Disco: Running Commodity Operating Systems on Scalable Multiprocessors
Bugnion, Devine, and Rosenblum
SOSP 1997

1. What was the goal of Disco?

Instructor Notes -119 Noland

Disco: Running Commodity Operating Systems on Scalable Multiprocessors
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Run commodity OS on NUMA

2. What are the pros and cons of a CC-NUMA architecture (vs SMP UMA)? What are some issues with building or modifying an OS for CC-NUMA?

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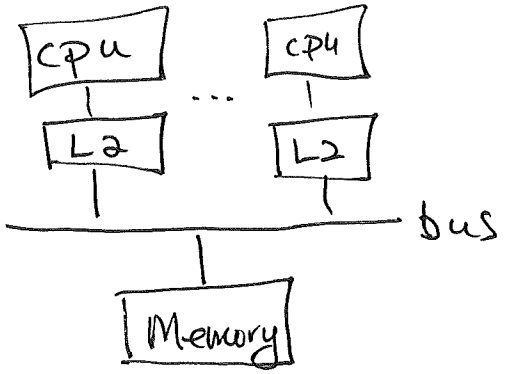
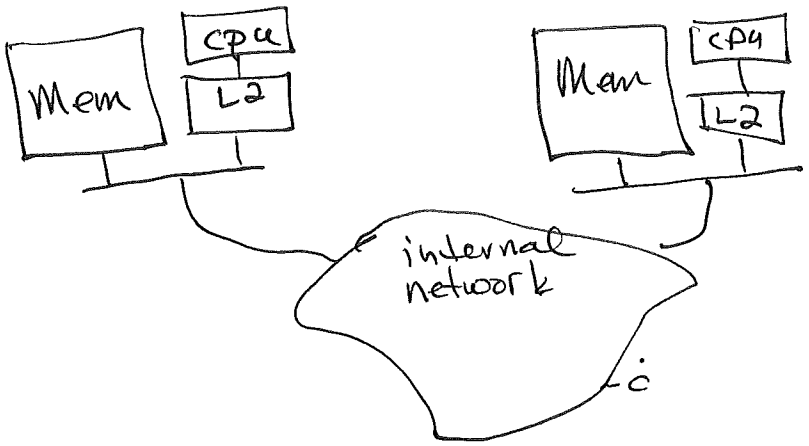
cache-coherent Non-Uniform Memory Architecture





+ same performance to all memory from everywhere

- hard to make hw scalable - hit limits of bus

- crazy perf
+ scalable hw

(correctness the same)

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0) Write from scratch

Difficulties:

1) Take existing OS + port: huge, ugly, difficult to understand

- need to allocate OS data structures across NUMA (hard enough for SMPs)
  - locks

⇒ VMM!

3. What are the advantages of Virtual Machines?

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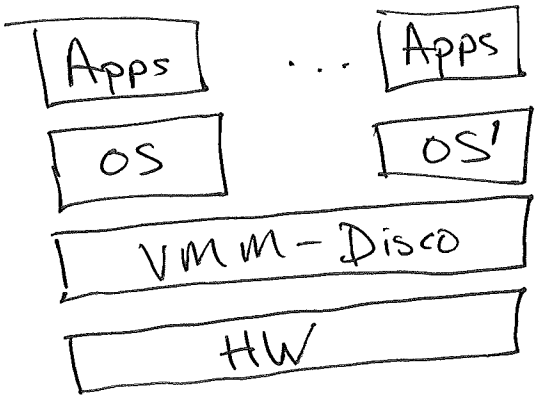

add new layer

- hide tough issues from OS
- portability layer
- smaller, easier to understand + trust
- run different OSes concurrently (almost unmodified)

4. At a high level, what are some of the challenges of Virtual Machine?

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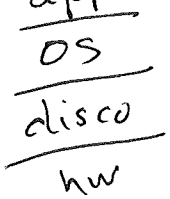
1) Overhead - cost of virtualizing

a) Time:

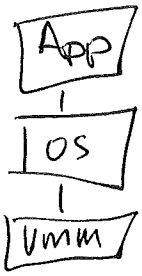


vmm acts as emulator
- most instr can just run, but priv. instr. + TLB inst must be trapped + emulated

b) Space:

- multiple copies wastes memory
- OS code + file cache

2) Resource management



- lose information about what is being used
  a) cpu - idle thread?
  b) memory - free list

3) Sharing problems
- most OS require exclusive access to disk

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a c

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b

- most: direct execution
  - track each VM that must be run, set real registers to VCPU regs, jmp to VPC (similar to OS + process table entries)
  - hard? priv. instr.

