Parallelizing Network Analysis

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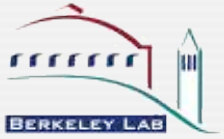
Motivation

- NIDSs have reached their limits on commodity hardware
  - Keep needing to do *more analysis* on *more data* at *higher speeds*
  - Analysis gets richer over timer, as attacks get more sophisticated
  - However, single CPU performance is not growing anymore the way it used to
  - Single NIDS instance (Snort, Bro) cannot cope with >=1Gbps links
- Key to overcome current limits is *parallel analysis*
  - Volume is high but composed of many *independent* task
  - Need to exploit parallelism to cope with load

Orthogonal Approaches

- The NIDS Cluster
  - Many PCs instead of one
  - Communication and central user interface creates the impression of one system
- Vision: Parallel operation within a single NIDS instance
  - In software: multi-threaded analysis on multi-CPU/multi-core systems
  - In hardware: compile analysis into a parallel execution model (e.g., on FPGAs)

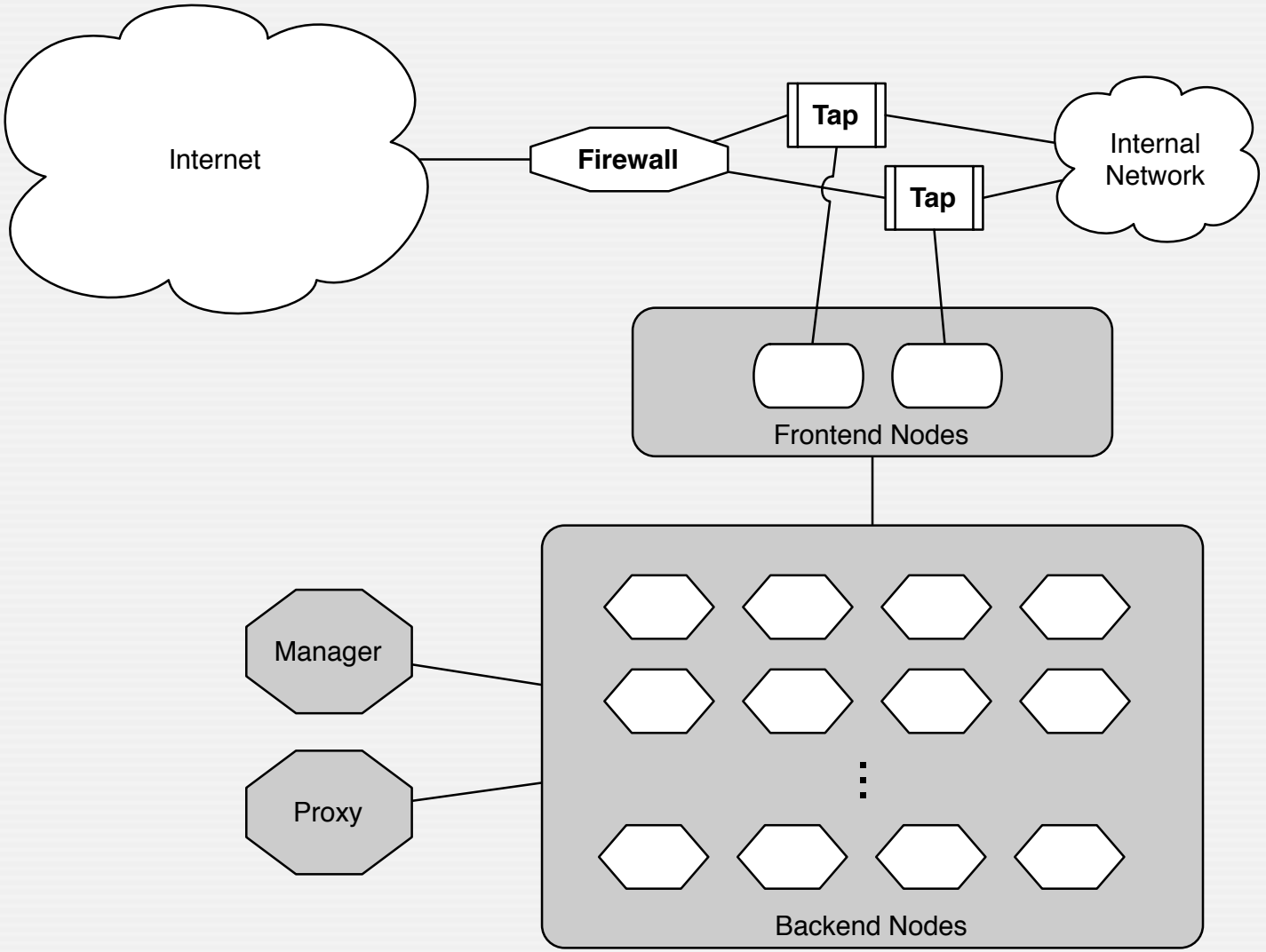
The NIDS Cluster



The NIDS Cluster

- Load-balancing approach: use many boxes instead of one
- Most NIDS provide support for multi-system setups
- However they work independent in operational setups
  - Central manager collects alerts of independent NIDS instances
  - Aggregates results instead of correlating analysis
- The NIDS cluster works *transparently* like a single NIDS
  - Gives same results as single NIDS would if it could analyze all traffic
  - No loss in detection accuracy
  - Scalable to large number of nodes
  - Single system for user interface (log aggregation, configuration changes)

