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TOWARDS TRUSTWORTHY EMBEDDED SOFTWARE

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Embedded System are Ubiquitous

The are becoming an essential part of everyday life

Lessons from Desktop Systems

Desktop computer systems suck:

- They crash
- They get hacked
- They get infected

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How about embedded systems?

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Future systems highly vulnerable!

- ➜ challenges at least as bad as in PC world
- ➜ defences aren't better

TRUSTWORTHINESS

Why is it a problem?

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  - ➜ several millions loc in a mobile-phone handset
  - ➜ Gigabytes of software in top-range automobiles
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Can such a large system ever be made trustworthy?

- Yes, if its *trusted computing base* (TCB) is trustworthy!
  - ➜ **TCB:** The part of the system that can circumvent security

TRUSTED COMPUTING BASE — TRUSTWORTHY?

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- Proof?
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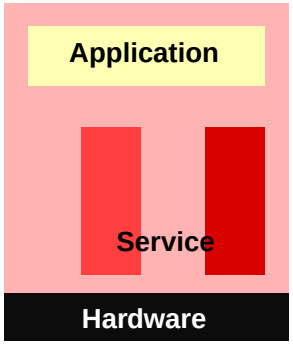
- Modularity?
  - ➜ can reduce complexity of verification problem
  - ➜ doesn't help if interfaces aren't enforced
  - ➜ can't guarantee if not type-safe or privileged-mode execution

EMBEDDED SYSTEMS TCB

Traditional approach: Real-time executive



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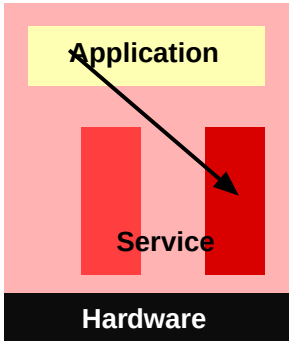

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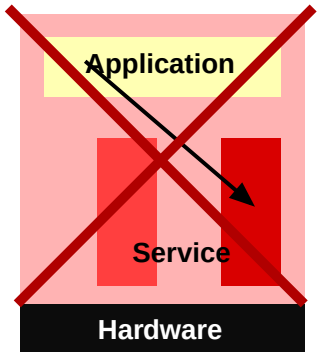

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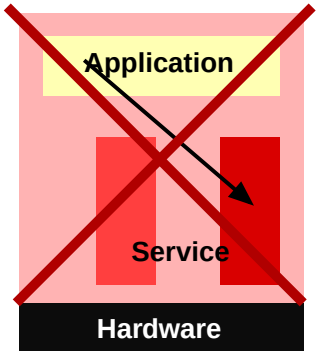

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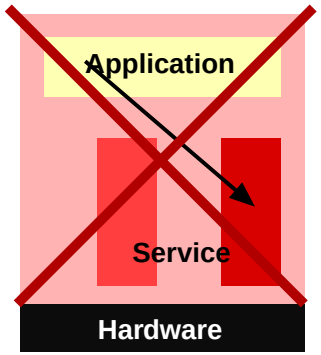

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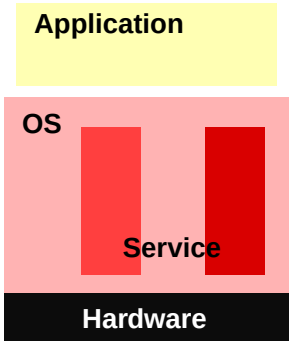

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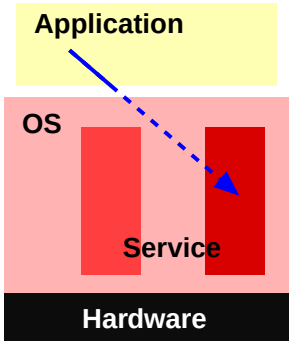

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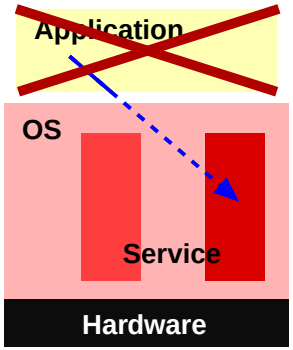

