Next Stop 100 Gb/s: Scaling Network Security Monitoring to New Operational Challenges

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ICSI Board Meeting
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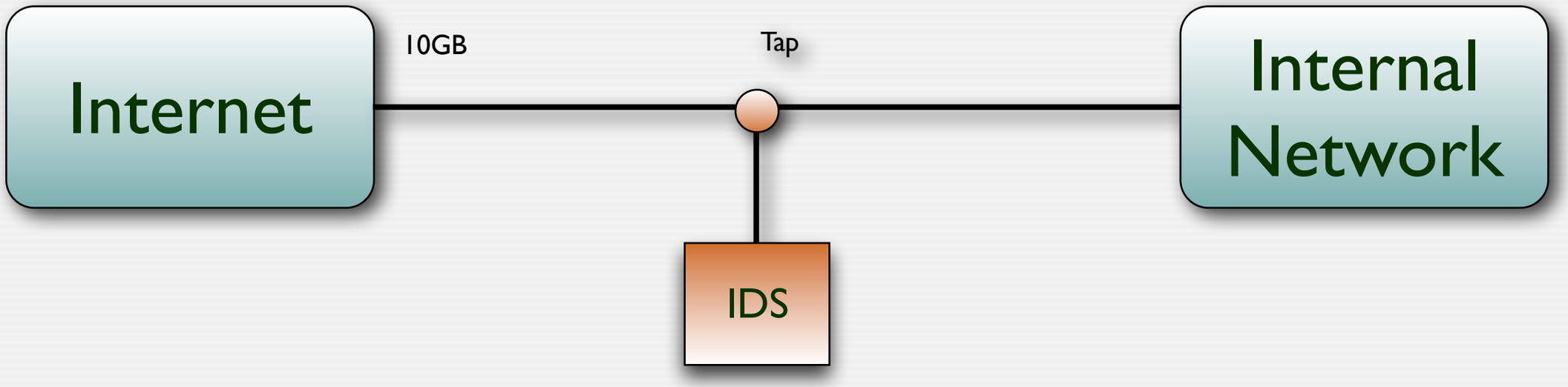
Monitoring Network Security

Traditional process is conceptually quite simple.



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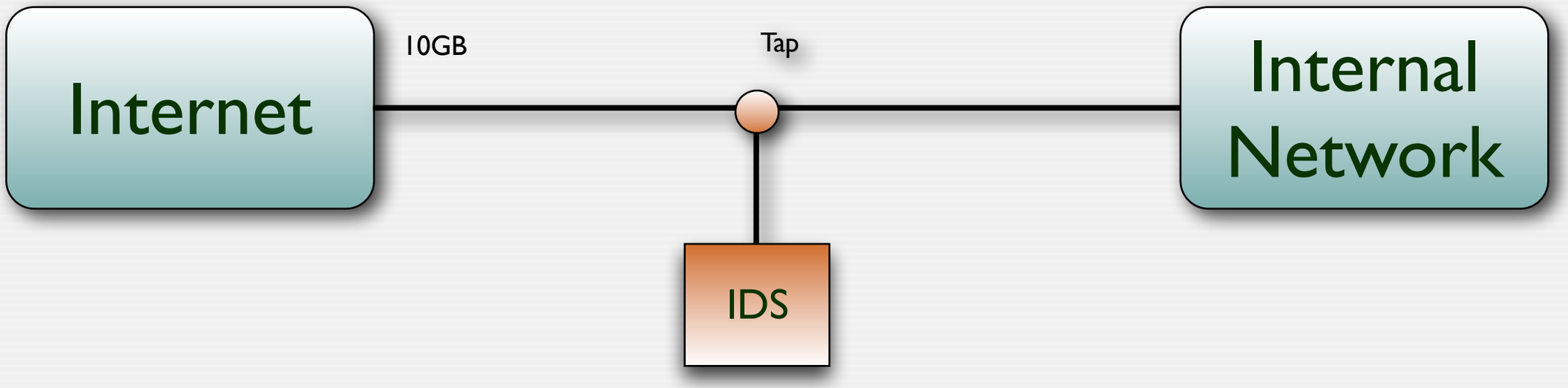

Example: Finding downloads of known malware.

1. Find and parse all Web traffic.
2. Find and extract binaries.
3. Compute hash and compare with database.
4. Report, and potentially kill, if found.

Back in 2005 …

Data: Leibniz-Rechenzentrum, München

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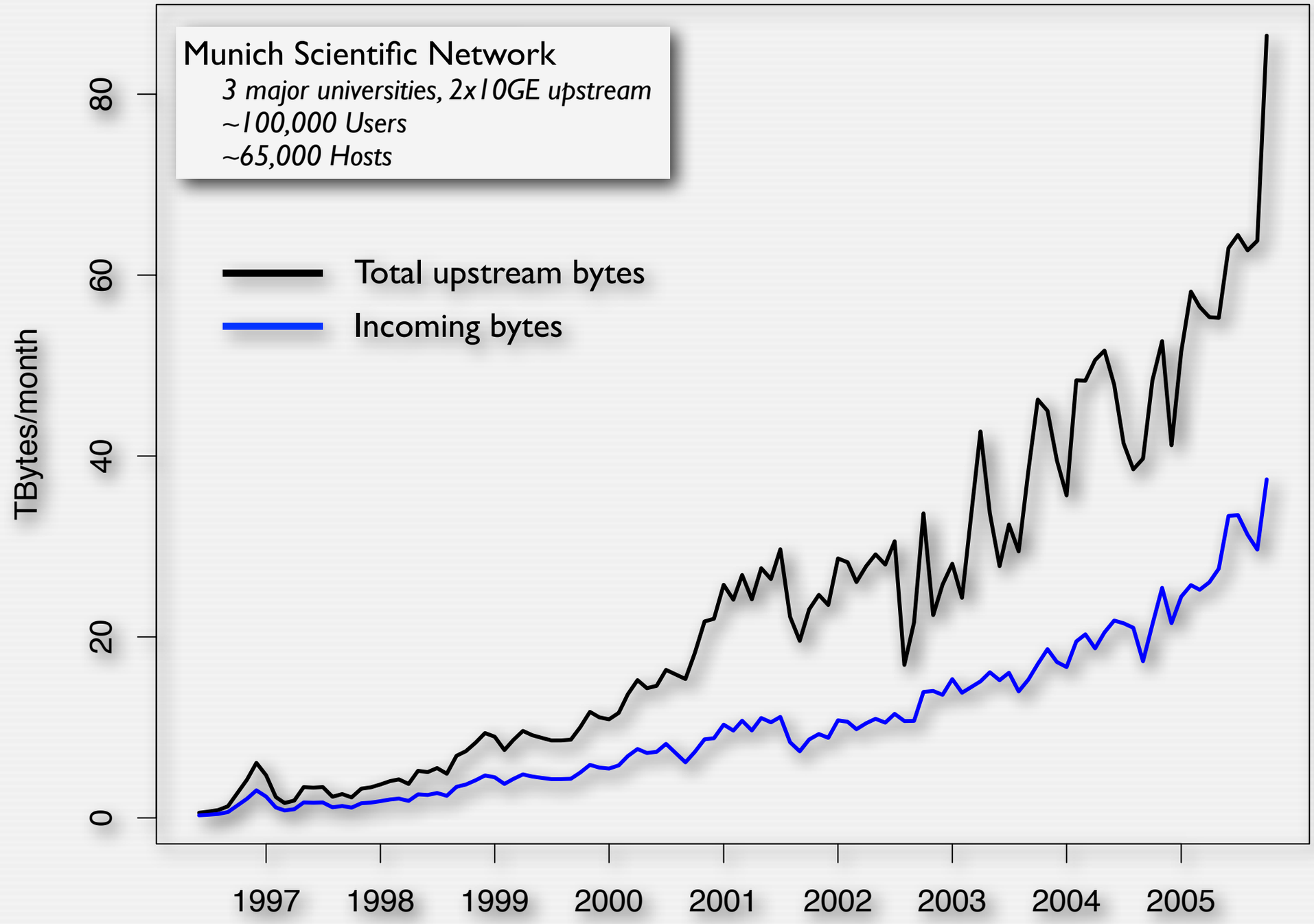

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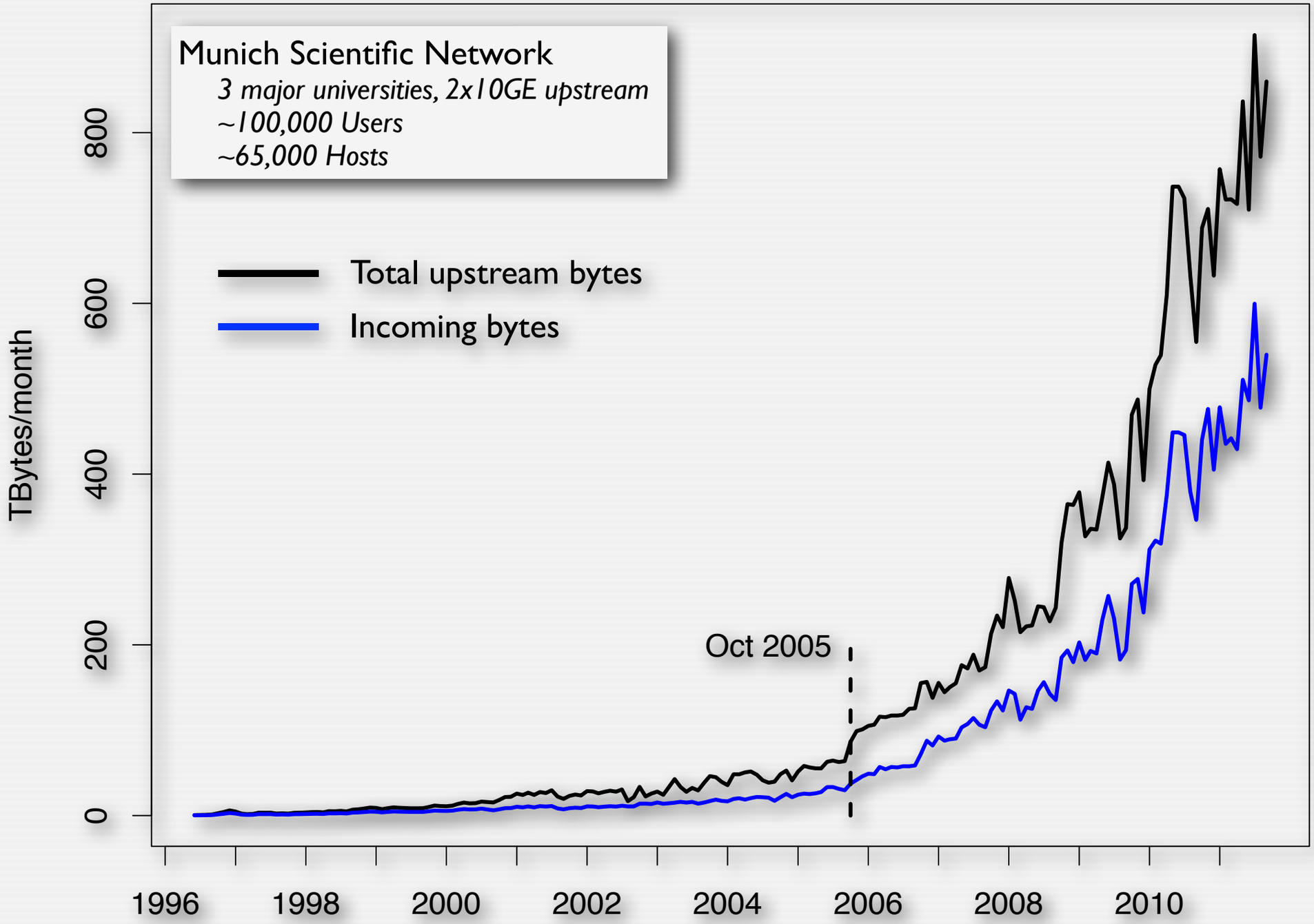
Today ...



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Gap: Research vs Operations

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Conceptually simple tasks can be hard in practice.

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- Operations cannot leverage academic results.

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- Close collaborations with several large sites (LBNL,UC Berkeley, NCSA).
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Operational constraints pose research questions.

- Results go back into operations.

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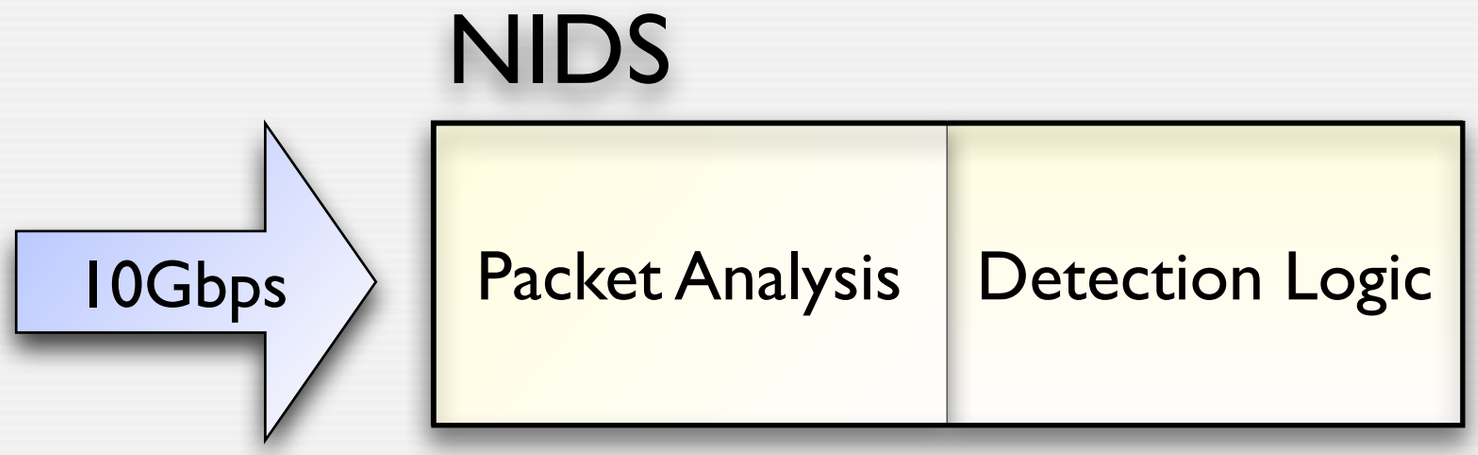
Example: Processing performance.

LBNL operations had trouble keeping up.
Research question: How can Bro scale?

