Extensibility, Safety and Performance in the SPIN Operating System

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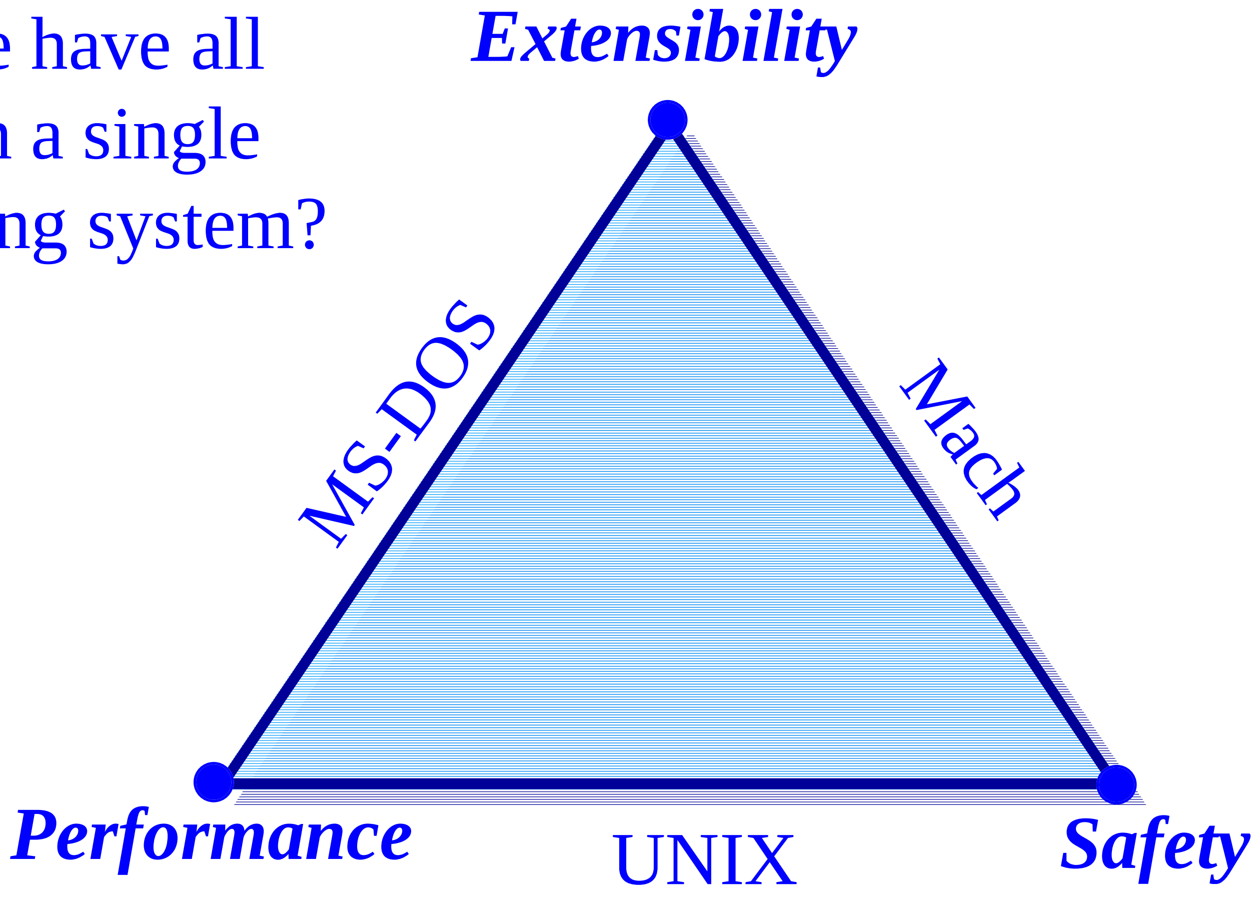
Goals

- Extensibility
  - Applications can dynamically extend system to provide specialized services
- Safety
  - Kernel is protected from actions of extensions
- Performance
  - Extensibility and safety have low cost

Why is this hard?

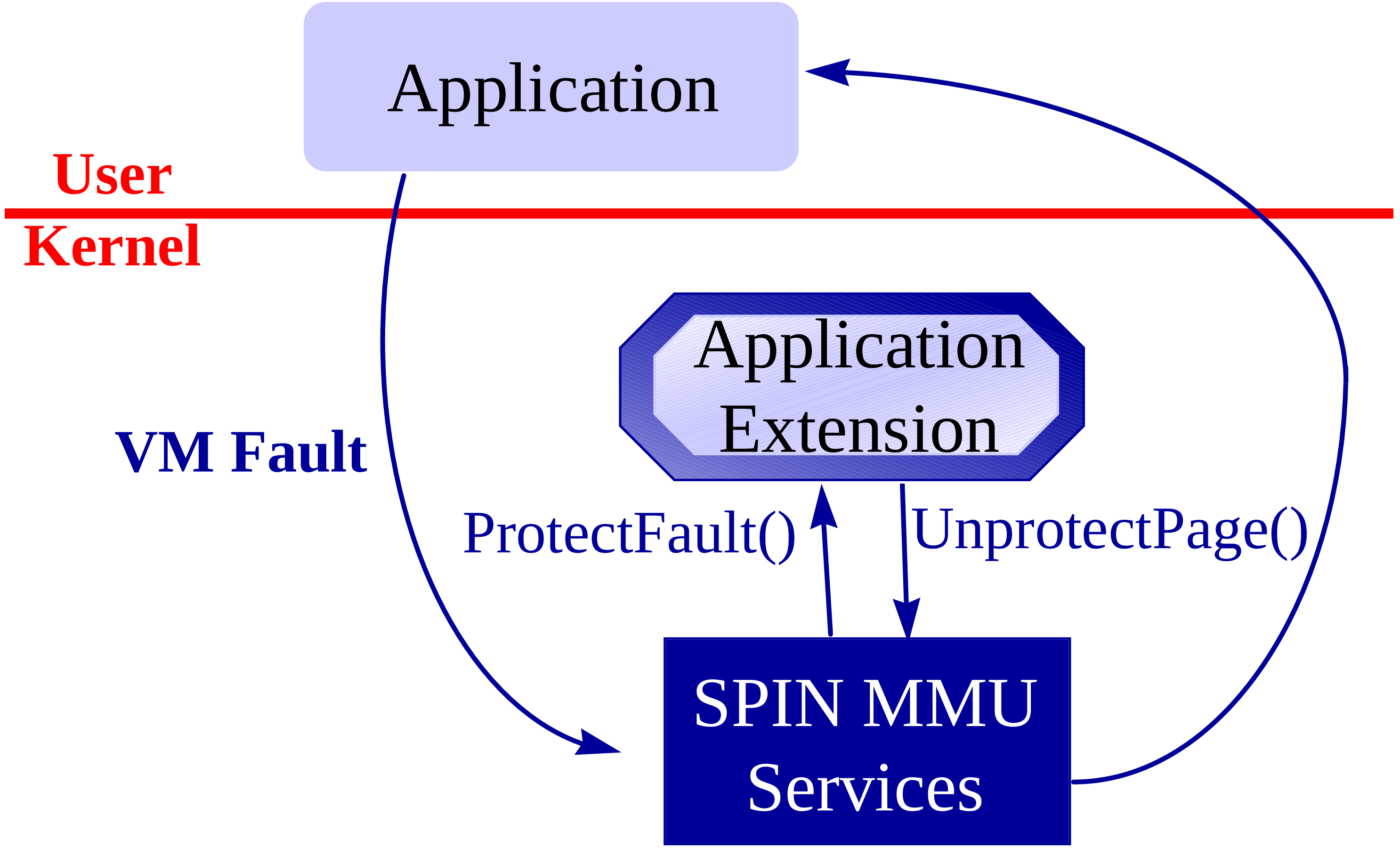
Can we have all three in a single operating system?



