Performance Forecasting: Finding bottlenecks before they happen

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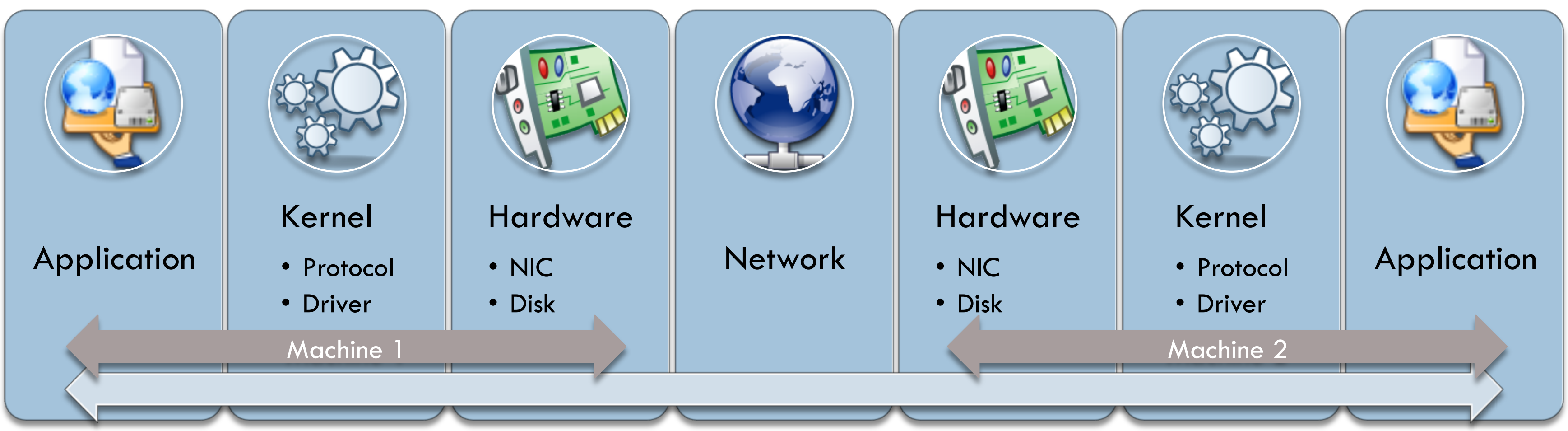
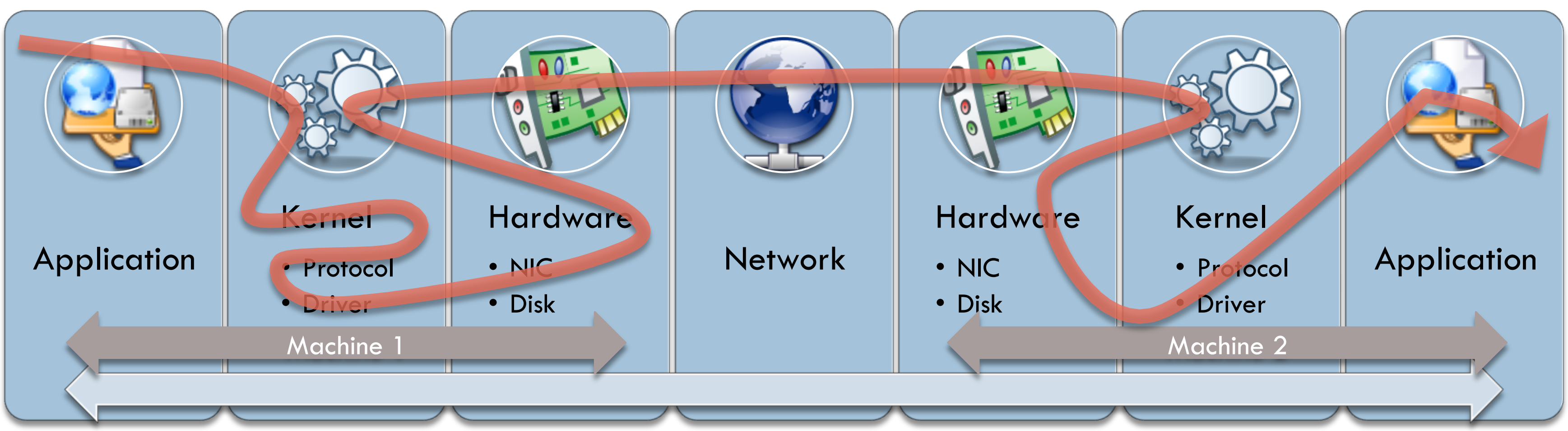
Performance Analysis Challenge

- Today's workloads & systems are complex
  - Many layers of HW (disk, network), SW (app, OS)
- How to evaluate systems in design stage?
  - Where are the bottlenecks?
- Conventional tools inadequate



Solution: Global Critical Path

- Directly identifies true bottlenecks
  - Accounts for overlapped latencies
- Used successfully in past in isolated domains
  - Fields et al. → out-of-order CPU
  - Barford and Crovella→ TCP
  - Yang and Miller → MPI



Building a Global Critical Path

- Requires global event dependence graph

Challenge:
typically requires detailed knowledge
across many domains!

