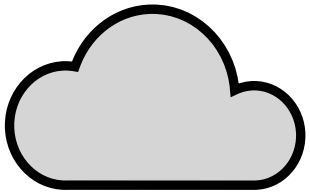
ISTD 50.012 Networks
Final Research Project
Term 6 - Fall 2021

Does it pay to be selfish?

A study of congestion control abuse and countermeasures

VS Ragul Balaji, Huang He, James RT, Han Xing Yi, Zhang Peiyuan, Qiao Yingjie

** not the real SUTD network **



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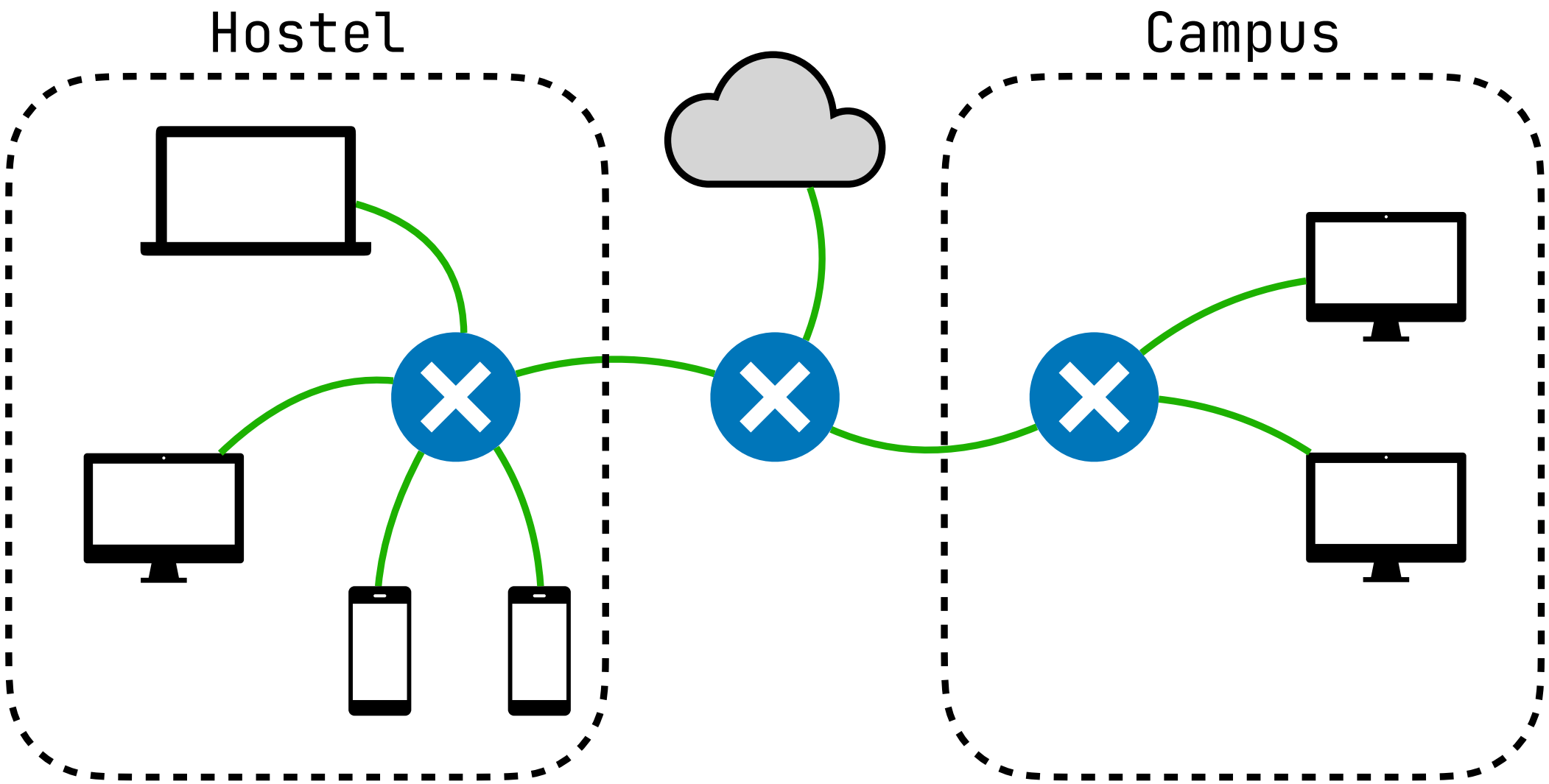

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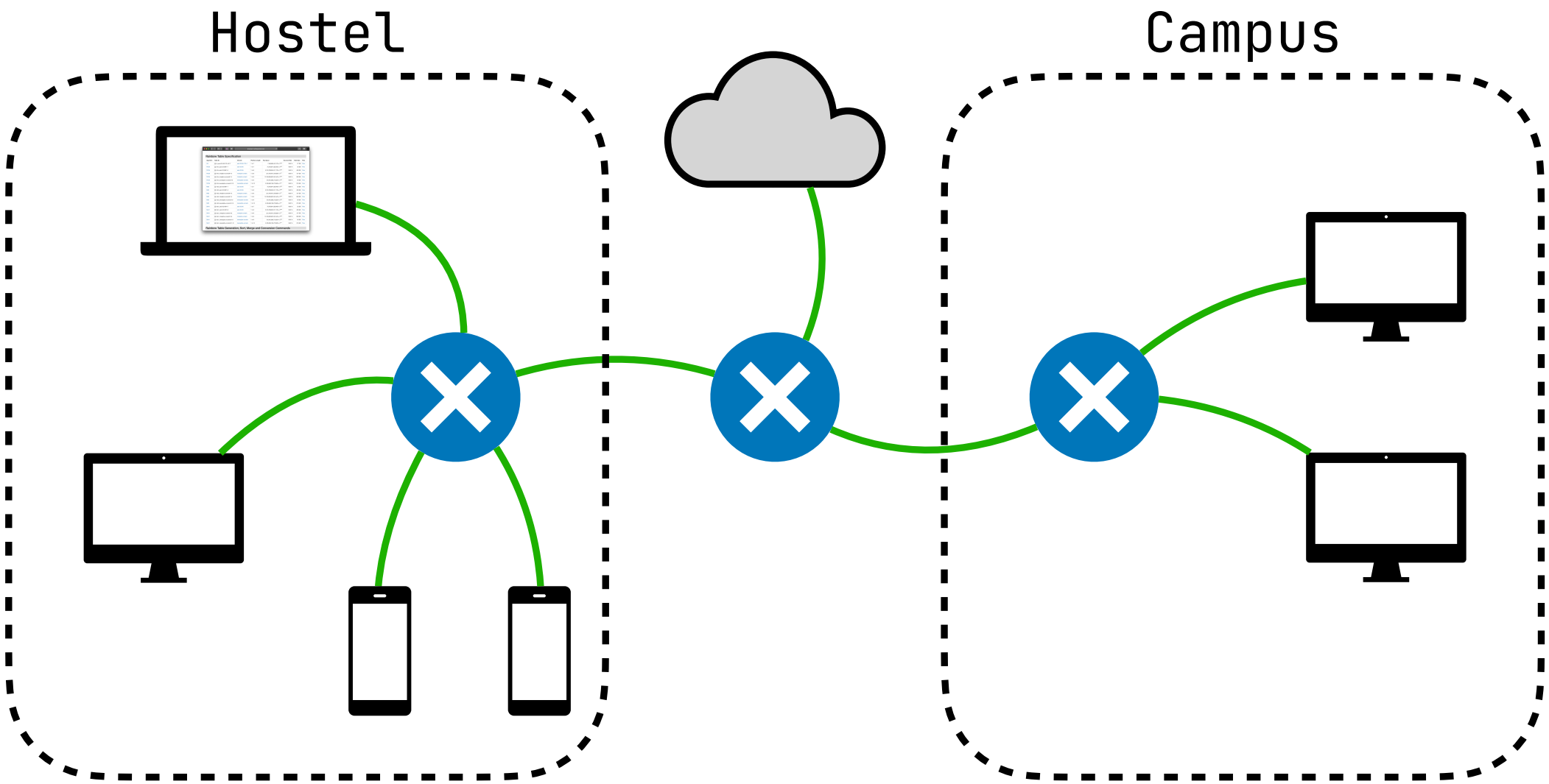

