NIZZA

Hermann Härtig
TU Dresden ♦OS
August 2004

Dresden

dresden – past, present and future

capital of saxony

more than 800 years history

half million inhabitants

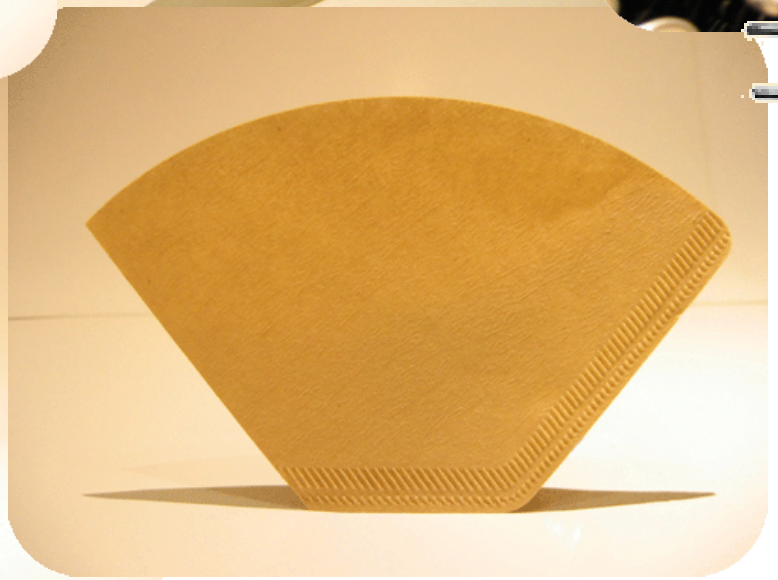
center of saxon silicon valley

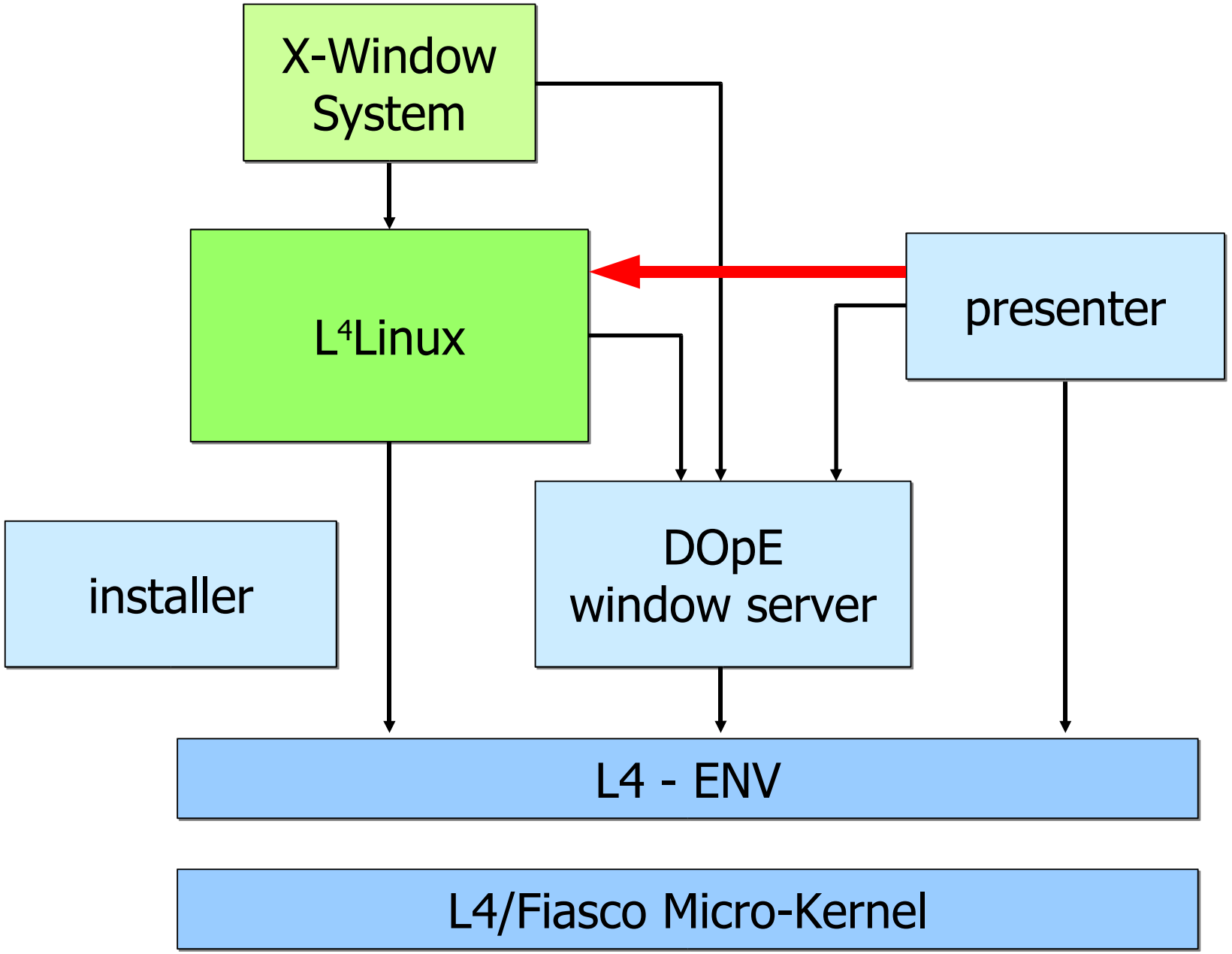
dresden - impressions

dresden – art collections

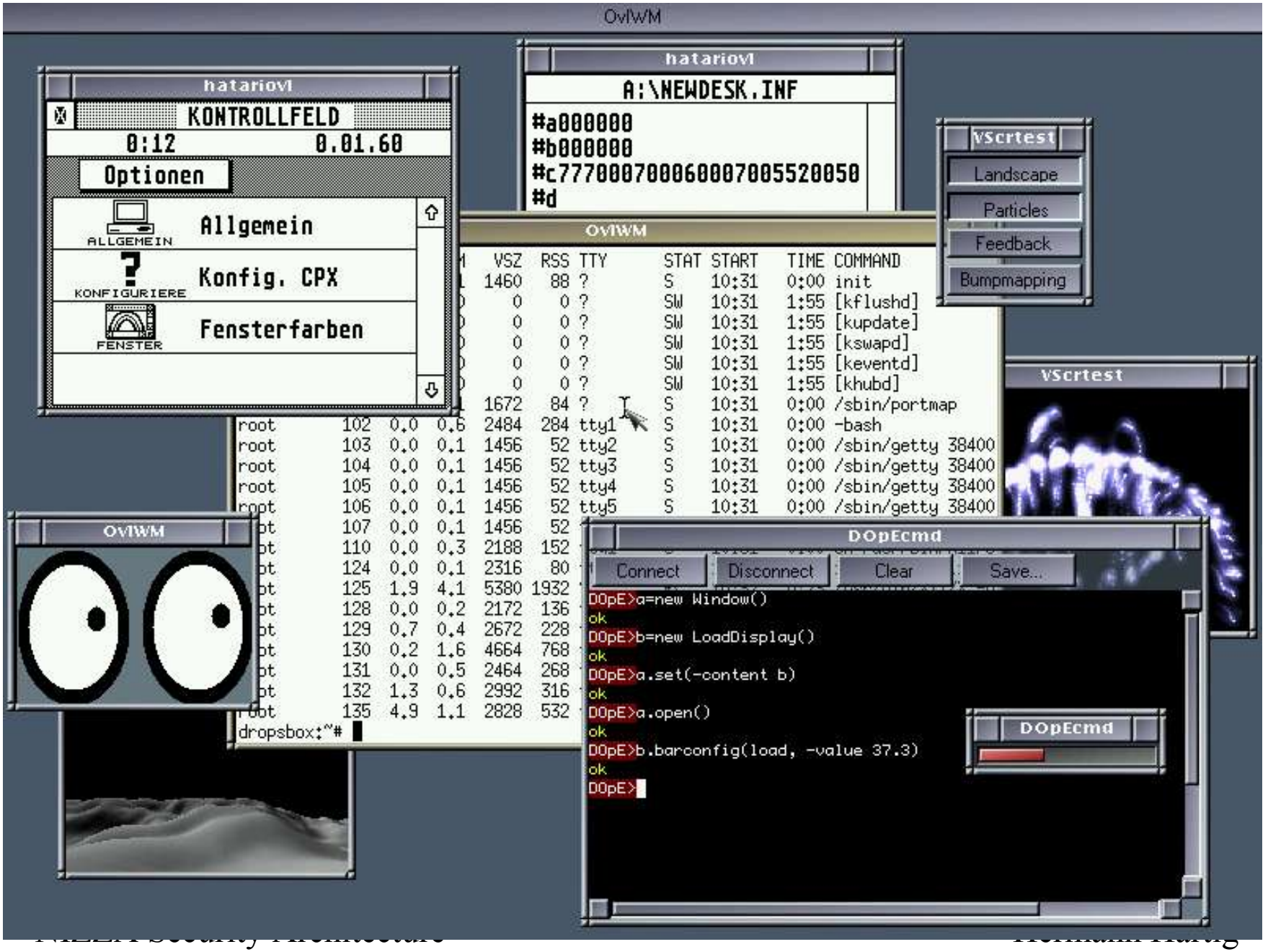
dresden – home of expressionism

inventions - made in dresden

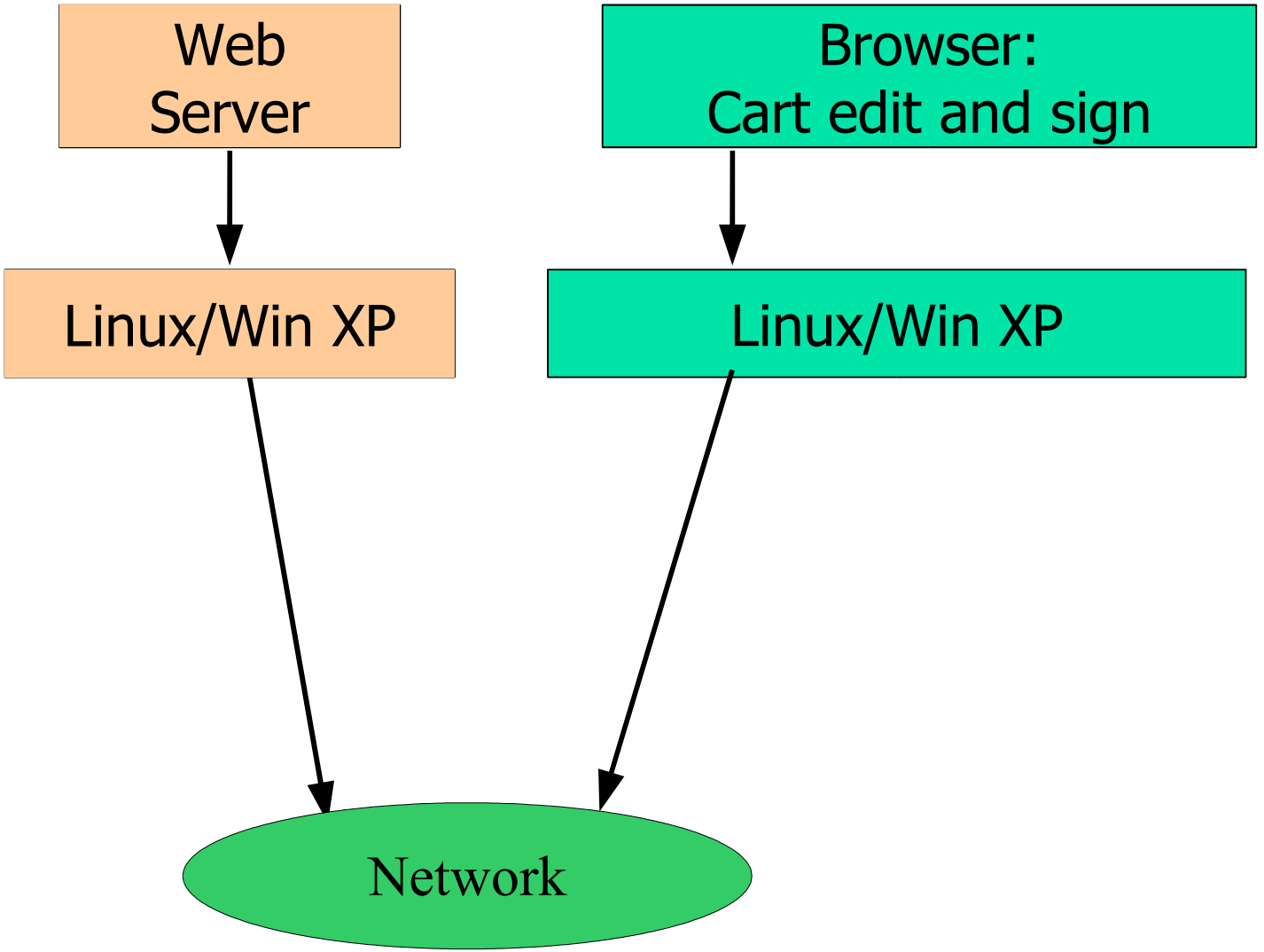



X-Window System
L4Linux
presenter
installer
DOpE window server
L4 - ENV
L4/Fiasco Micro-Kernel

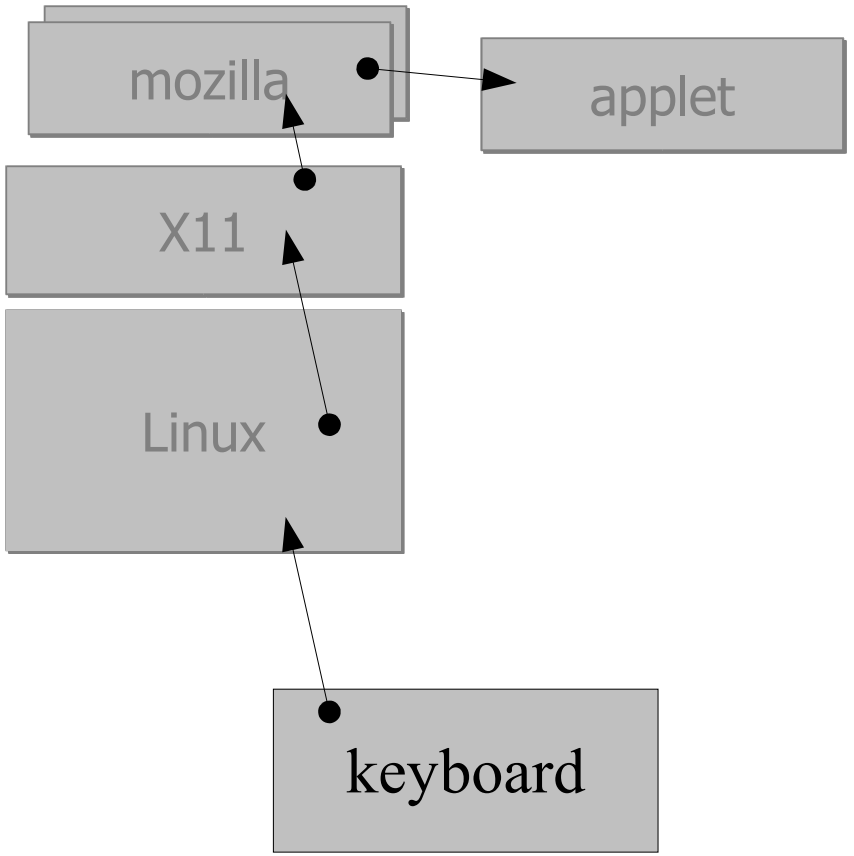
Screen Shot


OvlWM
hatariovl
KONTROLLFELD
0:12
0.01.60
Optionen
Allgemein
Konfig. CPX
Fensterfarben
ALLGEMEIN
KONFIGURIERE
FENSTER
hatariovl
A:\NEWDESK.INF
#a000000
#b000000
#c777000700060007005520050
#d
VScrtest
Landscape
Particles
Feedback
Bumpmapping
OvlWM
VSZ RSS TTY STAT START TIME COMMAND
1460 88 ? S 10:31 0:00 init
0 0 ? SW 10:31 1:55 [kflushd]
0 0 ? SW 10:31 1:55 [kupdate]
0 0 ? SW 10:31 1:55 [kswapd]
0 0 ? SW 10:31 1:55 [keventd]
0 0 ? SW 10:31 1:55 [khubd]
1672 84 ? S 10:31 0:00 /sbin/portmap
root 102 0.0 0.6 2484 284 tty1 S 10:31 0:00 -bash
root 103 0.0 0.1 1456 52 tty2 S 10:31 0:00 /sbin/getty 38400
root 104 0.0 0.1 1456 52 tty3 S 10:31 0:00 /sbin/getty 38400
root 105 0.0 0.1 1456 52 tty4 S 10:31 0:00 /sbin/getty 38400
root 106 0.0 0.1 1456 52 tty5 S 10:31 0:00 /sbin/getty 38400
dropsbox:~#
VScrtest
OvlWM
DOpEcmd
Connect
Disconnect
Clear
Save...
DOpE>a=new Window()
ok
DOpE>b=new LoadDisplay()
ok
DOpE>a.set(-content b)
ok
DOpE>a.open()
ok
DOpE>b.barconfig(load, -value 37.3)
ok
DOpE>
DOpEcmd

Internet Transaction



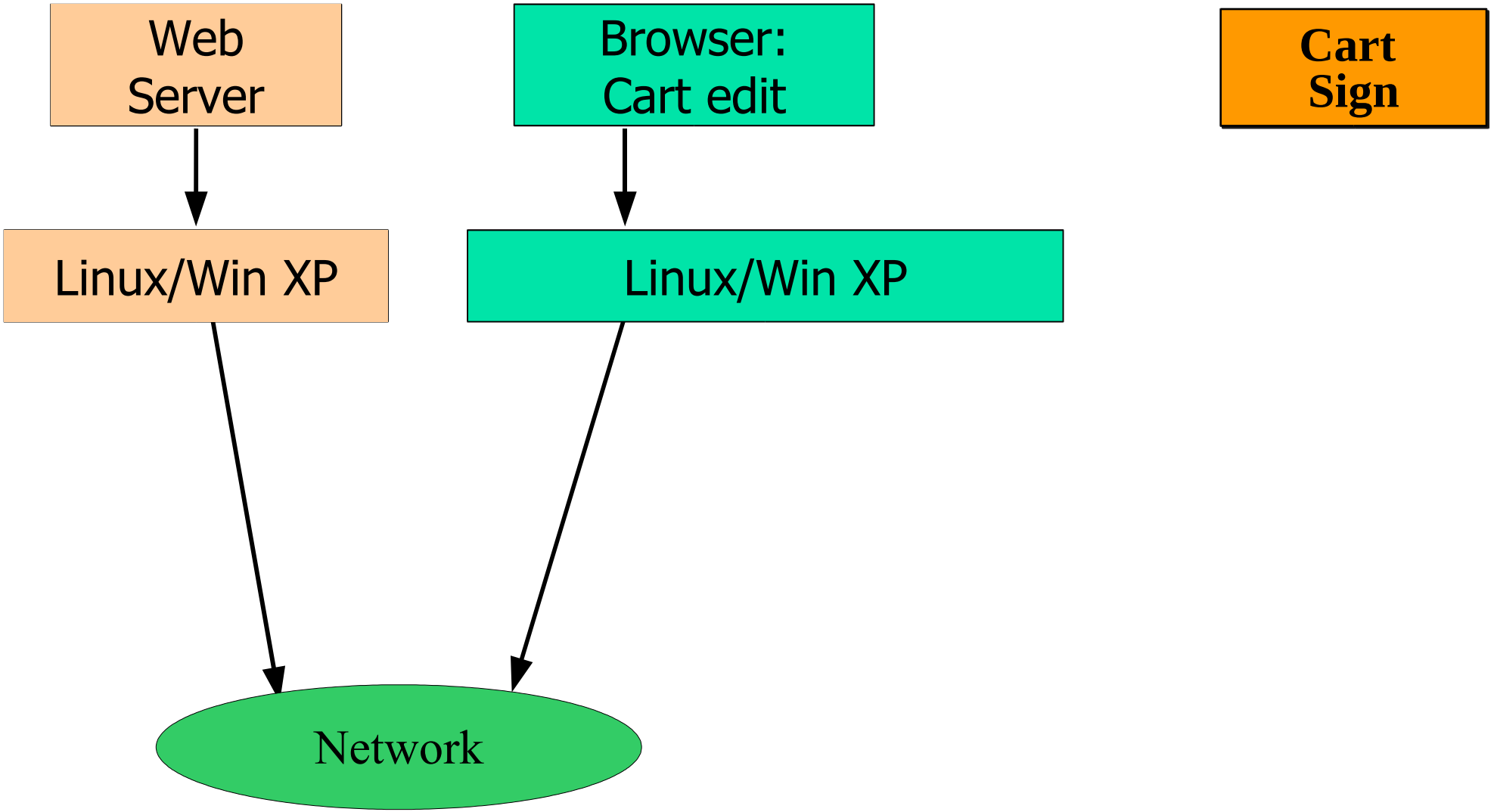
Your password(s), credit card number, ...



see:

Understanding Data Lifetime
via Whole System Simulation
Jim Chow, Ben Pfaff, Tal Garfinkel, Kevin Christopher, and Mendel Rosenblum, Stanford University
Usenix Security 04

Lenin's Transaction



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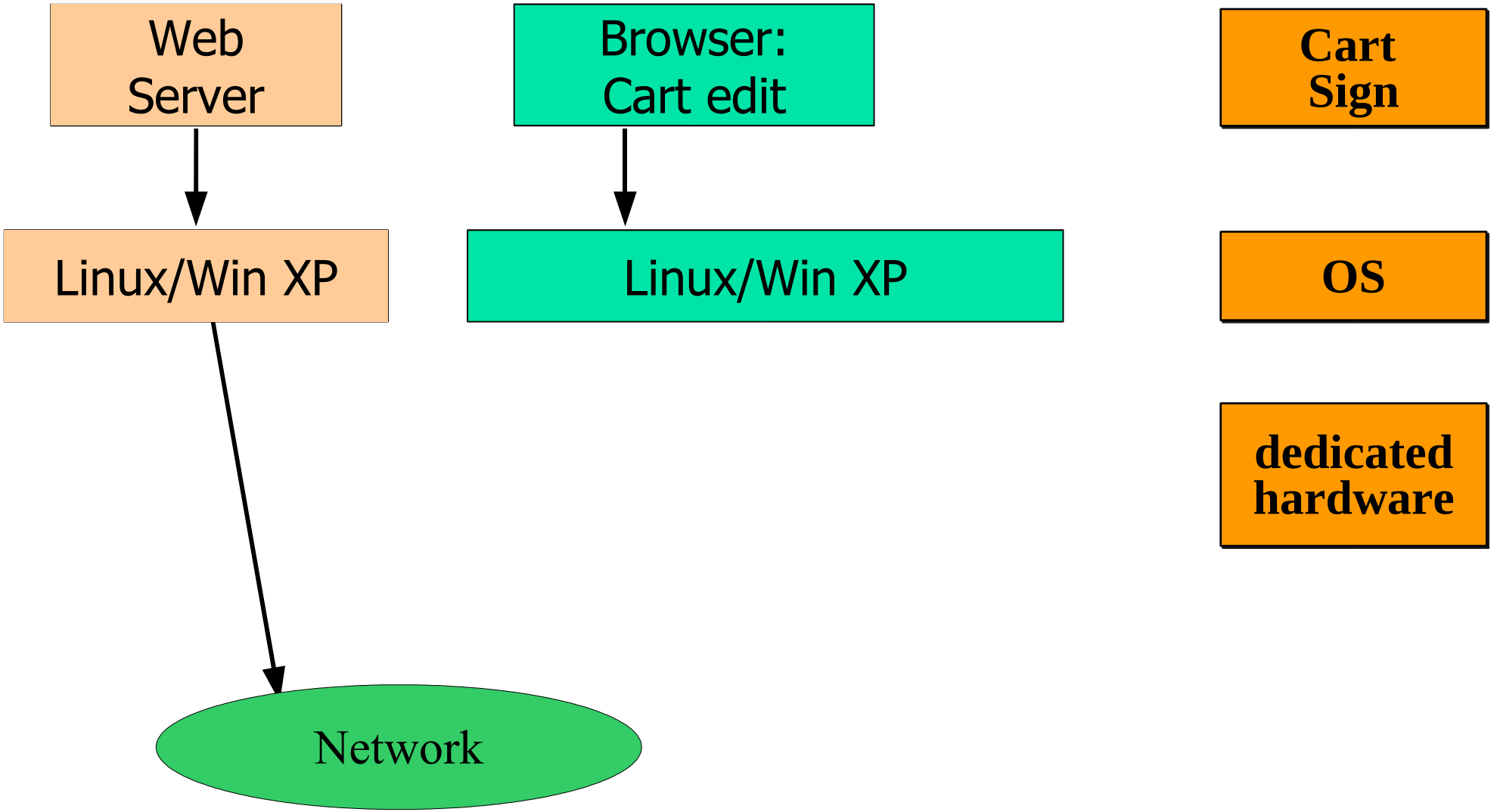

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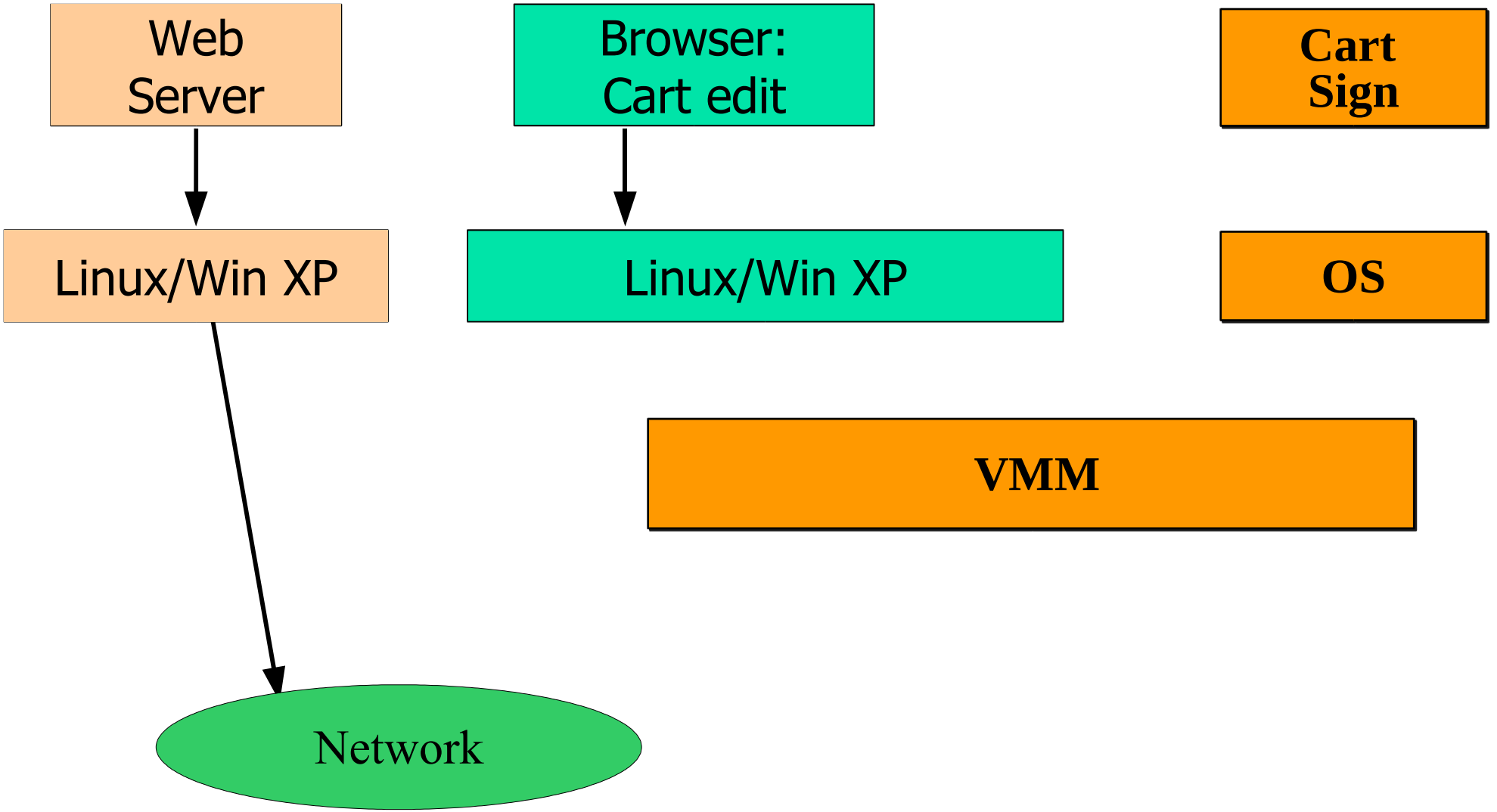

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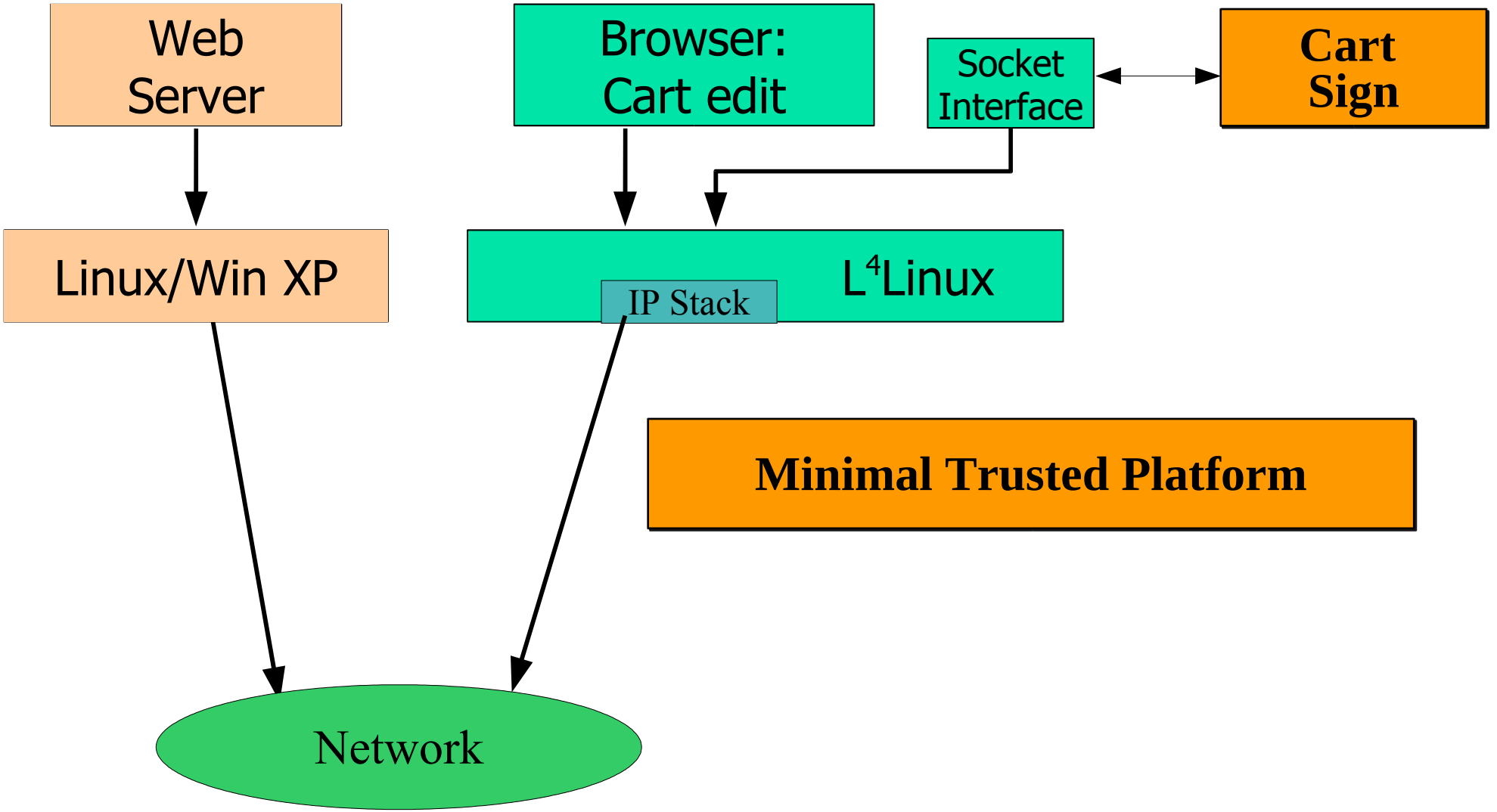

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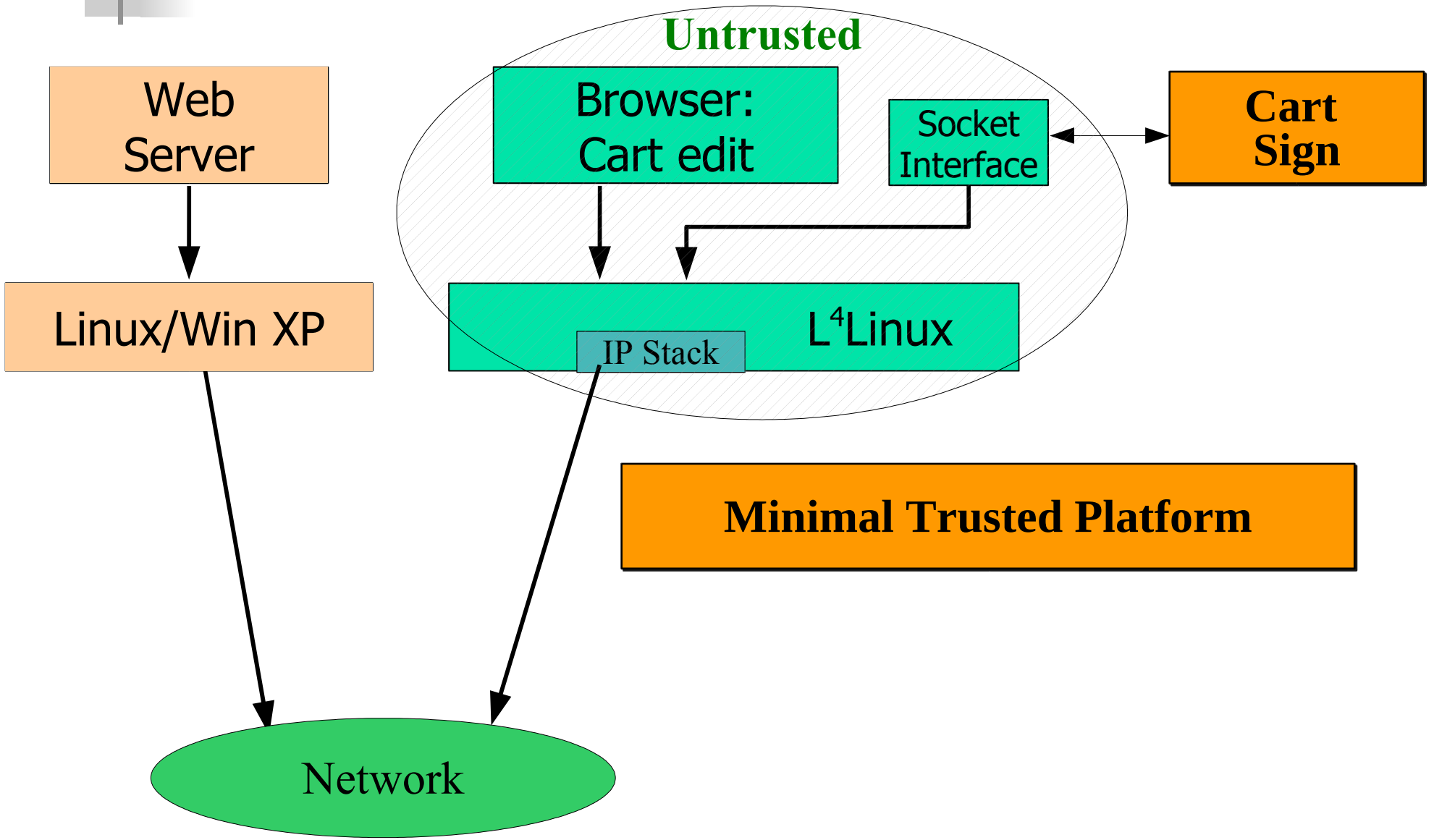

