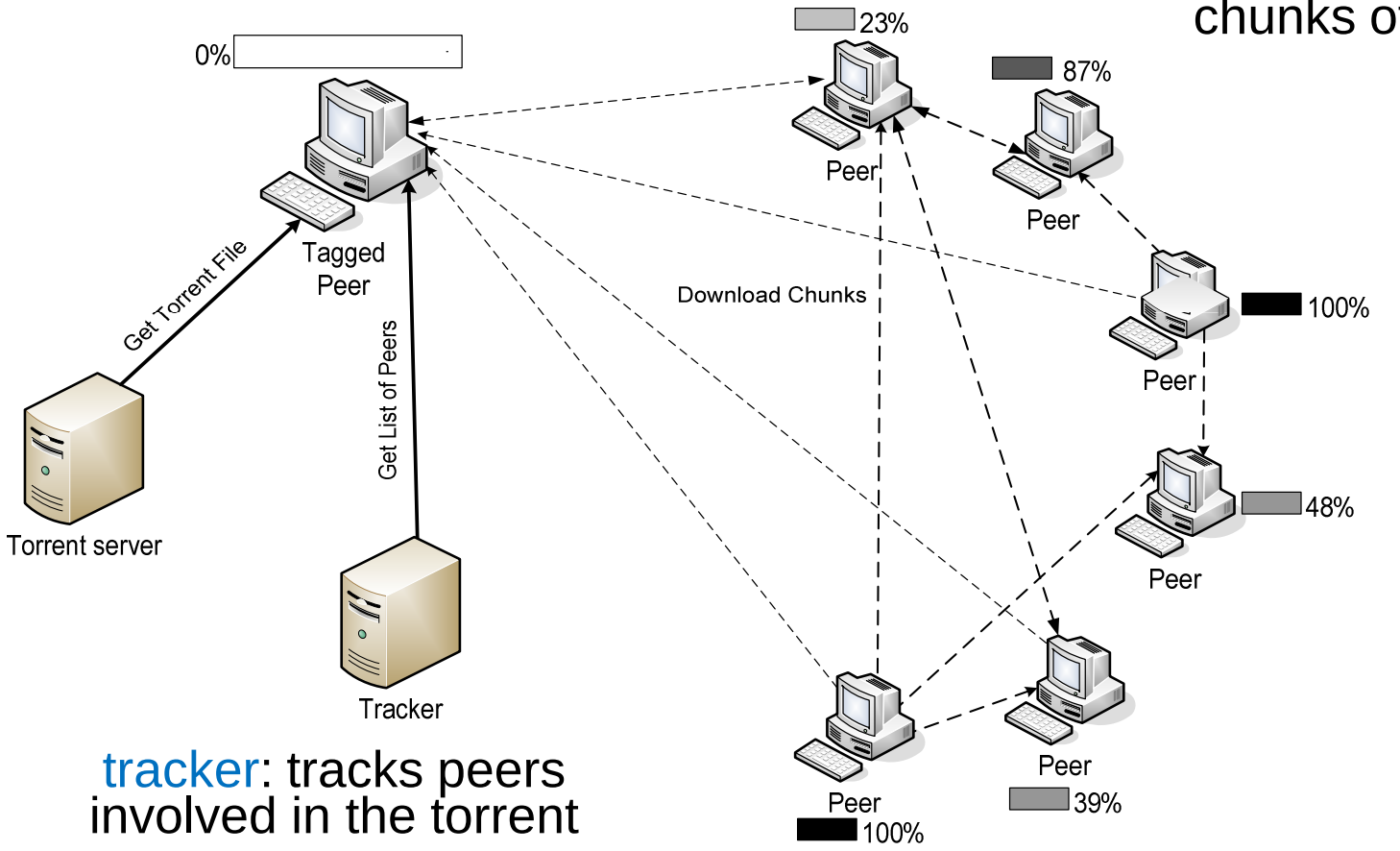
peer: node of the BitTorrent overaly

torrent: group of peers exchanging chunks of a file



tracker: tracks peers involved in the torrent

BitTorrent Protocol

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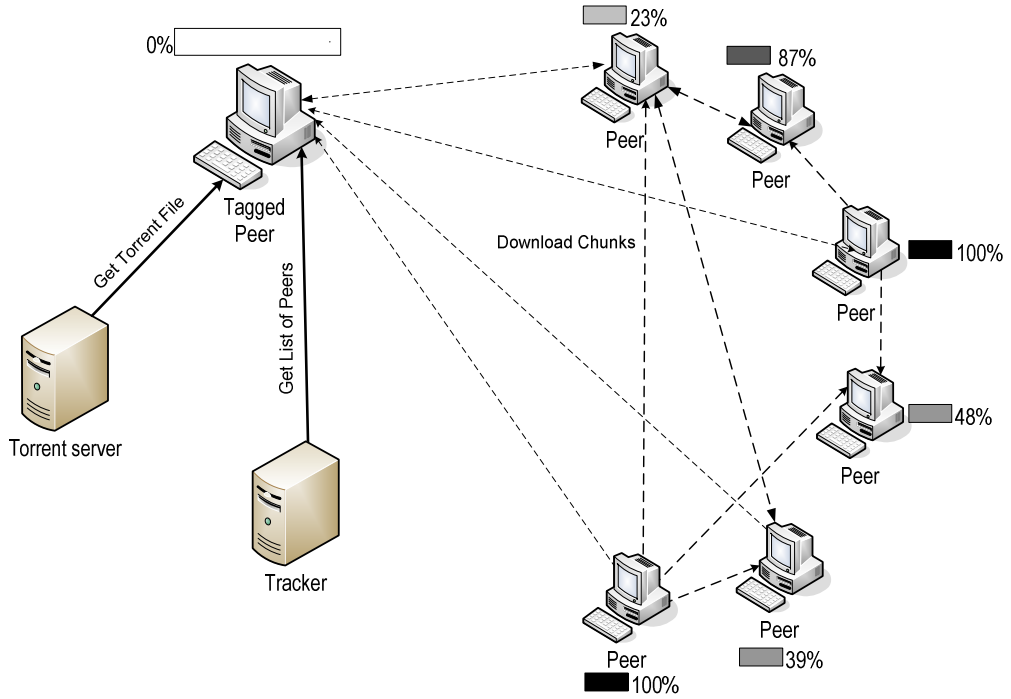
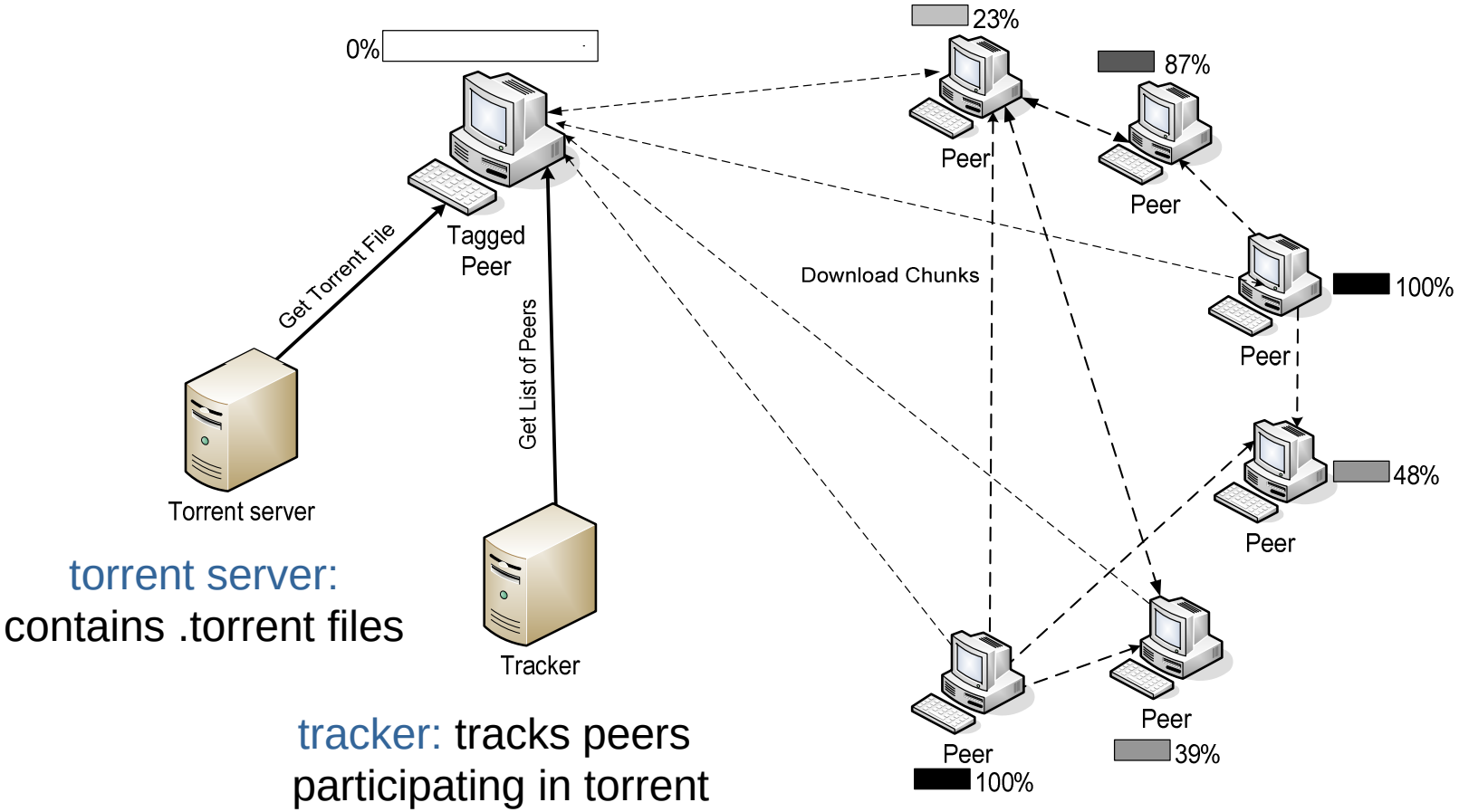
- File divided into 256KB *chunks*.
- Peers download chunks from a multitude of other peers
  - Instead from a single server, as in the traditional C/S approach
- While downloading, peers upload chunks to other peers.
- Once a peer has entire file, it may (selfishly) leave or (altruistically) remain
  - Peers may come and go