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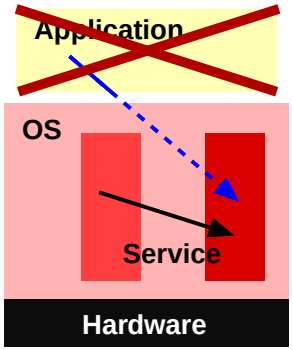

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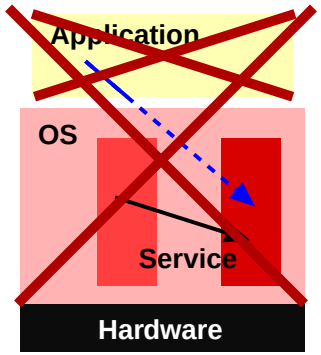

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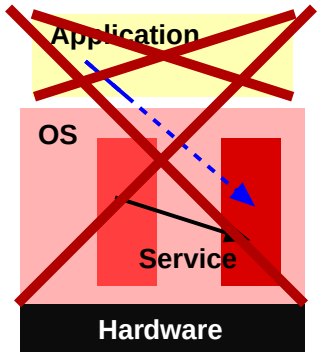

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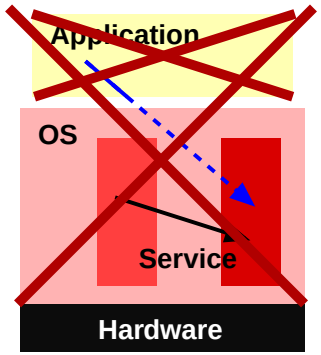

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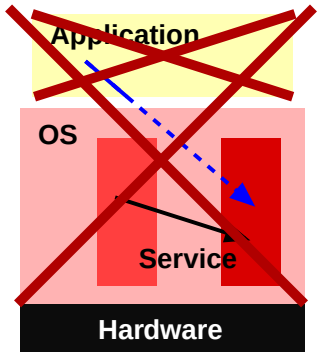

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- *TCB: kernel + some user-level code* (100,000s of lines!)

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- Of course, this alone is *insufficient* for trustworthiness
  - ➜ no guarantee that whole system operates as intended
  - ➜ solution left as an exercise for the reader 

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- Kernel *must be a microkernel*

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  - ➜ e.g., code that manipulates processor state, MMU, ...
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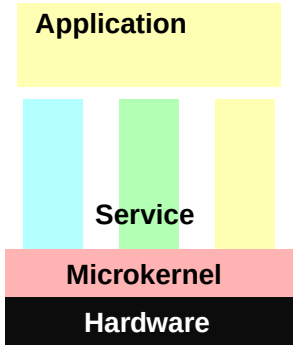

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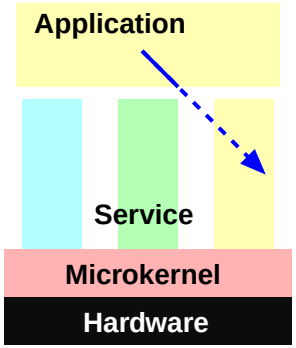

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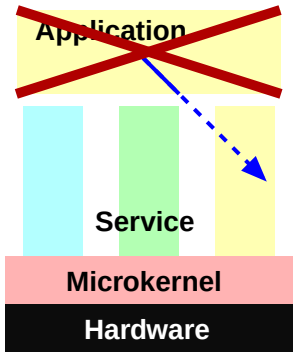

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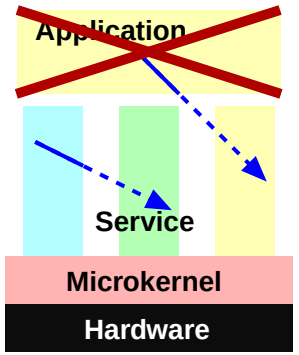