Architecture



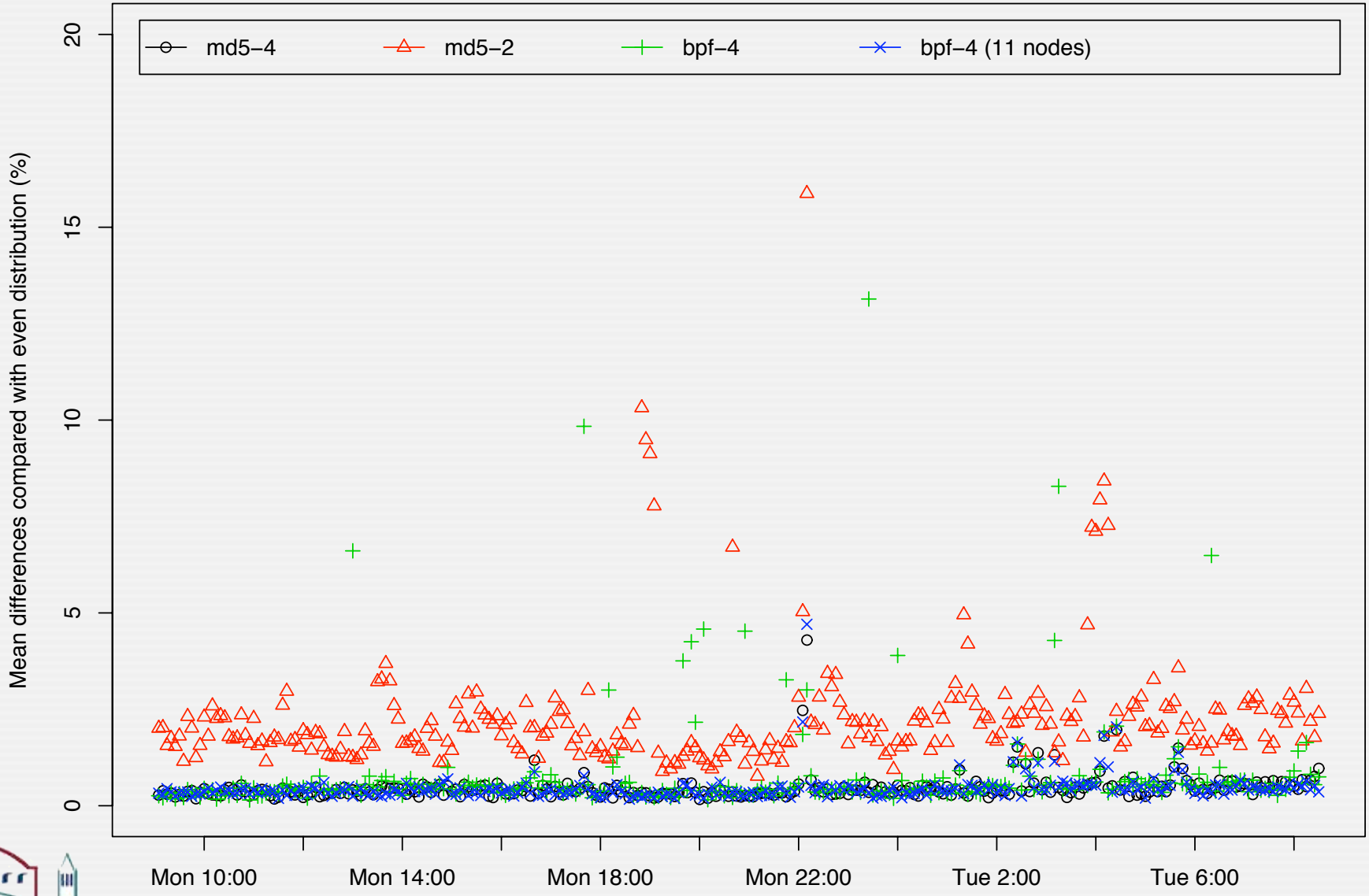
Prototype Setups

- Lawrence Berkeley National Laboratory
  - Monitors 10 Gbps upstream link
  - 1 front-end, 10 backends
- University of California, Berkeley
  - Monitors 2x1Gbps upstream links
  - 2 front-ends, 6 backends
- IEEE Supercomputing 2006
  - Conference's 1 Gbps backbone network
  - 100 Gbps *High Speed Bandwidth Challenge* network (partially)
- Goal: Replace current operational security monitoring

Front-Ends

- Distribute traffic to back-ends by rewriting MACs
  - In software via Click
  - In hardware via Force-10's P10 (prototype in collaboration with F10)
- Fault-tolerance
  - Easy to retarget traffic if a back-end node fails
- Per connection-hashing
  - Either 4-tuple (addrs,ports) or 2-tuple (addrs)
  - MD5 mod n, ADD mod n

