Local Operating Systems R&D And Opportunities for Students

COMP9242

2006/S2 Week 14

OVERVIEW

Cool systems stuff happening at:

- UNSW
  - ➜ Gelato@UNSW
  - ➜ Linux scalability and performance on Itanium
- National ICT Australia (NICTA)
  - ➜ Embedded, Real-Time and Operating Systems (ERTOS) Program
  - ➜ world-class research agenda on embedded operating systems
- Open Kernel Labs, Inc
  - ➜ brand-new ERTOS spinout with a global business
  - ➜ microkernels for millions of people
- Opportunities
  - ➜ summer projects
  - ➜ theses
  - ➜ employment

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  - ➜ members: UNSW, ANU, NSW and ACT governments
  - ➜ partners: USyd, UMelb, UQ, QUT, Griffith, QLD+Vic governments
  - ➜ locations: Sydney (Kensington, ATP), Canberra, Melbourne, Brisbane
- Aim: change the Australian ICT landscape
  - ➜ conduct world-class research
  - ➜ improve quality of Australian ICT PhDs
  - ➜ commercialise research outputs
  - ➜ achieve real impact
  - ➜ become one of the top-ten ICT research institutions in the world

NICTA Structure

- Presently $\approx$ 300 researchers, 250 PhD students
- Most researchers belong to *Research Programs*
  - ➜ aligned with discipline areas ($\approx$ 5–10 researchers)
  - ➜ ERTOS is one of them (currently largest)
  - ➜ medium- to long-term vision
- *Projects* focused on specific outcomes
  - ➜ collaborative or client-focused
  - ➜ 1–20 people, 1–5 years

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  - ➜ J Vuillemin (VP, INRIA), D Rombach (Head, Fraunhofer IESE), R Newton (Dean UCB), R Brooks (Head MIT CSAIL), S Feldman (VP, IBM)
- *International Business Advisory Group*
  - ➜ D Zitzner, (ret exec VP, HP), N Murthy (Chairman, Infosys), C Mudge (Dir , Macq Innov), B Bishop (V. Chairman, SGI), H Killen (MP Hemisphere Capital)

Embedded, Real-Time and Operating Systems — The ERTOS Program

- One of presently 15 Research Programs in NICTA
  - ➜ 6 PhD-qualified researchers (more being recruited)
  - ➜ 6 engineers / research assistants (1 PhD)
  - ➜ 11 PhD, 1 ME students
- Competencies in
  - ➜ operating systems, microkernels
  - ➜ networking
  - ➜ real-time systems
  - ➜ hardware design

ERTOS Agenda

ERTOS Vision

To make highly reliable, safe and secure embedded systems a widely-deployed reality.

ERTOS Mission

To establish ERTOS-developed embedded operating systems as de-facto industry standards.

EMBEDDED SYSTEM





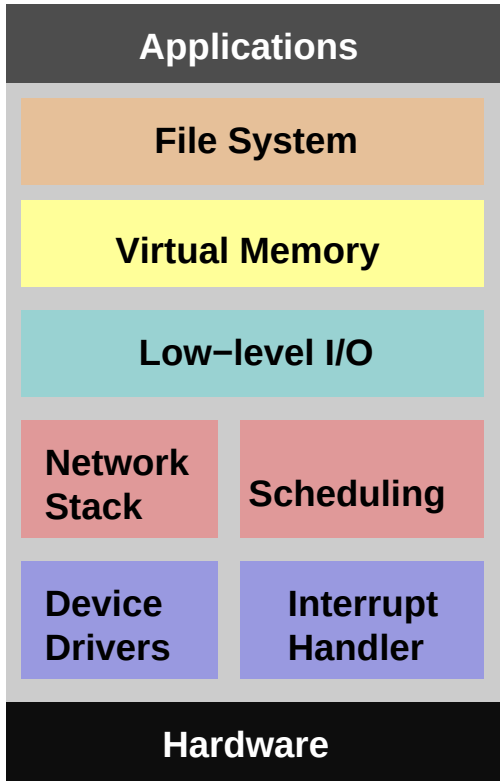



Computer system that is part of a larger system

General-Purpose vs. Embedded

Traditional view:

general-purpose system



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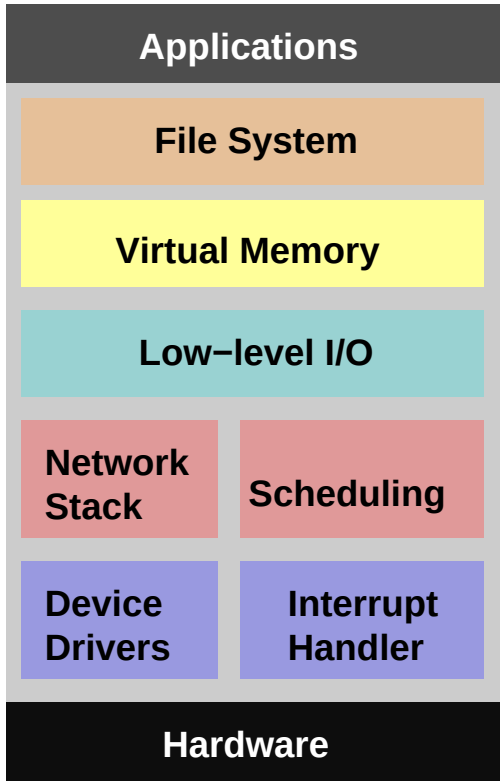

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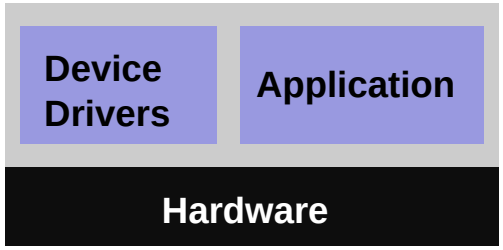

