TECHNISCHE UNIVERSITÄT DRESDEN

Faculty of Computer Science Institute of Systems Architecture, Operating Systems Group

RESOURCE MANAGEMENT

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AGENDA

- done: time, drivers
- today: misc. resources
  - architectures for resource management
  - solutions for specific resources
  - capabilities to manage resource access
- upcoming: applications, legacy support

KERNEL RESOURCES

PROBLEM

- kernel needs memory for its abstractions
  - tasks: page tables
  - threads: kernel-TCB
  - capability tables
  - IPC wait queues
  - mapping database
- kernel memory is limited
- opens the possibility of DoS attacks

IDEA

- memory management policy should not be in the kernel
- account all memory to the application it is needed for (directly or indirectly)
- kernel provides memory control mechanism
- exception for bootstrapping:
  initial kernel memory is managed by kernel

SOLUTION

- untyped memory in seL4
- all physical memory unused after bootstrap is represented by untyped memory capabilities
- can be granted, split or retyped
- restricted to powers of 2 (see flexpages)
- initial resource manager gets all (see σ_0)
- user code decides how to use them

SOLUTION

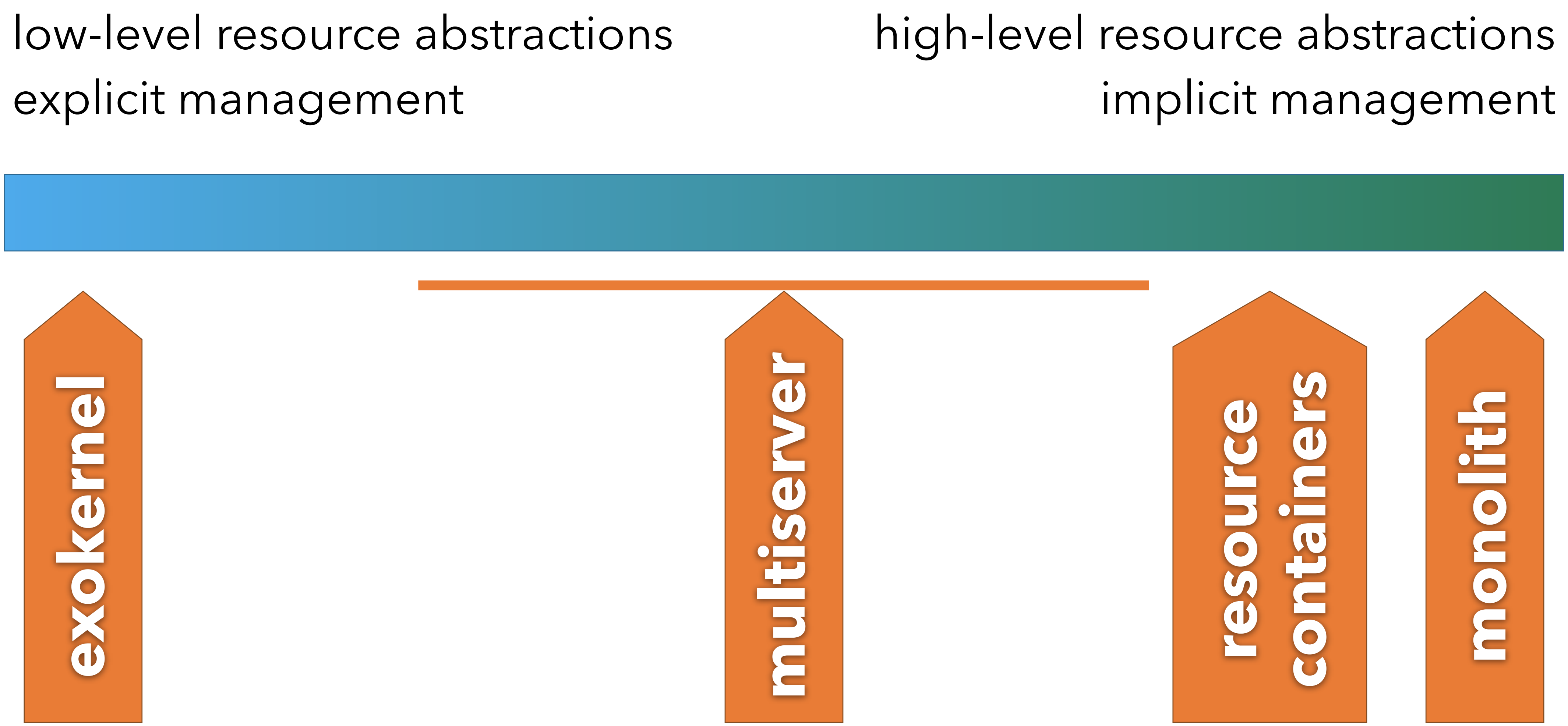
- application retype UM to kernel objects
  - TCB, endpoint, CNode, VNode, frame, interrupt
  - all kernel bookkeeping for the object uses the underlying physical memory
  - no implicit memory allocation by the kernel
- retyping and splitting is remembered in capability derivation tree
  - revoking recursively destroys all derived capabilities and kernel objects