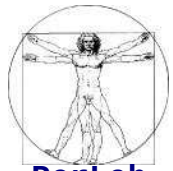
BitTorrent Protocol



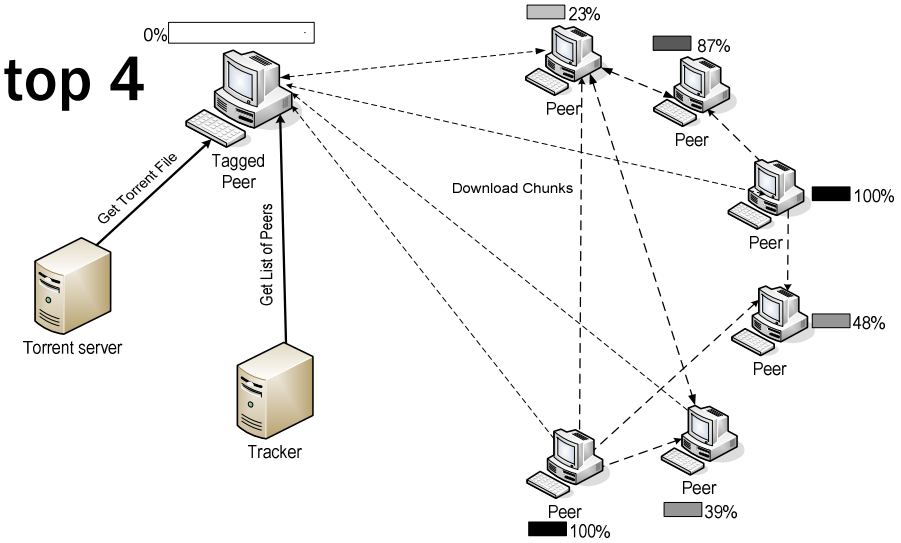
torrent server:
contains .torrent files

tracker: tracks peers participating in torrent

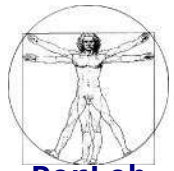
Tit-for-Tat Policy



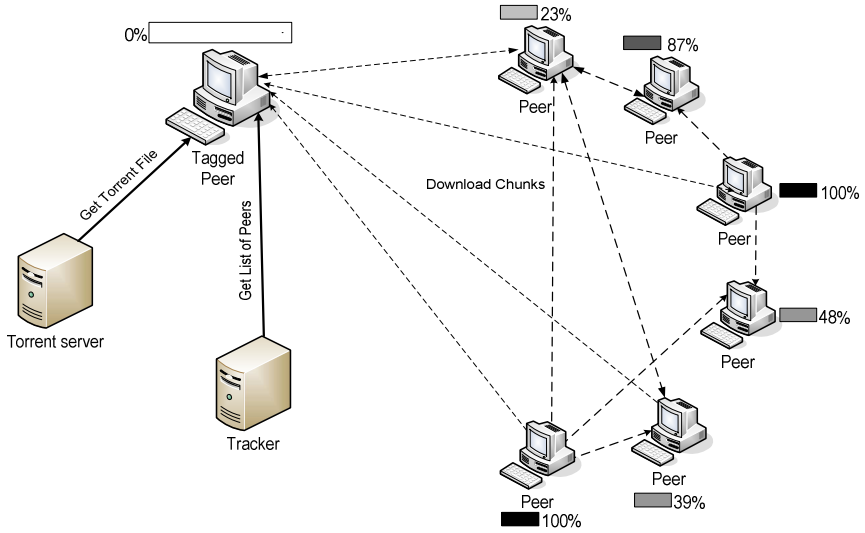
- A peer continuously measures the bit rate achieved by each of its neighbors
- And uploads chunks to the 4 neighbors from which it is achieving the *highest bit rate*
  - re-evaluate top 4 every 10 secs
- Every 30 secs: randomly select another peer, starts sending chunks
  - newly chosen peer may join top 4
  - "optimistically unchoke"



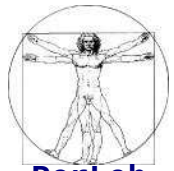
Rarest First Policy



- At any given time, different peers have different file chunks
- Periodically, a peer asks each neighbors for the list of chunks they have.
- And sends requests for missing chunks, giving priority to chunks that are less spread
  - *rarest first*

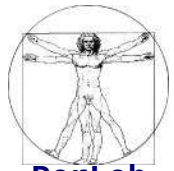


BitTorrent and Energy Efficiency



- BitTorrent is not “energy friendly”
  - BT peers must remain connected during the entire download process
    - ⇨ Powering off a peer stops the download process
  - Coordinated strategies for energy efficiency are unfeasible
    - ⇨ They would be in contrast with the BT design paradigm

BitTorrent and Energy Efficiency



- Energy Efficiency in BitTorrent has not received significant attention so far
  - Most of the proposed optimizations are aimed at improving performance
  - Only indirectly address energy efficiency

- Energy-Efficient Mobile BitTorrent
  - Targeted to mobile devices

I. Kelenyi, A. Ludanyi, J. Nurminen, I. Pusstinen, **Energy-efficient Mobile BitTorrent with Broadband Router Hosted Proxies**, Proc. *IFIP Wireless and Mobile Networking Conference (WMNC 2010)*, Budapest, Hungary, October 13-15, 2010.

I. Kelenyi, A. Ludanyi, J. Nurminen, **BitTorrent on Mobile Phones – Energy Efficiency of a Distributed Proxy Solution**, Proc. *International Green Computing Conference (IGCC 2010)*, Chicago, USA, August 15-18, 2010.