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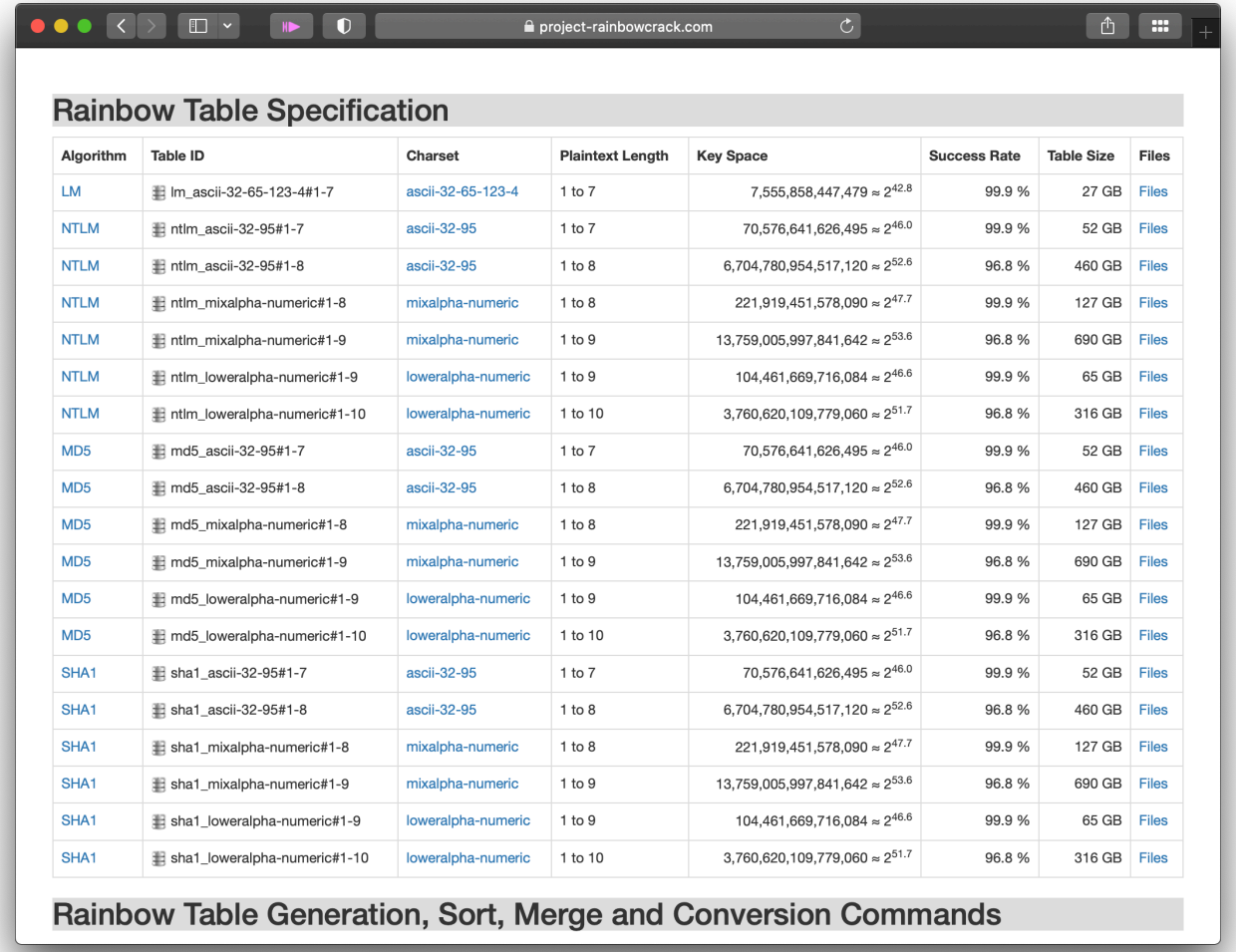

Rainbow Table Specification

Algorithm	Table ID	Charset	Plaintext Length	Key Space	Success Rate	Table Size	Files
LM	lm_ascii-32-65-123-4#1-7	ascii-32-65-123-4	1 to 7	7,555,858,447,479 ≈ $2^{42.8}$	99.9 %	27 GB	Files
NTLM	ntlm_ascii-32-95#1-7	ascii-32-95	1 to 7	70,576,641,626,495 ≈ $2^{46.0}$	99.9 %	52 GB	Files
NTLM	ntlm_ascii-32-95#1-8	ascii-32-95	1 to 8	6,704,780,954,517,120 ≈ $2^{52.6}$	96.8 %	460 GB	Files
NTLM	ntlm_mixalpha-numeric#1-8	mixalpha-numeric	1 to 8	221,919,451,578,090 ≈ $2^{47.7}$	99.9 %	127 GB	Files
NTLM	ntlm_mixalpha-numeric#1-9	mixalpha-numeric	1 to 9	13,759,005,997,841,642 ≈ $2^{53.6}$	96.8 %	690 GB	Files
NTLM	ntlm_loweralpha-numeric#1-9	loweralpha-numeric	1 to 9	104,461,669,716,084 ≈ $2^{46.6}$	99.9 %	65 GB	Files
NTLM	ntlm_loweralpha-numeric#1-10	loweralpha-numeric	1 to 10	3,760,620,109,779,060 ≈ $2^{51.7}$	96.8 %	316 GB	Files
MD5	md5_ascii-32-95#1-7	ascii-32-95	1 to 7	70,576,641,626,495 ≈ $2^{46.0}$	99.9 %	52 GB	Files
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Rainbow Table Generation, Sort, Merge and Conversion Commands