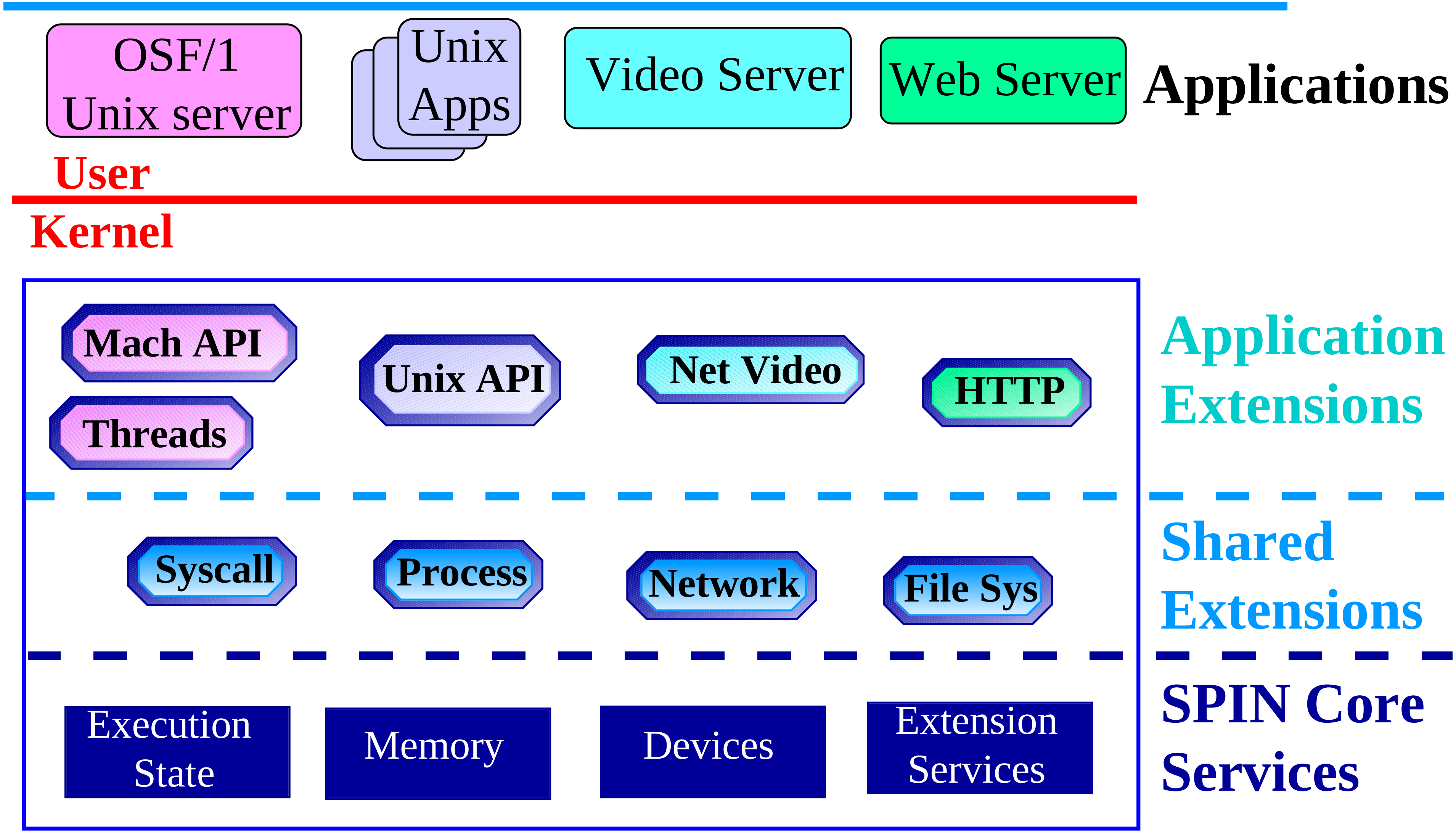
Approach

- Put extension code in the kernel
  - Cheap communication
- Use language protection features
  - Static safety
- Dynamically interpose on any service
  - Fine-grained extensibility