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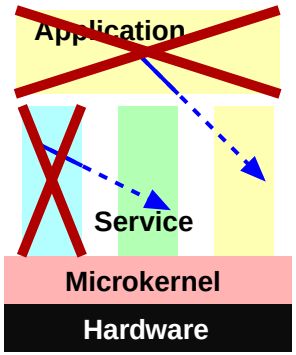
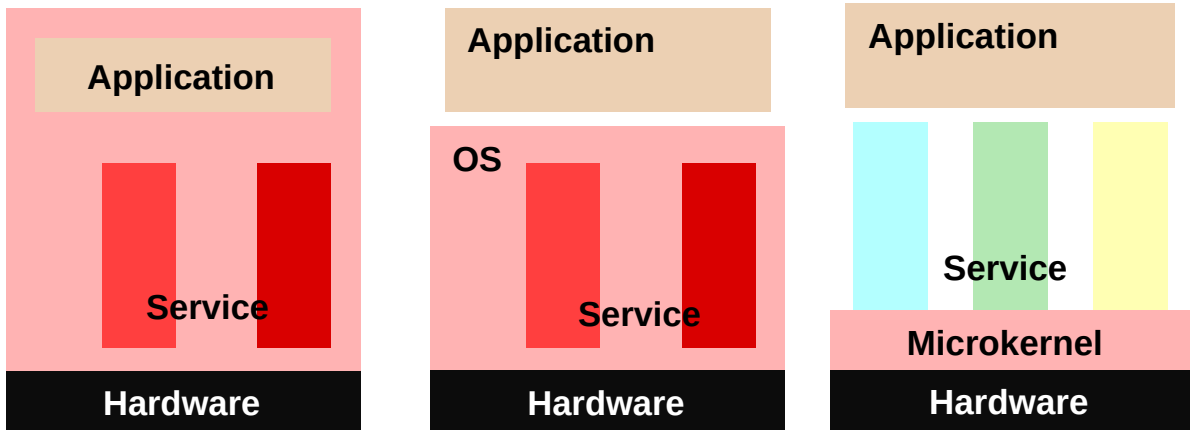
- Faults can be contained
  - ➜ removes more code from TCB
  - ➜ kernel size: ≈ 10,000 loc

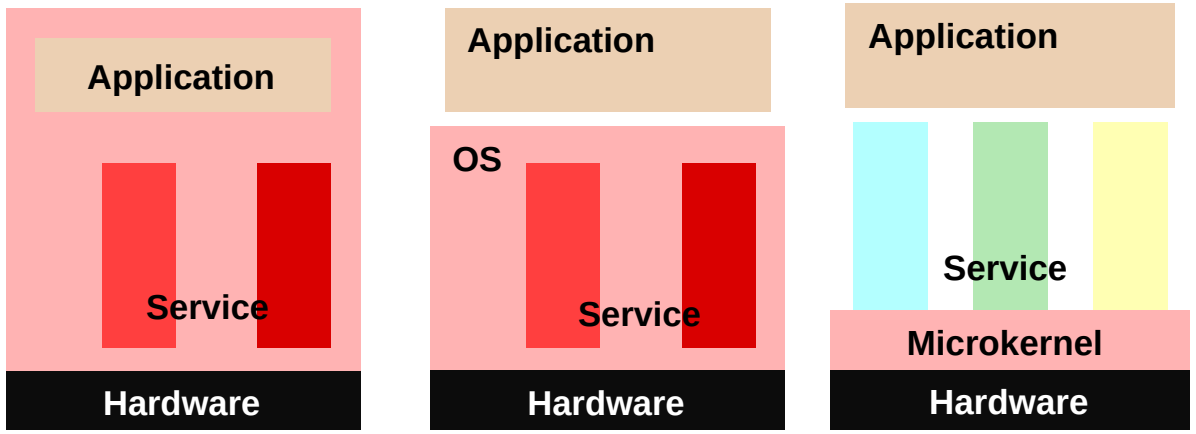


EMBEDDED SYSTEMS TCB COMPARISON



System:	traditional embedded	Linux/ Windows	Microkernel-based (L4)