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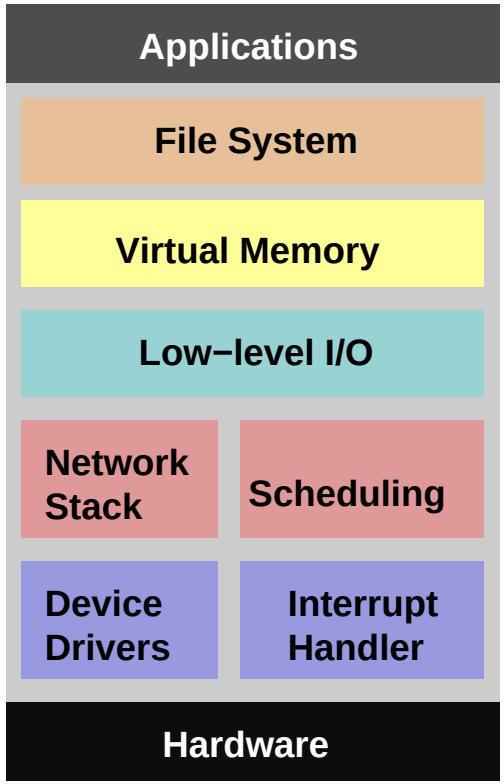

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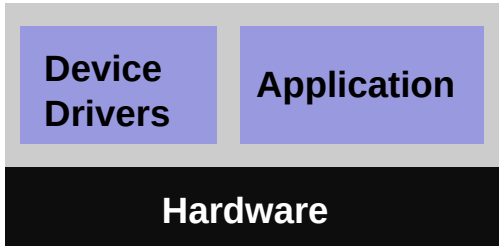

- ➜ minimal
- ➜ no OS at all or small "real-time executive"
- ➜ no protection

Security Challenges

- Growing functionality
- Wireless connectivity
- Downloaded contents (entertainment)
- Increasing dependence on embedded systems

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  - ➜ increasing software complexity
    - ➜ millions LOC on phone handsets
    - ➜ Gigabytes of code in cars
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  - ➜ increased exposure to embedded-systems security weaknesses

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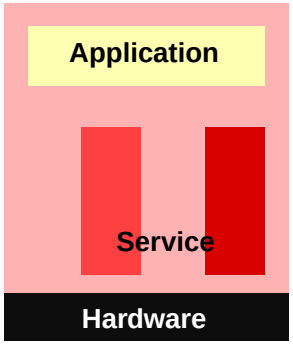

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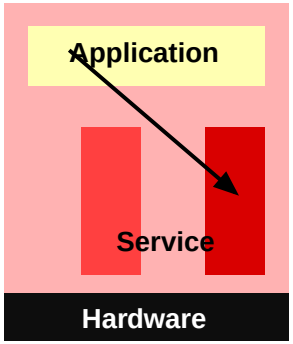

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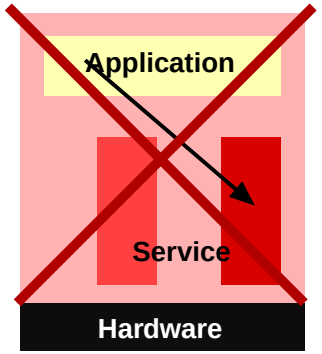

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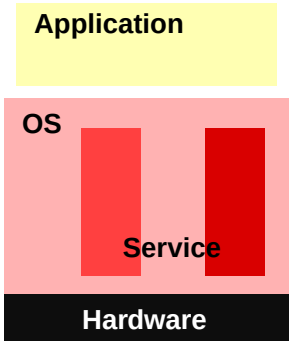
  - ➜ every small bug/failure is fatal
  - ➜ no defence against viruses, limited defence against crackers

Present Approaches 2: Linux, Windows Embedded, ...



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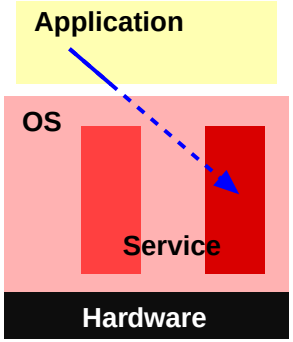

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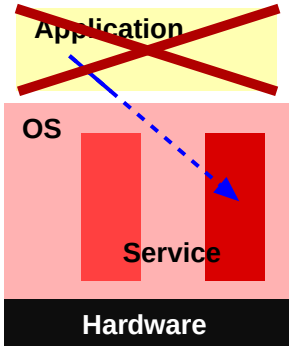

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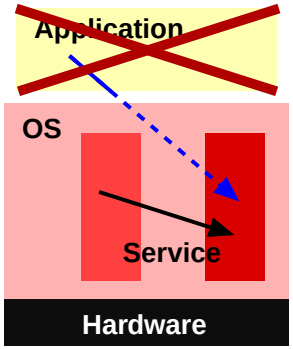

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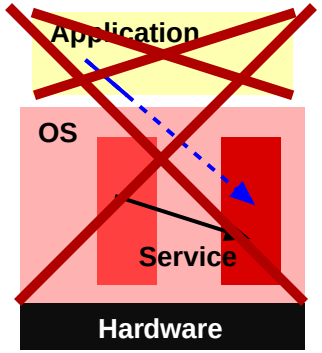

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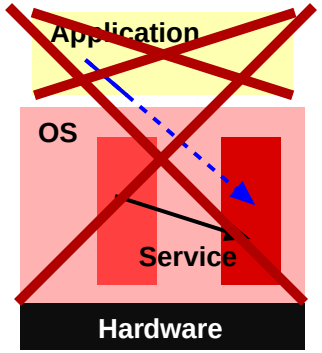

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  - ➜ operating system protected from application misbehaviour
  - ➜ excessive code base for small embedded system
  - ➜ too much code on which security of system is dependent
- Dubious or non-existent real-time capabilities
  - ➜ unsuitable for hard real-time systems

Embedded Systems Requirements:

Reliability, trustworthiness, security:

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  TCB: The part of system that must *be relied on for the correct operation of the system*
- Why minimal TCB?
  - ☑ minimise exposure to bugs/faults
  - ☑ minimise exposure to attacks (internal and external)
  - ☑ support poorly-scaling verification methods

Trusted Computing Base

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- *Everything* on MPU-less processors
  ☒ no memory-protection hardware ⇒ no memory protection

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- *Minimal TCB required* $\Rightarrow$ *microkernel required!*