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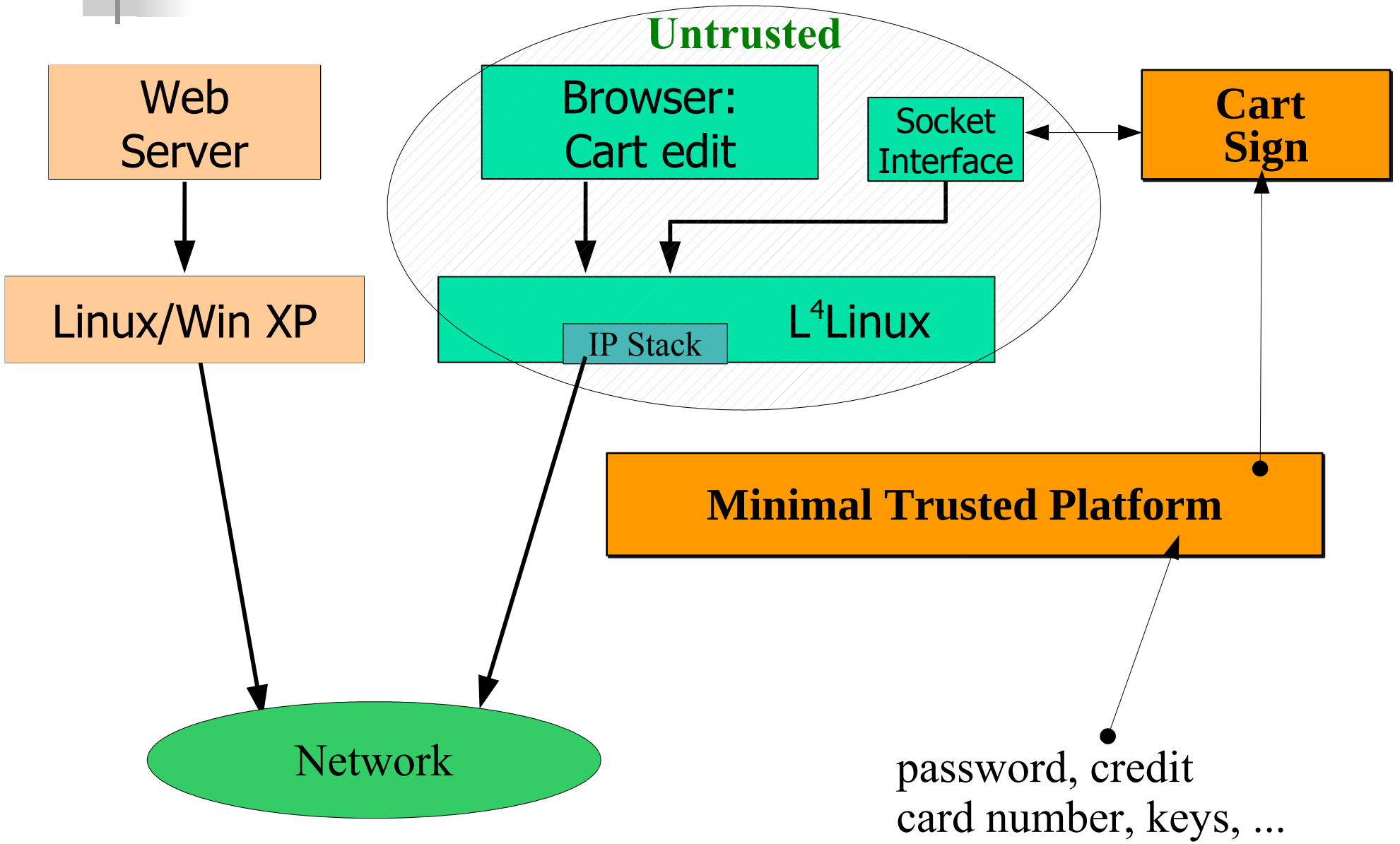
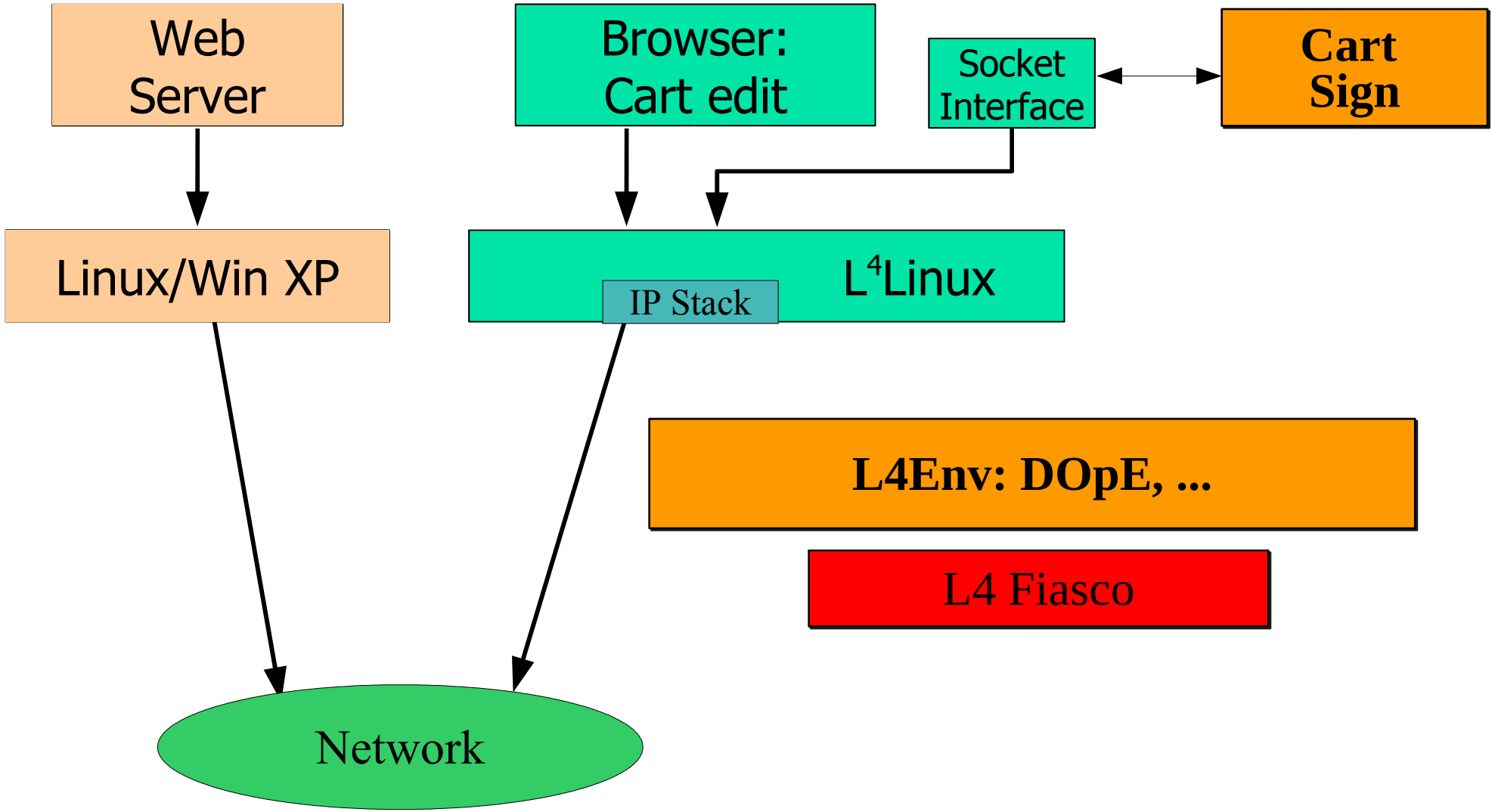
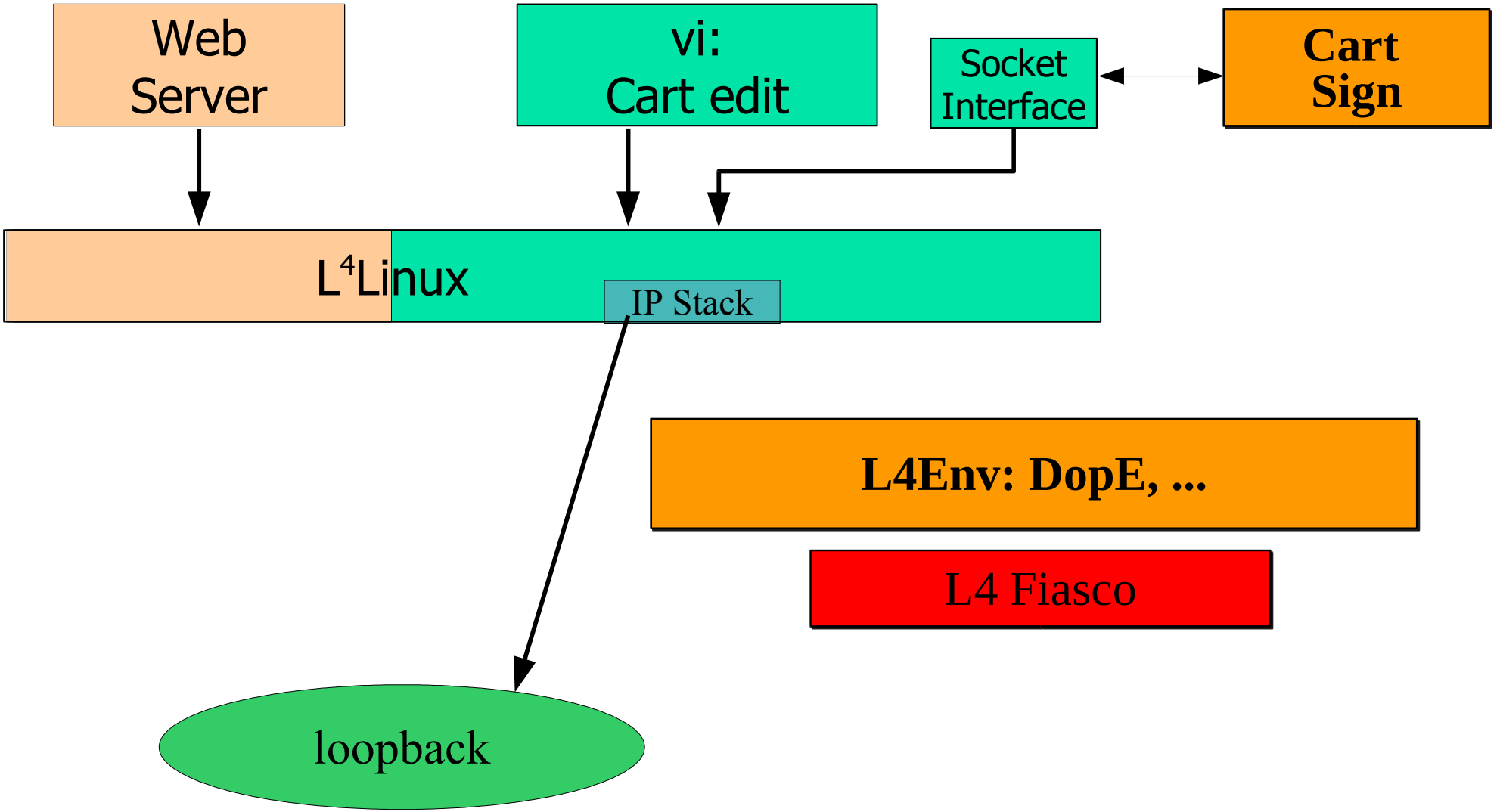


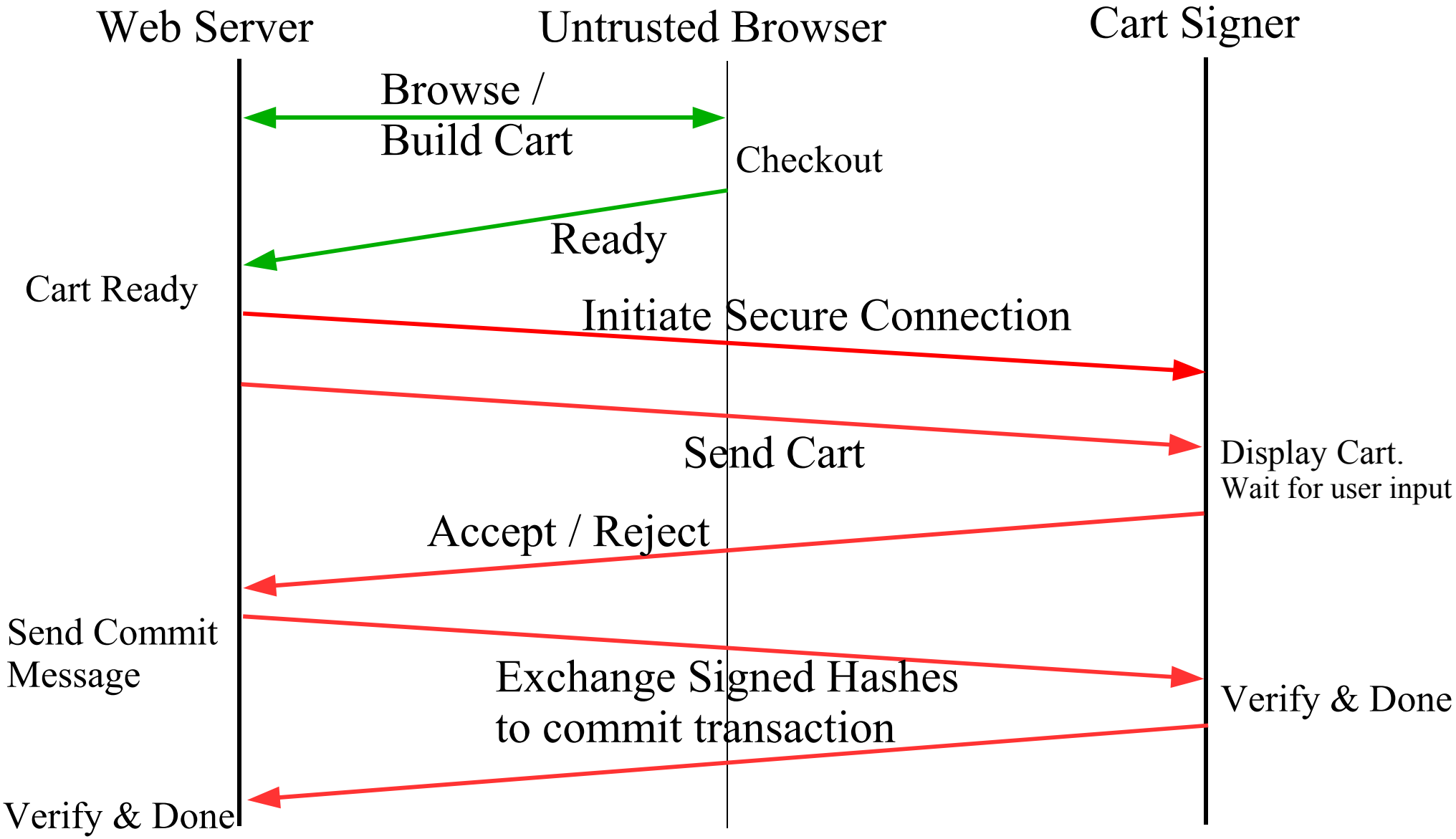
Lenin's Demo


Web Server
Browser: Cart edit
Socket Interface
Cart Sign
Linux/Win XP
L4Linux
IP Stack
L4Env: DOpE, ...
L4 Fiasco
Network

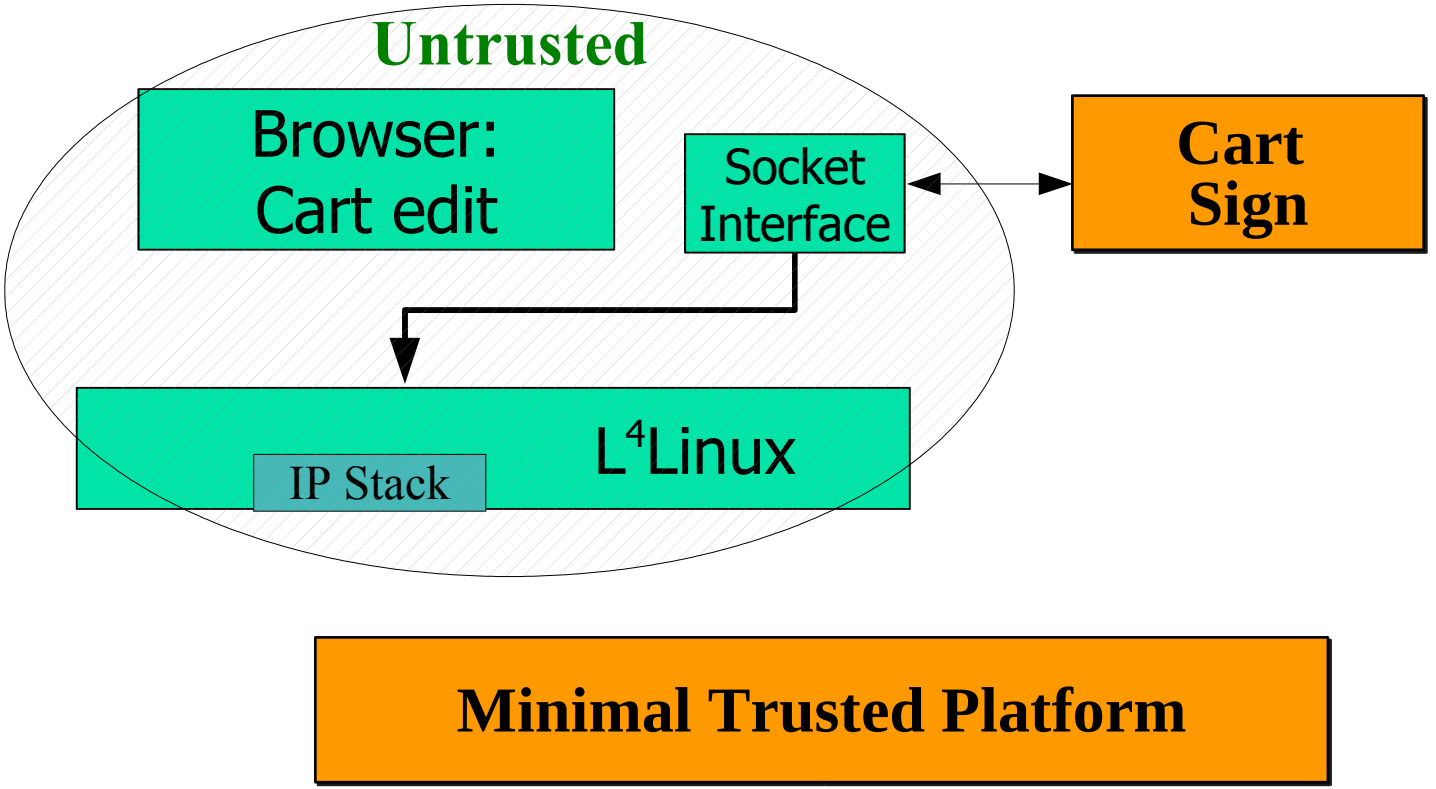
Lenin's Demo


Web Server
vi: Cart edit
Socket Interface
Cart Sign
L4Linux
IP Stack
L4Env: DopE, ...
L4 Fiasco
loopback

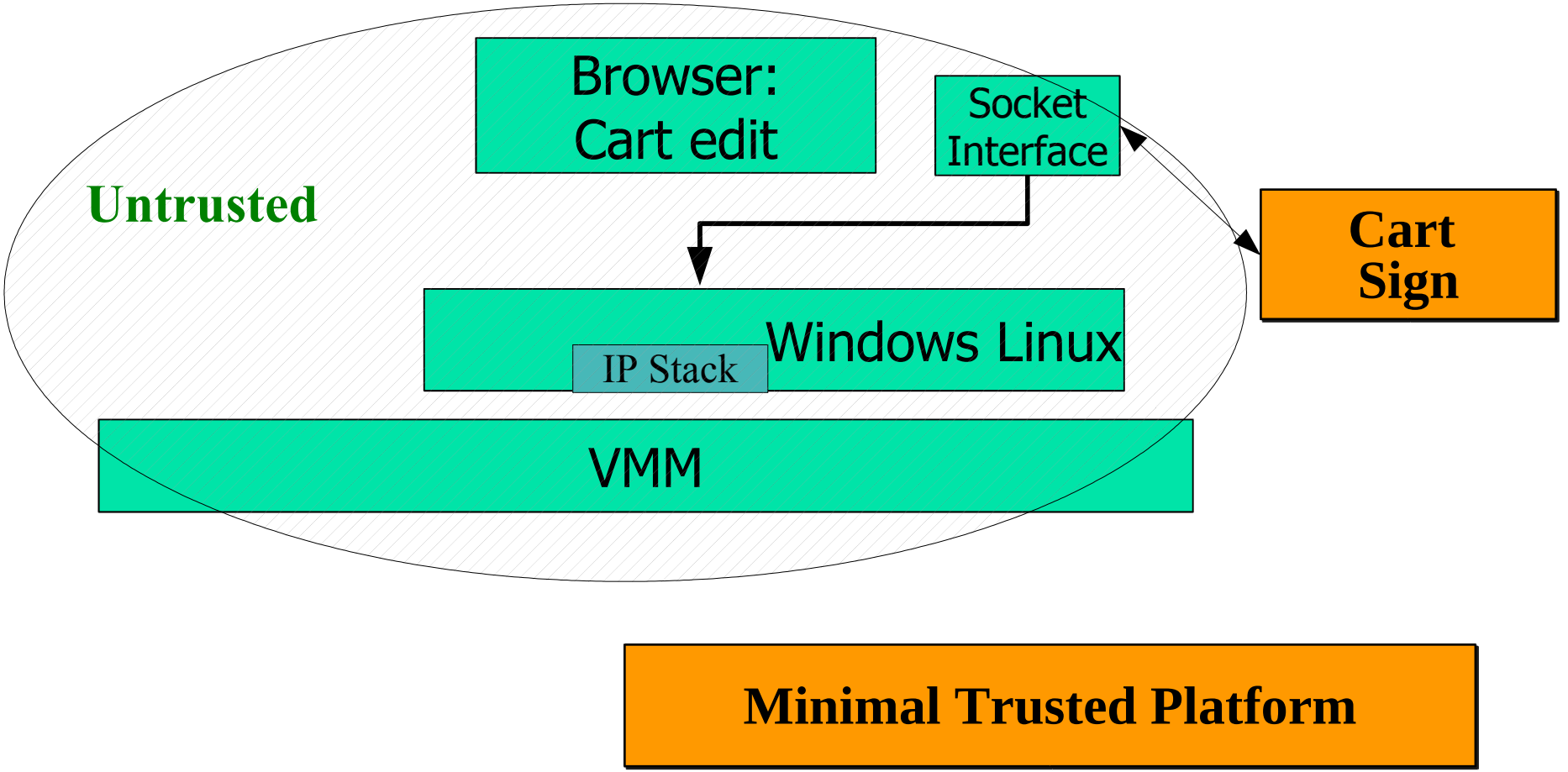
Message Sequence

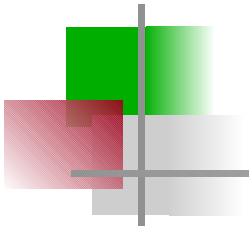


Challenge: Untrusted VMM



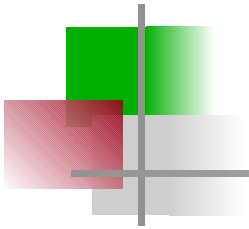
Challenge: Untrusted VMM





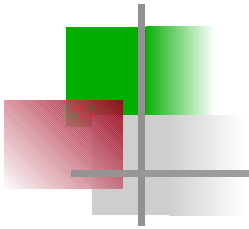
Outline

- propaganda
- some names
- security and system security objectives
- design principles
- architecture and components
  - use cases
  - components: current and future
- Nizza vs. Virtual Machine Monitors and other related work
- technical risks



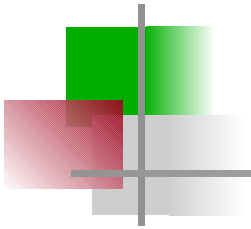
Names

- TUD♦OS Technische Universität Dresden OS
  - DROPS Dresden Real-Time OS
  - Nizza Security Architecture
    - Micro-Sina A Nizza Application (use case)
  - L^4Env set of servers and libraries
    - DOpE Window manager for DROPS and Nizza
  - L^4Linux Linux kernel as user-level server
- L4 a micro-kernel interface
- L4/Fiasco, L4/Pistacchio: L4 implementations



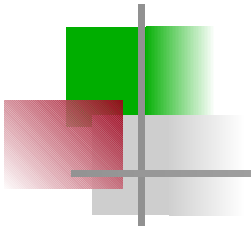
Objectives: Security

- confidentiality
  no unauthorized access to information
- integrity
  no unauthorized, **unnoticed** modification of information
- recoverability
  no permanent damage to information
- availability
  timeliness of service



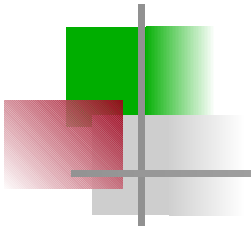
Objectives: System Security

- Secure and unsecure applications



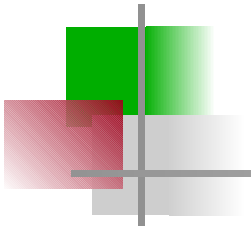
Objectives: System Security

- Secure and unsecure applications
- Compatibility:
  - Legacy applications
  - Legacy/Fashionable Hardware



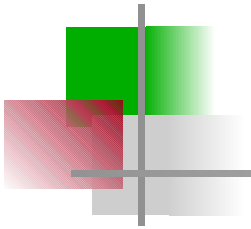
Objectives: System Security

- Secure and unsecure applications
- Compatibility
- Flexible sandboxing



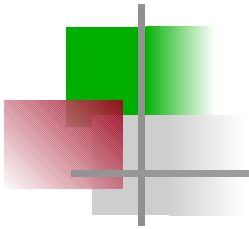
Objectives: System Security

- Secure and unsecure applications
- Compatibility
- Flexible sandboxing
- Resource Control



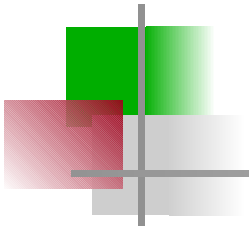
Objectives: System Security

- Secure and unsecure applications
- Compatibility
- Flexible sandboxing
- Resource Control
- Small TCB:
  complexity acceptable, if for a small group
  - Each member fully understands interaction of all components.
  - Each component is understood by one member.



Principles

- Trusted Computing Base: per application
- platform:
  - small set of small components (servers, ...)
  - small interfaces
  - select components of platform per application

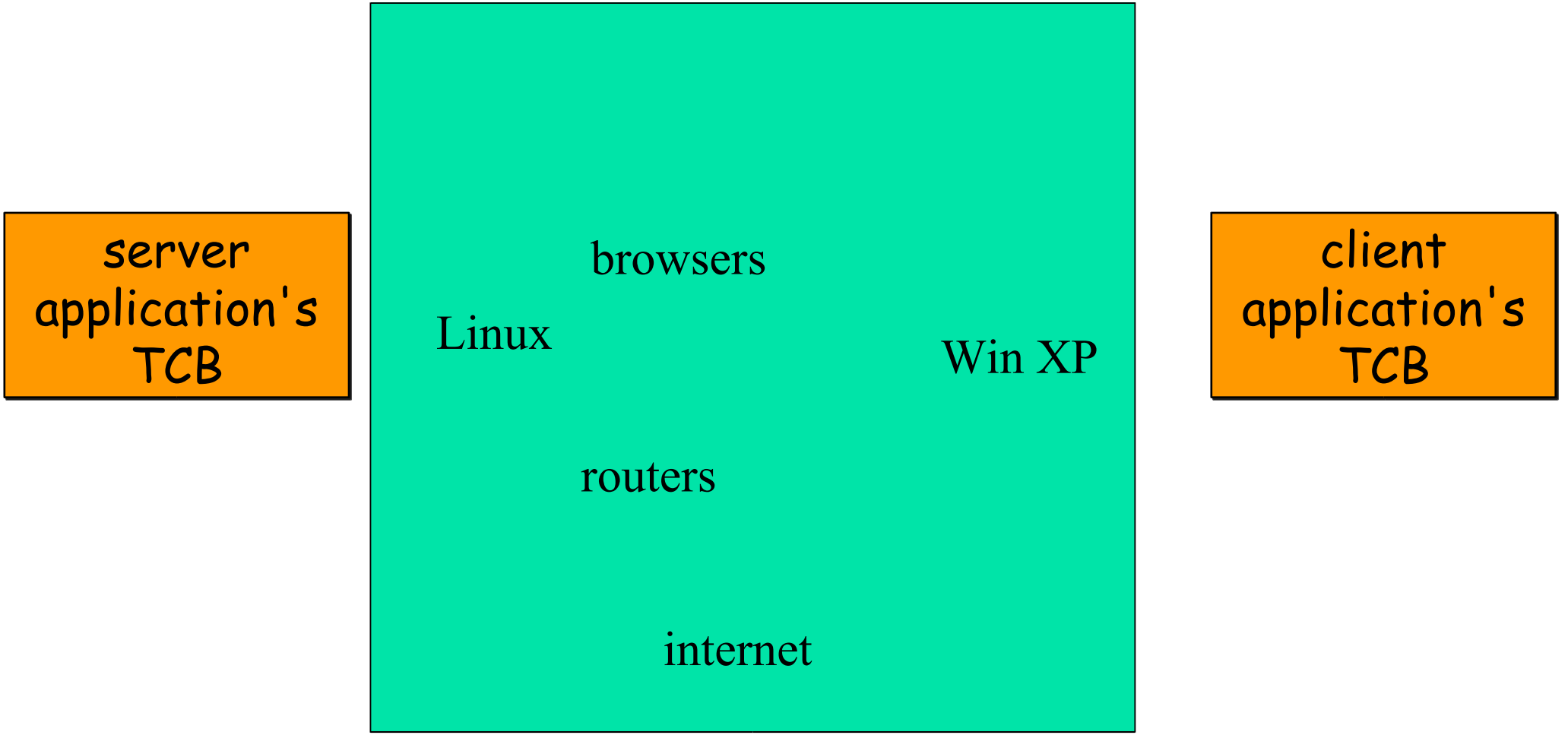


Principles, continued

- split applications and services:
  sensitive part in/on trusted platform
  and *other* part
- reuse legacy for *other* part
  –> trusted wrappers / tunneling

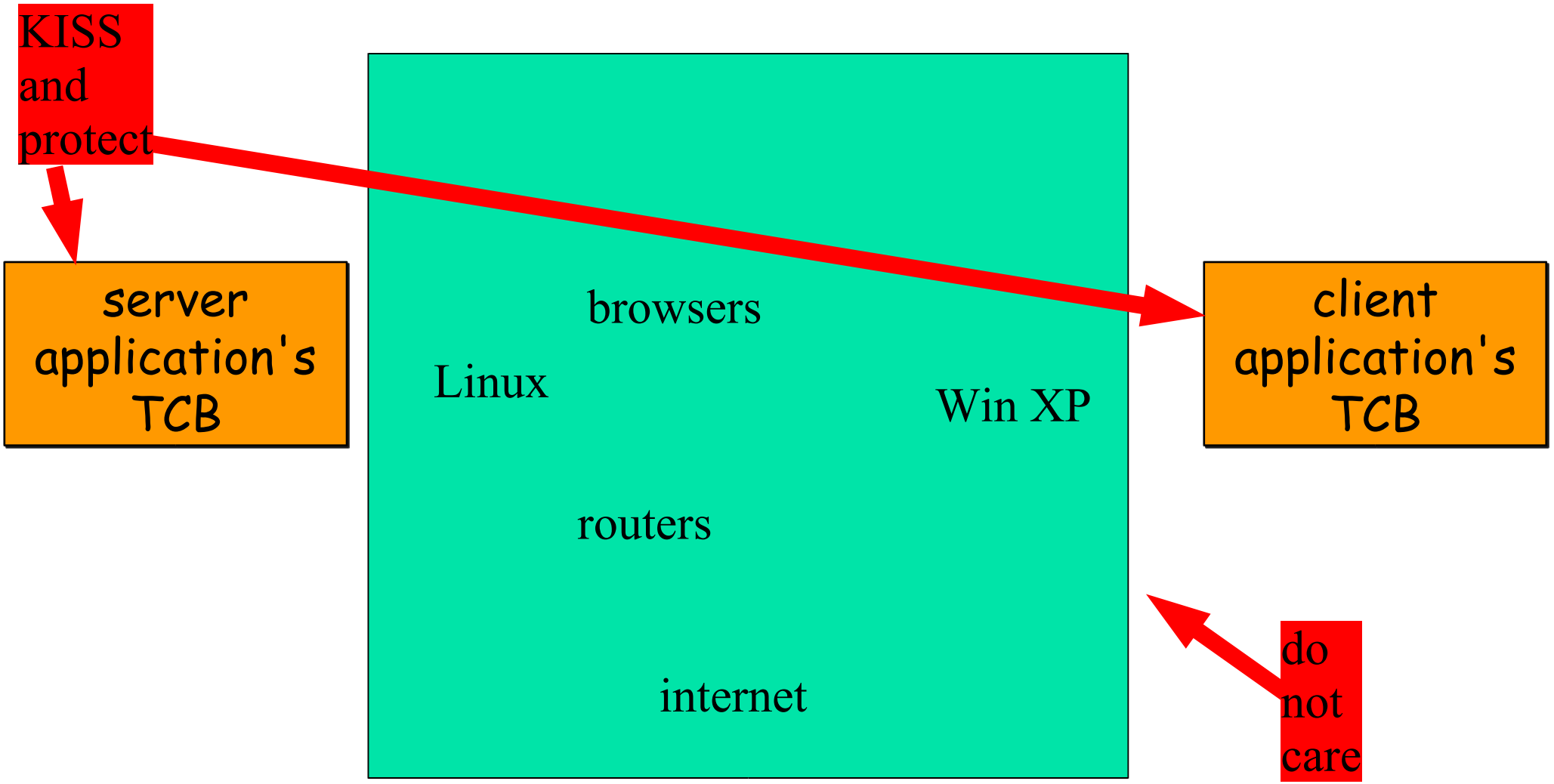
Principles

- push end-to-end argument to the extreme



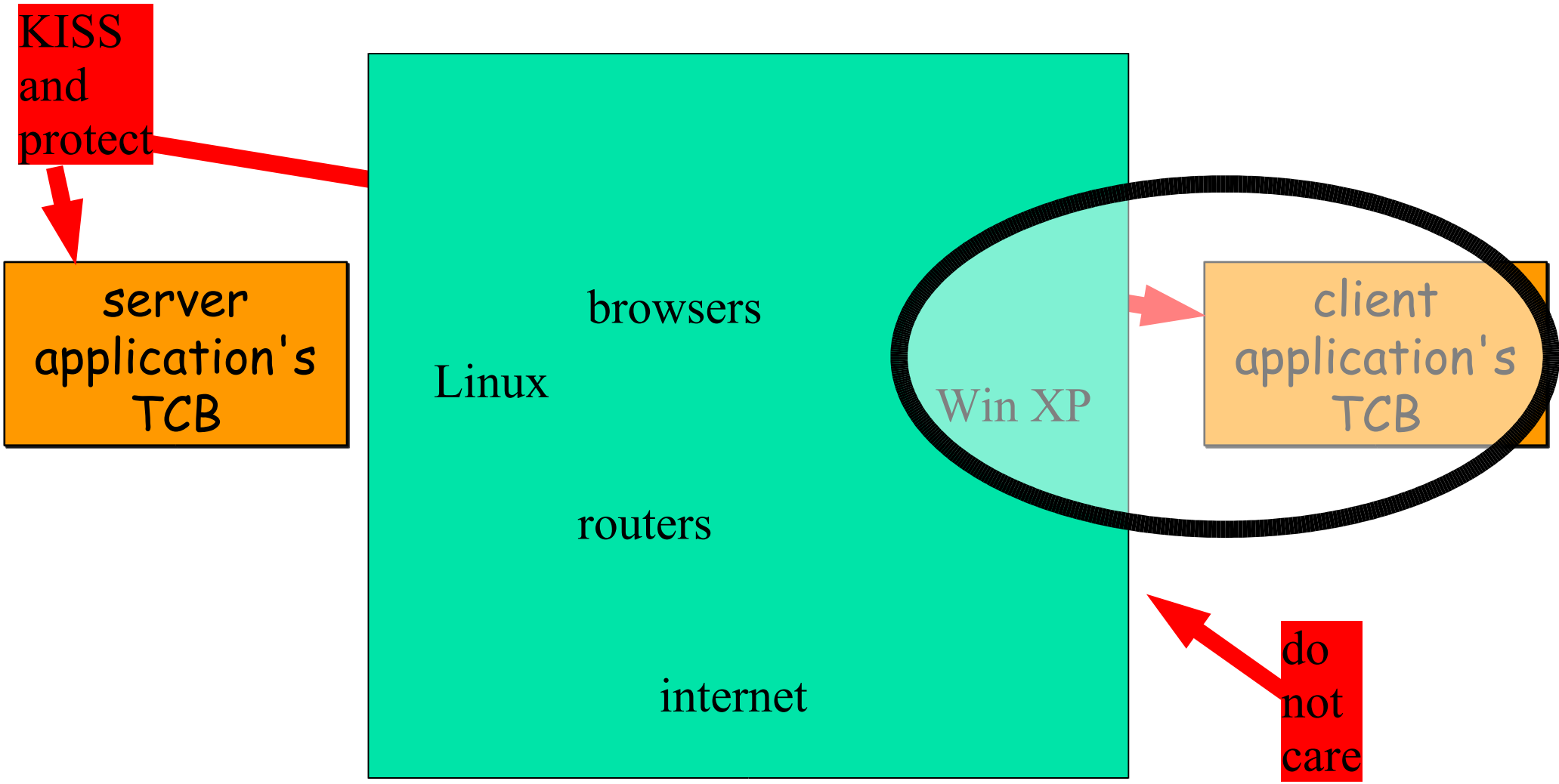
Principles

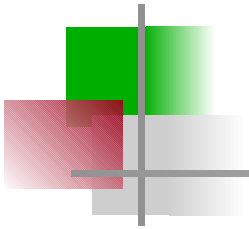
- push end-to-end argument to the extreme