Simulation of Hashing Schemes



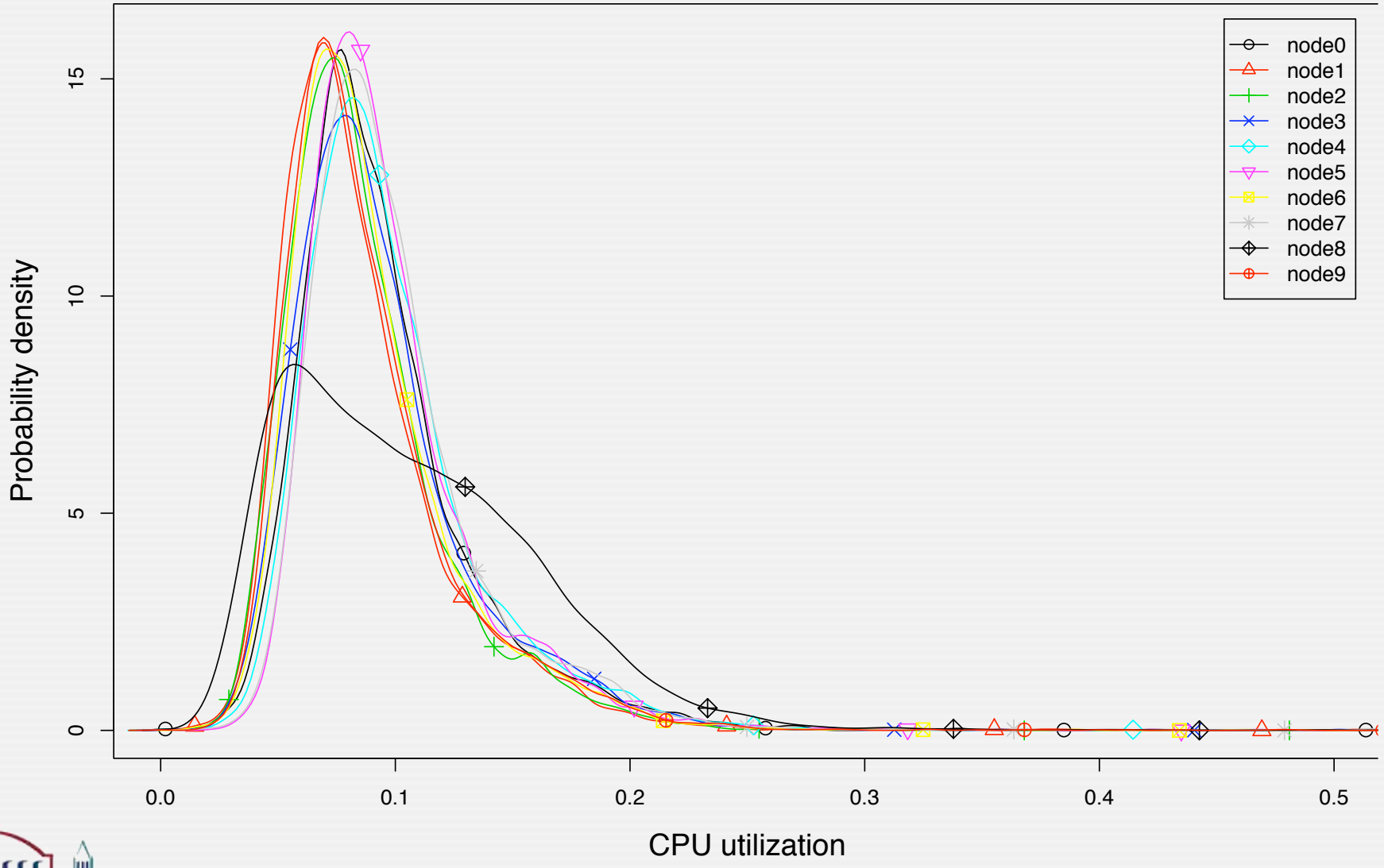
Back-ends

- Running Bro as their analysis engine
- Bro provides extensive communication facilities
  - Independent state framework
  - Sharing of *low-level* state
  - Script-layer variables can be *synchronized*
- Basic approach: pick state to be synchronized
  - A few subtleties needed to be solved
- Central manager
  - Collects output of all instances
  - Raises alerts
  - Provides dynamic reconfiguration facilities