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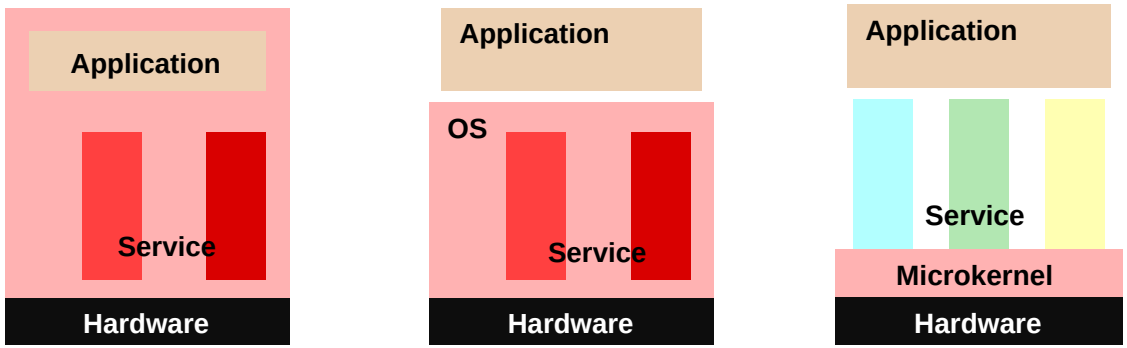

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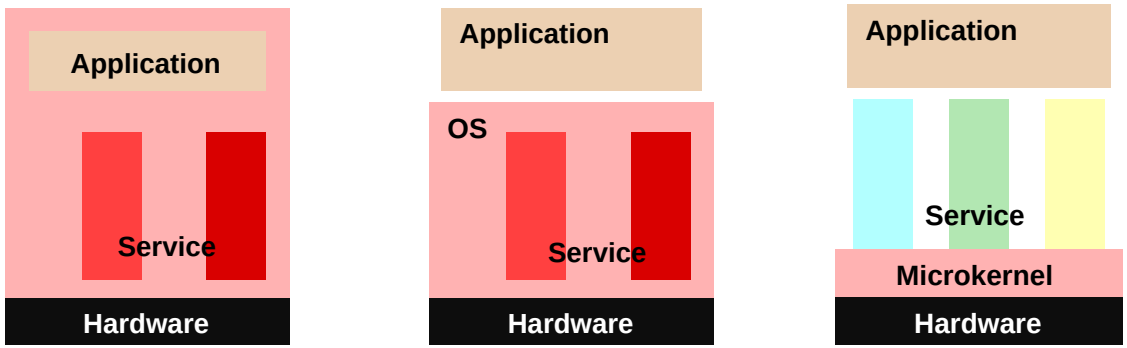

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- Small kernel ⇒ potentially small TCB
- Small TCB ⇒ more trustworthy TCB!

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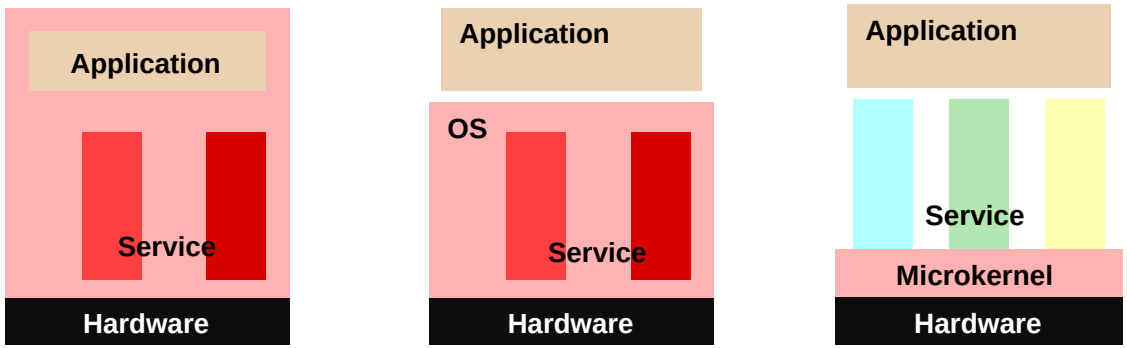

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Challenge: Can we *guarantee* the trustworthiness of the TCB?

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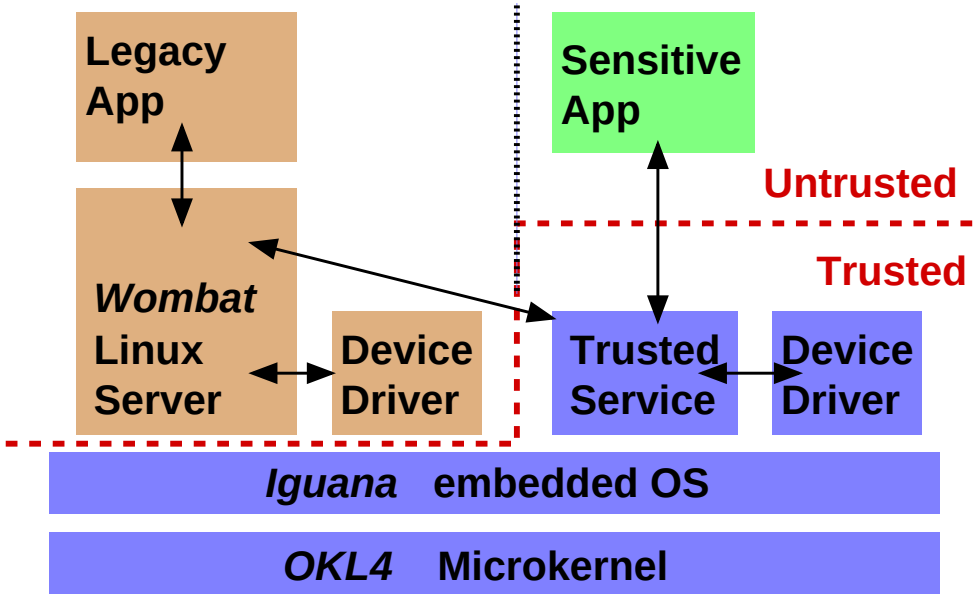