project-rainbowcrack.com

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NTLM	ntlm_loweralpha-numeric	loweralpha-numeric	1 to 9	10 716 ≈ $2^{46.6}$	99.9 %	65 GB	Files
NTLM	ntlm_loweralpha-numeric#1	loweralpha-numeric	3 620,1 ≈ $2^{51.7}$	96.8 %	316 GB	Files
MD5	md5_ascii-32-95#1-7	ascii-32-95	1 to 7	46.0	99.9 %	52 GB	Files
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MD5	md5_loweralpha-numeric#1-9	loweralpha-numeric	1 to 9	4 ≈ $2^{46.6}$	99.9 %	65 GB	Files
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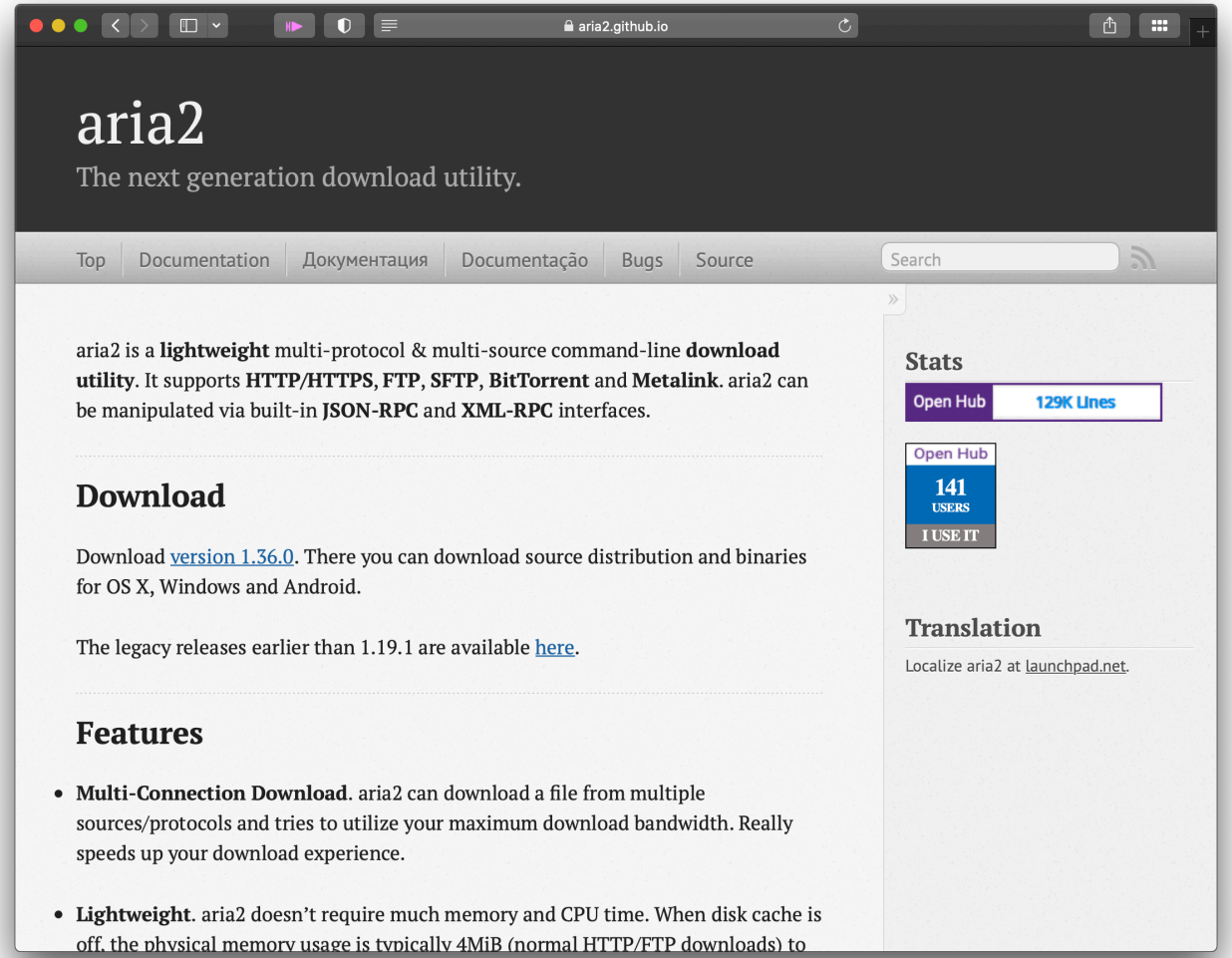
Rainbow Table Generation, Sort, Merge and Conversion Commands


aria2.github.io
aria2
The next generation download utility.
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aria2 is a lightweight multi-protocol & multi-source command-line download utility. It supports HTTP/HTTPS, FTP, SFTP, BitTorrent and Metalink. aria2 can be manipulated via built-in JSON-RPC and XML-RPC interfaces.
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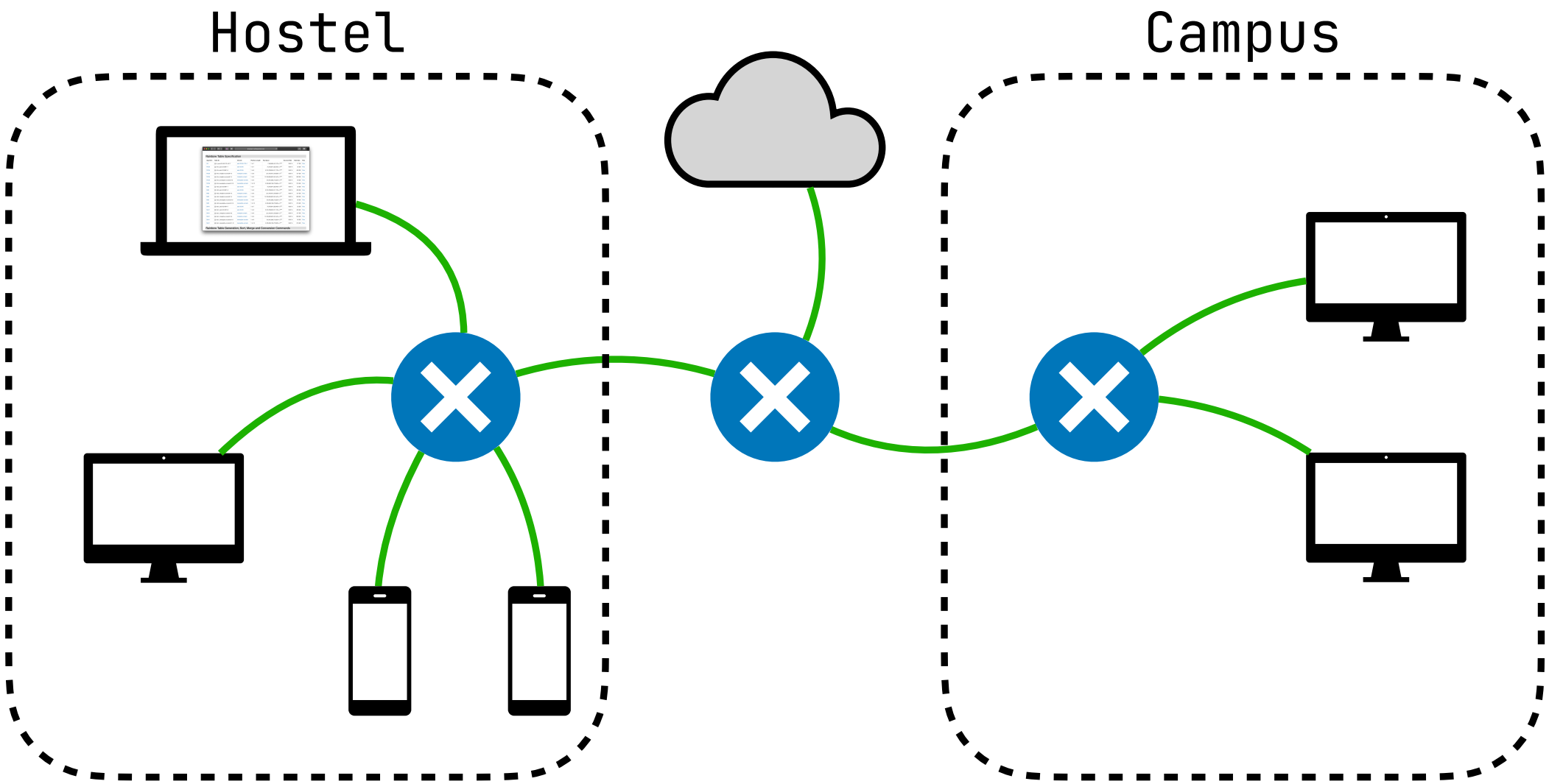
Features
Multi-Connection Download. aria2 can download a file from multiple sources/protocols and tries to utilize your maximum download bandwidth. Really speeds up your download experience.
Lightweight. aria2 doesn't require much memory and CPU time. When disk cache is off, the physical memory usage is typically 4MiB (normal HTTP/FTP downloads) to
Stats
Open Hub
129K Lines
Open Hub
141
USERS
I USE IT
Translation
Localize aria2 at launchpad.net.