Load-balancing Architecture

[Vallentin et al. 2007]

Load-balancing Architecture



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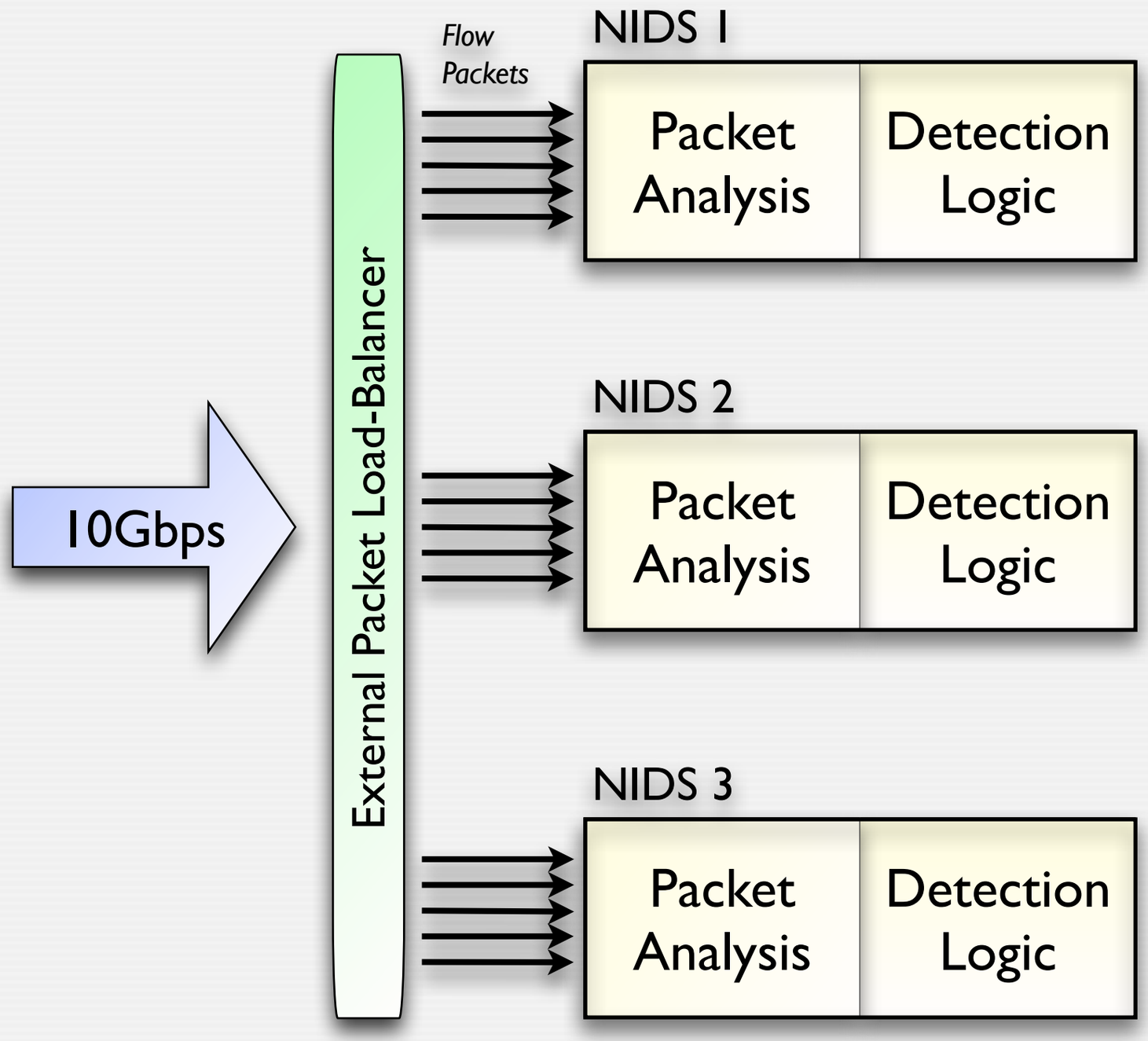

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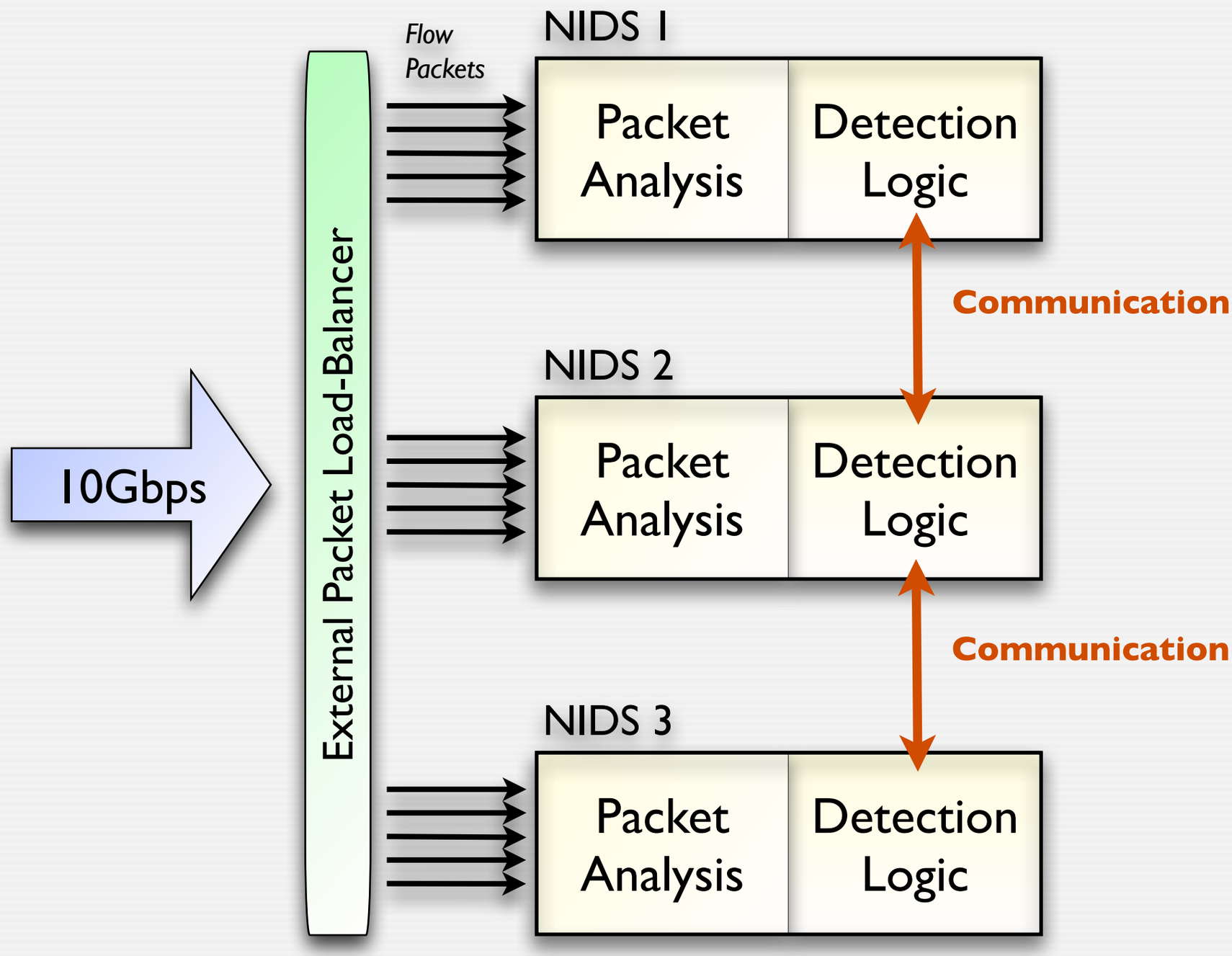

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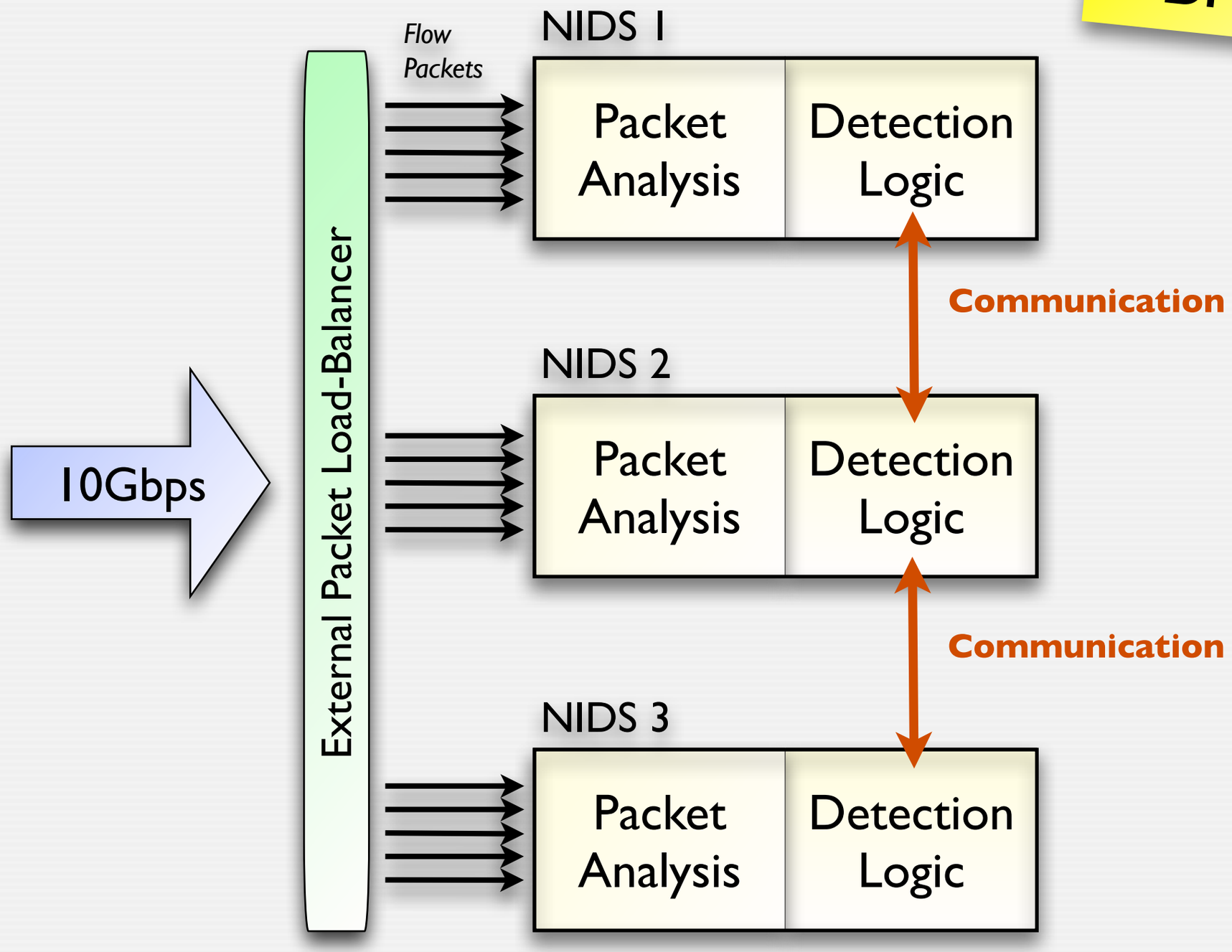
Load-balancing Architecture

"Bro Cluster"



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Cluster goes Operation

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Load-balancer operates a line-rate.

1. Receive packet.
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LBNL wanted reliable 10 Gb/s device.

Difficult to find a robust line-rate solution.

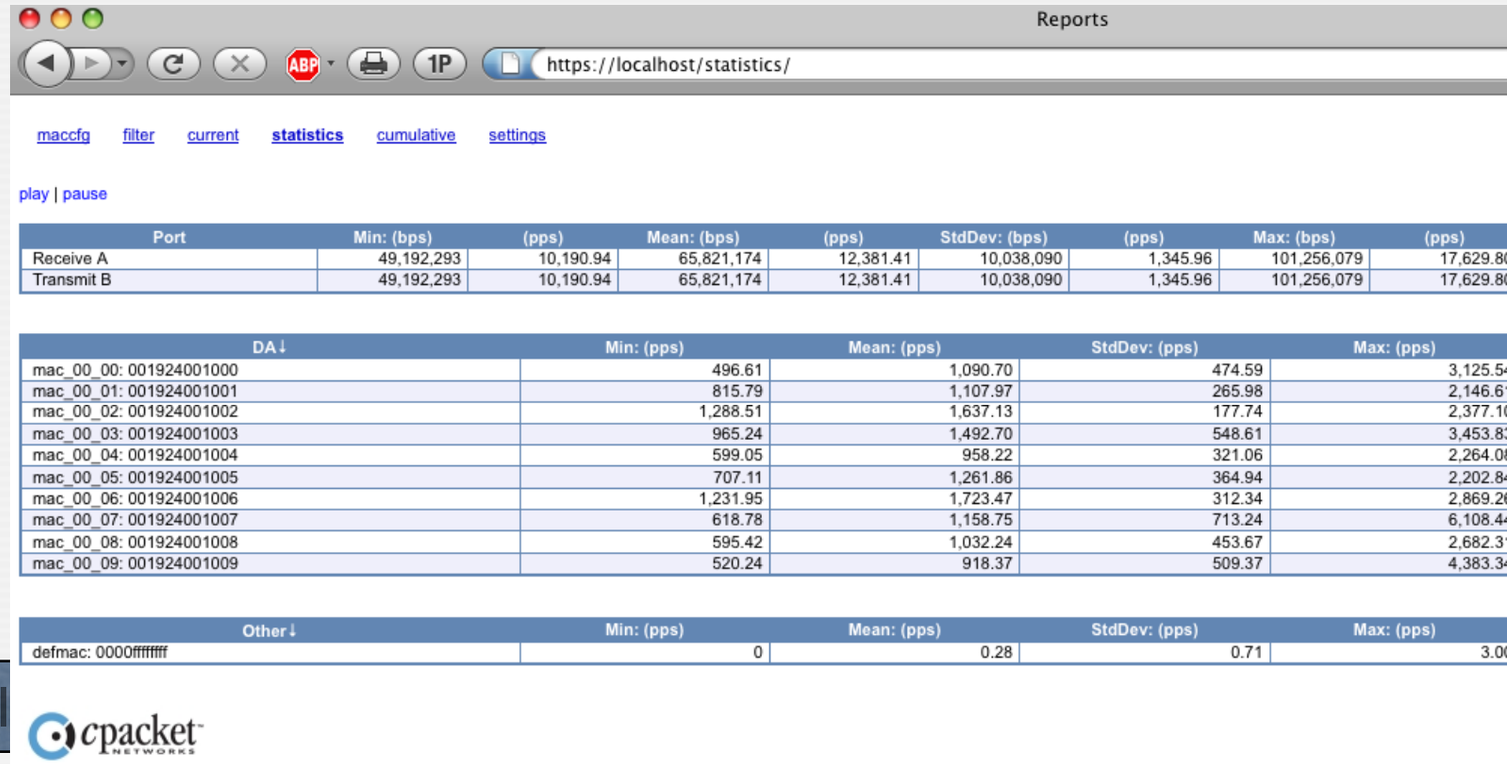
Eventually contracted vendor to build device.