PRINCIPLE

separate **enforcement** and **management**

ARCHITECTURES

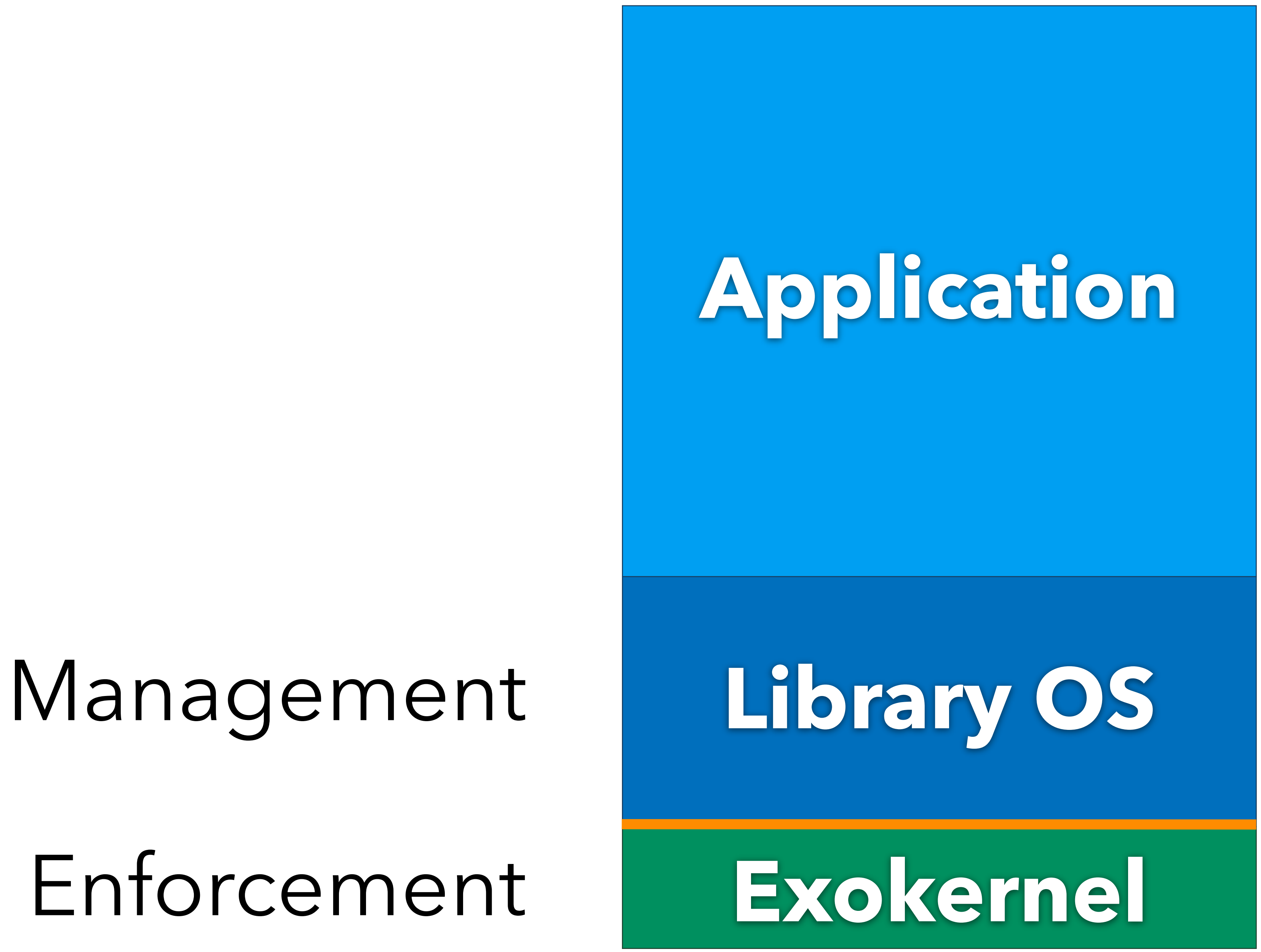
SPECTRUM


low-level resource abstractions
explicit management
high-level resource abstractions
implicit management
exokernel
multiserver
resource containers
monolith

- enforcement and management implicitly tied to process abstraction

- resource containers were proposed to make resource management explicit
- bags of resources assigned to subsystems

EXOKERNEL


Application
Management
Library OS
Enforcement
Exokernel

DESIGN

- provide primitives at the lowest possible level necessary for protection
- use physical names wherever possible
- resource management primitives:
  - explicit allocation
  - exposed revocation
  - protected sharing
  - ownership tracking

CONSEQUENCES

- applications can use their own library OS
- library OS'es cannot trust each other
- no global management for resources
- think of a file system
  - kernel manages disk block ownership
  - each library OS comes with its own filesystem implementation
- one partition per application?

SHARING

- invariants in shared resources must be maintained
- 4 mechanisms provided by the exokernel
  - software regions for sub-page memory protection, allows to share state
  - capabilities for access control
  - critical sections
  - wakeup predicates: code downloaded into the kernel for arbitrary checks

MULTISERVER

works on monolithic kernels too

LEVELS

different abstraction levels for resources

basic resources	memory, CPU, IO-ports, interrupts
hardware	block device, framebuffer, network card
compound resources	file, GUI window, TCP session

HIERARCHIES

- applications can access resource on the abstraction level they need
- servers implementing a resource can use other, lower-level resources
- isolation allows managers to provide real-time guarantees for their specific resource
- DROPS:
  Dresden Real-time OPerating System

EXAMPLES

VIRTUAL NIC

- driver for physical network card
- built with DDE using Linux drivers
- provides multiple virtual network cards
- implements a simple virtual bridge