Our Proposal

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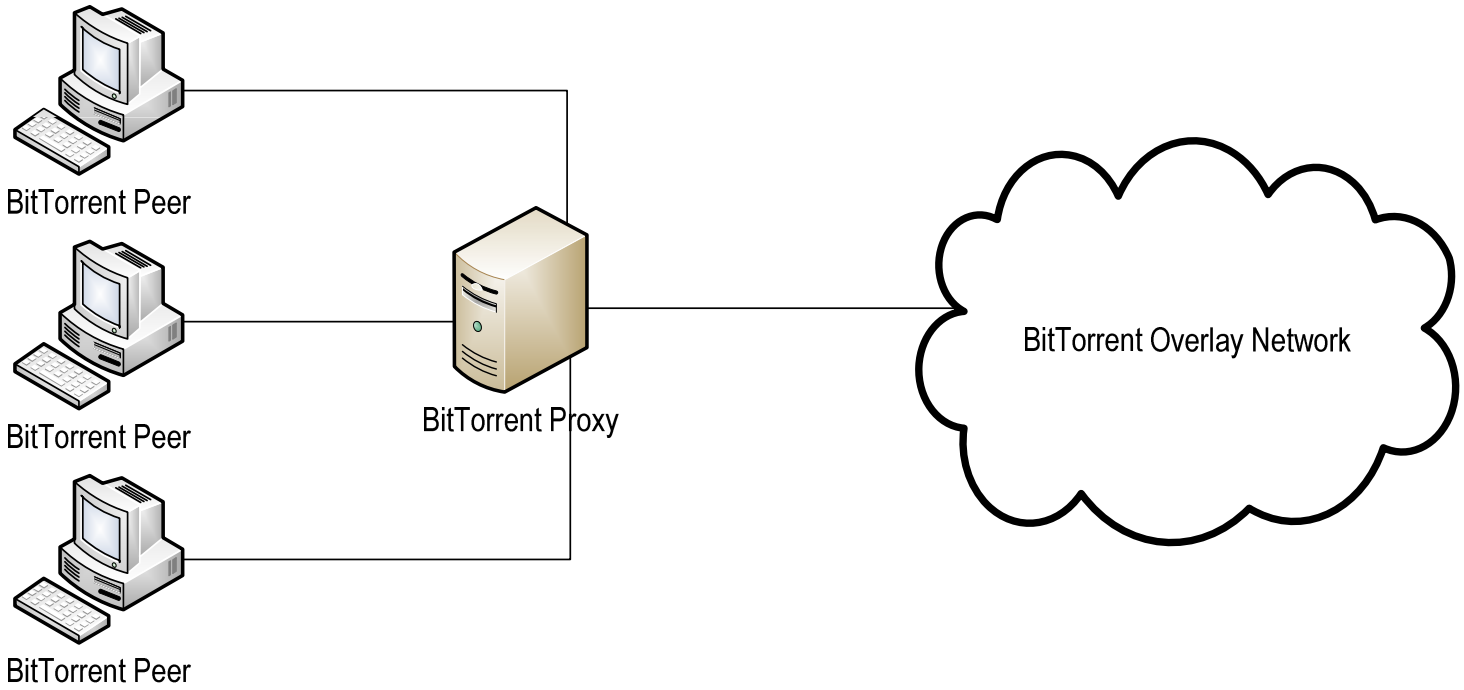
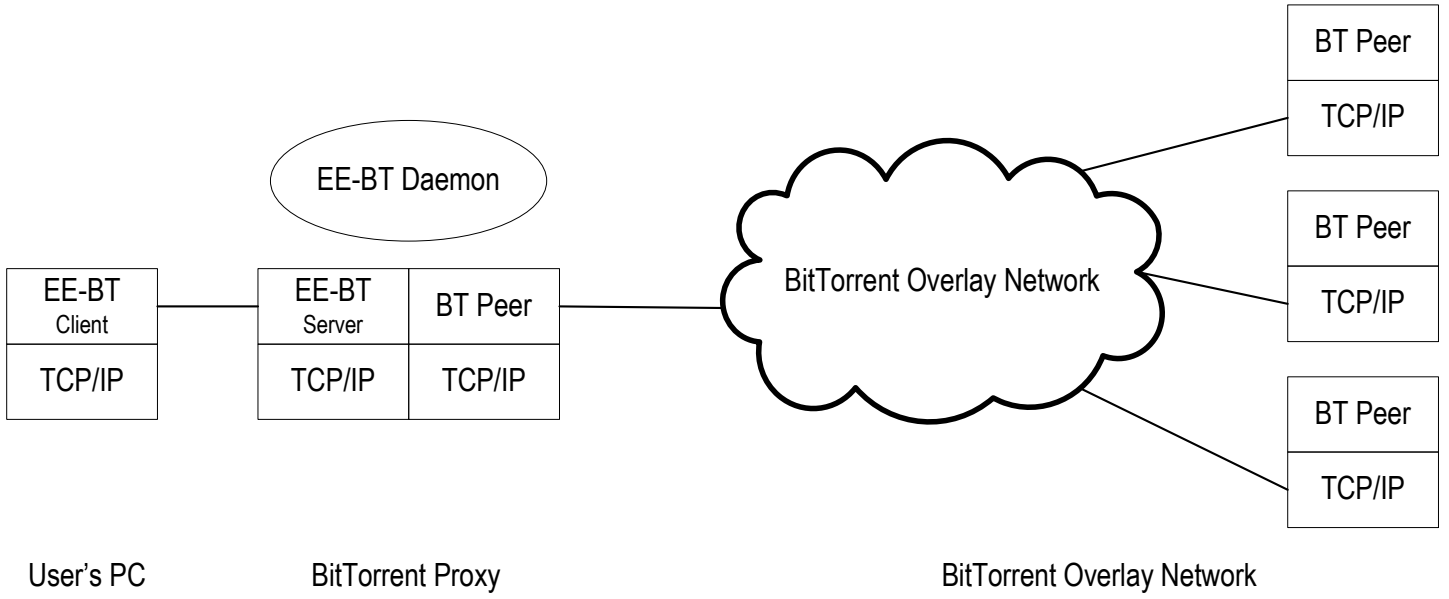
- EE-BitTorrent
  - Proxy-based version of BitTorrent
  - One BT Proxy for a large number of peers (PCs)