Principles

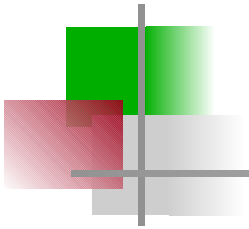
- push end-to-end argument to the extreme





Principles and Techniques

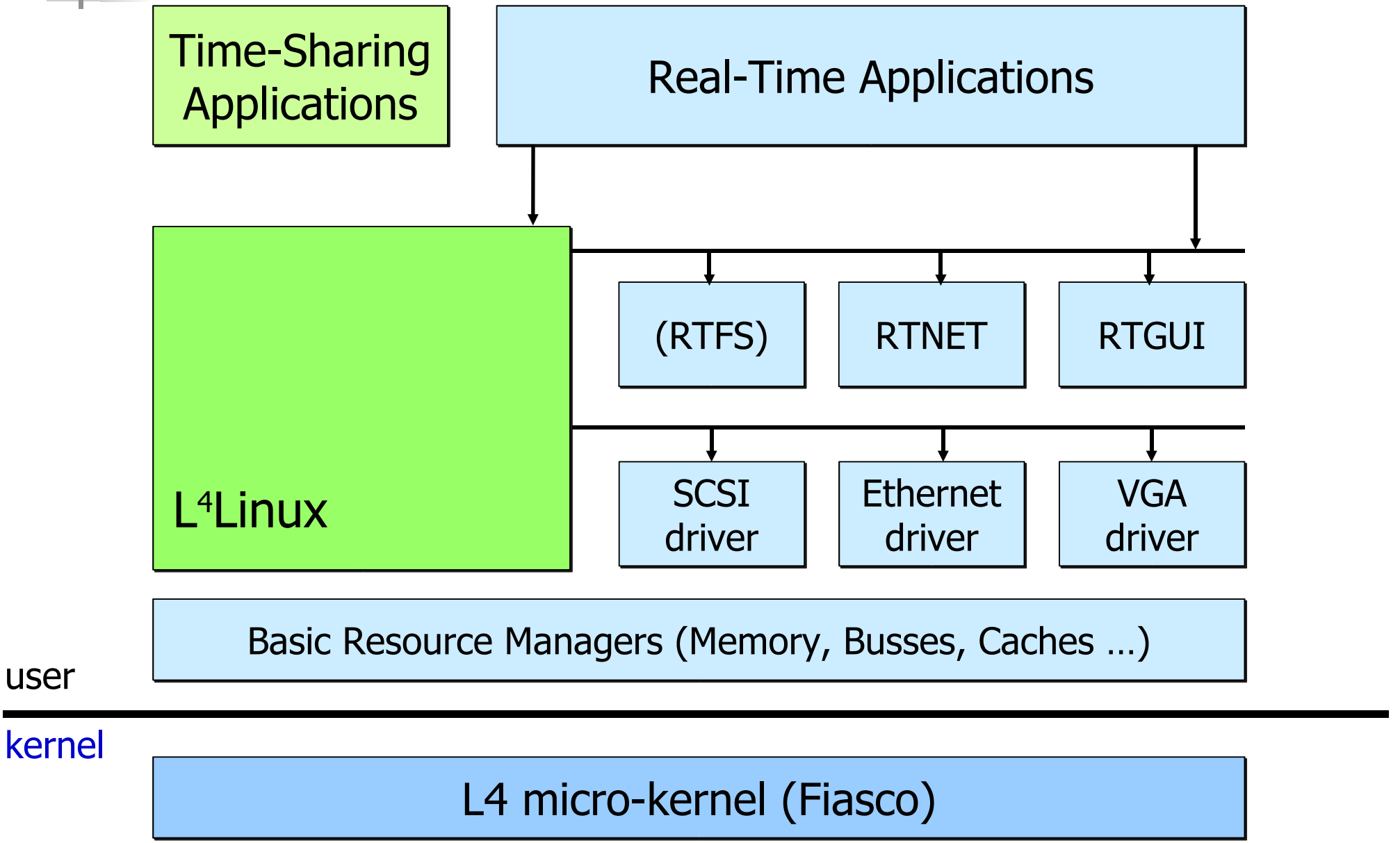
- micro kernel:
  - separates legacy from sensitive partitions
  - separates components of small platform
  - provides mechanisms for access control mediates communication
- contract-based access control
- secure booting / attestation + trusted path to user

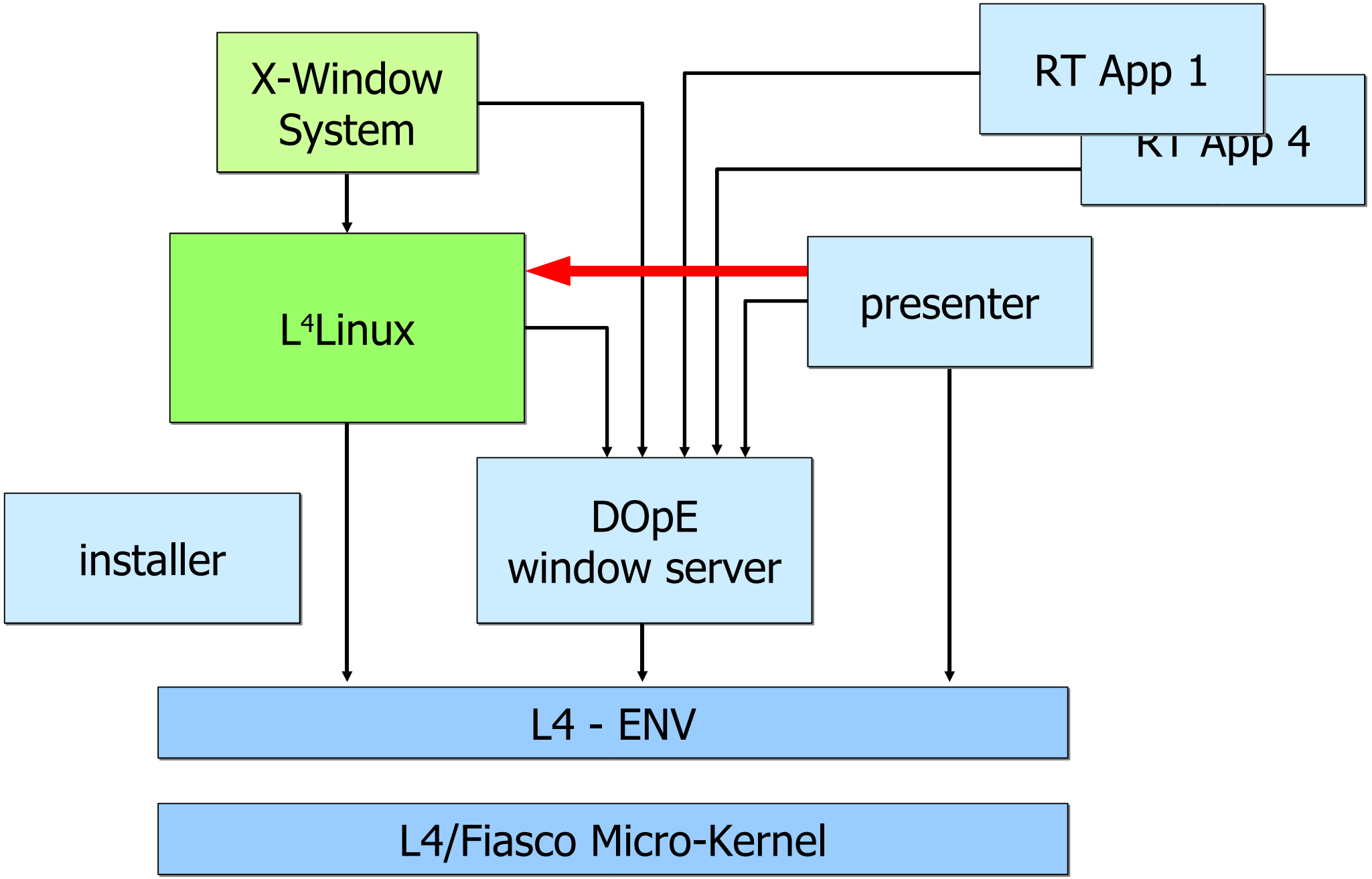


Architecture + Components

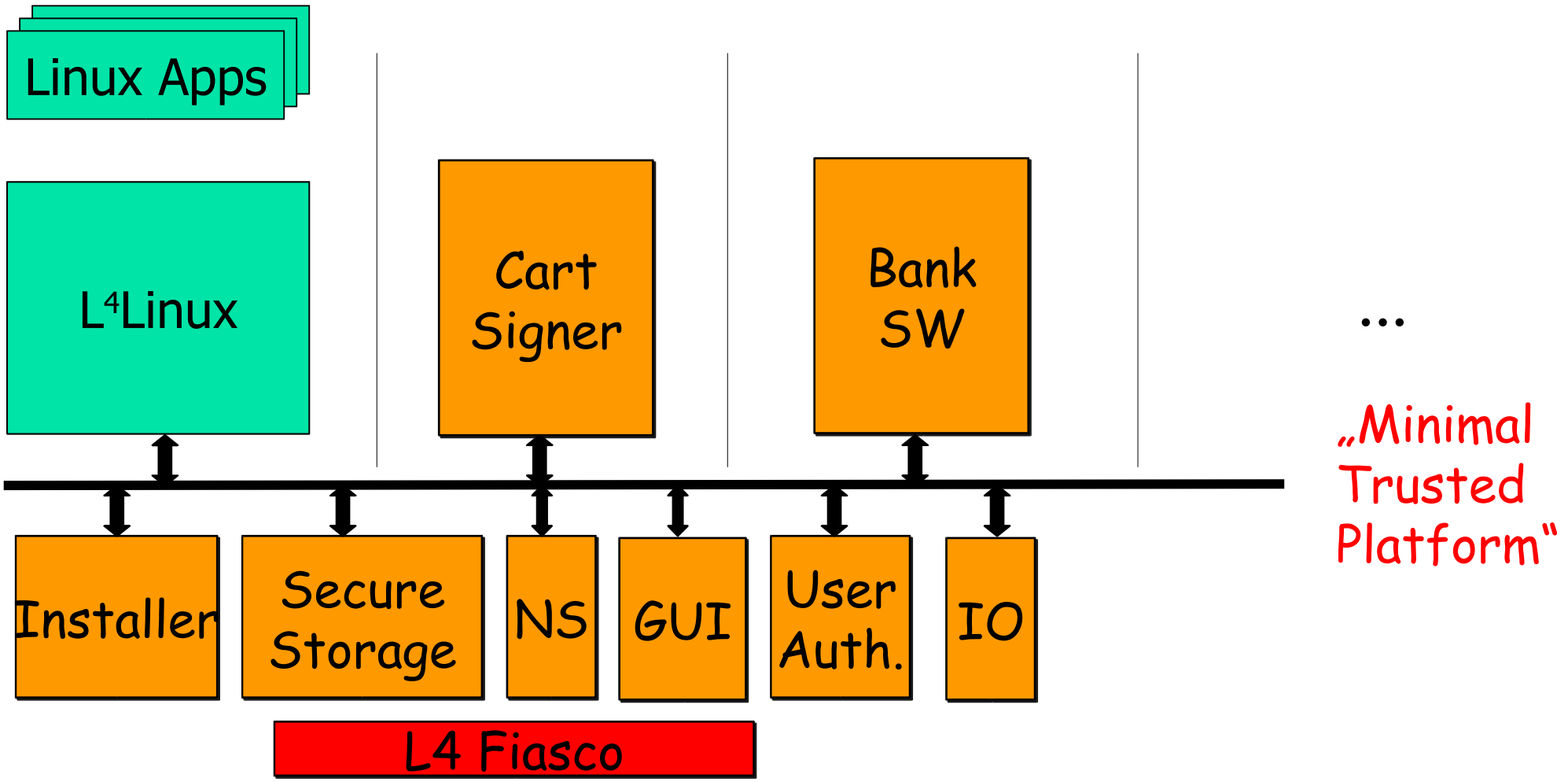
- the origin: Dresden Real-time OPerating System
- Nizza architecture
- use cases
- some Nizza components

Starting Point: DResden Real-Time OS

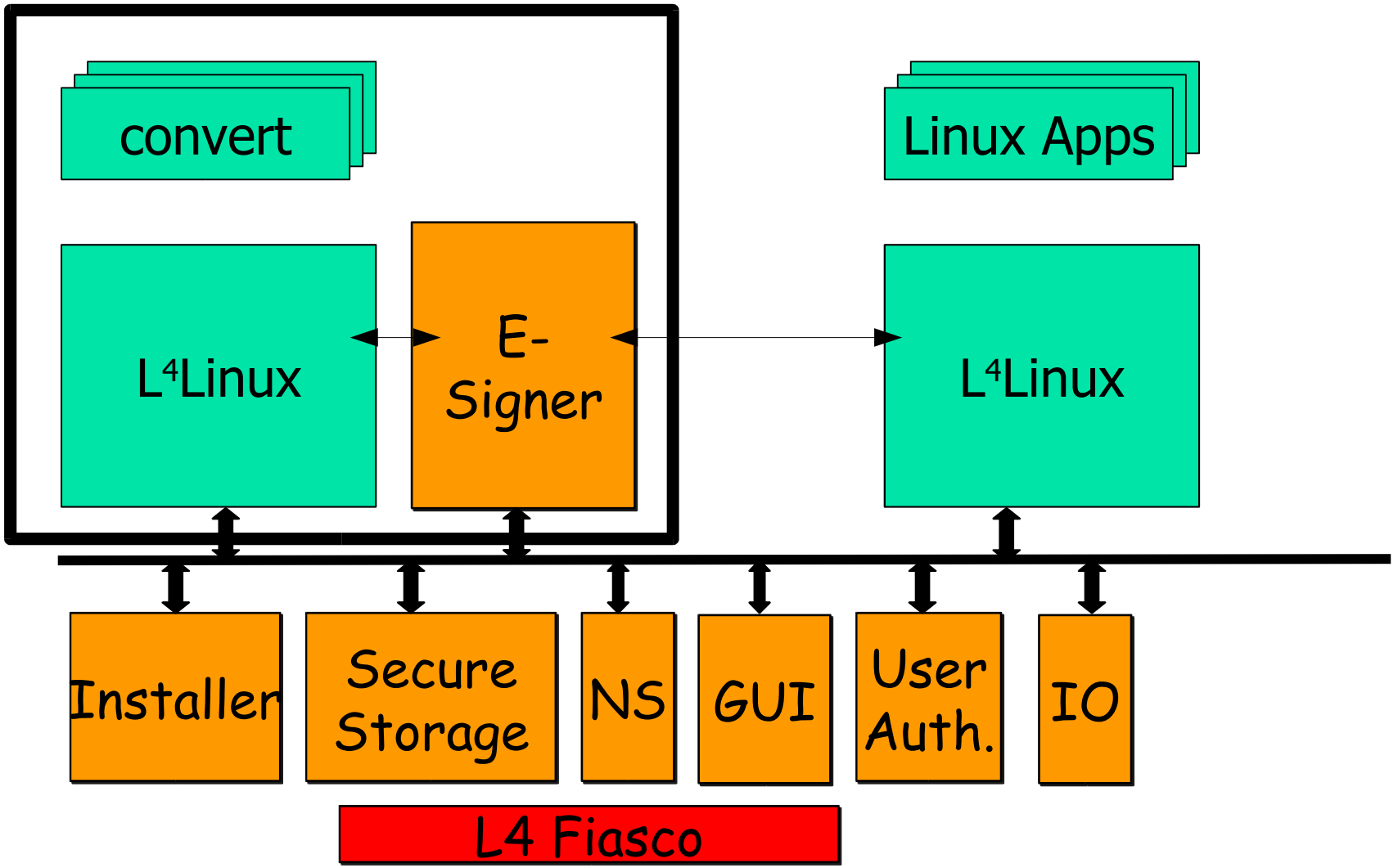



X-Window System
RT App 1
RT App 4
L4Linux
presenter
installer
DOpE window server
L4 - ENV
L4/Fiasco Micro-Kernel

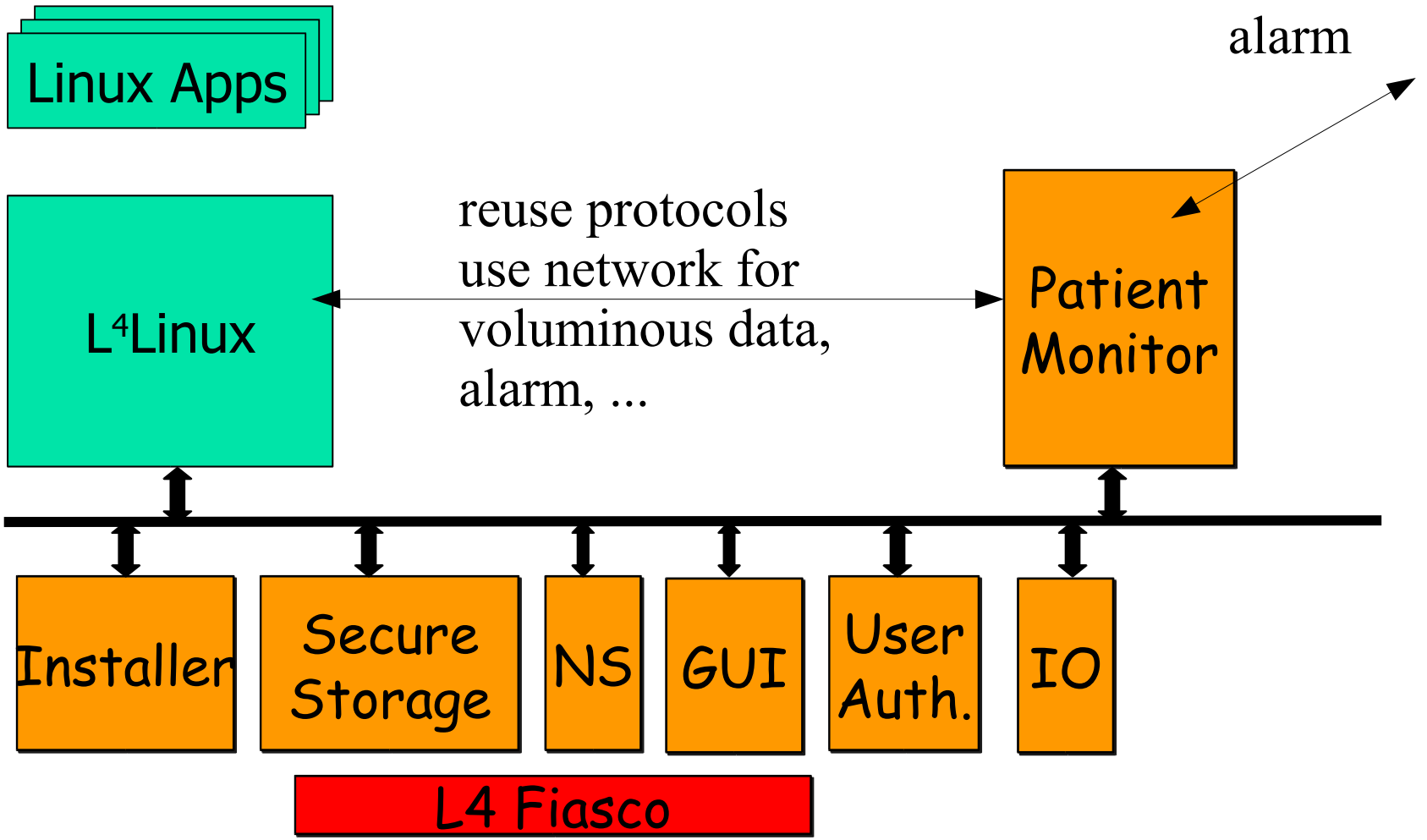
NIZZA Architecture



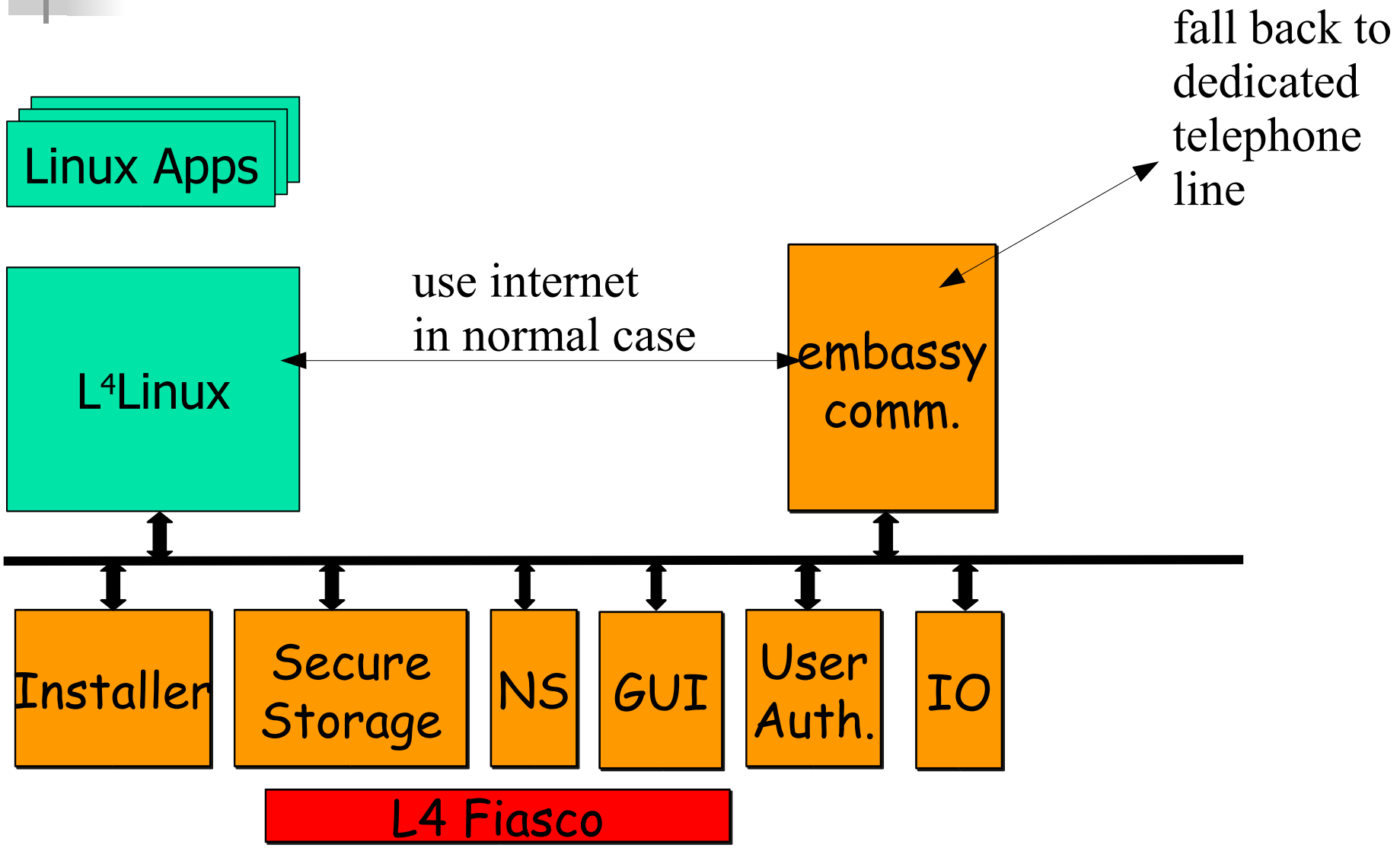
More Use Cases



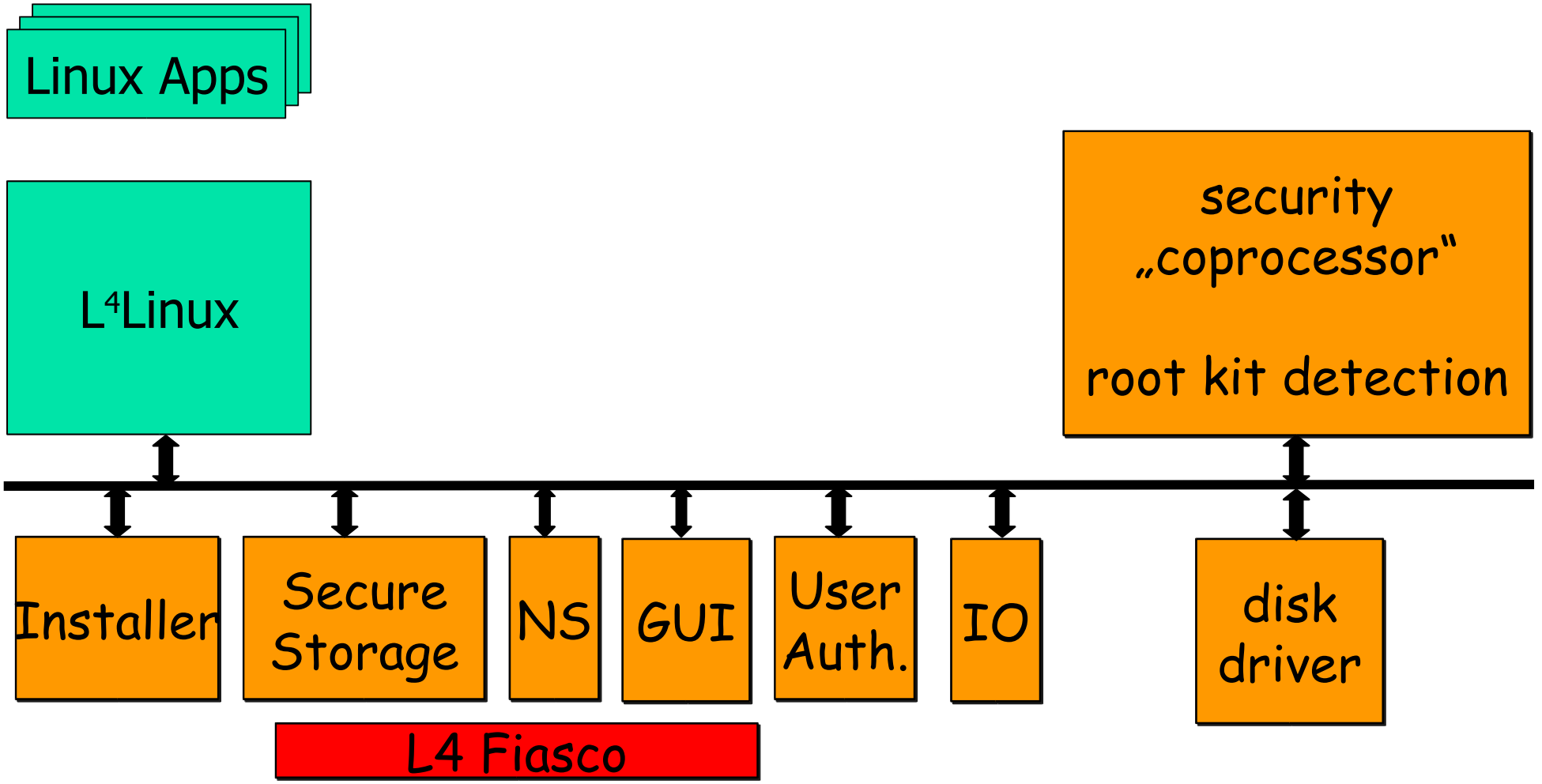
More Use Cases



More Use Cases



More Use Cases



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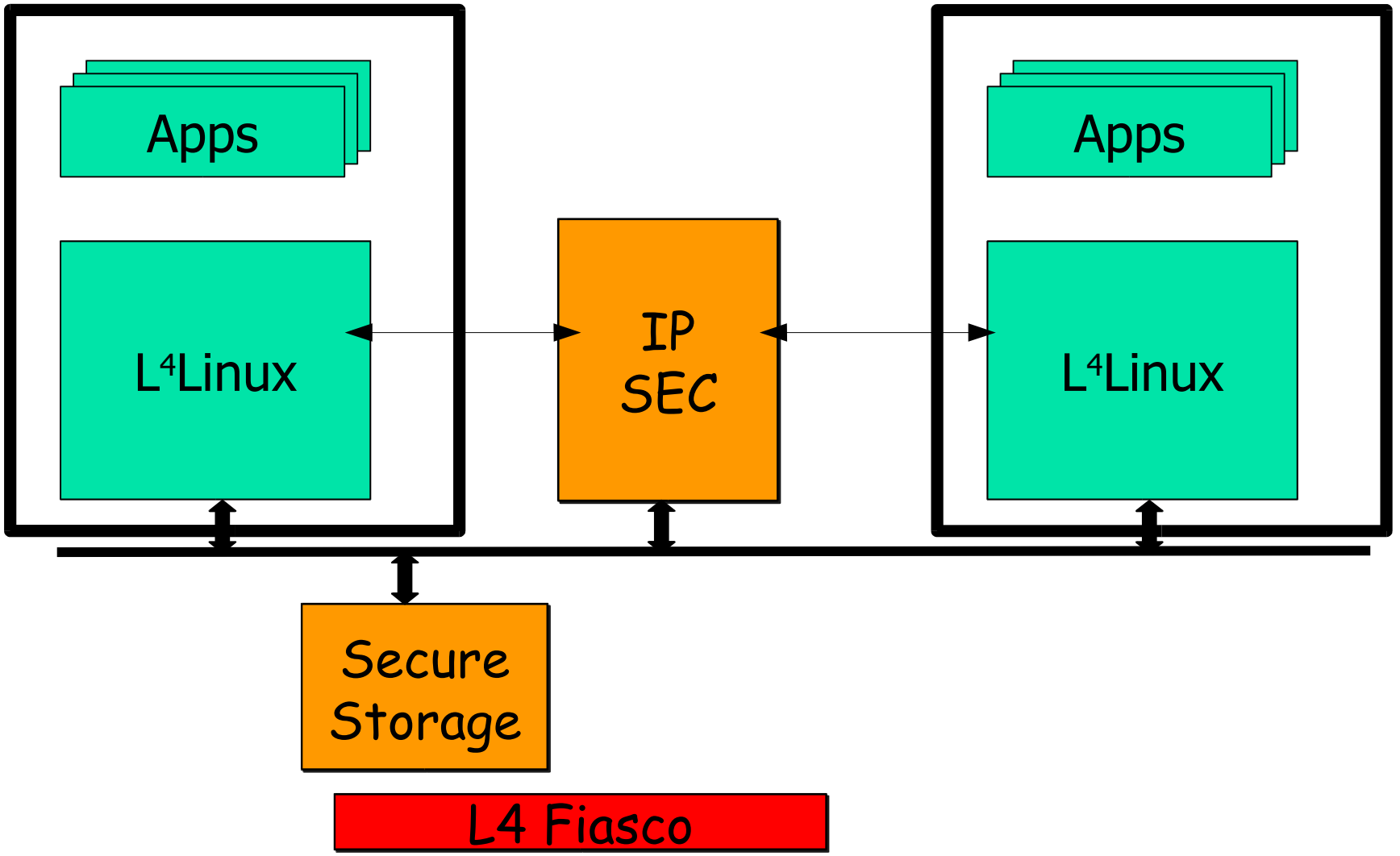
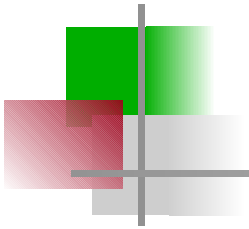
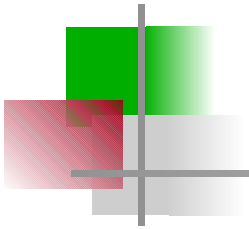




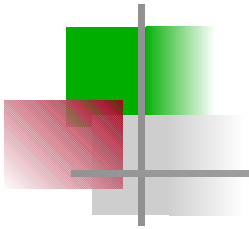
Architecture + Components

- the origin: Dresden Real-time OPerating System
- Nizza architecture
- use cases
- **some Nizza components**
  - L4 micro kernel: present and future
  - L^4Linux: encapsulation and reuse
  - secure booting + trusted path
  - secure storage with small TCB (future)



L4 Micro-Kernel: evolution

- the original:
  address spaces, threads, IPC
- L4/Fiasco-RT: real-time:
  periodic threads, fine grained scheduling support, etc
- **L4/Fiasco-X.e:**
  unified access control +
  kernel resource management
- L4-Next: virtualization support

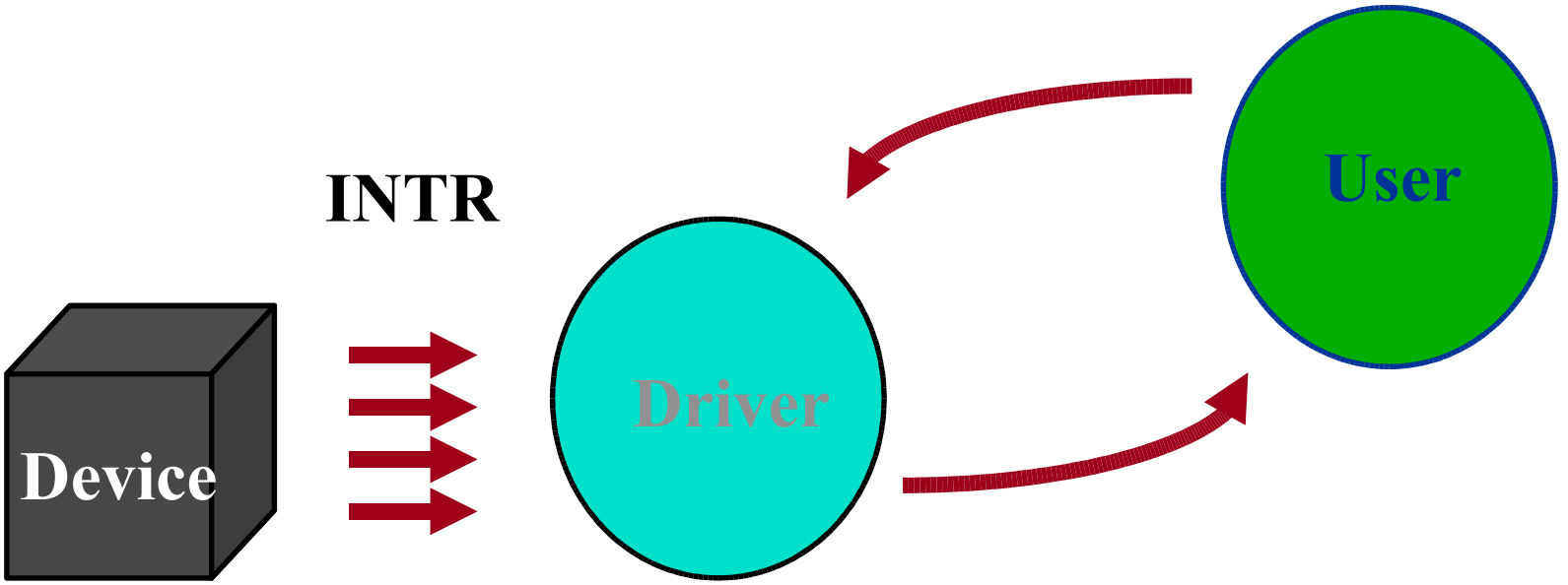


L4 micro kernel (Jochen Liedtke)

fundamental abstractions

- address spaces (separation)
- threads
- inter process communication (IPC)
  - explicit
  - interrupts
  - faults and mappings