A Production Load-Balancer

cFlow: 10GE line-rate, stand-alone load-balancer

10 Gb/s in/out
Web & CLI
Filtering capabilities

Available from cPacket



Port	Min: (bps)	(pps)	Mean: (bps)	(pps)	StdDev: (bps)	(pps)	Max: (bps)	(pps)
Receive A	49,192,293	10,190.94	65,821,174	12,381.41	10,038,090	1,345.96	101,256,079	17,629.8
Transmit B	49,192,293	10,190.94	65,821,174	12,381.41	10,038,090	1,345.96	101,256,079	17,629.8

DA↓	Min: (pps)	Mean: (pps)	StdDev: (pps)	Max: (pps)
mac_00_00: 001924001000	496.61	1,090.70	474.59	3,125.5
mac_00_01: 001924001001	815.79	1,107.97	265.98	2,146.6
mac_00_02: 001924001002	1,288.51	1,637.13	177.74	2,377.1
mac_00_03: 001924001003	965.24	1,492.70	548.61	3,453.8
mac_00_04: 001924001004	599.05	958.22	321.06	2,264.0
mac_00_05: 001924001005	707.11	1,261.86	364.94	2,202.8
mac_00_06: 001924001006	1,231.95	1,723.47	312.34	2,869.2
mac_00_07: 001924001007	618.78	1,158.75	713.24	6,108.4
mac_00_08: 001924001008	595.42	1,032.24	453.67	2,682.3
mac_00_09: 001924001009	520.24	918.37	509.37	4,383.3

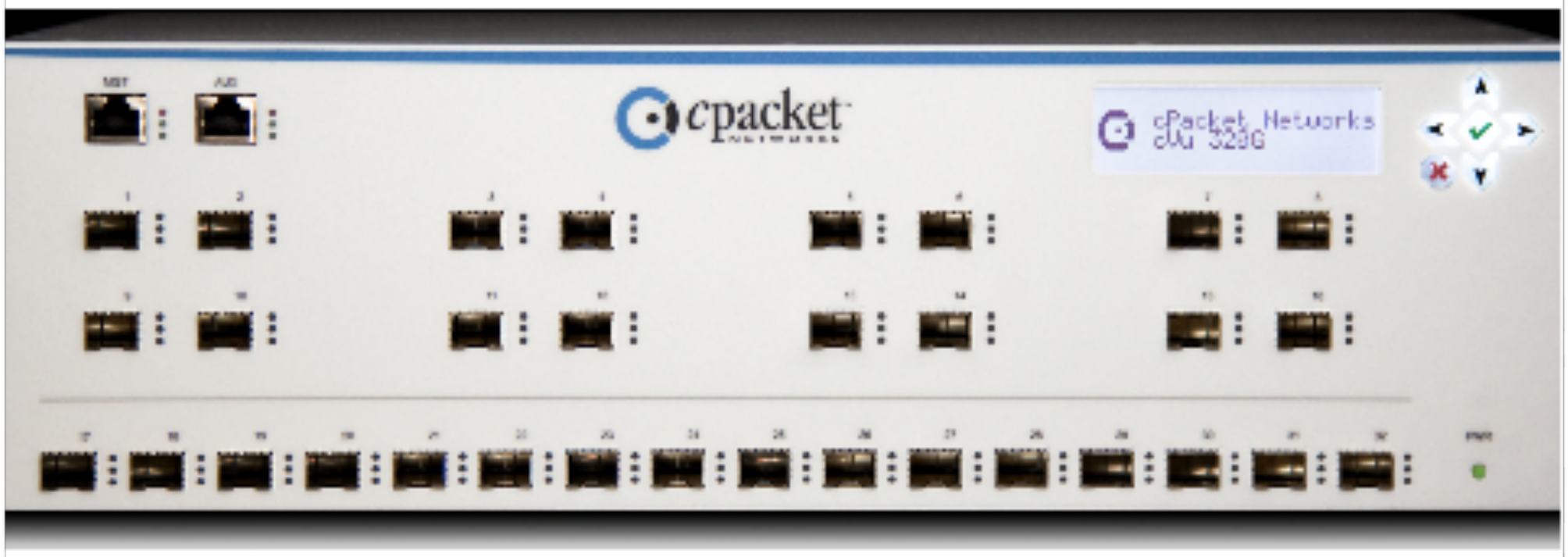
Other↓	Min: (pps)	Mean: (pps)	StdDev: (pps)	Max: (pps)
defmac: 0000ffffffff	0	0.28	0.71	3.0

A Production Load-Balancer

cPacket cVu 320G

cpacket NETWORKS

32 x 10G SFP+ Traffic Monitoring Switch
Aggregation, Complete Packet Inspection Filtering, Automatic Flow Balancing



Available from cPacket

mac_00_02: 001924001002	1,288.51	1,637.13	177.74	2,377.10
mac_00_03: 001924001003	965.24	1,492.70	548.61	3,453.83
mac_00_04: 001924001004	599.05	958.22	321.06	2,264.08
mac_00_05: 001924001005	707.11	1,261.86	364.94	2,202.84
mac_00_06: 001924001006	1,231.95	1,723.47	312.34	2,869.26
mac_00_07: 001924001007	618.78	1,158.75	713.24	6,108.44
mac_00_08: 001924001008	595.42	1,032.24	453.67	2,682.31
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cpacket NETWORKS

What Does This Mean for Us?

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- Other sites have, or are building, similar setups.

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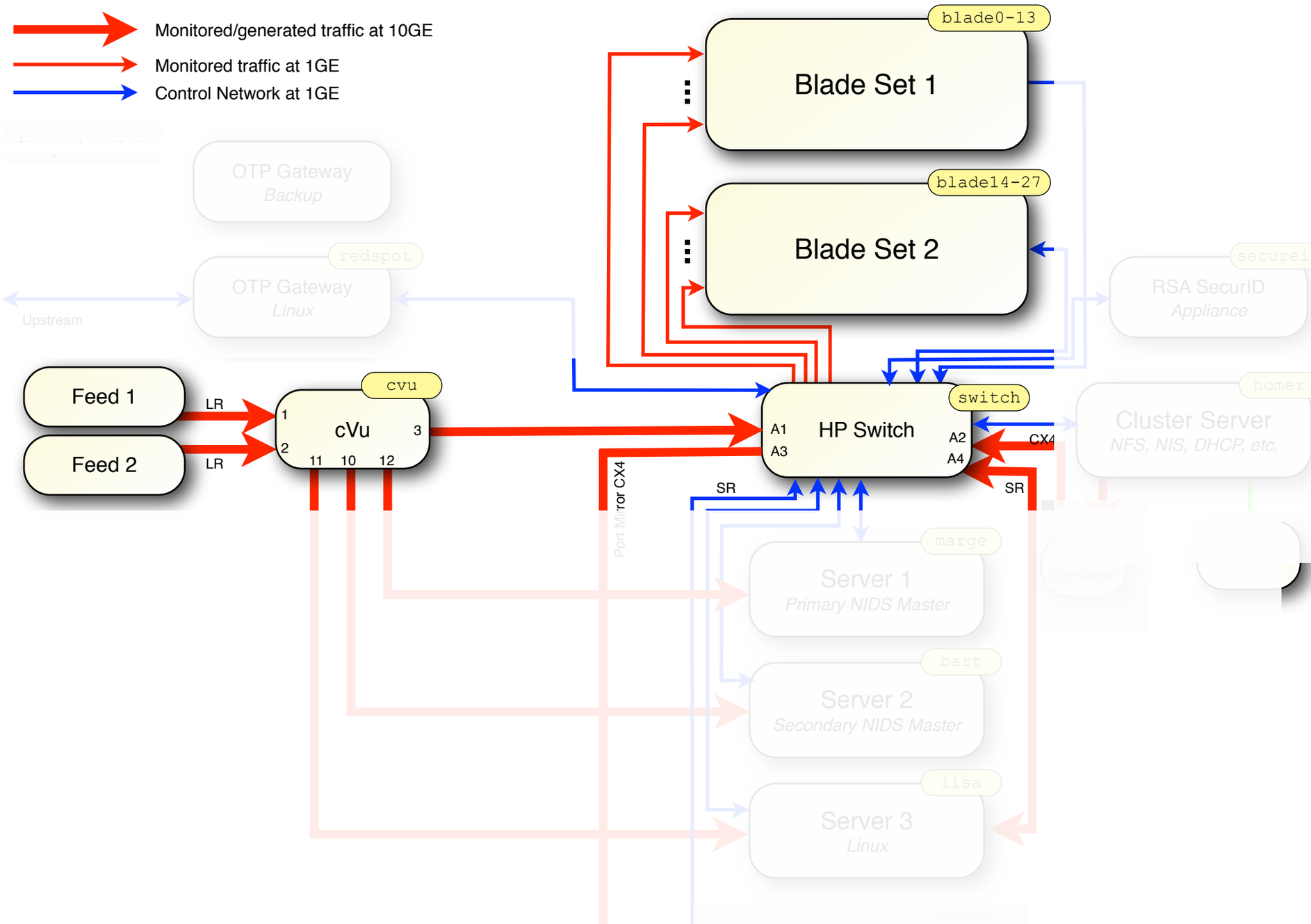
UC Berkeley Cluster

Large-scale network, 100,000 hosts, 2x10Gbps upstream, 2-4Gb/sec.
30 individual machines. Collaboration with Campus SNS.
Funded by NSF's Computing Research Infrastructure program.

UC Berkeley Cluster



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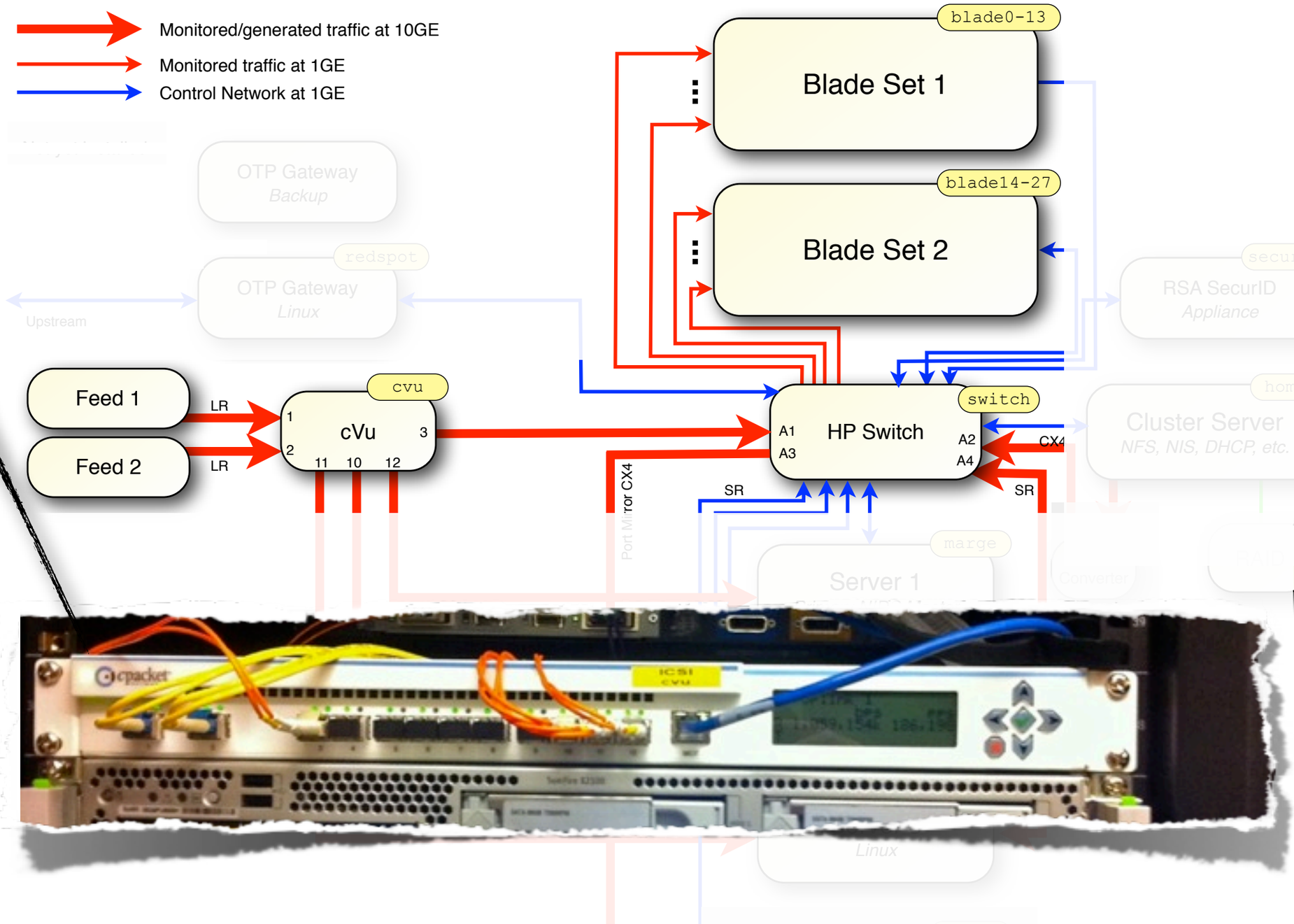

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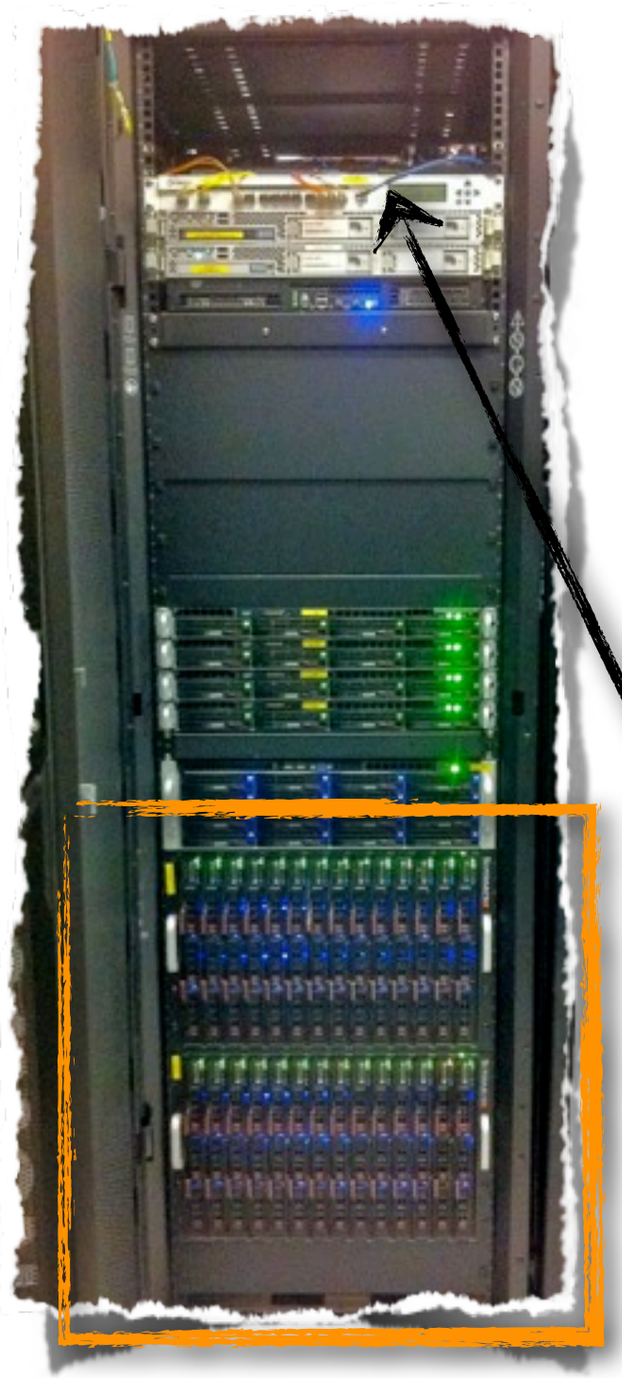