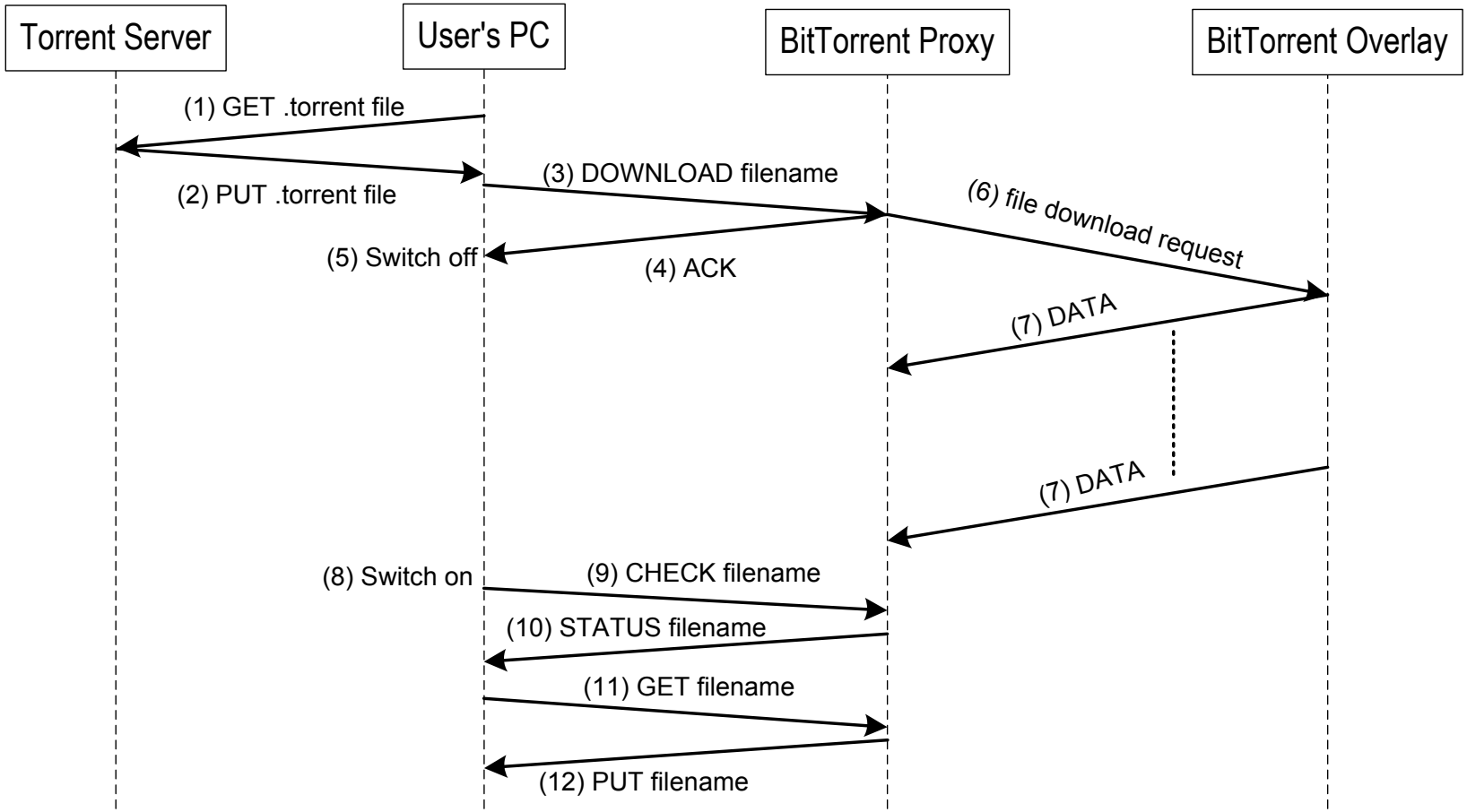


Architecture

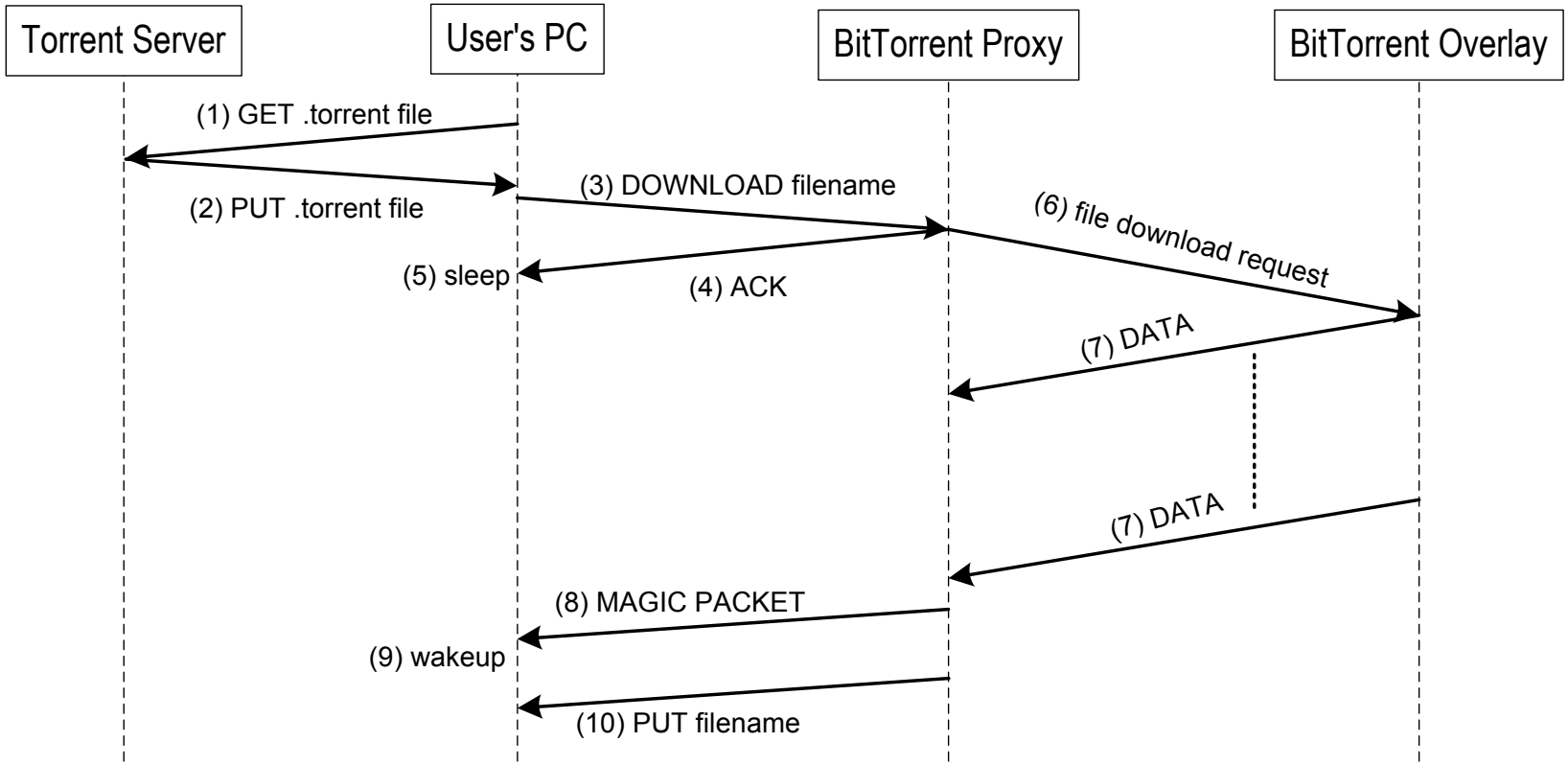


- EE-BitTorrent (EE-BT)
  - Clients and Proxy (clients side)
  - Client/Server scheme
- Traditional BitTorrent (BT Peer)
  - Proxy (P2P Network side)

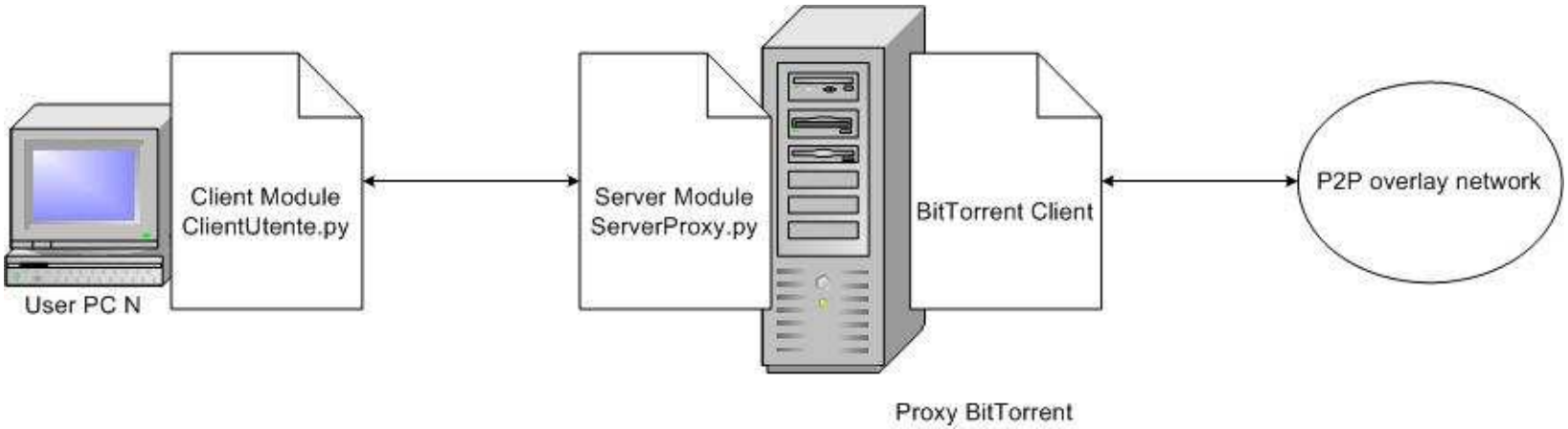
EE-BT Protocol – version 1



EE-BT Protocol – version 2

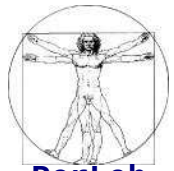


Implementation



- Energy Efficient BitTorrent modules
  - Client – Server scheme
    - Server (Proxy)
    - Client (user PC)
- Programming language: Python
- Libtorrent Rasterbar: library for BitTorrent
- Command-line BitTorrent client

Performance Metrics



- Relative Energy Saving

$$S = 1 - \frac{E_P}{E_L}$$

- Absolute Energy Saving

$$\Delta E = E_L - E_P$$

Performance metrics (cont'd)

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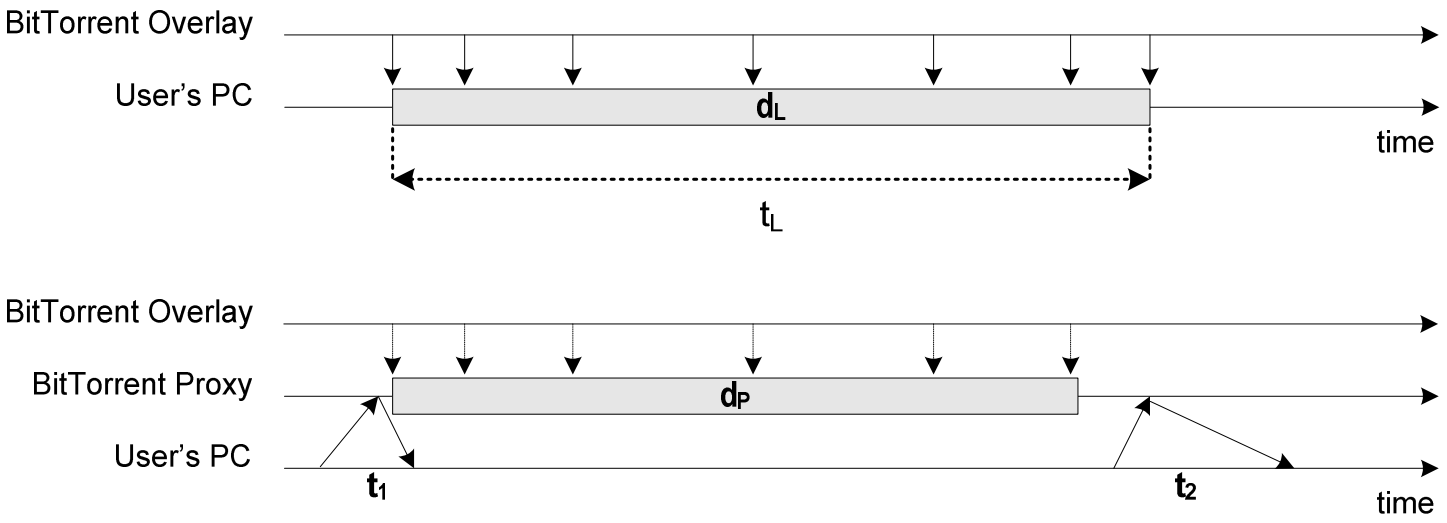
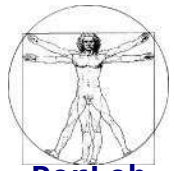
- **Assumption:**
  - **All PCs and proxy have the same power consumption**
    - ⇨ **Energy Consumption proportional to power-on time**



Performance metrics (cont'd)



- **Relative Energy Savings**
  - *The proxy is a multi-server machine*

$$S'(n) = 1 - \frac{\sum_{i=1}^{n} t_1(i) + t_2(i)}{\sum_{i=1}^{n} d_L(i)}$$

  - *The proxy is a dedicated machine*

$$S''(n) = 1 - \frac{d_P^{max} + \sum_{i=1}^{n} t_1(i) + t_2(i)}{\sum_{i=1}^{n} d_L(i)}$$