A SPIN extension



SPIN structure



Safety

Language-based protection

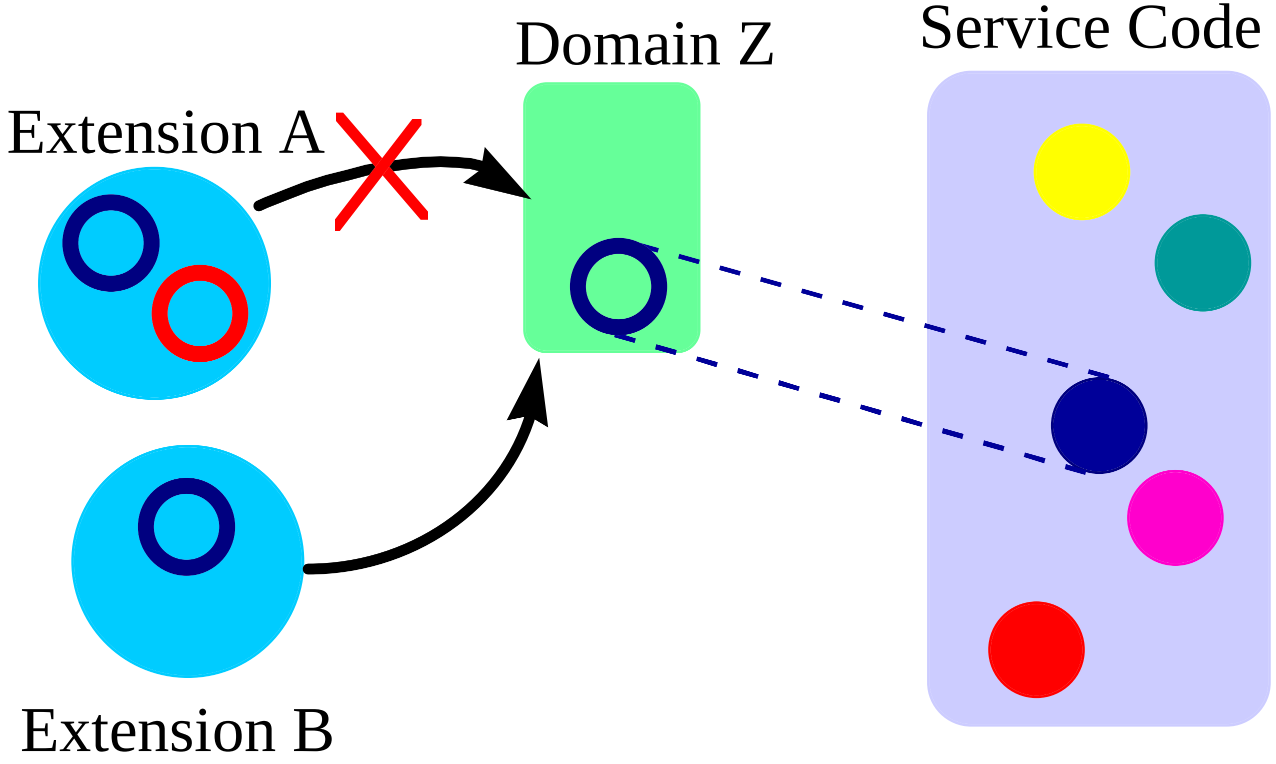
Modula-3

- Memory safe
- Interfaces for hiding resources
- Cheap capabilities

Restricted dynamic linking

Goal: control access to interfaces cheaply

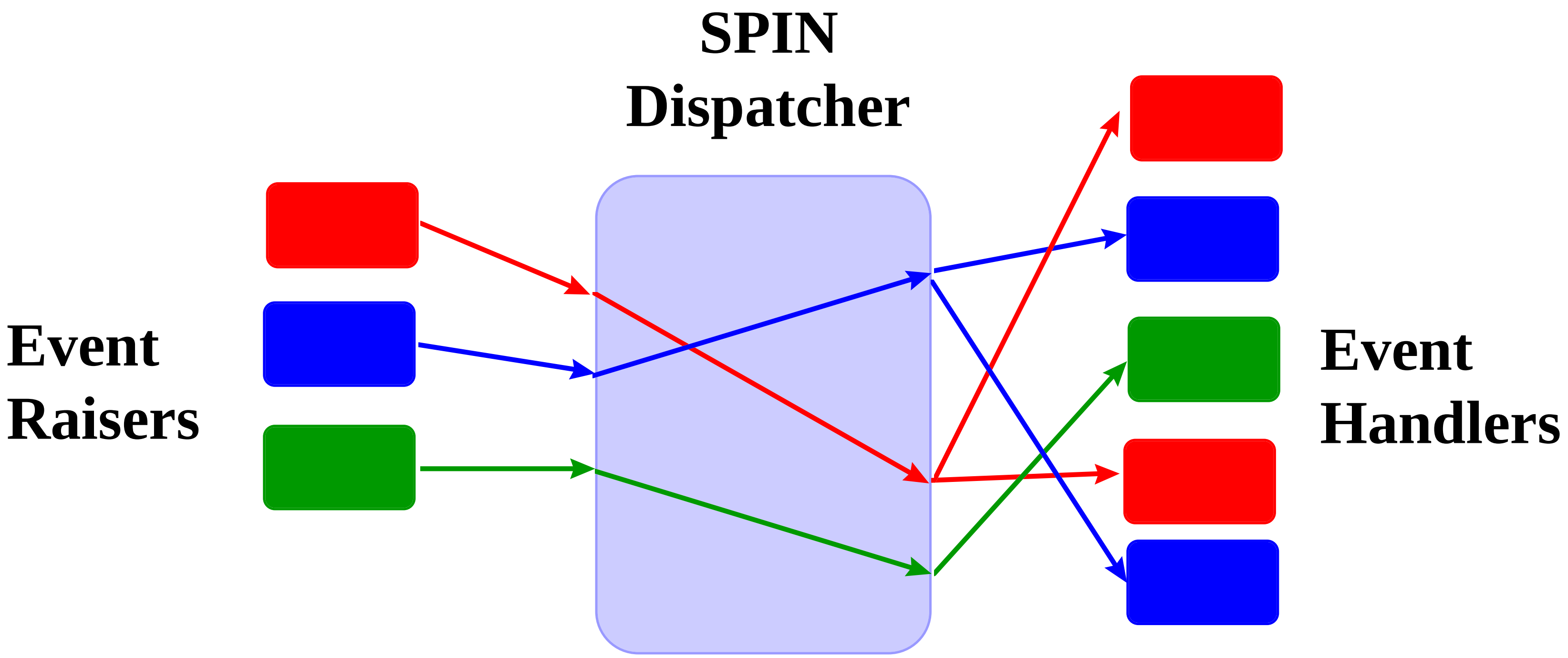
Strategy: restrict access at dynamic link-time