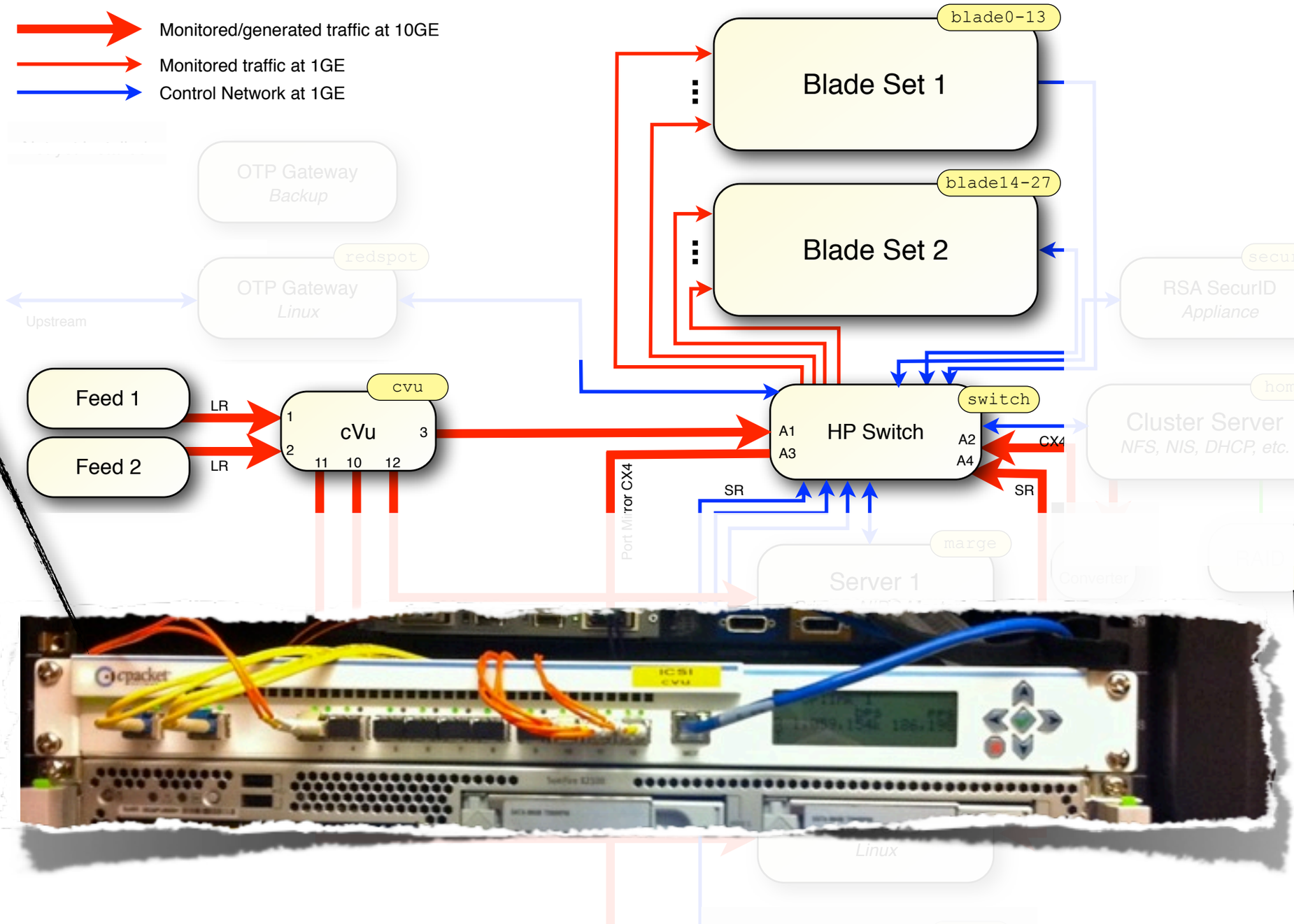

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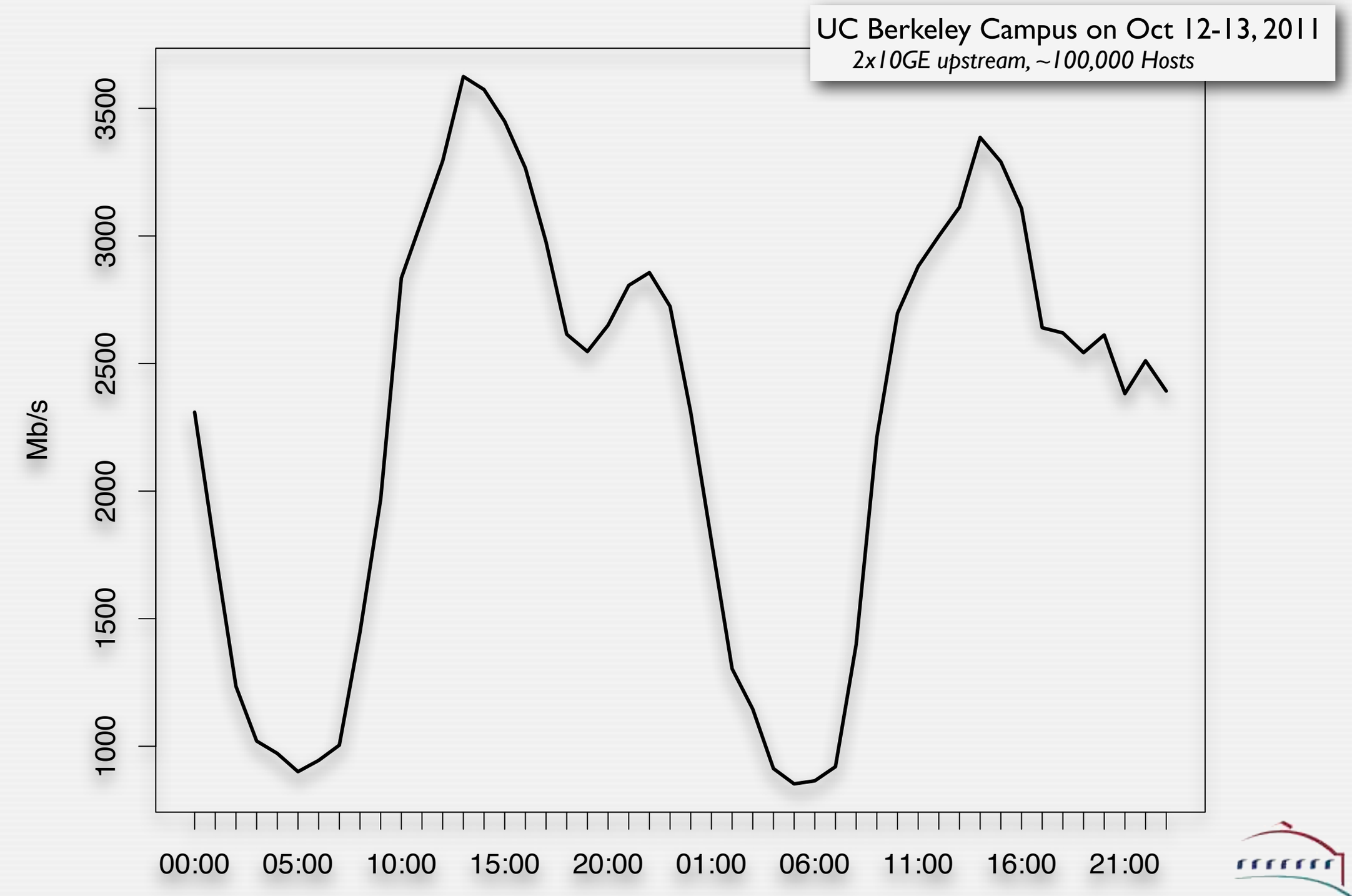
Campus Traffic



Campus Bro Cluster

shire

Name	Type	Node	Pid	Proc	VSize	Rss	Cpu	Cmd
manager	manager	marge	56355	parent	131M	113M	35%	bro
proxy-1	proxy	marge	56417	parent	38M	20M	0%	bro
worker-00	worker	blade0	68859	parent	320M	294M	25%	bro
worker-01	worker	blade1	5069	parent	330M	314M	27%	bro
worker-02	worker	blade2	40406	parent	330M	308M	25%	bro
worker-03	worker	blade3	39416	parent	322M	306M	32%	bro
worker-04	worker	blade4	74771	parent	322M	294M	38%	bro
worker-05	worker	blade5	9257	parent	324M	294M	21%	bro
worker-06	worker	blade6	1915	parent	322M	293M	26%	bro
worker-07	worker	blade7	36112	parent	324M	304M	28%	bro
worker-08	worker	blade8	13415	parent	332M	299M	29%	bro
worker-09	worker	blade9	1391	parent	326M	299M	22%	bro
worker-10	worker	blade10	86072	parent	324M	308M	35%	bro
worker-11	worker	blade11	886	parent	326M	309M	32%	bro
worker-12	worker	blade12	89545	parent	328M	310M	29%	bro
worker-13	worker	blade13	5854	parent	342M	319M	27%	bro
worker-14	worker	blade14	24363	parent	324M	302M	26%	bro
worker-15	worker	blade15	49775	parent	324M	308M	23%	bro
worker-16	worker	blade16	433	parent	328M	300M	35%	bro
worker-17	worker	blade17	87068	parent	330M	308M	42%	bro
worker-18	worker	blade18	434	parent	328M	296M	21%	bro
worker-19	worker	blade19	89307	parent	330M	314M	22%	bro
worker-21	worker	blade21	64289	parent	344M	315M	29%	bro
worker-22	worker	blade22	21382	parent	324M	309M	21%	bro
worker-23	worker	blade23	1878	parent	324M	300M	22%	bro
worker-25	worker	blade25	59300	parent	336M	313M	19%	bro
worker-27	worker	blade27	1563	parent	352M	332M	25%	bro

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1. Going beyond 10GE ...

Next Stop: 100 Gb/s

DOE/ESNet
100G Advanced Networking Initiative

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Moving Data at the Speed of Science: Berkeley Lab Lays Foundation for 100 Gbps Prototype Network

JULY 13, 2011

Source: ESNet

Source: ESNet

100 Gb/s Load-balancer

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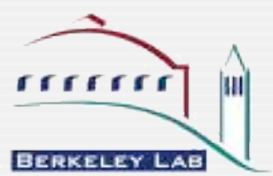
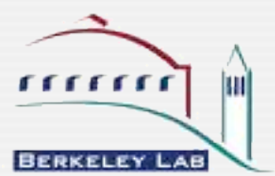


100 Gb/s Load-balancer

SBIR Phase 2 project.

Just awarded to cPacket & ICSI.



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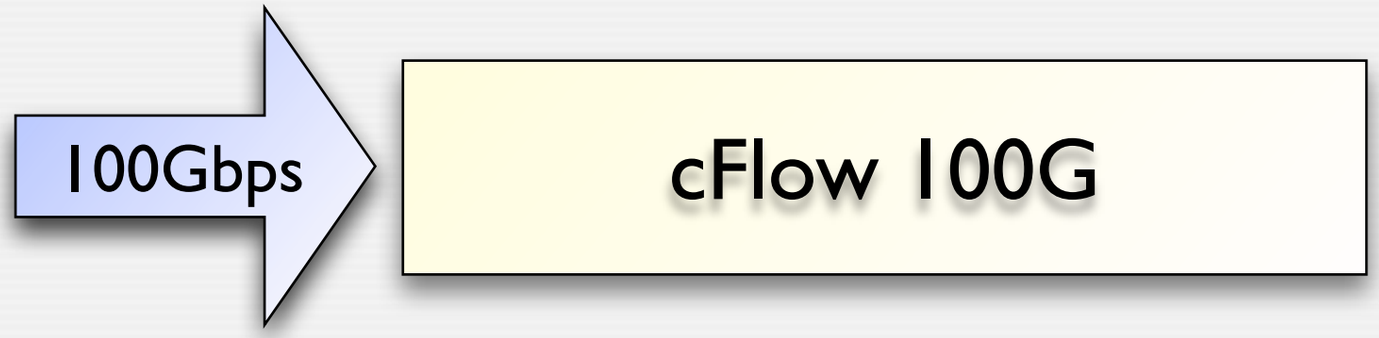

ICSI International Computer Science Institute

Berkeley Lab

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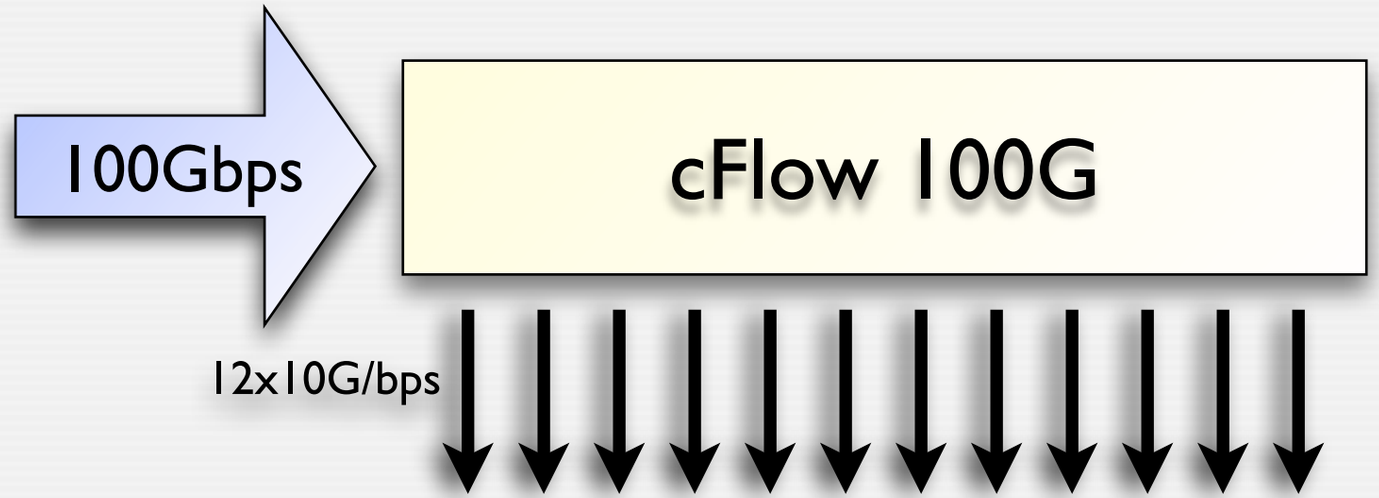

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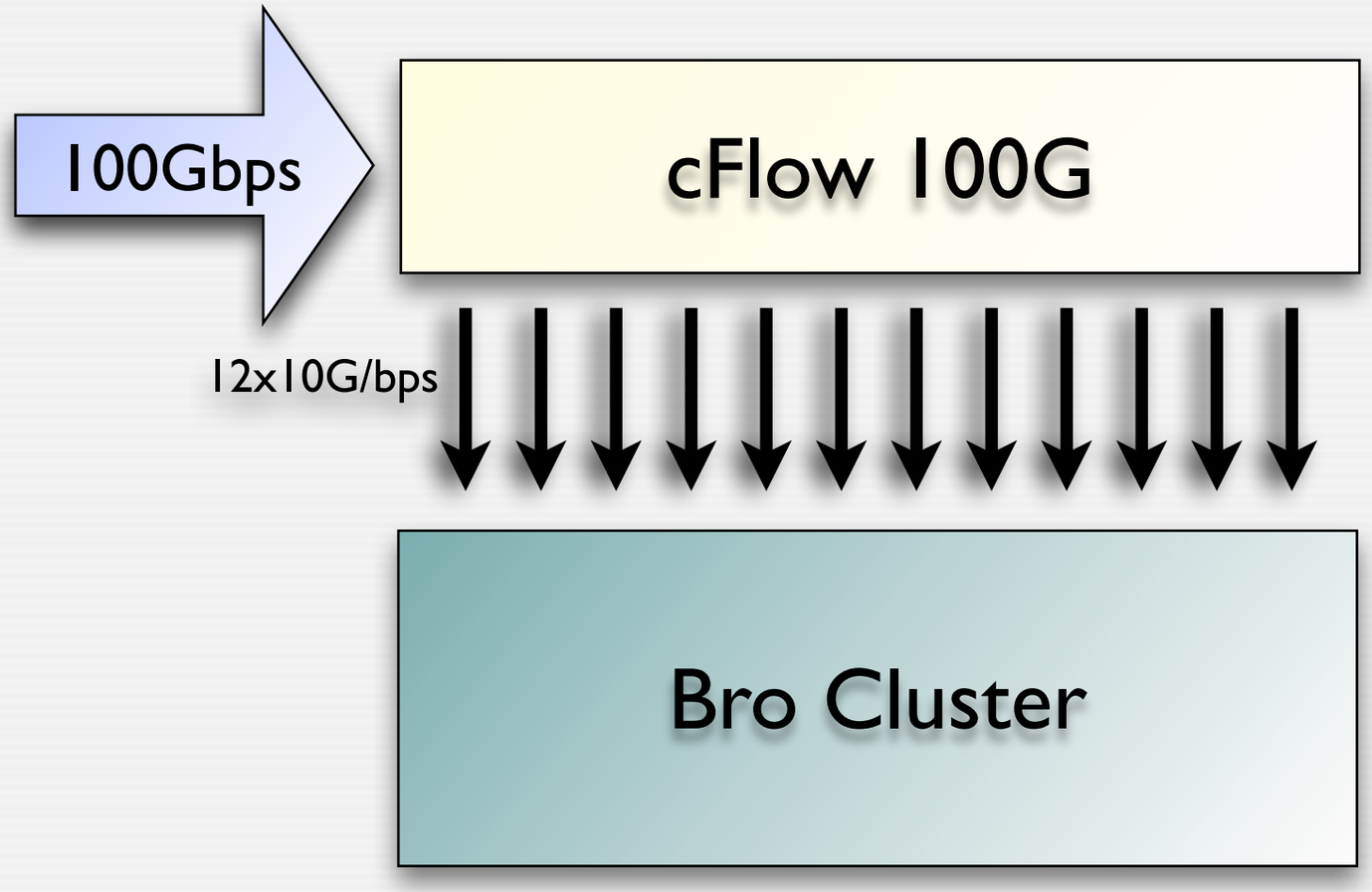

