15-410

"Delayed Impact"

Scheduling on Mars
Mar. 15, 2004

Dave Eckhardt

Bruce Maggs

What Happened On Mars?

Mars Pathfinder probe (1997)

Nice launch

Nice transit

Nice de-orbit

Nice thump-down (inflatable air-bag)

Nice rover disembarkation

Nice rover *spontaneous reboots*

Internal Architecture

"Information bus" (blackboard/whiteboard/...)

- High-priority bus manager thread

Meteorological data gathering

- Occasional activity
- Low-priority weather data thread

Communication with Earth

- Medium-priority communication thread

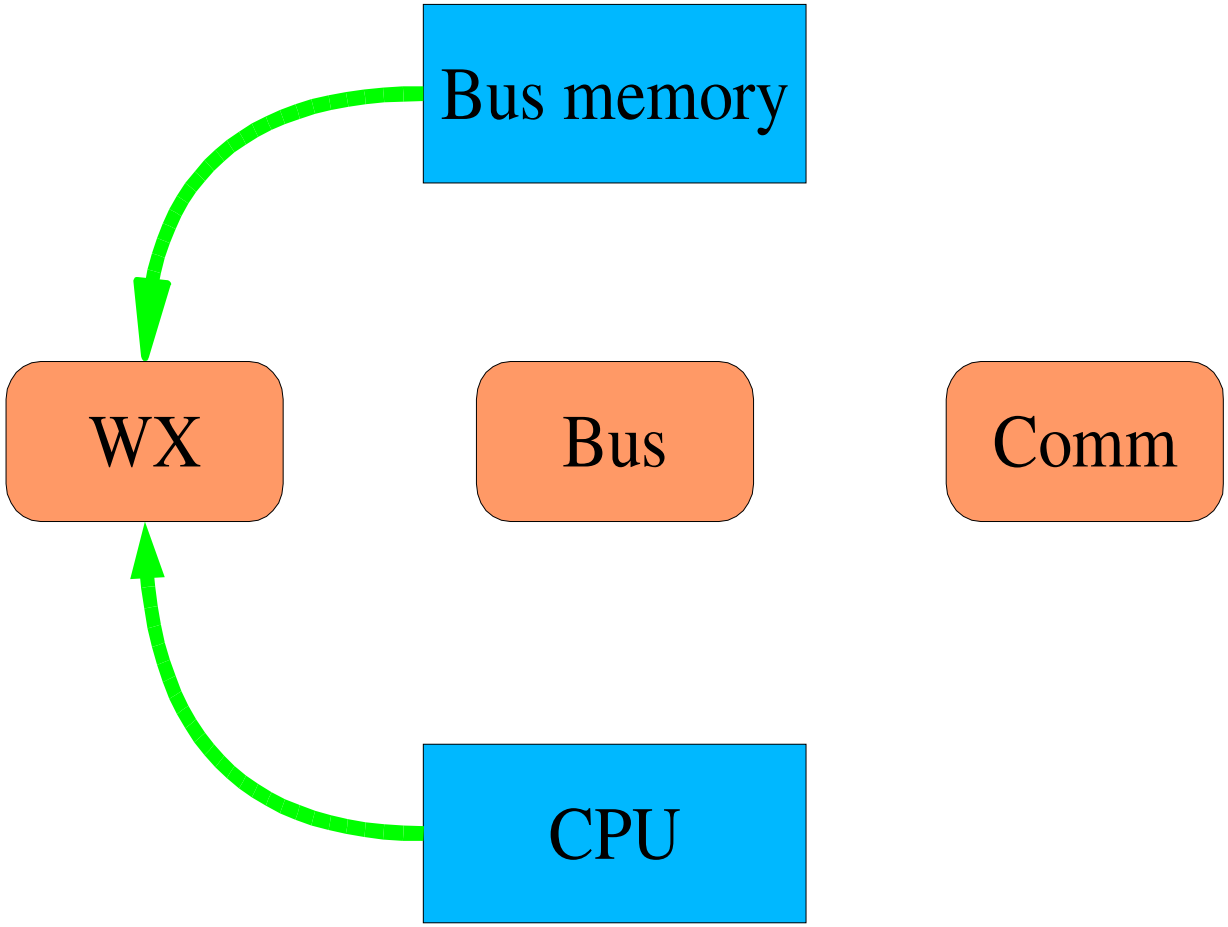
Watchdog thread: "too quiet"? *Reboot*

What could go wrong?

Weather data locks “bus” memory to publish

High-priority bus manager must wait

What could go wrong?