Embedded Systems TCB Comparison

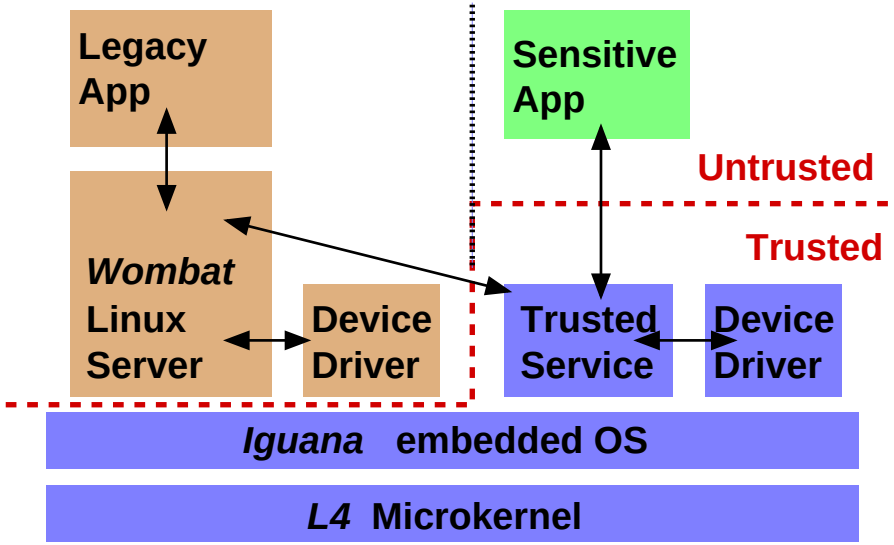


System:	traditional embedded	Linux/ Windows	Microkernel-based (L4)
TCB:	**all** code	$\geq$ 200,000 loc	$\geq$ 20,000 loc

Note: size (TCB) $\geq$ size (kernel)

VIRTUALISATION: BEST OF BOTH WORLDS

- Minimal secure environment (L4 + Iguana)
  - ➜ small TCB
  - ➜ fully real-time capable
- Virtualised legacy OS for application support
  - ➜ binary compatibility with native legacy code
  - ➜ performance close to native



- Secure subsystem can provide services to legacy system
  - ➜ e.g. device drivers

Requirements for Trusted Systems

0. Very small, high-performance microkernel: L4
1. Microkernel mechanisms for secure systems
2. Verification of microkernel implementation
3. Trustworthy temporal model of microkernel
4. Techniques for building high-performance microkernel-based systems

seL4: Microkernel Mechanisms for Secure Systems

seL4: Microkernel for secure embedded systems:

- Security requirements for embedded systems:
  - ➜ Integrity: protecting data from damage
  - ➜ Availability: ensuring system operation
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- Issue: Present L4 API unsuitable for highly-secure systems
  - inefficient information flow control mechanisms
    - ➜ present mechanisms double or triple IPC costs
  - insufficient resource isolation (kernel memory pool)
    - ➜ applications can force kernel to run out of memory
    - ➜ present countermeasures are inflexible

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- C implementation: Dec '06

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    3
  - Result to be usable in existing deployments
    - ➜ no sacrificing of performance for verifiability
  - On track...