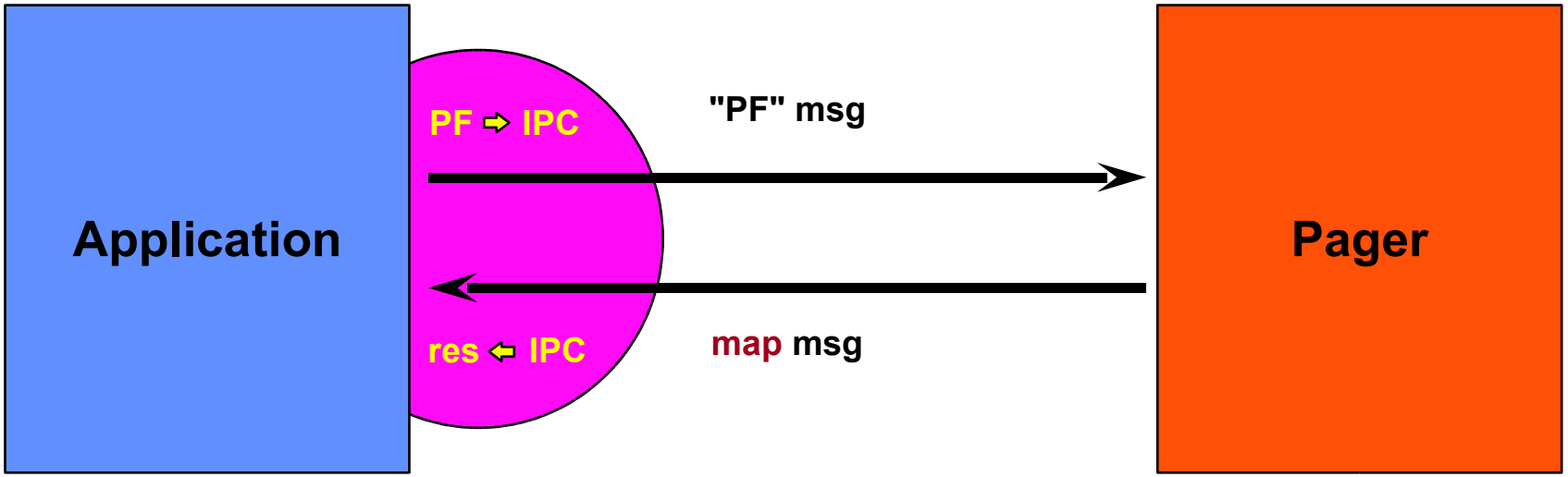
Drivers at User Level



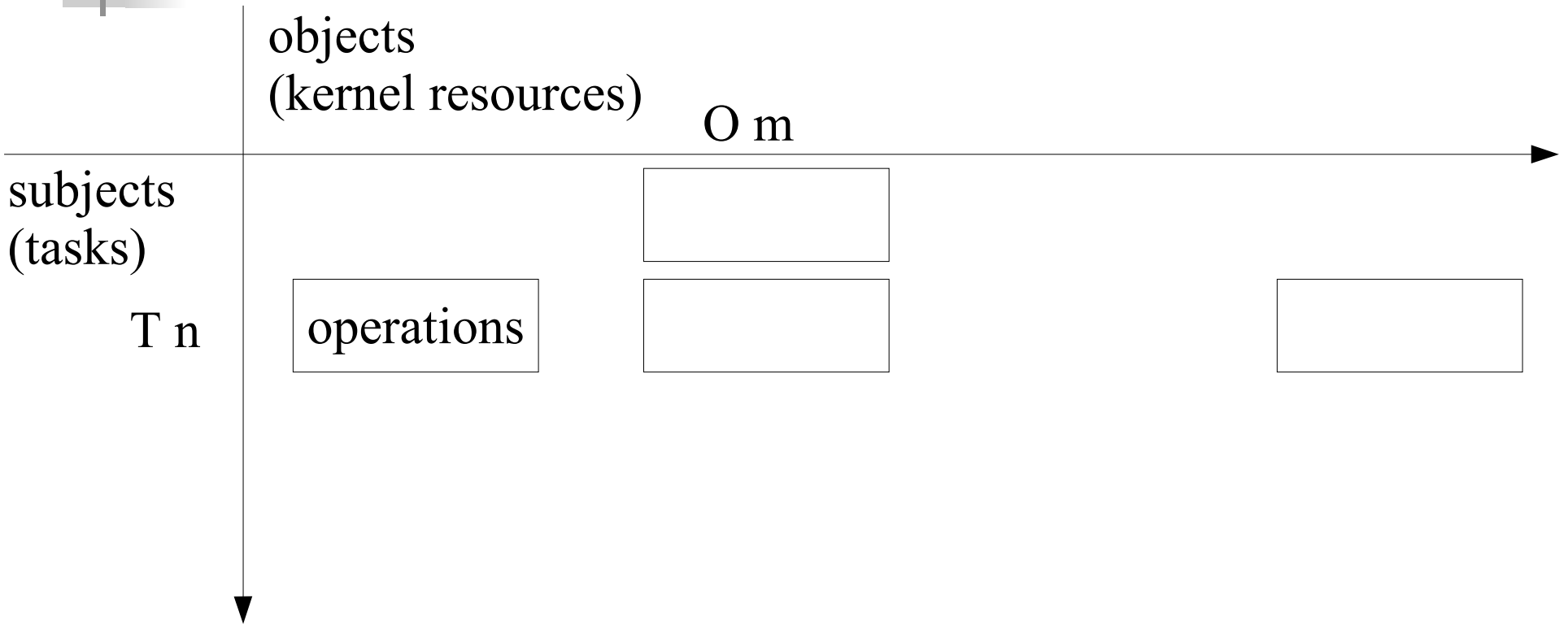
= ipc

- **IO ports: part of the user address space**
- **interrupts: messages from hardware**

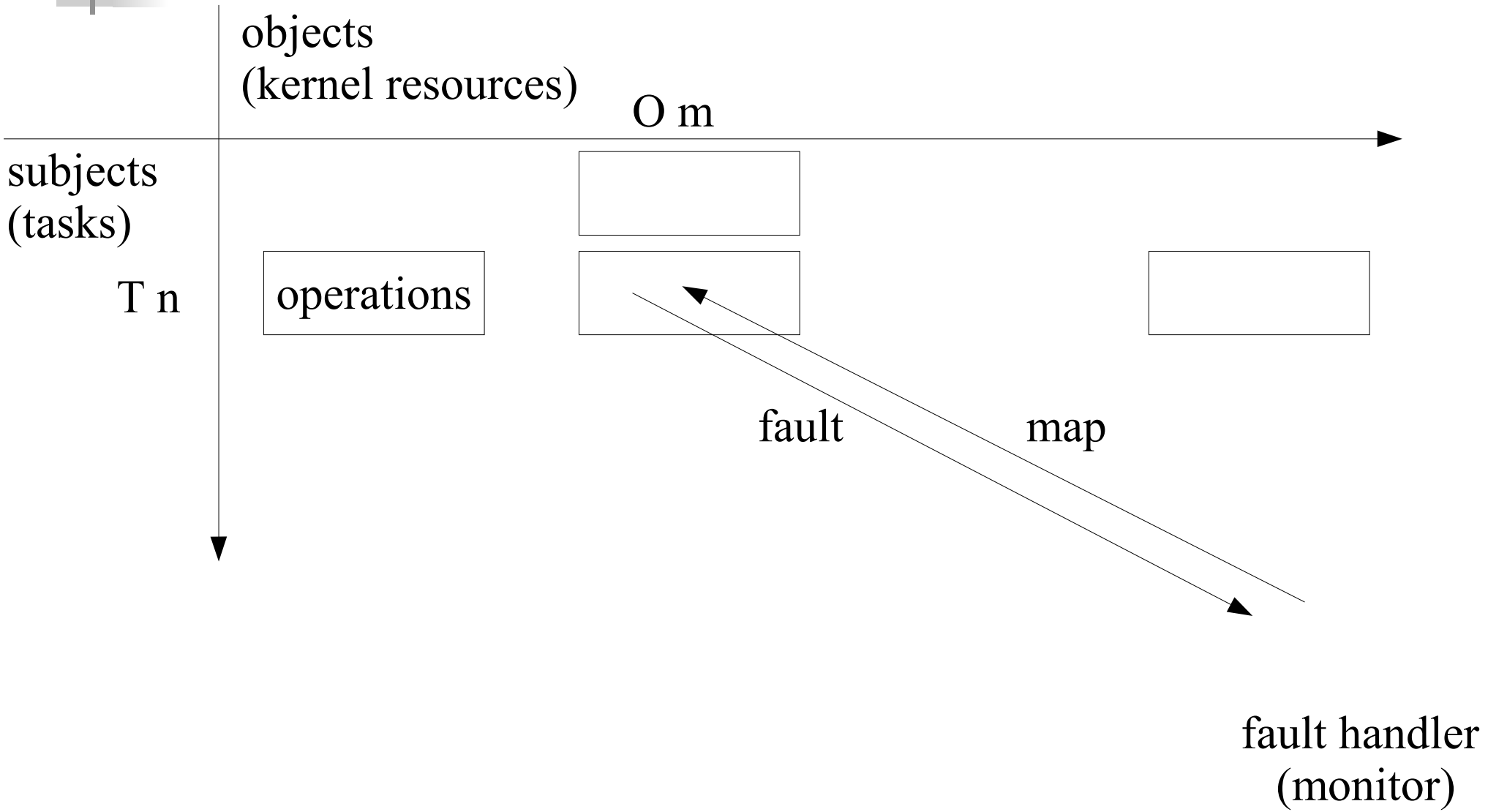
Memory Pages



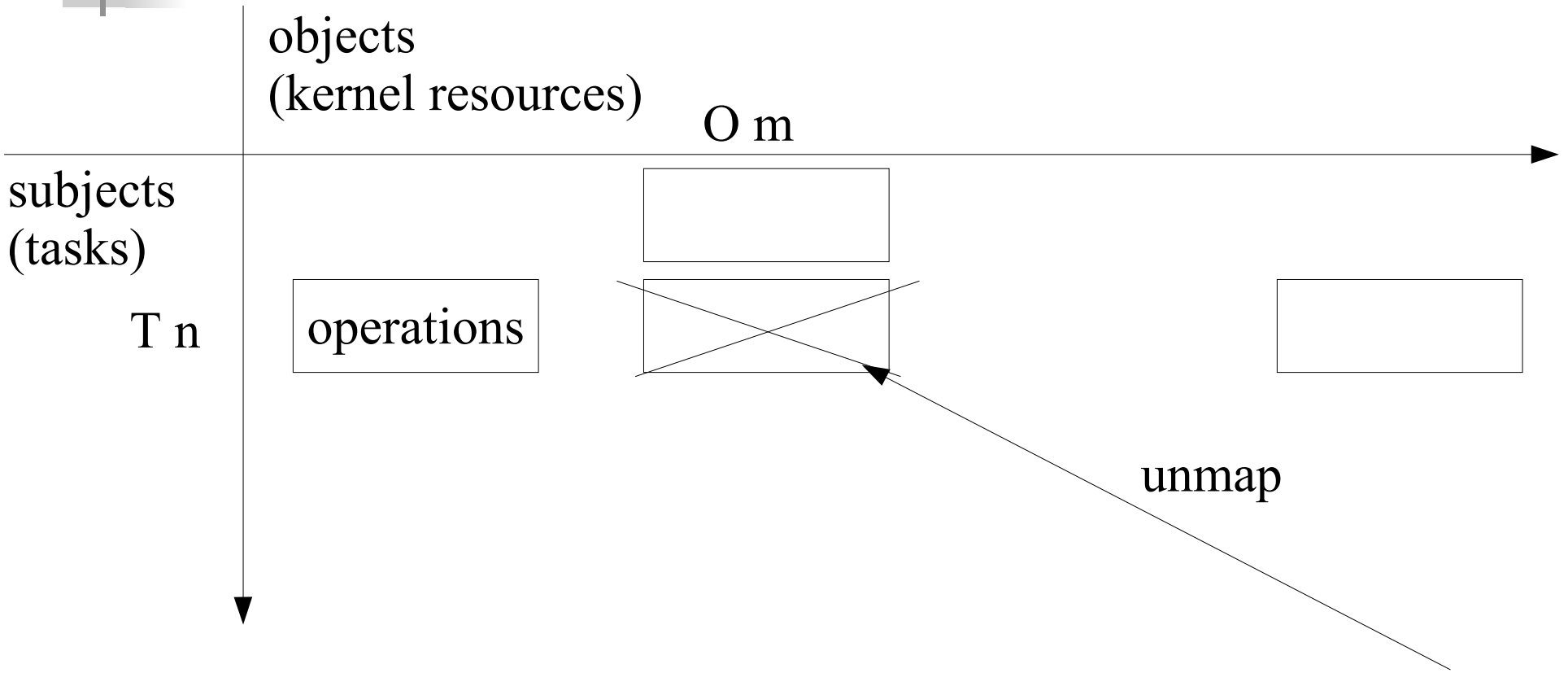
L4 X.e: Unifying Access Control



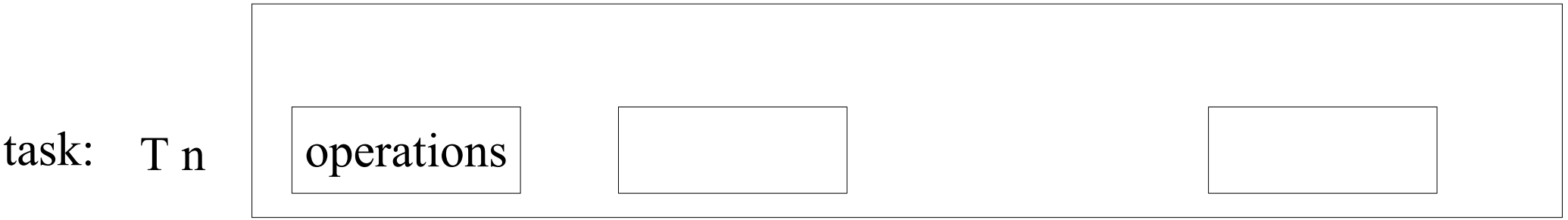
L4 X.e: Unifying Access Control



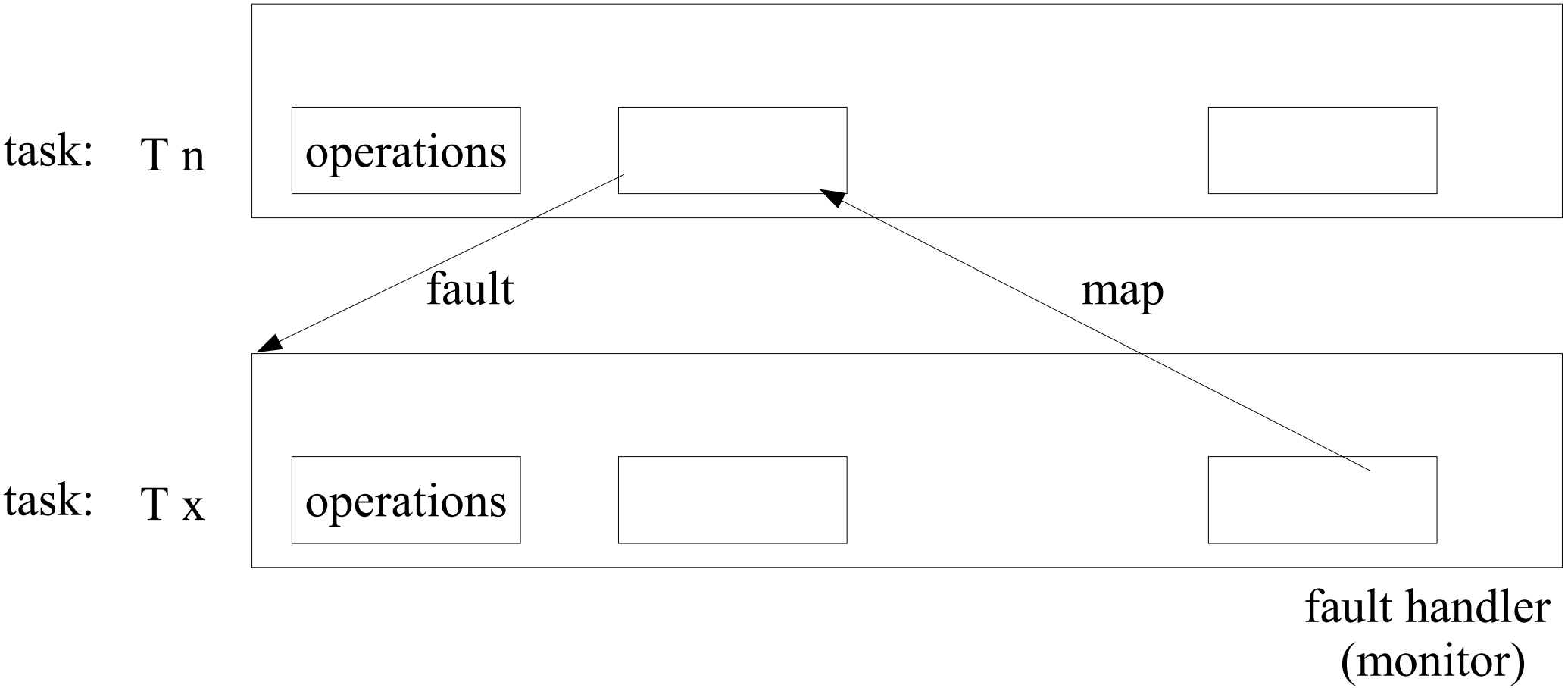
L4 X.e: Unifying Access Control



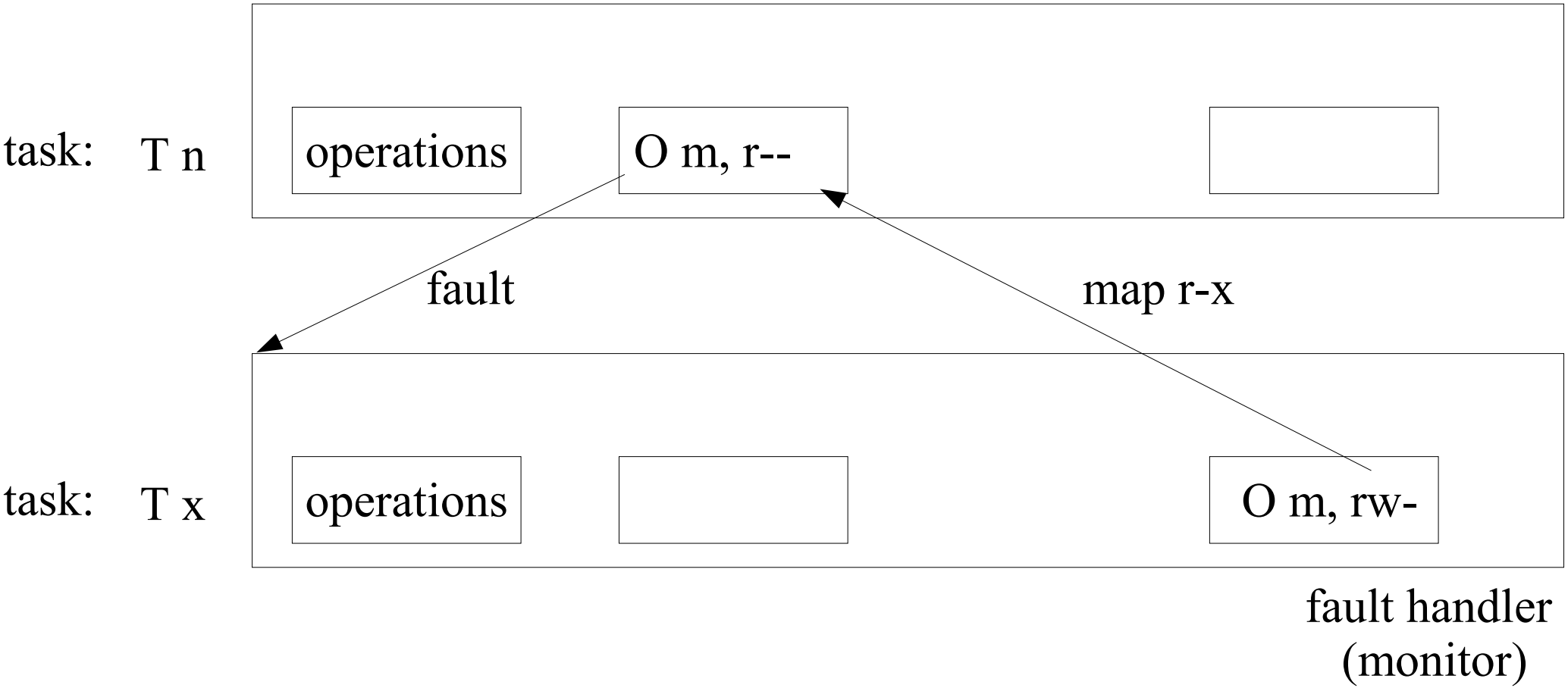
L4 X.e: Unifying Access Control



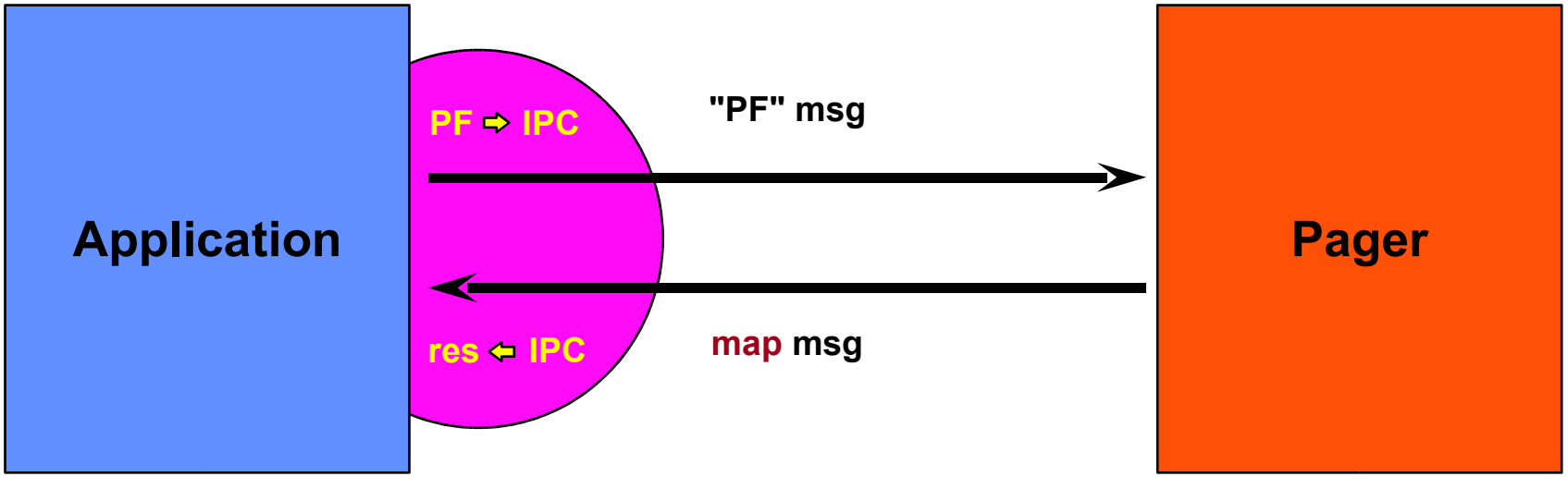
L4 X.e: Unifying Access Control



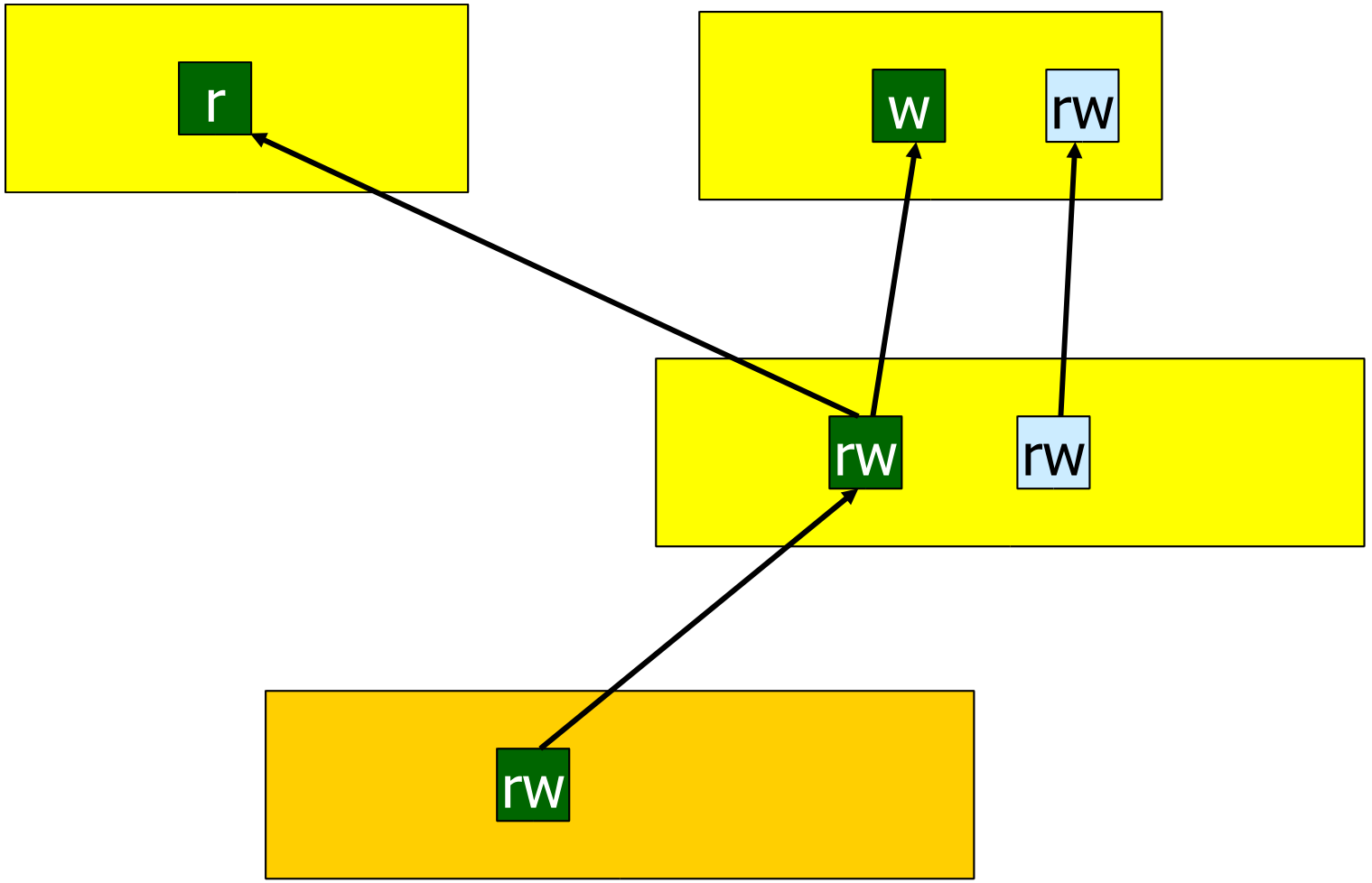
L4 X.e: Unifying Access Control



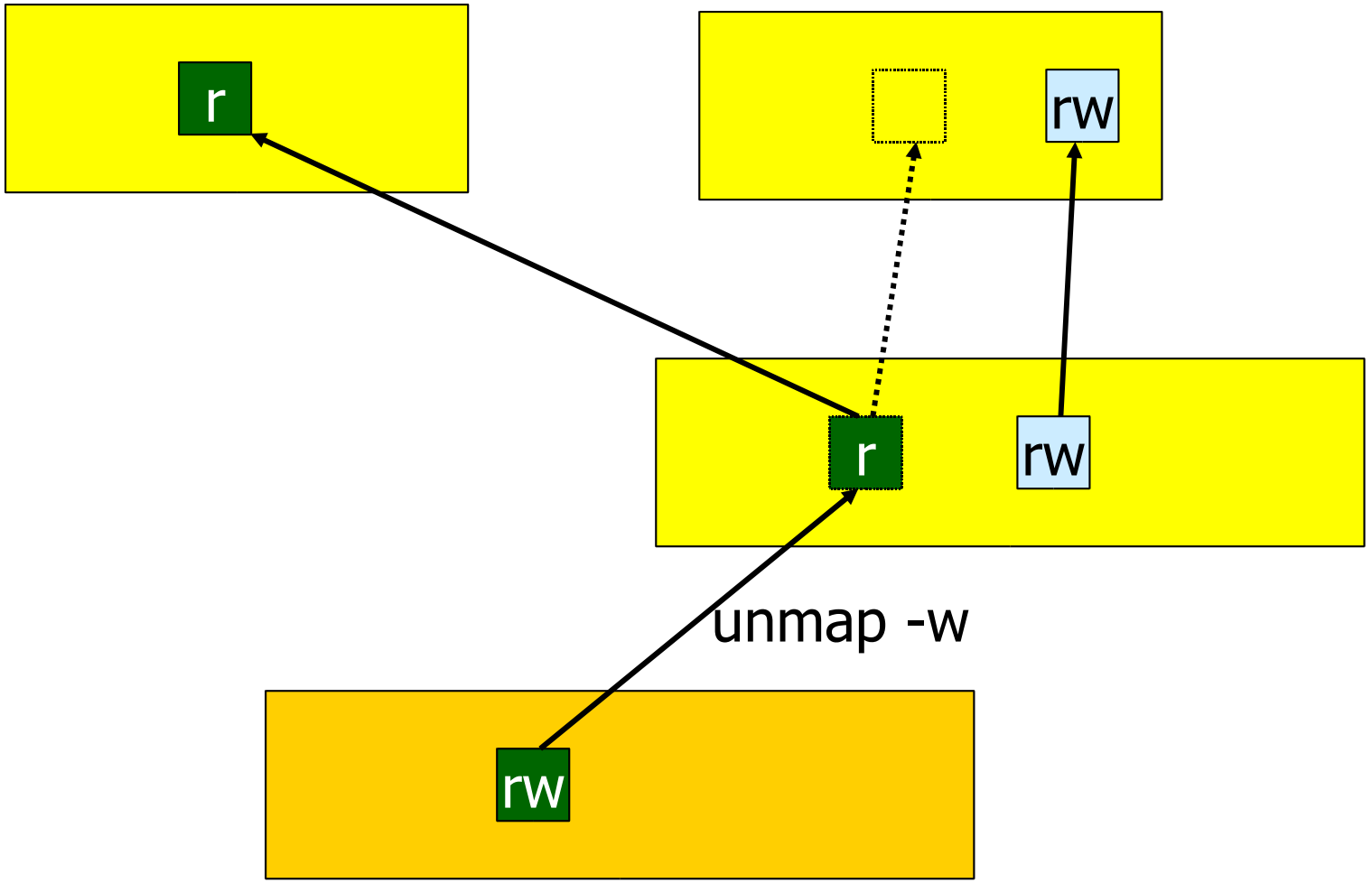
Memory Pages



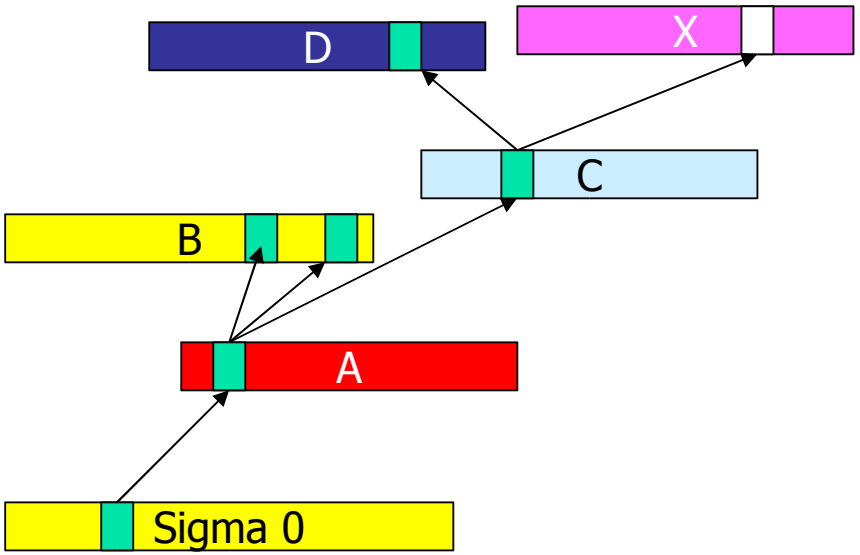
Fault, Map, Unmap

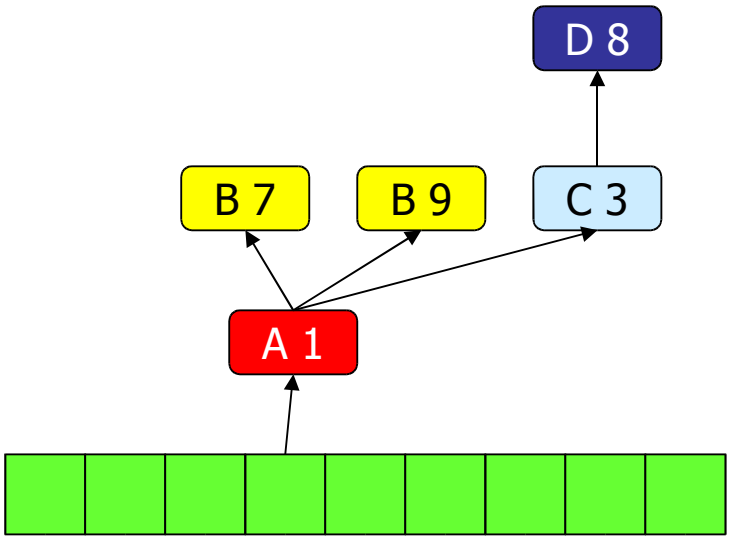


Fault, Map, Unmap



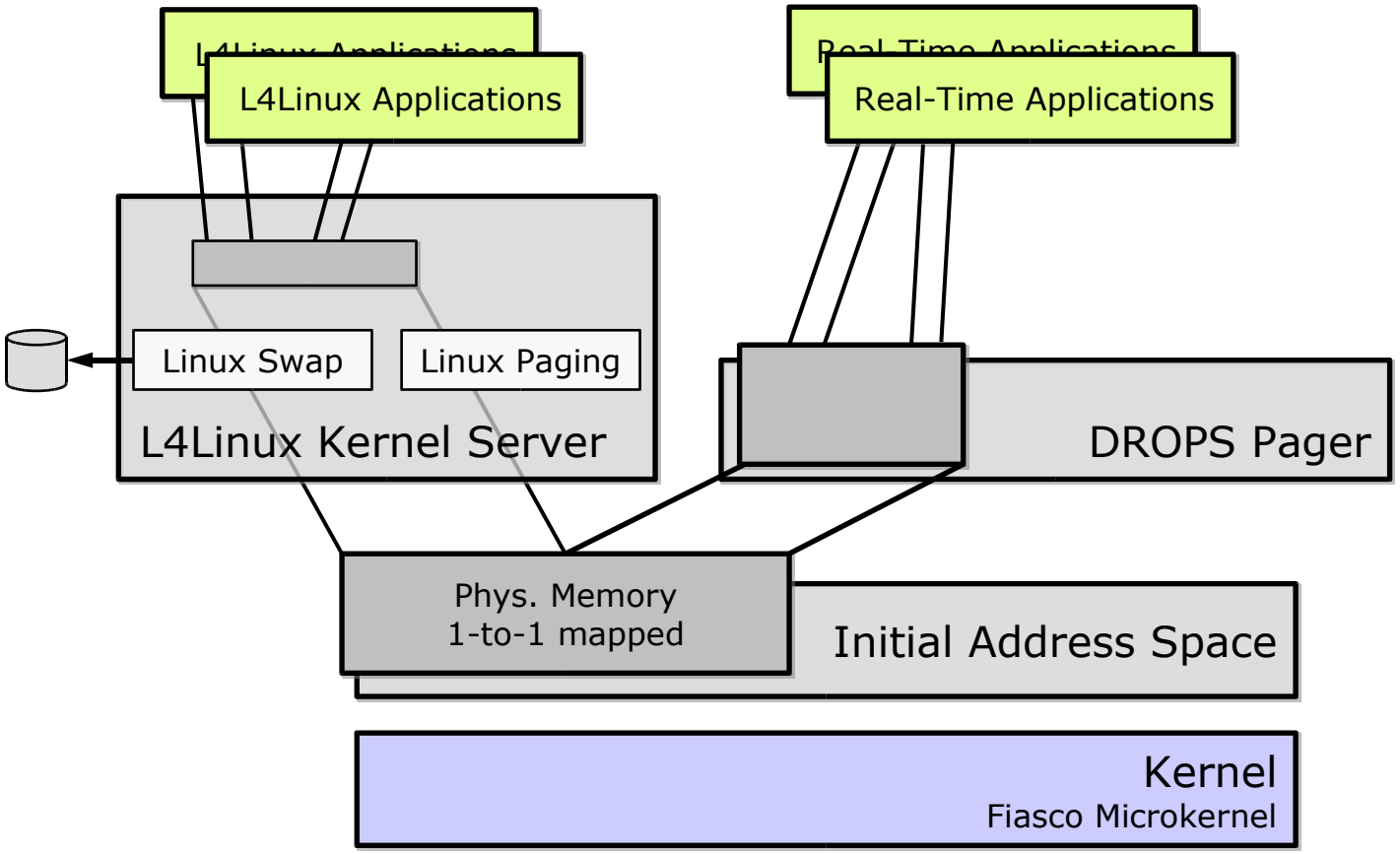
Map Trees



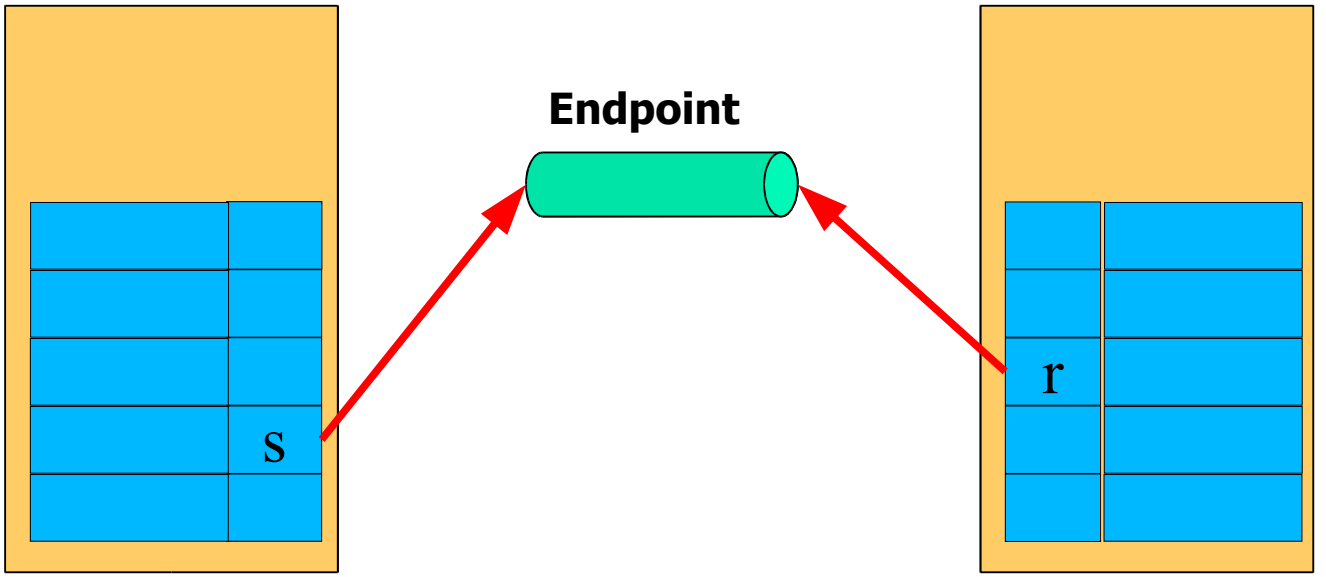


Tiles (physical memory frames)

