

# Towards Real-Time Clouds for CPS

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Chenyang Lu

Cyber-Physical Systems Laboratory

Department of Computer Science and Engineering

<http://www.cse.wustl.edu/~lu/>

 Washington University in St. Louis

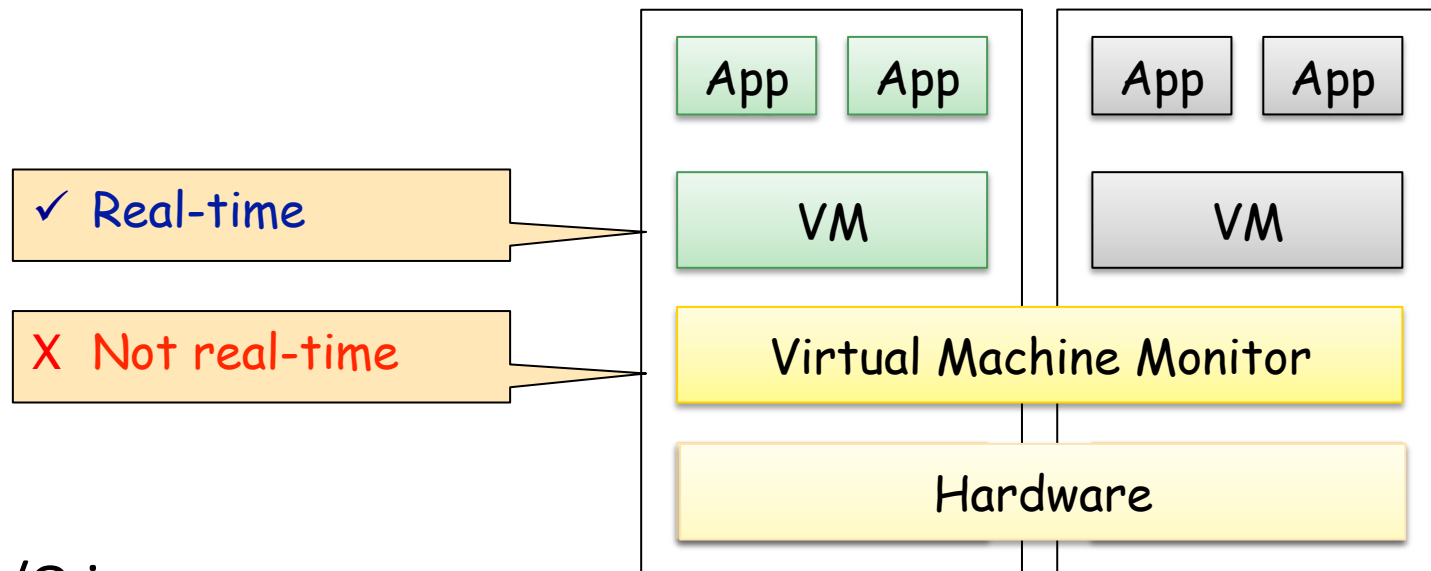
# Challenge: Real-Time Clouds

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- Support multiple CPS applications on shared resources
- Preserve real-time performance guarantees
  
- Multi-level real-time resource management
  - ❑ Real-time virtualization within a host
  - ❑ Distributed resource management within a cloud
  - ❑ Real-time networking

# Clouds are *not* real-time today

- Virtualization technology underlying clouds
  - Xen: virtual machine monitor for Amazon EC2
- CPU: proportional-share scheduling



- I/O is worse
  - ❑ Vague “performance indicator”: low/medium/large
  - ❑ Or pay a lot to get dedicated physical network resources

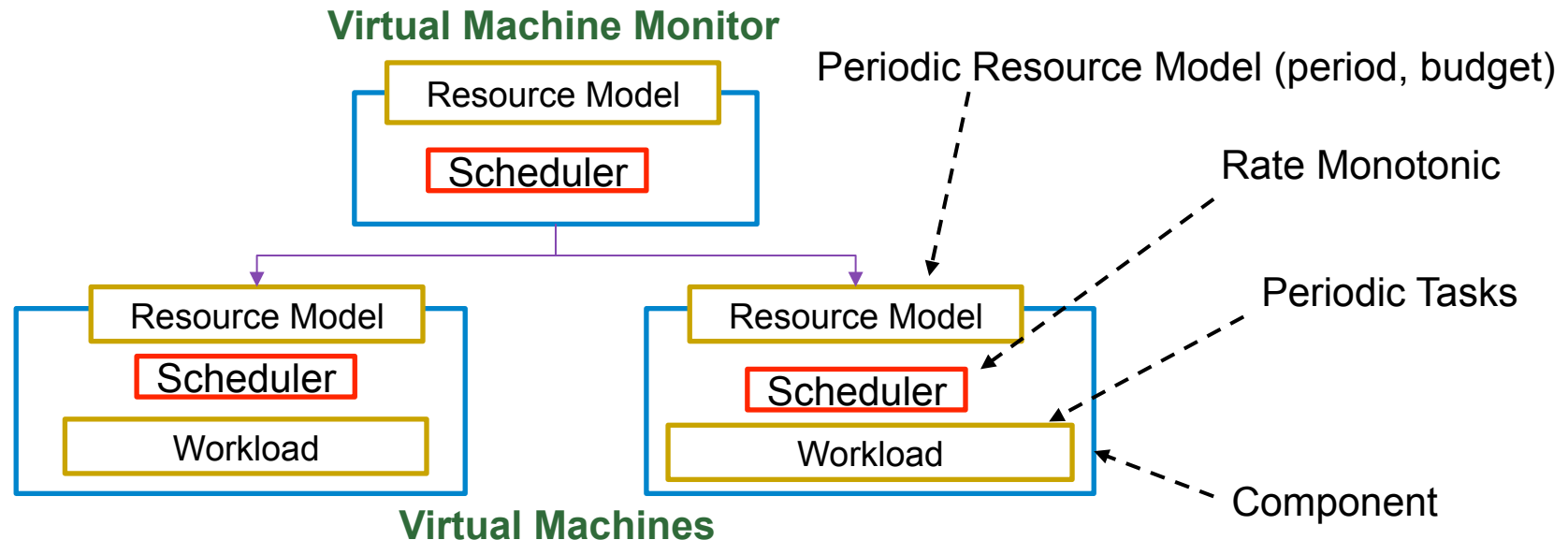
# RT-Xen

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- Real-time virtualization platform based on Xen
- Compositional real-time CPU scheduling for VMs
- Real-time communication architecture
- Open-source: <http://sites.google.com/site/realtimexen/>

