The Nix Manycore Operating System

Shamelessly cribbed from a Bell Labs talk by Noah Evans
Work supported by URJC in Madrid and DOE/SC

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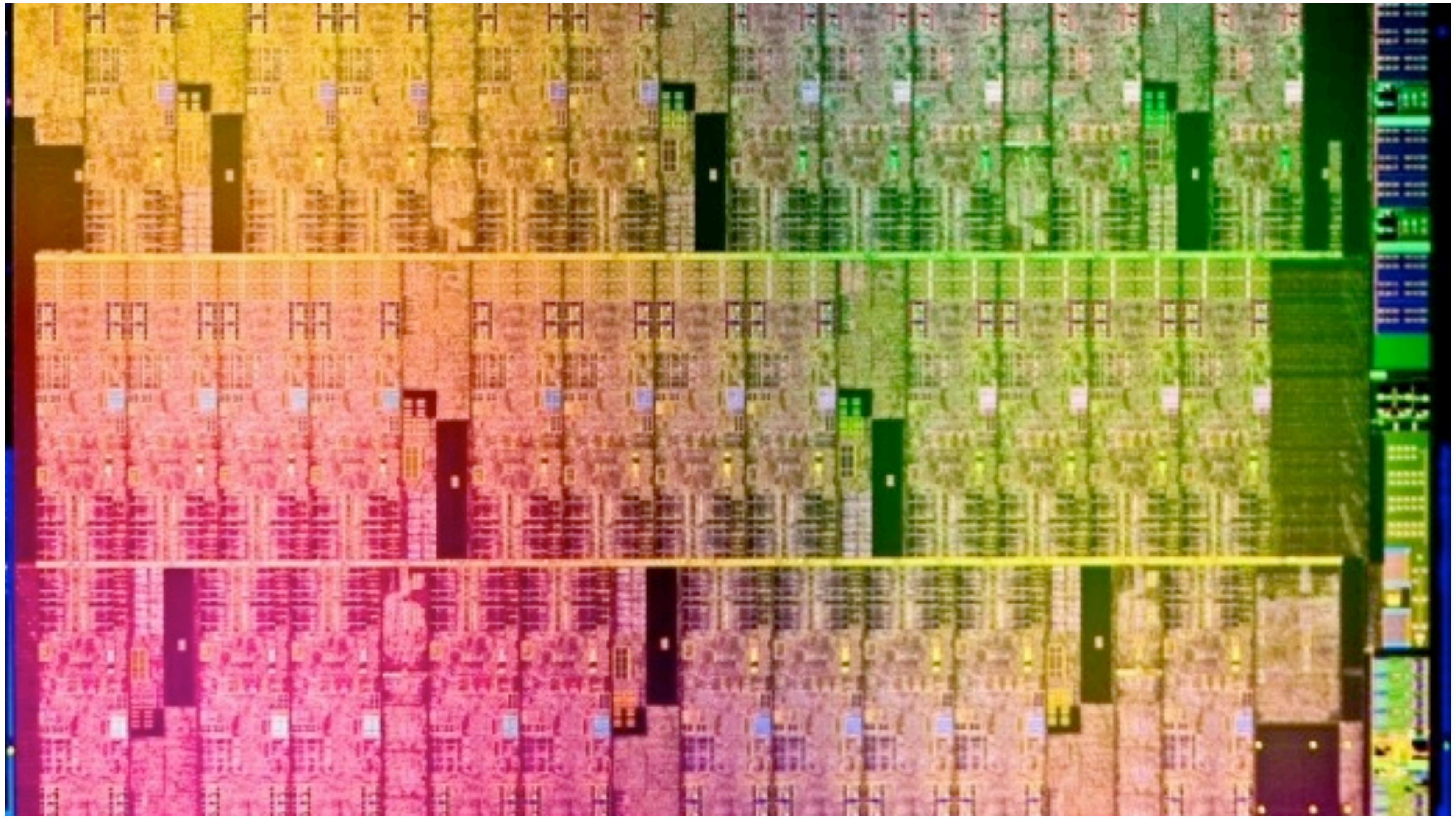
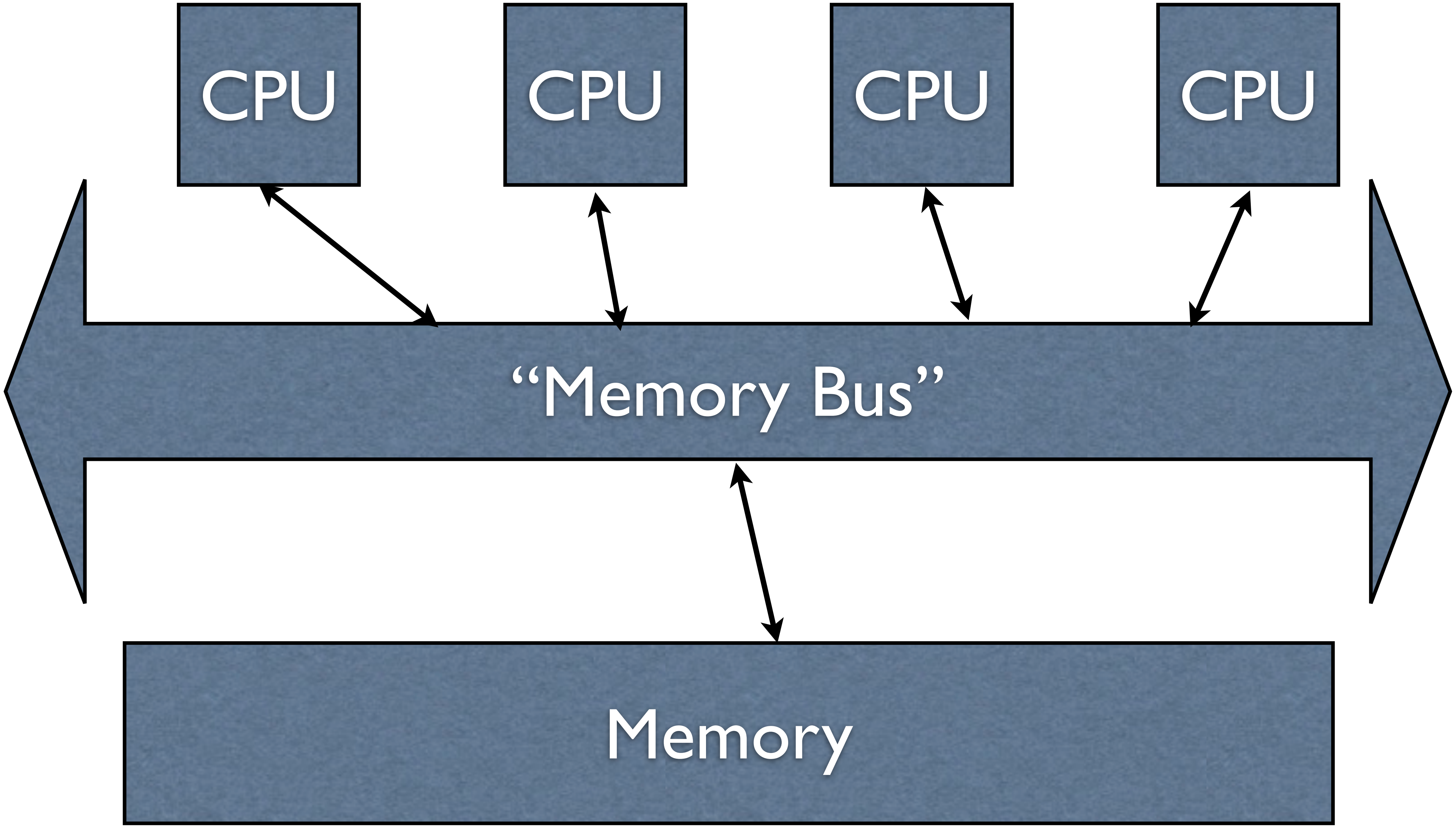
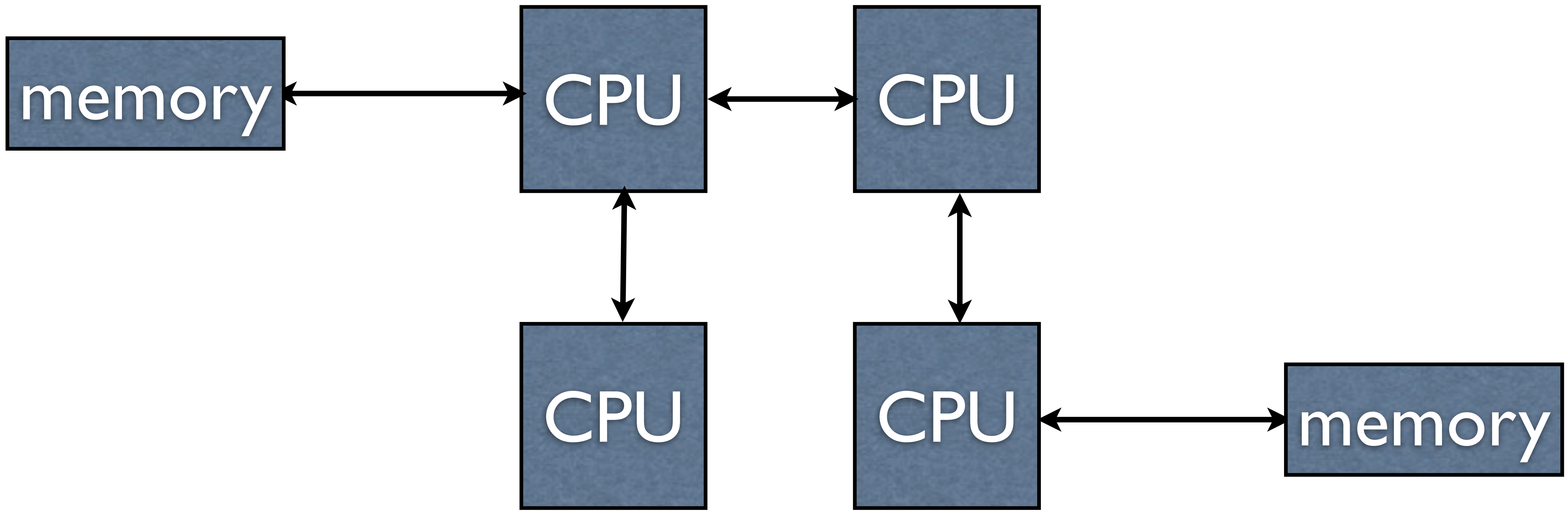