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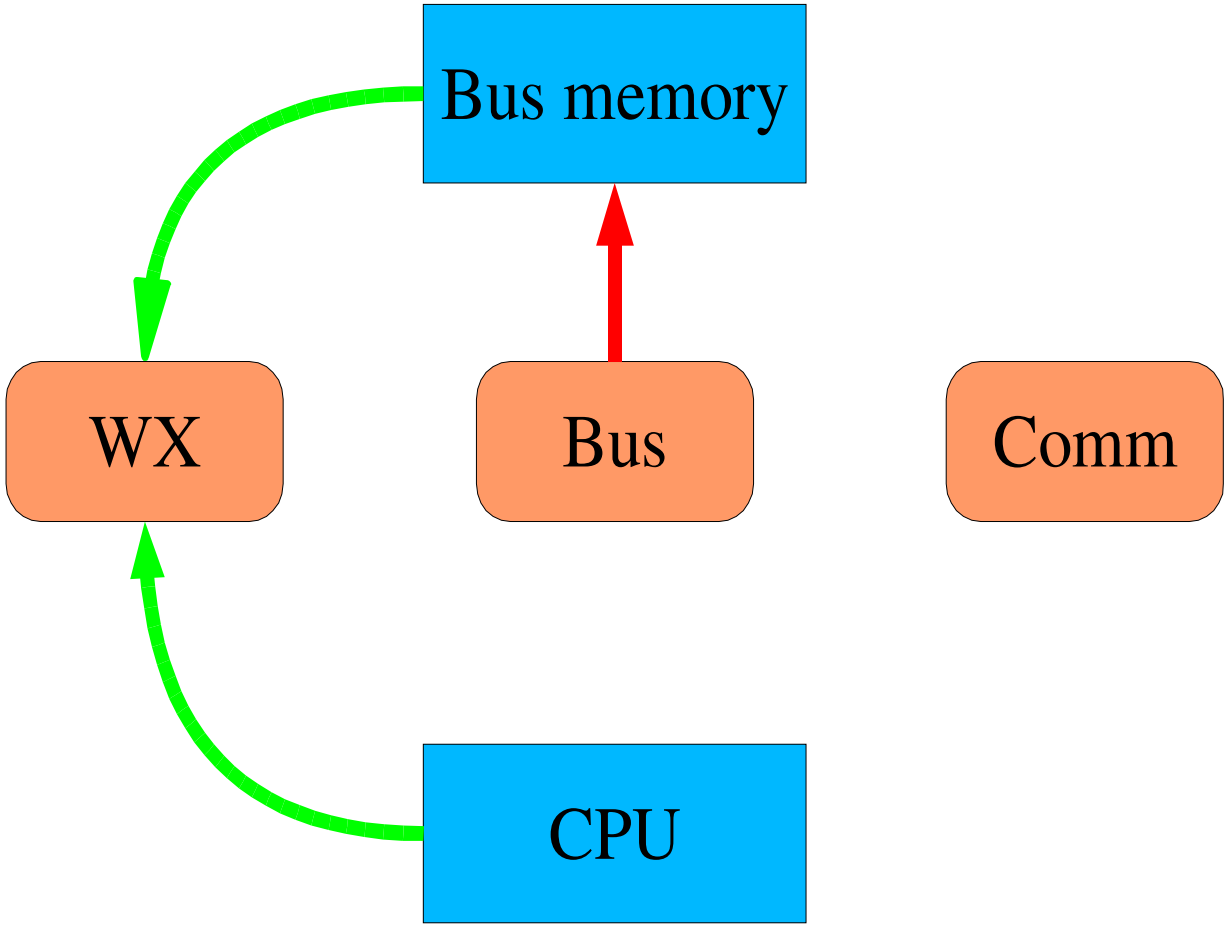


What could go wrong?