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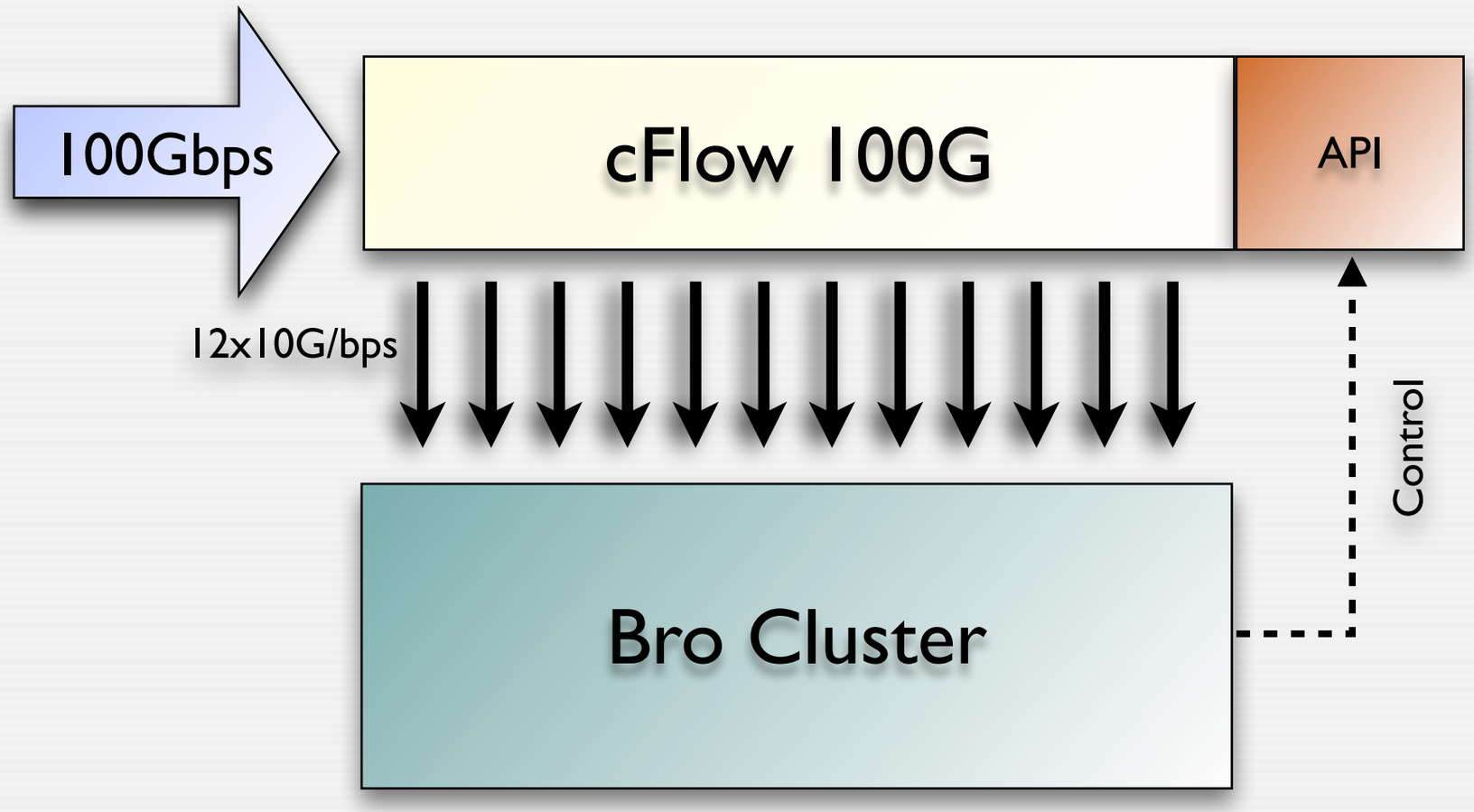

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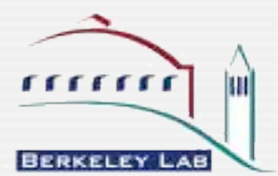
1. Going beyond 10GE ...
2. **From multi-system to multi-core ...**

Bro is Single-Threaded ...



Bro is Single-Threaded ...

Cluster clearly has short-comings.

- Backends have multiple cores, which are mostly idling.

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We *really* want multi-threading.

Must scale well with increasing numbers of cores.

Must be transparent to the operator.

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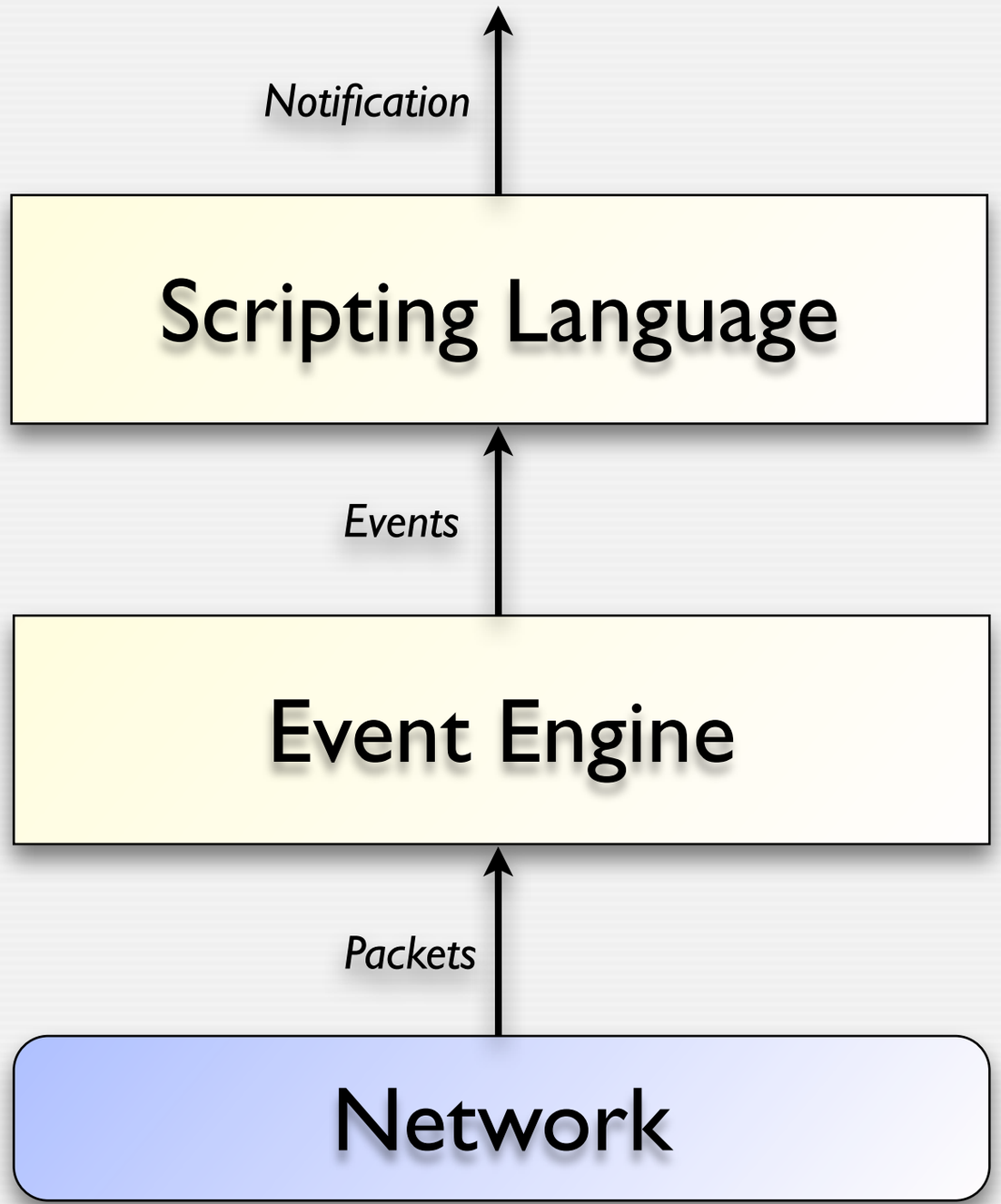
For some IDS, that's not so hard.

For others, it is ...

Bro's Architecture

Detection Logic

Packet Analysis



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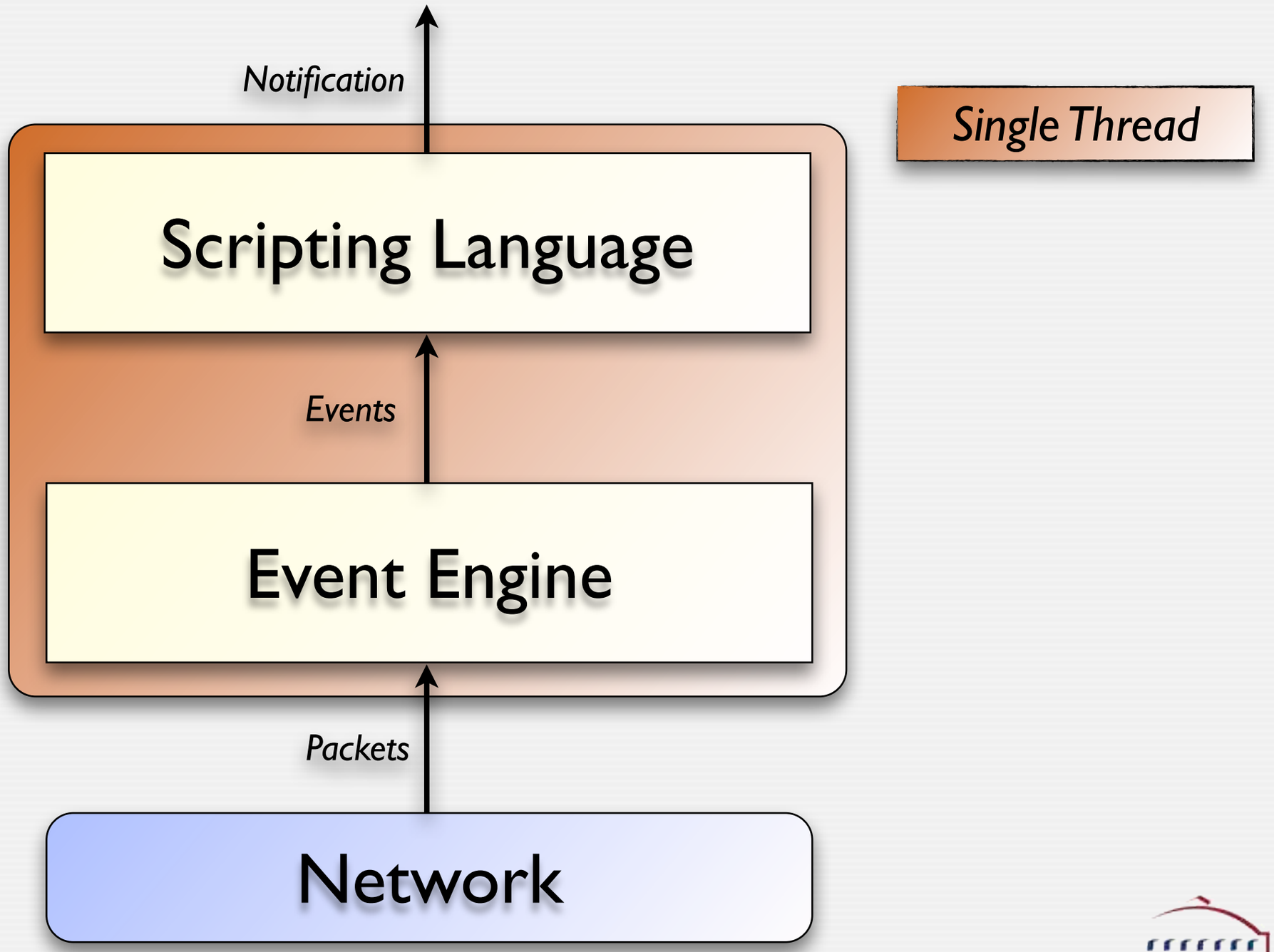

Single Thread

Bro's Architecture

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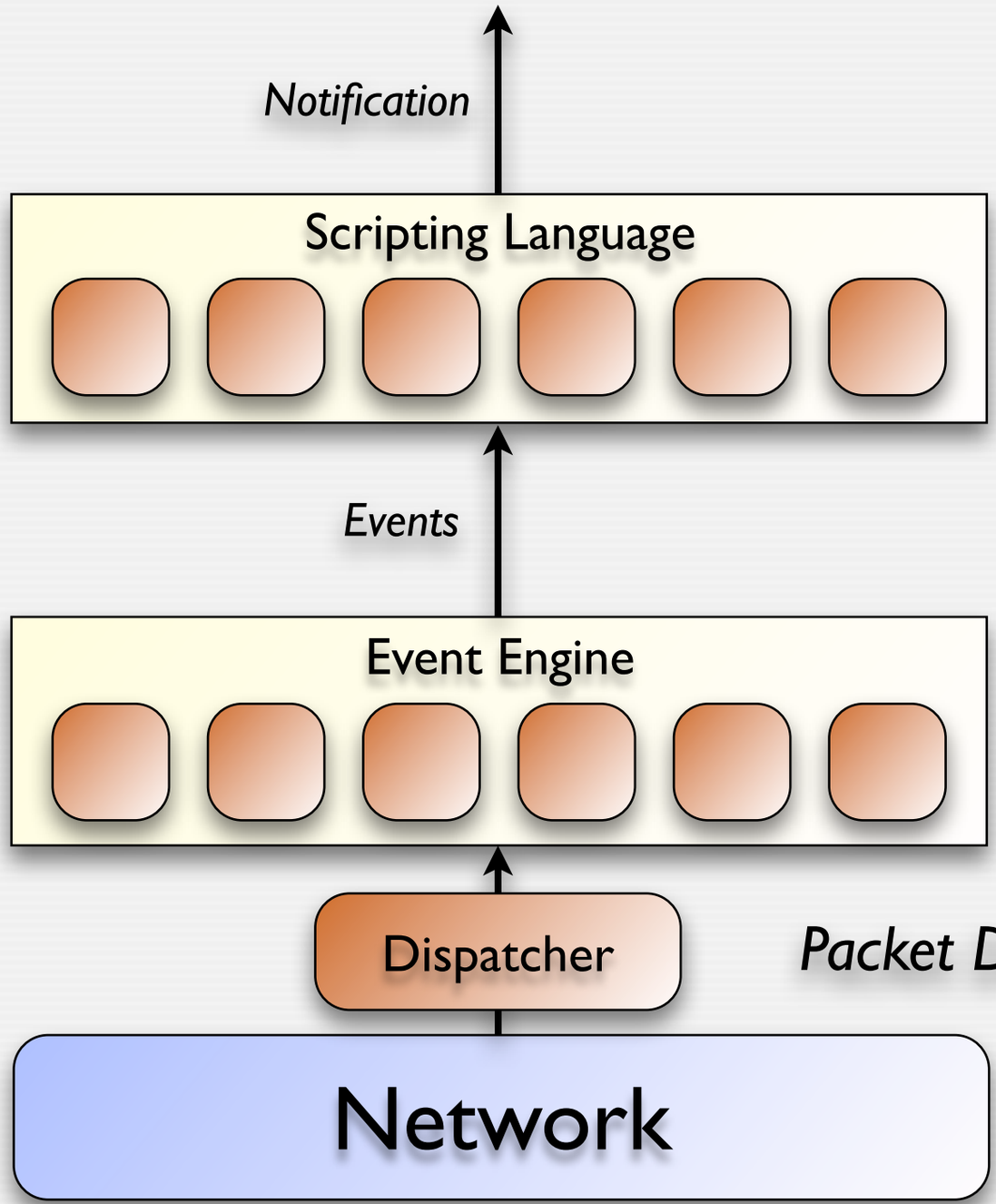


