ComputerScience

Boston University

# Quest-V – A Separation Kernel for Mixed Criticality Systems

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BU Operating Systems and Services

## Objective

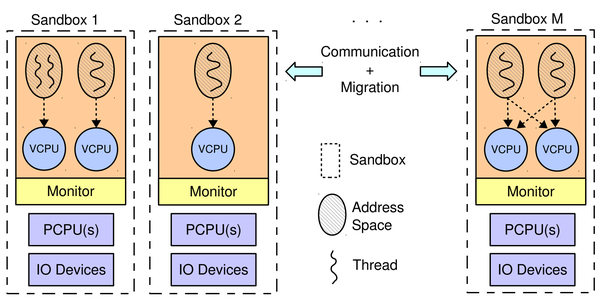
- Develop high-confidence (embedded) systems
  - Target multicore SBCs (Intel Joule, Edison, etc)
  - Mixed criticalities: Timeliness & Safety
  - Predictable, Secure, Fault Tolerant

## Applications

- Healthcare
- Avionics
- Automotive
- Factory Automation
- Robotics
- Space exploration
- IoT, Industry 4.0 “Smart factories”

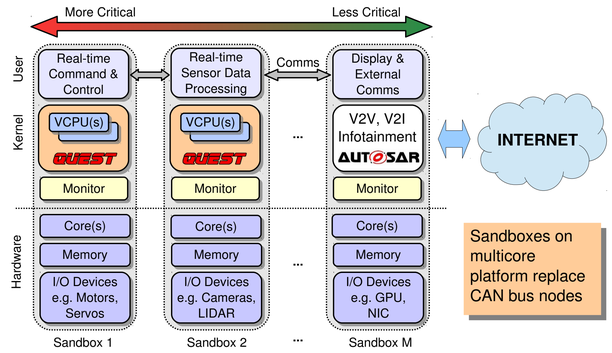
## Approach

- Quest-V for multicore processors
  - Distributed system on a chip
  - Time as a first-class resource
  - Sandboxes sub-components using hardware-assisted memory virtualization (e.g., Intel EPTs)




**Quest-V**

## Example Mixed Criticality System



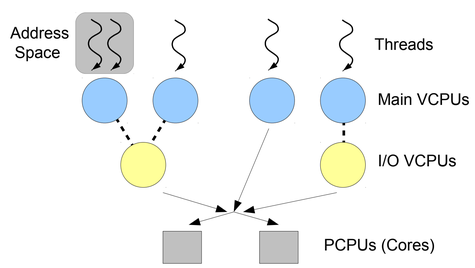

**Multicore Automotive System**

## Isolation

- Memory virtualization using shadow paging isolates sandboxes and their components
- Dedicated physical cores assigned to sandboxes
- I/O passthrough for direct device access
- Hardware performance monitoring for shared cache and bus isolation
  - Monitors blacklist illegal port-based I/O device accesses
  - EPTs prevent unauthorized memory-mapped device access

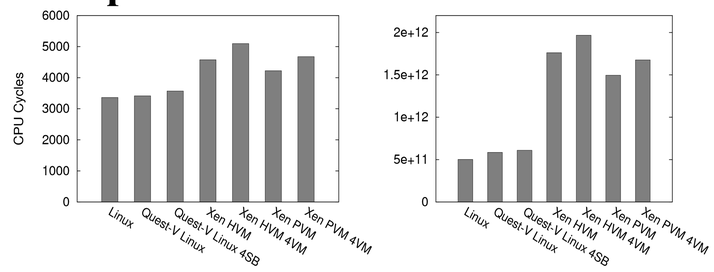
## Predictability

- Virtual CPUs (VCPUs) for time budgeted real-time execution of threads and system events (e.g., interrupts)
- Sandbox kernels perform local scheduling on assigned cores
  - Avoid VM-Exits to Monitor – eliminate cache/TLB flushes




**VCPU Scheduling Hierarchy**

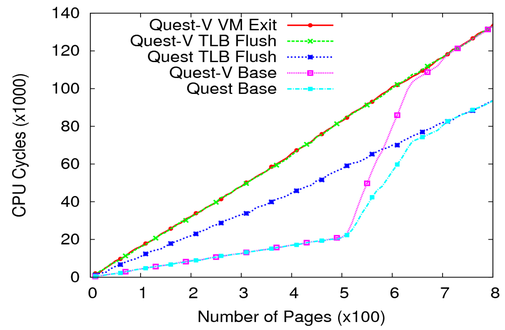
## Example Performance




100 Million Page Faults

1 Million *fork-exec-exit* Calls

- Data TLB overheads, Xeon E5506 4-core @ 2.13GHz, 4GB RAM




## Recent Developments

- Real-time fault detection and recovery (e.g., Triple Modular Redundancy of replicated sandboxes)
- MARACAS – memory-aware, real-time aware, cache-aware scheduling for multicores
- QduinoMC – Quest-Arduino real-time multithreaded (& multicore) API
  - World's first secure & smart 3D printer

## Conclusions

- Quest-V real-time chip-level separation kernel
- Uses hardware virtualization for time and space isolation of guest services
- Eliminates overheads of a hypervisor

## Quest Website: www.questos.org

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