Solution:
automatically extract dependence graph
from interacting state machines

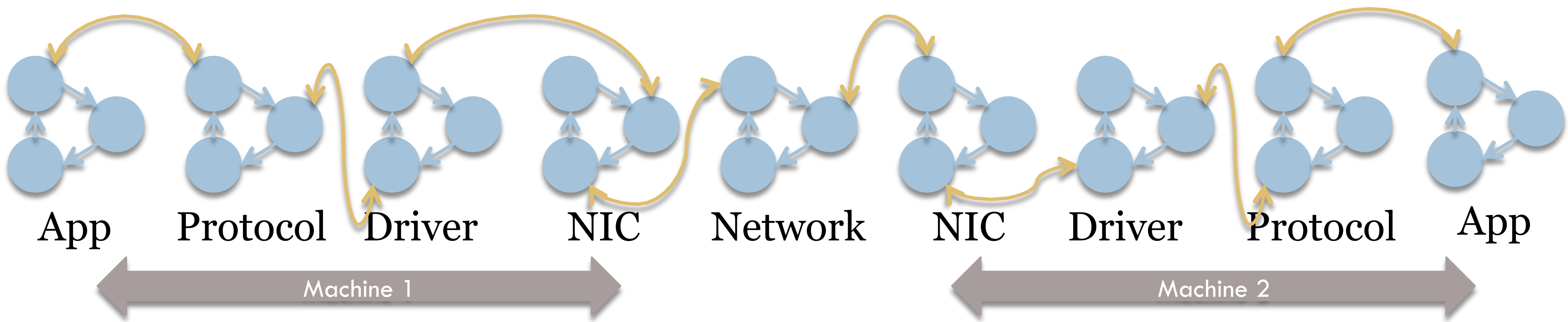
End Result

- Our simulation technique directly identifies:
  - The current bottleneck
  - How much improvement until next bottleneck
  - What the next bottleneck will be
- Conventional simulation approach:
  - Hypothesize bottleneck
  - Prototype solution
  - Simulate solution
  - Test hypothesis, repeat if incorrect