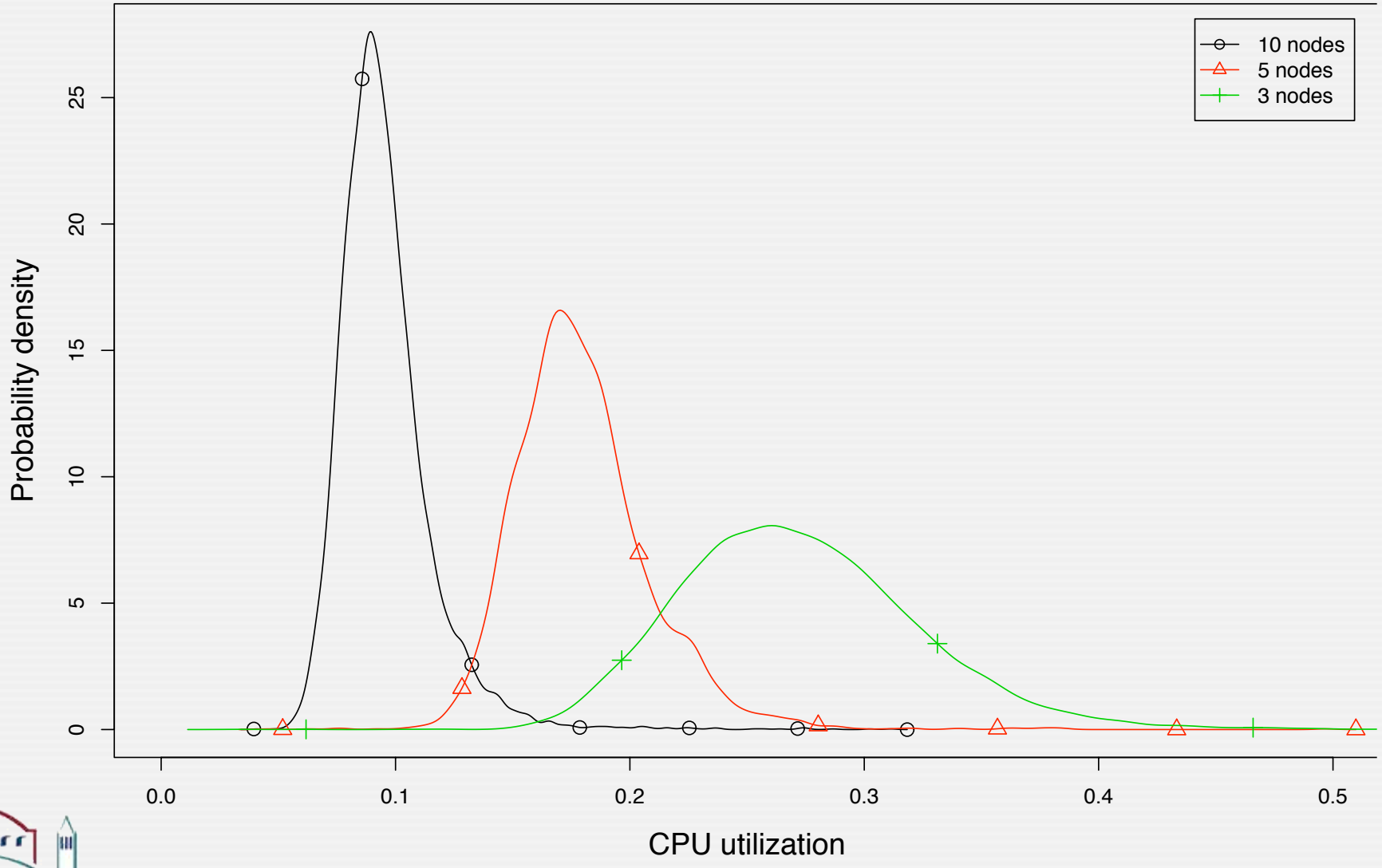
Evaluation & Outlook

- Prototypes are running nicely
  - Are able to perform analysis not possible before
  - E.g., full HTTP analysis & Dynamic Protocol Detection/Analysis
- Now in the process of making it production quality
- Evaluation
  - Verified accuracy by comparing against single Bro instance
  - Evaluated performance wrt load-balancing quality, scalability, overhead