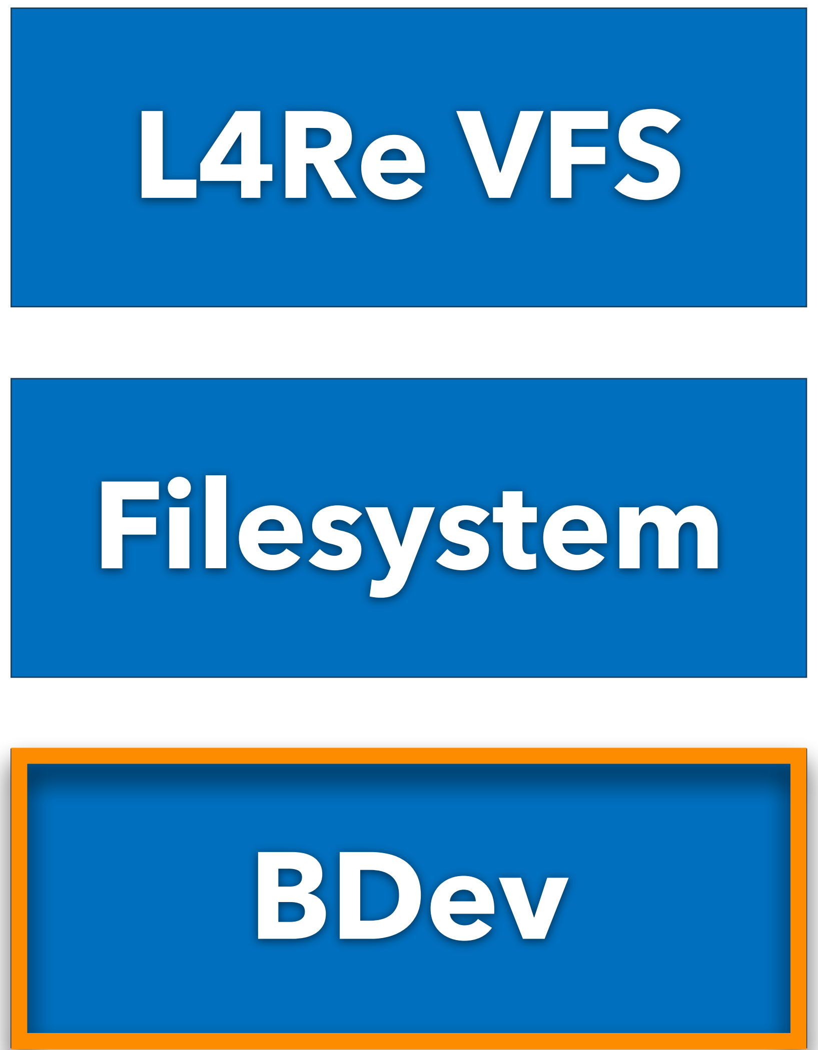
LIGHT-WEIGHT IP

- light-weight IP Stack
- TCP/IP, UDP, ICMP

SOCKET CLIENT

- clients can use standard BSD socket interface

BLOCK SERVER



- NVMe driver to access hard disks
- provides block device interface

FILESYSTEM

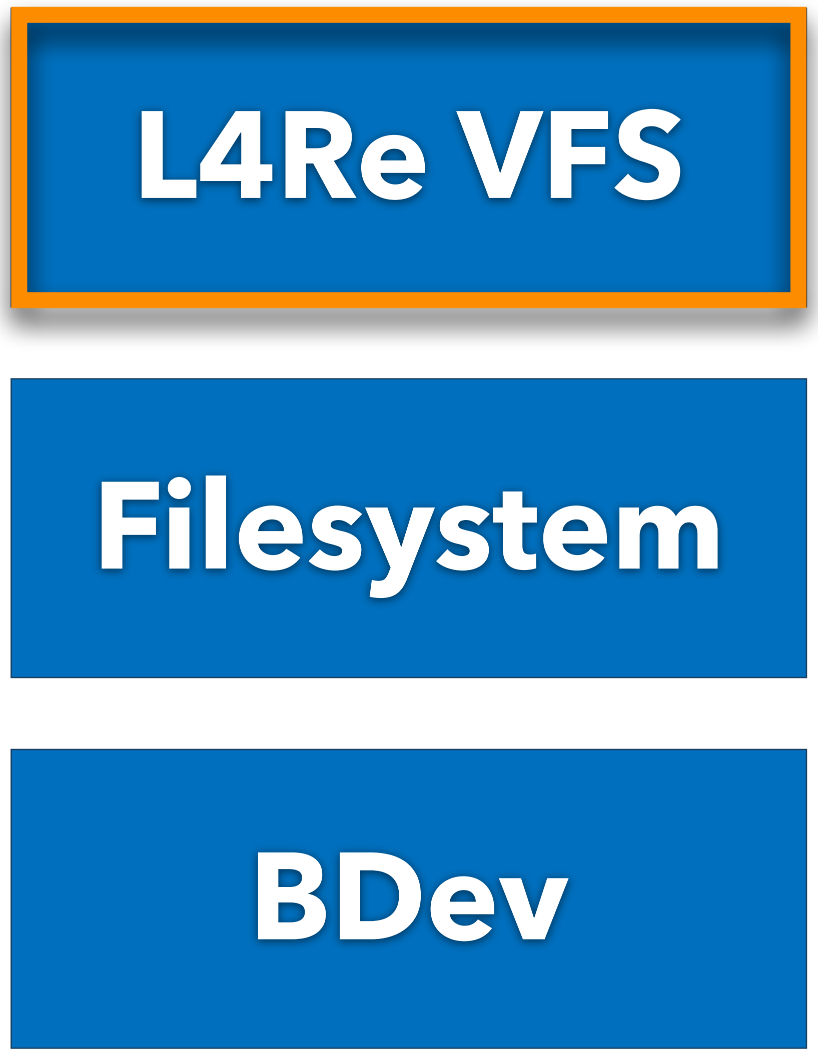
L4Re VFS

Filesystem

BDev

- ext2 port available
- tmpfs uses RAM as backing store
- VPFS: securely reuse a Linux filesystem

L4RE VFS



- hierarchical name space
- connects subtrees to different backend servers
- aka mounting

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FRAMEBUFFER

Terminal

mag

fb-drv

- finds hardware framebuffer
- provides it as a memory object to clients

MAG

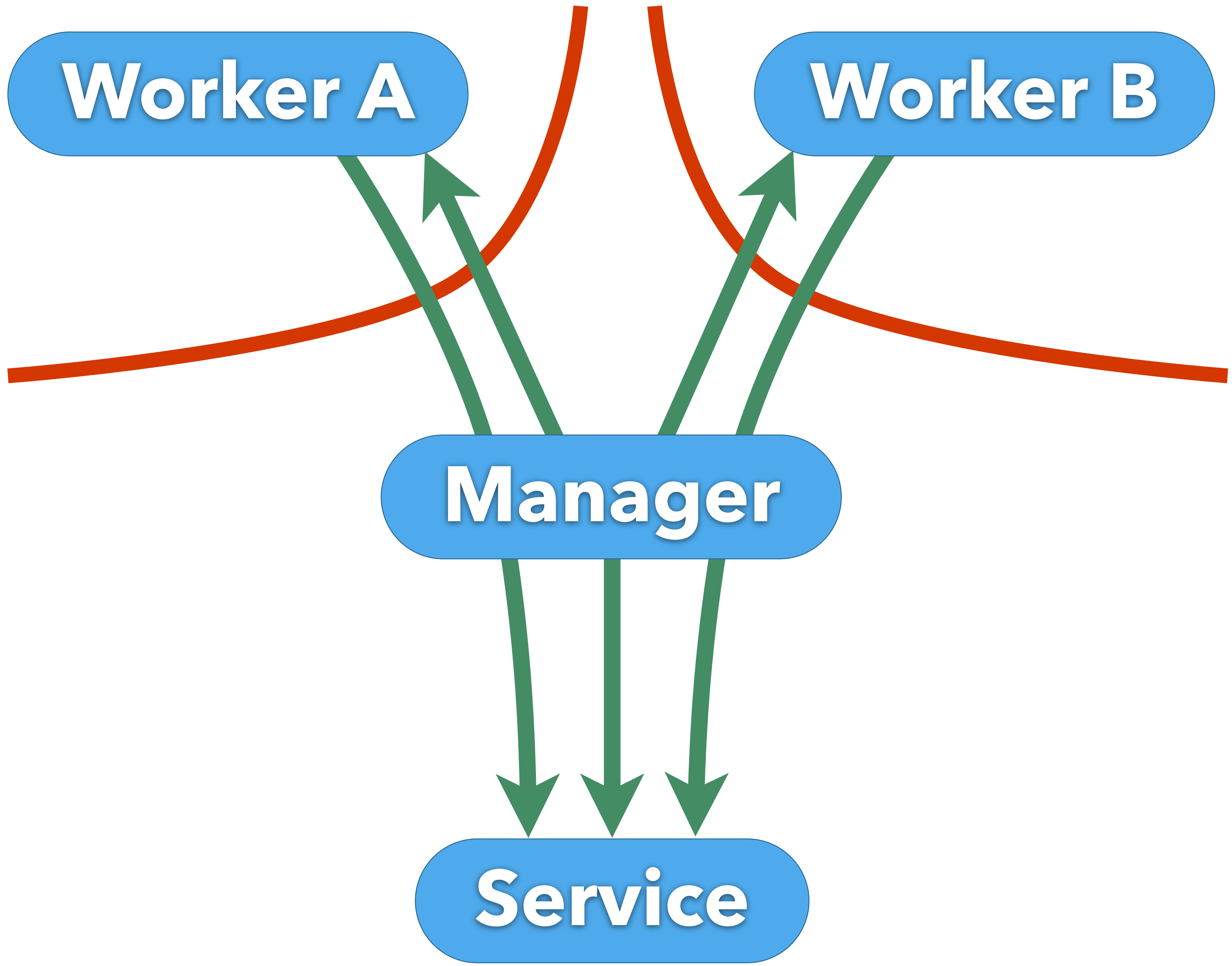
- multiplexes the frame buffer
- no virtual desktops, but window merging
- details in the legacy / security lectures