MINUTES

HOURS / DAYS

Constructing a Dependence Graph



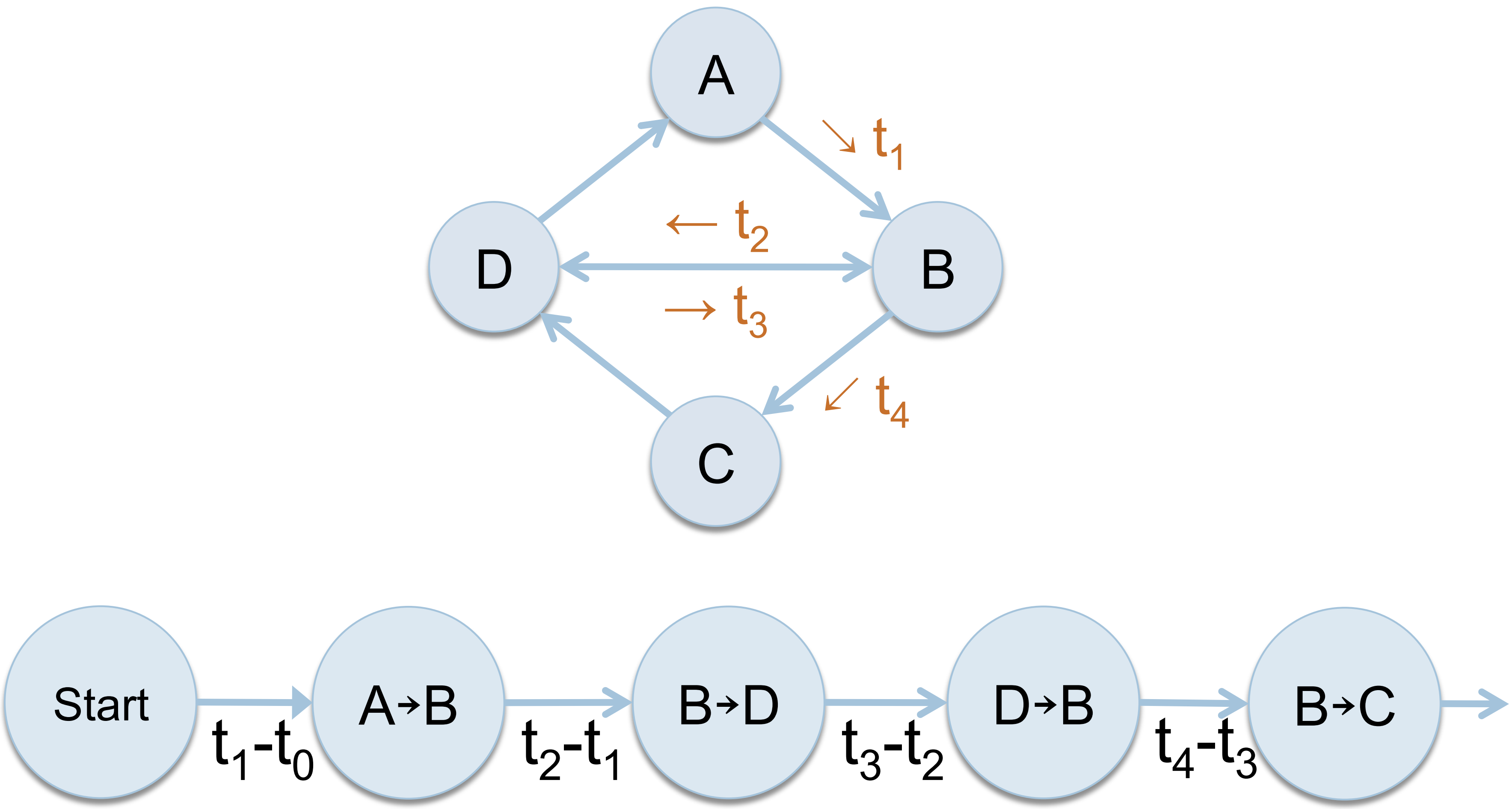
- Systematically map state machines into a global dependence graph
  - Most HW is already specified as a state machines
  - Extract implicit state machines from SW

Explicit State Machine Conversion

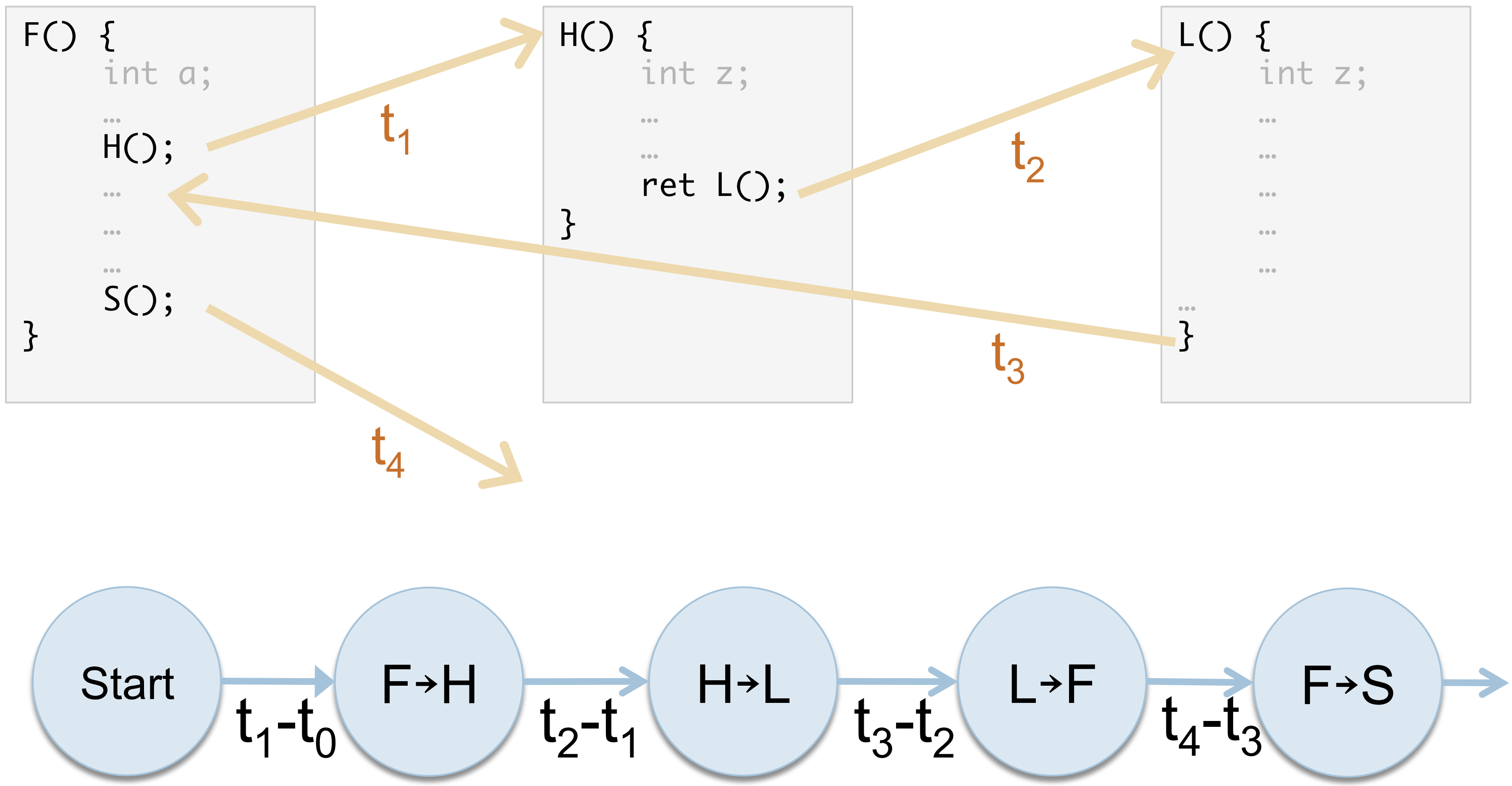
State Machine	Dependence Graph
Edges →	Nodes
Nodes →	Edges