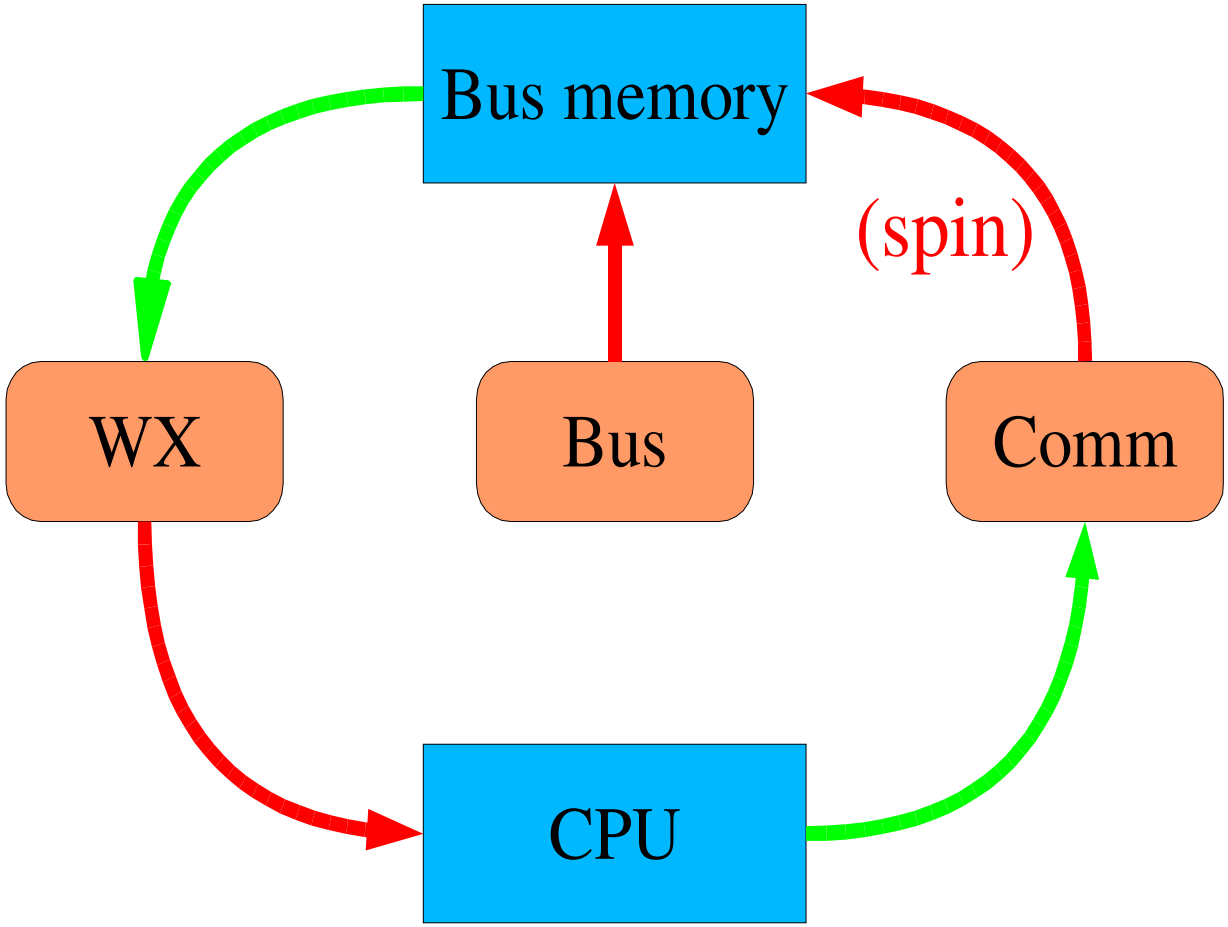
Weather data locks "bus" memory to publish

High-priority bus manager must wait

***Interrupt* makes communication runnable**

- "Medium" priority, so preempts weather data
- communication then attempts to lock bus
- Highest-priority runnable task, so it spin-waits

What could go wrong?



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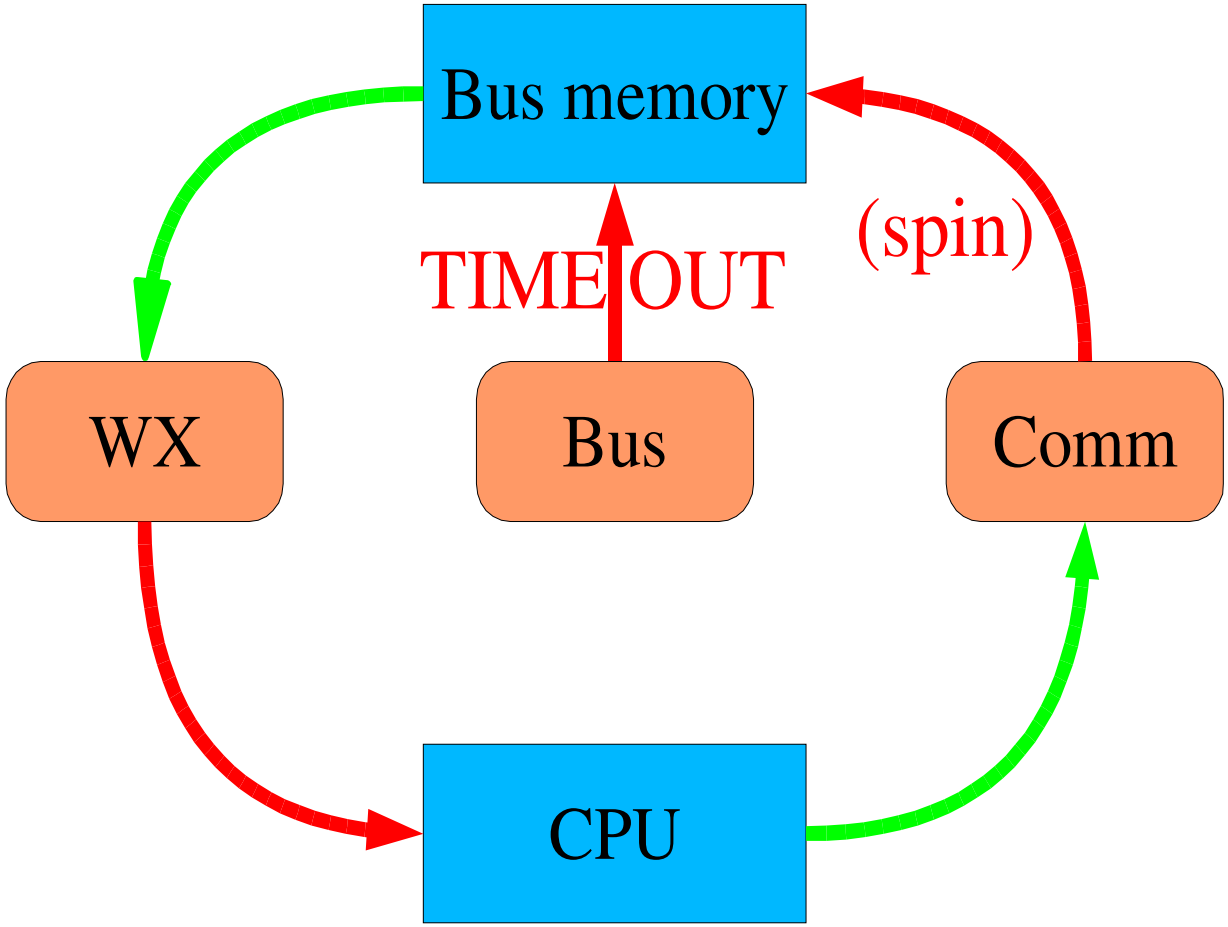

