Graduate Operating Systems

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Today’s Paper

Traditional Operating Systems

- Traditional operating systems use a “one-size-fits-all” interface and implementation of OS abstractions

Example: Exokernel
Problems with Traditional OS

- **Performance**
  - Denies applications the advantages of domain-specific optimizations

- **Flexibility**
  - Restricts the flexibility of application builders
  - Concept: “with more information exposed, resources can be utilized 'better'”!

- **Functionality**
  - Discourages changes to the implementations of existing abstractions

Solution: Exokernel

- **Separate protection from management!**
  - Allows user level to manage resources
    - Application libraries implement OS abstractions
  - Exokernel exports (not emulate) resources
    - Low level interface
    - Protects, does not manage
    - Exposes hardware

- End-to-end argument; “applications know better”
Exokernel + Library OS

- **Exokernel**'s resource management:
  - Allocate, revoke, share, track ownership

- **Library OS**:
  - Uses low-level exokernel interface, provides higher-level abstractions; provides special purpose implementations

An application can choose the library which best suits its needs, or even build its own.
Exokernel

• Hypotheses:
  – Exokernels can be very **efficient**
  – Low-level, secure multiplexing of hardware resources can be implemented **efficiently**
  – Traditional operating system abstractions can be implemented **efficiently** at application level
  – Applications can create **special-purpose implementations** of these abstractions

Library Operating Systems

• Simpler
• Specialized
• Multiple can exist
• Few kernel crossings
Design Challenge

• How can an Exokernel allow libOSes to freely manage physical resources while protecting them from each other?
  – Track ownership of resources
    • Secure bindings – libOS can securely bind to machine resources
  – Guard all resource usage
    • Invisible/visible resource revocation
  – Revoke access to resources
    • Abort protocol

Design Principles

• Securely expose hardware
  • Kernel should provide secure low-level primitives that allow all hardware resources to be accessed as directly as possible.
• Expose allocation
  • Allow to request specific physical resources
• Expose names
  • Export physical names.
  • Remove a level of indirection: Translation
• Expose revocation
  • Utilize a visible resource revocation protocol
Secure Bindings

- Exokernel allows LibOSes to bind resources using secure bindings
- Decouples authorization from the actual use of a resource
- Multiplex resources securely
- Performs authorization only at bind time
  - Allows the kernel to protect resources without having to understand them

Some Terminology

- Packet filters
- TLB
- Physical memory: capabilities for page
- Downloadable code (ASH)
- RPC
- DMA
Kernel Comparisons

Microkernels

- A good idea in the 1970s and 80s
- Not up to demands of modern processors
  - Virtual memory
  - Heavy caching
- Not up to demand of modern operating systems
- “Resurrection”:
  - Compare to concepts of virtual machines
  - Mobile and wearable devices:
    - Fixed or limited functionality
    - No general purpose files
    - No dynamic virtual memory
    - Simple context switches
    - All code already in memory
    - Easy IPC