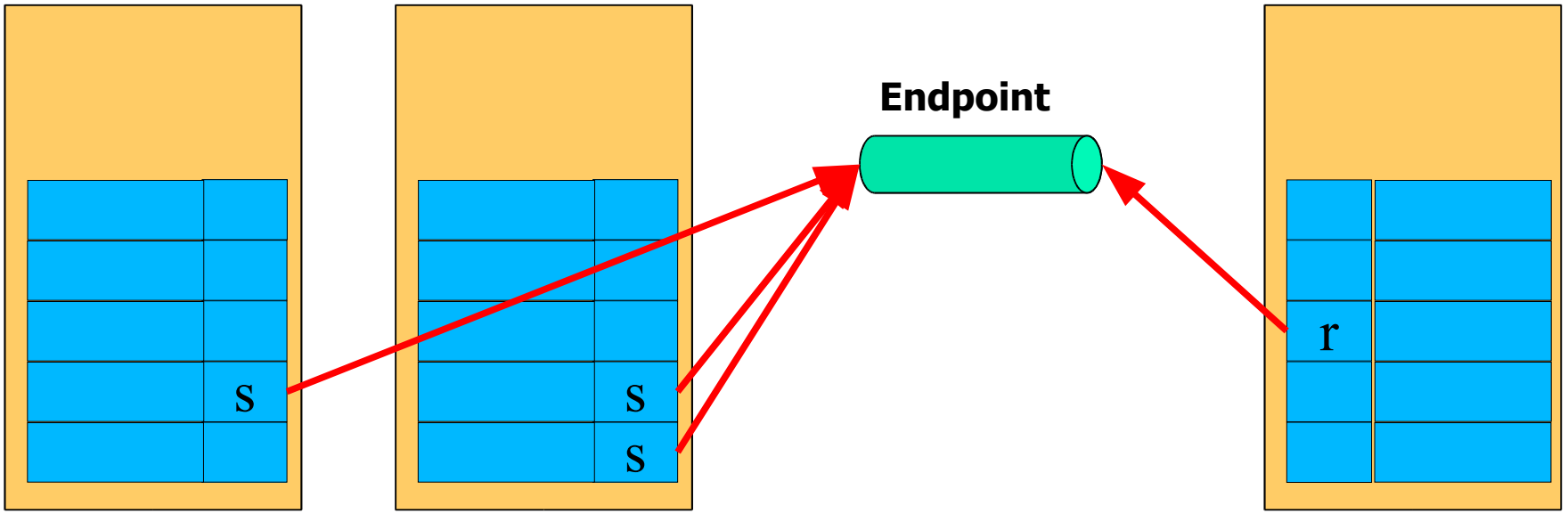
Pager Example



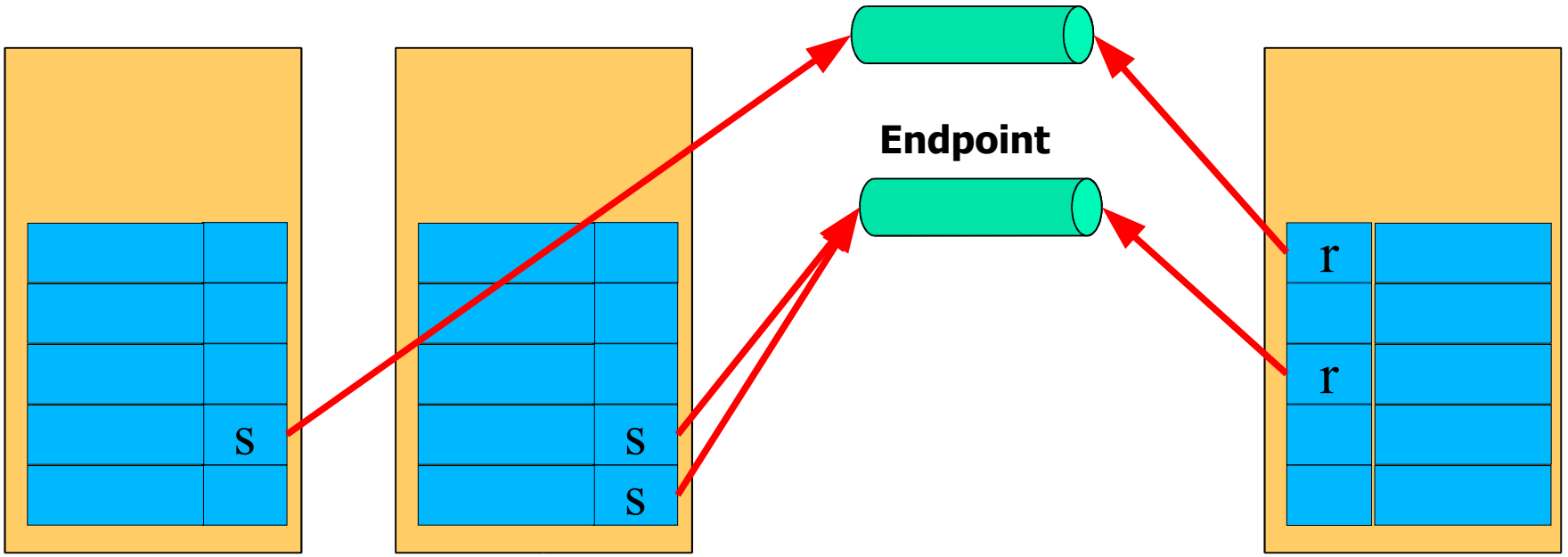
Communication



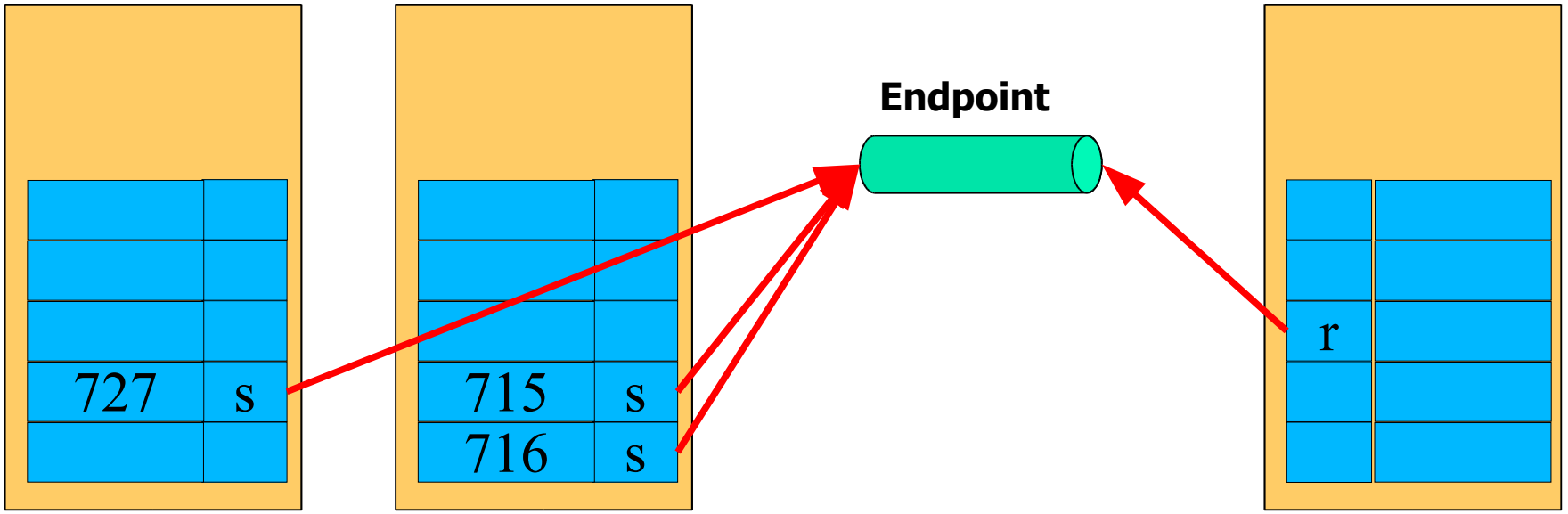
Communication



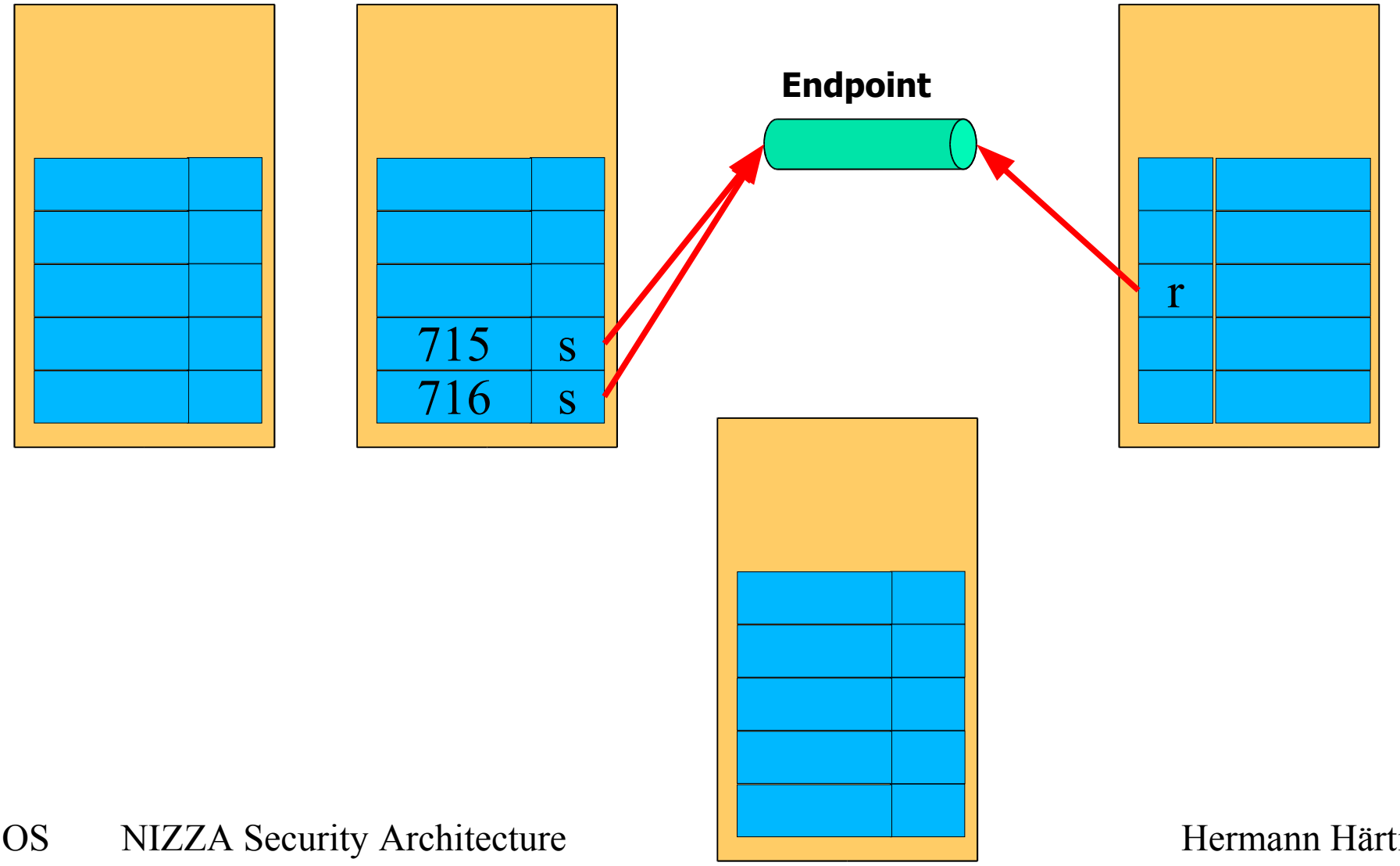
Communication



Communication



Communication



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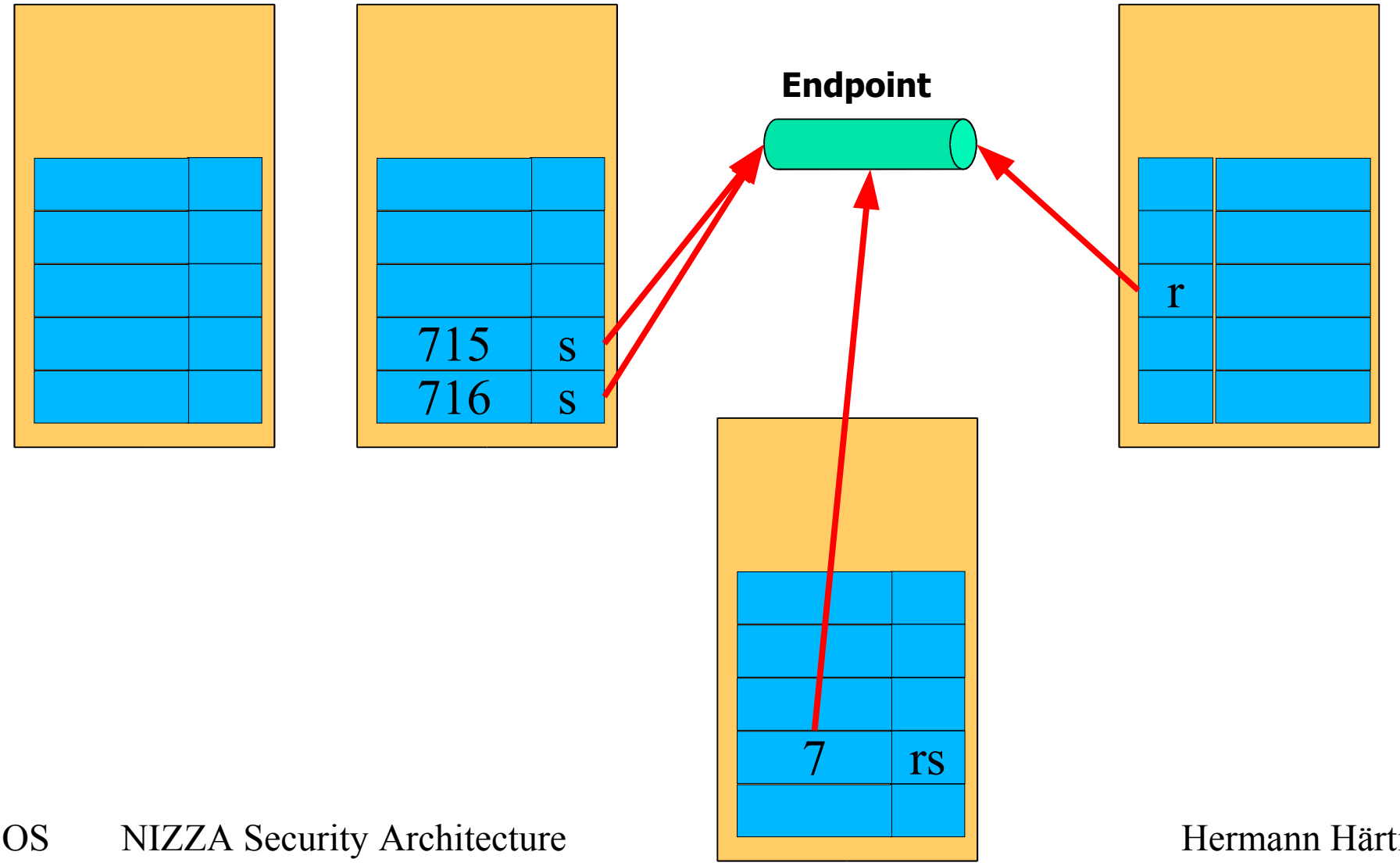

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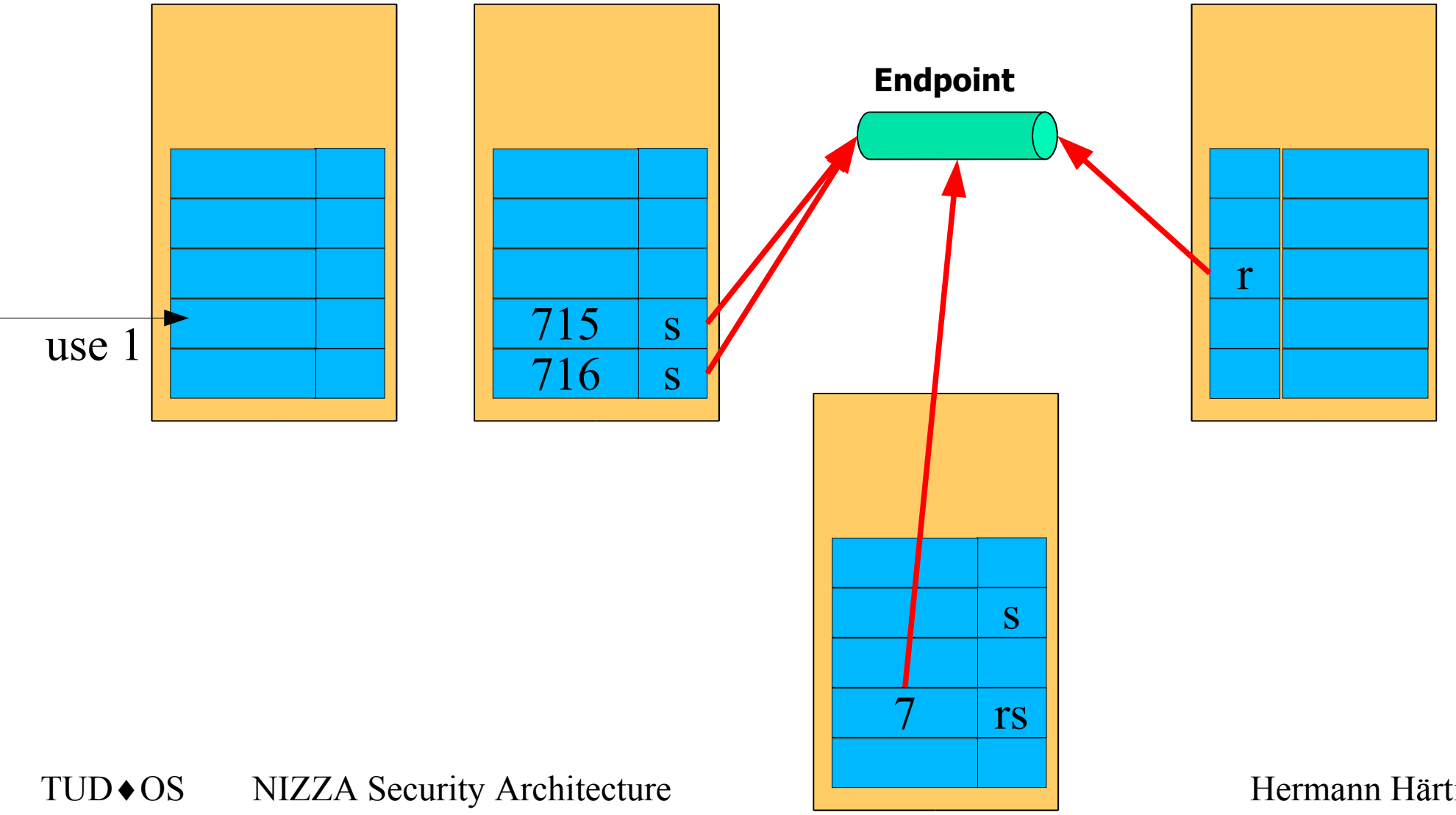

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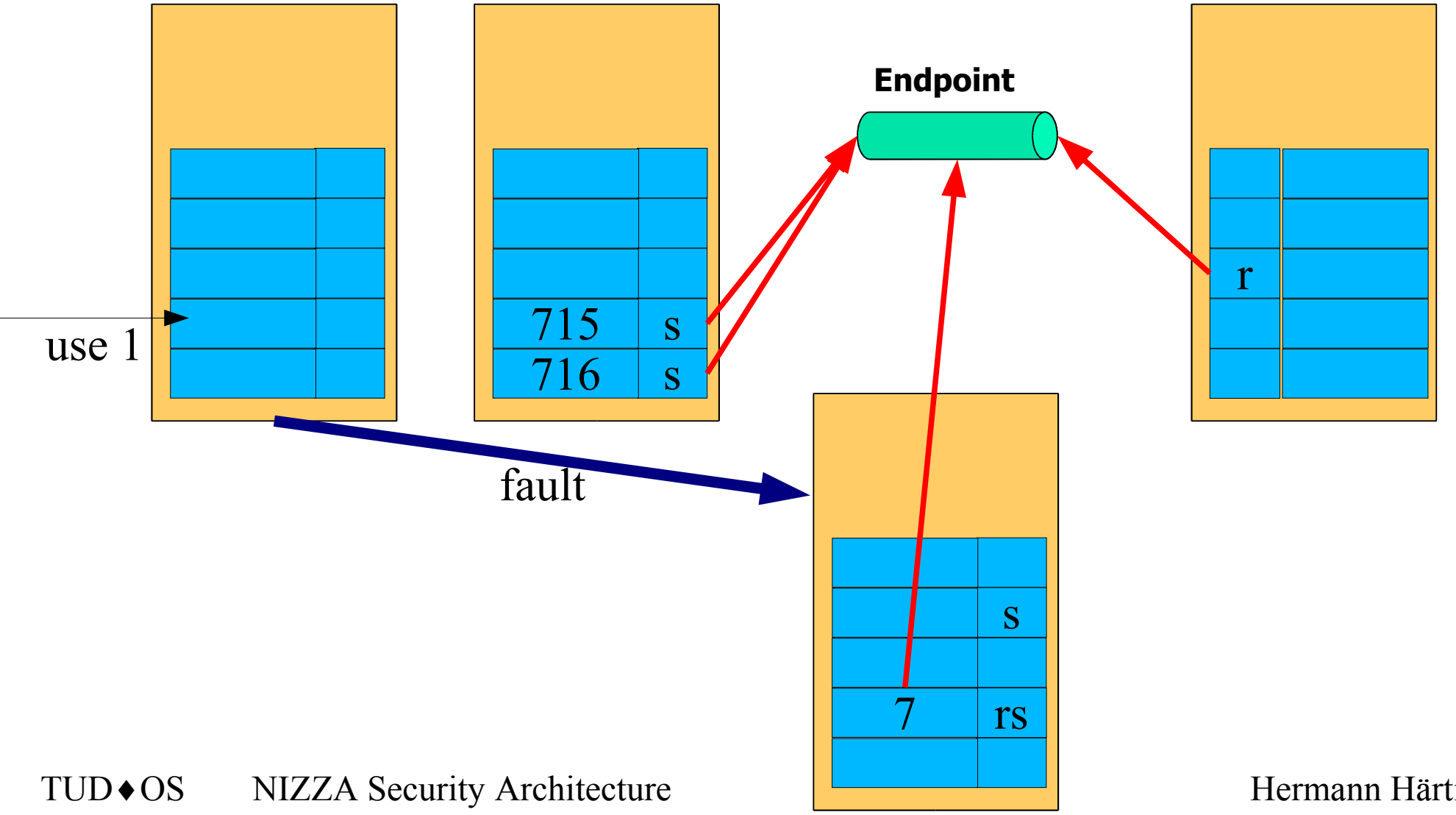

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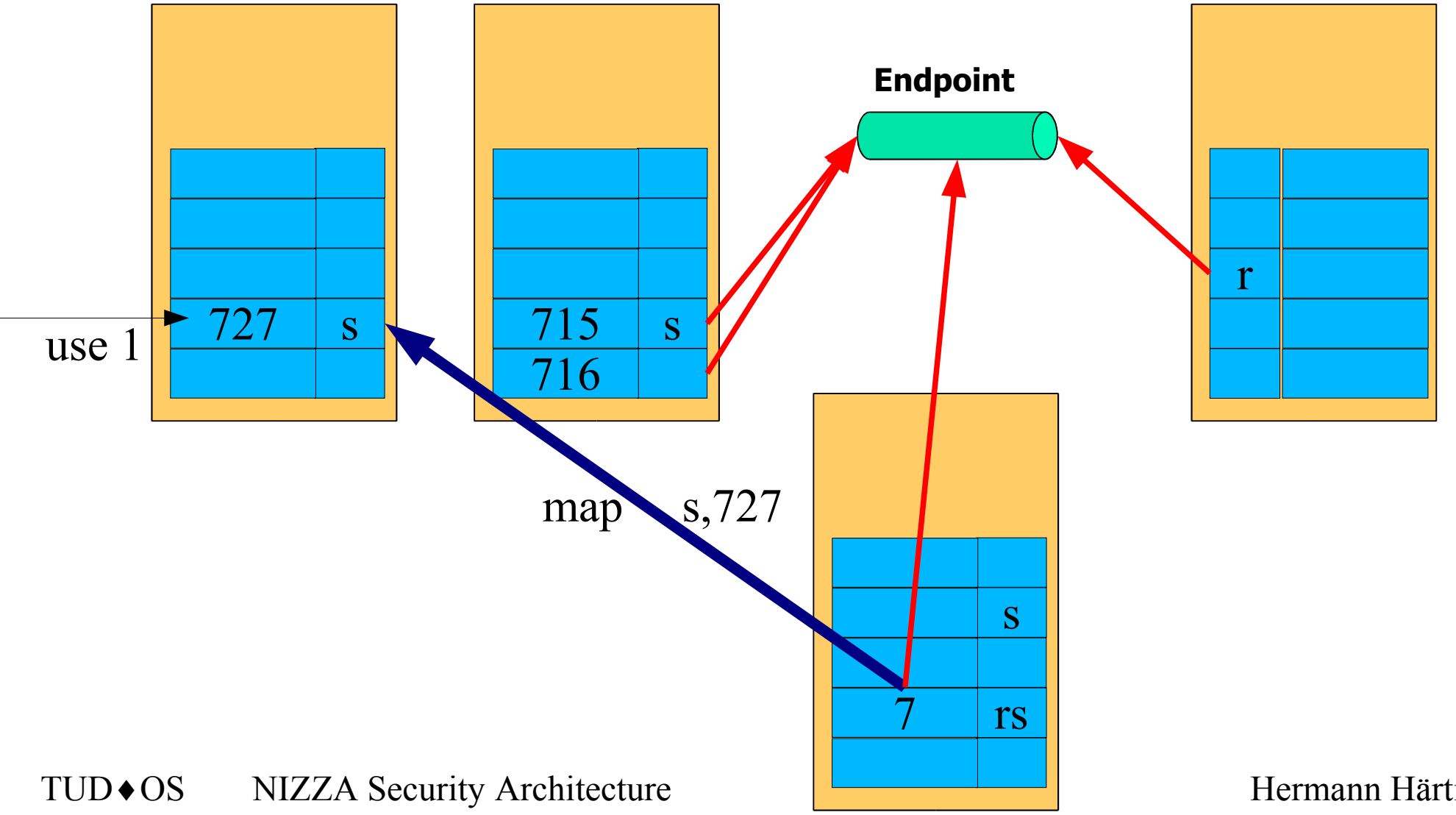