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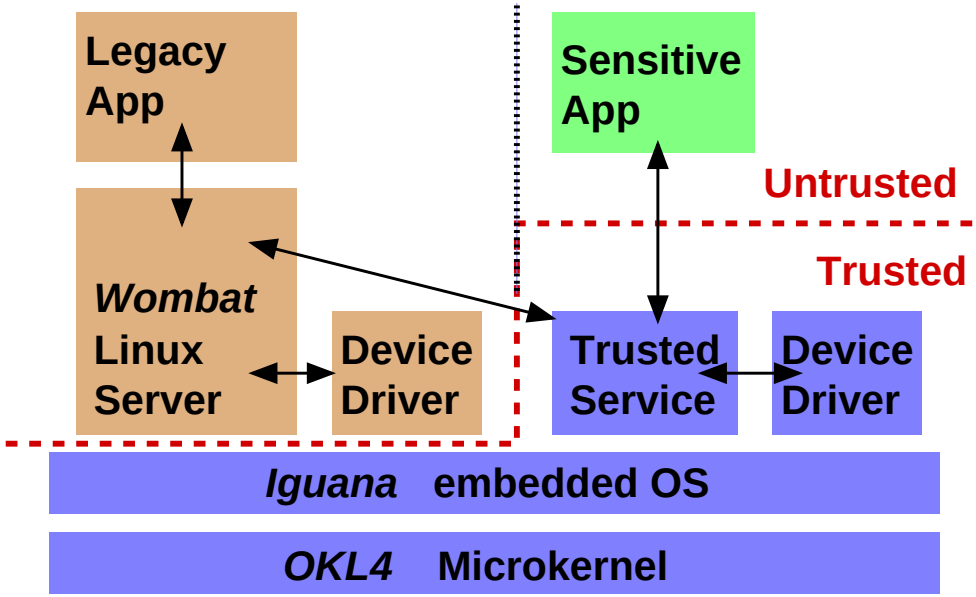

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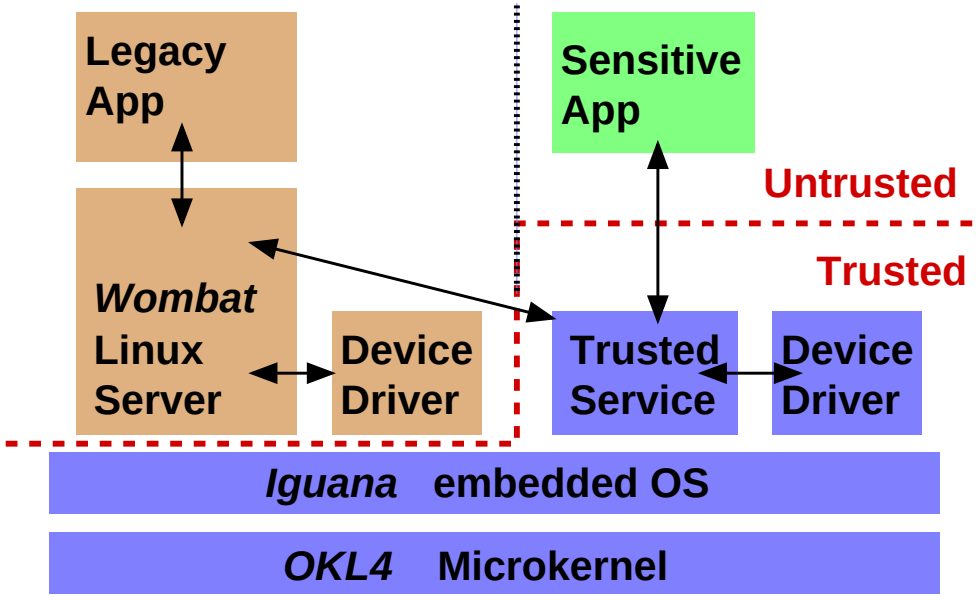

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- Standard API supported by de-privileged Linux server
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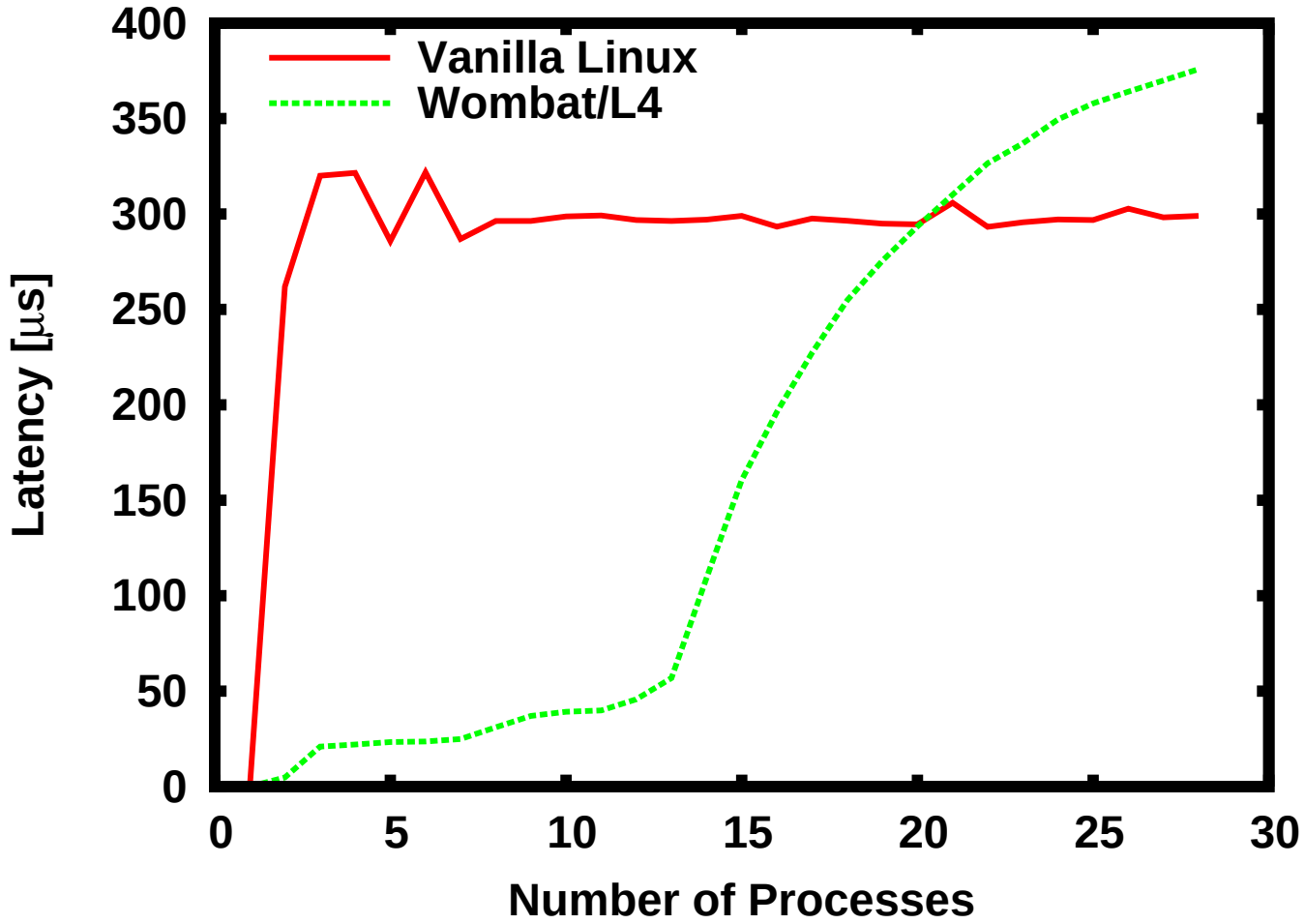
- Compromised legacy system cannot interfere with trusted part