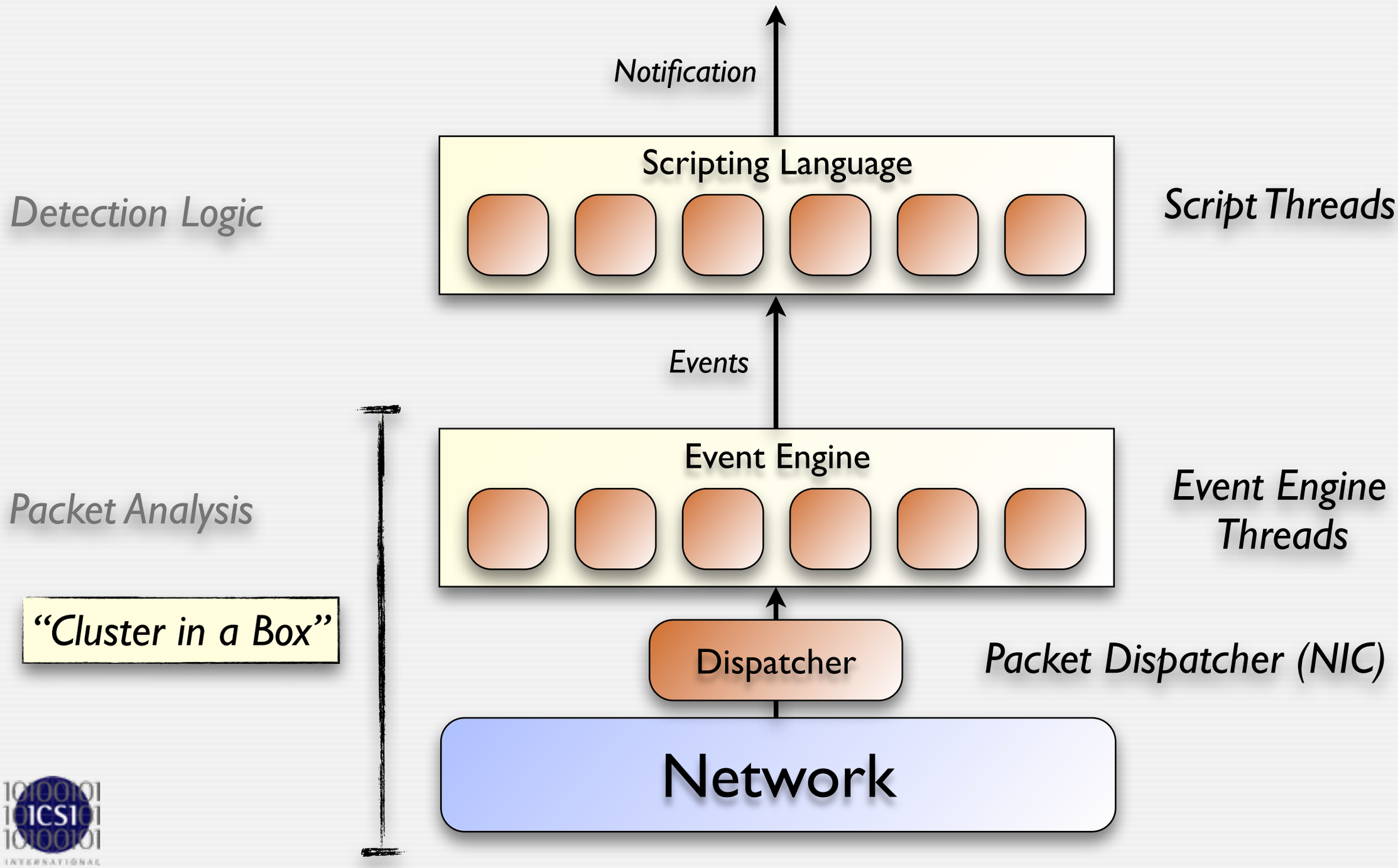
Script Threads

Event Engine Threads

Packet Dispatcher (NIC)

Packet Analysis

Bro's Architecture



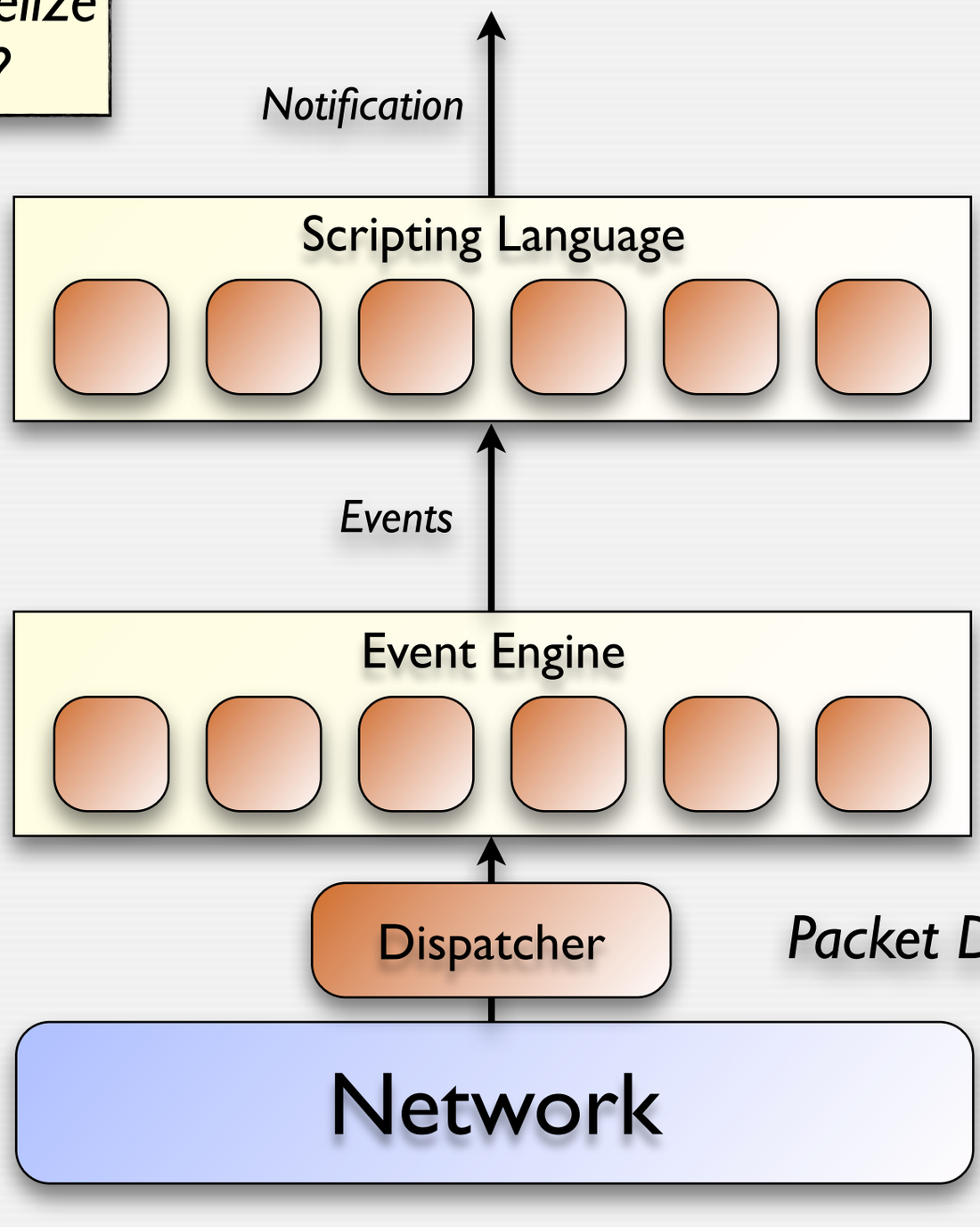
Bro's Architecture

Research: How to parallelize a scripting language?

Detection Logic

Packet Analysis

"Cluster in a Box"



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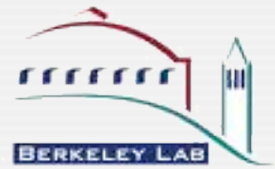
Towards Multi-Threaded Bro



Towards Multi-Threaded Bro

Analysis structured around *units*.

Processing and state expressed in such terms.

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Simulations predict excellent scalability.

There are plenty independent unit instances in traffic.

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Can leverage units for scheduling.

Run-time tracks current unit.

Scheduler steers events to thread in charge.

Simulations predict excellent scalability.

There are plenty independent unit instances in traffic.

Implemented a prototype inside Bro

Works somewhat, but painful.

HILTI Abstract Machine

A **H**igh-Level **I**ntermediary **L**anguage for **T**raffic **I**nspection

HILTI Abstract Machine

A **H**igh-Level **I**ntermediary **L**anguage for **T**raffic **I**nspection

Domain-specific Data Types	State Management	Concurrent Analysis	Real-time Performance	Robust/Secure Execution	High-level Standard Components
First-class networking types built-in	Containers with state management support	Domain-specific concurrency model	Scalability through parallelization	Well-defined, contained execution environment	Platform for building high-level, reusable functionality on
	Timers can drive execution	Support for incremental processing	Compilation to native code	Static type-system, and robust error handling	
			Extensive optimization potential		

HILTI Abstract Machine

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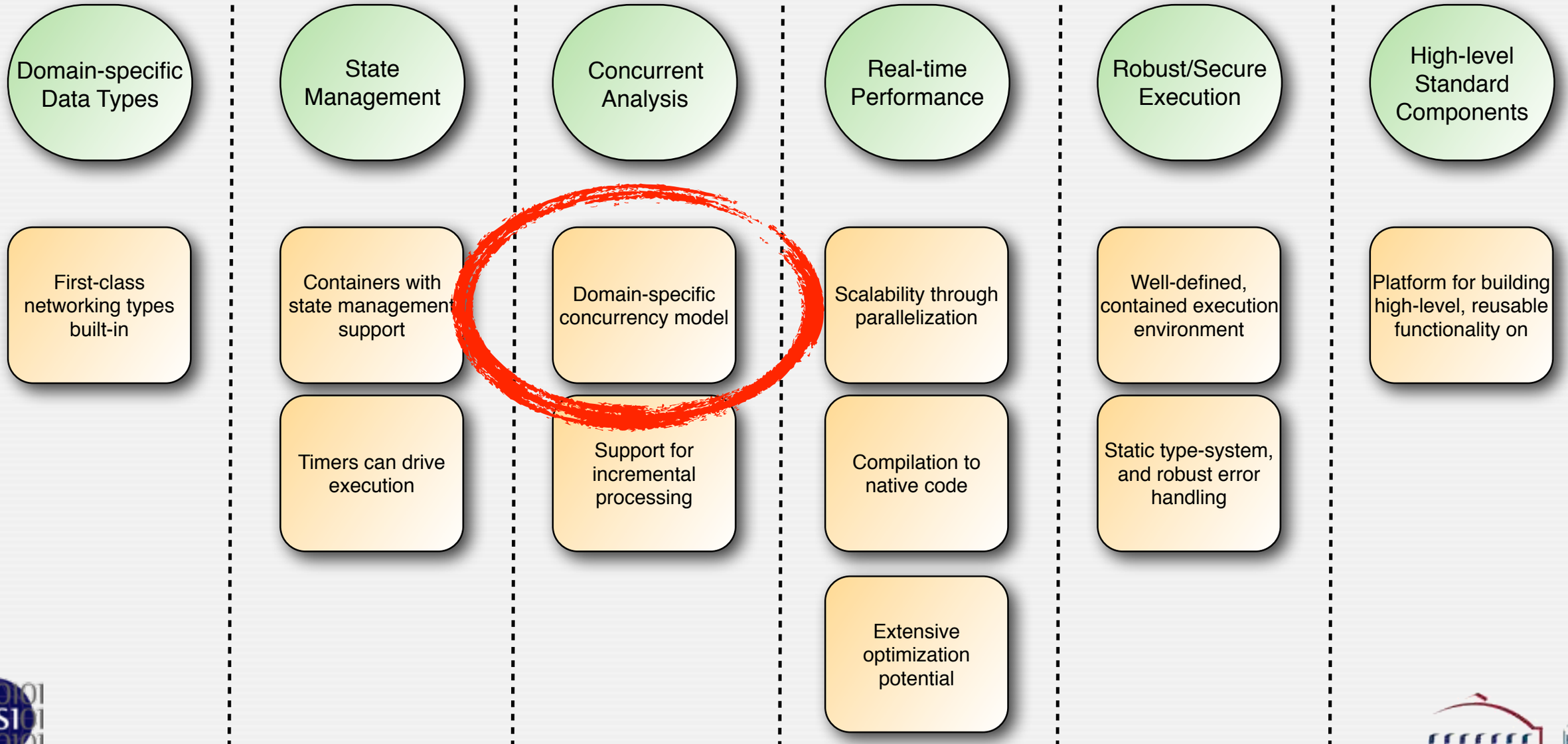

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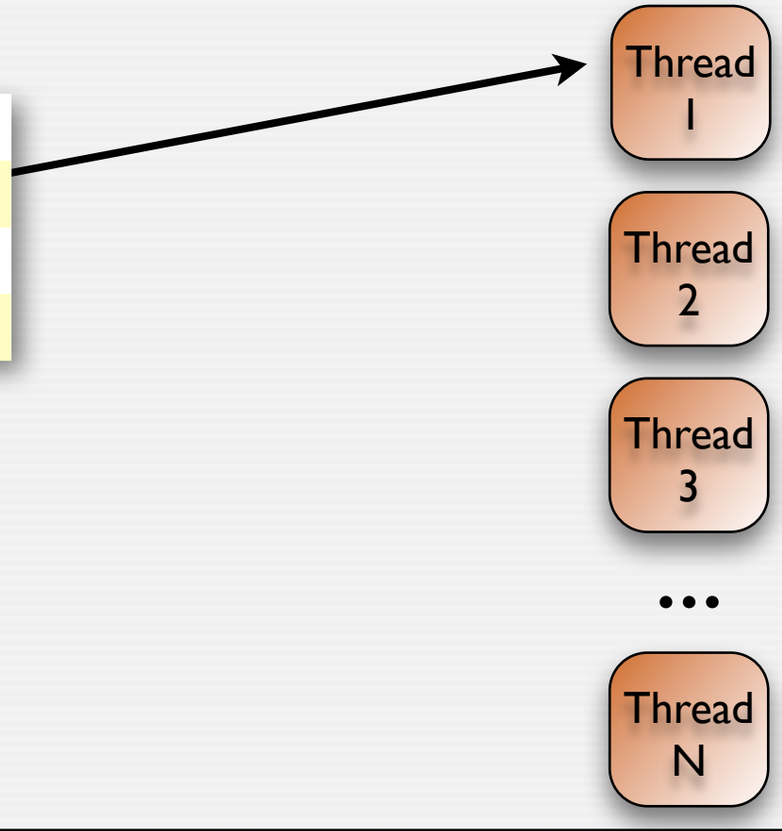

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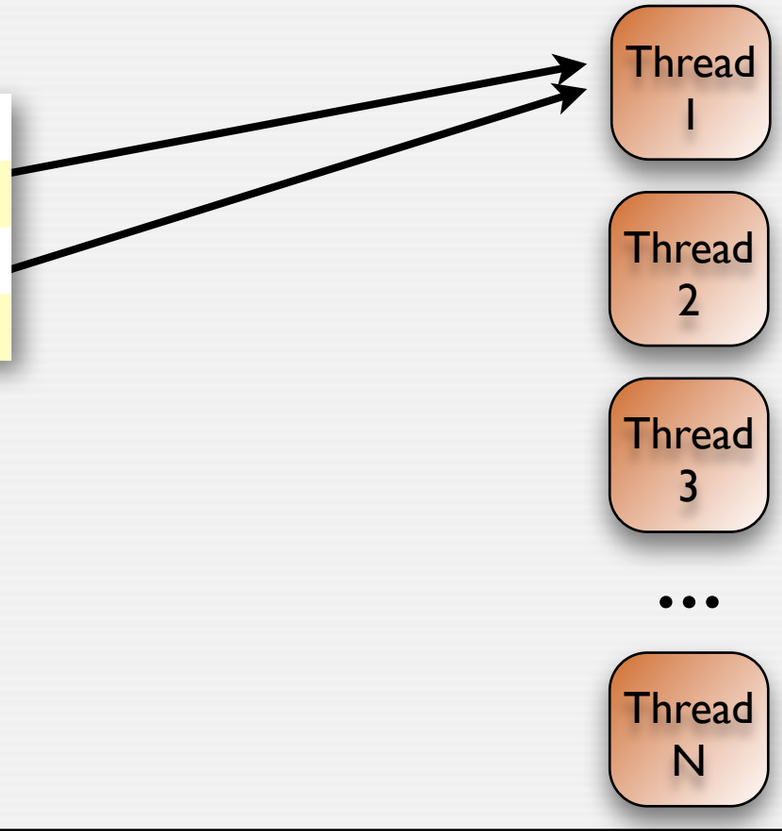

