Lock Inference for Systems Software

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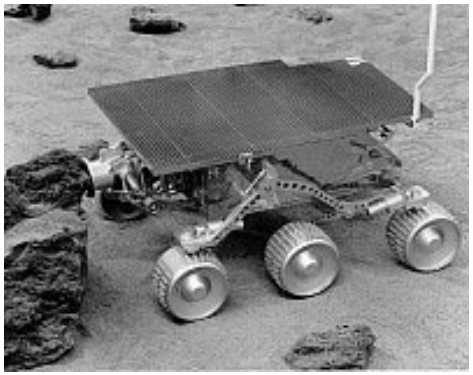
March 17, 2003

Embedded Systems

- **Properties:**
  - **Important**
  - **Resource constrained**
  - **Evolve significantly**
  - **Contain multiple execution environments**



Execution Environments

- Sets of
  - Idioms and abstractions for structuring software
  - Rules for sequencing actions
  - Rules for sharing information
- Examples
  - Low-level: Cyclic executive, interrupts, threads, event loop
  - High-level: Dataflow graph, time triggered system, hierarchical state machines

Diversity in Execution Environments is…

- **Good:**
  - **Diversity can be exploited**
    - **To create efficient systems**
    - **To match design problems**
- **Bad:**
  - **Environments have rules**
  - **Interacting environments have rules**

Concurrency

- **Embedded software is fundamentally concurrent**
  - **Interrupt driven**
  - **Response time requirements**
- **Critical sections are a functional aspect**
  - **But choice of lock implementation can be a non-functional aspect**

Task Scheduler Logic (TSL)

- Formalizes locking concerns across execution environments
  - Currently unchecked
- Finds races and other errors
- Generates mapping from each critical section in a system to an appropriate lock
  - Lock inference

Why Infer Locks?

- Locking rules are hard to learn, hard to get right
- Sometimes no lock is needed
- Components can be agnostic with respect to execution environments
- Global side effects can be managed

TSL Concepts

- Tasks – units of computation
- Asymmetric preemption
  - A « B means “B may preempt A”
- Schedulers
  - S ◄ B means “S schedules B”
- Locks
  - S ↵ L means “S provides L”
  - A «$_L$ B means “B may preempt A while A holds L”