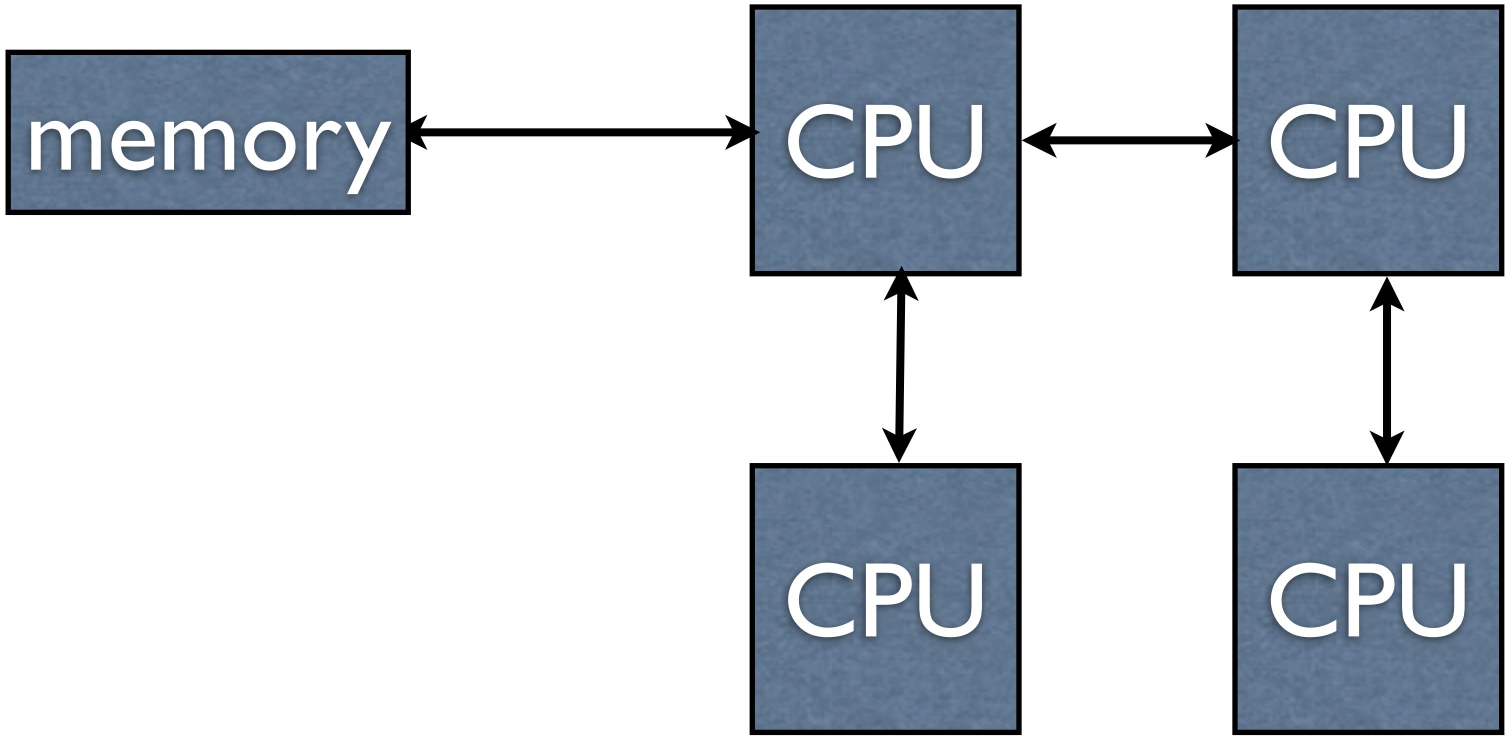
Manycore OS?