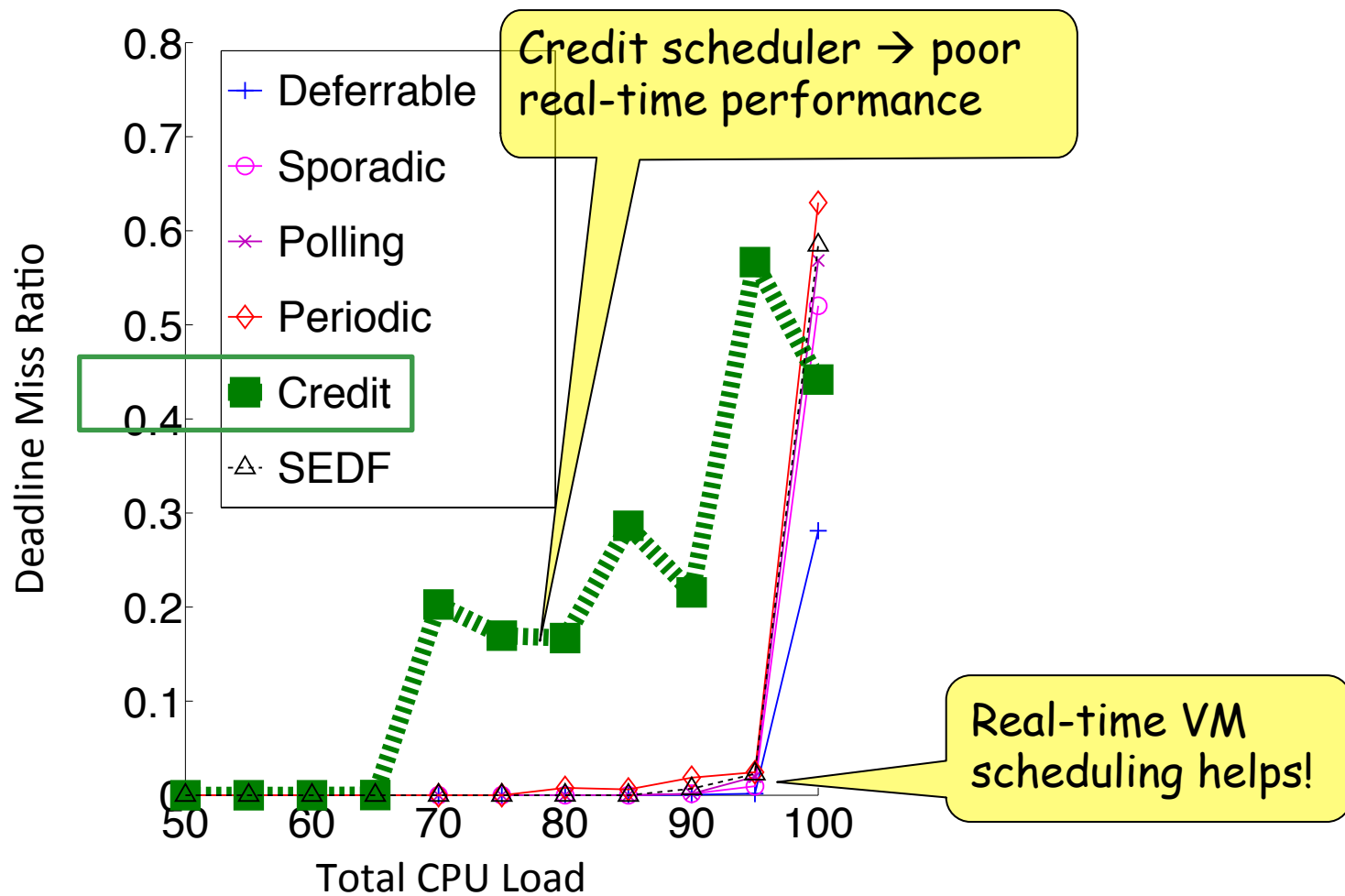
# RT-Xen: Compositional Scheduling

- Provides temporal isolation and real-time guarantee
- Computes minimum-bandwidth resource models for VMs



*“Realizing Compositional Scheduling through Virtualization”,  
Real-Time and Embedded Technology and Application Symposium (RTAS), 2012*

# Xen Credit vs. Real-Time VM Scheduling



*"RT-Xen: Towards Real-Time Hypervisor Scheduling in Xen",  
ACM International Conferences on Embedded Software (EMSOFT), 2011*

# Towards Real-Time Clouds

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- RT-Xen is only a small step
  - ❑ Real-time scheduling → virtualization shows promise
  
- Open challenges
  - ❑ Semantics of service guarantees for CPS applications
  - ❑ Parallel real-time computing in the cloud
  - ❑ Distributed resource management in the cloud
  - ❑ Predictable adaptation to dynamic CPS workloads and failures
  - ❑ Real-time clouds at a global scale
  - ❑ Integration with virtualized real-time networking