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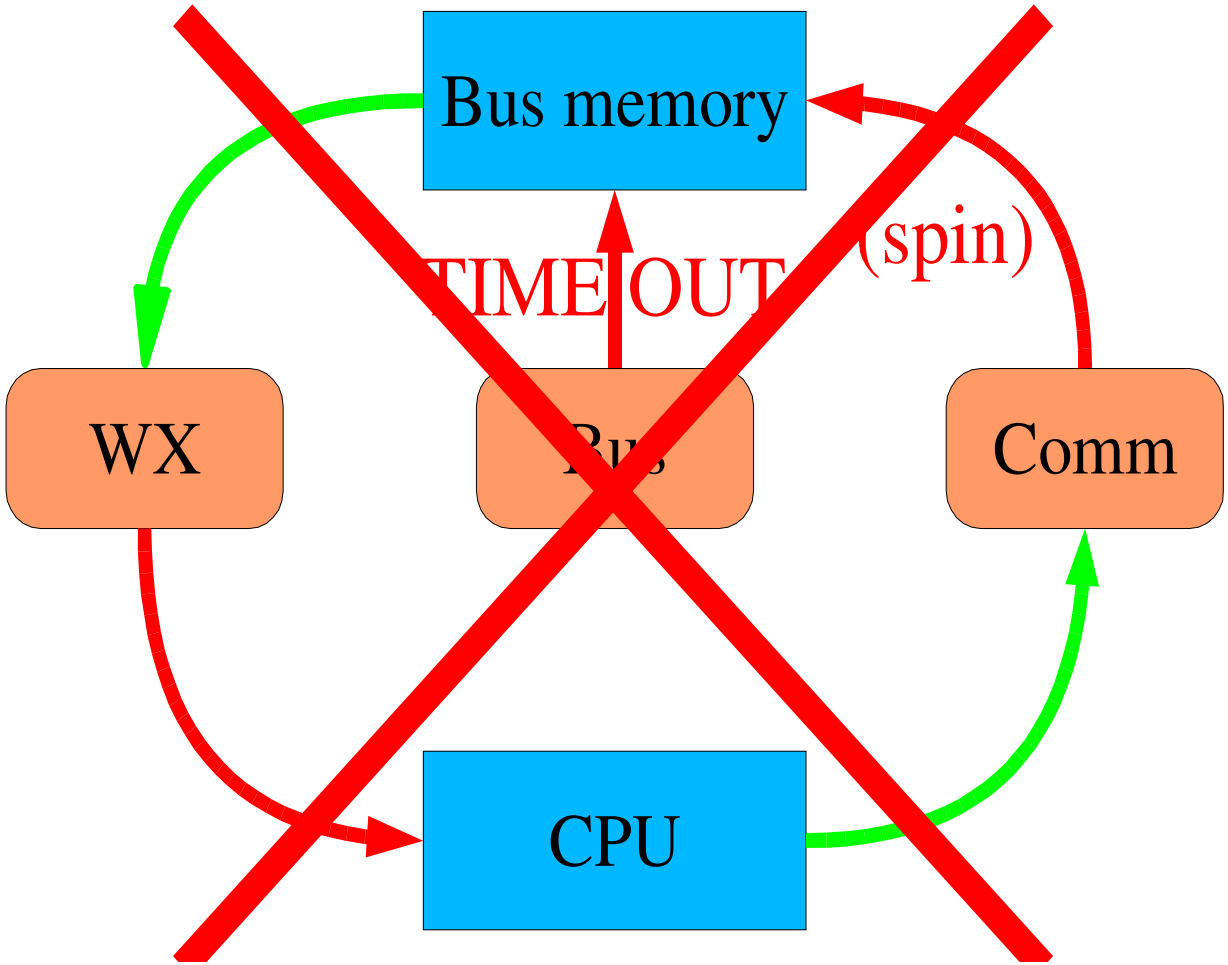


Solution?