WOMBAT PERFORMANCE: LMBENCH LAT CTX



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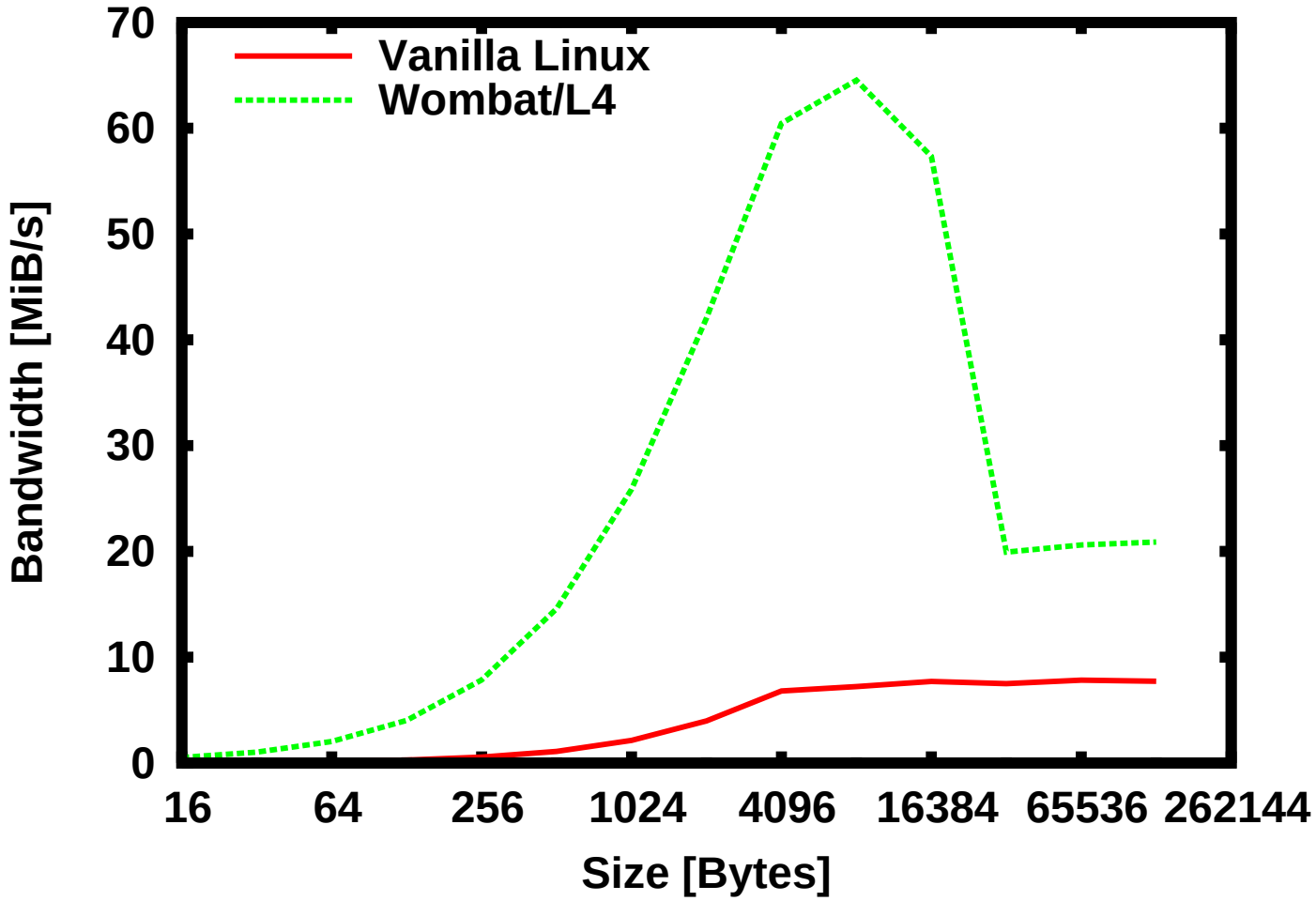

WOMBAT PERFORMANCE: OTHER BENCHMARKS

Benchmark	Linux	Wombat/L4	Ratio
lmbench latencies, (μs), smaller is better			
`lat_fifo`	510	49	10.4
`lat_pipe`	509	49	10.3
`lat_unix`	1015	77	13.3
`lat_sem`	199	14	14.6
AIM7 multitasking benchmark (jobs/min/task)			
1 task	45.15	43.62	0.97
2 tasks	23.35	22.62	0.97
3 tasks	15.79	15.30	0.97

seL4: Microkernel Mechanisms for Secure Systems

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- Security requirements for embedded systems:
  - ➜ Integrity: protecting data from damage
  - ➜ Availability: ensuring system operation
  - ➜ Privacy: protecting sensitive data from loss
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  - inefficient information flow control mechanisms
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- Note: Interim solutions for those issues presently in place
  - ➜ seL4 working on clean and general model
  - ➜ production kernel API adapts continuously (and gently)

seL4: Microkernel Mechanisms for Secure Systems

Communications control:

- Targeting confinement, including covert storage channels
- Capability-based IPC authorisation
- Aim: control communication between arbitrary subsystems
- Session-based communications (no *resume cap*)
  - ➜ reply cap passed explicitly on each IPC, or
  - ➜ passed once on session establishment

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Resource management:

- Aiming at complete control of kernel memory allocation
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- Provide model for synthesising new kernel objects (+ caps)
- Possible due to L4 simplicity, small number of objects:
  - ➜ TCBs
  - ➜ Physical frames for virtual memory
  - ➜ synchronous endpoints (like ports with no resume caps)
  - ➜ asynchronous notifation objects
  - ➜ capability nodes
  - ➜ few more for interrupt controllers, page tables, synchronisation

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- Prototype implementation in Haskell, integrated with ISA simulator
  - ➜ rapid prototyping: API changes implemented in hours/days
  - ➜ can build and execute apps using standard build tools
  - ➜ used for porting user-level software

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  - ➜ can build and execute apps using standard build tools
  - ➜ used for porting user-level software
- C implementation in progress
  - ➜ prototype in Dec '06

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  - Result to be usable in existing deployments
    - ➜ no sacrificing of performance for verifiability
  - On track...