TERMINAL

- GUI client providing a terminal window
- VT100 emulation
- can support readline applications
  - shell
  - python

RESOURCE ACCESS

EXAMPLE



GOOGLE CHROME

better way...

TWO WORLDS

POSIX	POLA
operations allowed by default	nothing allowed by default
some limited restrictions apply	every right must be granted
ambient authority	explicit authority

L4Re – the L4 Runtime Environment

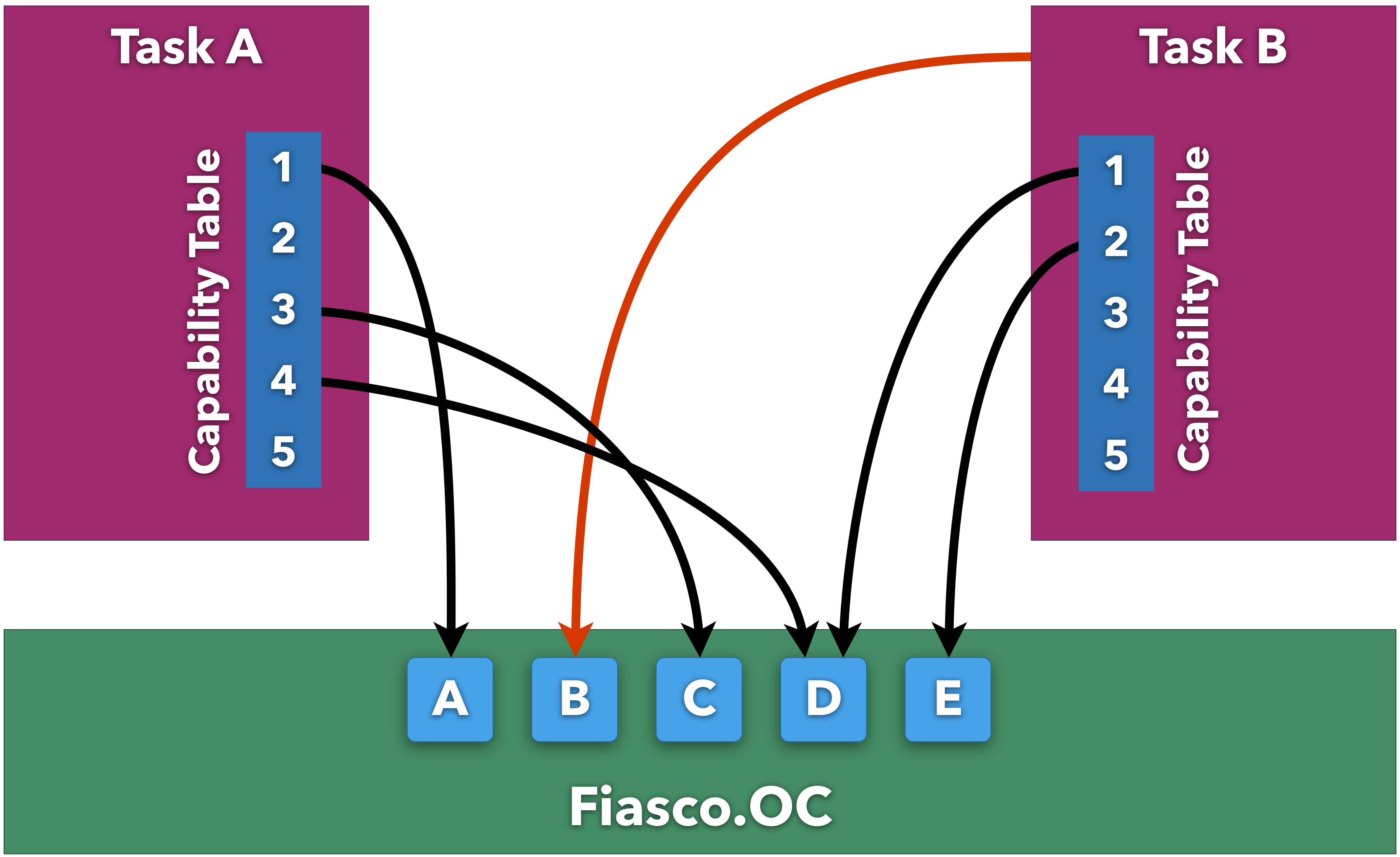
set of libraries and system services on top of the Fiasco.OC microkernel

top of the Fiasco.OC microkernel

CAPABILITIES

- Fiasco.OC and L4Re form an object-capability system
- actors in the system are objects
  - objects have local state and behavior
- capabilities are references to objects
  - any object interaction requires a capability
  - unseparable and unforgeable combination of reference and access right