dependence edge weight =
time spent in state

Explicit State Machine Conversion



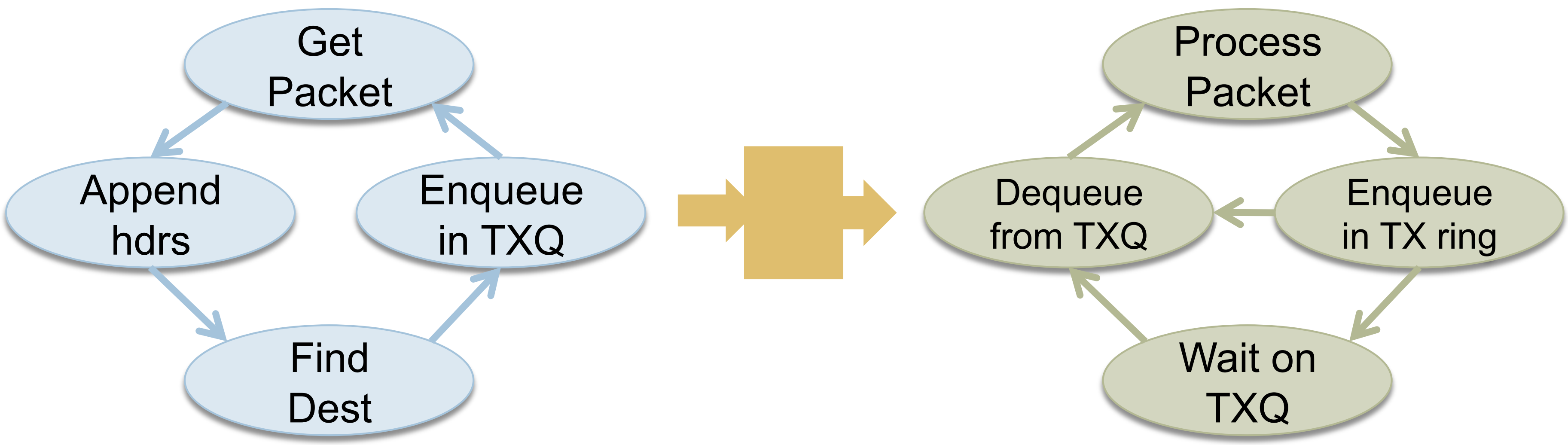
What about software?