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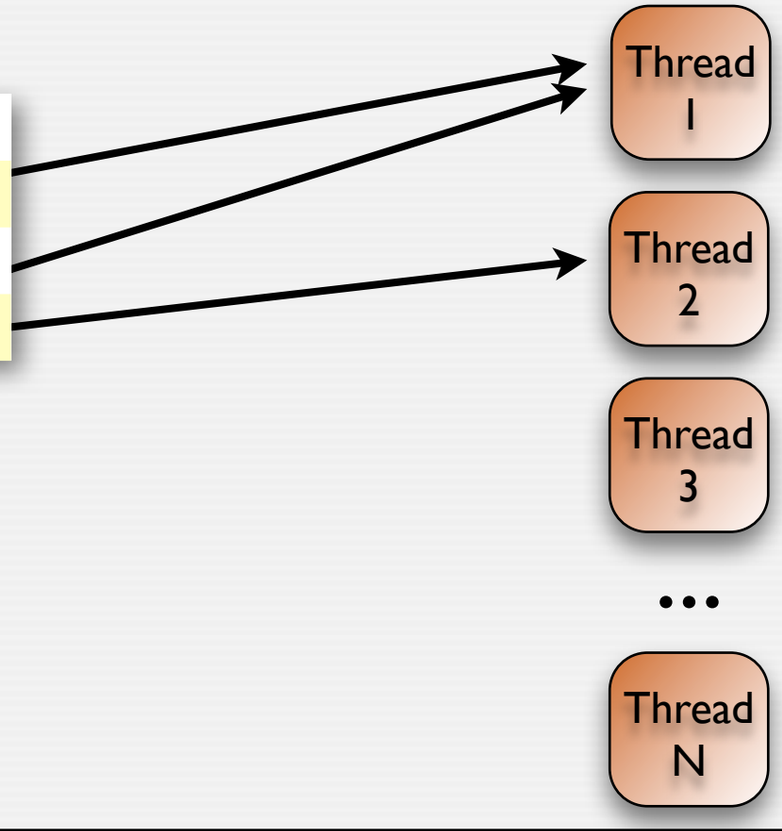

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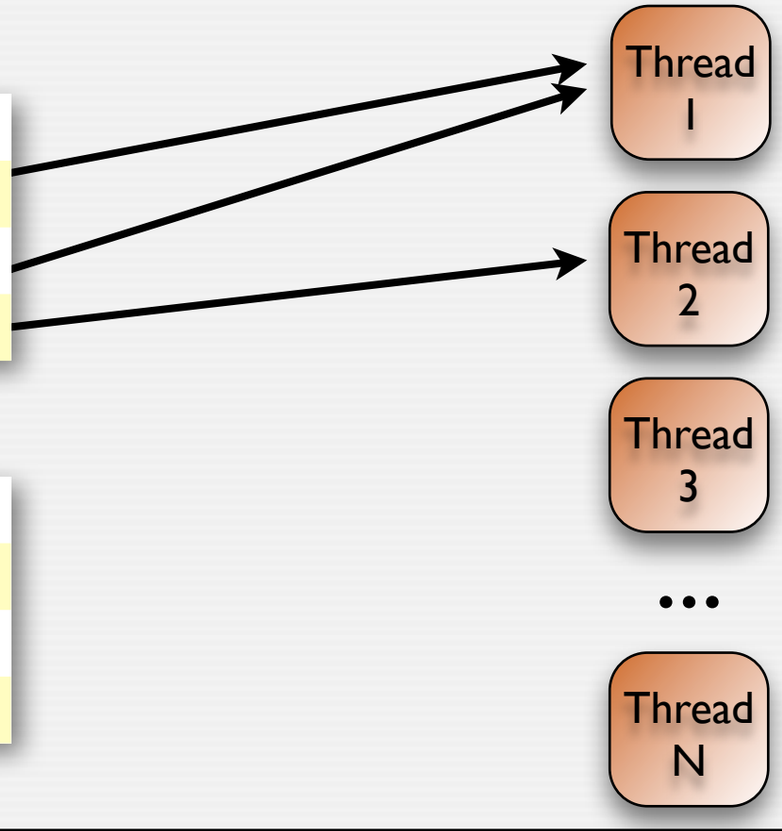

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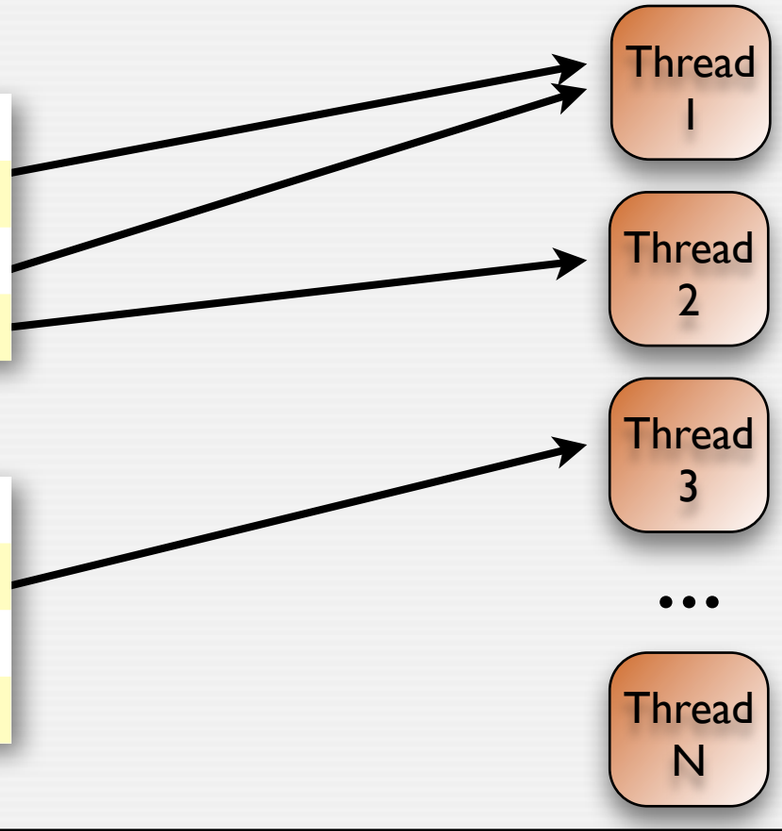

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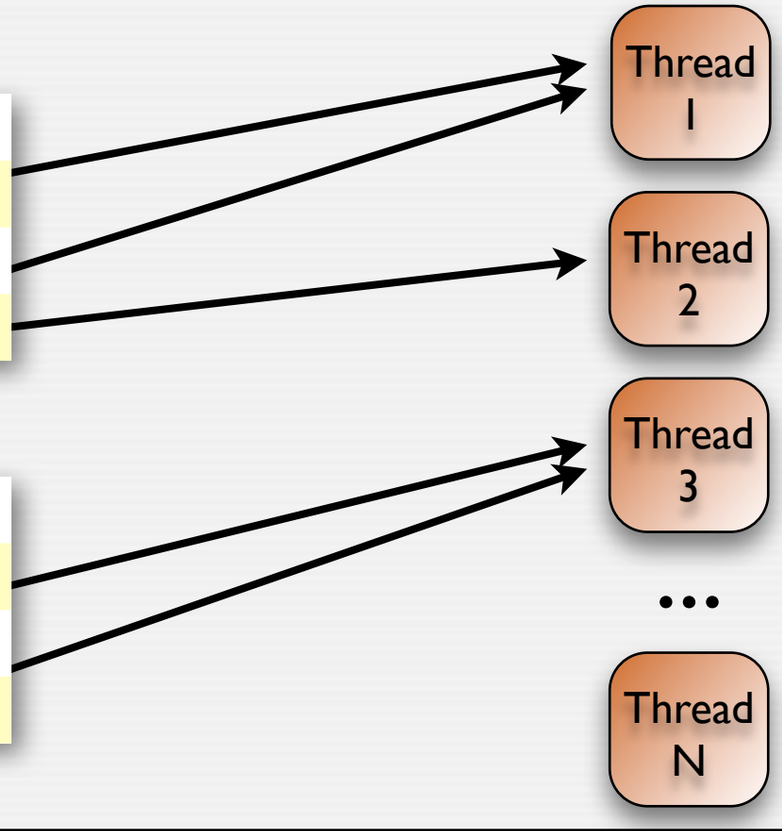

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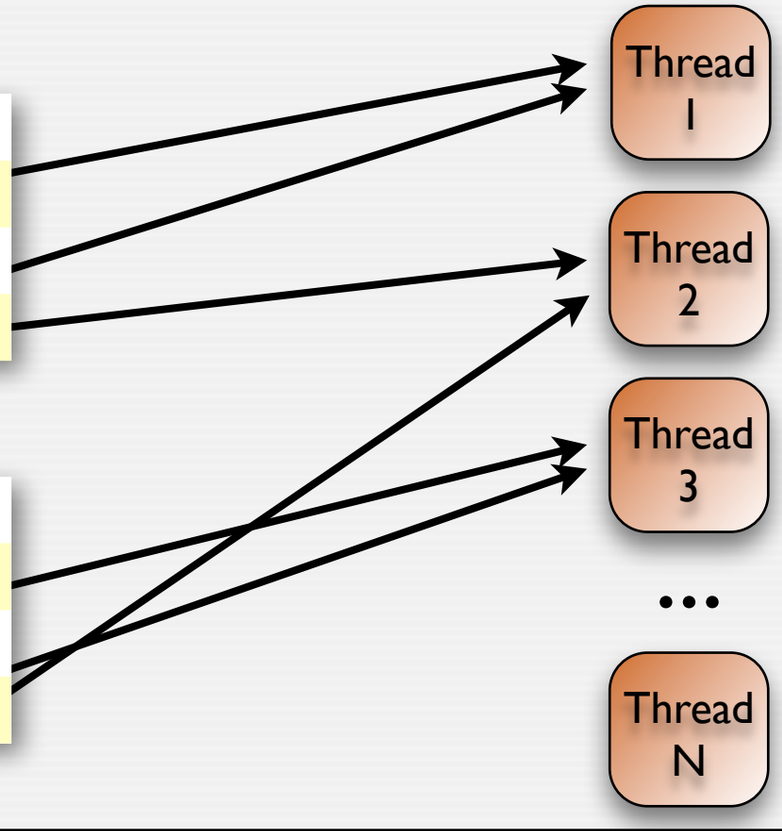
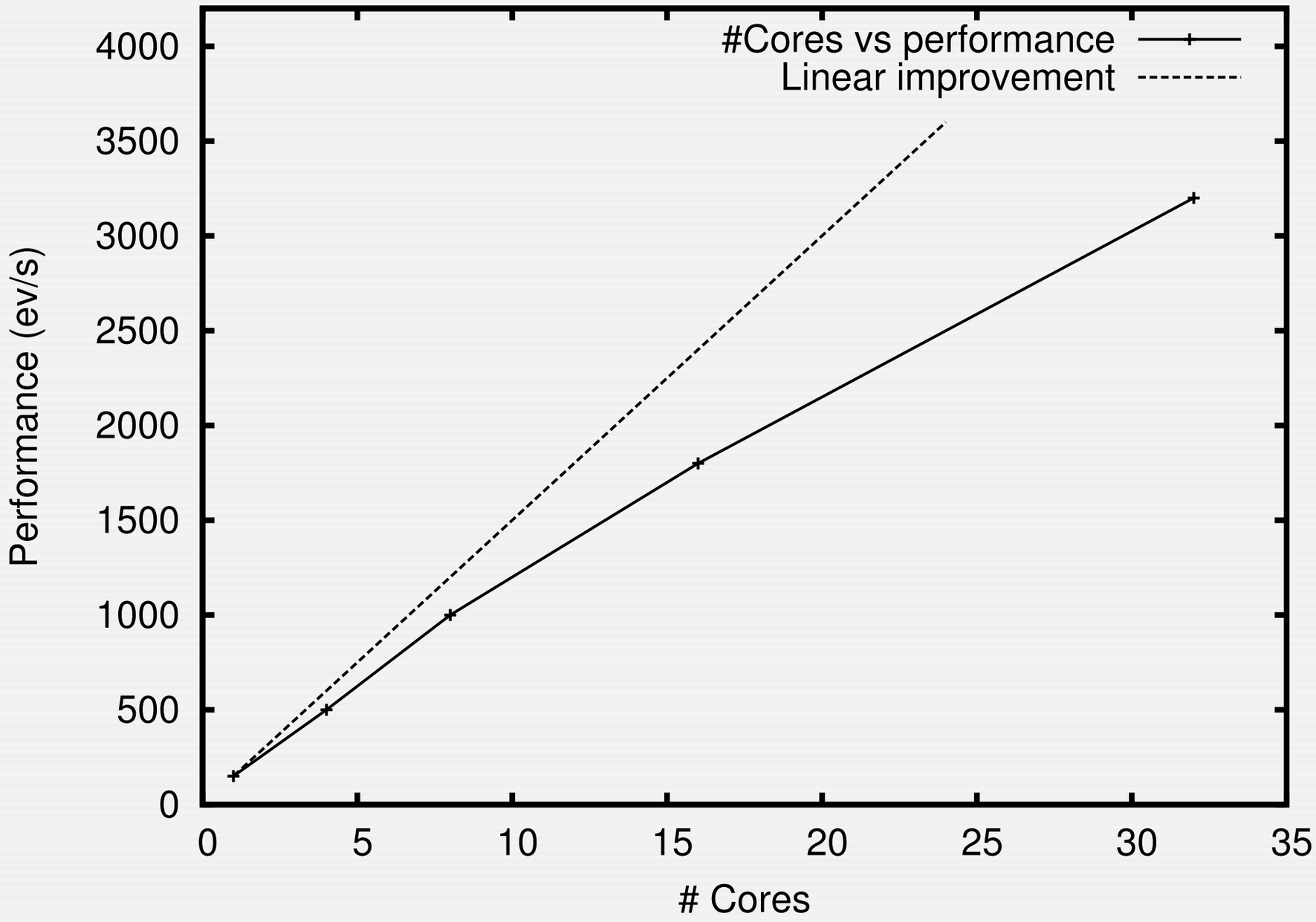
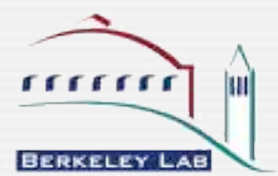


Simulation on Tilera CPU



15s of UC Berkeley campus TCP traffic, 1M event groups.
TileExpress-Pro20G, 64 cores (32 for simulation), 4GB RAM.

HILTI Prototype



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Built a prototype HILTI environment.

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Aiming for production-state compiler

- Performance currently limited.
- Needs engineering effort to address bottlenecks.

Bro: The Curse of Success

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NSF supports work through a 3-year *engineering* grant.

- Bro changed a lot over the last year.
- Collaboration with National Center for Supercomputing Applications.

Target: Blue Waters @ NCSA

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10 PF/s peak performance

>1 PF/s sustained on applications
>300,000 cores
>1 Petabyte memory
>10 Petabyte disk storage
>0.5 Exabyte archival storage

Hosted in 88,000-square-foot facility

Target: NCSA

Blue Waters Update—NCSA/IBM Joint Statement

Effective August 6, 2011, **IBM terminated its contract with the University of Illinois** to provide the supercomputer for the National Center for Supercomputing Applications' Blue Waters project.