- **Absolute Energy Savings**
  - *The proxy is a multi-server machine*

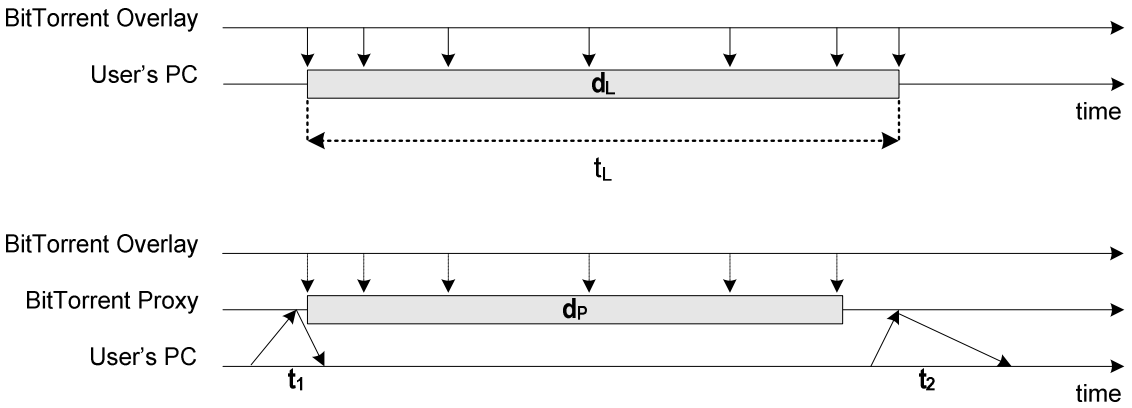
$$\Delta E'(n) = \left(\sum_{i=1}^{n} d_L(i) - \sum_{i=1}^{n} [t_1(i) + t_2(i)] \right) \cdot P_{PC}$$

  - *The proxy is a dedicated machine*

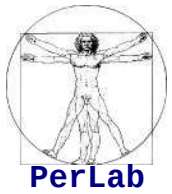
$$\Delta E''(n) = \left(\sum_{i=1}^{n} d_L(i) - \sum_{i=1}^{n} [t_1(i) + t_2(i)] - d_P^{max} \right) \cdot P_{PC}$$

Experimental Testbed

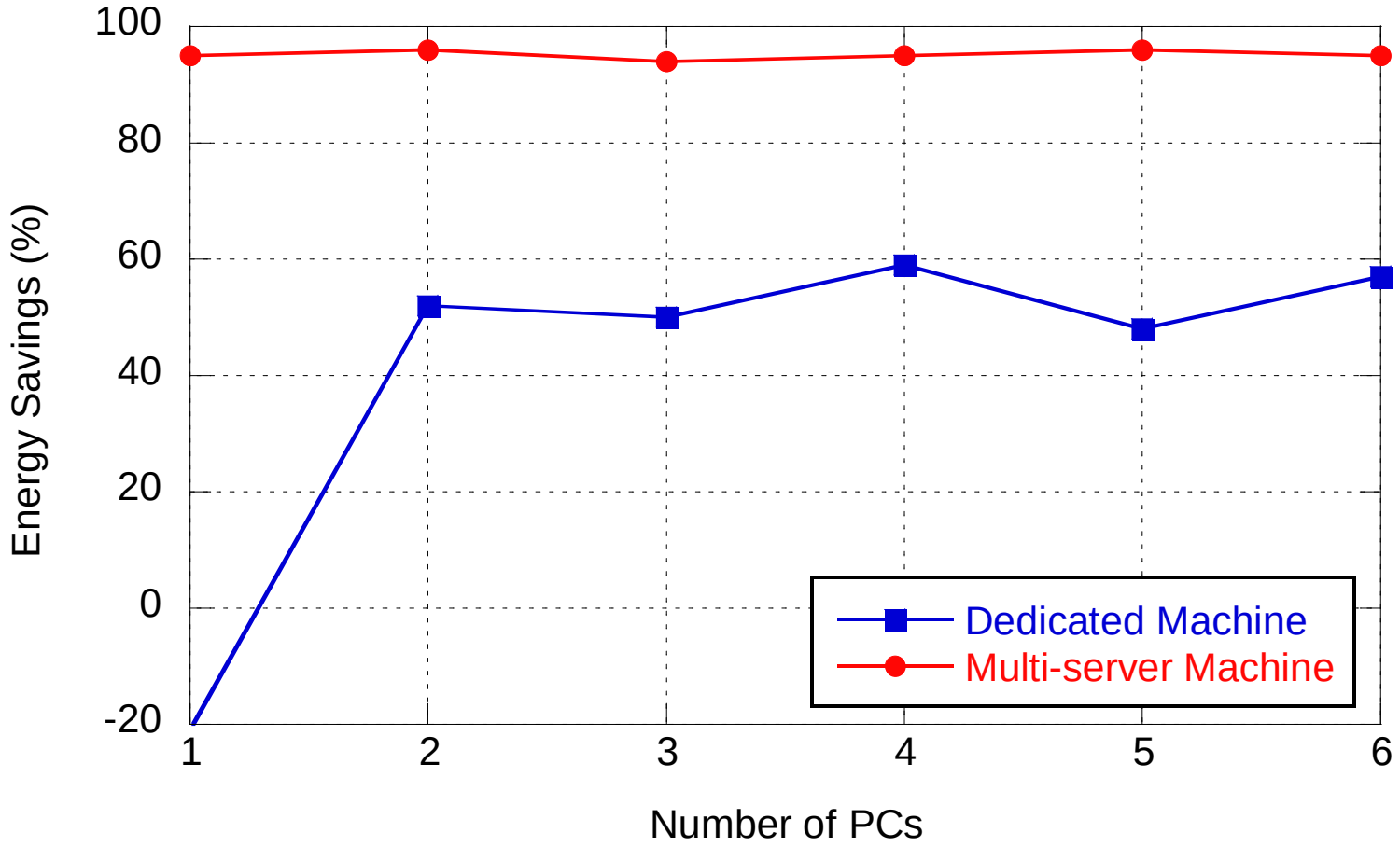
- Two systems:
  - Legacy BitTorrent
  - EE-BitTorrent
- Connectivity:
  - Ethernet LAN
  - 100 Mbps link
- Downloaded files
  - Size: ~4GB [3.95 GB – 4.71 GB]
  - Initial number of seeds: 200 - 800
- Experiments replicated
  - several times per day
  - in different days



Relative Energy Savings



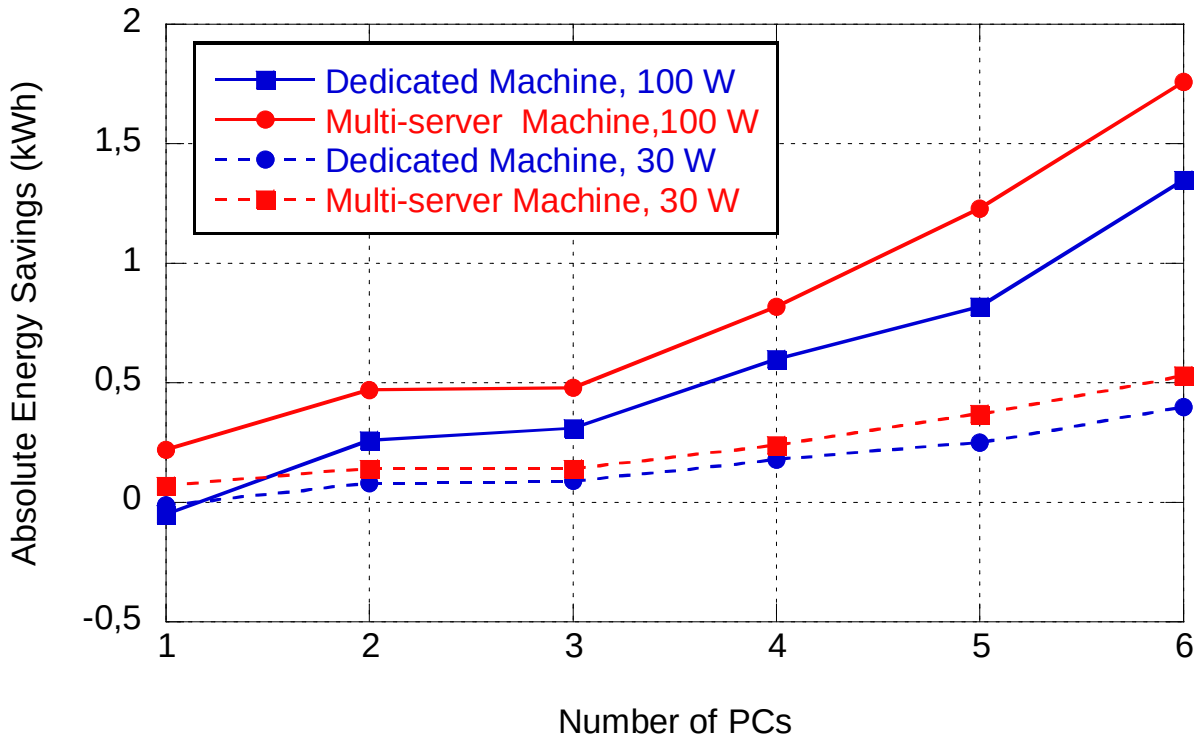
- Multi-server Machine ➔ $S'(n)$
- Dedicated Machine ➔ $S''(n)$



