Computer Architecture in Action

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Question:

How many microprocessors are there in your computer?

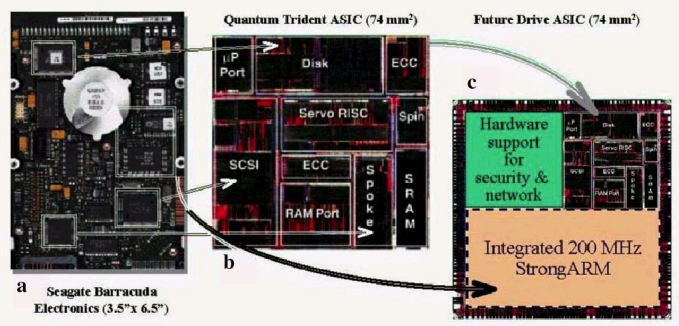
Answer:

- There is more than one:
  - CPU(s)
  - Hard Disk Drive
  - Graphics Card
  - Network Card
  - DSL/Cable Modem
  - Printer!
- The vast majority of processors are **not** CPUs.

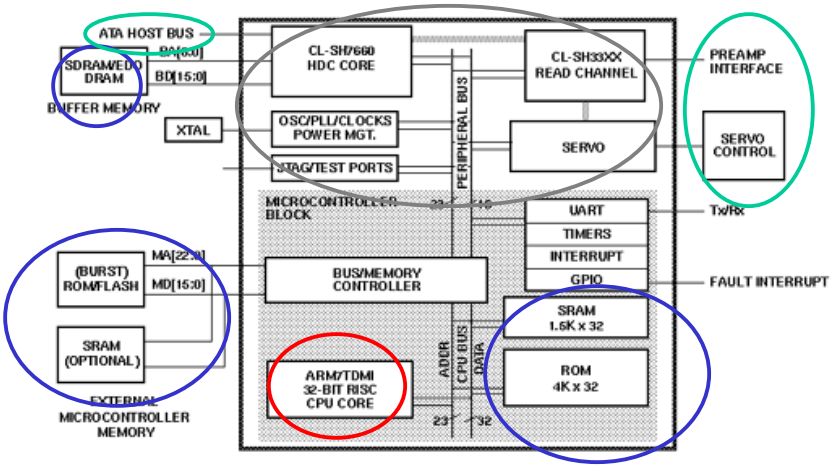
Outline

- Microprocessors: more than just CPUs
- **2 Examples of other uses**
- How does the use of a microprocessor effect its design?
- Network processor case study