VxWorks has two mutex flavors

- **Normal**
- ***Priority Inheritance***

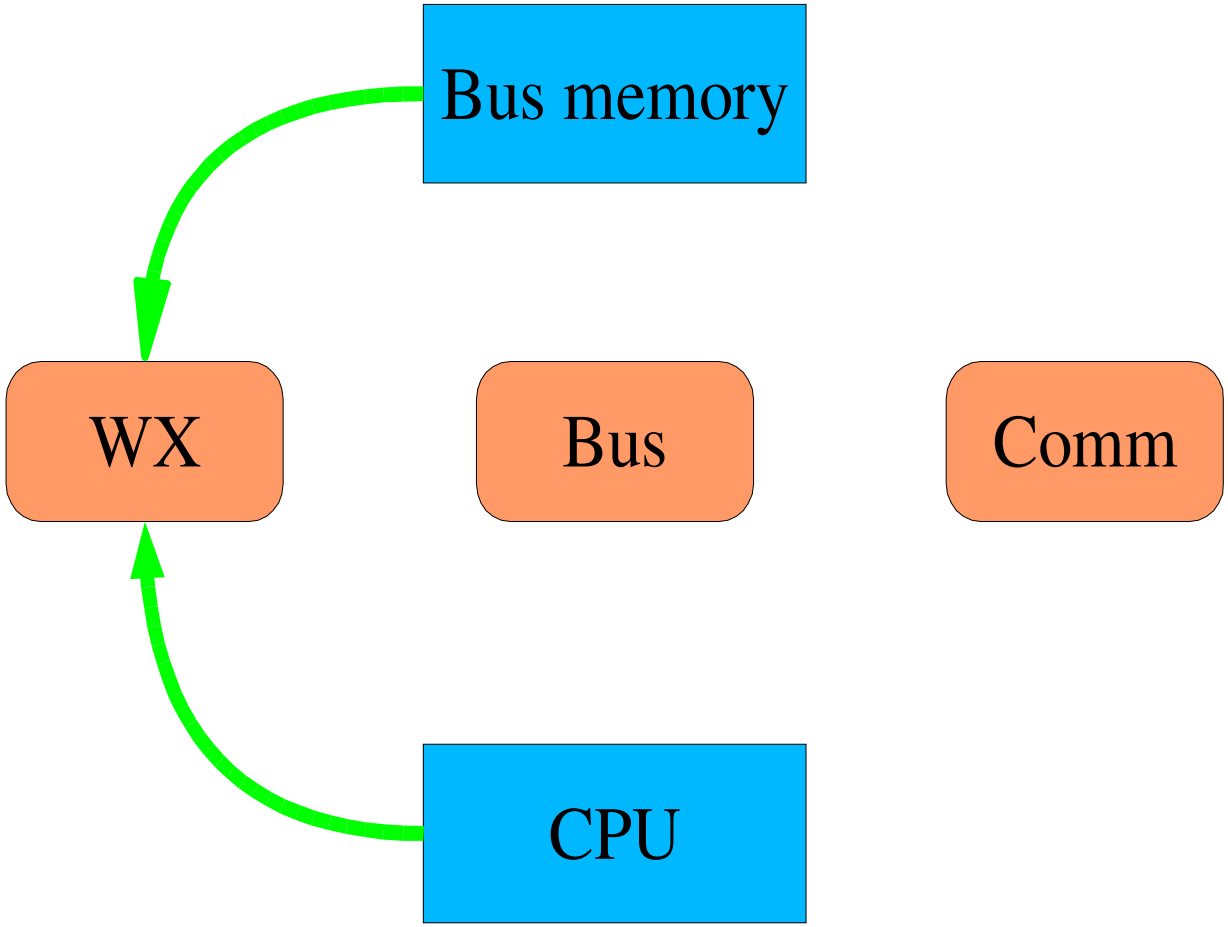
Rover code initialized flavor via global variables

Rover flew with "debug" interpreter enabled

- **Read-eval loop waiting for commands**
- **% assign bus_mutex_flavor = MF_P_INHERIT**