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- Measurement-based approach augmented by static analysis
  - ➜ *measure* execution-time profiles of basic blocks
  - ➜ convolute into overall execution-time profile
  - ➜ static analysis to ensure worst case observed
  - ➜ static analysis to reduce pessimism

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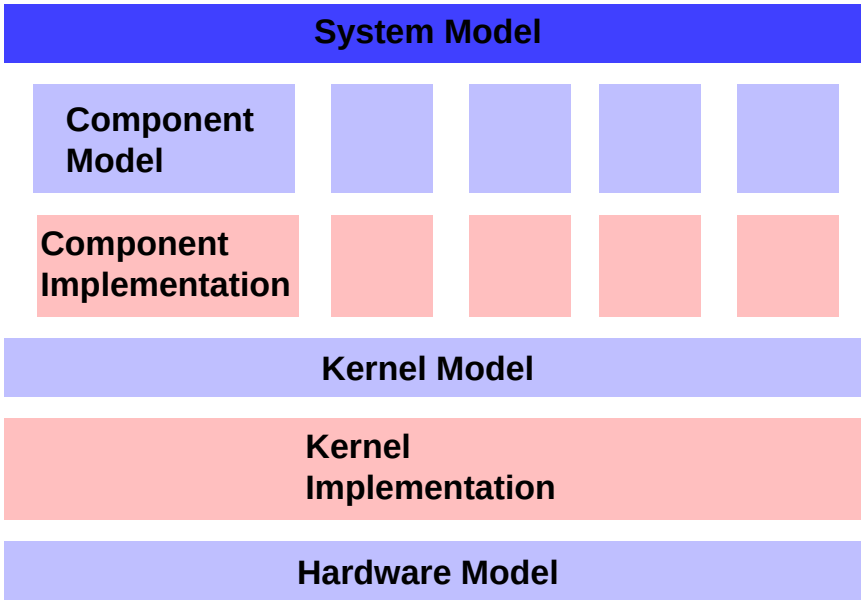

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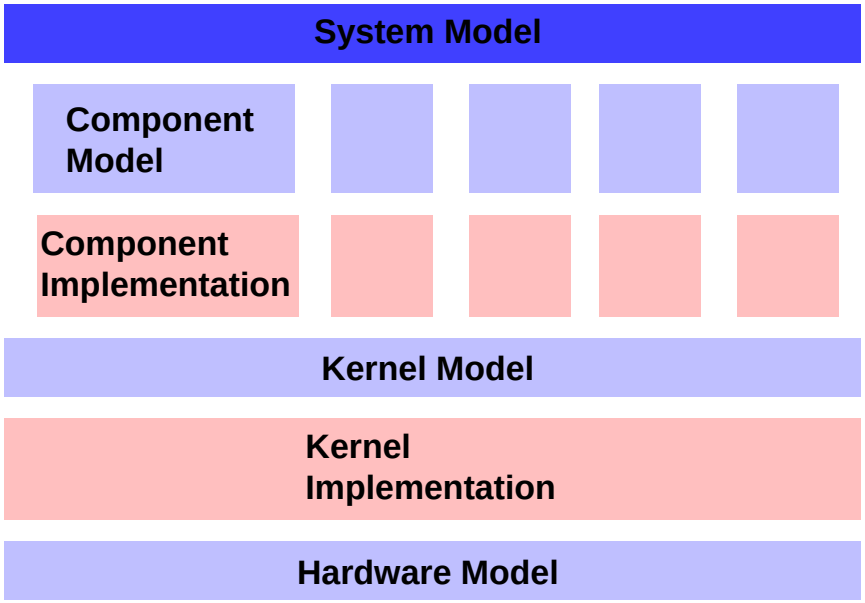

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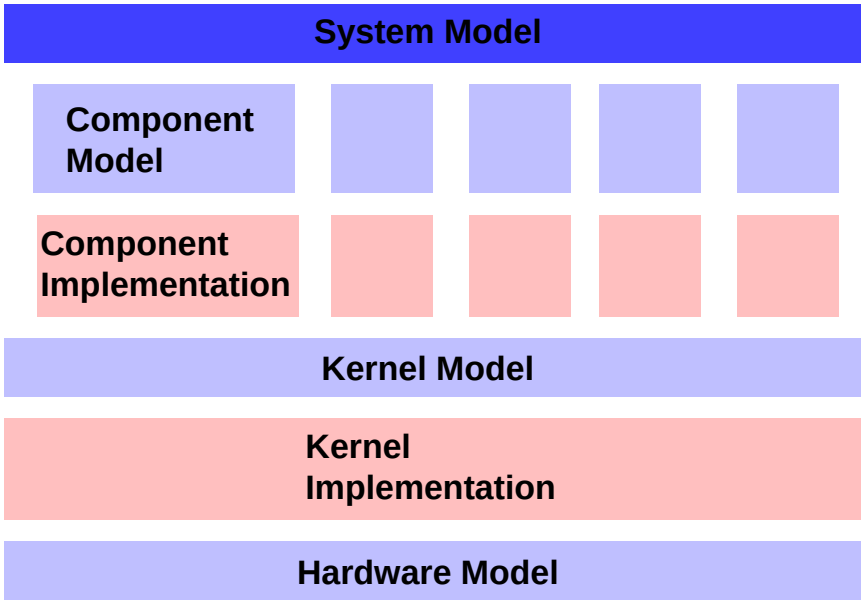