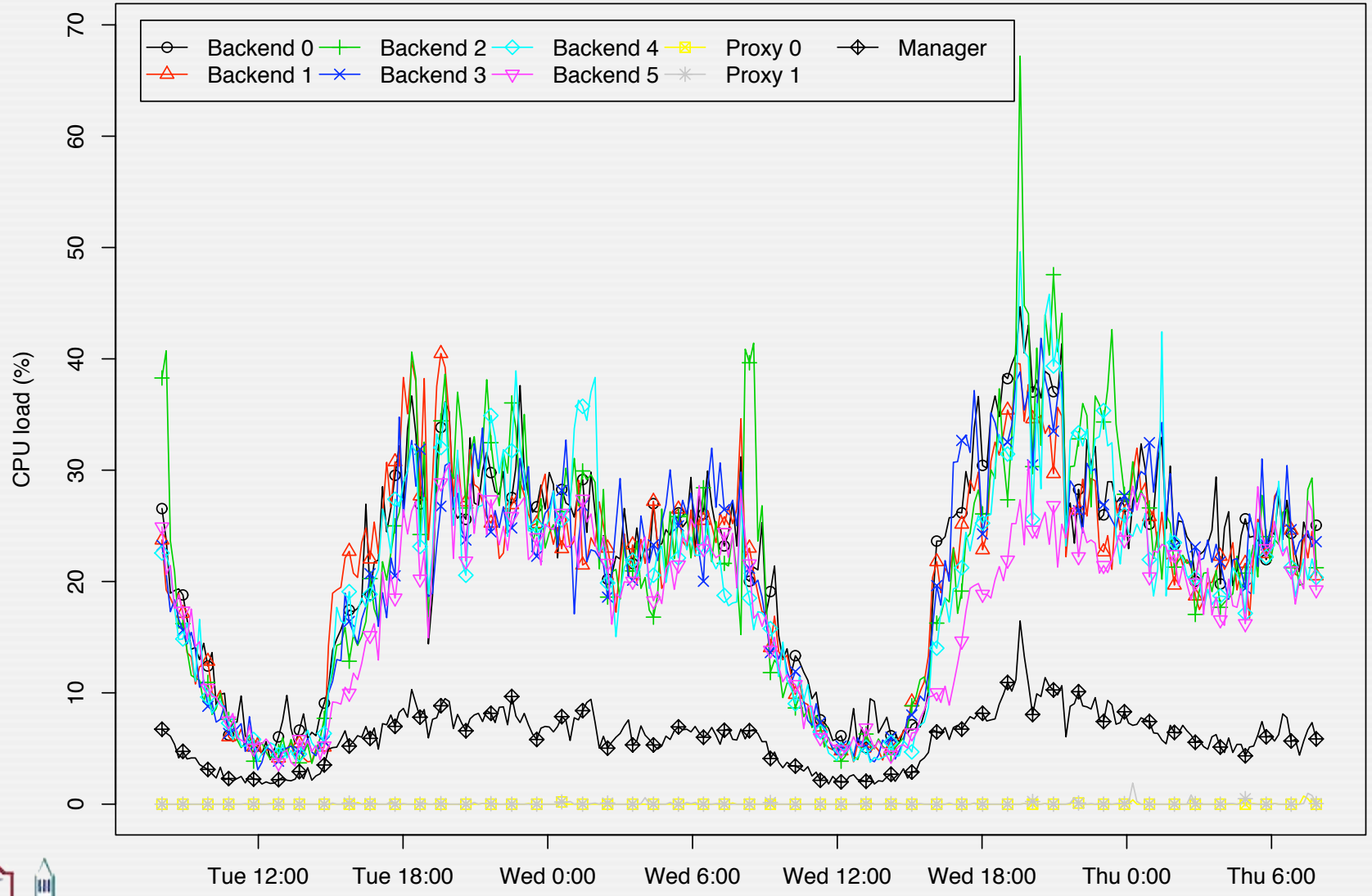
CPU Load per Node



Scaling of CPU



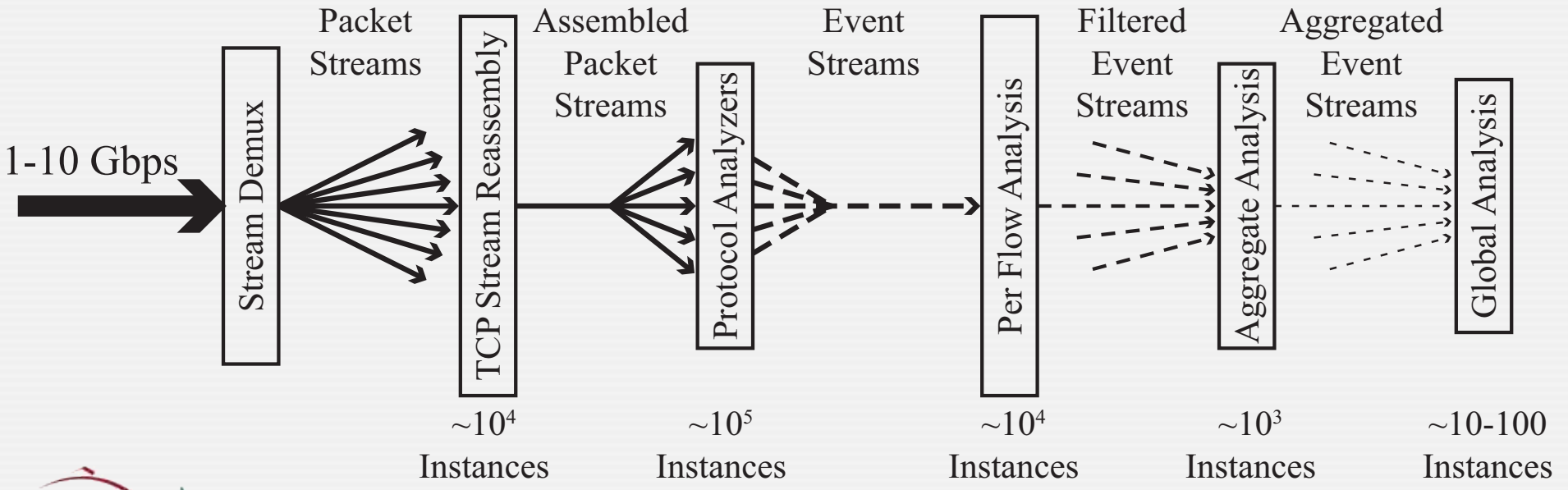
Load on Berkeley Campus