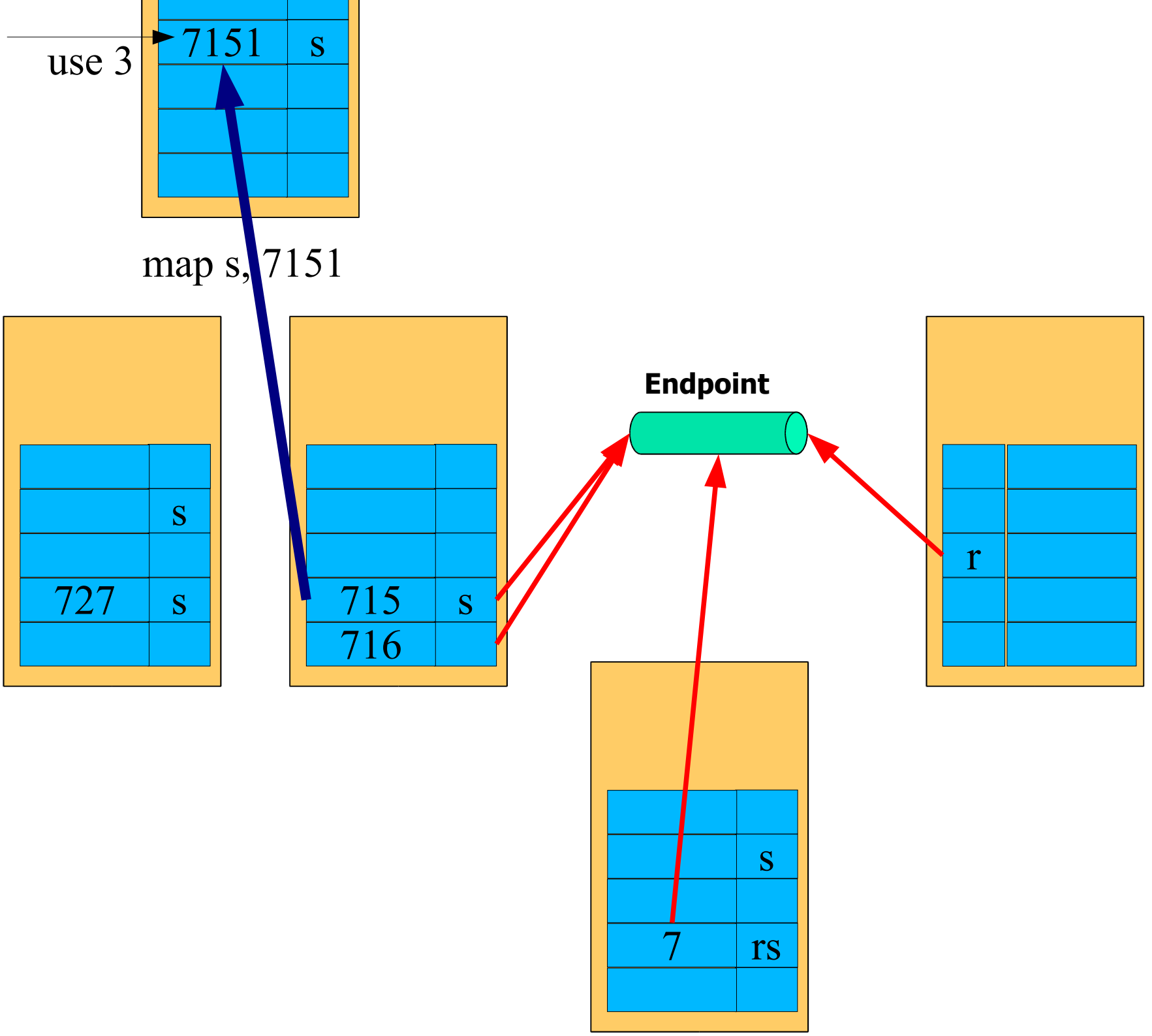
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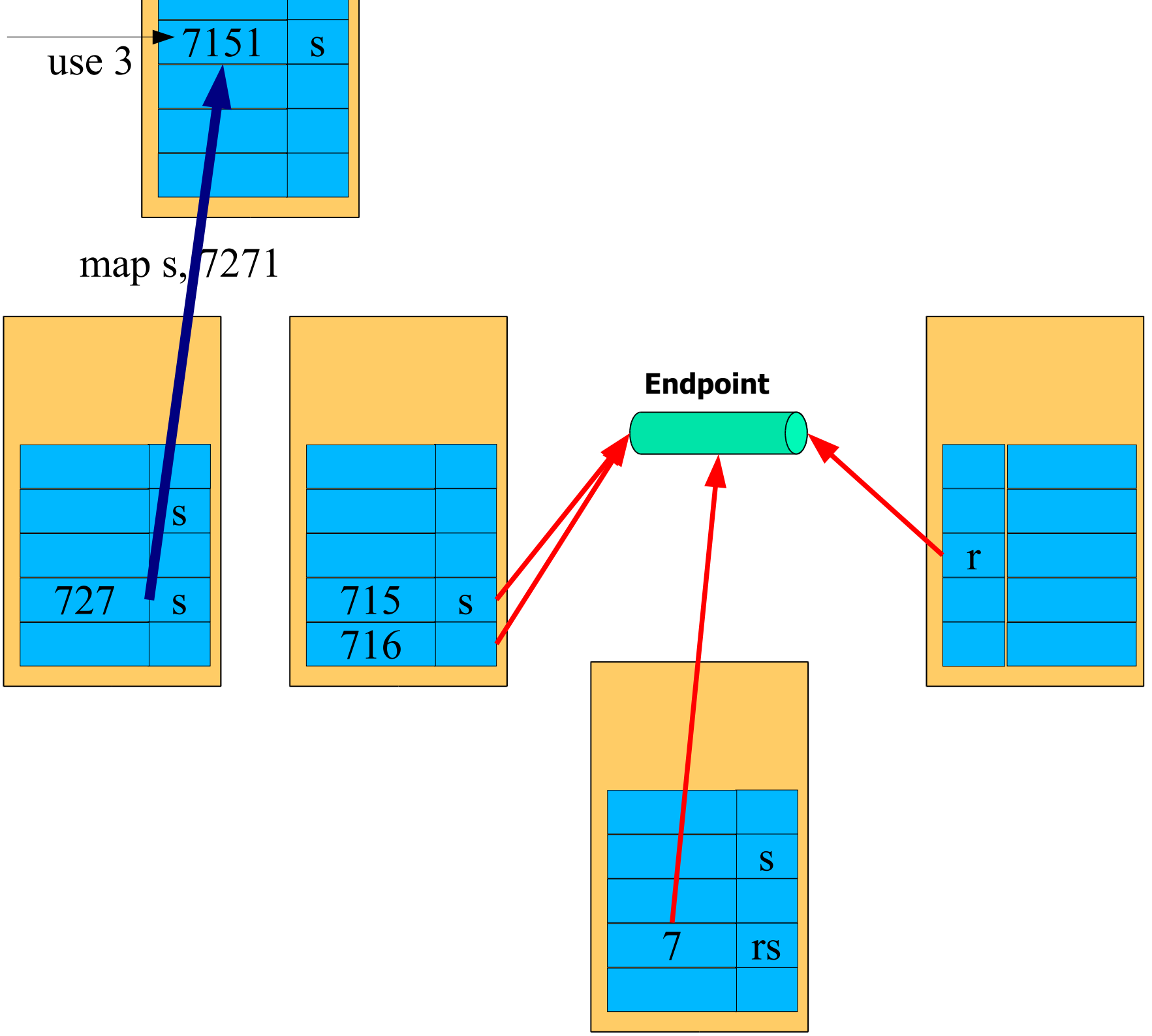
7151
s
map s, 7151
s
727
s
715
716
s
Endpoint
r
s
7
rs


use 3
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map s, 7271
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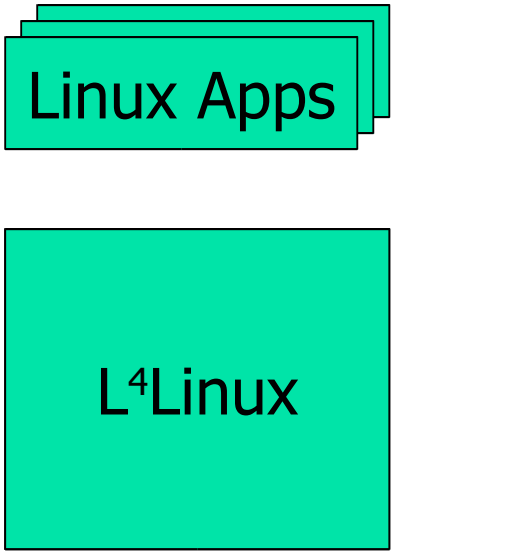
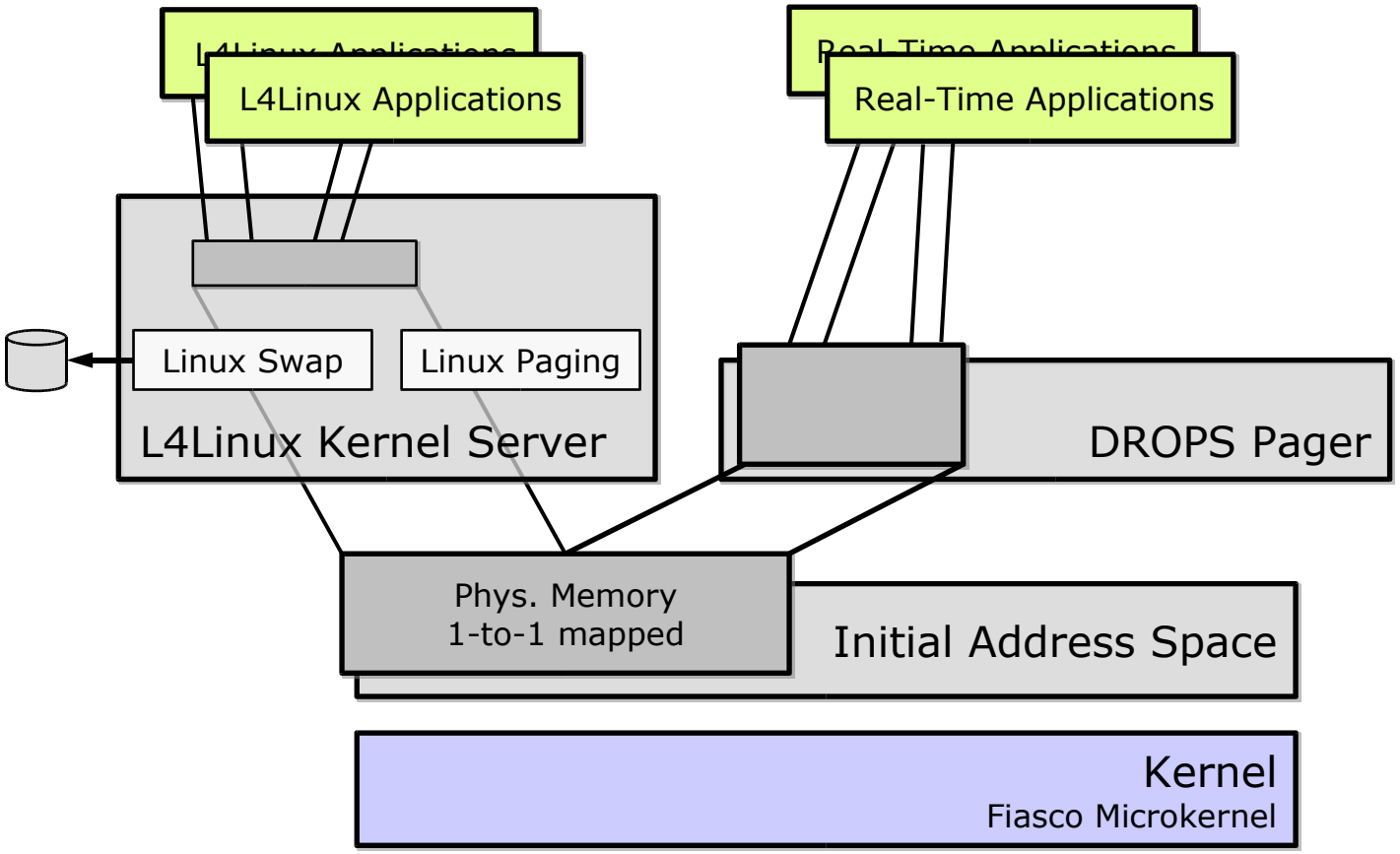
Endpoint
r
s
7
rs

L4Linux

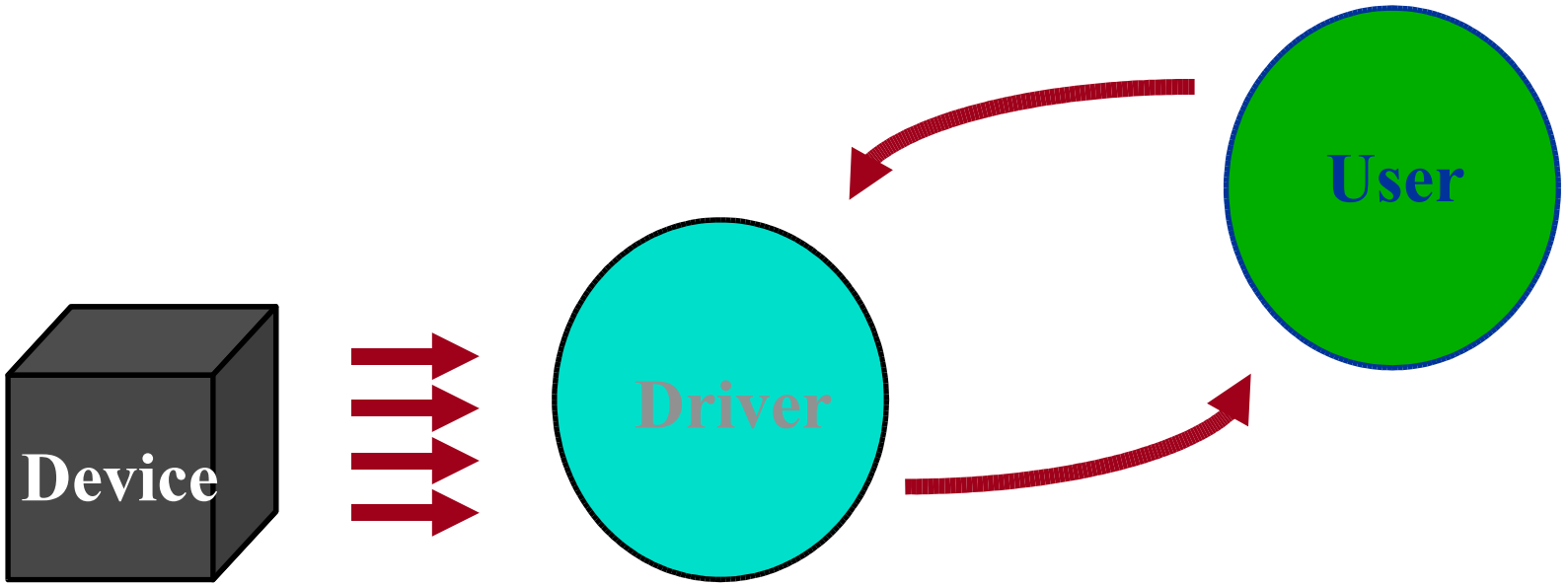


L4 Fiasco

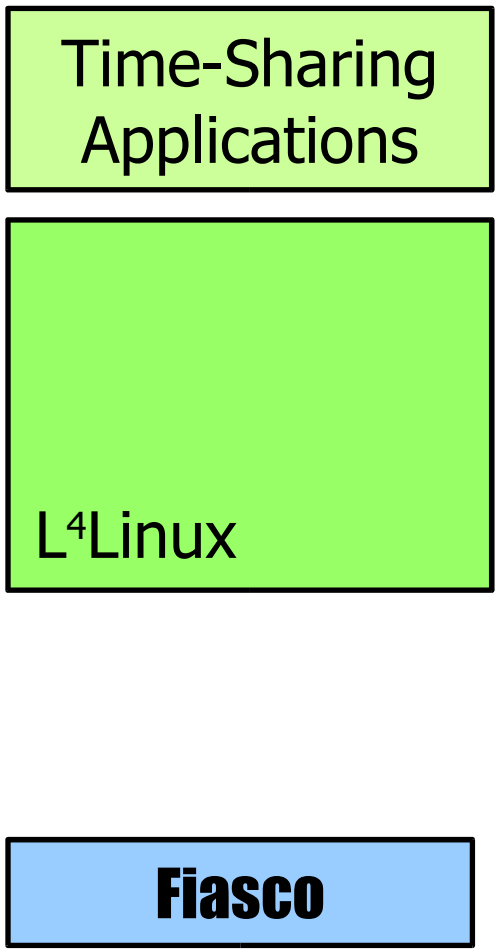
Pagers

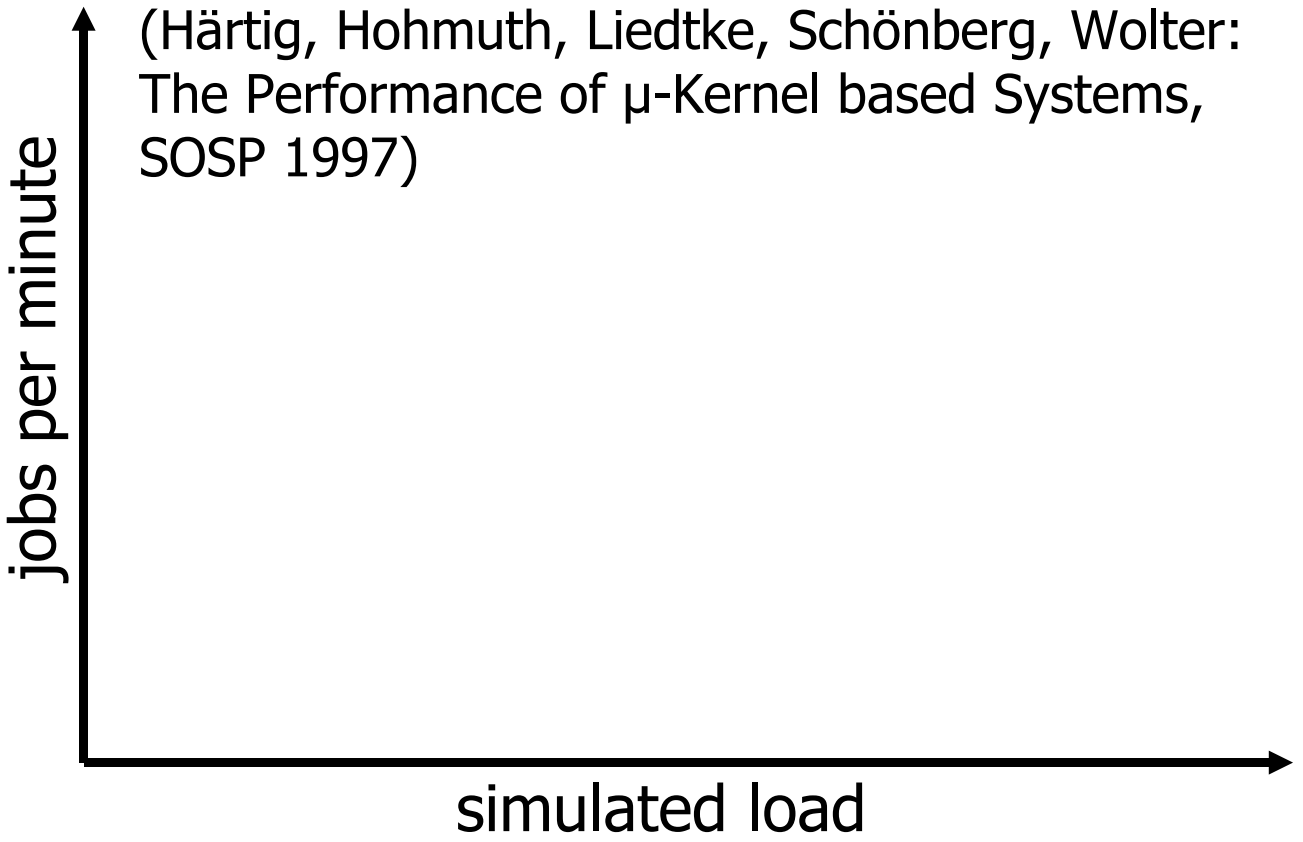

L4Linux Applications
Real-Time Applications
Linux Swap
Linux Paging
L4Linux Kernel Server
DROPS Pager
Phys. Memory
1-to-1 mapped
Initial Address Space
Kernel
Fiasco Microkernel

Linux “top halves” as threads



Performance



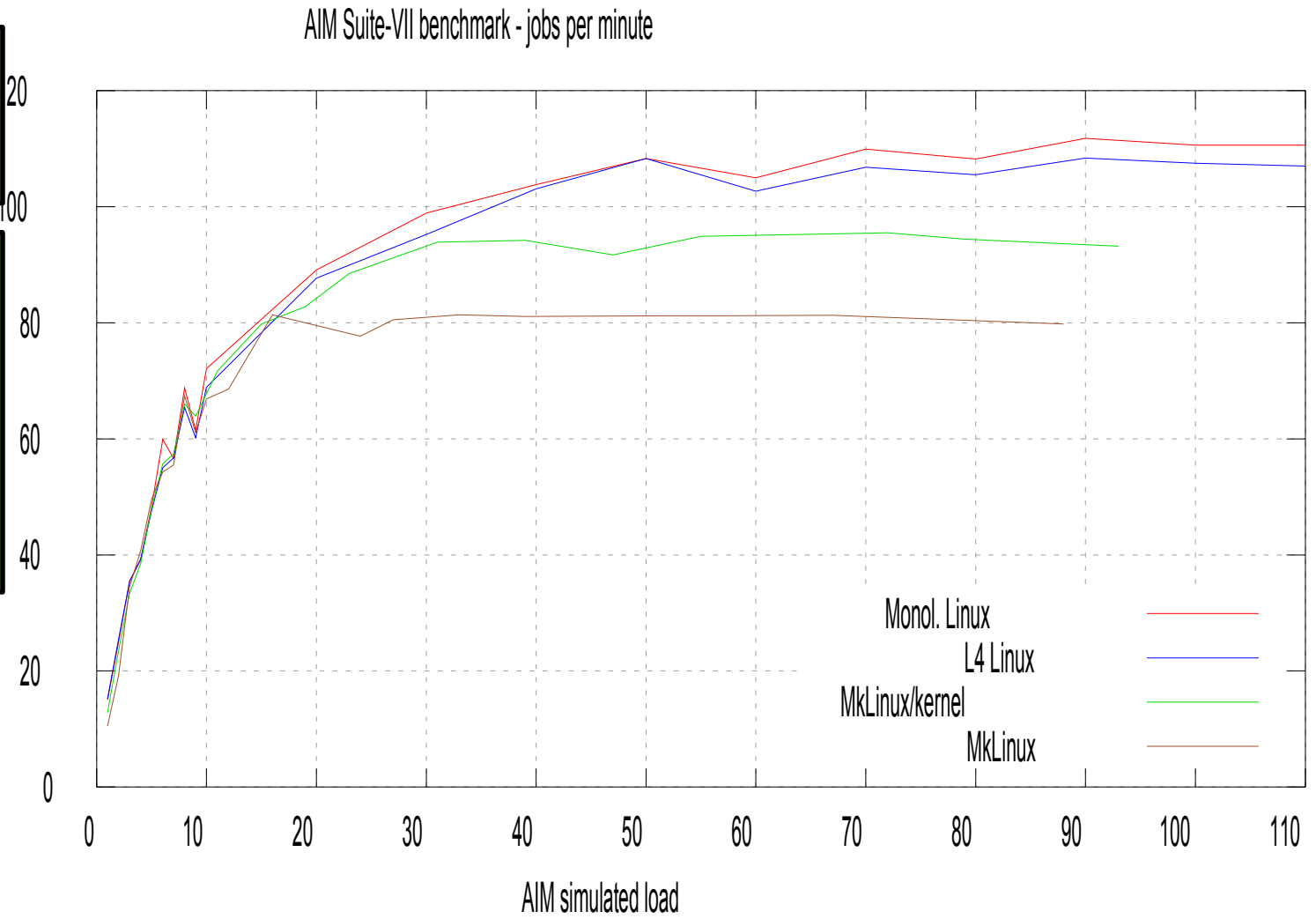


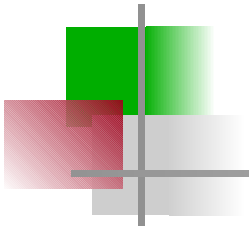
L4Linux compared to MACH

Time-Sharing Applications

L4Linux

Fiasco



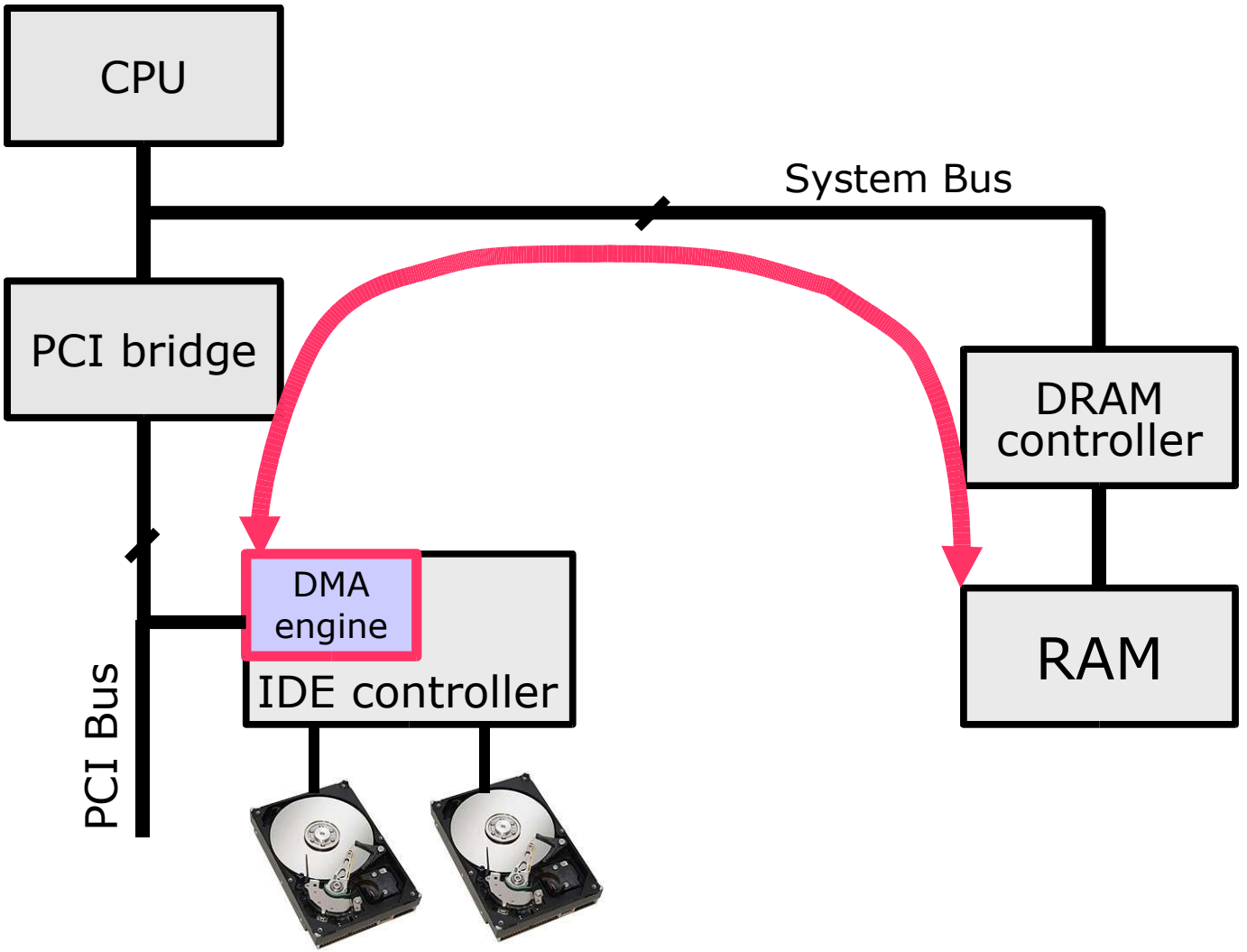


The DMA Problem

- separation is enforced by MMU
- devices access memory using bus master DMA
- DMA uses physical addresses
  (on most architectures)

➔ malicious devices
(or malicious device drivers, firmware!)
can access/modify all components of a system

The DMA Problem



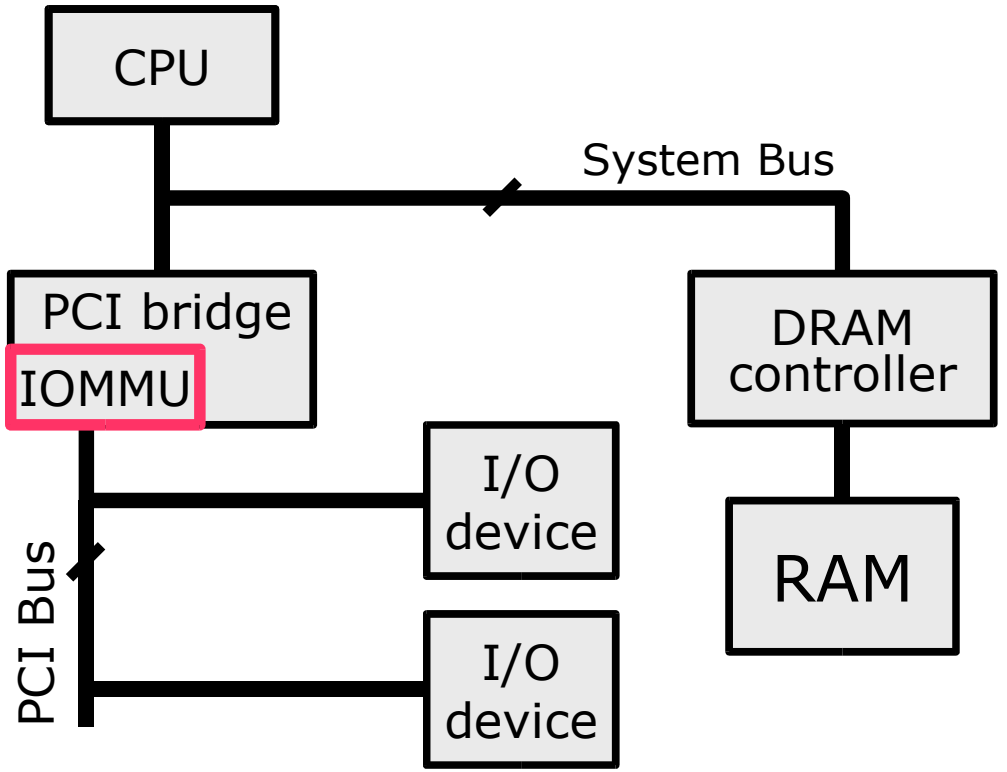
IOMMU

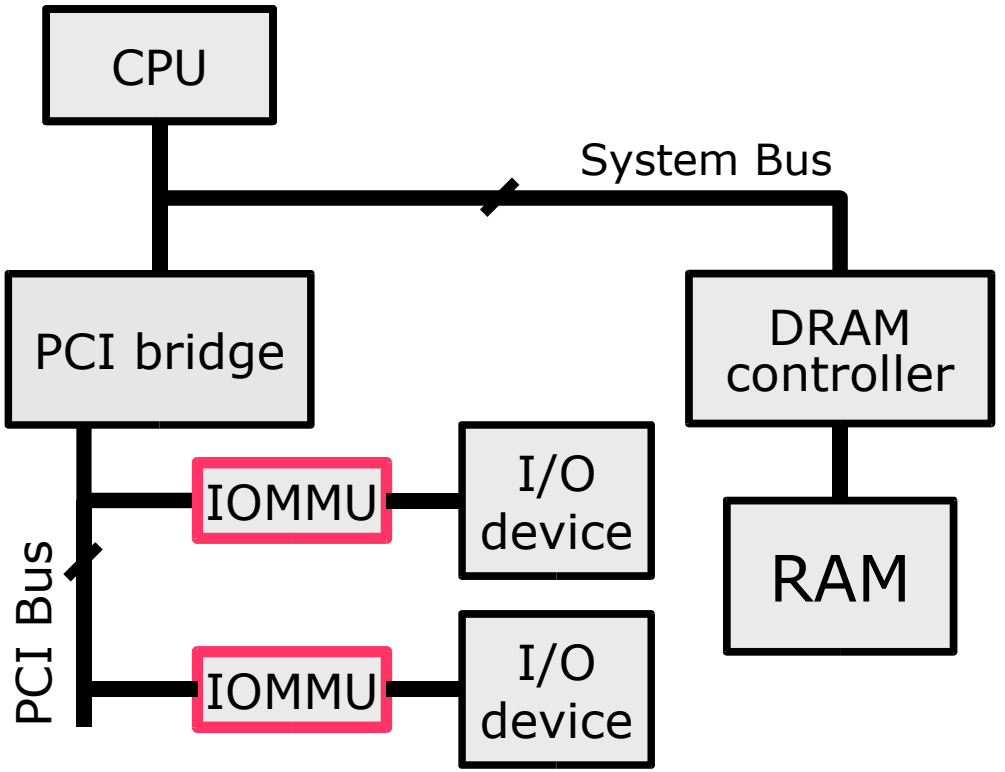
per-bus IOMMU:

- IA64 chipsets
- Opteron

per-device IOMMU:

- **n/a** in current hardware!

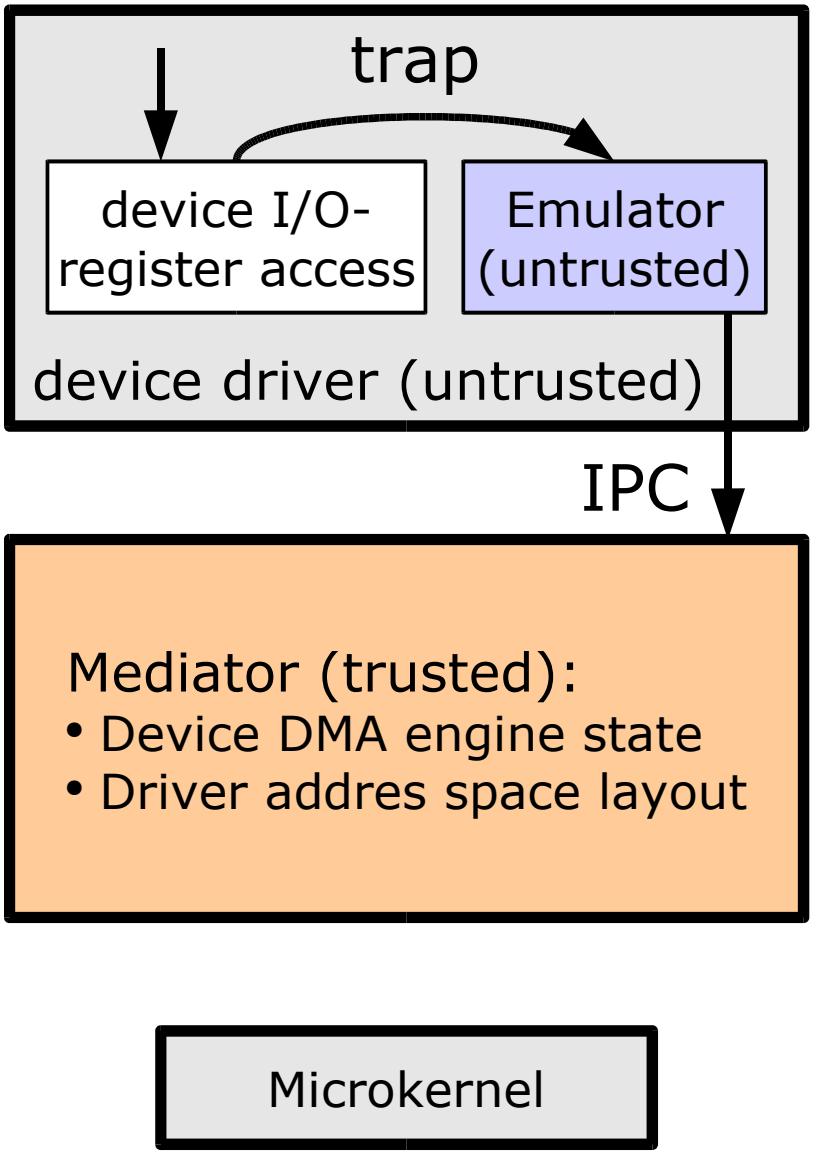


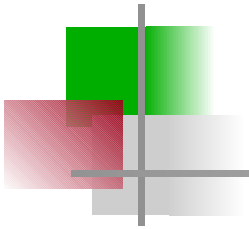


IOMMU in Software

Make sure that device cannot perform malicious DMA:

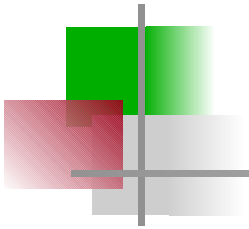
- **Trap** read/write access to I/O-registers of the device
- An **emulator** (untrusted) determines size and value to be read/written
- A **mediator** (trusted) checks and performs the access





IOMMU in Software

- **Emulator**:
  - in driver's address space ➡ untrusted
  - malfunction does only decrease availability of device
  - ~ 500 LoC
- **Mediator**:
  - trusted, own address space
  - specific for a device or a class of devices
  - ~ 300 LoC