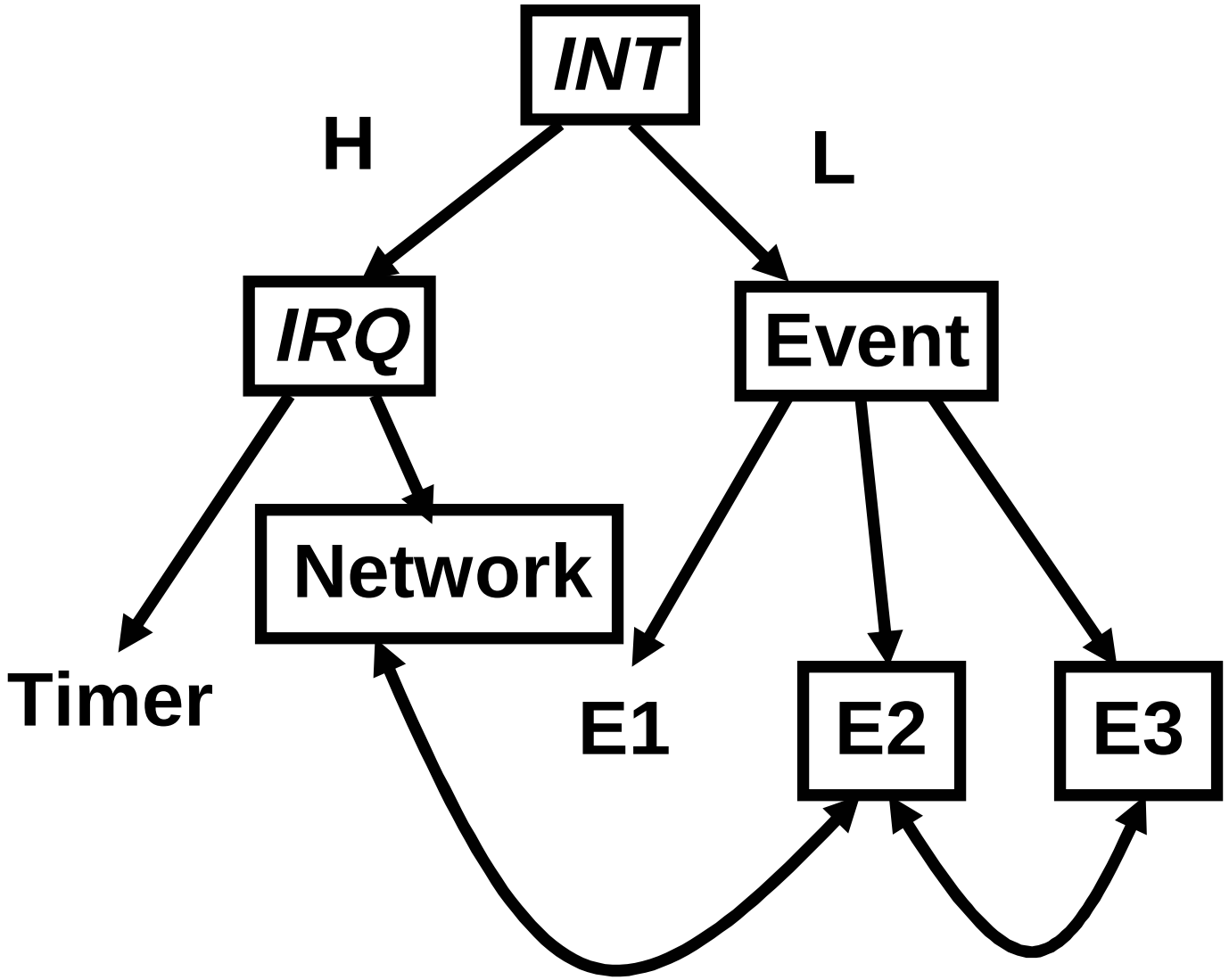
Resources and Races

- **Resources**
  - **$A \rightarrow_L R$ means "A holds L while accessing R"**
- **Race (A, B, R) = $A \rightarrow_{L1} R$**

  $\wedge$ $B \rightarrow_{L2} R$

  $\wedge$ $A \neq B$

  $\wedge$ $A \ll_{L1 \cap L2} B$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Event
Network
Timer
E1
E2
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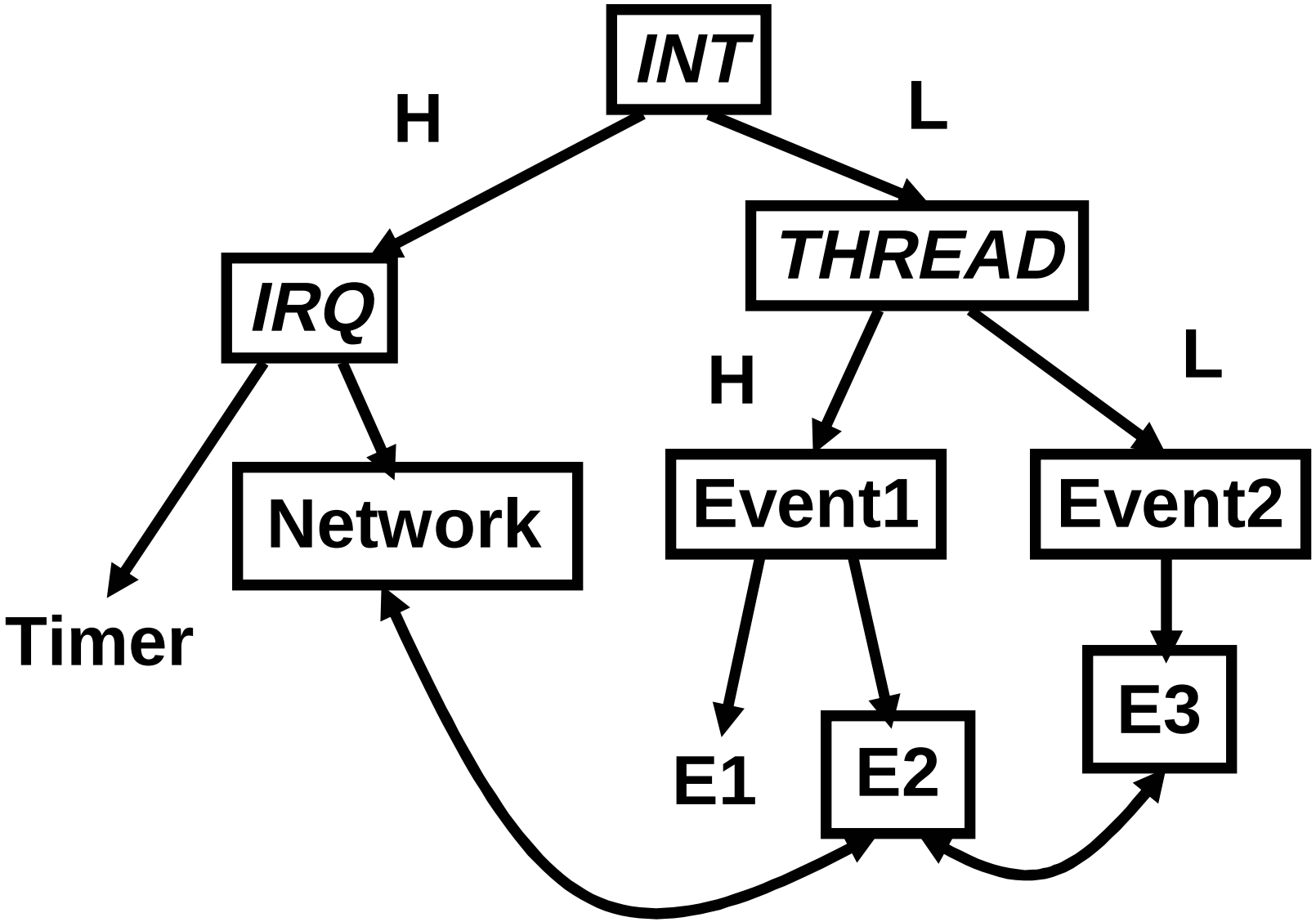
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Applying TSL

- **Applied to embedded monitoring system with web interface**
  - **116 components**
  - **1059 functions**
  - **5 tasks**
  - **2 kinds of locks + null lock**

Summary

- **Contributions**
  - **Reasoning about concurrency across execution environments**
  - **Automated lock inference**
- **Future work: Optimal lock inference**
  - **Minimize run-time overhead**
  - **Maximize chances of meeting real-time deadlines**

More info and papers here:

http://www.cs.utah.edu/~regehr/