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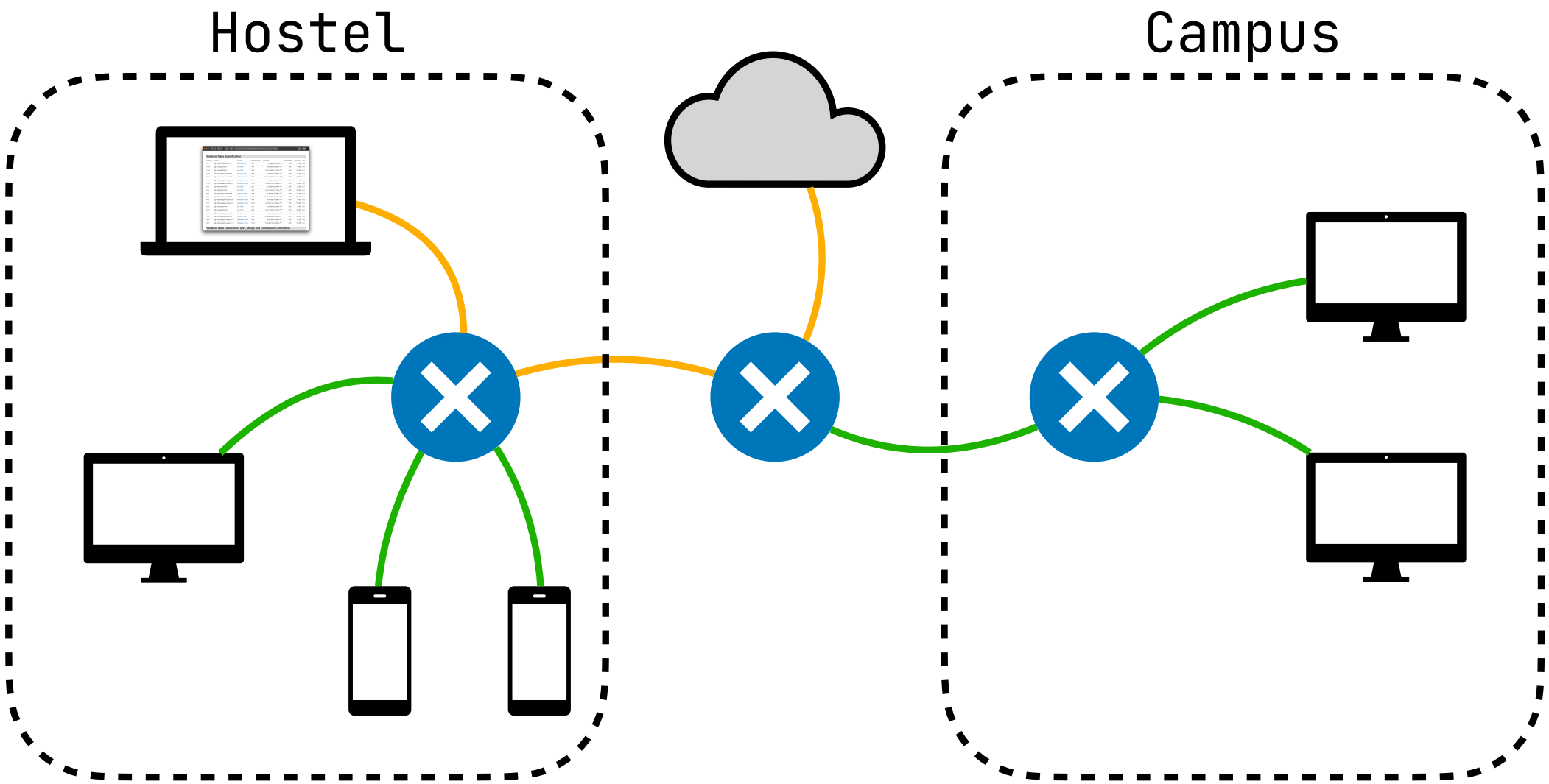