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  - ➜ convolute into overall execution-time profile
  - ➜ static analysis to ensure worst case observed
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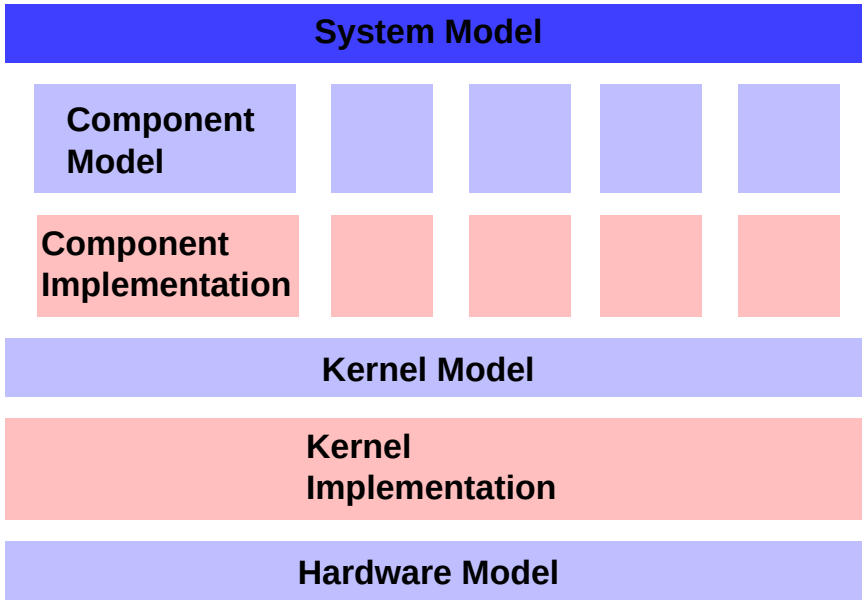

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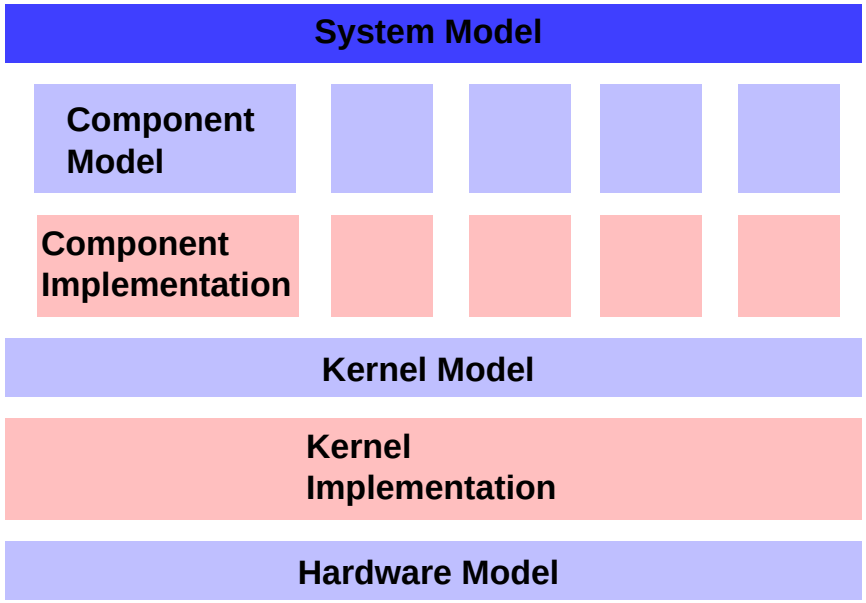

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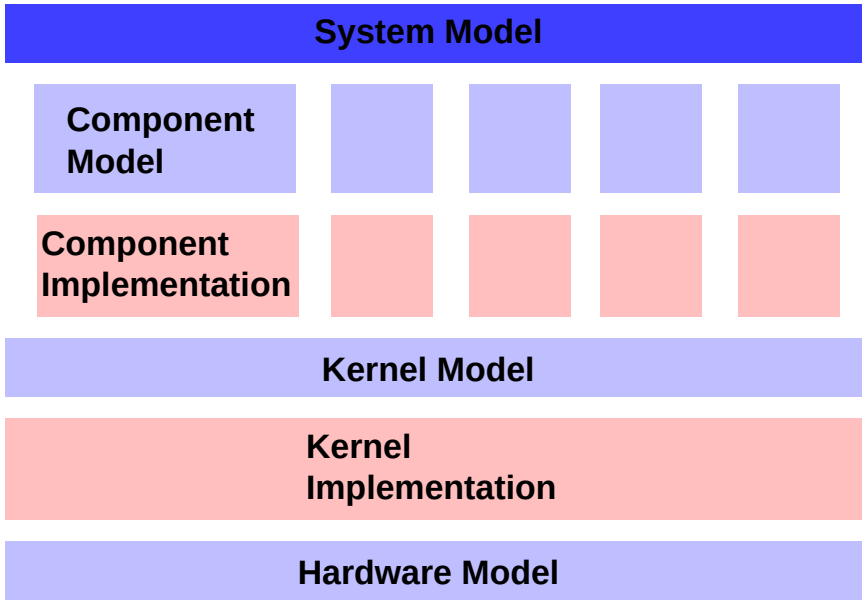
- Status: static prototype