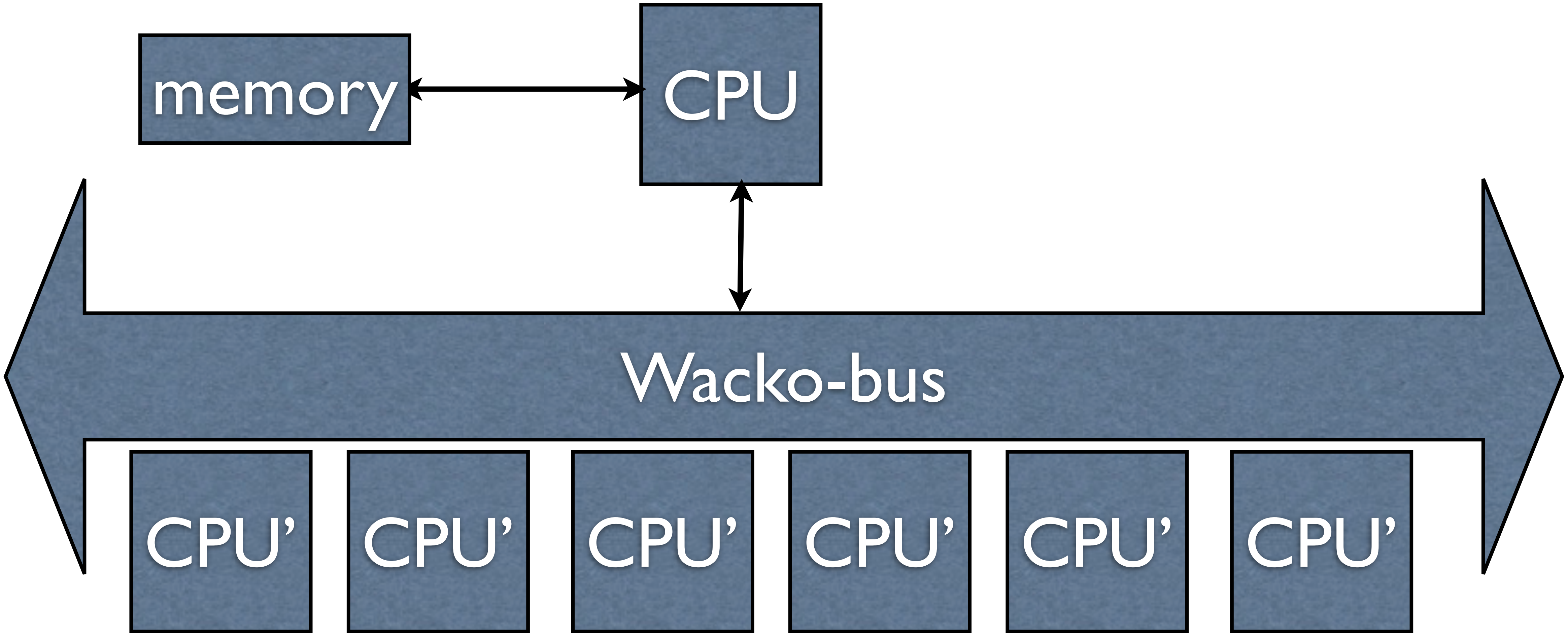
What we think we see



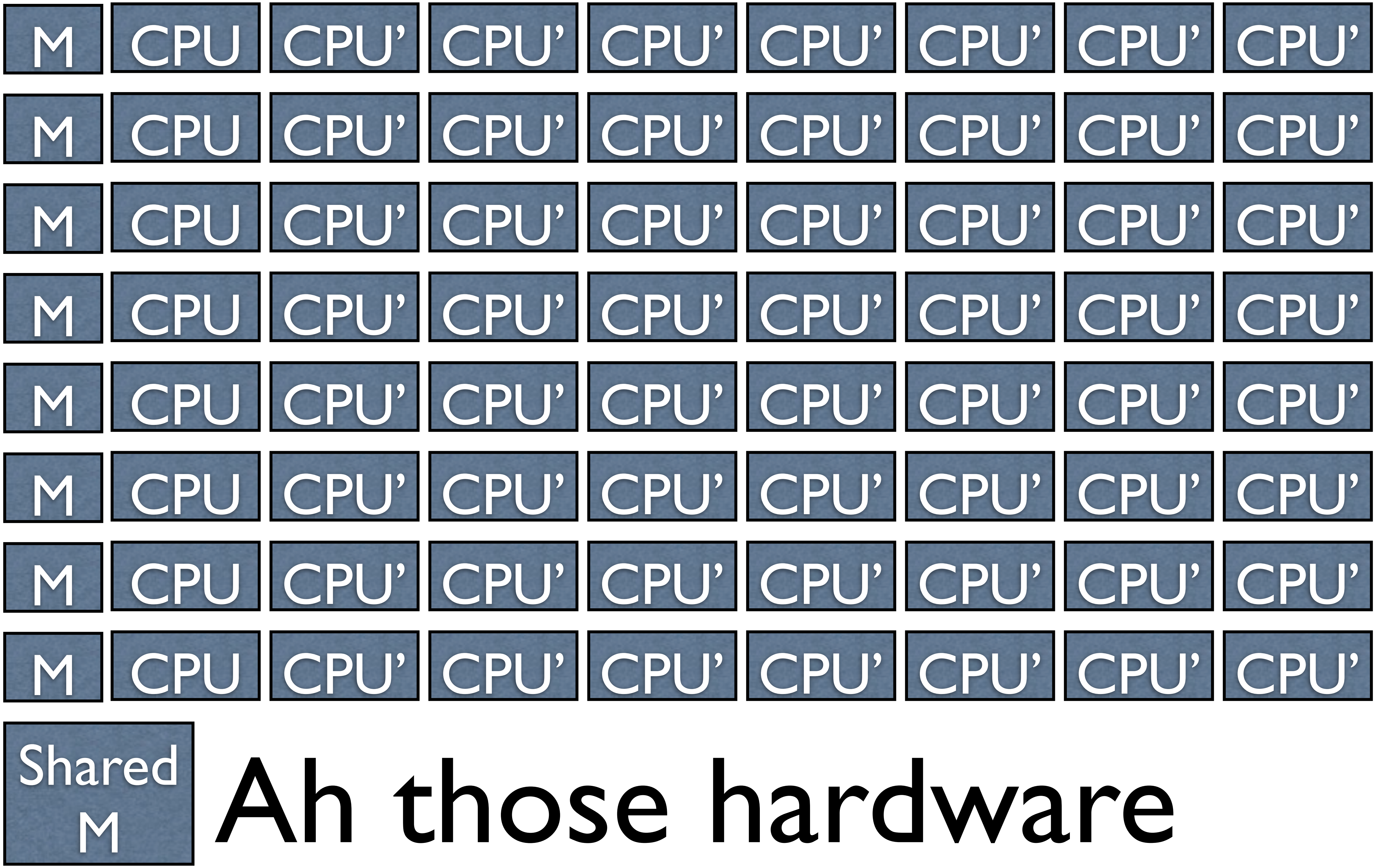
The sad reality



multicore ... can be the same



Or worse (e.g. cell)



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Shared M

Ah those hardware guys ...