All fixed

Weather Thread is Busy



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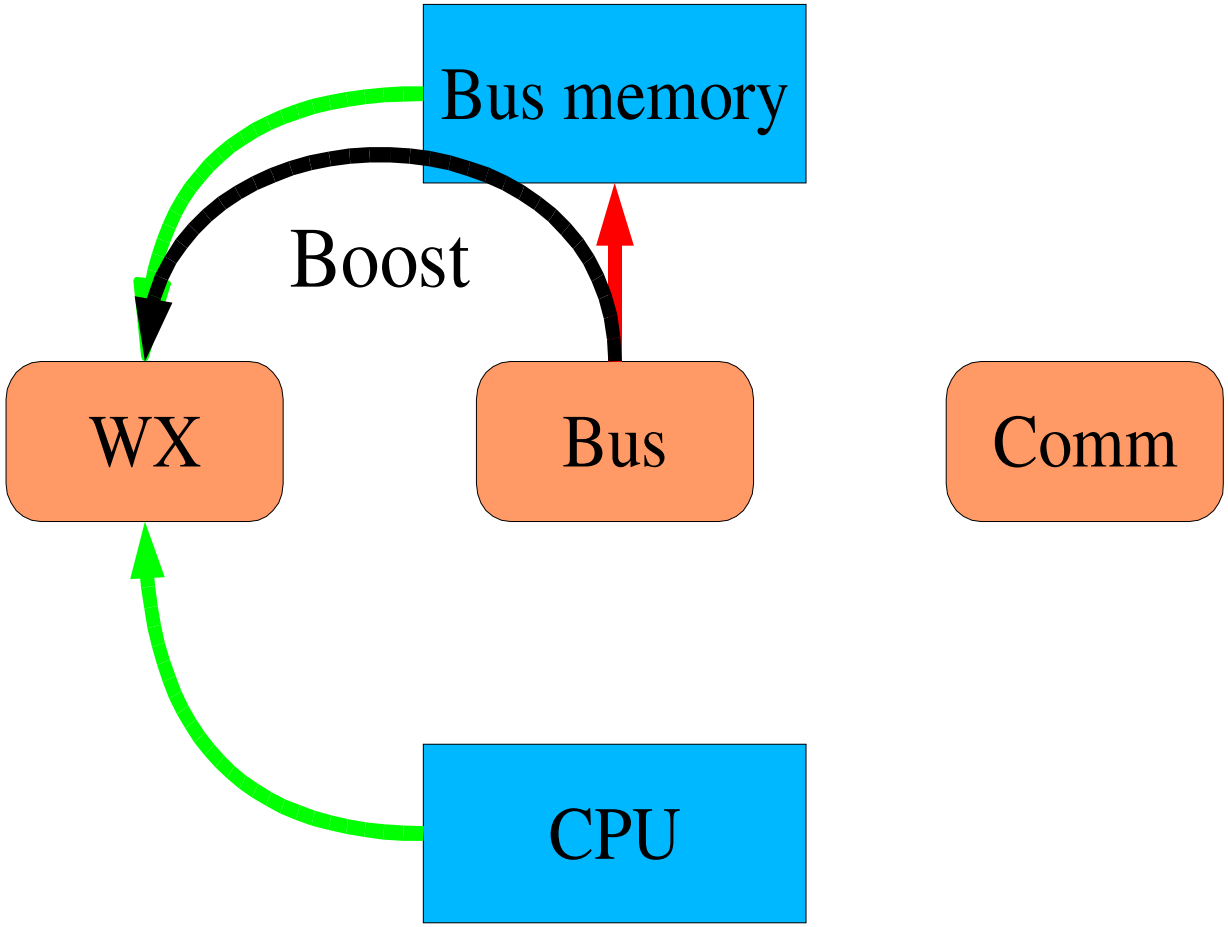