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

Present State

- Pistachio: Mature microkernel
  - ➜ 10,000 lines of code (shrinking)
  - ➜ highly efficient
- Iguana: Core OS services
  - ➜ naming, protection, memory...
  - ➜ device drivers
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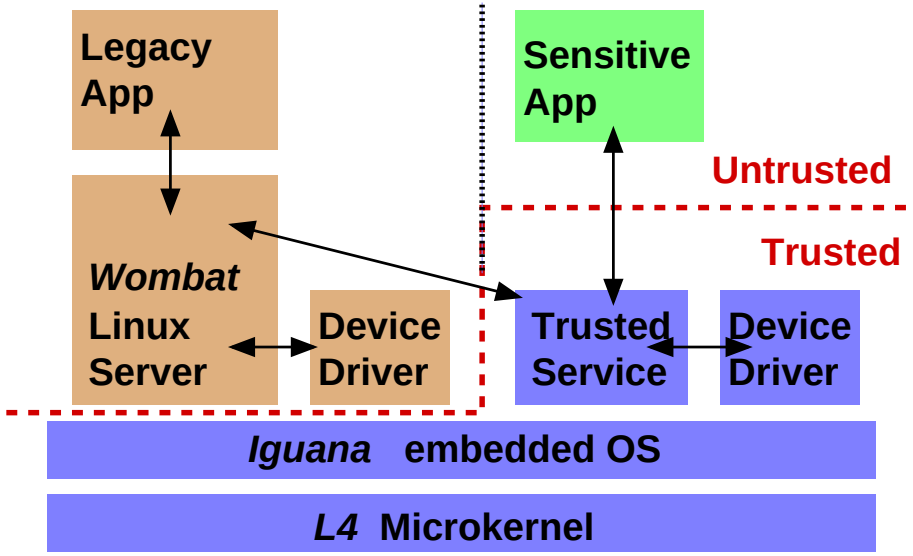

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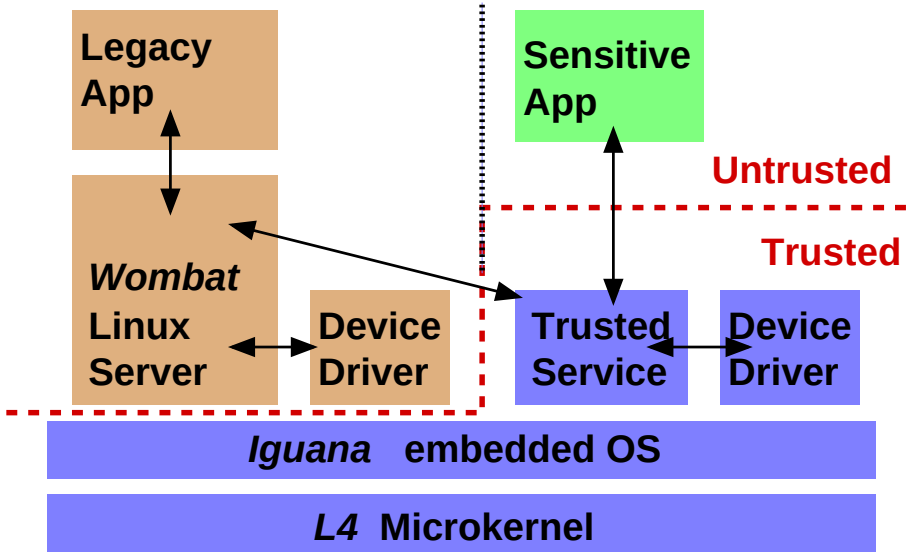