Disk Controller Trends

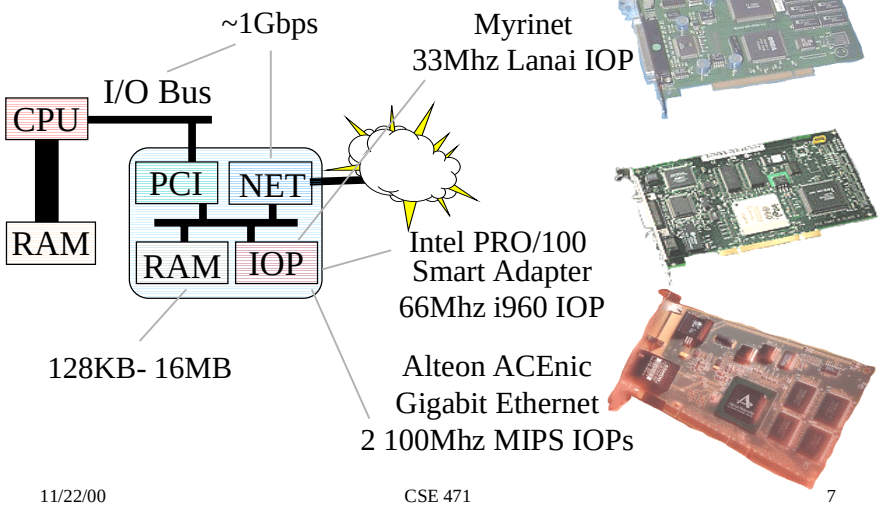


Disk Controller Design

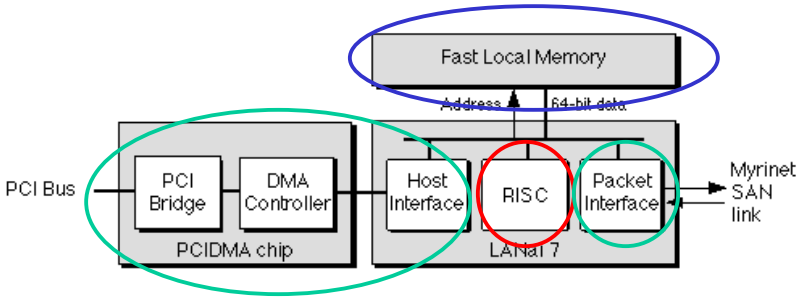


Processor Memory Communication Disk-specific logic

Network Card Trends



Network Card Design



Processor Memory Communication

Outline

- Microprocessors: more than just CPUs
- 2 Examples of other uses
- **How does the use of a microprocessor effect its design?**
- Network processor case study

How does the use of a microprocessor influence its design?

- Cost
- Power consumption
- Performance
- Compatibility
  - software
  - existing I/O standards

Where do you start?

- Does your disk's processor need:
  - a 2-level branch predictor?
  - any branch predictor?
  - caches?
- Can a better branch predictor help us process packets at 10 Gbps?
- How do you answer these questions?

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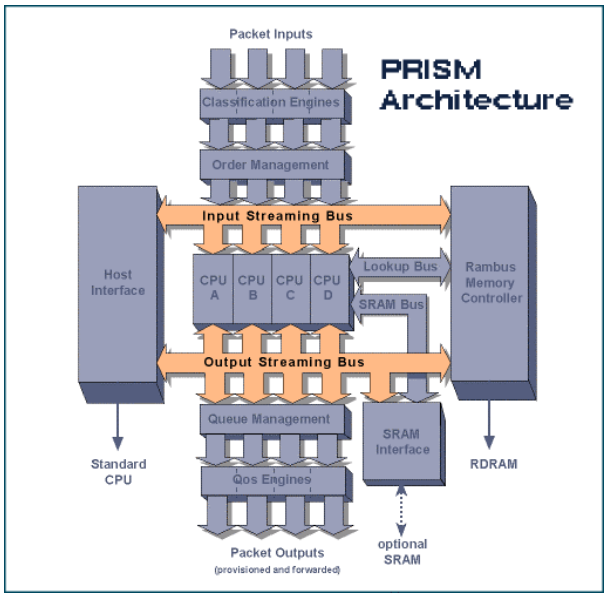
- **Network processor case study**

Network Processors

- … are processors used to perform network-related tasks.
- You find them in:
  - network cards
  - routers
  - special purpose, “edge” devices
    - web server load balancing
    - virtual private networks (VPN)
- Challenge: the processor needs to keep up with network speeds!

Prism Network Processor



The Plan

- Investigate network processor workloads, choose benchmarks
- Simulate the execution of benchmarks on high-performance architectures
- How do these processors fare?

Workloads

Applications	Description
Packet Classification/Filtering	Claim/forward/drop decisions, statistics gathering, and firewalling.
IP Packet Forwarding	Forward IP packets based on routing information.
Network Address Translation	Translate between globally routable and private IP packets. Useful for IP masquerading, virtual web server, etc.
TCP connection management	Traffic shaping within the network to reduce congestion.
TCP/IP	Offload TCP/IP processing from Internet/Web servers.
Web Switching	Web load balancing and proxy cache monitoring.
Virtual Private Network (VPN) IP Security (IPSec)	Encryption (DES) and Authentication (MD5)
Data Transcoding	Converting a multimedia data stream from one format to another within the network.
Duplicate Data Suppression	Reduce superfluous duplicate data transmission over high cost links.