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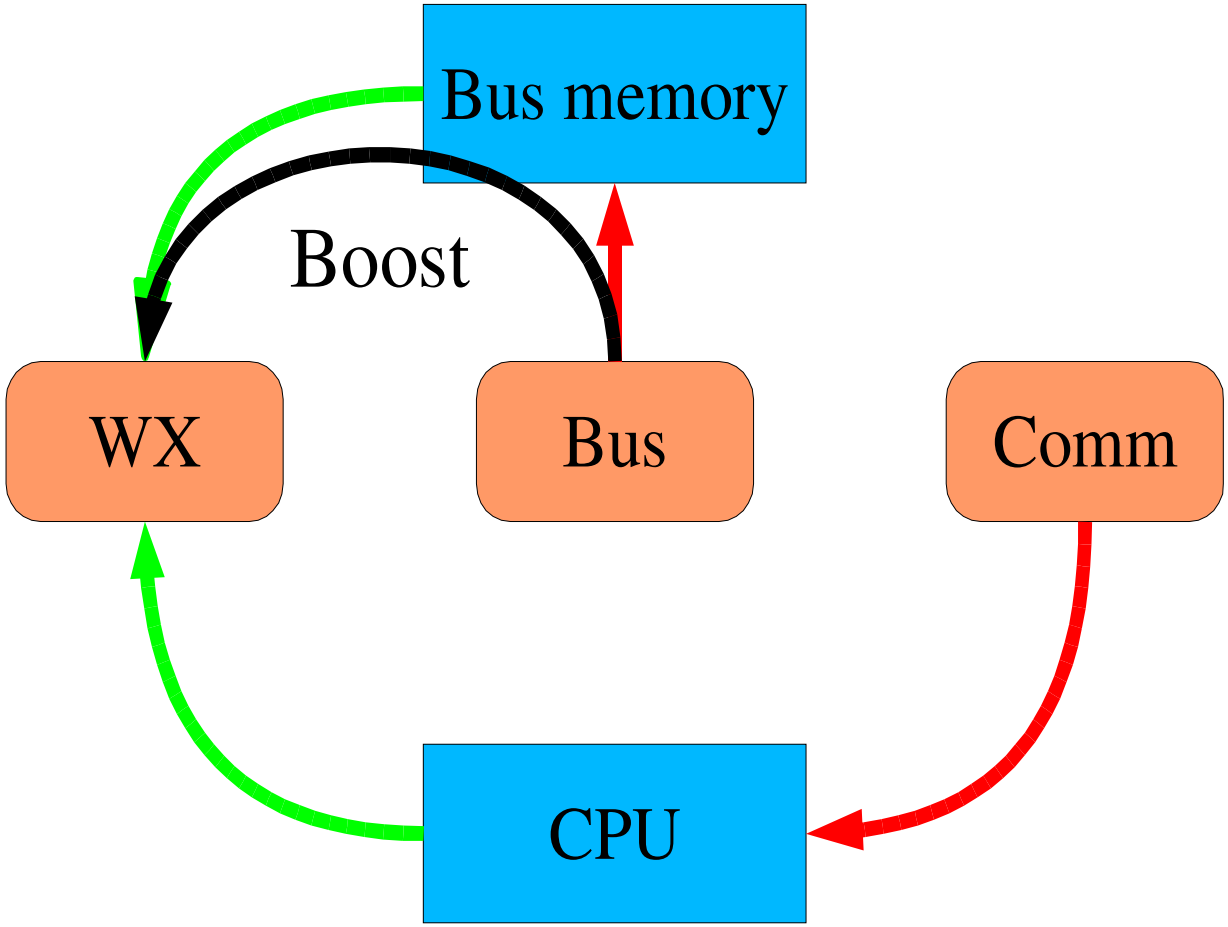
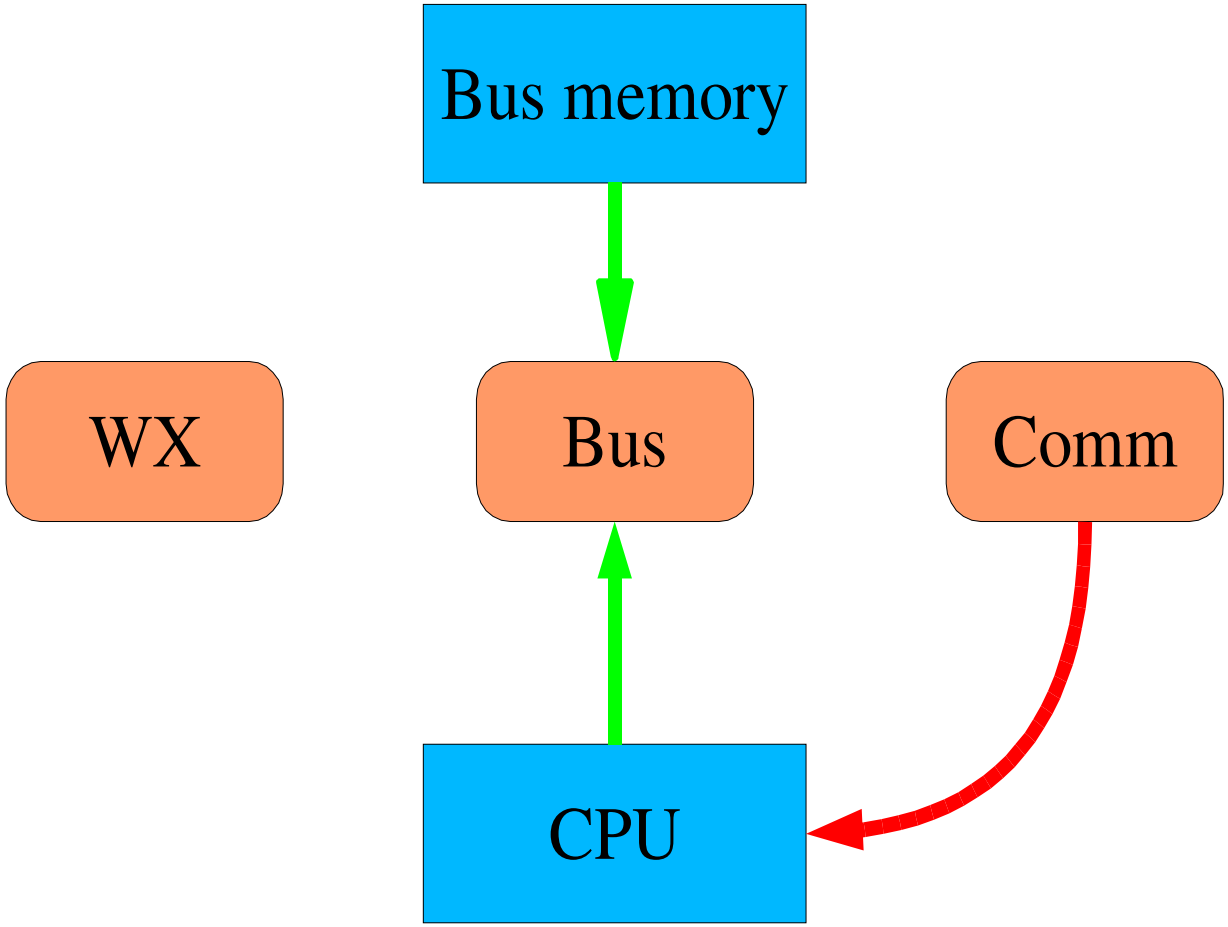