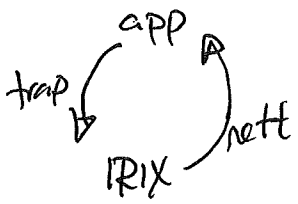
MIPS detail:

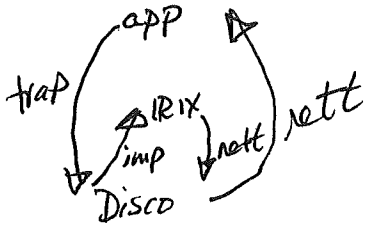
user
supervisor
kernel

- access all segments of mem, but not priv. instr, or phys mem

usual	Disco
app	app
—	OS - IRIX
IRIX	DISCO

OS can still access all of memory + manage apps





6. How does Disco virtualize memory? What will be held in the TLB? What happens on a TLB miss with w/o and w/ Disco? What data structure does Disco add?

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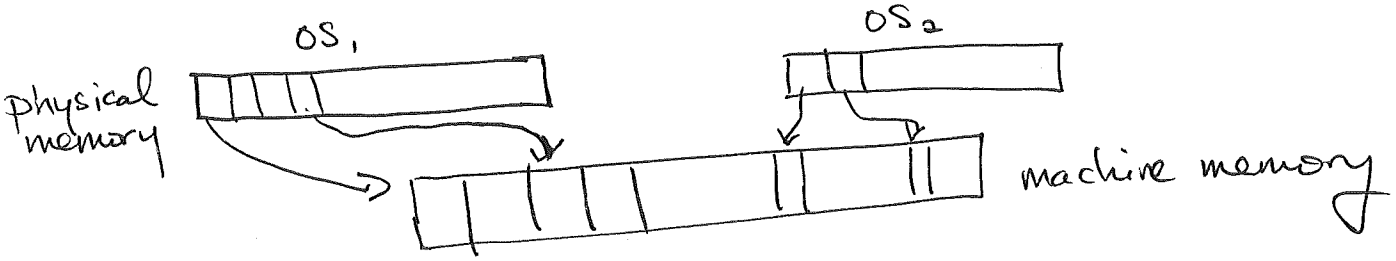
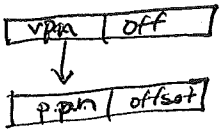


V.a. → p.a. → m.a.

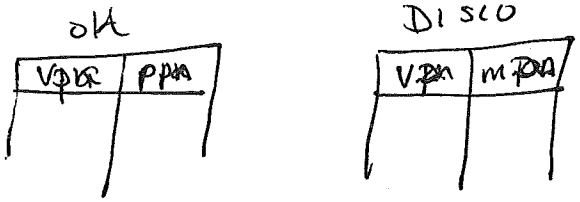
~~Do thru TLB?~~

normal



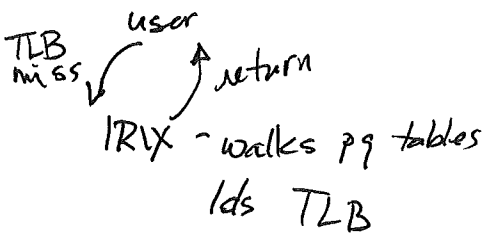
use page tables

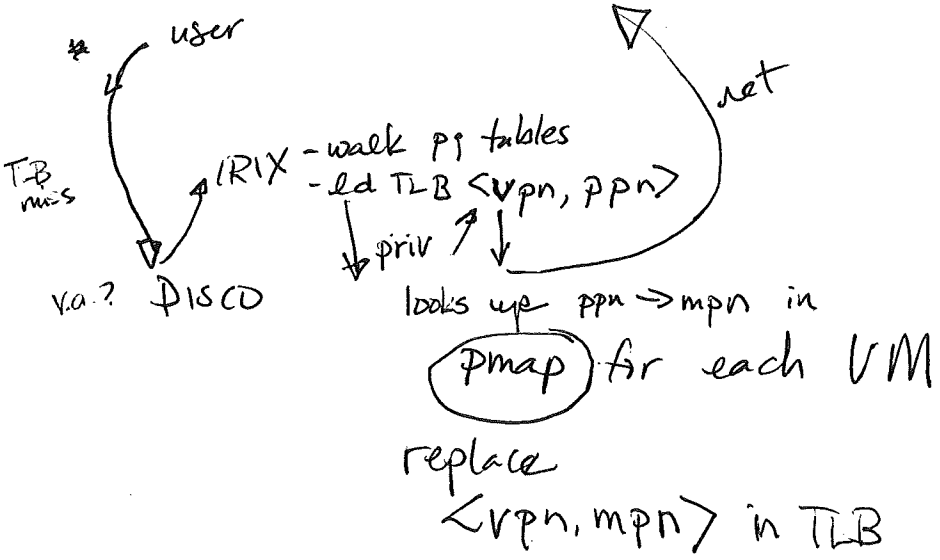
could trap on every ld + st,



TLB miss?

