Limits to Growth?

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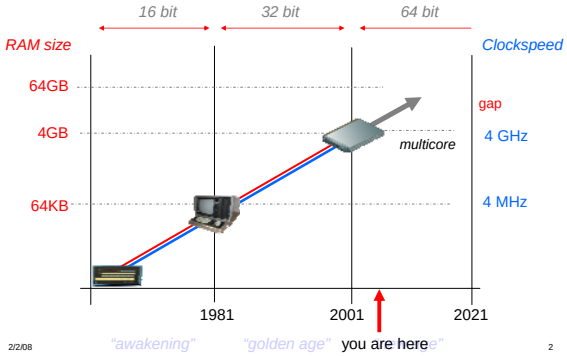
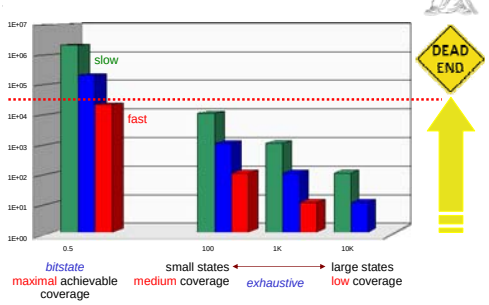
evolution of the desktop PC



time to fill 10 GB of RAM

10^4 states per second; 10^5 states per second; 10^6 states per second
(up to 10^{10} states in bitstate mode; upto 10^8 states in normal mode)

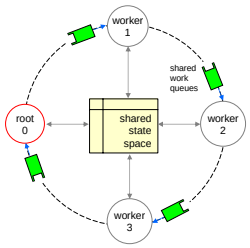


scaling

- in one day we can explore no more than 10^{10} states
  - *no matter how much RAM or disk we have!*
  - if Moore's curve for clock-speed had continued, we would have continued to expand this range
- using multi-core, *in the best case* we could increase our range by using multiple CPU cores
  - *but concurrency != scalability*
- some verification problems are *larger* than what we can handle (and not amenable to symbolic methods or abstraction)
  - *how do we handle those?*
  - *the infinite state space and the infinite memory*

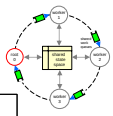
spin version 5

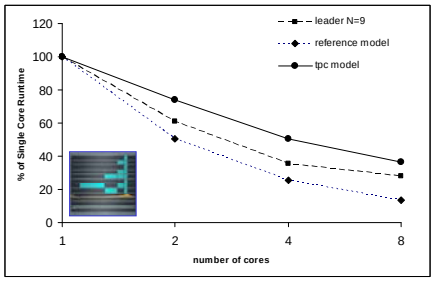
- supports multi-core verification
- developed on a dual quad-core system with 32 GB of memory
- linear scaling is achieved in the best cases measured



multi-core model checking

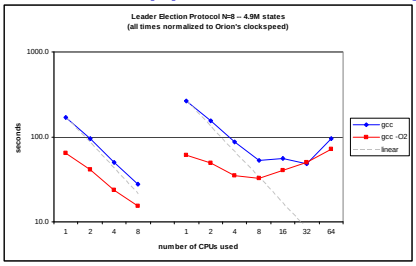
leader election (N=9), reference model, and a phone switch model





0.5 M states

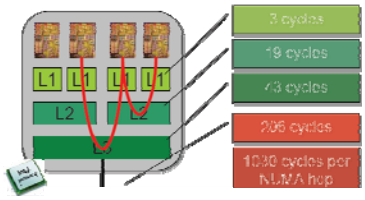
beyond 8 cores: and apparent anomaly



what happened to the nice linear scaling?

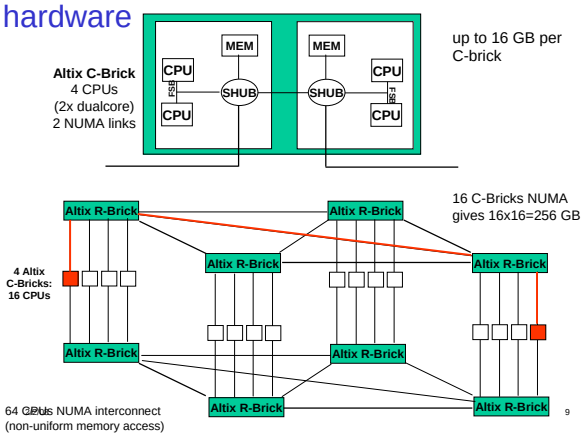
hypothesis: are *memory caching protocols* getting in our way?

memory access on SGI Altix with fast NUMA interconnect



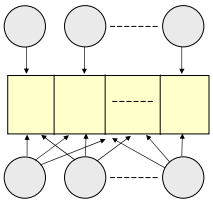
Source: *Scalability: The Software Problem*
Jonathan Appavoo, Volkmar Uhlig , Dilma da Silva,
Proc. STMCS'07, San Jose, CA, March 2007.
Second Workshop on Software Tools for Multi-Core Systems

hardware



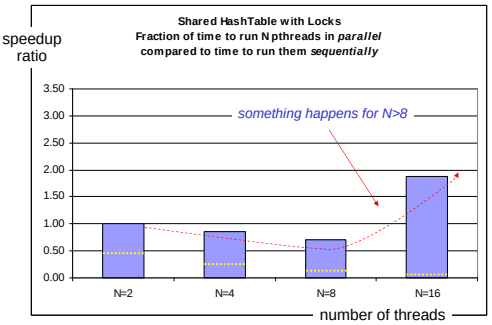
a simple experiment

- a small test program that writes S "states" of V bytes each into memory
  - the program simulates the actions of a model checker: randomly generating states, computing hashes, and storing the state in memory
- execute this program as N parallel threads, with each thread
  1. using *separate* memory arenas -- comparable to running the threads *sequentially*
  2. using a *shared* memory arena with locking



measurement on the SGI Altix

200,000 states stored, 100 bytes/state



what this means…

- there is a growing performance gap
  - memory size continues to grow
  - but cpu speed no longer does
  - the standard approach to handling large problem sizes has stopped working
    - new algorithms, approaches are needed to leverage *large* multi-core systems
    - exploiting multi-core systems with shared memory is much harder than it would seem