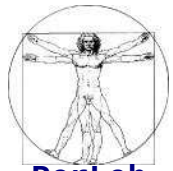
Absolute Energy Savings

PerLab

- Assumptions
  - All PC have the same power consumption
  - BT Proxy has the same power consumption of PCc
- Power Values
  - ⇨ 100 W (desktop PC), 30 W (laptop PC)

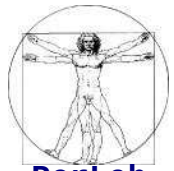


Summary



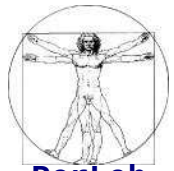
- Departmental scenario
  - PCs and Proxy connected to the same high-speed LAN
- In the analyzed scenario EE-BitTorrent provides a significant reduction in energy consumption
  - When the number of parallel download operations is larger than 1
  - Energy Efficiency increases with the number of parallel download operations
    - ⇨ The energy consumed by the proxy is shared among a larger number of users

Key Question



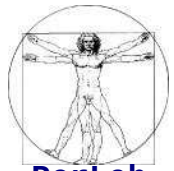
What about users with residential access?

Additional Scenarios



- Residential Access Networks
  - ADSL
    - ⇨ Dowlink rate: up to 8 Mbps
    - ⇨ Uplink rate: up to 512 Mbps
  - UMTS
    - ⇨ Dowlink rate: up to 7.2 Mbps
    - ⇨ Uplink rate: up to 2.0 Mbps

Additional Scenarios



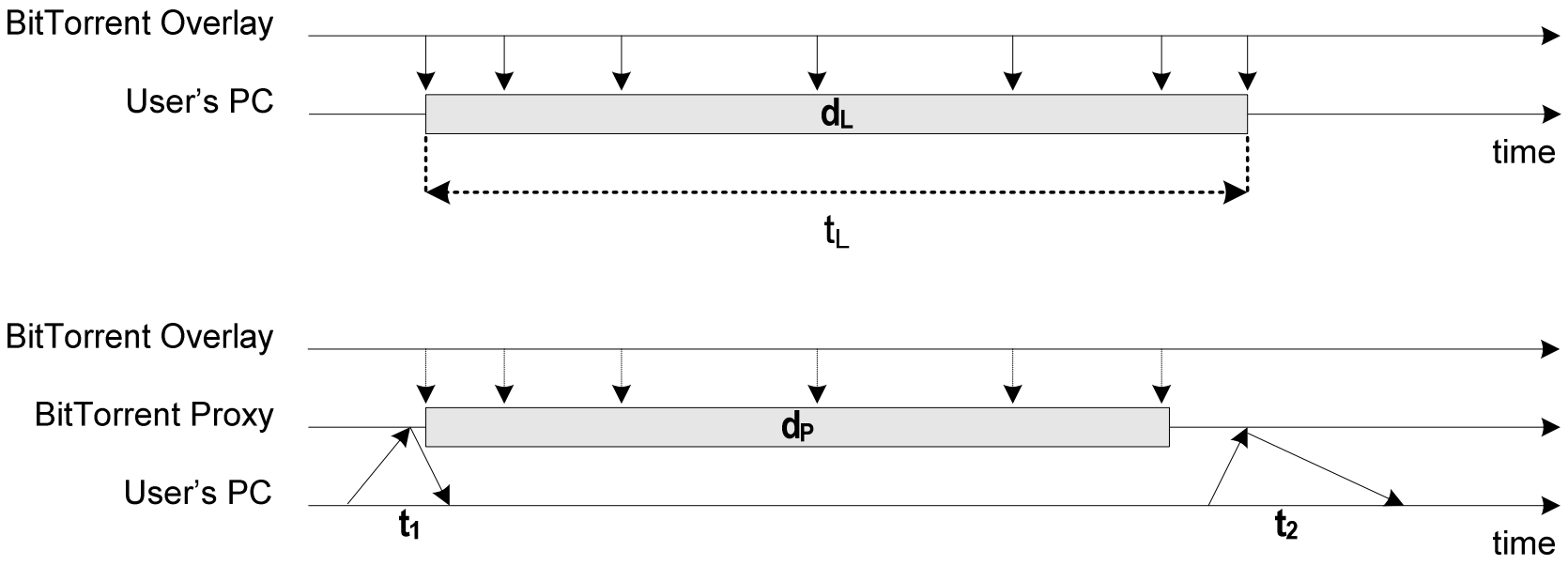
- Single User
  - Legacy BitTorrent
  - Proxy-based BitTorrent

- File Types:
  - 135 MB
    - ⇨ Audio CD (MP3)
  - 350 MB
    - ⇨ Episode of a TV Series (AVI)
  - 4 GB
    - ⇨ Ubuntu 10.10 Distribution (ISO)