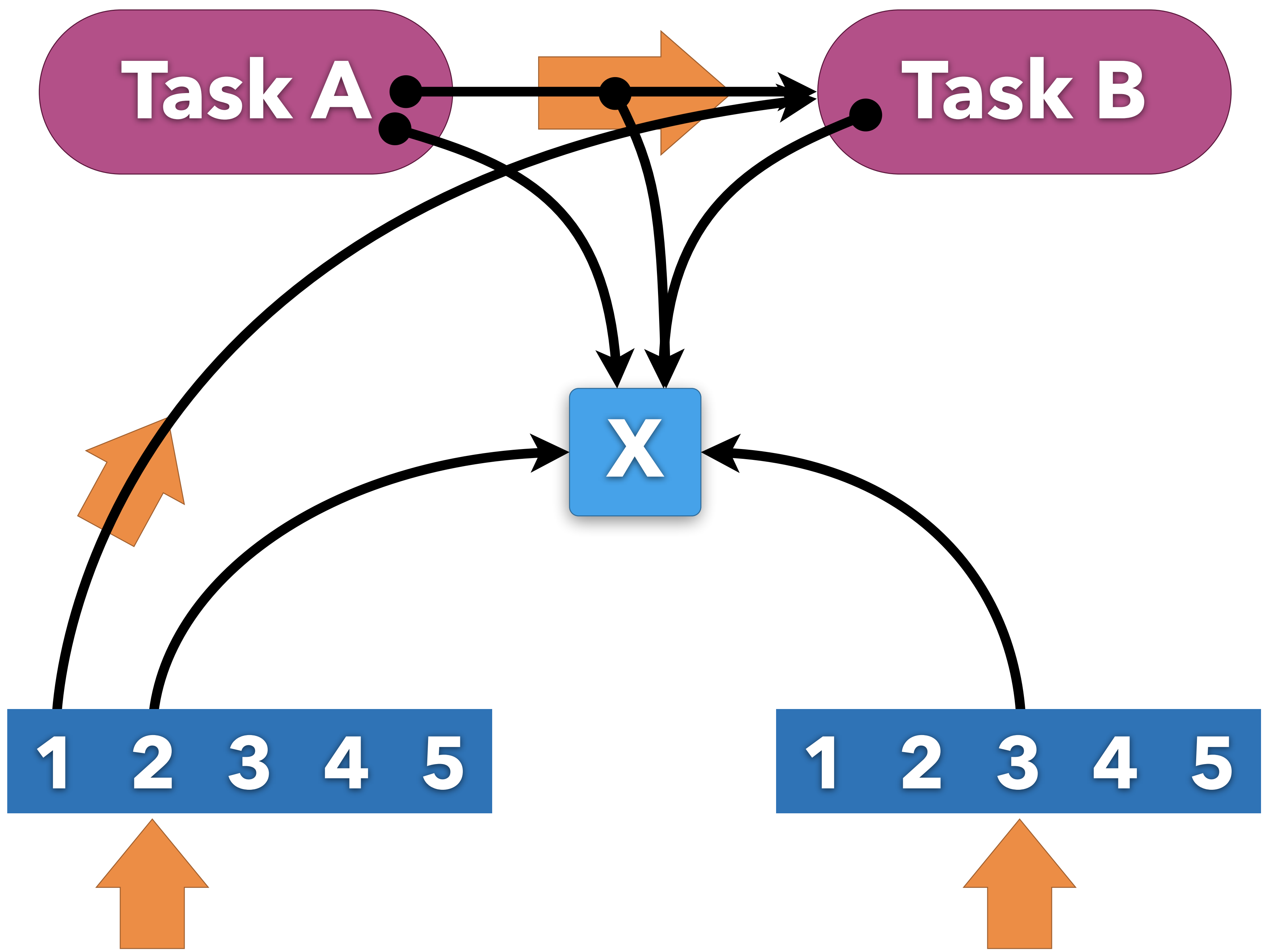
CAPABILITIES



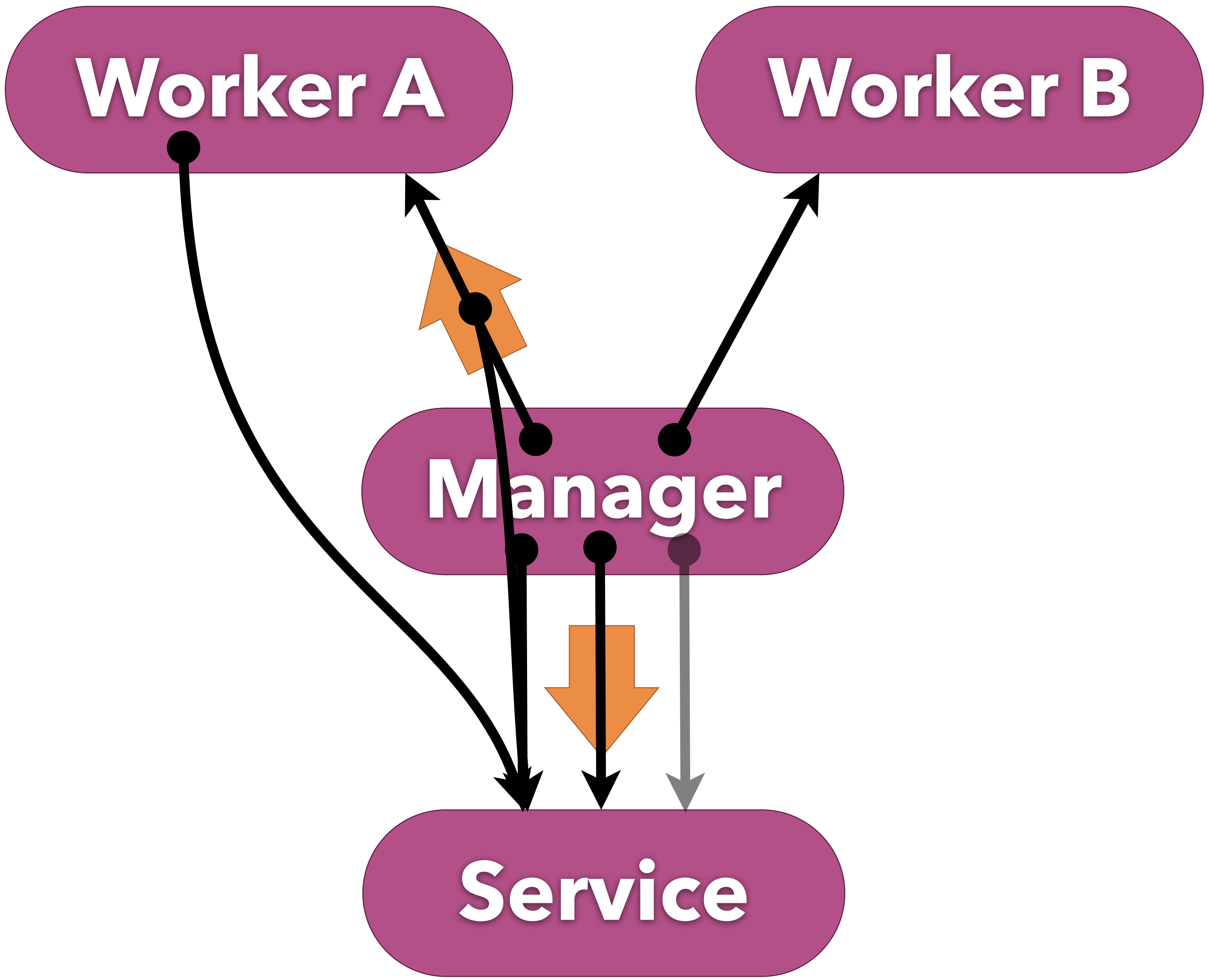
HOW TO USE?