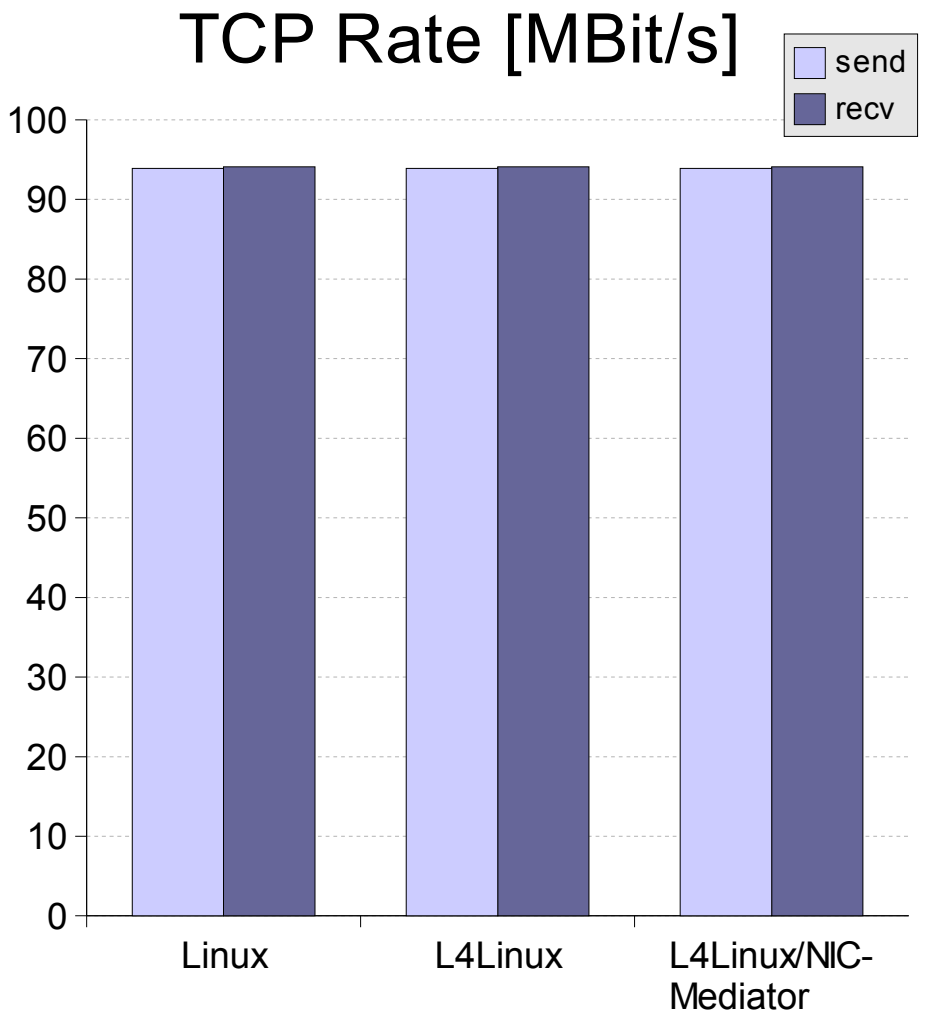


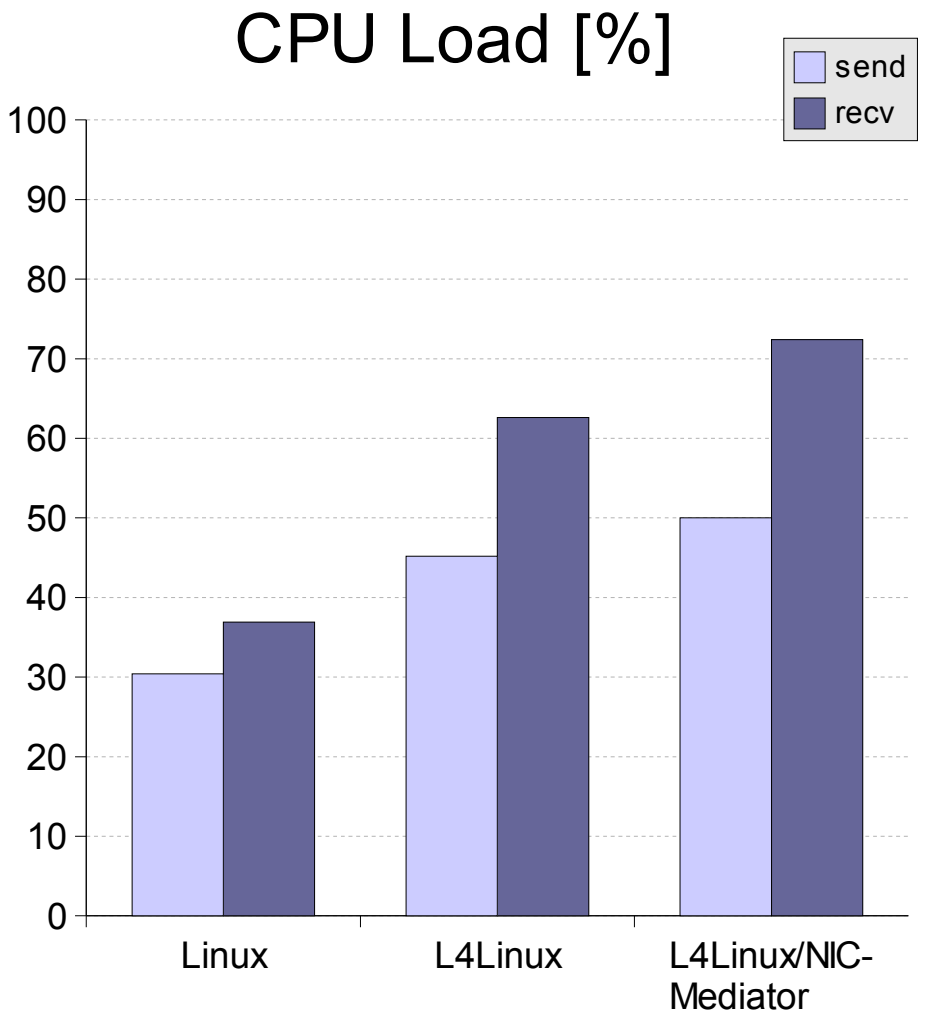
IOMMU in Software

- Implemented for:
  - Fast Ethernet card (DEC Tulip 21143)
  - ATA Controllers
- Does not work for firmware-programmable devices:
  - private interface between device driver and firmware
  - no protection mechanism between firmware and device

IOMMU in Software: NIC Performance

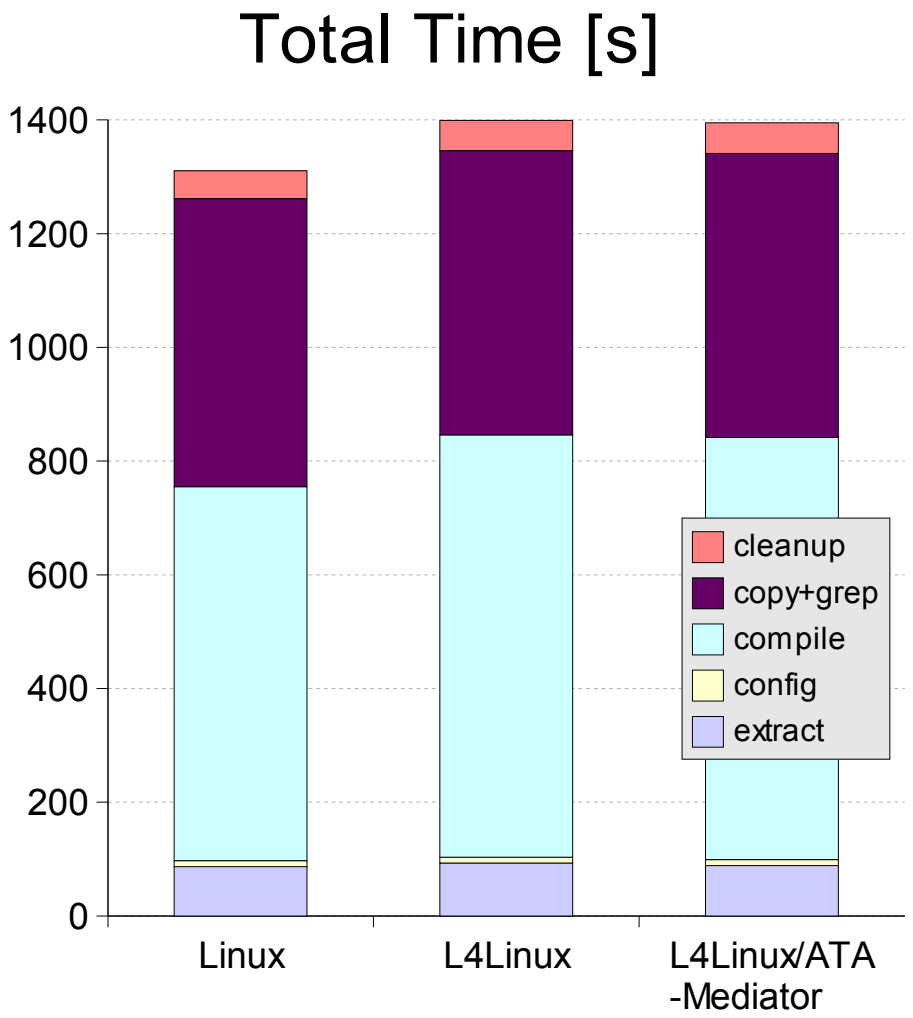
Pentium-III 800 MHz, Fast Ethernet

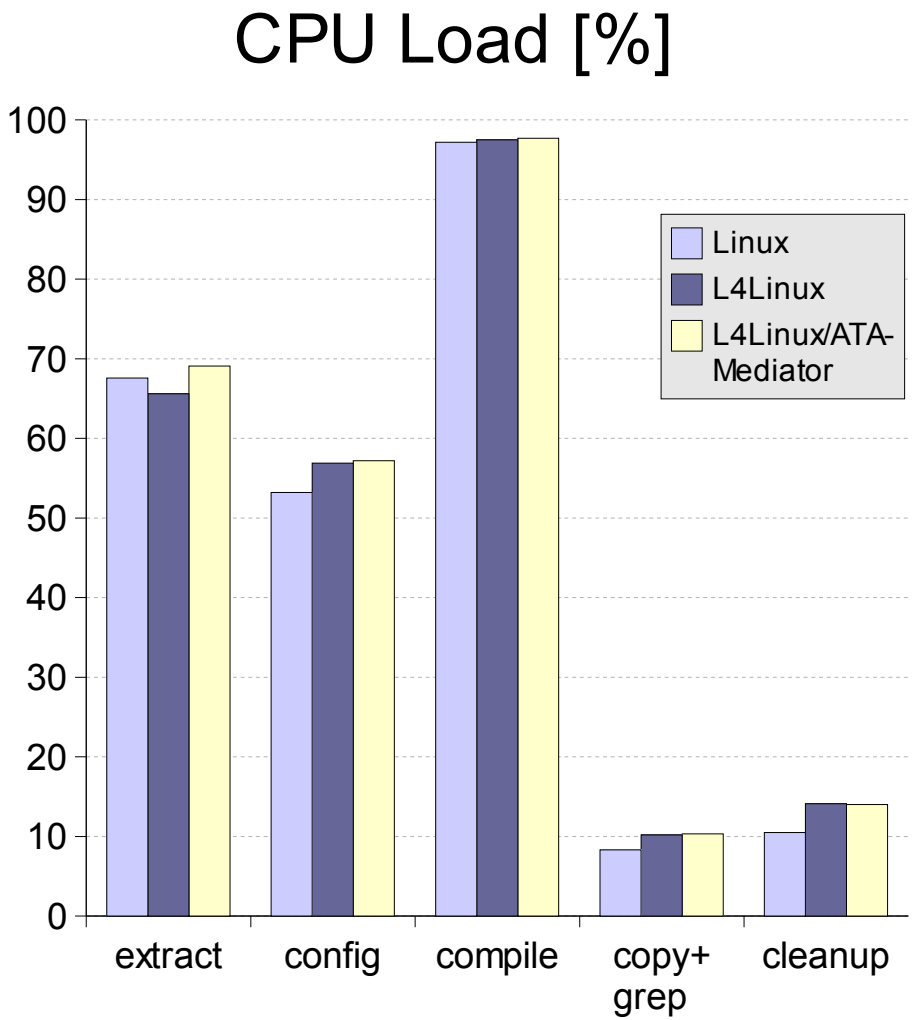




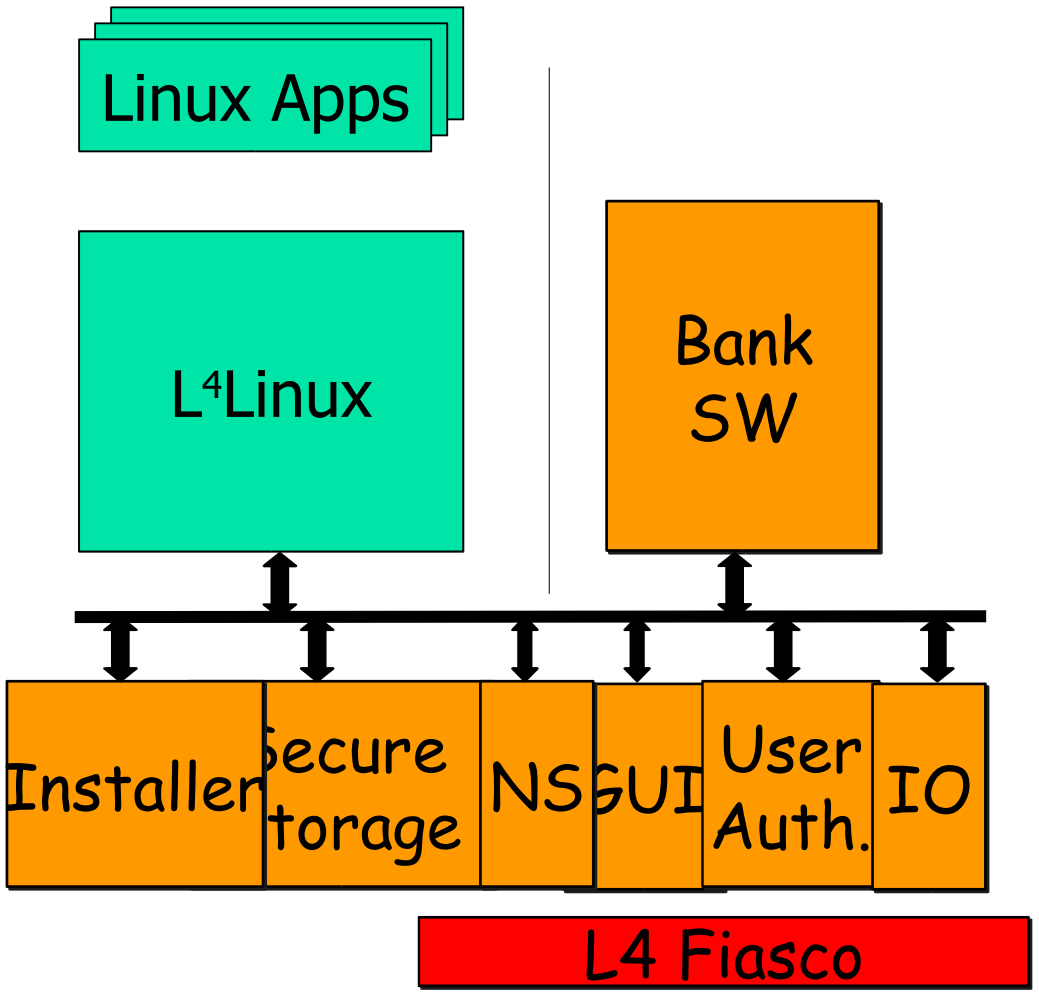
IOMMU in Software: ATA Performance

Pentium-III 800 MHz, VIA82C586 ATA Controller





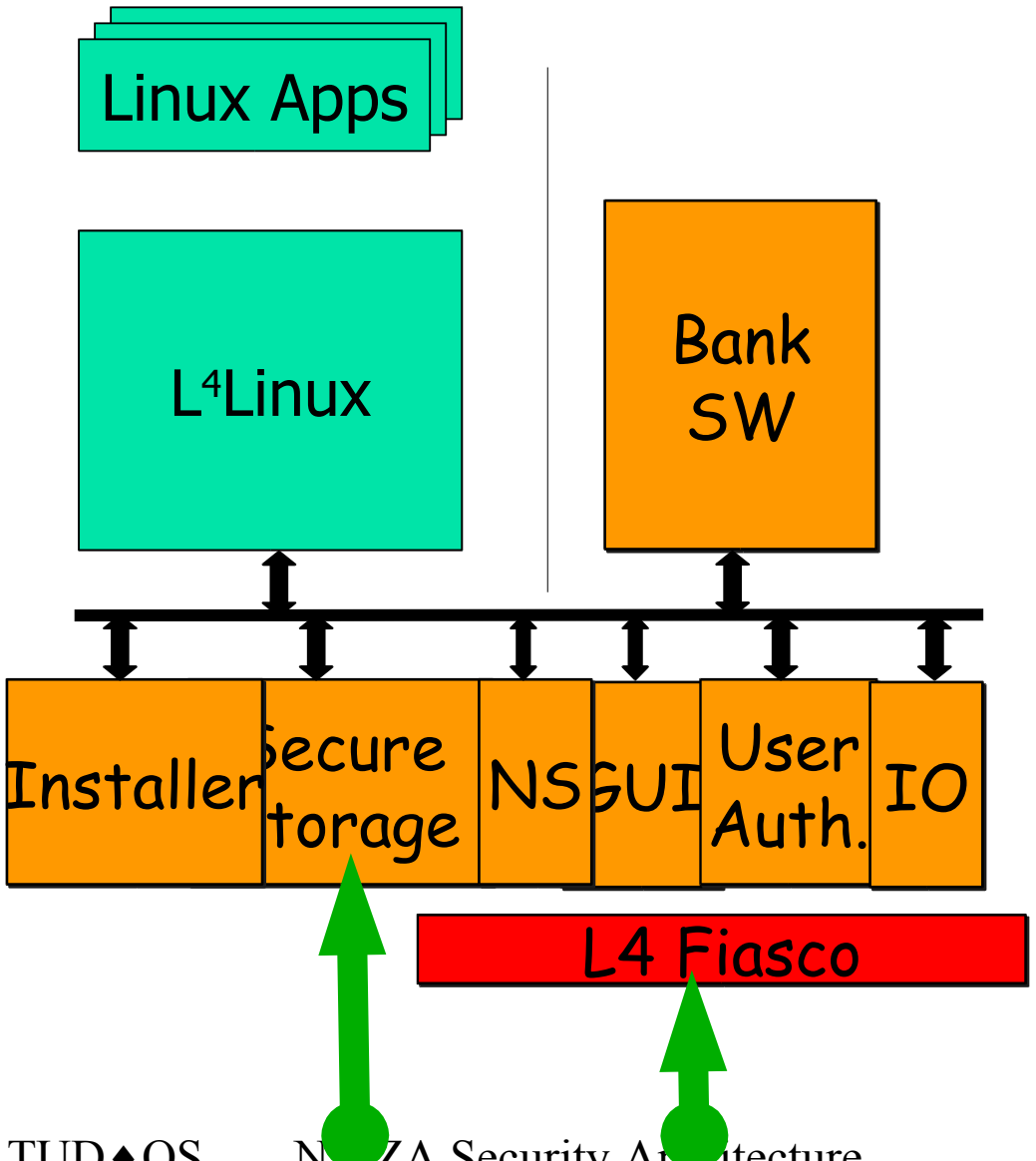
Secure Booting, Remote Attestation and Trusted Path



Authentic application/system:

- how does the remote bank know ?
- how does the local client/user know ?

Secure Booting, Remote Attestation and Trusted Path



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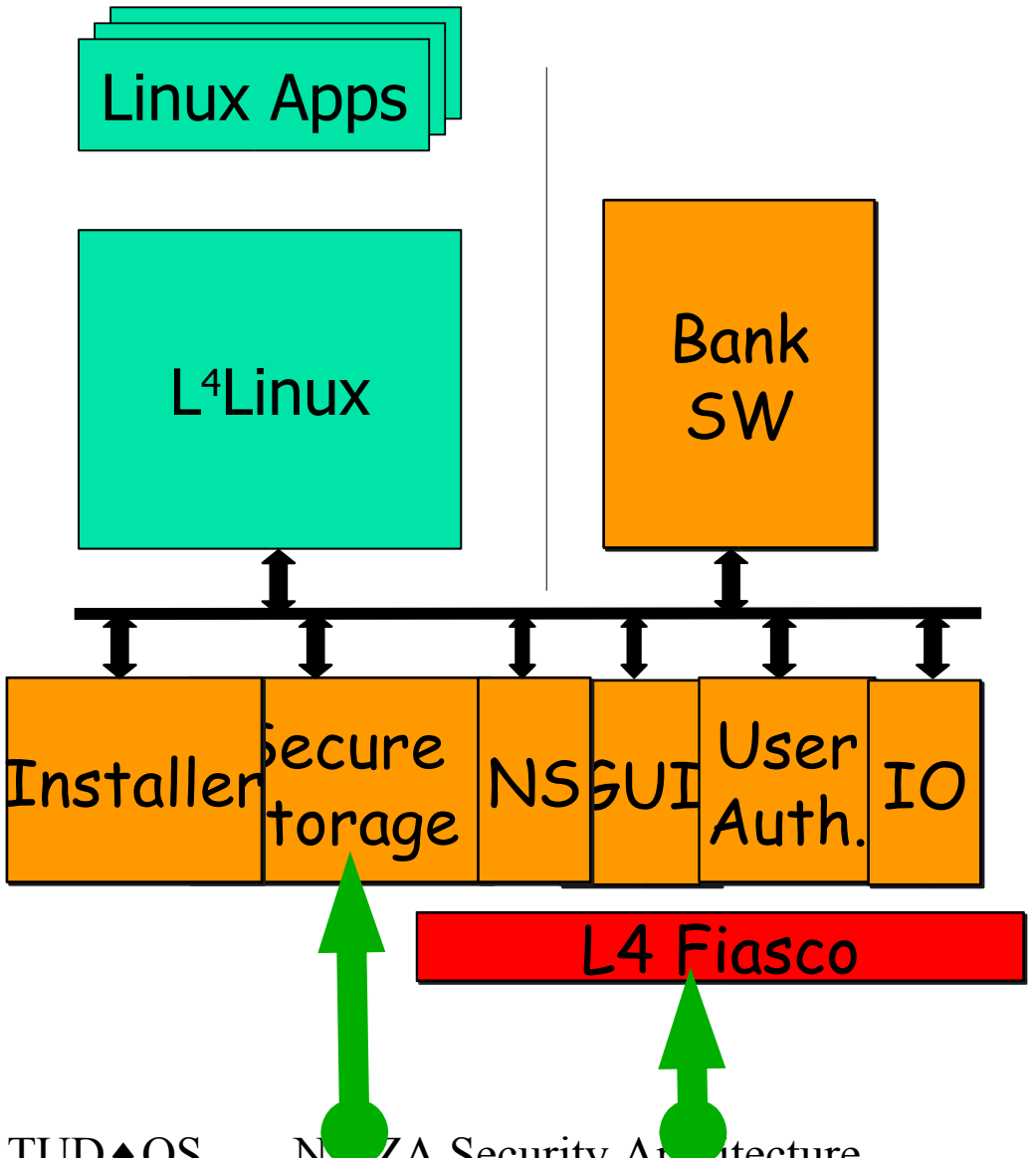
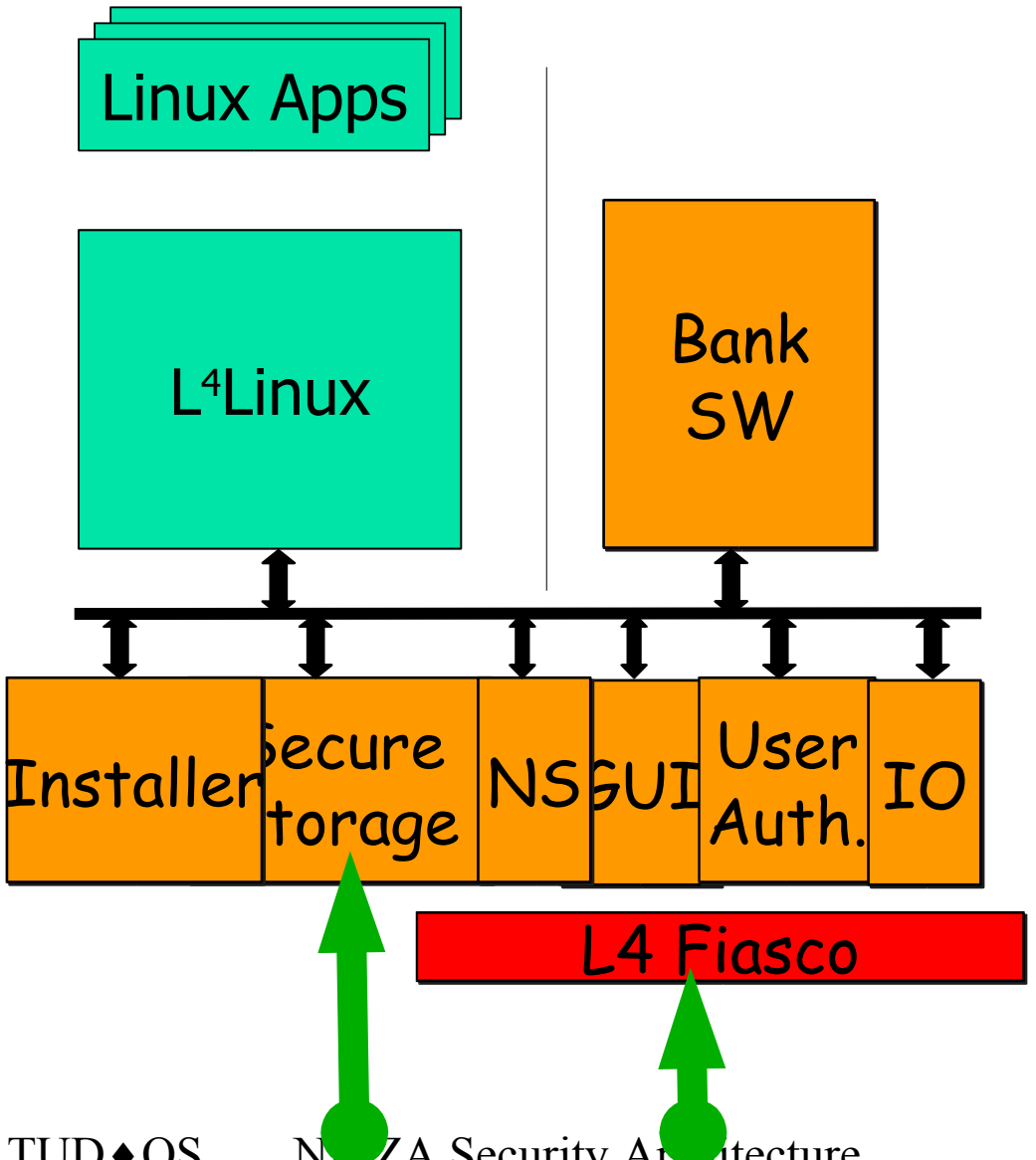
Secure Booting, Remote Attestation and Trusted Path



Authentic application/system:

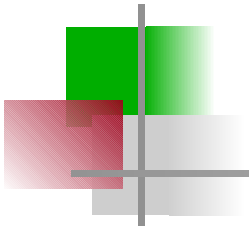
- how does the remote bank know ?
  - attestation protocol up to Nizza trusted platform
  - mediate other communication thru trusted installer

Secure Booting, Remote Attestation and Trusted Path



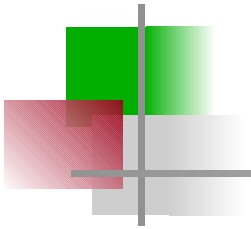
Authentic application/system:

- how does the local client/user know ?
  - attestation protocol up to Nizza trusted platform
  - indicate “red/green”
  - handover to DOpE



Secure Storage with small TCB (future)

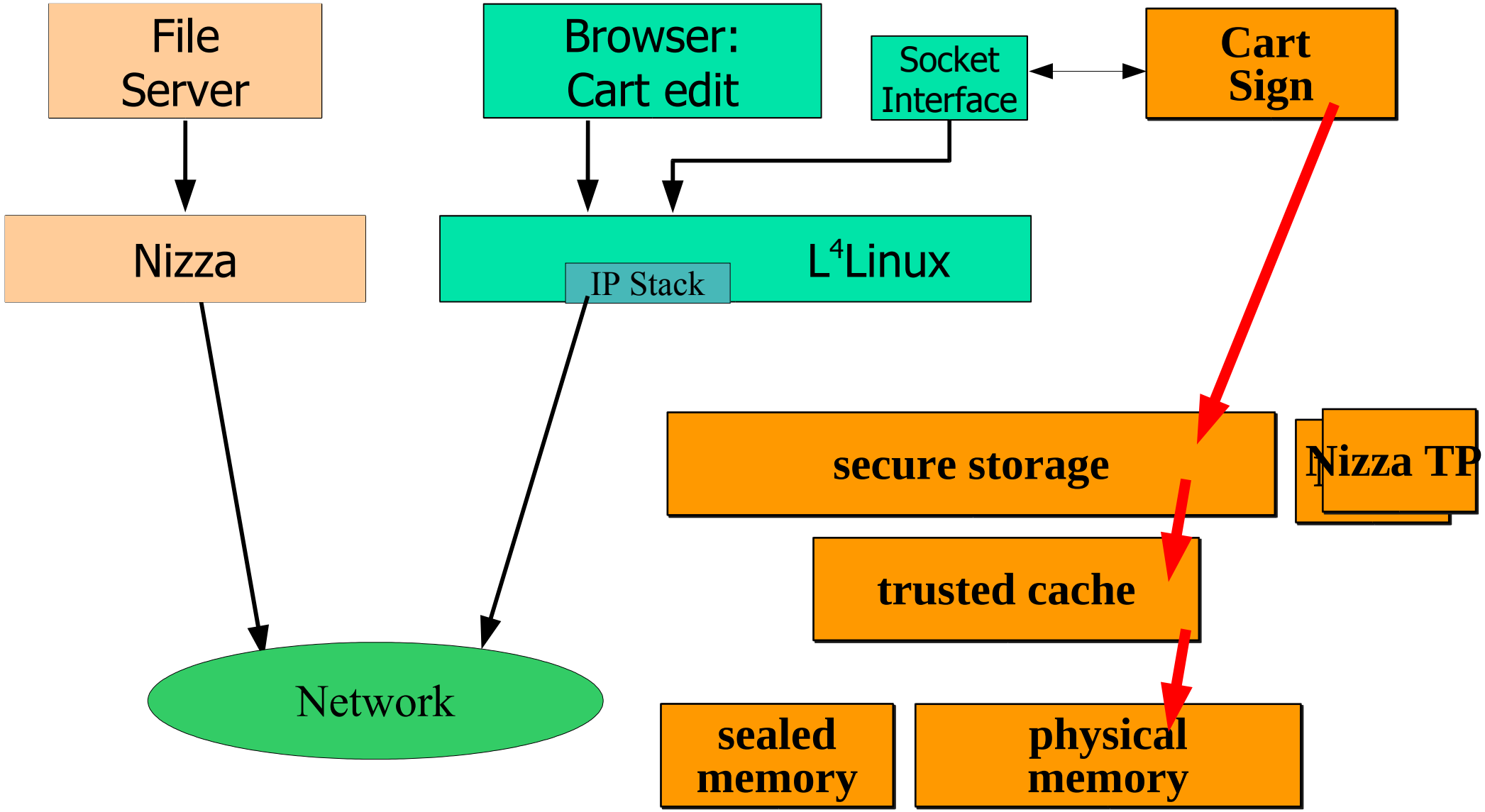
- objectives:
  - security
    - confidentiality, integrity,
    - recoverability
    - availability
  - system security
    - small TCB
    - attacks:
      - theft/loss of device
      - full penetration of L4Linux
-



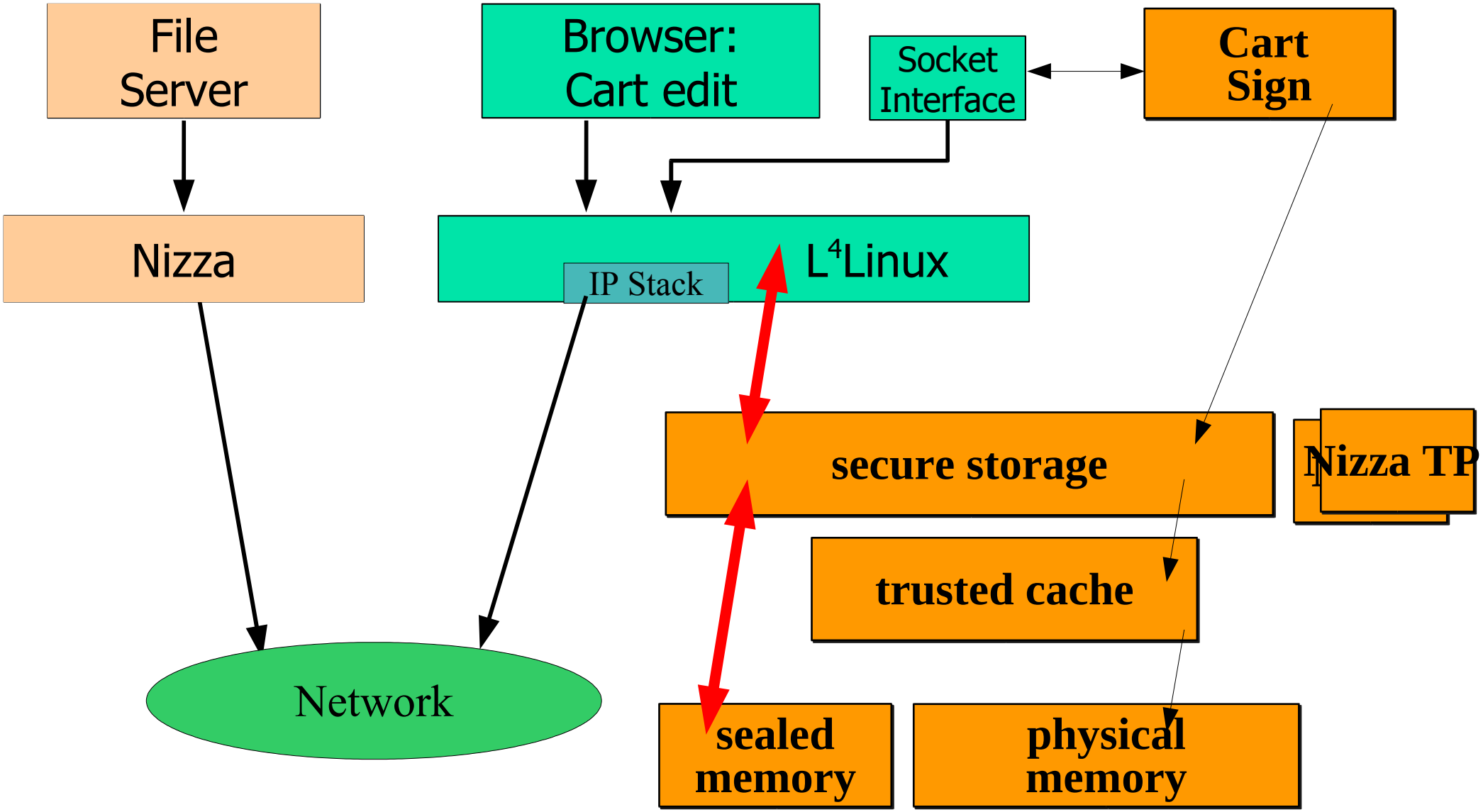
Secure Storage with small TCB (future)

- techniques:
  - use Sealed Memory as key storage
  - reuse L4Linux file system as mass storage
  - use trusted file server for recoverability
  - use resource allocation for availability