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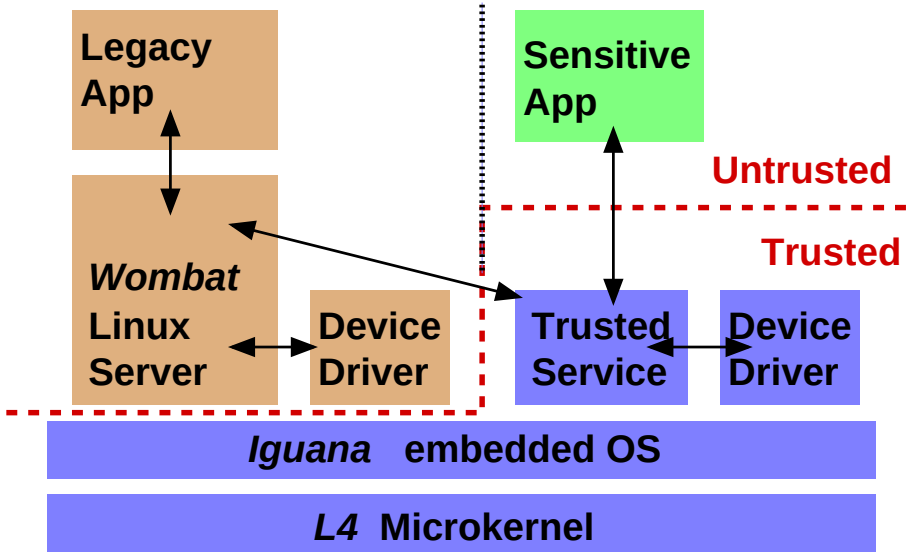
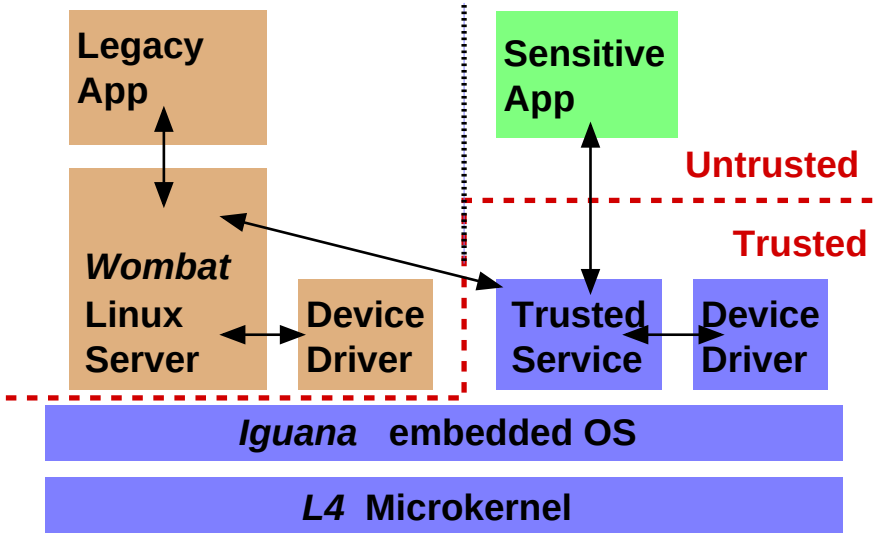
- Commercially deployed
  - ➜ new base of Qualcomm CDMA chip firmware
  - ➜ other deployments in pipeline



System Performance

Benchmark	Native Linux	Wombat
1 Task	47.5	46.3
2 Tasks	24.8	24.1
3 Tasks	16.7	16.3

- AIM7 "compute server mix", jobs/min/task
- All on PLEB2 (Intel PXA 255 XScale, 200MHz CPU, 100MHz RAM)



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- Maybe, but
- A trustworthy TCB is a starting point and seems doable
- Prerequisite: small TCB, small kernel
- We are on track to deliver a trustworthy TCB
- ... without sacrificing performance
- ... usable in real systems