- invocation of any object requires a capability to that object
  - no global names
- no sophisticated rights representation beyond capability ownership
  - just four rights bits on objects
- C++ language integration
- capabilities passed as message payload

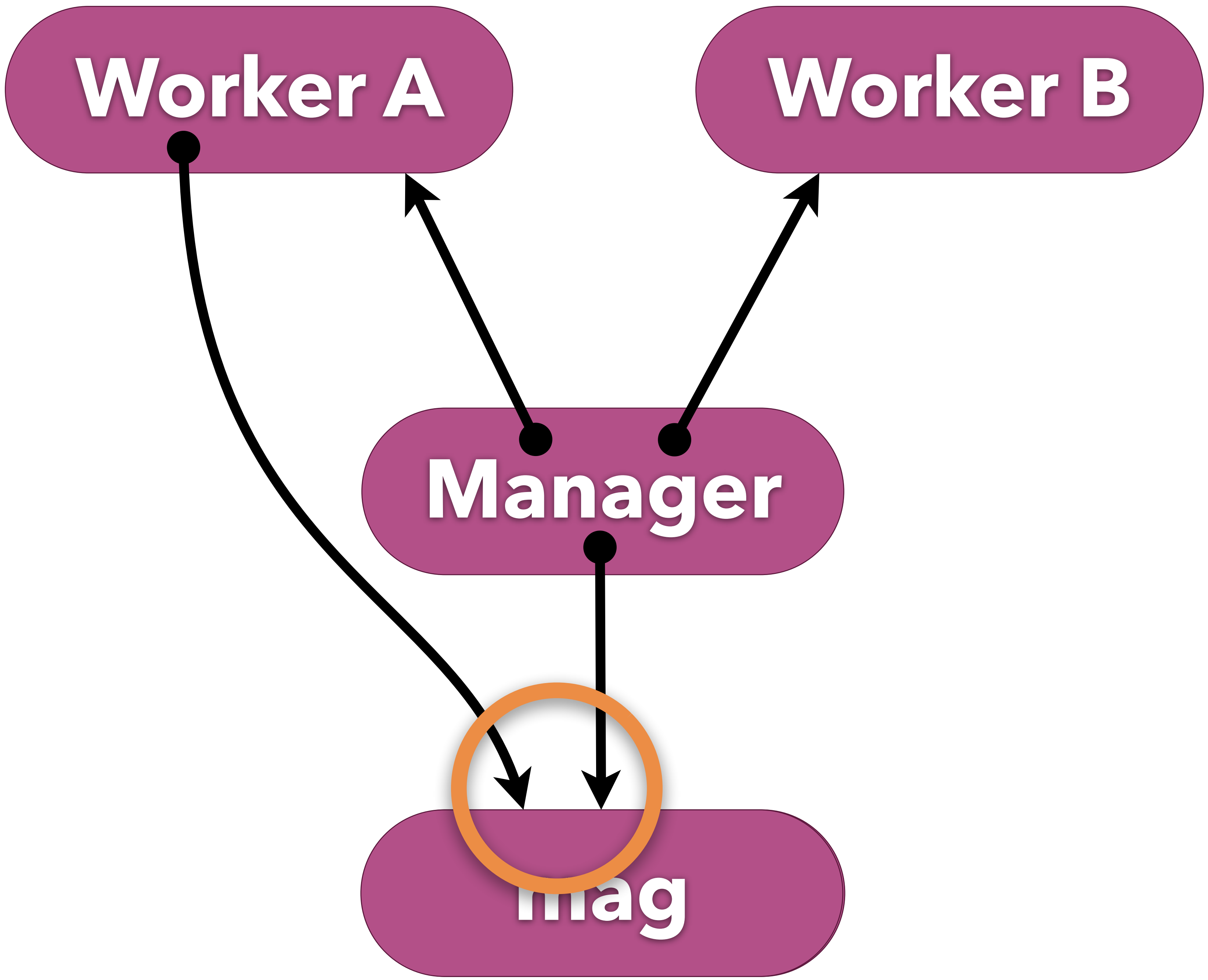
CAP TRANSFER



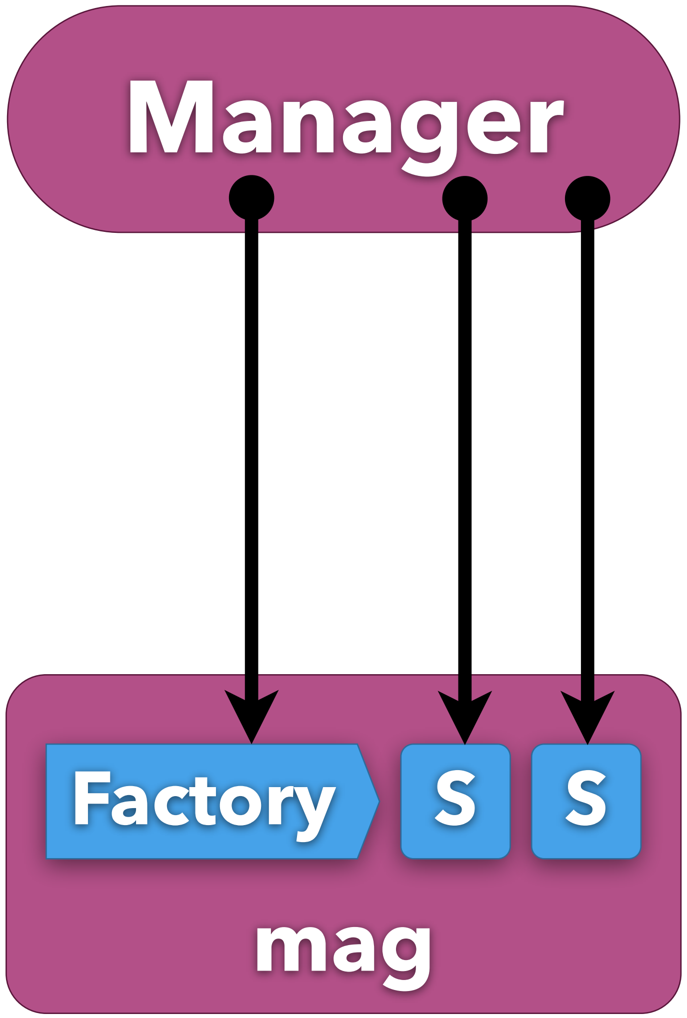
EXAMPLE



EXAMPLE

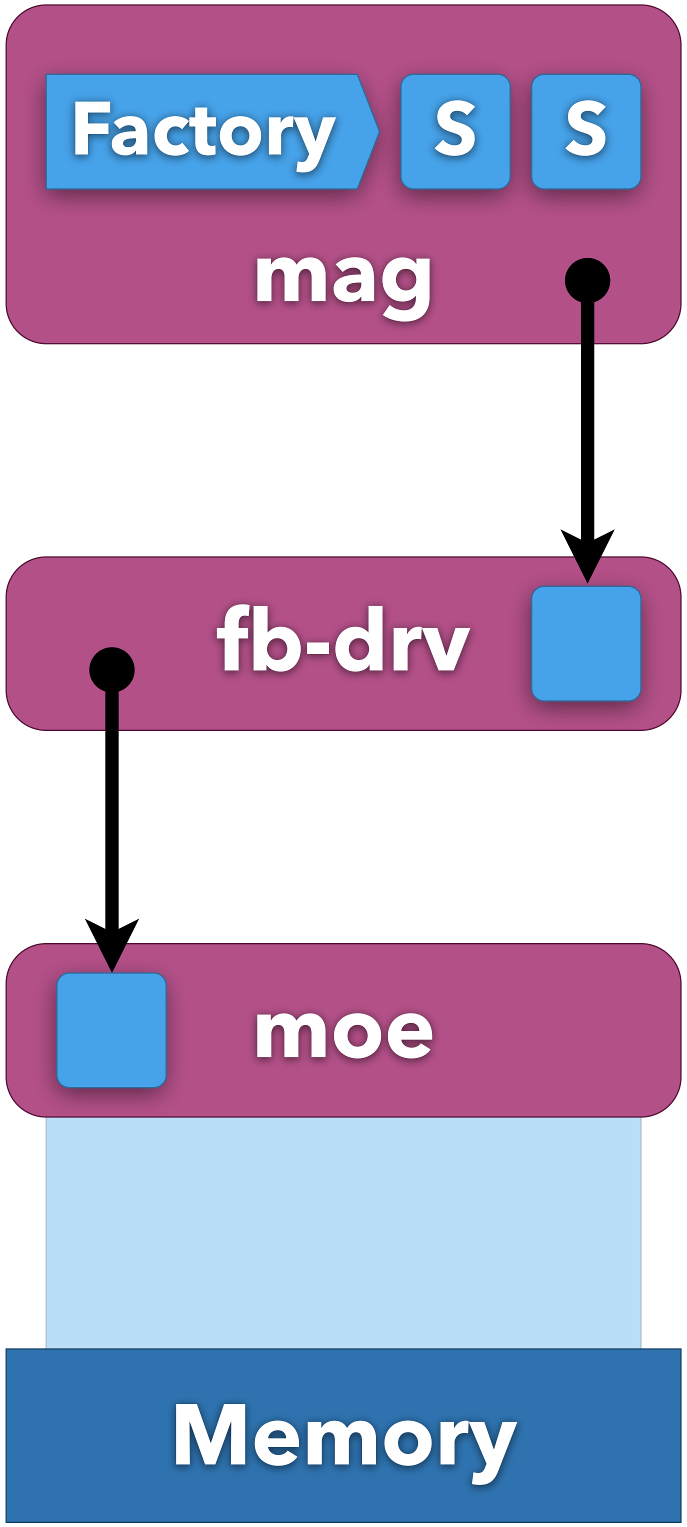


MAG