normal





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KSEG0 - unmapped physical memory

→ can't interpose via TLB

- all OS memory references ~~would be~~ ...

→ Relink IRIX to use different segment

8. Why are TLB misses more significant with Disco? What is Disco's solution?

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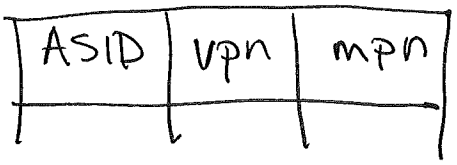
1) more costly

2) more of them

a) OS is using TLB too

b) must flush TLB between VCPU switches; Why?

TLB



difficult/ costly to virtualize ASID across all VMs, so instead flush

⇒ Add 2nd-level TLB in SW to do quick replacements - no need to walk pt in IRIX

(modify prev. diagram)

9. What are Disco's goals that are specific to NUMA? When should a page be replicated? migrated? How does Disco perform replication and migration? What should happen if a page is heavily write-shared?

9. What are Disco's goals that are specific to NUMA? When should a page be ~~replicated~~ MvSi-d? ~~migrated~~ rep? How does Disco perform ~~replication~~ mig and ~~migration~~ rep? What should happen if a page is heavily write-shared?

- Handle performance of NUMA (not correctness)
  - cache misses from CPU handled in local memory

Key: Use VA → PA → MA to handle issues

- Replicate?
  - Read sharing ~~(OS text)~~
- Migrate?
  - Activity on new CPU (e.g. Disco scheduler moved VM) w/ affinity, tries not to, but...

How?

- modify old TLB appropriately
- migration: invalidate! old mpn entries
- replication: doongrade to read-only

If heavily-write-shared?

Don't migrate or replicate

10. Why are large memory footprints a concern for Disco? Why does sharing occur across VMs? Why is copy-on-write useful?

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- Multiple OSes now running; encourage use of NFS server for shared file access (text-code, data)

- OSes share same code; NFS shares file data across client + server

Figure 3.

- intercept DMA from block X
- if already in memory, just record PA→MA
- record copy-on-write to track shared data efficiently

Figure 4.

① send becomes additional mapping (device emulate)

② copy becomes add. mapping

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(1) Some priv. ops are very simple (reading regs)
→ replace w/ ld/st to mem. addresses

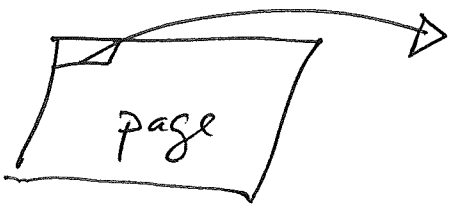
(2) zero'ed pages:
- ~~both~~ OS does when allocates new page to process (must for privacy)
- Disco must across VMs
- avoid double work

(3) Pages on free list - Disco should know about

(4) CPU is idle
- Disco detects low power

(5) bcopy → remap in NFS client

(6) mbuf structure



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- more for compute-bound w/ TLB misses
  - pmake uses many system services

- zeroing pages
- 2nd-level TLB

13. What does Figure 6 show? Does Disco do a decent job sharing buffer cache space across VMs? Of sharing IRIX text? IRIX data?

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yes yes no

- pmake workload
- virtual footprint vs. machine memory

14. What does Figure 7 show? Where can you find an evaluation of Disco's replication and migration policies?

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8 - processor cc-NUMA

IRIX · Lots of time in kernel ∴ memlock scalability limit

IVM · just add DISCO overhead

2VM → 8VM actually improves because DISCO does not have bad lock

turned off migration + replication

Fig. 8.

- much less time accessing remote mem

15. Conclusions?

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Strengths

+ Power of layering/indirection
+ small monitor hides tough NUMA + parallel issues
+ Really works - useful in many settings (not just cc-NUMA)

Problems:

- True virtualization tricky
- Handling info loss thru stack