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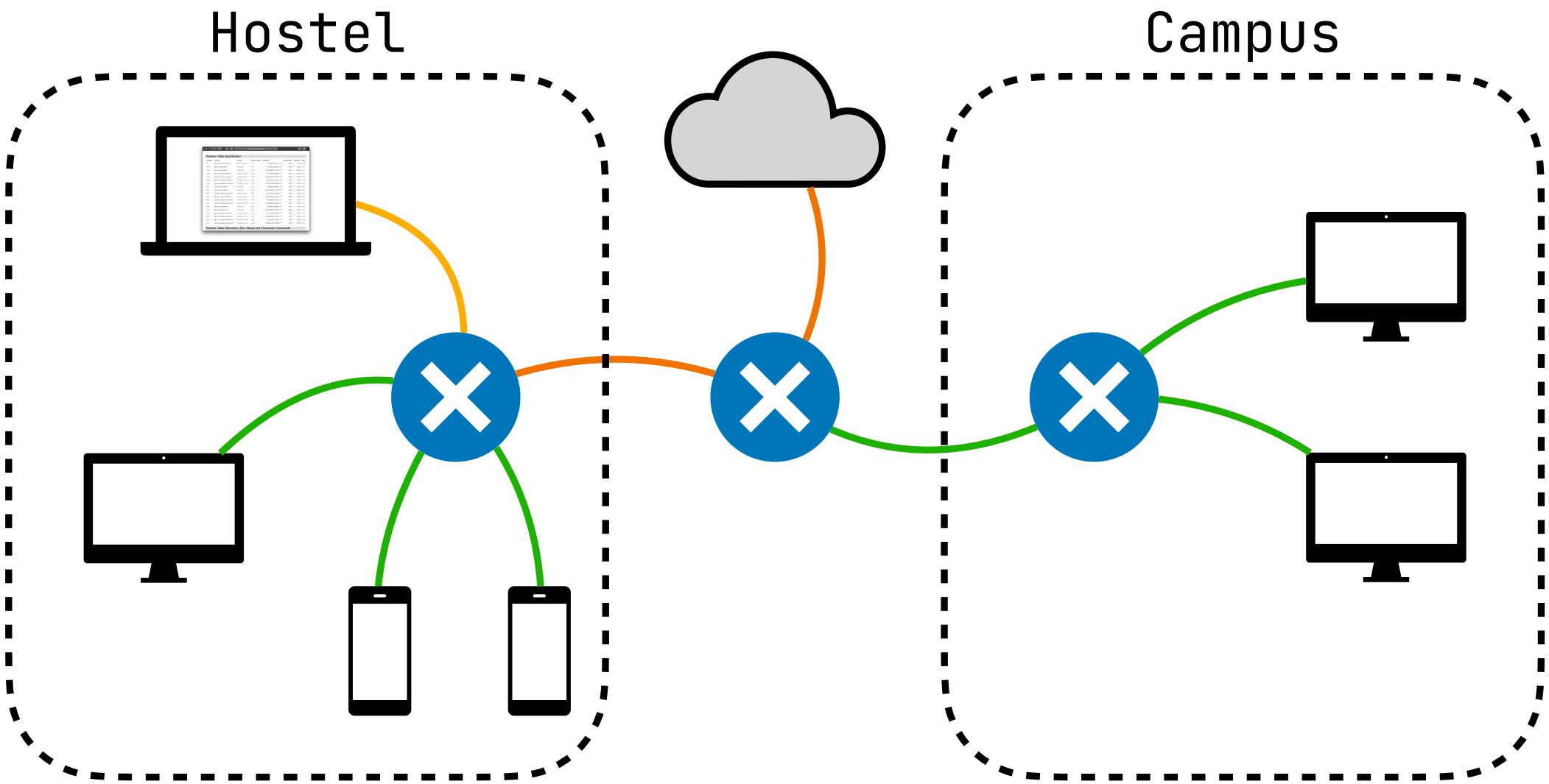

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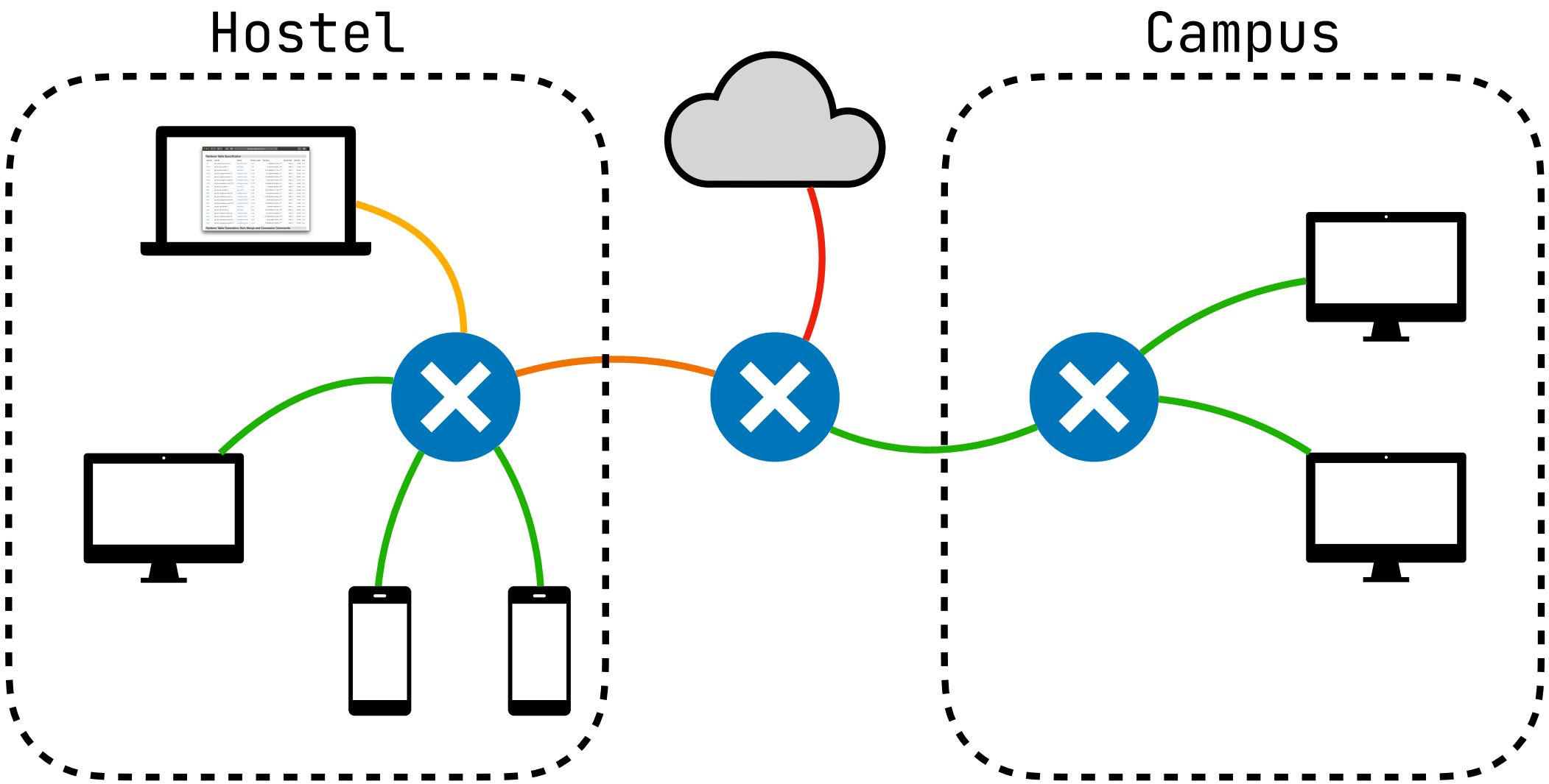