- factory for new framebuffer sessions
- session object
  - backing store memory
  - view: visible rectangle on the backing store
  - metadata, refresh method
- How does it appear on the screen?

MAG



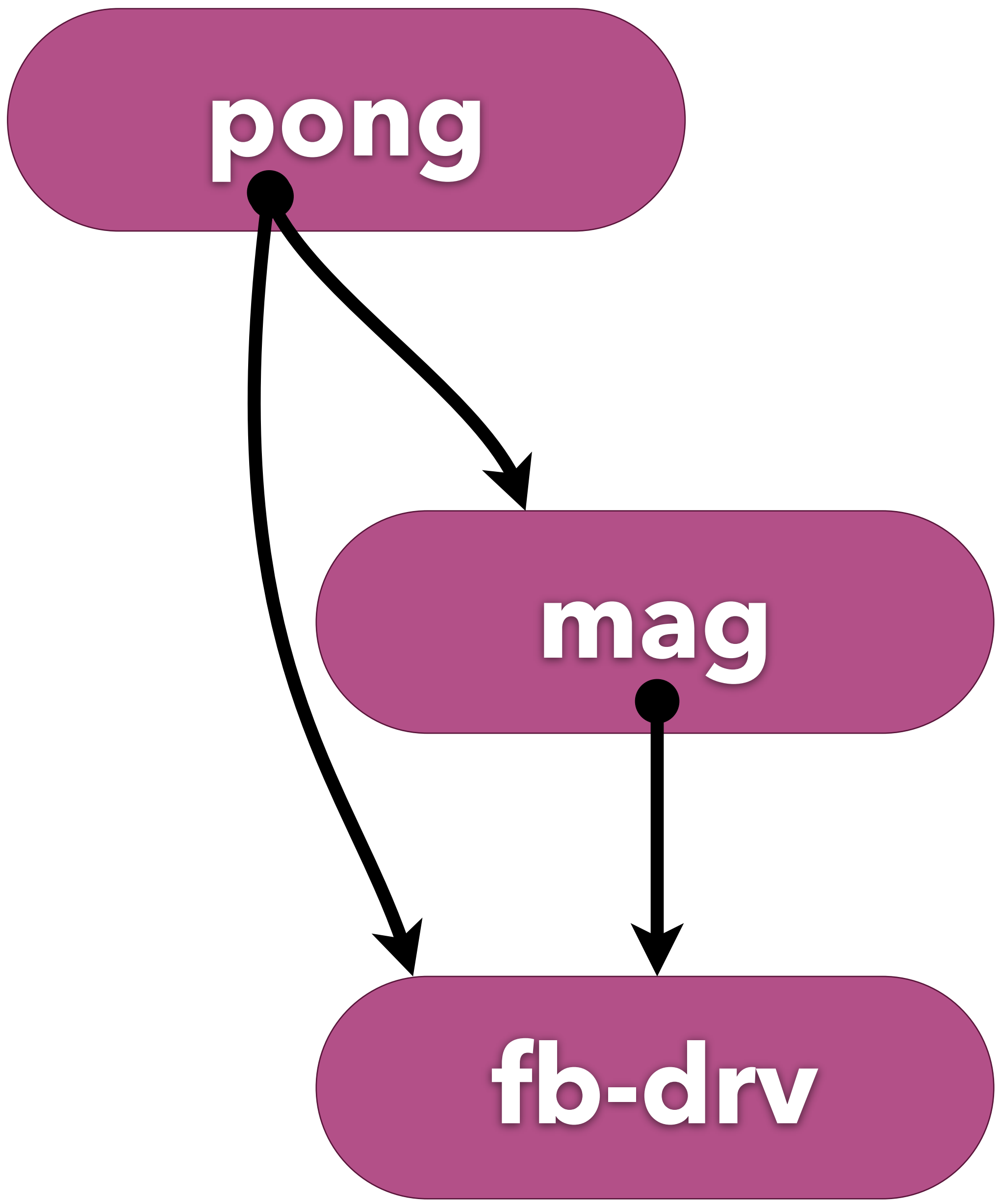
- hardware framebuffer is memory with side effect
- all memory is initially mapped to the root task
- **framebuffer driver**
  - find framebuffer memory
  - wrap in FB-interface
- same interface as mag