State Machine Interactions

- Link up piece of dependence graph through these interactions
- Queues are interaction points
  - Without them back pressure can’t be modeled
  - Abstract entities
- Annotated in models and code
  - Developed iteratively
  - Analysis can pinpoint problems

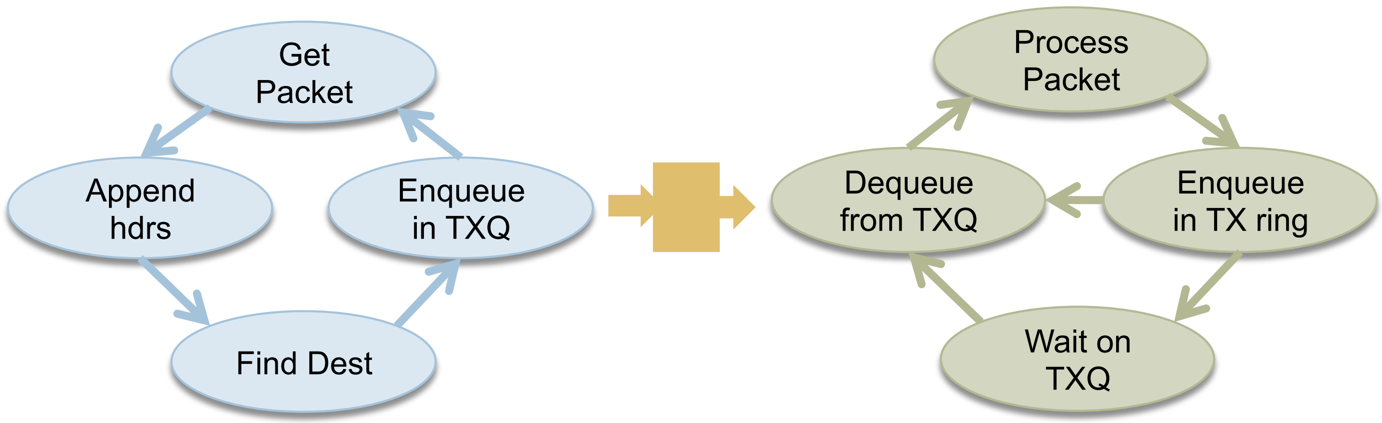
Interaction Example



Simplified IP stack state machine

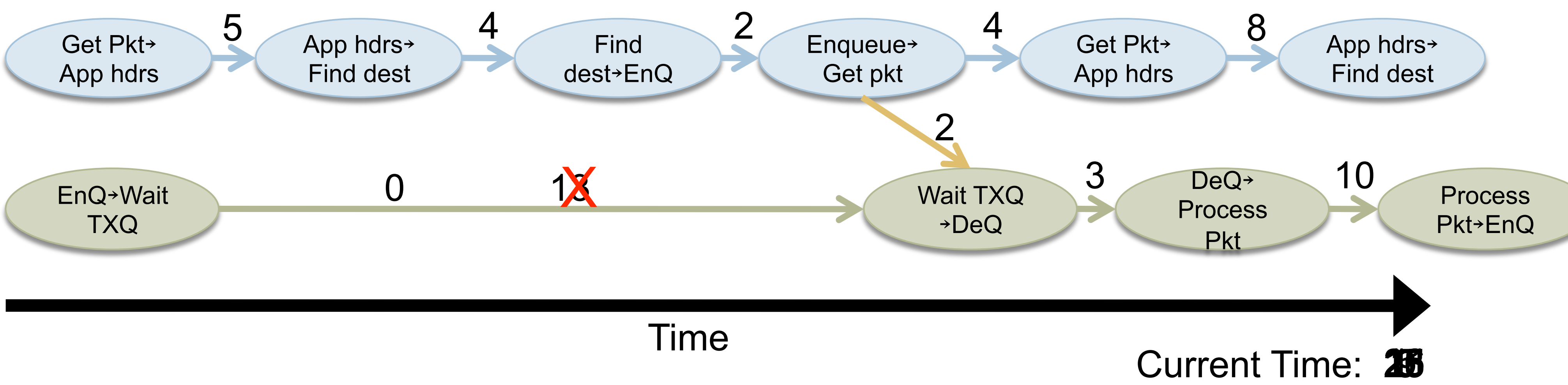
Simplified TX NIC driver state machine

Interaction Example



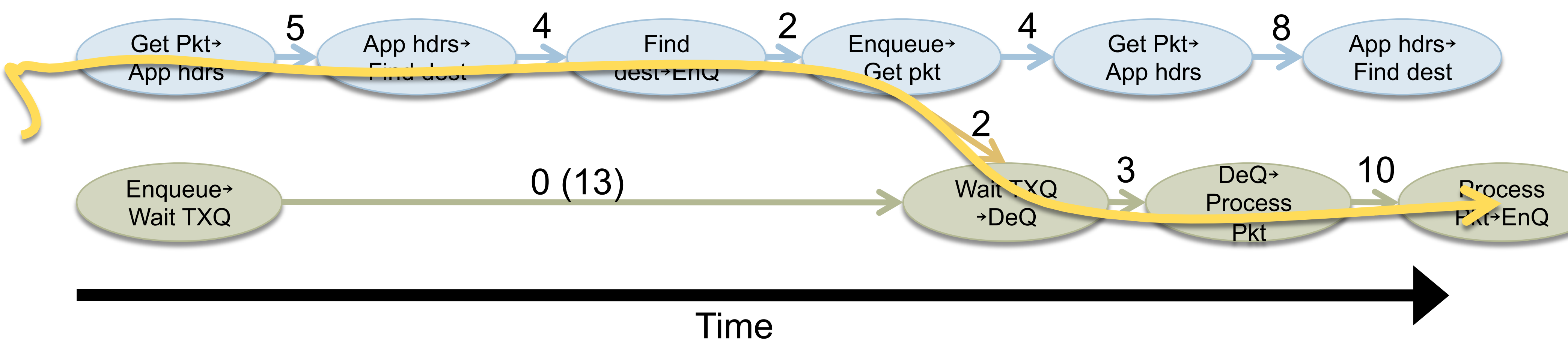
Simplified IP stack state machine

Simplified TX NIC driver state machine



Finding Global Critical Path

- Use standard graph analysis techniques