Extensibility

Dispatcher

Event-based communication model



Using Events

```
INTERFACE Network;
PROCEDURE PacketArrived(p:Pkt);

END Network.
```

Event definition

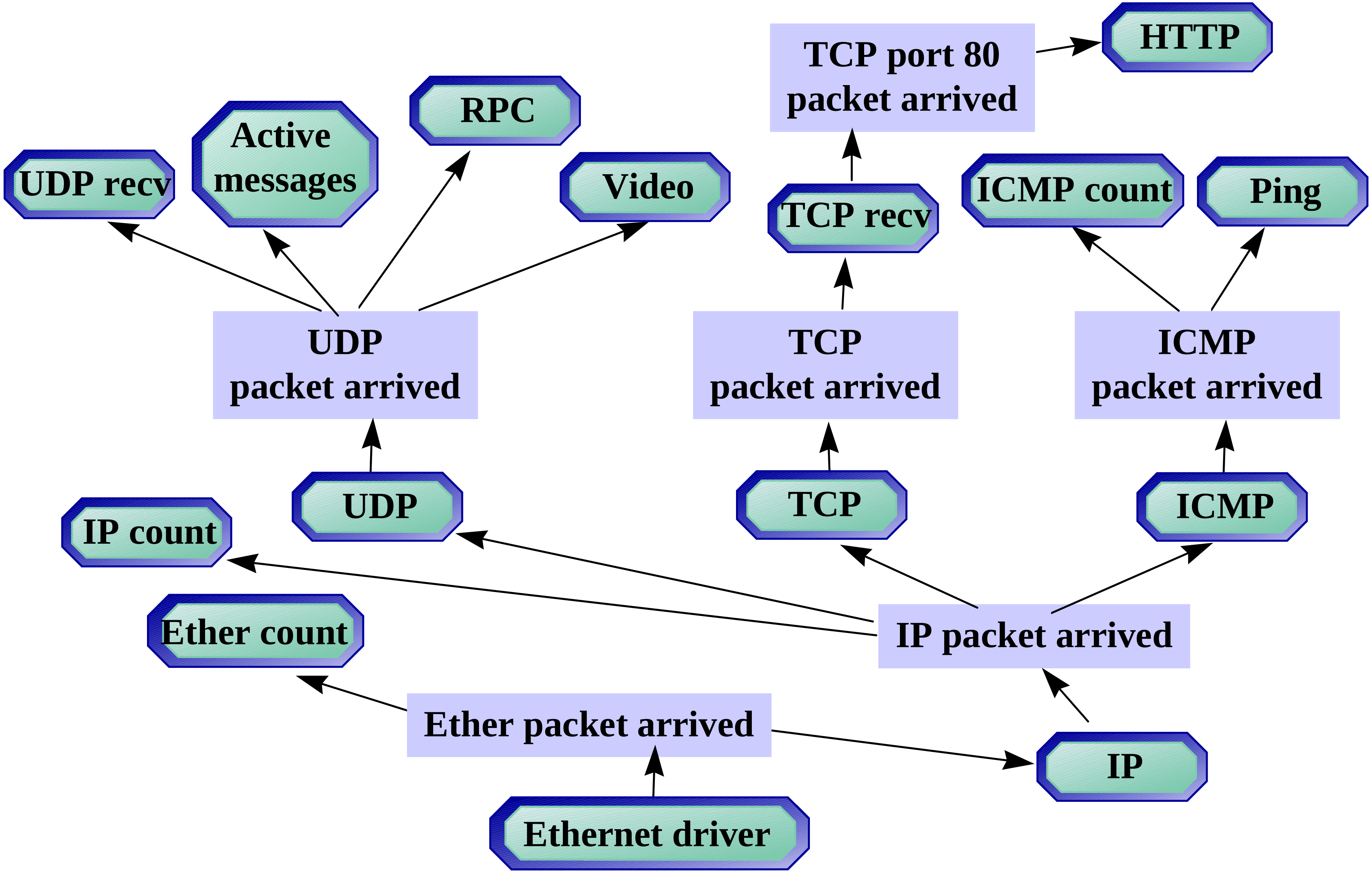
```
MODULE EthernetDriver;
PROCEDURE Interrupt(p: Pkt) =
  BEGIN
      Network.PacketArrived(p);
  END Interrupt;
```

Event raise

Other services

- Almost all “system” services are extensions
  - Network protocols
  - File systems
  - System call interface
- SPIN only implements services which cannot be safely implemented as extensions
  - Processor execution state
  - Basic interface to MMU and physical memory
  - Device IO/DMA
  - Dynamic linker and Dispatcher

A protocol graph in SPIN



Design summary

- Safety
  - Memory safe language for extensions
  - Link-time enforcement for access control
- Extensibility
  - Fast and safe centralized control transfer switch
- Result
  - Allows fast and safe fine-grained service extension

Performance

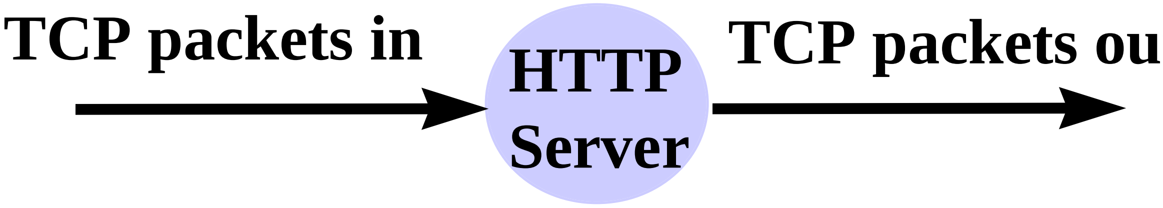
Platform

- SPIN runs on DEC Alpha platforms
- Measurements
  - DEC AXP 3000/400 @ 133Mhz
- Comparison systems
  - DEC OSF/1 V2.1
  - Mach 3.0