Modern systems

- Multi-core, multi-socket
- Different ways of accessing memory (NUMA)
- Move towards heterogeneous processors
  - CellBe and Wirespeed
  - Save die size by having a few smart cores and lots of dumb ones
    - Dumb can be really, really dumb

Nix

Nix design space

- Multi-socket, multi-core
  - heterogeneous cores
- Not all memory is shared
- N^2 CPUS but N can run kernel code
  - Some might have only user-mode ISA
- First pass was on 24-core 4-socket K10

NIX Structure

- Cores have roles
- (Limited) Shared memory between cores
  - Used for comms
  - Confession: we don't always adhere to this rule
- Big pages
  - i.e. regular pages are 2MiB, big are GiB

Messaging: Inter-Core Call

- Essentially an active message
- Uses notion of small memory window between cores
- Trick: code address in all cores is same (works even if unshared memory)
    - So send address, not code, for active messages

```
struct ICC
{
        /* fn is kept in its own cache line */
        union{
                void    (*fn)(void);
                uchar _ln1_[ICCLNSZ];
        };
        int     flushtlb;       /* on the AC, before running fn */
        int     rc;             /* return code from AC to TC */
        char*   note;           /* to be posted in the TC after returning */
        uchar data[ICCLNSZ];    /* sent to the AC */
};
```

Core types

- TC == Timesharing Core
- AC == Application Core
- KC == Kernel Core

Timesharing Core

- Standard kernel
  - handles all hardware interrupts
  - schedules processes
  - driver interfaces

Application Core

- Runs user applications to completion/yield
  - Only FPU interrupts
  - New process state "Exotic"
- When idle, waits for ICC (message shown above)
  - polls ICC struct for non-nil fn pointer
- Currently: loaded from shared memory of TC
- Kernel context stays on TC

Kernel Core

- Running kernel tasks
  - kthreads that never context switch out
- a "noise" core
- No current use but we think there might be applications of it
- e.g. drivers without interrupts

One other rule

- Existing binaries run unchanged
- Instead of a "redo the world" approach
- Many such "redo the world" efforts, after a few years, have gone nowhere -- still no useful user mode, for example
- We wanted to avoid that situation

Implementation

Nix structure

- Inter Processor Interrupt to bring the cores up (standard approach, even in BIOS)
- infinite loop on ACs while they wait for work
  - i.e. ACs wait for ICC active message fn pointer to be non-NULL
- ACs Issue async system calls.

New calls

- execac(int core, char *path, char *args[]);
  - for non-shared-memory case
- rfork(RFCORE)
  - move from TC to AC
- rfork(RFCCORE)
  - move from AC to TC

System Calls

- System call code (kernel code) is not run on AC
- On K8, “Migrate” process from AC to TC, run call on TC, then move it back
  - significantly slower(~10x)
- We also have system call queues for K8
  - 2 Queues: request, reply; 2x slower
- On Cell-like systems, we would use Tubes (later) to forward system calls/connect to services

New “optimistic” semaphore

- void upsem(int *sem);
- void downsem(int *sem);
- int altsems(int *sems[], int nsems);
- Can proceed if no need to block
  - Else drop into kernel after several spins
- 124 lines user; 310 lines kernel
- Useful for supporting IPC such as ...