Parallelizing Analysis

Potential

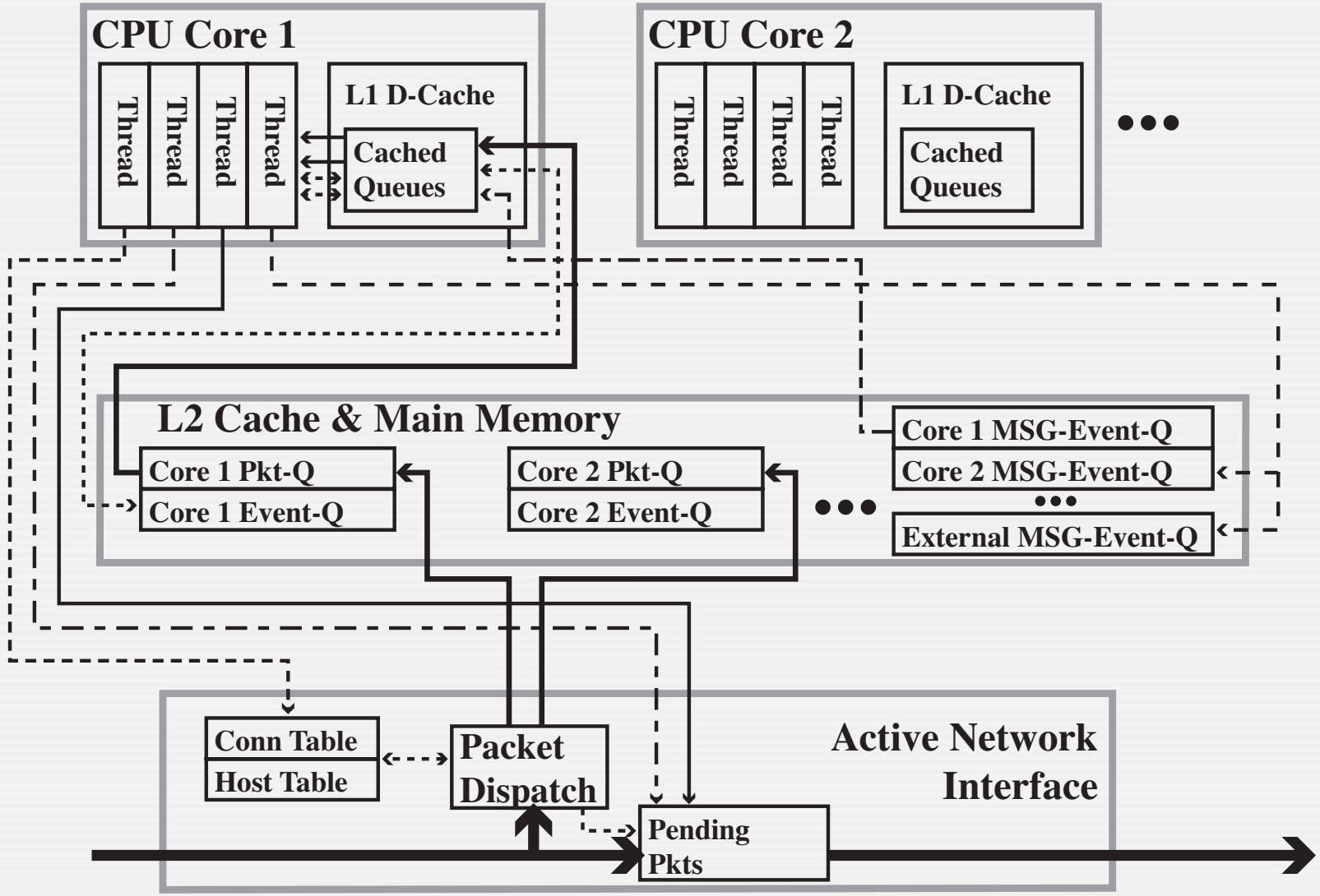
- Observation
  - Much of the processing of a typical NIDS instance can be done in parallel
  - However, existing systems do not exploit the potential
- Example: Bro NIDS
  - Assume Gbps network with 10,000 concurrent connections