- Working on dynamic system, performance, non-functional properties

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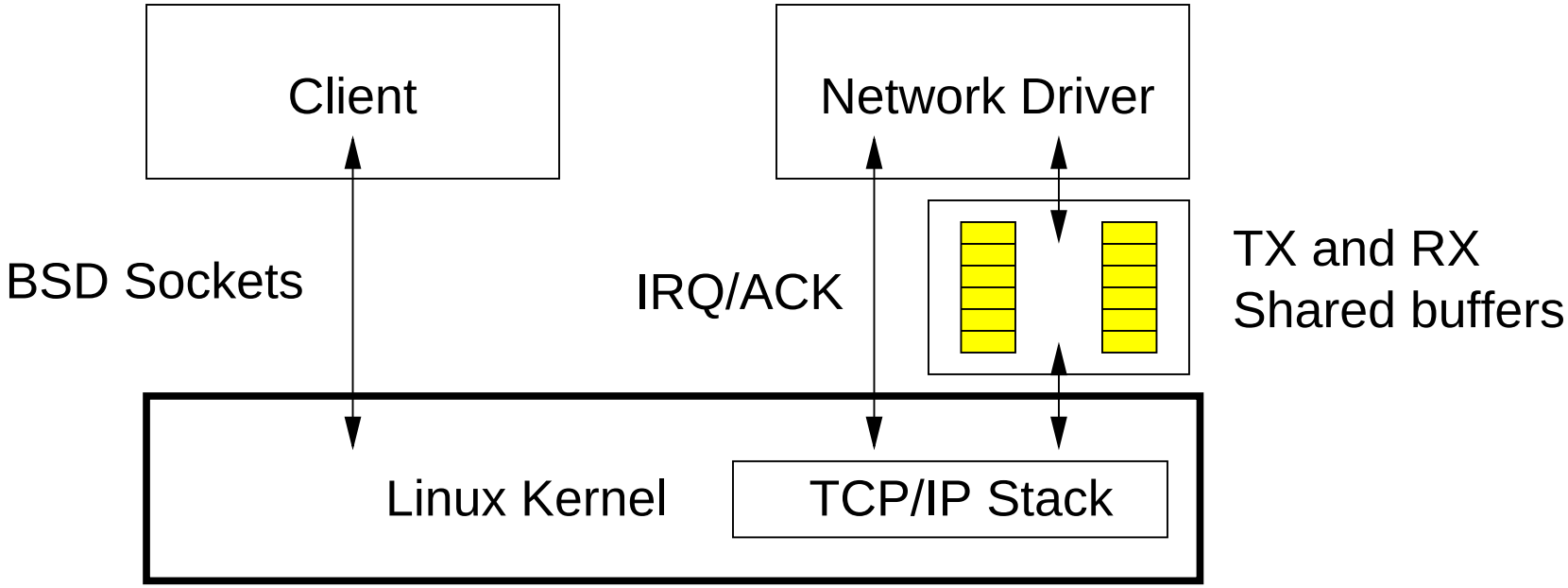
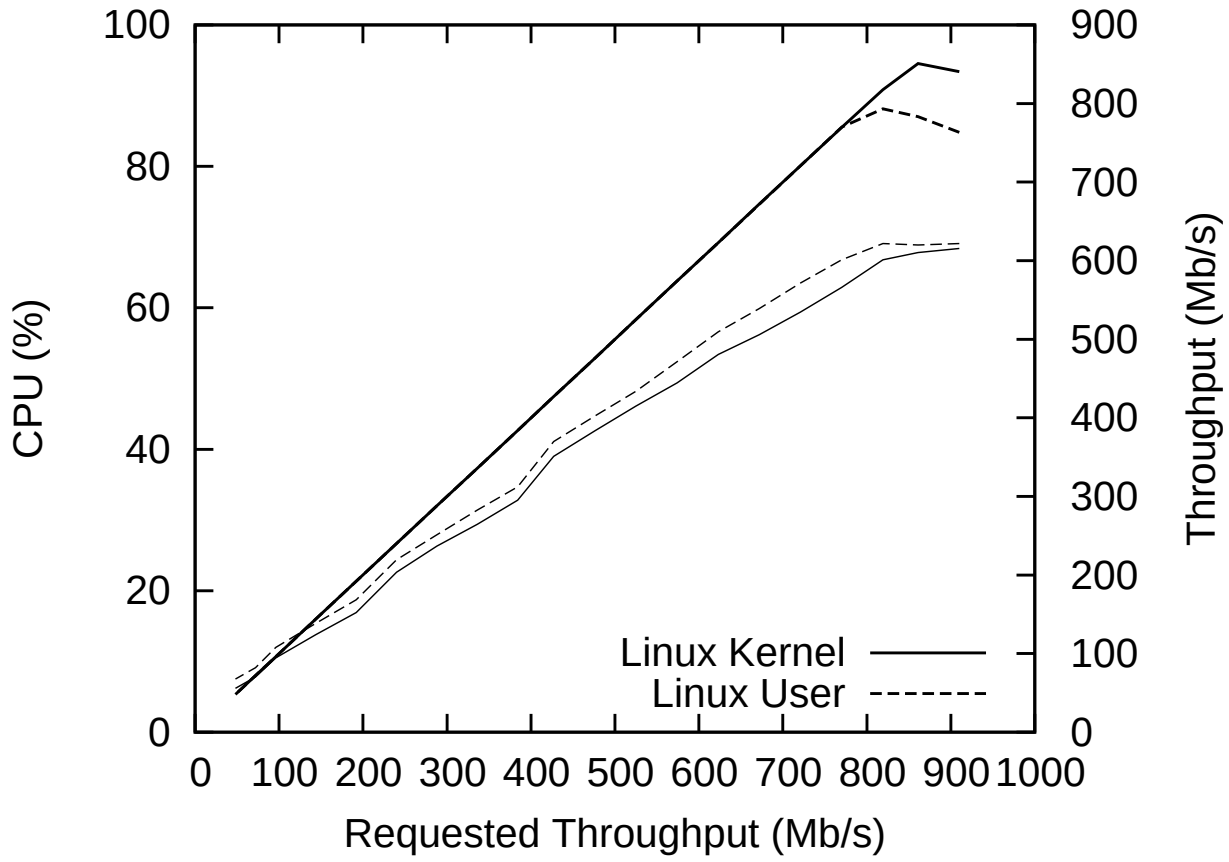
  - with well-designed driver interfaces can achieve good performance