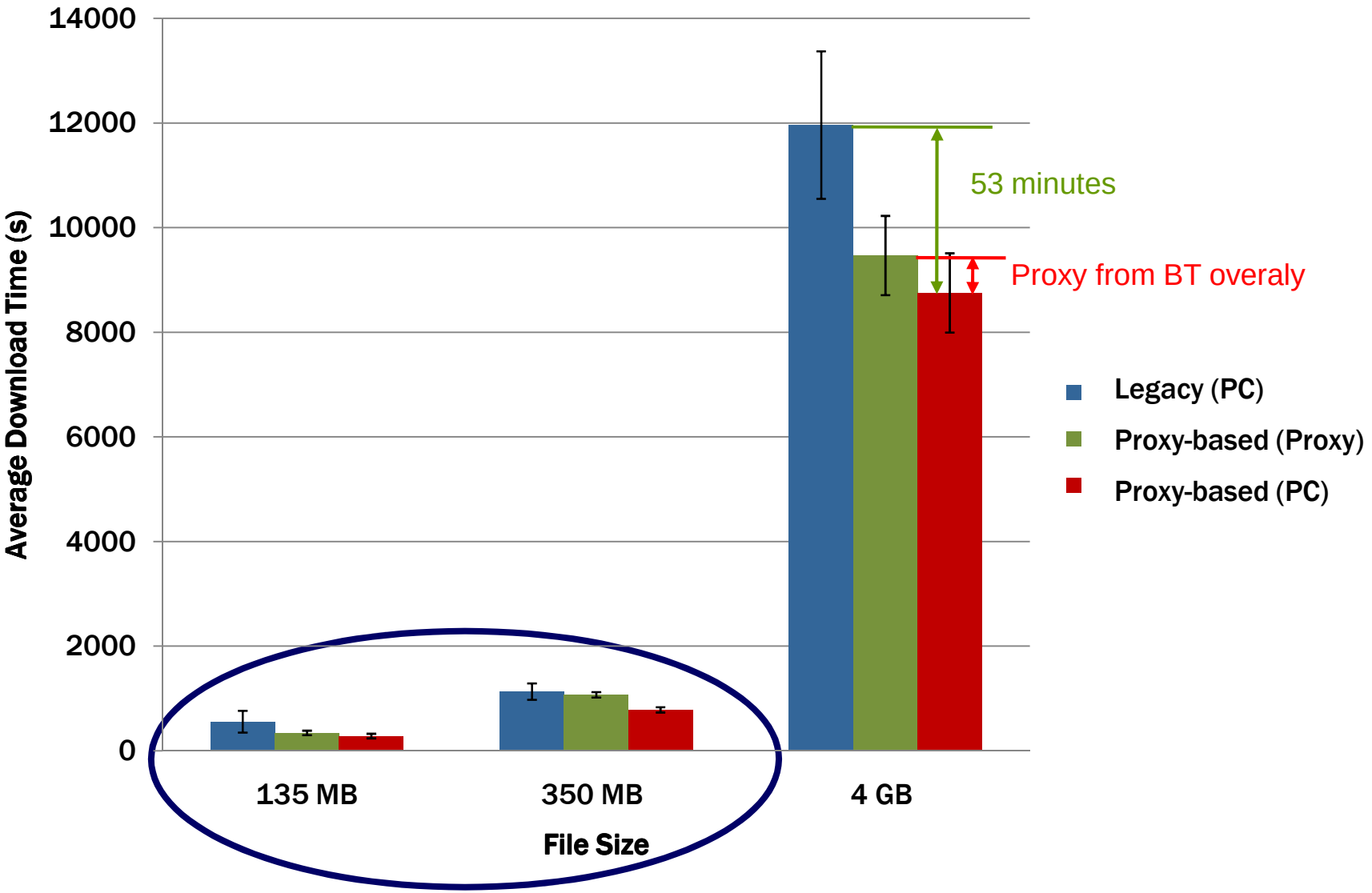
Performance metrics

PerLab

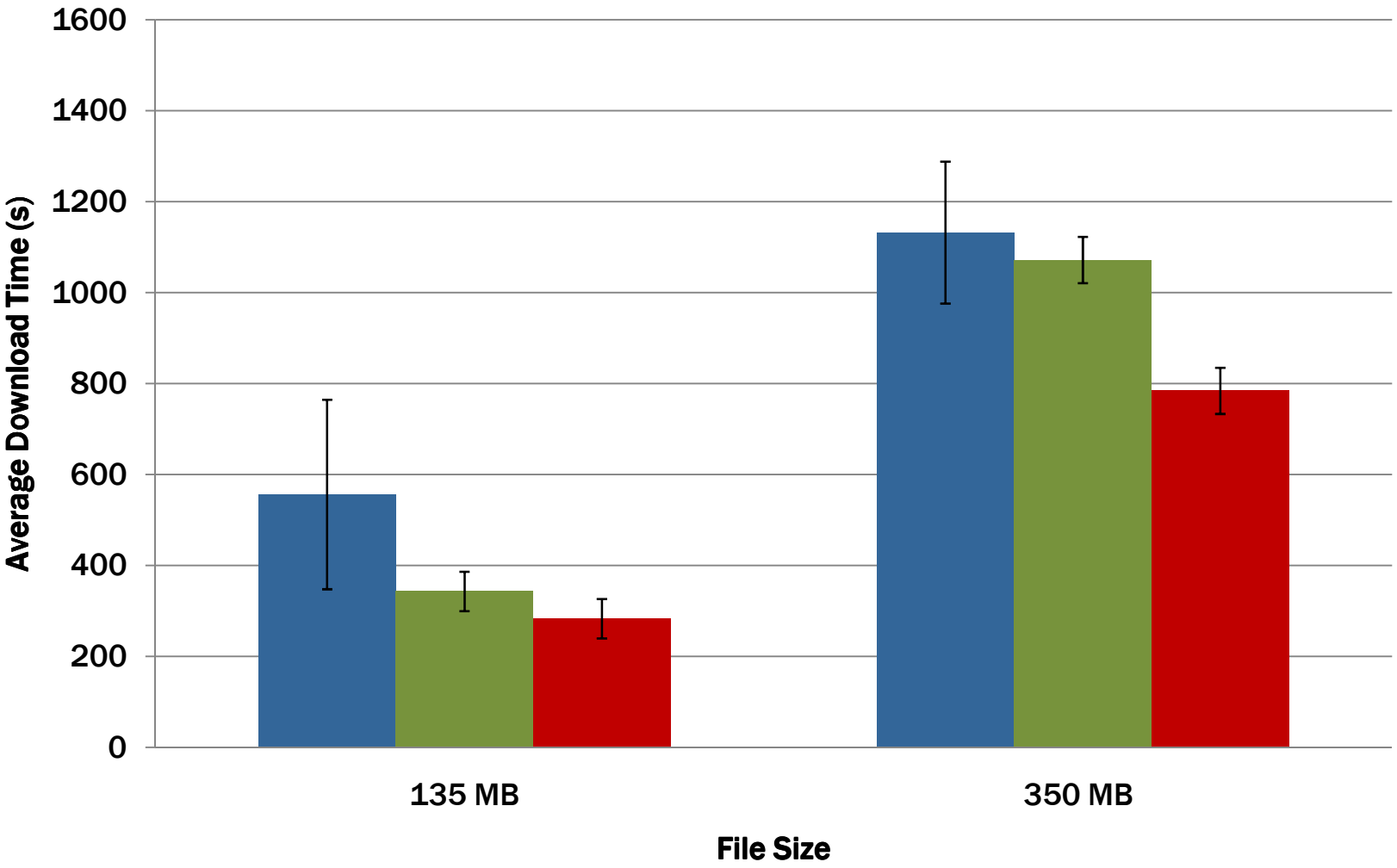
- **Assumption:**
  - **User's PC and Proxy have same power consumption**
    - ⇨ **Energy Consumption proportional to power-on time**



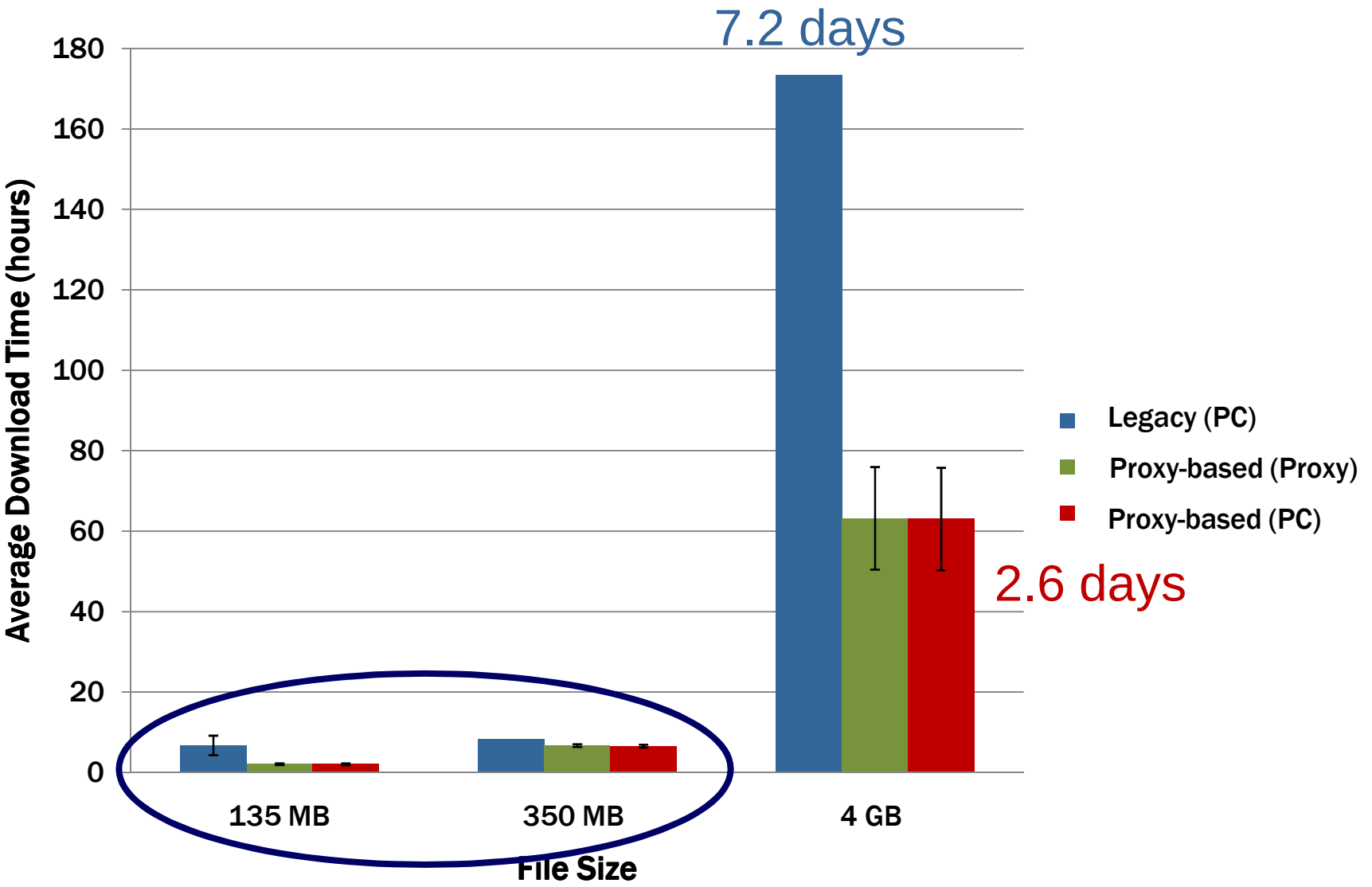
ADSL Access


14000
12000
10000
8000
6000
4000
2000
0
Average Download Time (s)
53 minutes
Proxy from BT overaly
Legacy (PC)
Proxy-based (Proxy)
Proxy-based (PC)
135 MB
350 MB
4 GB
File Size