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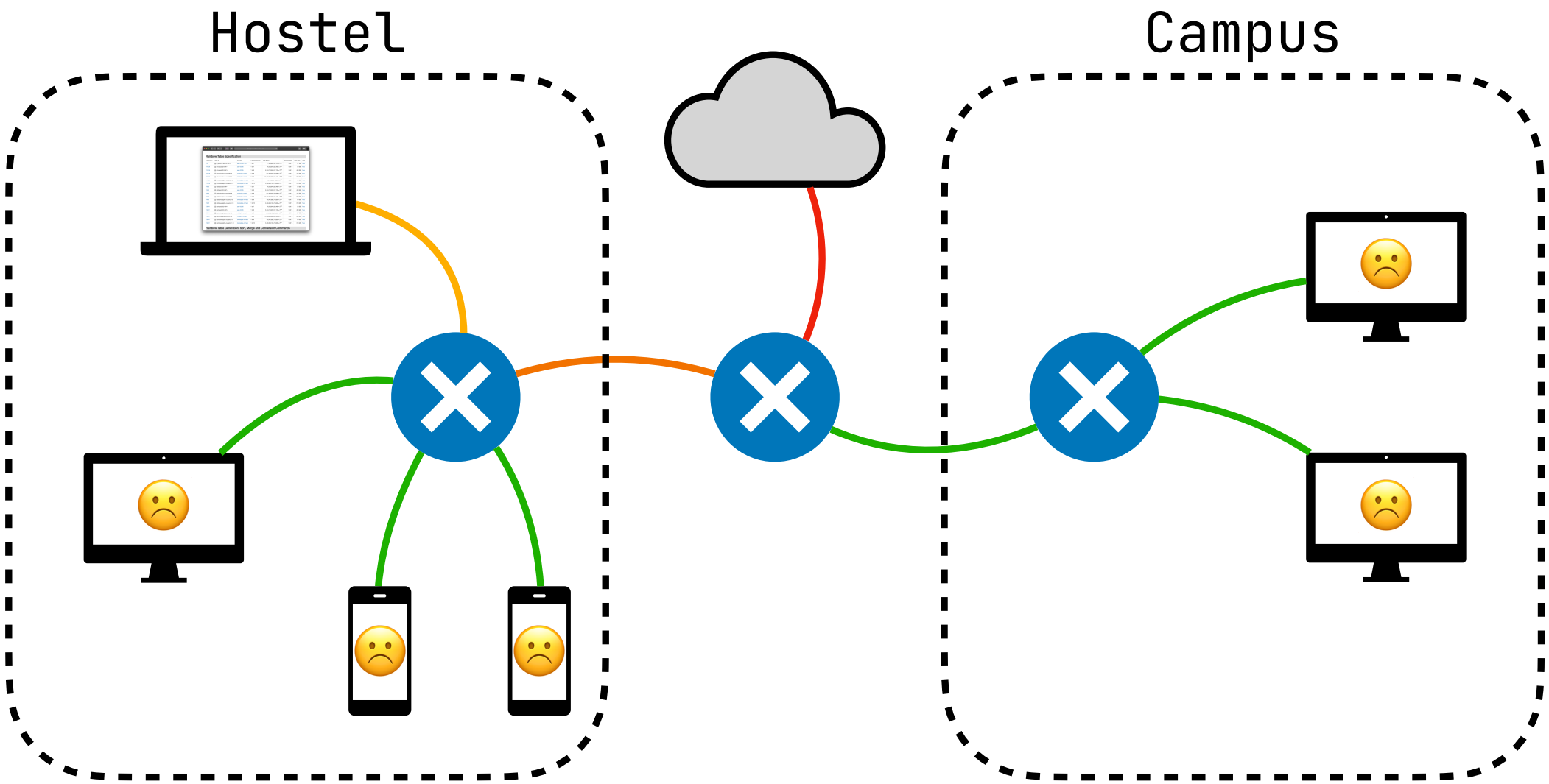

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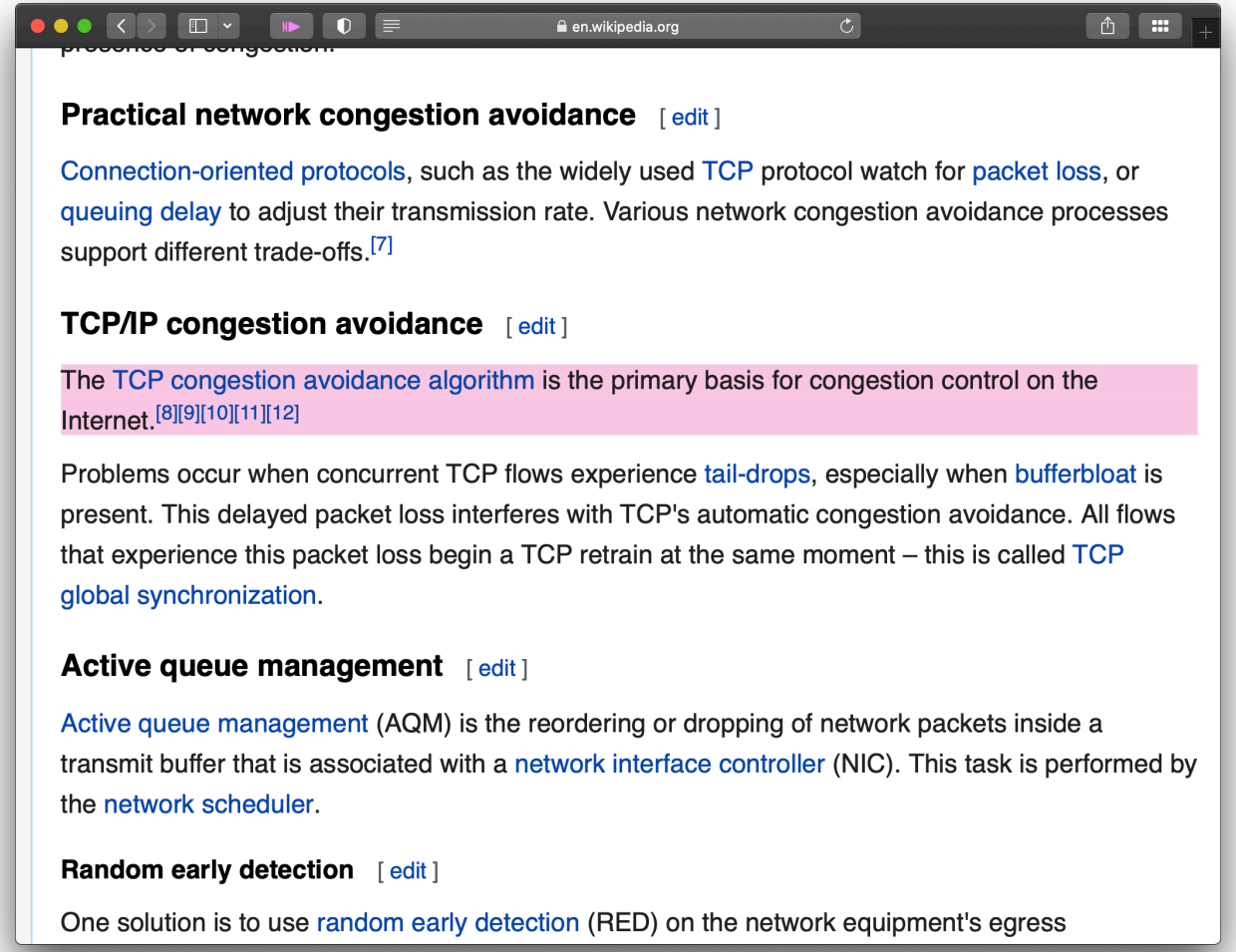

https://en.wikipedia.org/wiki/Network_congestion#TCP/IP_congestion_avoidance

Problem Background

1. TCP **congestion control is implemented at the edge of the network**.

2. The **responsibility lies in the hands of the client** to carry out the algorithm in good faith.

3. As such, there is a **possibility that it can be abused**.

Problem Statement

What is the maximum threshold of selfishness* in a network that benefits* the adversary without causing major disruptions* to other users?