NCSA is confident that its goal of building a sustained-petascale supercomputer remains achievable in a timely manner. **NCSA is coordinating with the National Science Foundation to ensure project continuity** and that the goals of the project are achieved.

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NCSA is already planning for 100 Gb/s as well.

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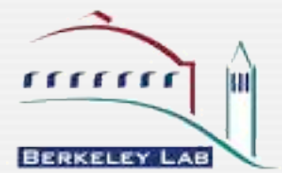
Making results usable costs additional effort.

- Lots of work that does not go into any research paper.
- Separate funding for such efforts can be extremely helpful.

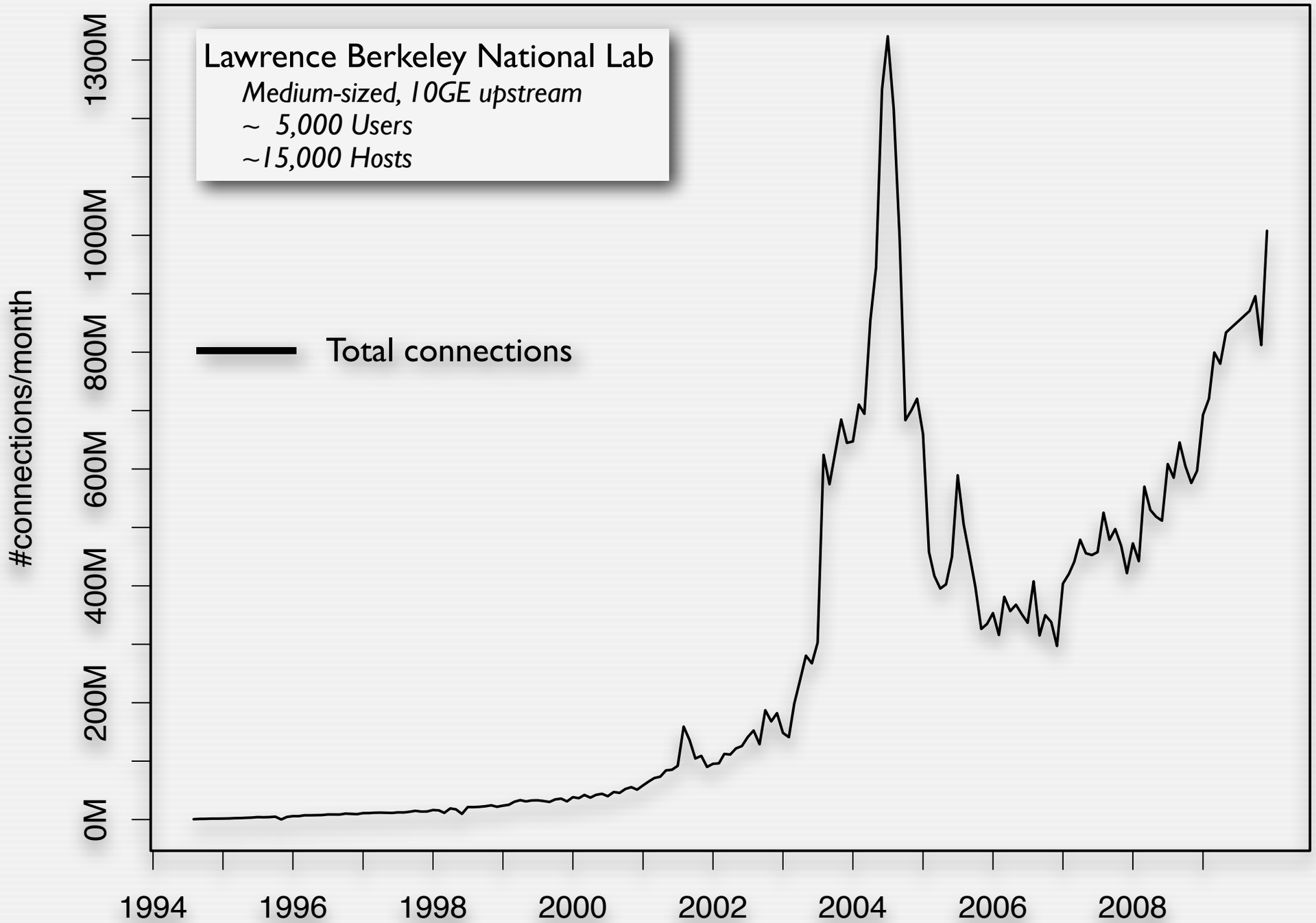
Thanks for your attention.

Robin Sommer
International Computer Science Institute, &
Lawrence Berkeley National Laboratory

robin@icsi.berkeley.edu
http://www.icir.org



Internet Traffic: Connections



Data: Lawrence Berkeley National Lab

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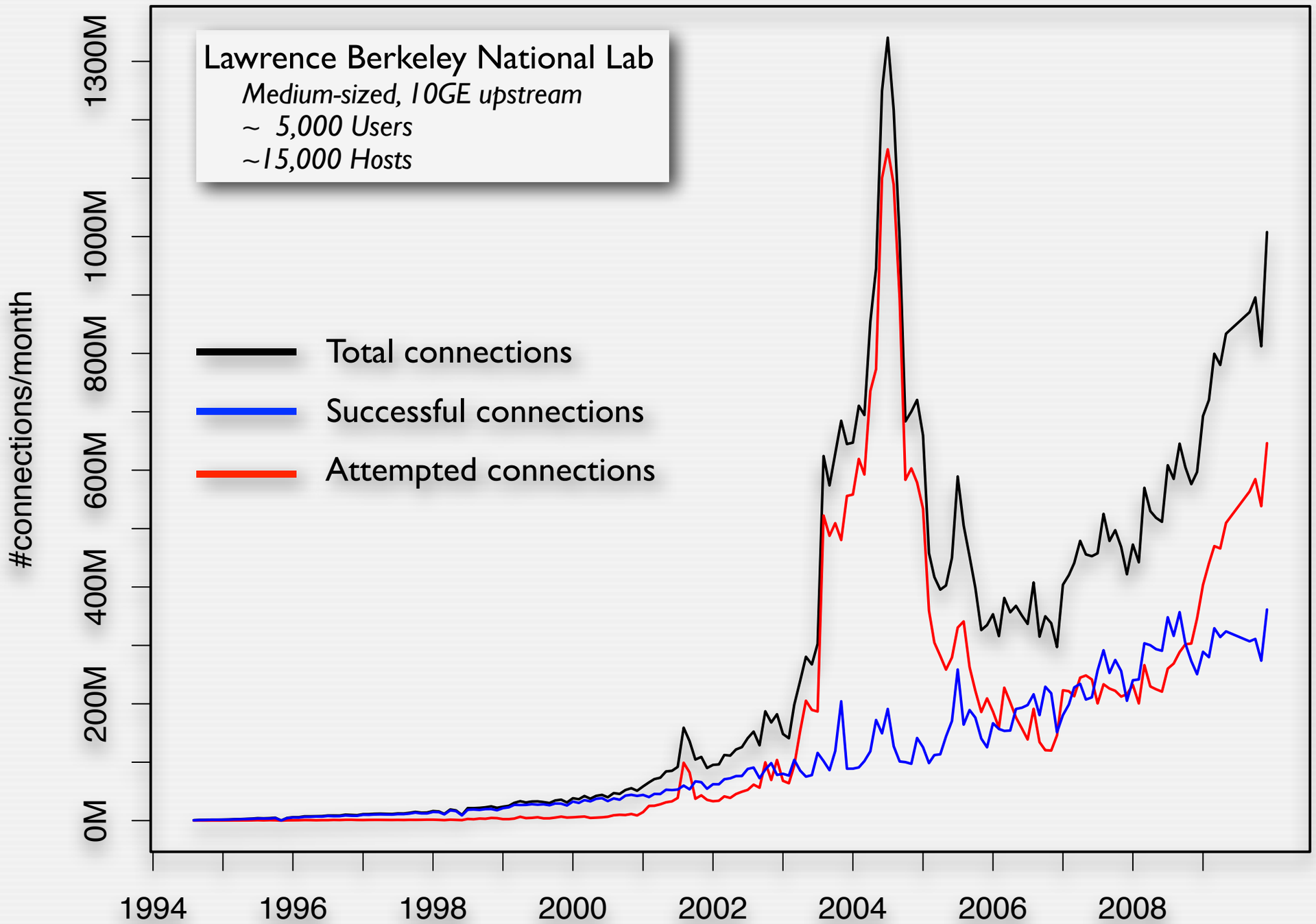

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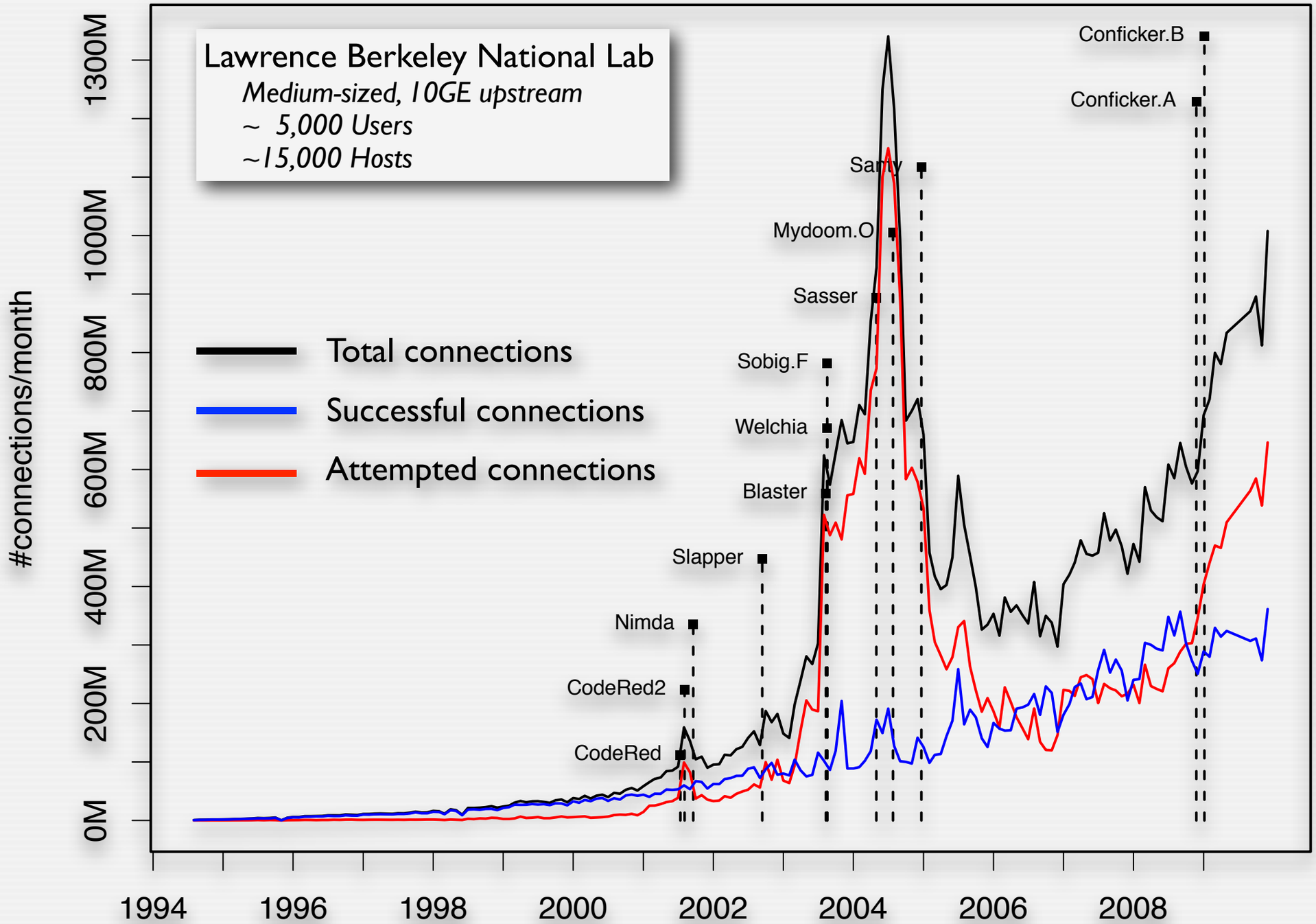

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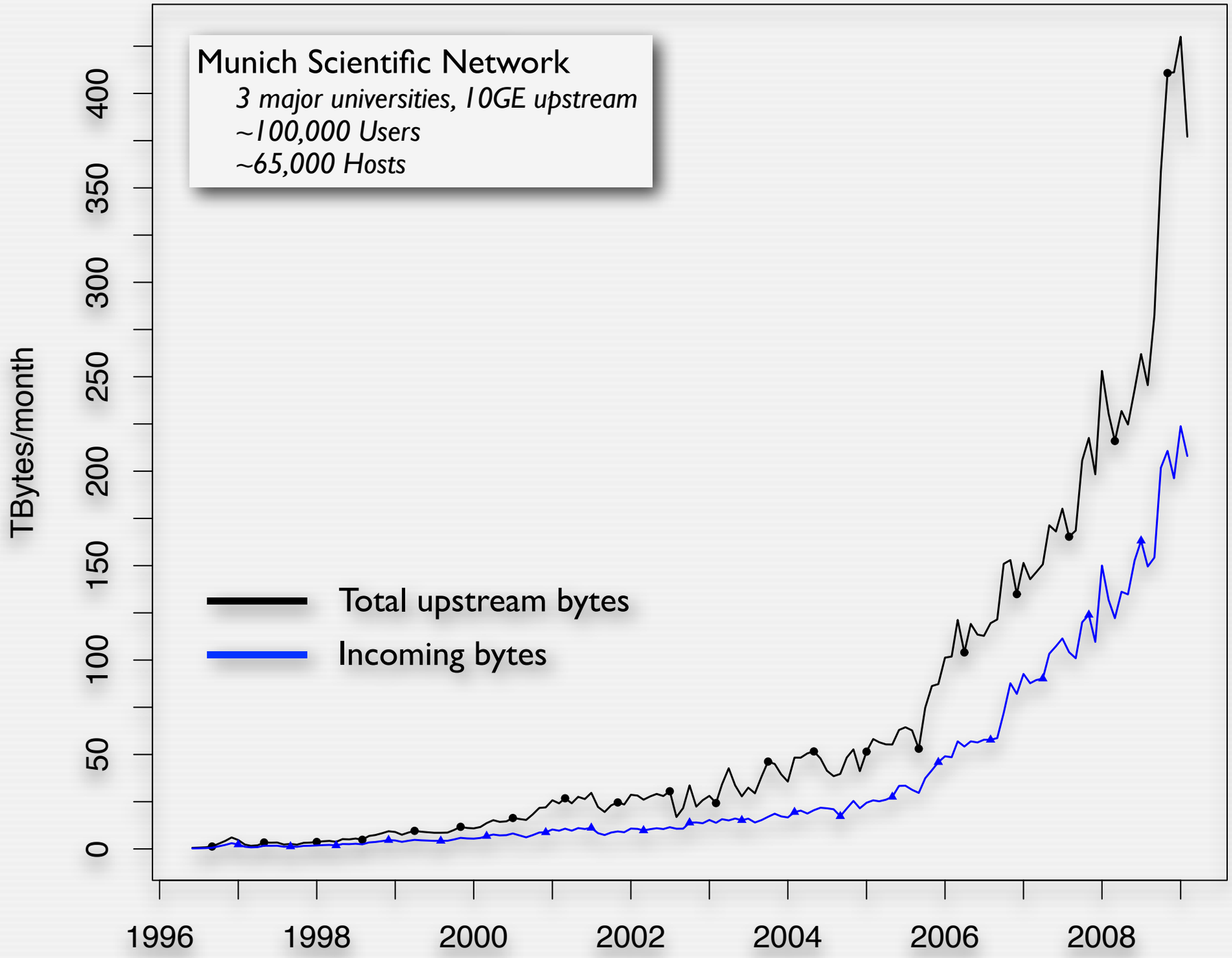
Development of Internet Traffic



Data: Leibniz-Rechenzentrum, München