“Low-Priority” Thread Finishes Fast



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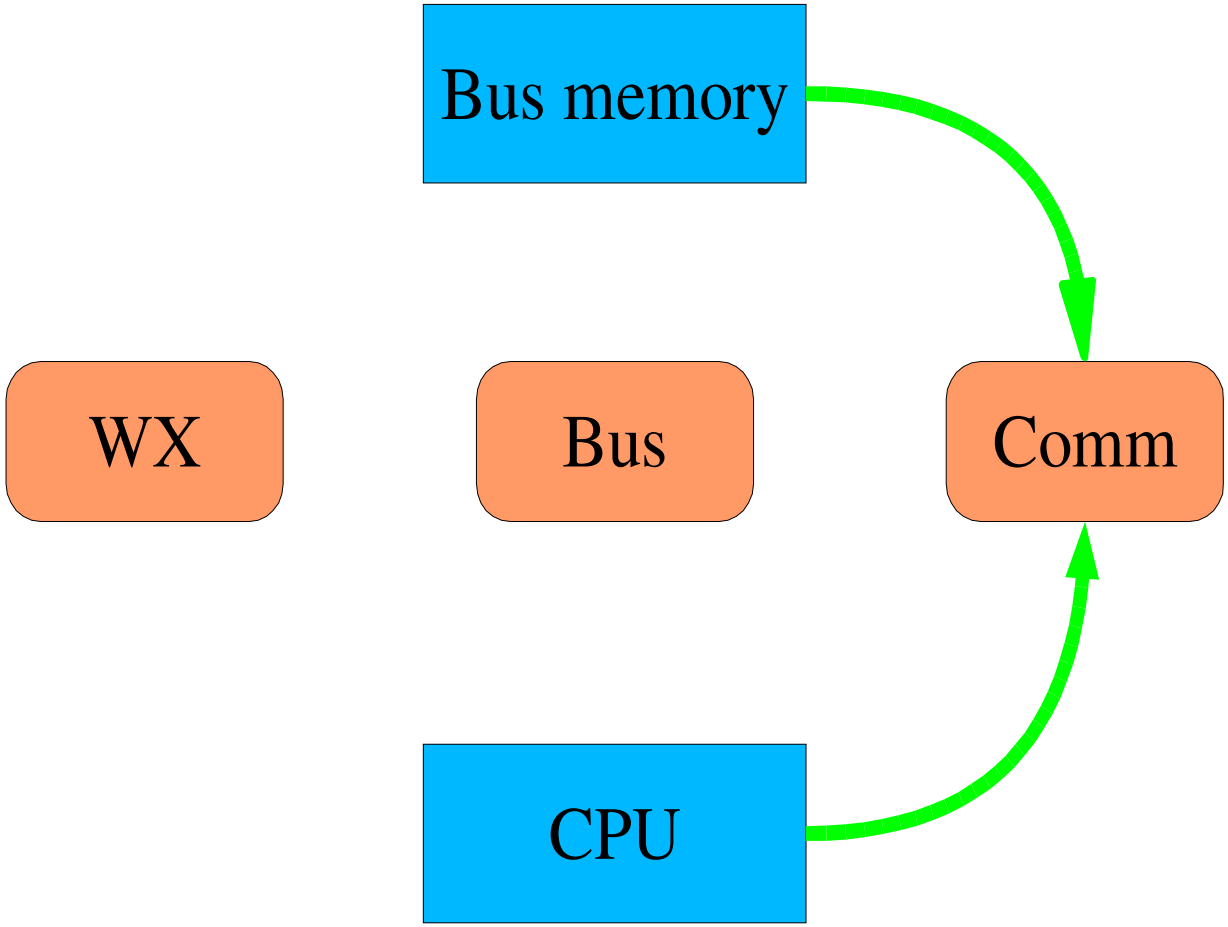

History of an Idea

Priority Inheritance Protocols: An Approach to Real-Time Synchronization

- IEEE Transactions on Computers 39:9
  - Lui Sha (CMU SEI)
  - Ragunathan Rajkumar (IBM Research -> CMU ECE)
  - John Lehoczky (CMU Statistics)

History of an Idea

Events

- 1987-12 “Manuscript” received
- 1988-05 Revised
- 1990-09 Published
- 1997-07 Rescues Mars Pathfinder

History courtesy of Mike Jones

- http://www.cs.cmu.edu/~rajkumar/mars.html