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What is the maximum threshold of selfishness* in a network that benefits* the adversary without causing major disruptions* to other users?

Our Definitions

selfishness → maximise benefits via active techniques
benefits ⟶ higher goodput / lower delay per task
disruptions → lower average goodput / higher average delay per task

Literature Review

"*A mathematical model for the TCP Tragedy of the Commons.*" *by López et al.* proves that there **exists a threshold whereby evil greediness will cause the game to take the form of “Tragedy of the Commons”**.

López, L., Almansa, G. d. R., Paquelet, S., & Fernandéz, A. (2005, October 10). A mathematical model for the TCP Tragedy of the Commons. Theoretical Computer Science, 343(1-2), 4-26. https://doi.org/10.1016/j.tcs.2005.05.005

Literature Review

"*TCP connection game: a study on the selfish behavior of TCP users" by Zhang et al.* found that there is a Nash Equilibria and the overall network efficiency loss is bounded when given either a **user's computation powers is limited or the user is socially responsible**.

Zhang, H., Towsley, D., & Gong, W. (2005). TCP connection game: a study on the selfish behavior of TCP users. 13TH IEEE International Conference on Network Protocols (ICNP'05), 10 pp•-310. 10.1109/ICNP.2005.40}

Literature Review

"*TCP congestion control with a misbehaving receiver" by Savage et al.* explored 3 possible attacks that a receiver can exploit on the TCP Daytona congestion control behavior by **abusing the frequency of ACKs the receiver sends back to the sender**.

Savage, S., Cardwell, N., Wetherall, D. J., & Anderson, T. E. (1999, October 5). TCP congestion control with a misbehaving receiver. ACM SIGCOMM Computer Communication Review, 29(5), 71–78. 10.1145/505696.505704

Literature Review

"*Tolls for heterogeneous selfish users in multicommodity networks and generalized congestion games" by Fleischer et al.* proved the existence of tolls when heterogeneous network **users independently choose routes minimizing their own linear function of tolls versus latency** to collectively form the traffic pattern of a minimum average latency flow.

Fleischer, L., Jain, K., & Mahdian, M. (2004). Tolls for heterogeneous selfish users in multicommodity networks and generalized congestion games. Annual IEEE Symposium on Foundations of Computer Science, 45(1), 9. https://ieeexplore.ieee.org/document/1366247

Literature Review

"*Performance Analysis of TCP Congestion Control Algorithms" by Truc et al.* did a comparative study in which we present the results obtained by simulating multiple TCP variants: NewReno, Vegas, HighSpeed, Scalable, Westwood+, BIC, CUBIC, and YeAH using a fat tree architecture. Each protocol is evaluated in terms of **queue length, number of dropped packets, average packet delay, and aggregate bandwidth as a percentage of the channel bandwidth.**

Truc, Nguyen Nhat & Gangadhar, Siddharth & Sterbenz, James. (2016). Performance Evaluation of TCP Congestion Control Algorithms in Data Center Networks. 21-28.

Literature Review

1. We know a selfishness threshold exists. (López et al., 2005)

2. User's computation powers and socially responsibilities affect that threshold. (Zhang et al., 2005)

3. One method is a user can open many connections to obtain greater goodput at the Nash Equilibrium state. (Zhang et al., 2005)

4. Another method is strategically abusing the frequency of ACKs the receiver sends back to the sender. (Savage et al., 1999, 71-78)

5. Other network users will adjust to any disruptions caused by independently choosing routes minimizing their own delay / maximising their own goodput (Fleischer et al., 2004, 9)

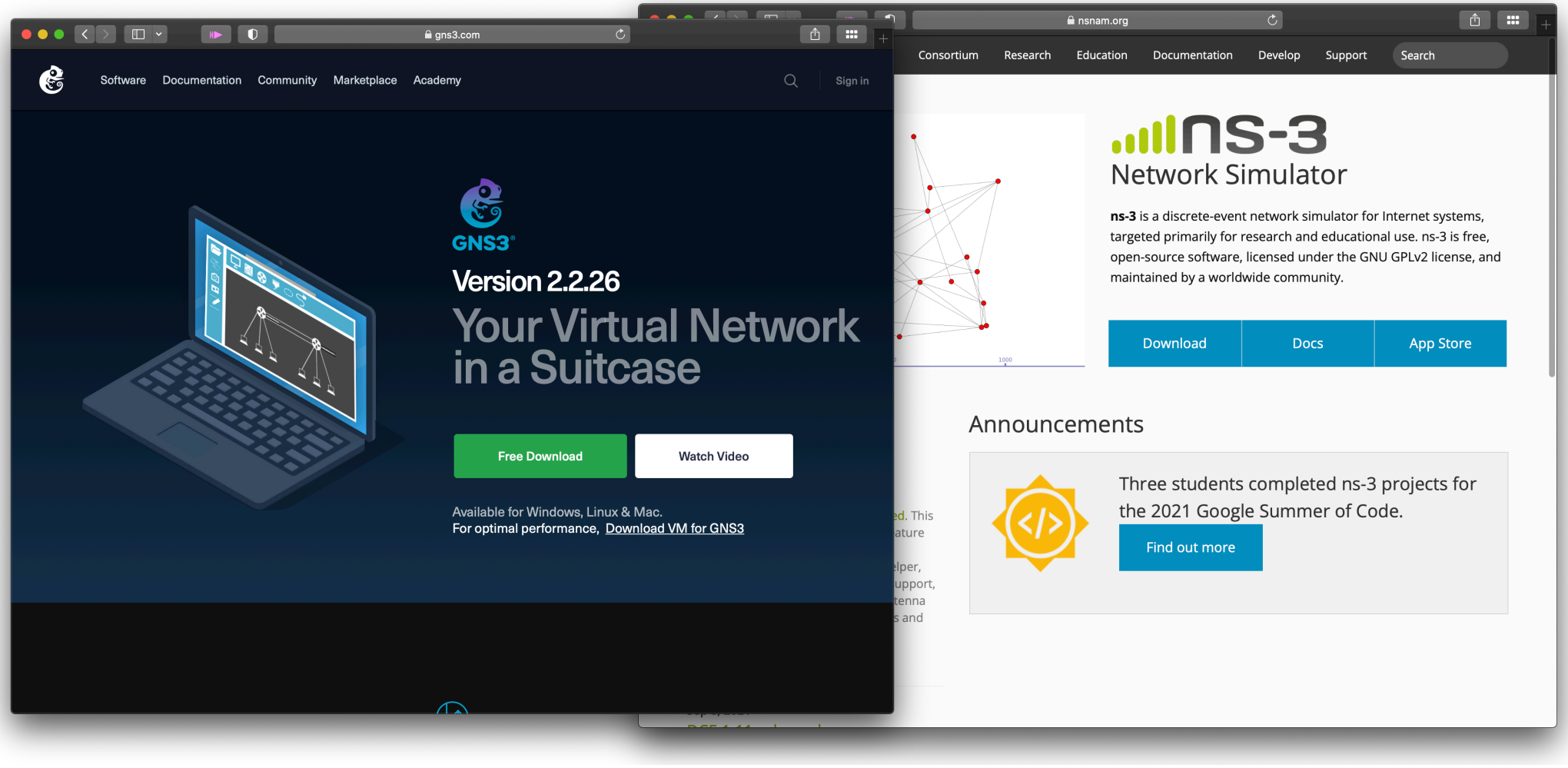
Proposed Research Approach

1. We will create model networks and run simulations on those networks (assisted by Mininet) to:
   1.1. Iteratively find the maximum degree of selfishness through:
      1.1.1. Opening **multiple parallel TCP connections**
      1.1.2. Emulating **misbehaving receivers**
      1.1.3. **Aggressively sending packets**