SPIN performance advantages

- Extensions provide specialized service
  - Don’t execute unnecessary code
- Extensions close to kernel services
  - Low latency response to faults/interrupts
  - Invoking services is cheap

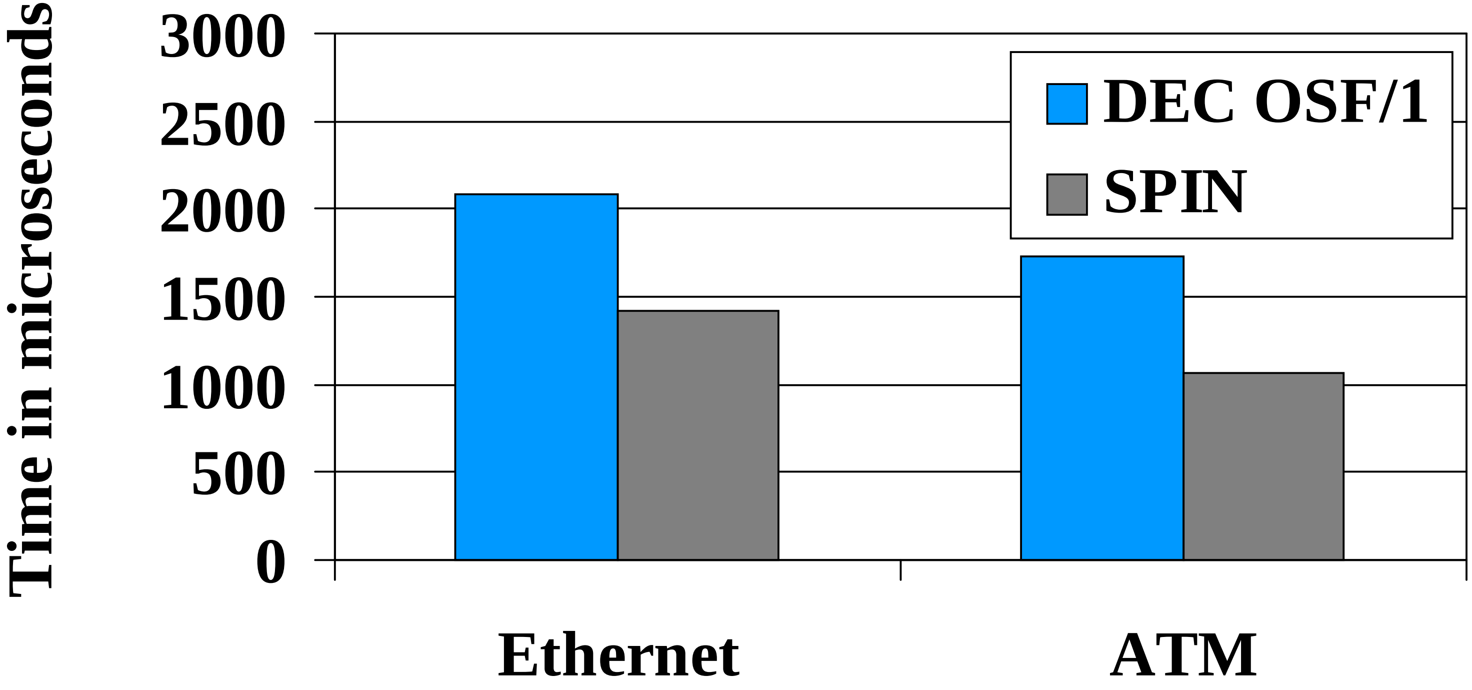
Per-port TCP packet forwarding



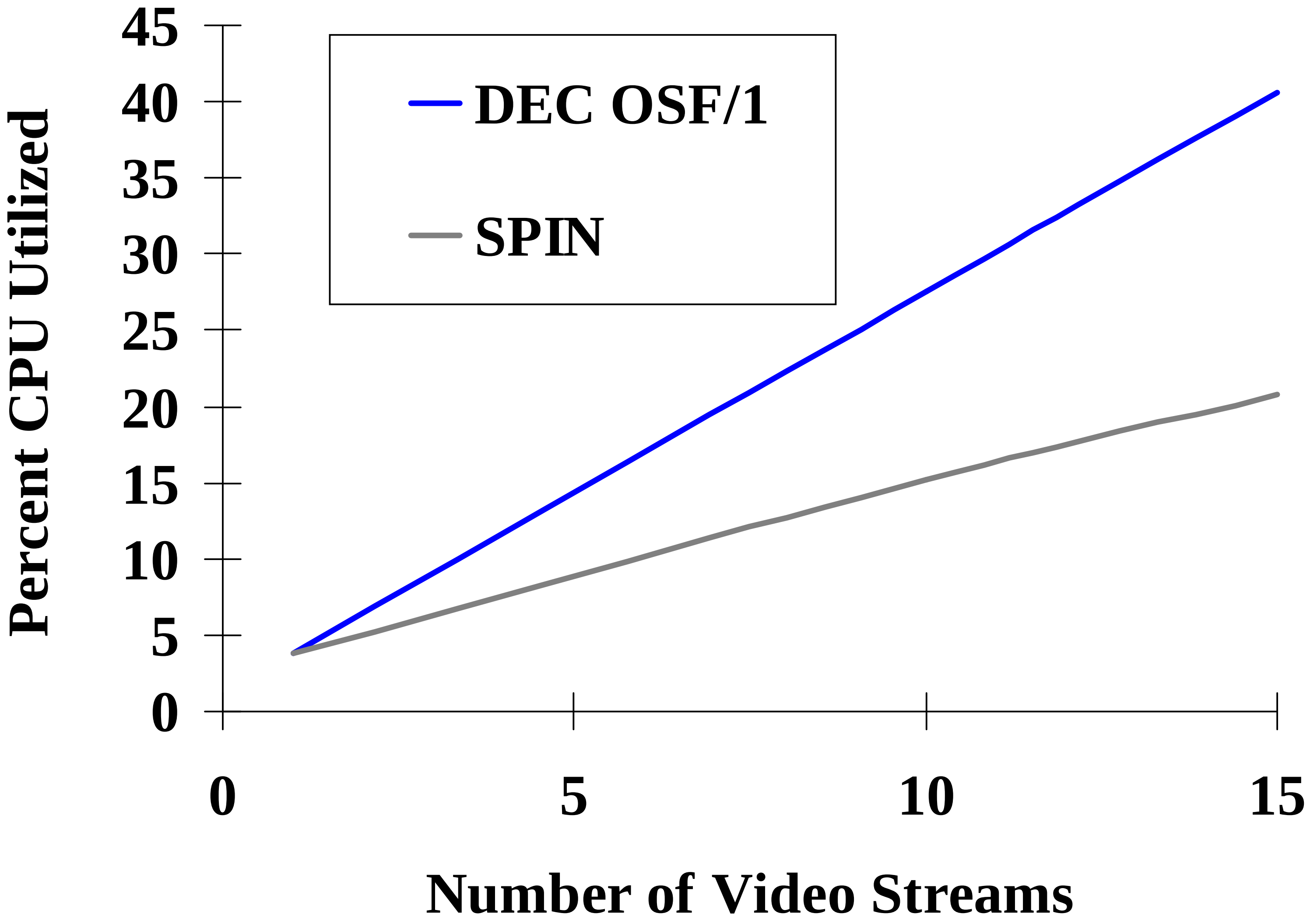
TCP packets in

HTTP Server

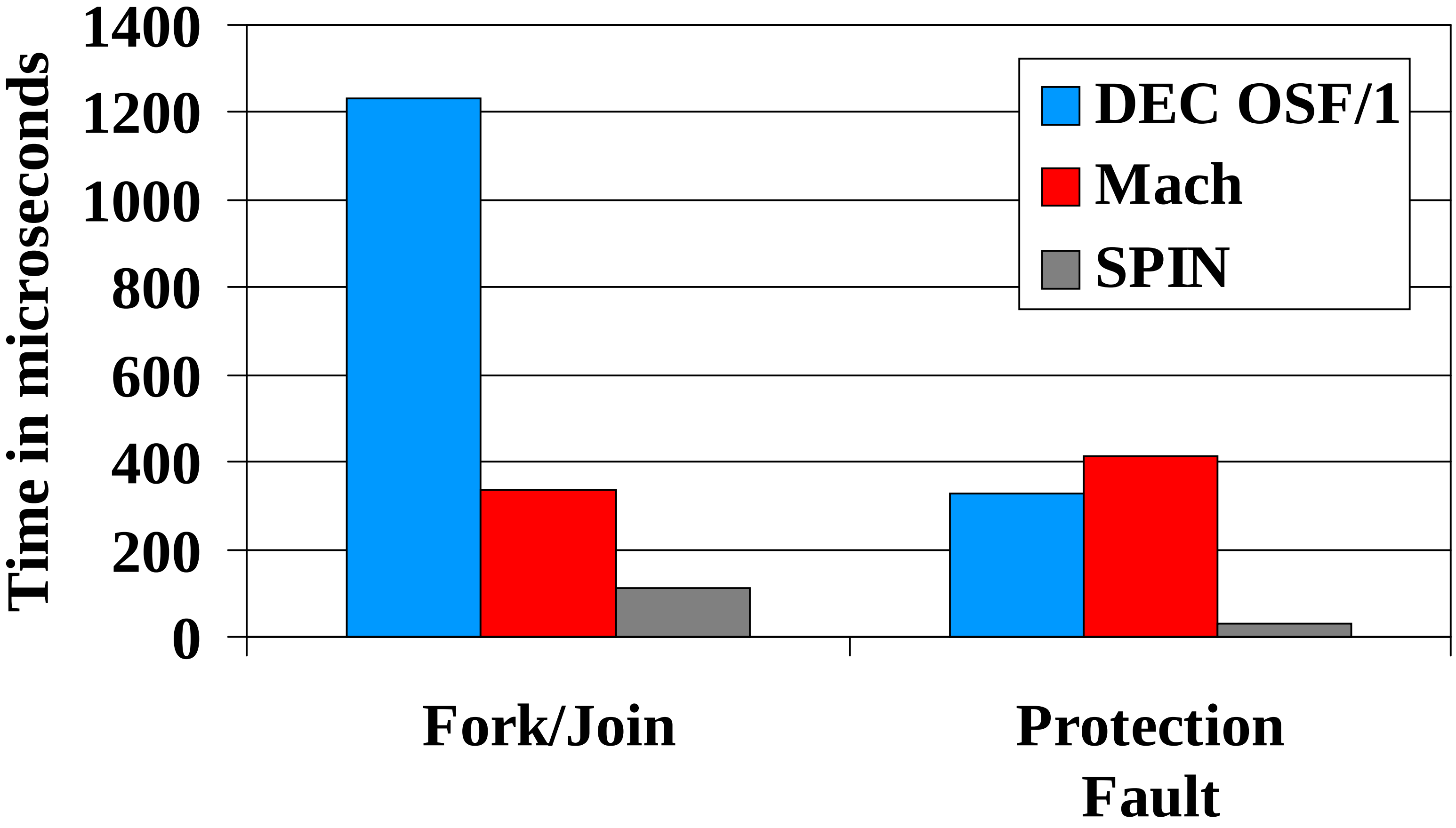
TCP packets out



Video service

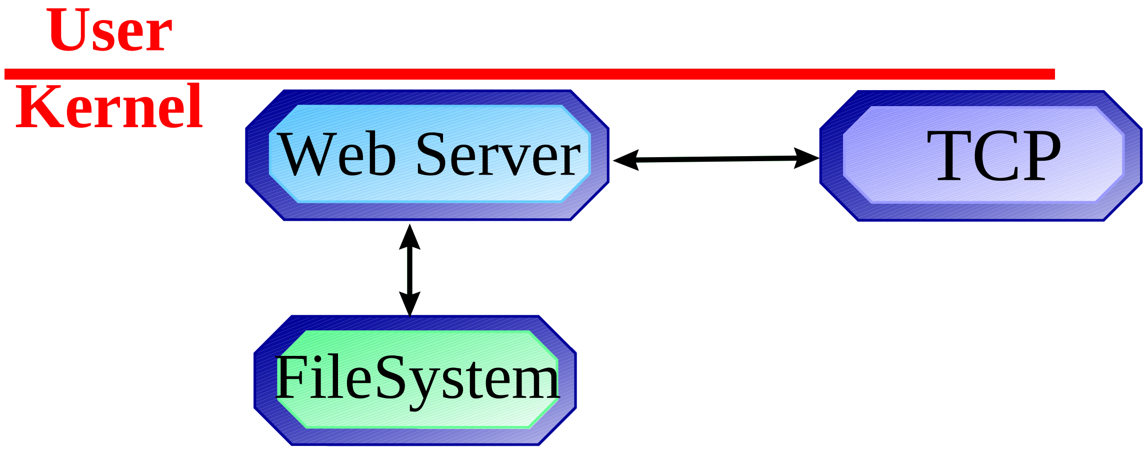


Other basic system services



Conclusions

- It is possible to combine extensibility, safety and performance in a single system
- Static mechanisms, implemented through the compiler, make this possible
- **http://www-spin.cs.washington.edu/**



Language-based capabilities

```
INTERFACE PageTable;
TYPE T <: REFANY;

PROCEDURE New(): T;
END PageTable.
```

```
INTERFACE PageTableInternal;
REVEAL PageTable.T =
          BRANDED REF RECORD
            PTBase: ADDRESS;
            …
          END;
END PageTableInternal.
```