Commodity Hardware

- Multi-thread/multi-core CPU provide necessary power
  - Inexpensive commodity hardware
  - *Aggregated* throughput does in fact still follow Moore's law
- Need to structure applications in highly parallel fashion
  - Do not get the performance gain out of the box
  - Need to tructure processing into separate low-level threads
- Need to address
  - Intrusion *prevention* functionality
  - Exchange of state between threads for global analysis
  - Yet minimize inter-thread communication
  - Factor in memory locality (within one core / across several cores)
  - Provide performance *debugging* tools

Proposed Architecture

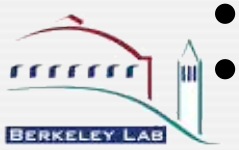


Active Network Interface

- Only non-commodity components currently
  - Prototype to be based on NetFPGA platform ($2000)
  - Commodity hardware might actually be suitable later
    (E.g., Sun's Niagara 2 has 8 CPU cores plus 2 directly attached 10GE controller!)
- Thread-aware Routing
  - ANI copies packet directly into thread's memory (cache)
  - ANI keeps per-flow table of routing decisions
  - Dispatcher thread takes initial routing decision per flow
- Selective packet forwarding
  - ANI holds packets until it gets the clearance (might use caching per e.g. flow/ip)
- Normalization

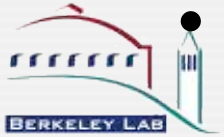
Parallelized Network Analysis

- Architecturally-aware Threading
  - Need to identify the right granularity for threads
  - Protocol analysis consists of fixed blocks of functionality
  - Event processing needs to preserve *temporal* order
    → Multiple independent event queues (e.g., one per core)
- Scalable Inter-thread Communication
  - Can use shared memory
  - Need to consider nonuniformities in system's cache hierarchy
  - Potentially restructure detection algorithms to minimize communication (e.g., loosing semantics via probabilistic algorithms)
- Prevention Functionality
  - Only forward packet once all events are processed
- Evaluation, profiling & debugging
  - Race conditions & memory access patterns
  - Trace-based reproducability



Going Further: Custom Hardware

- Goal: *custom platform for highly parallel, stateful network analysis*
- Custom hardware (e.g., FPGAs) is ideal for parallel tasks
- Expose the parallelism and map it to hardware
- We can identify three types of functionality in Bro
  - Fixed function blocks →Handcraft (e.g., robust reassembly)
  - Protocol analyzers → Use BinPAC with new backend
  - Policy scripts → Compile into parallell computation model
- Envision using MIT's *Transactor* model
  - Many small self-contained units communicating via message queues
- Ambitious but highly promising
  - Generic network analysis beyond network intrusion detection



Thanks for your attention.

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