New IPC: Tubes

- Builds on sems
- Tube* newtube(ulong msz, ulong n);
- void freetube(Tube *t);
- int nbtrecv(Tube *t, void *p);
- int nbtsend(Tube *t, void *p);
- void trecv(Tube *t, void *p);
- void tsend(Tube *t, void *p);
- int talt(Talt a[], int na);

Uses of cores

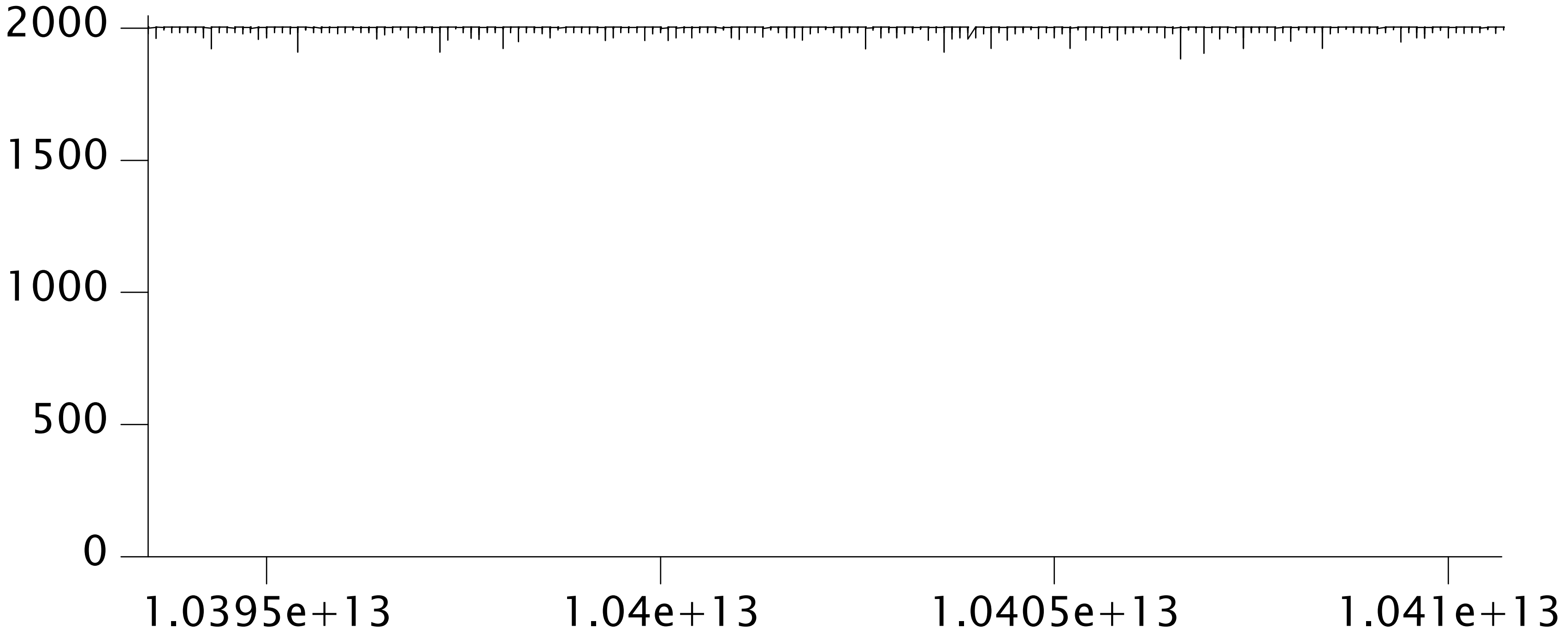
- Explicit request to run on an AC
- Implicit: consume enough full quantas, get moved to AC.
- Issue enough system calls, get moved to TC.
- Note the rule: use *more* CPU, *get even more* CPU: exact opposite of today