- Locate longest path through the graph



Critical States & Predicting Speedup

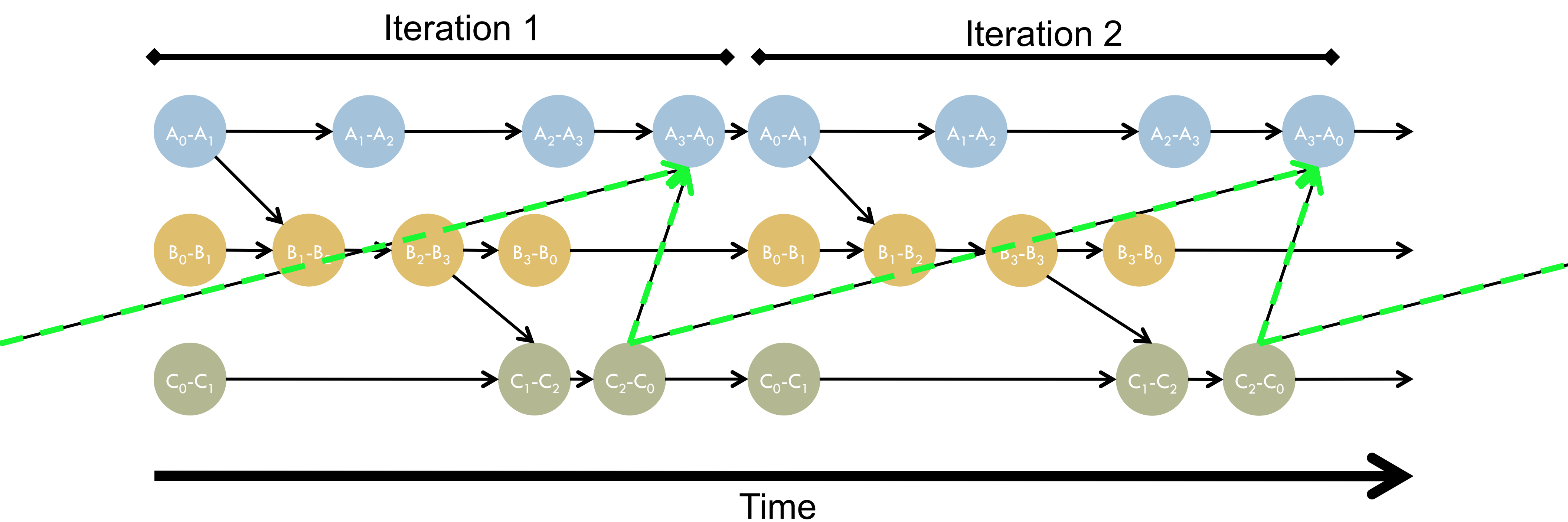
- Aggregate states on critical path
  - Most frequent state is the bottleneck
- Dependence graph contains all transitions and interactions
  - Not just the ones that compose critical path or where waiting occurred
- Modify weights on the critical path
  - Re-analyze data to see how critical path changes
  - Next critical path length → potential speedup

Resource Dependence Loops

- Critical path can sometimes be improved without reducing latency of any tasks
- In resource constrained environments critical path can be shorted by providing more resources