INTERFACES

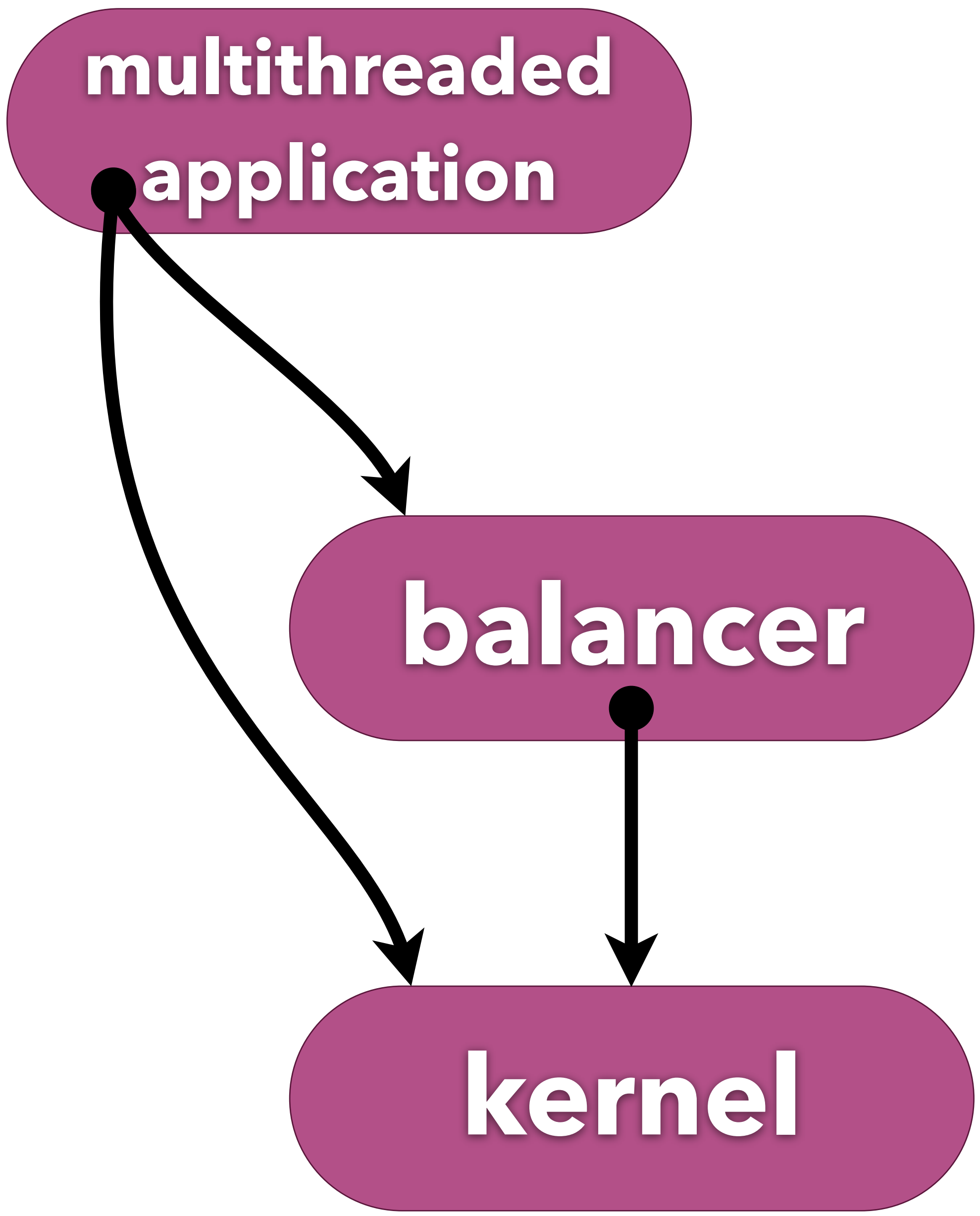
- **virtualizable interfaces**
- L4Re uses one interface per resource
  - independent of the implementation
  - servers can (re-)implement any interface
- the kernel is a special server: provides low-level objects that need CPU privileges
  - minimal policy
  - userland servers can augment

EXAMPLES

Graphics



Thread scheduling



CONCLUSION

- all services provided as objects
- uniform access control with capabilities
- invocation is the only system call
- virtualizable: all interfaces can be interposed
- resource refinement and multiplexing transparent to clients

SUMMARY

- kernel resource management
- basic resource management concepts
  - resource containers
  - exokernel
  - multiserver
- management details for specific resources
- object capabilities and virtualizable interfaces