Evaluation

Fixed Time Quantum: FTQ

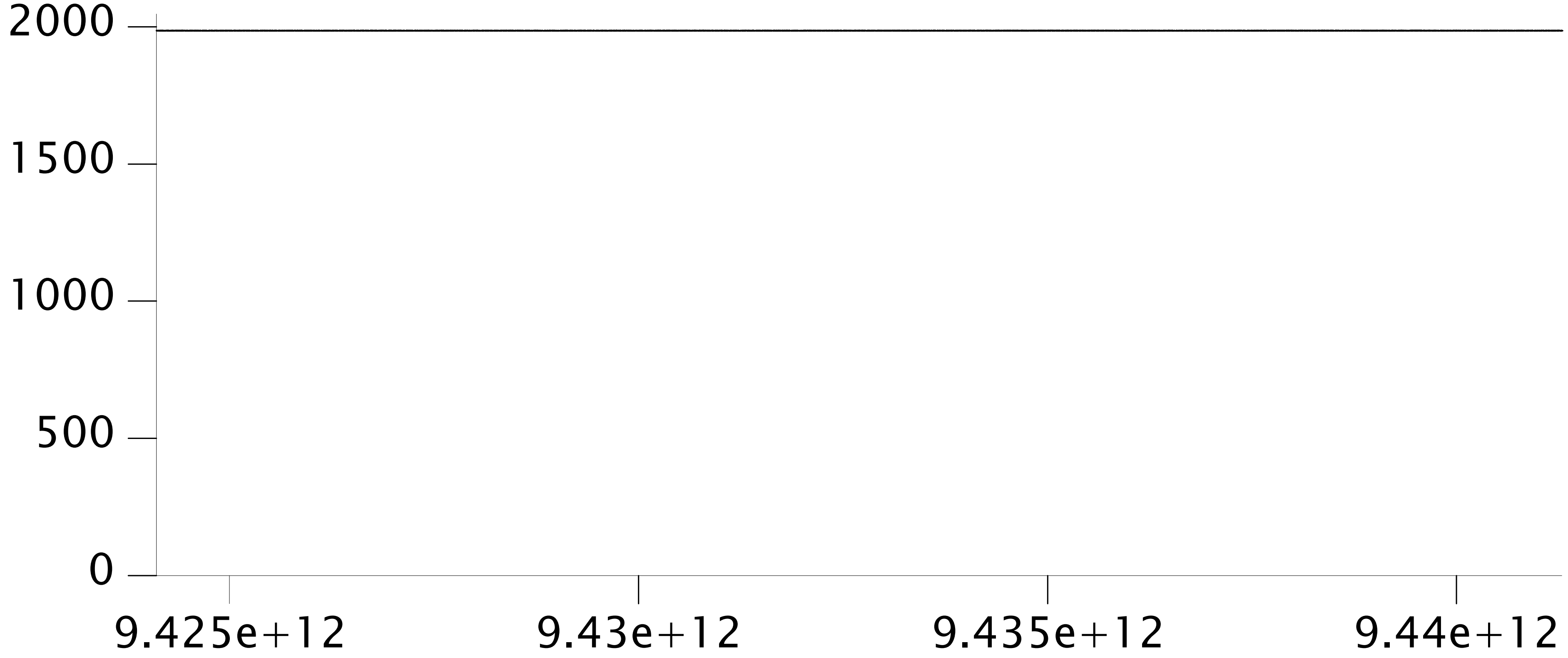
- Measure work per quanta (work/deltaT)
  - Careful implementation to ensure stationary, statistically useful time-series data
  - We've used it to find interference no on suspected (e.g. on Purple)
- Quantifies OS noise
- Used by Cray, IBM, DOE Labs, others

TC(Plan9)



FTQ on a TC
Work vs. Cycles
Smoother is better

AC



FTQ on an AC
Work vs. Cycles
Smoother is better

Current state

- Kernel and ACs work.
- 64 bit address space works (a bit better than on Linux)
- Transparent GiB PTEs went in 9/1/1
  - The AMD64 is a train wreck, gcc more so
  - But the Nix AMD64 support is far better
- In-kernel Linux emulation almost done

No kludgery needed (unlike Linux ...)

```
/* get top of heap */
p = segbrk(0, 0);
va = (uintptr)p;
/* round up to 64 GiB  (G as in Billion) */
va = ROUNDUP((va), 1ULL*GiB) + 64*GiB;

/* morecore */
np=(void*)va;
p = segbrk(p, np);
```

TODO

- AC statistics in /proc
- KC usage (implementation done)
- note (signal) handling on ACs
- optimization
- Power management

Conclusion

- New OS for future manycore CPUs
  - Differentiated cores
    - TC, AC and KC
  - Handle memory sizes
- Keep things working: Current implementation much faster for CPU bound tasks while still backwards compatible
  - If an AC is not available process works fine on a TC
- 400 new lines of assembly; 40 lines of “port”; 350 lines of AMD64 support (huge pages etc.)
- Far more work spent in design than actual coding