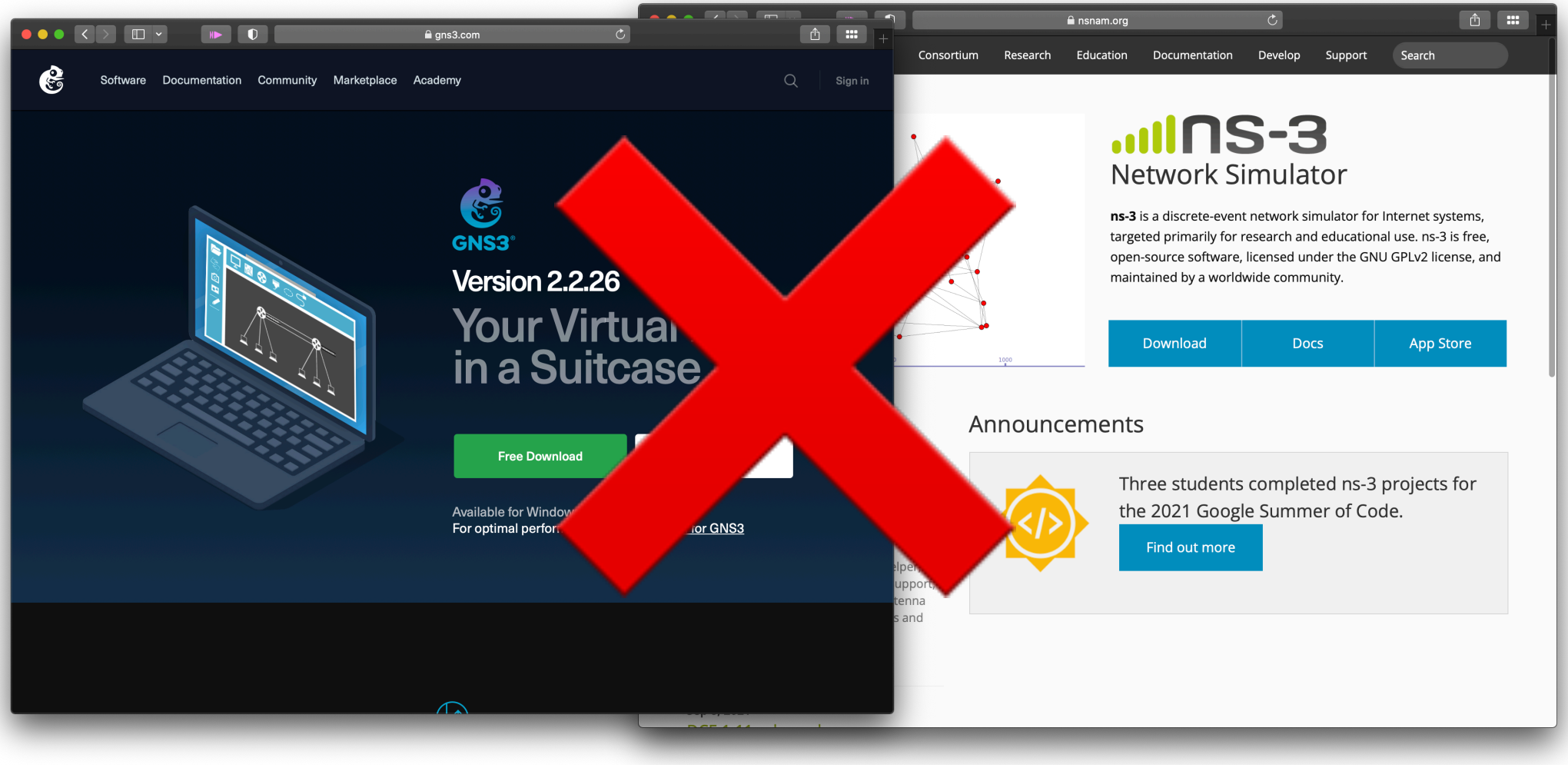
2. Repeat (1.) for:
   2.1. Different TCP versions:
      2.1.1. TCP Reno
      2.1.2. CUBIC TCP
      2.1.3. HighSpeed TCP
   2.2. UDP

3. Countermeasures (Stretch Goal!)

Proposed Research Approach



Proposed Research Approach



Proposed Research Approach

Not Secure — mininet.org

Mininet

An Instant Virtual Network on your Laptop (or other PC)

Mininet creates a **realistic virtual network**, running **real kernel, switch and application code**, on a single machine (VM, cloud or native), in seconds, with a single command:

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Mininet Wins ACM SIGCOMM Test of Time Paper Award

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Open Networking Foundation Promotes Mininet

Mininet Wins ACM SIGCOMM SOSR Software Systems Award !

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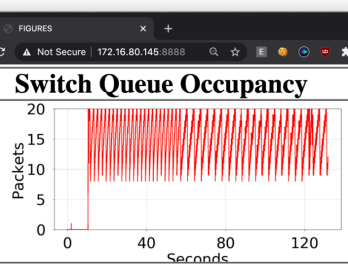
1004101_Networks_Lab4 (page 9 of 10)

50.012 Networks Lab 4 V S Ragul Balaji (1004101)

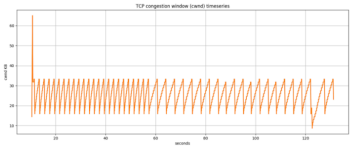
FIGURES

Not Secure | 172.16.80.145:8888

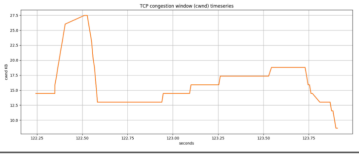
Switch Queue Occupancy



TCP CWND for iperf



TCP CWND for wget



172.16.80.145:8888/exp2_tcp_cwnd...

When the buffer is reduced from 100 packets to 20

Proposed Research Approach

Expected Deliverables

#	Attack Technique	Optimal Parameter Value	Optimal Parameter Type	TCP / UDP Variant (if any)
1	*Opening many parallel connections*	*10*	*Connections*	*TCP Reno*
2	*Receiver abuse frequency of ACKs sent*	*42*	*ACKs per second*	*TCP Tahoe*
3	*Opening many parallel connections*	*69*	*Connections*	*TCP Tahoe*
4	*Opening many parallel connections*	*420*	*Connections*	*UDP*
...	*...*	*...*	*...*	*...*

** these are ***obviously*** not real results **

Questions?