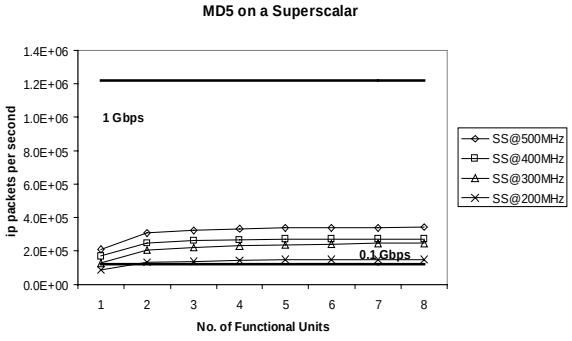
Key observation: packets can be processed *in parallel*.
(packet-level parallelism ≈ instruction level parallelism)

Benchmarks

Program	Insts Executed per Message	Loads/Stores (%)	Ctrl Flow (%)	Other (%)
IP forward	~200	25.4	12.7	61.9
MD5	~2000	10.7	2.8	86.5
3DES	~40000	17.8	1.2	81.0

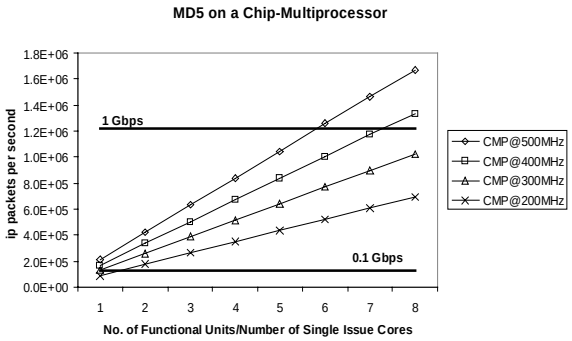
- 10x difference in computation per message (IP forward only inspects the packet header; the other two use the entire packet.)
- Instruction mix is SPEC-like (i.e., typical)
  - typical cache behavior, branch predictability
  - very little ILP (as we will see)
- Packets are processed independently
- *These programs must process packets at network speeds*

Superscalar Performance



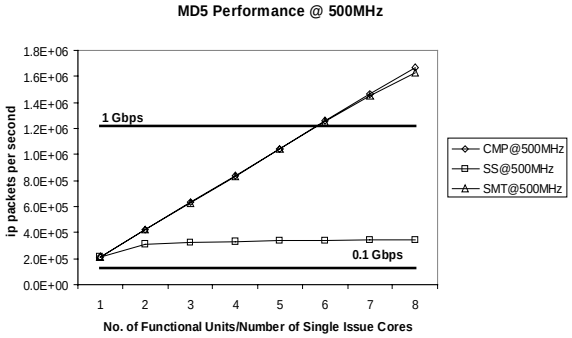
Superscalar: *not getting it done in the scalability department. Not enough ILP!*

CMP Performance



CMP: *succeeds by processing packets in parallel.*
Note: it exploits no ILP at all.

Performance Comparison



There is another way: Susan will talk about SMT later...

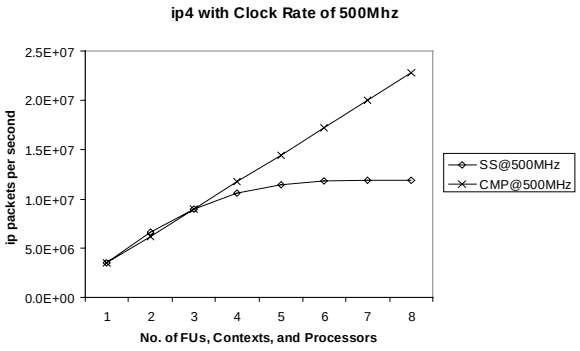
Network Processor Conclusions

- Workloads *very* parallel at the packet level
- Aggressive superscalar does not scale (not enough ILP in workloads)
- CMP scales by exploiting packet level parallelism

Summary

- Most microprocessors are **not** CPUs.
- Sometimes CPU techniques, which largely exploit ILP, are sufficient.
- Sometimes, as with network processors, ILP alone is insufficient.

ip4 Performance



3DES Performance