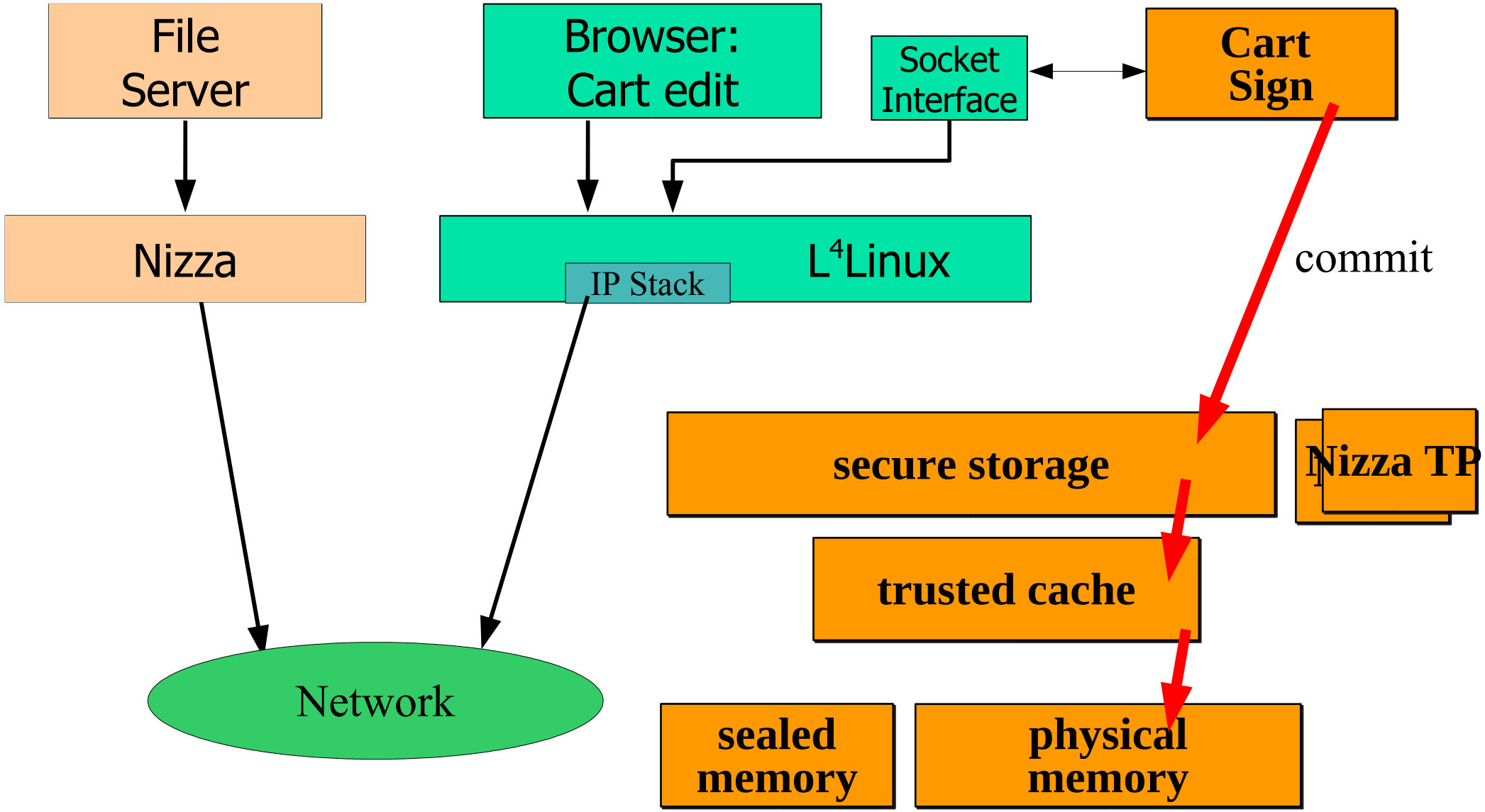
Confidentiality and Integrity



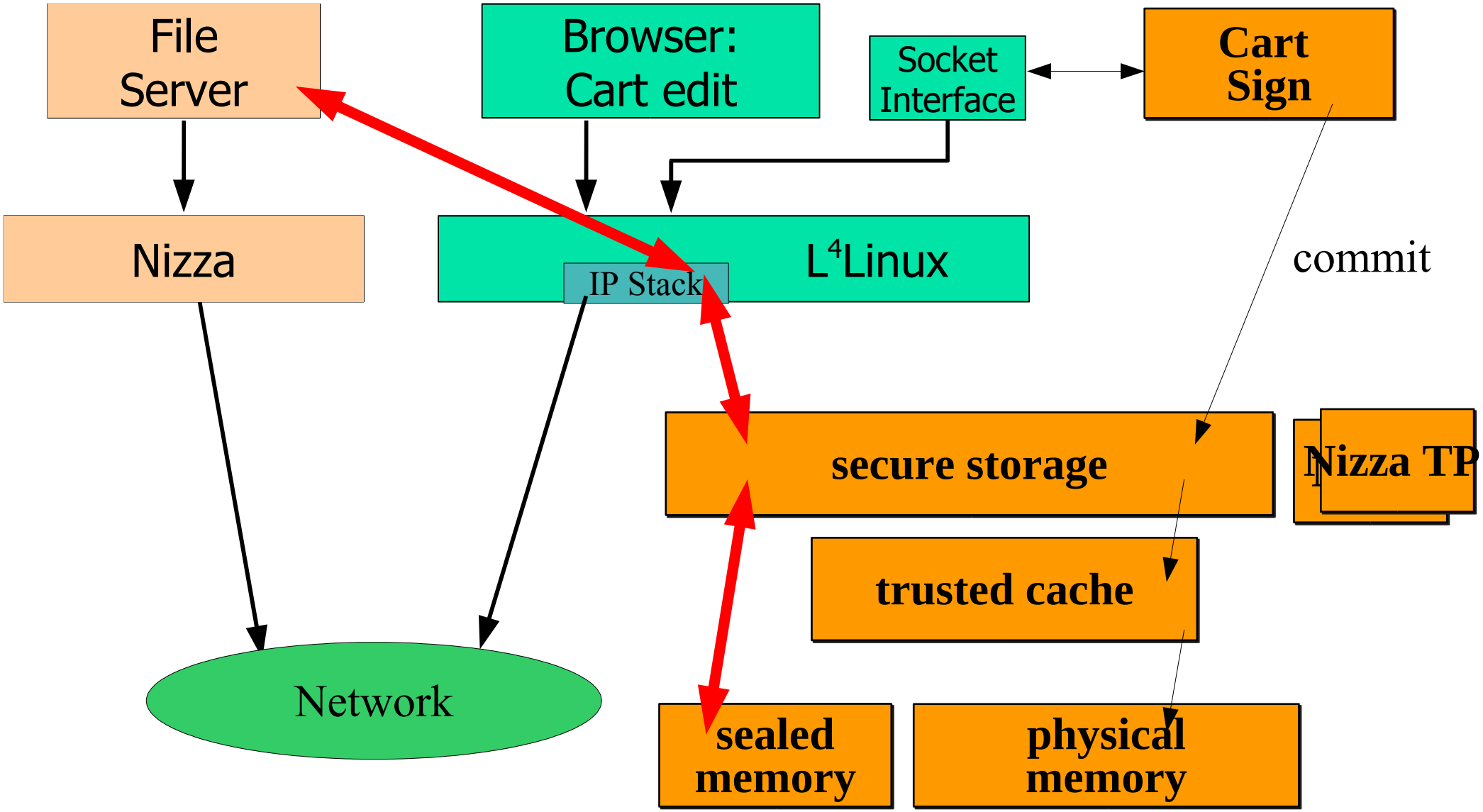
Mass Storage (File System) not part of TCB



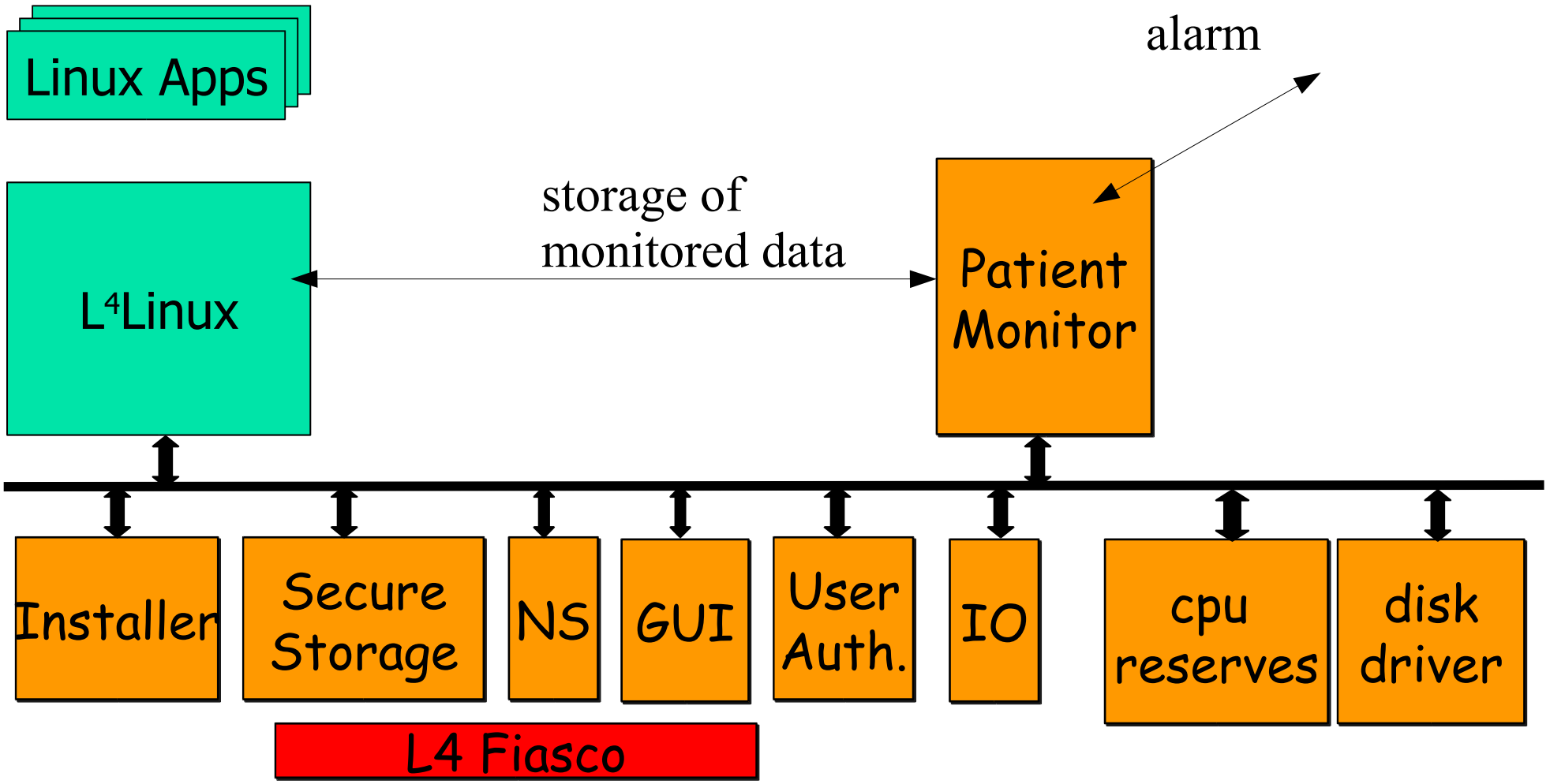
Recoverability

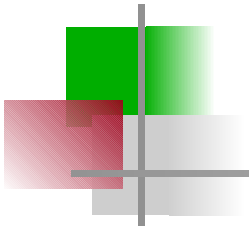


Recoverability



Availability for Secure Storage





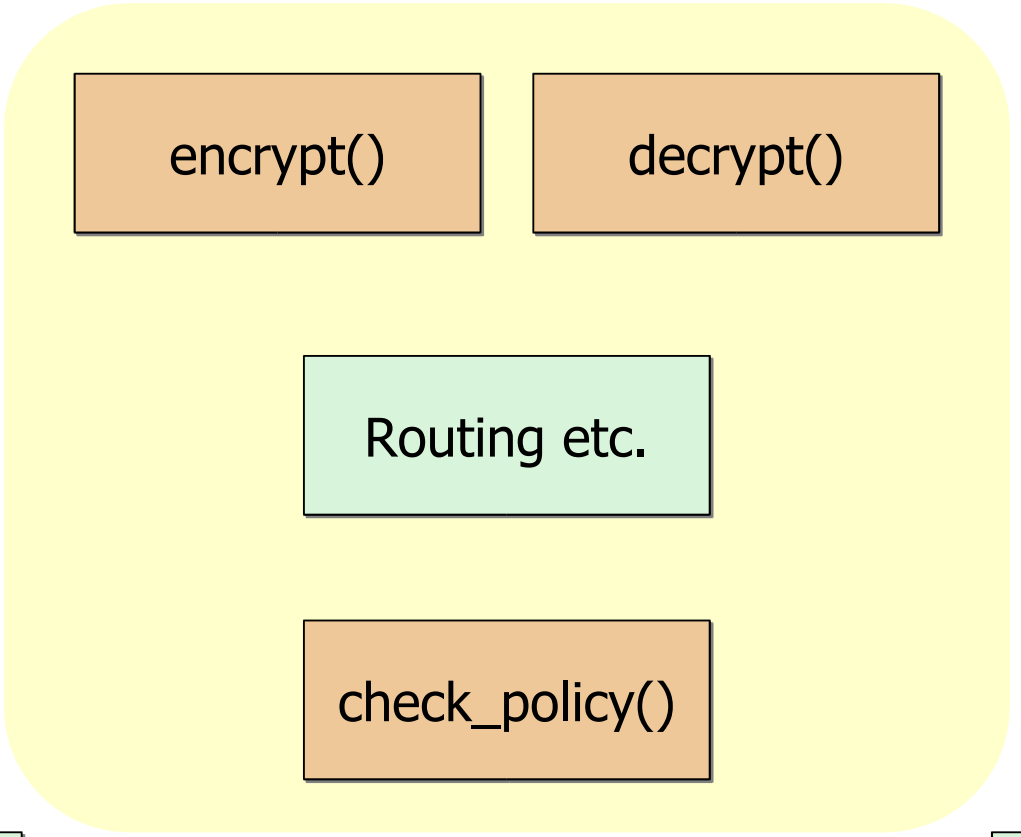
Micro-Sina

- VPN Box
- reengineering a commercial product

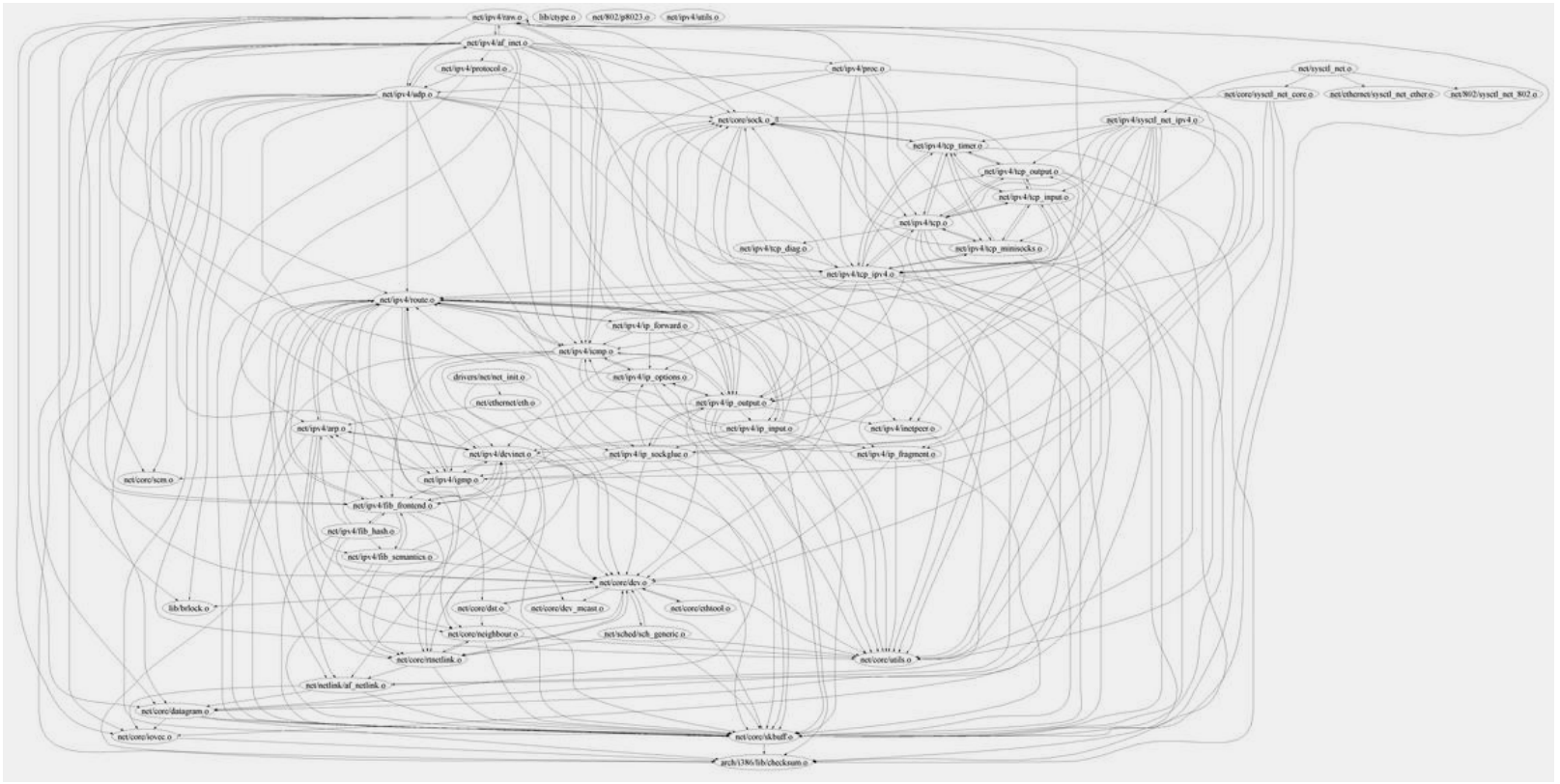
- first approach:
  split Linux' IP-Sec

First Approach

- Decompose network stack software on the basis of IP packet flow



Given up


net/ipv4/raw.o
lib/ctype.o
net/802/p8023.o
net/ipv4/utils.o
net/ipv4/af_inet.o
net/ipv4/protocol.o
net/ipv4/proc.o
net/sysctl_net.o
net/ipv4/udp.o
net/core/sock.o
net/core/sysctl_net_core.o
net/ethernet/sysctl_net_ether.o
net/802/sysctl_net_802.o
net/ipv4/sysctl_net_ipv4.o
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net/ipv4/tcp_output.o
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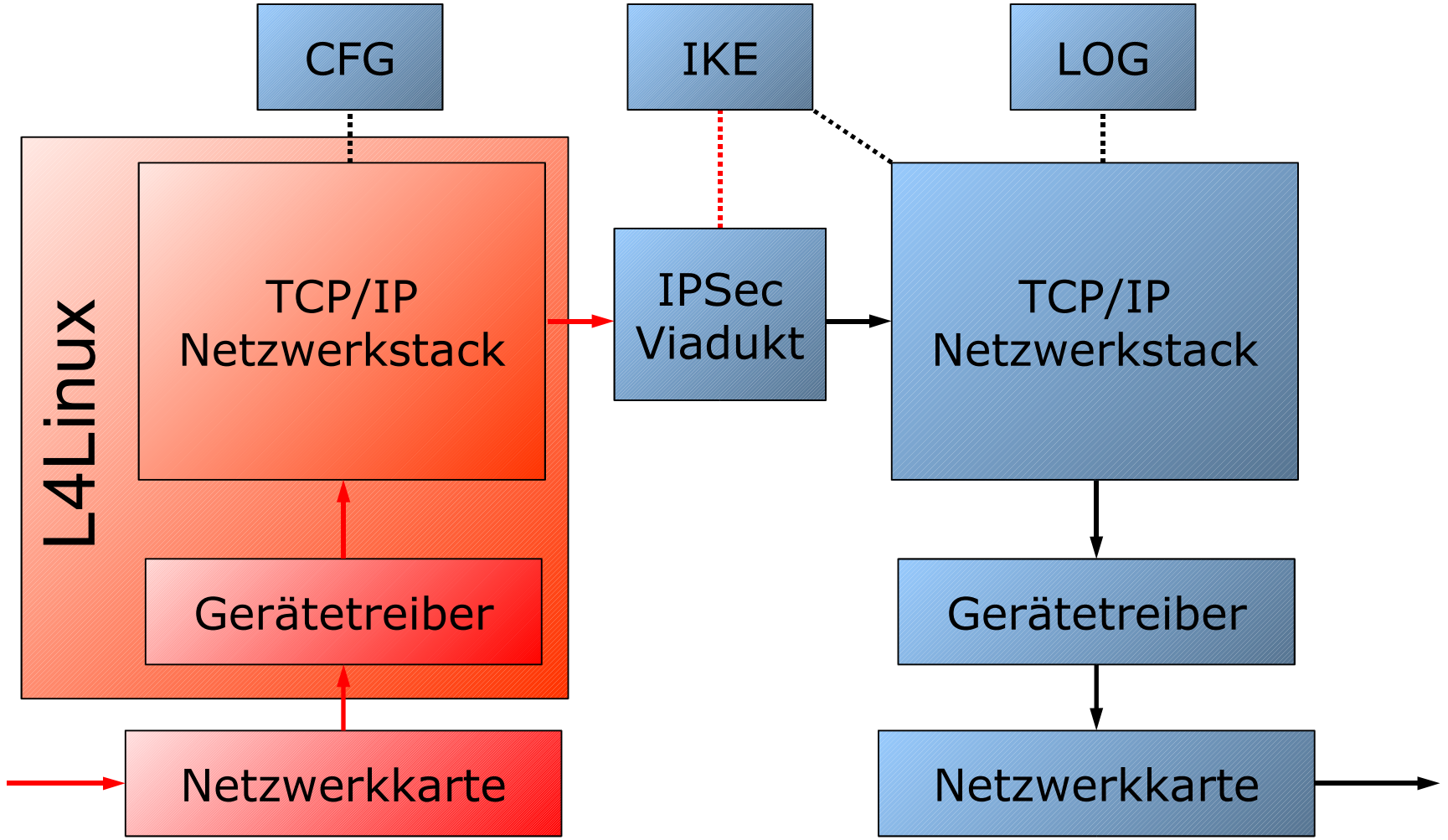
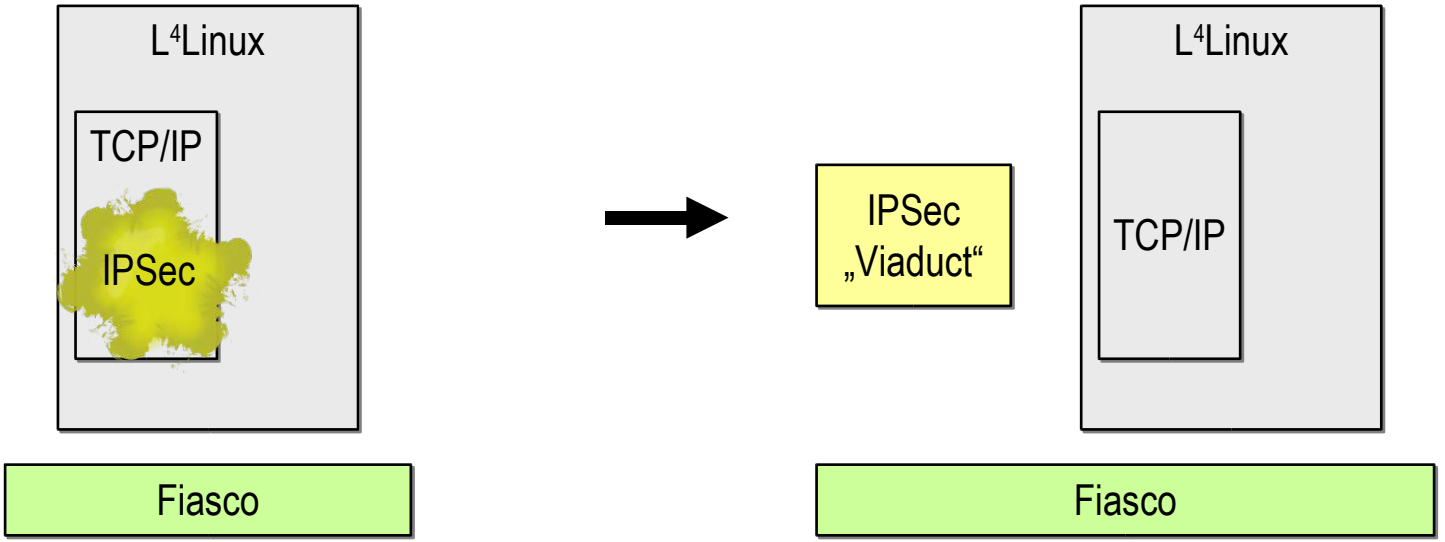
net/ipv4/tcp.o
net/ipv4/tcp_diag.o
net/ipv4/tcp_minisocks.o
net/ipv4/tcp_ipv4.o
net/ipv4/route.o
net/ipv4/ip_forward.o
net/ipv4/icmp.o
drivers/net/net_init.o
net/ipv4/ip_options.o
net/ethernet/eth.o
net/ipv4/ip_output.o
net/ipv4/arp.o
net/ipv4/ip_input.o
net/ipv4/inetpeer.o
net/ipv4/devinet.o
net/ipv4/ip_sockglue.o
net/ipv4/ip_fragment.o
net/core/scm.o
net/ipv4/igmp.o
net/ipv4/fib_frontend.o
net/ipv4/fib_hash.o
net/ipv4/fib_semantics.o
net/core/dev.o
lib/bcd.o
net/core/dst.o
net/core/dev_mcast.o
net/core/ethtool.o
net/core/neighbour.o
net/sched/sch_generic.o
net/core/rtnetlink.o
net/core/utils.o
net/netlink/af_netlink.o
net/core/datagram.o
net/core/iovec.o
net/core/skbuff.o
arch/i386/lib/checksum.o

Instead: Rewrite and Trusted Wrappers

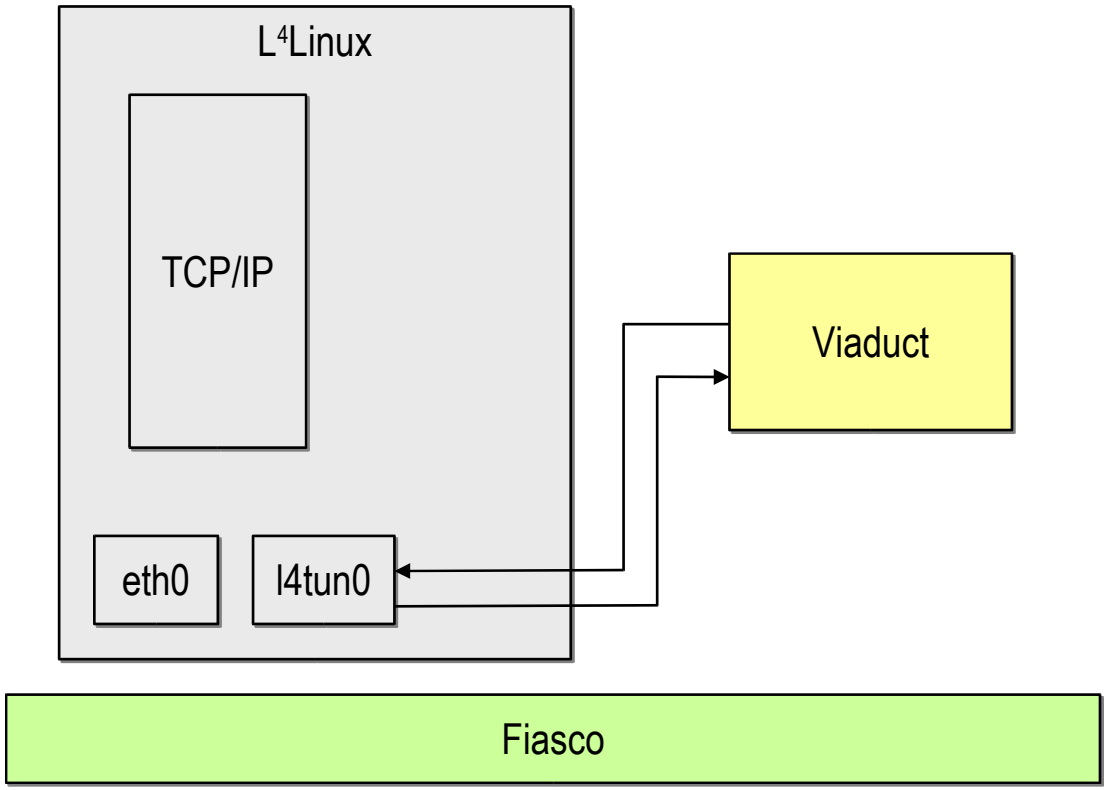


One Step Back



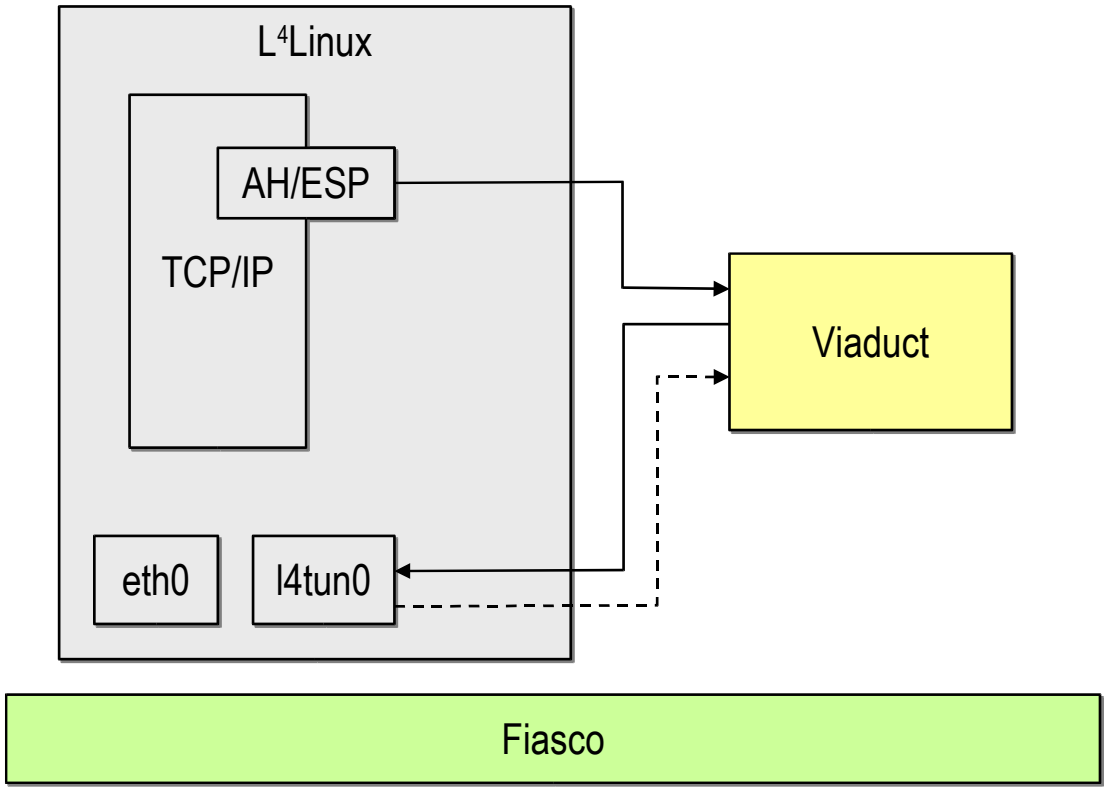
Technical Details (Viaduct)

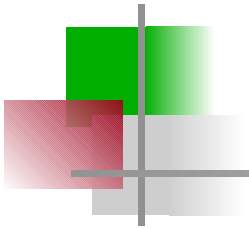
- IP packets must be passed to the Viaduct
  - L4 IPC as Virtual network driver in L⁴Linux



Technical Details (Viaduct)

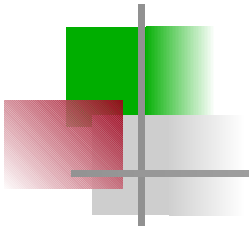
- IPSec can only handle unfragmented packets
  - Use L⁴Linux for complex reassembly





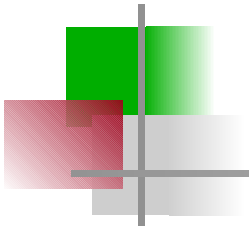
Related Work: EROS, Keykos and Nizza

- similar objectives
- moving target



Related Work: Microsoft NGSCB and Nizza

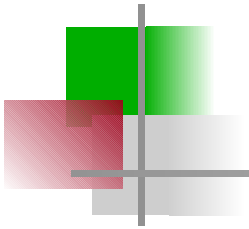
- similar objectives
- moving target



Related Work: XOM and Nizza

- XOM: take OS off trusted path

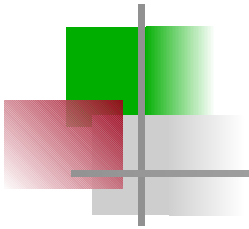
- Implementing an Untrusted Operating System on Trusted Hardware
  David Lie Chandramohan A. Thekkath Mark Horowitz
  SOSP 2003



Related Work: Terra and Nizza

- Terra: VMM as trusted platform
- many more projects down that line

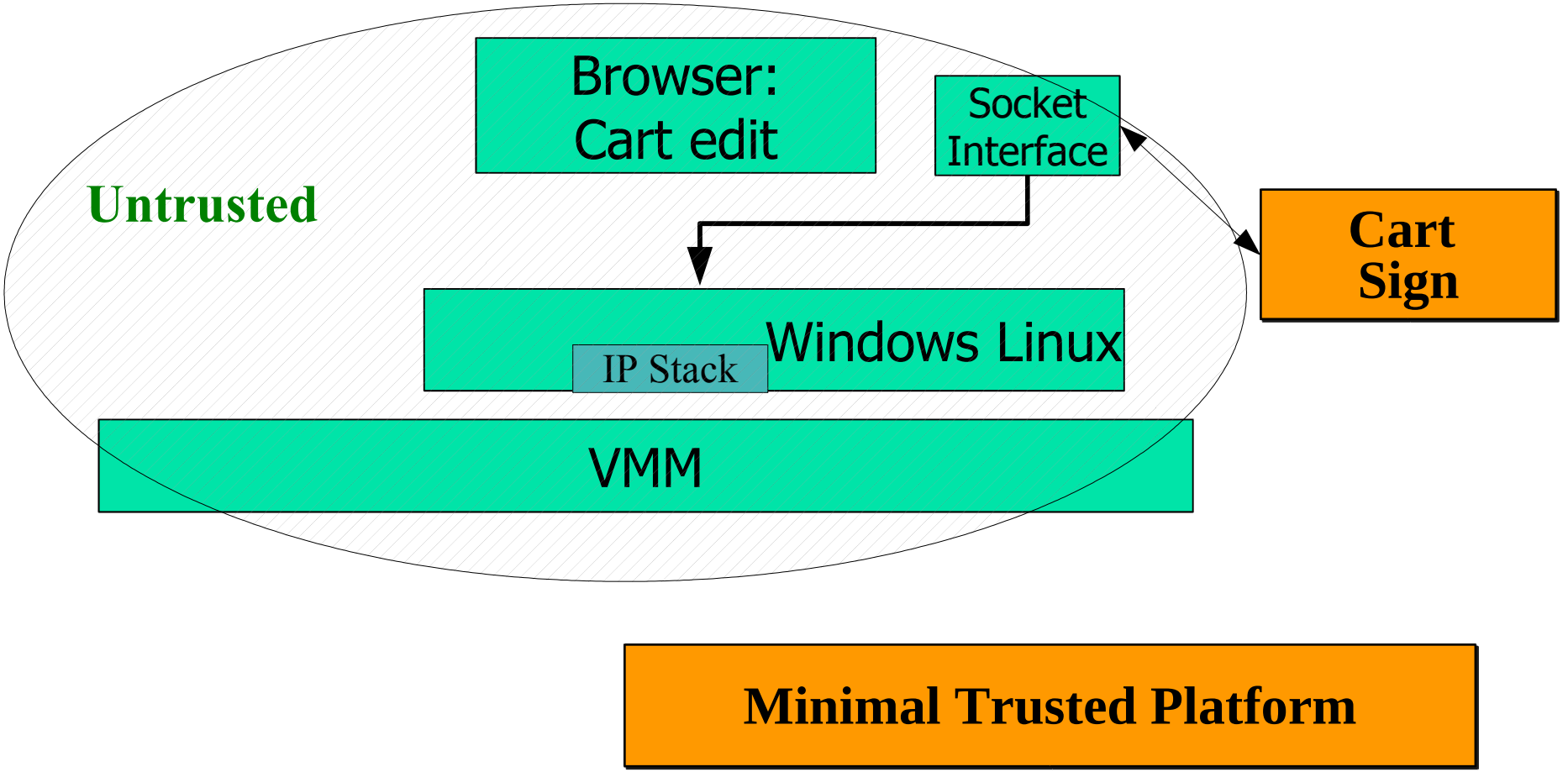
- A Virtual Machine-Based Platform for Trusted Computing
  Tal Garfinkel, Ben Pfaff, Jim Chow, Mendel Rosenblum and Dan Boneh
  SOSP 2003



Nizza vs. VMM approaches

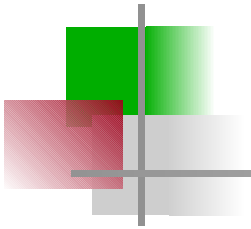
- advantages VMM:
  - support+reuse: unmodified legacy OS
  - anything else ?
- advantages Nizza
  - smaller TCP:
    no network device emulation and drivers
  - fine grained sharing
  - efficiency (optimized message passing)
- VMM untrusted on Nizza ?

Challenge: Untrusted VMM



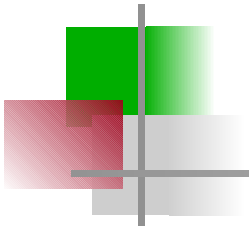
Related work “Useful” for Nizza

- Secure Storage on Untrusted Servers Secure Untrusted Data Repository (SUNDR)
  Jinyuan Li, Maxwell Krohn, David Mazire s, and Dennis Shasha ,
  New York University
- Privtrans: Automatically Partitioning Programs for Privilege Separation
  David Brumley and Dawn Song,
  Carnegie Mellon University



Technical Risks

- performance
  - copying overhead
  - context switching time (hardware)
  - increased memory (duplication of page tables)

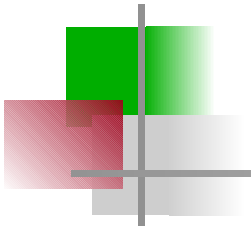


Context switches

- Register IPC between two address spaces (1 x send, 1 x receive; kernel entry with sysenter):

Pentium-III:	600 cycles
Opteron:	700 cycles
Prescott:	2200 cycles

??



Conclusion

technologies are in place

to build much better (securer) systems

need proper integration –> Nizza

TUD♦OS