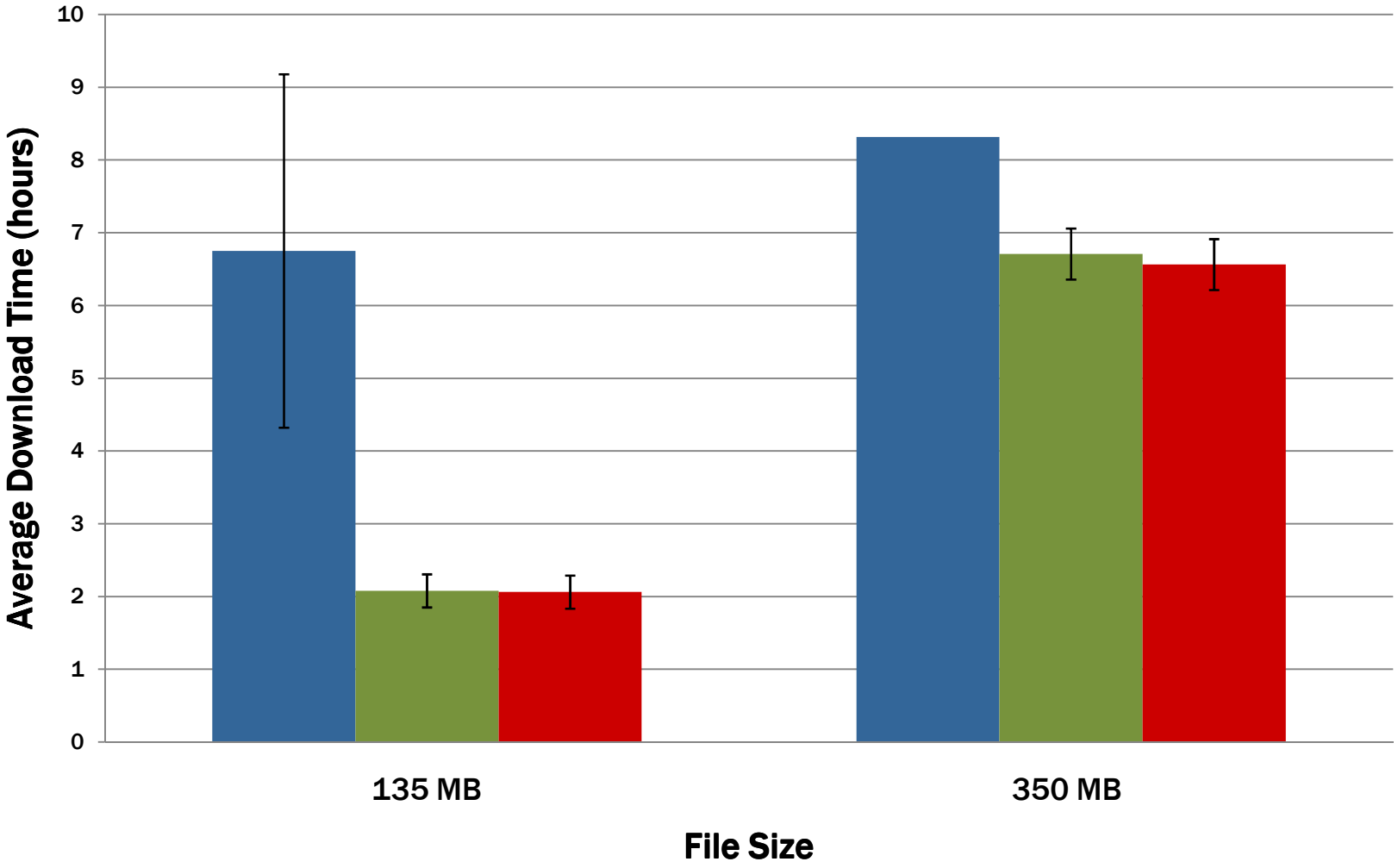
ADSL Access (2)



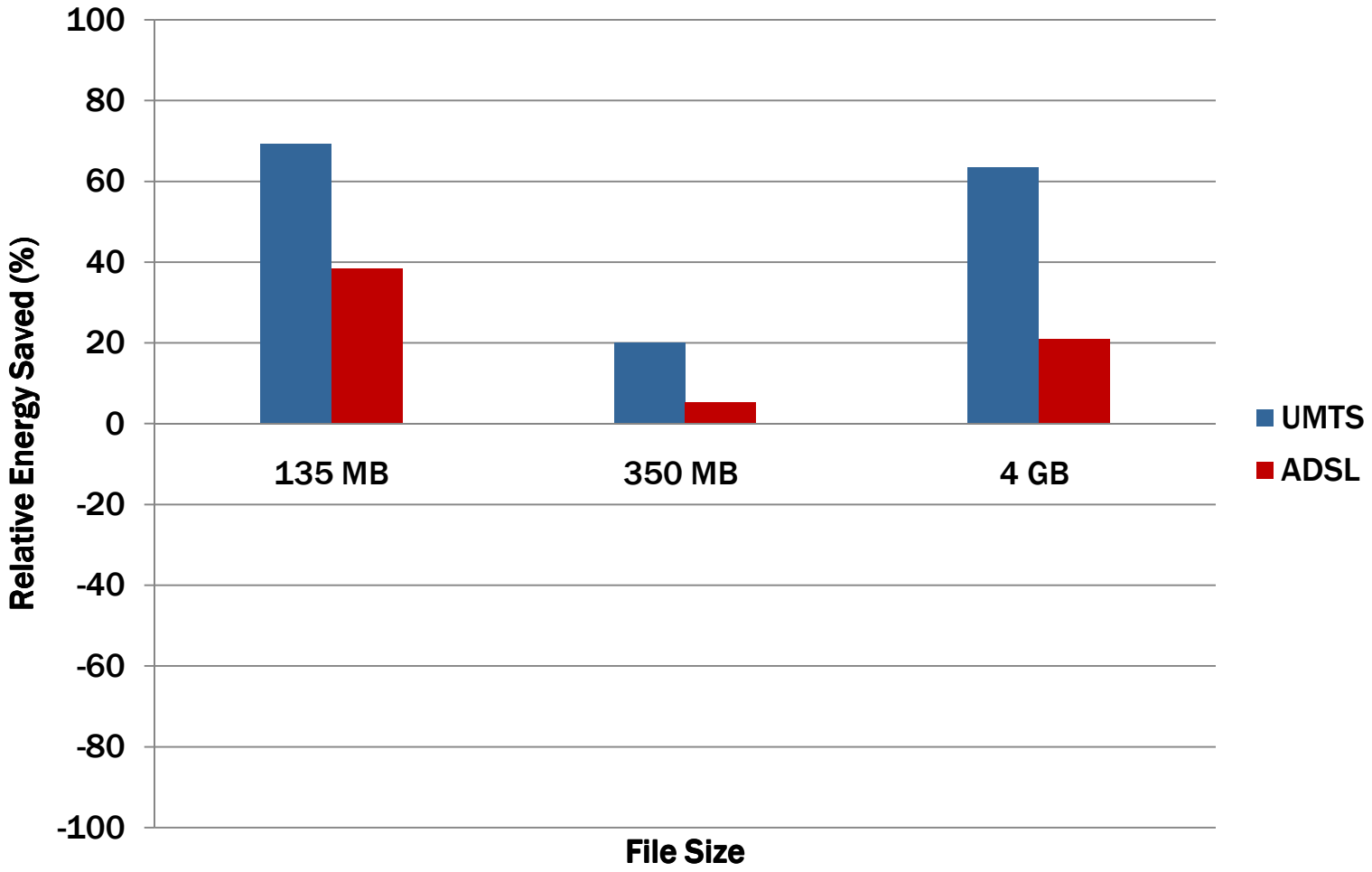
UMTS Access


7.2 days
2.6 days
Average Download Time (hours)
180
160
140
120
100
80
60
40
20
0
135 MB
350 MB
4 GB
File Size
Legacy (PC)
Proxy-based (Proxy)
Proxy-based (PC)

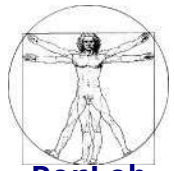
UMTS Access (2)



Relative Energy Saving

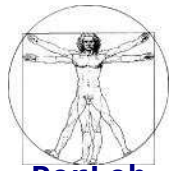


Where to place the BitTorrent Proxy?



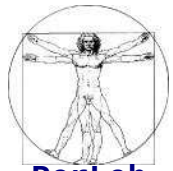
- Departmental Network
  - May be placed on a machine already used for some other services
  - Better access control (in addition to energy efficiency)
- Residential Users
  - Several Options
    - ⇨ Provided (for free) by ISP
    - ⇨ Cloud Proxy leased to users
    - ⇨ Proxy maintained and shared by a group of users (Social Proxy)
  - The proxy should have a high-speed connection
  - The proxy should be as close as possible to users

Conclusions



- Energy Efficient BitTorrent protocol
  - Based on a BitTorrent Proxy
- Implementation
  - Real testbed
- Experimental Analysis
  - EE-BitTorrent provides a significant reduction in energy consumption
  - Both in dept. and residential networks

Reference papers



- G. Anastasi, I. Giannetti, A. Passarella, A BitTorrent Proxy for Green Internet File Sharing: Design and Experimental Evaluation, *Computer Communications*, Vol. 33, N. 7, pp. 794-802, May 2010.

- G. Anastasi, M. Conti, I. Giannetti, A. Passarella, Design and Evaluation of a BitTorrent Proxy for Energy Saving, Proceedings *IEEE Symposium on Computers and Communications (ISCC 2009),* Sousse, Tunisia, July 5-8, 2009.

Thank you for your attention!

Questions?

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