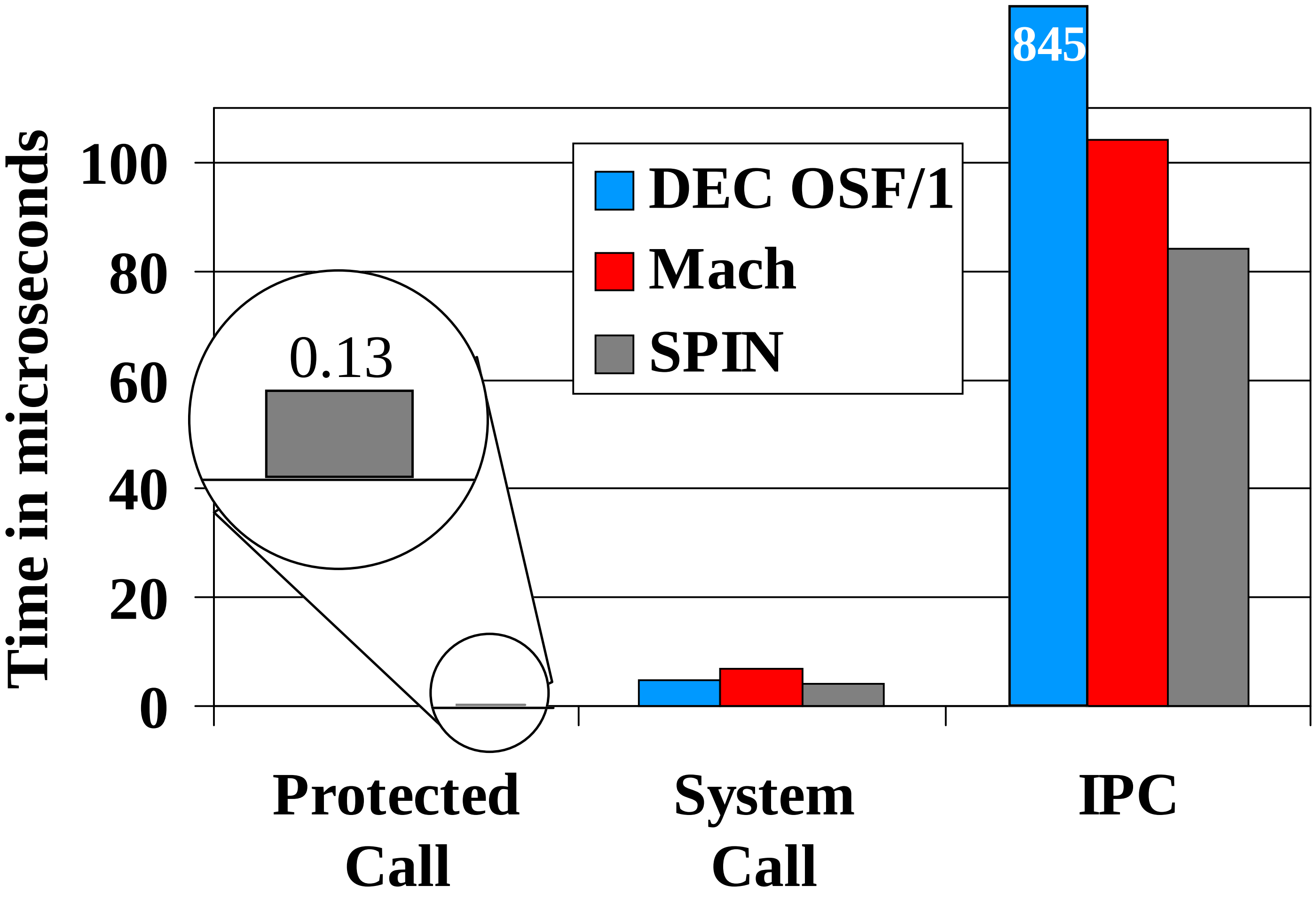
```
t := PageTable.New();
```

Event implementation

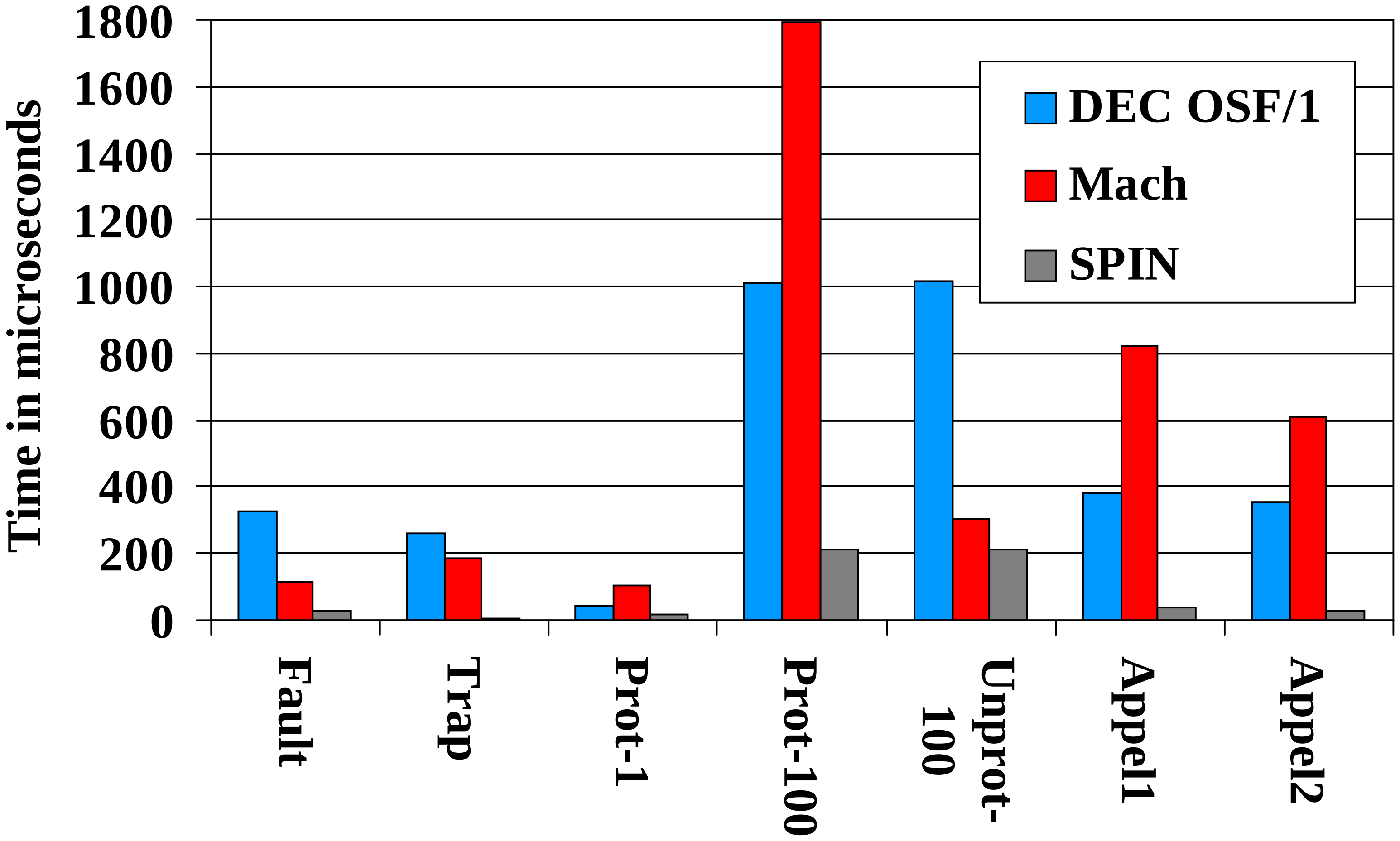
Use procedure call to define and invoke events

- Convenient syntax
- High performance implementation for common case
- Can protect events using domains
- Most procedures in the system can be extended

Protected communication



Memory management services



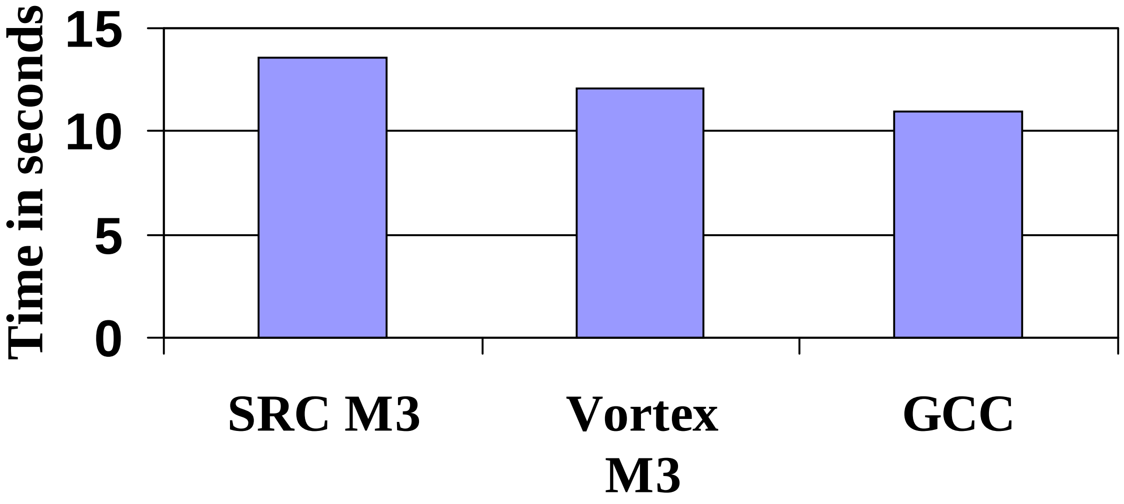
Modifications to Modula-3

- Memory safe cast
  - VIEW operator
- Procedures which may be terminated
  - EPHEMERAL procedure type
- Naming code
  - INTERFACE UNIT, MODULE UNIT
- Universal procedure type
  - PROCANY reference type

Performance of M3 vs C

- Most operations are compiled equivalently whether written in M3 or C
- M3 can sometimes introduce runtime checks to guarantee type safety

MD5 checksum benchmark


Time in seconds
SRC M3
Vortex M3
GCC