User-Level Device Drivers on Linux



Benchmarking setup

User-Level Device Driver Performance



Gigabit Ethernet echo on 900MHz Itanium-2 with 66MHz 64-bit PCI

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  - ➜ 1 PhD student

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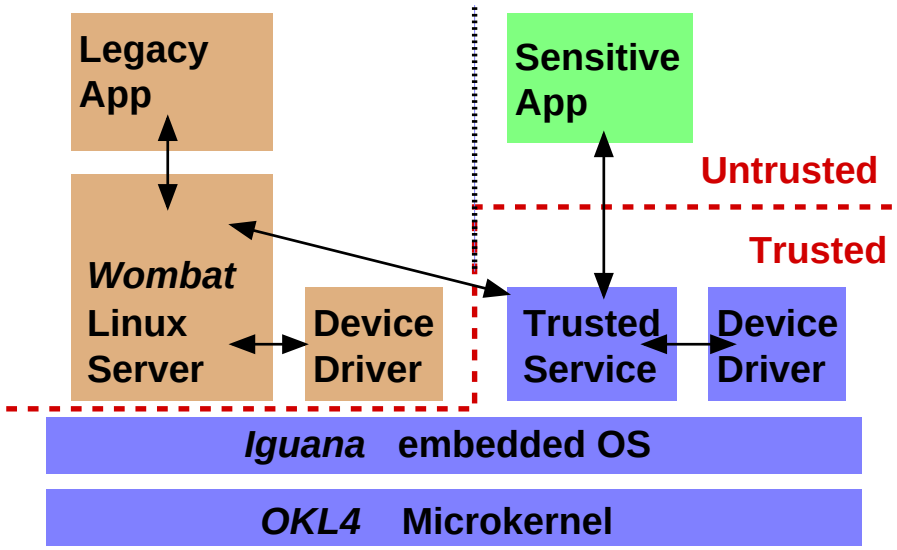

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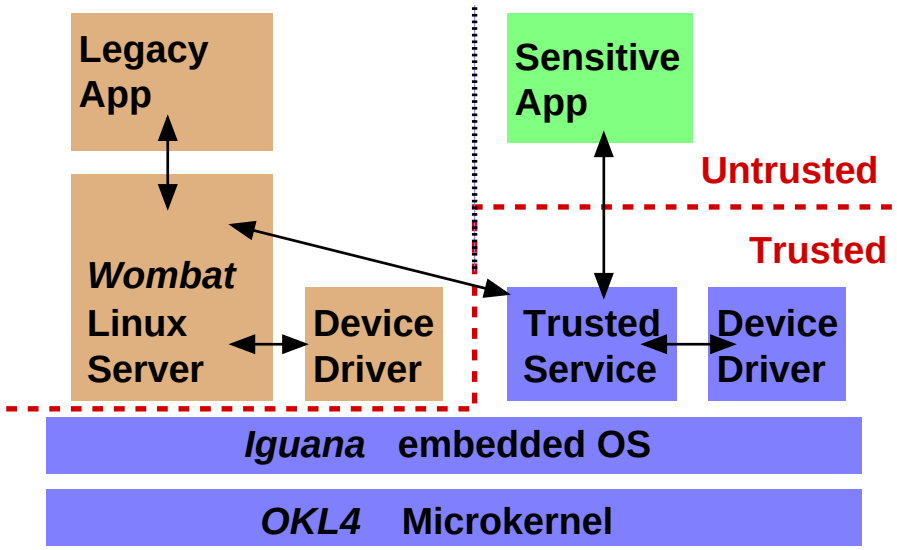

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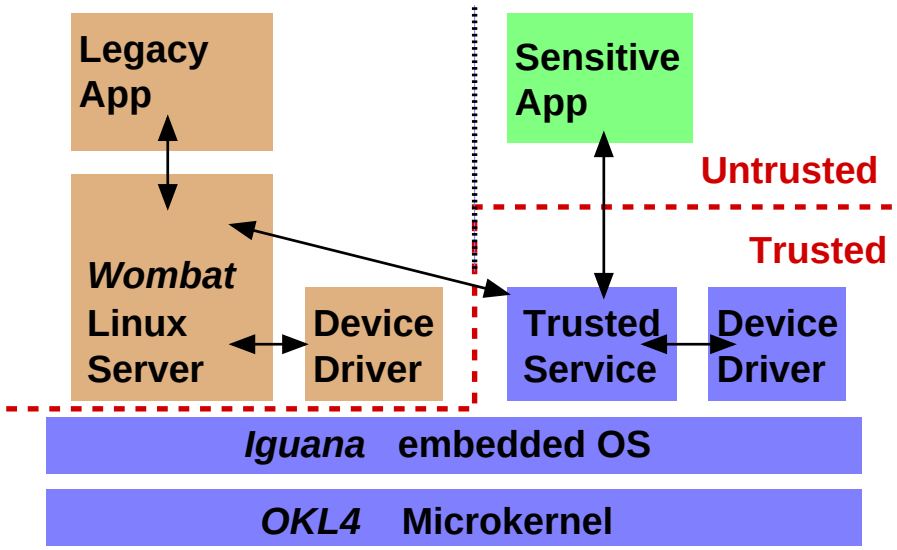
- Commercially deployed
  - ➜ new base of Qualcomm CDMA chip firmware
  - ➜ other deployments in pipeline



Open Kernel Labs (OKL)

- Startup company for commercialising ERTOS technology
- Created Sep 2006 (still in setup process)
  - Steve Subar, CEO
    ➜ startup veteran
  - Gernot Heiser, CTO
  - ca 15 engineers, growing 1-2 per month
    ➜ probably largest group of top kernel hackers outside major multinationals
  - US HQ, Sydney-based engineering
- Projects with 5 large multinationals, several others in pipeline
  ➜ mobile communication chipsets and phone handsets
  ➜ multimedia
  ➜ some huge stuff we can't talk about

Open Kernel Labs — A Unique Approach

OKL-NICTA Joint Venture:

- OKL provides services
- NICTA/ERTOS does research
- Outcomes industrialised and commercialised by OKL

OKL/NICTA Ongoing Relationship:

- Students move into either OKL or ERTOS
  ➜ working on similar stuff
- ERTOS staff move into OKL with their projects
  ➜ efficient industrialisation/commercialisation
- OKL staff move back to ERTOS
  ➜ do PhD on research issues identified by OKL

Student Opportunities

Would you like to work on cool systems people actually use???

- Gelato — kernel work for supercomputers
  ➜ with significant research issues
- BLUEsat — L4 in space!
  ➜ but first it needs an OS!
- ERTOS research — trustworthy embedded systems
  ➜ ... will change the industry!
- Open Kernel Labs — microkernels in billions of devices
  ➜ hot startup building cool systems