Resource Dependence Loops

- Analysis automatically find candidates
- Addition of buffering changes critical path



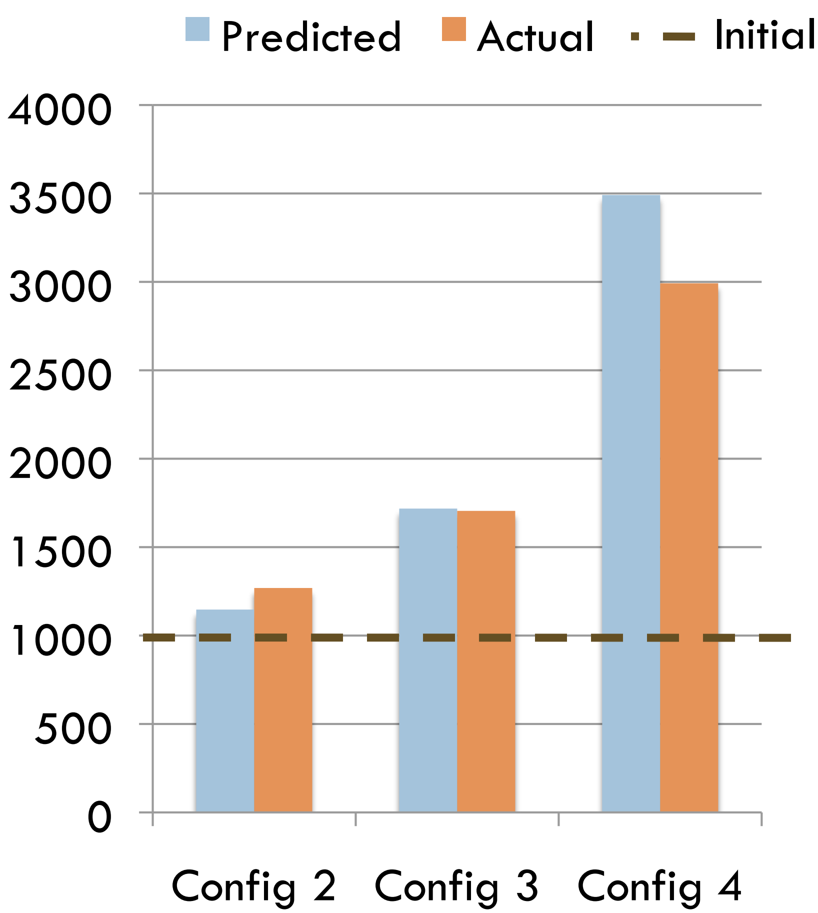
Workloads

- Linux 2.6.18
- SinkGen – Streaming benchmark from CERN
  - Analyzed the transmit side
- Lighttpd – High-performance web server
  - Uses non-blocking I/O to manage connections
  - Used by large websites
- Metric is bandwidth achieved

TCP Transmit

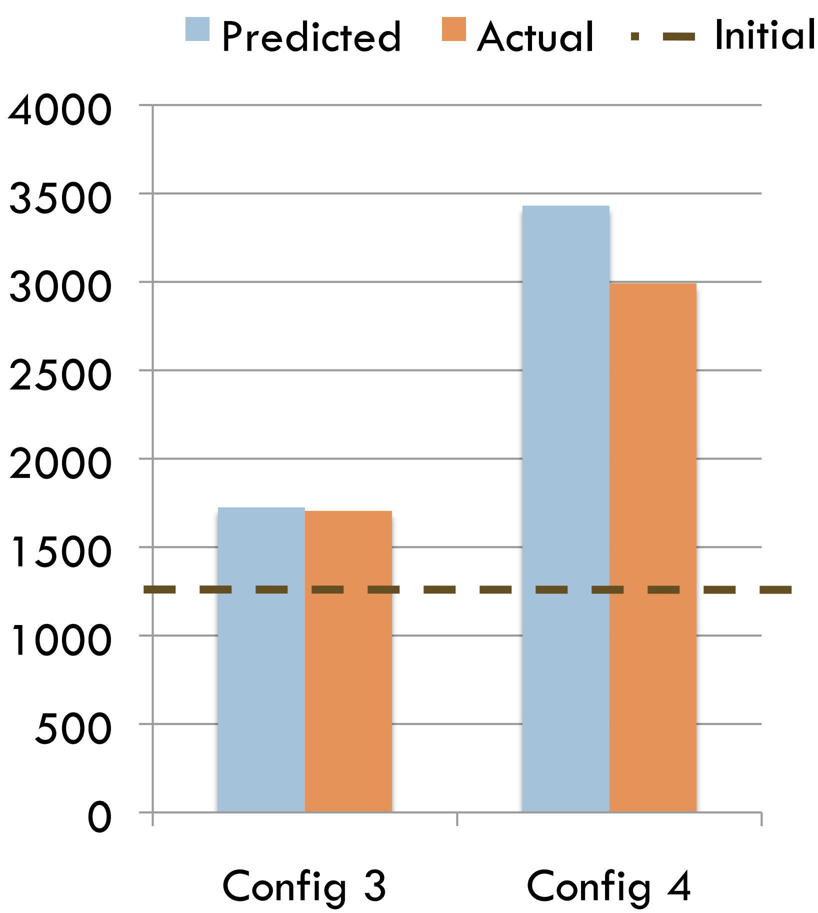
- Start with default M5 system parameters
  1. Capture bottleneck data from that system
  2. Locate current bottleneck
  3. Predict performance when bottleneck is removed
  4. Repeat steps 2 and 3 for successive bottlenecks
  5. Verify that the locations and predictions are correct

TCP Streaming Benchmark



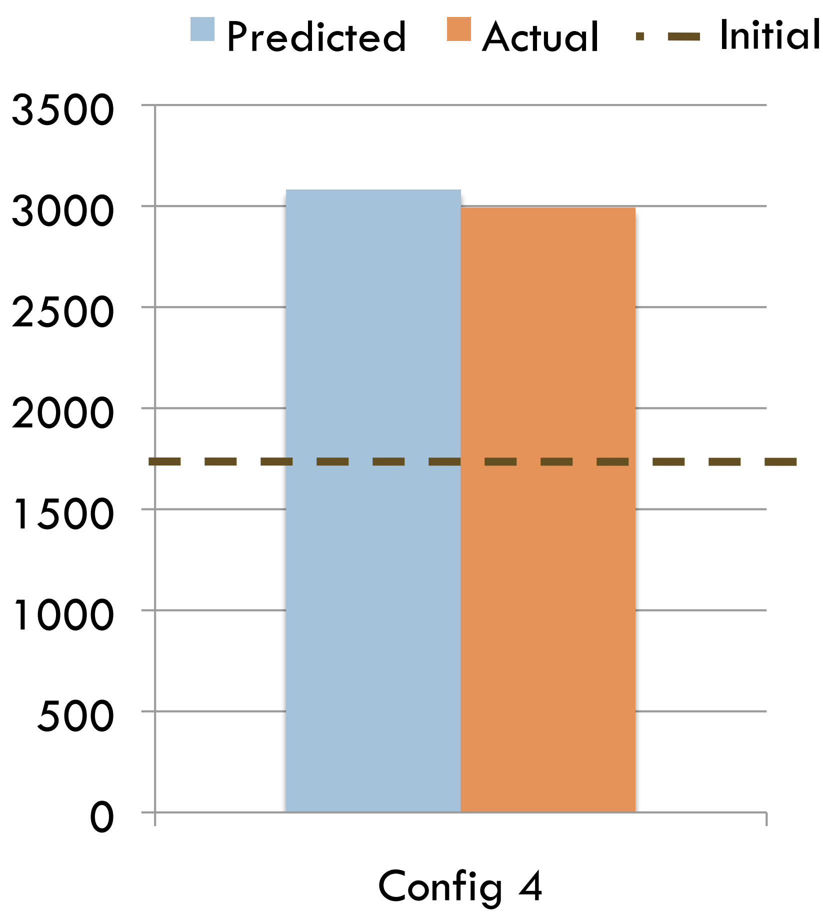
- How did we do?
  - Run experiments making the above suggested changes

TCP Streaming Benchmark



- Predict performance again, this time starting with configuration 2
  - Config 3: 1%
  - Config 4: 15%

TCP Streaming Benchmark



- Predict performance one last time, starting with configuration 3
  - 3% error

Experiments and Errors

- Additional experiments are in the paper
  - Multi-core speed up of web server
- Describe why errors occurred
  - Compare modified dependence graph to observed graph from new simulation

Conclusion

- Architects are increasing looking at system-level issues for performance
- Apply critical path analysis to complete systems composed of concurrent components
  - Span multiple layers of HW &SW
  - Automate extraction of dependence graphs
- Identify end-to-end bottlenecks in network systems
  - Critical tasks
  - Resource dependence loops
  - Performance of hypothetical systems
  - Minutes not hours

Questions?