Parallel Languages: Past, Present and Future

Katherine Yelick

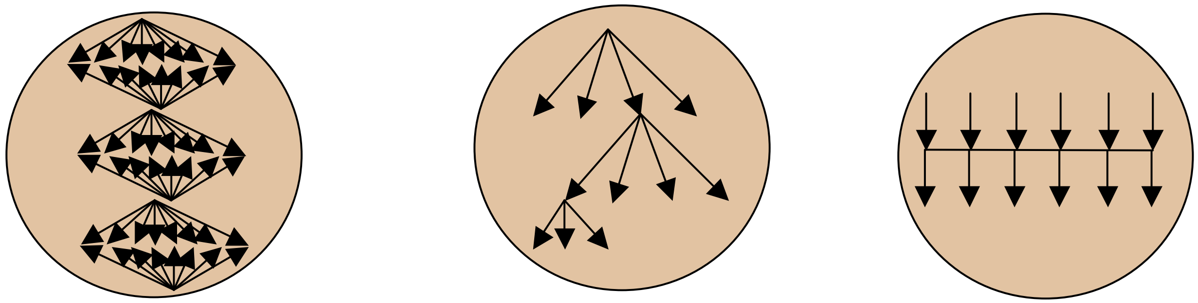
U.C. Berkeley and Lawrence Berkeley National Lab

Internal Outline

- **Two components: control and data (communication/sharing)**
- **One key question: how much to virtualize, i.e., hide machine?**
  - Tradeoff: hiding improves programmability (productivity), portability, while exposing gives programmers control to improve performance
- **Important of machine trends**
  - Future partitioned vs. cc shared
  - Transactions will save us
- **PGAS: what is it? What about OpenMP?**
  - Looking ahead towards multicore: these are not SMPs. Partitioned vs cc shared memory
- **What works for performance: nothing virtualized *at runtime*, except Charm++**
- **Open problem: load balancing with locality**

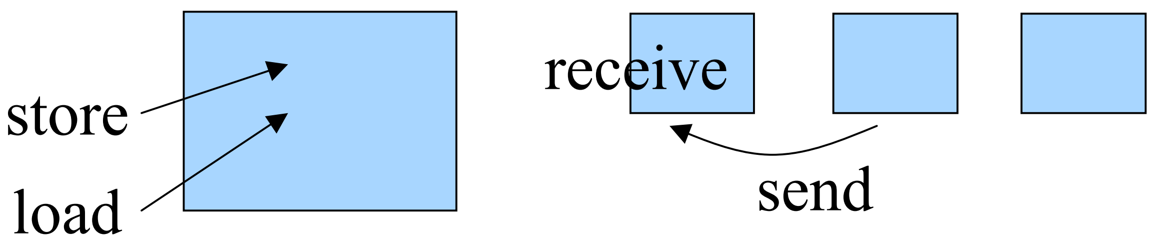
Two Parallel Language Questions

- **What is the parallel control model?**



data parallel (singe thread of control) | **dynamic threads** | **single program multiple data (SPMD)**

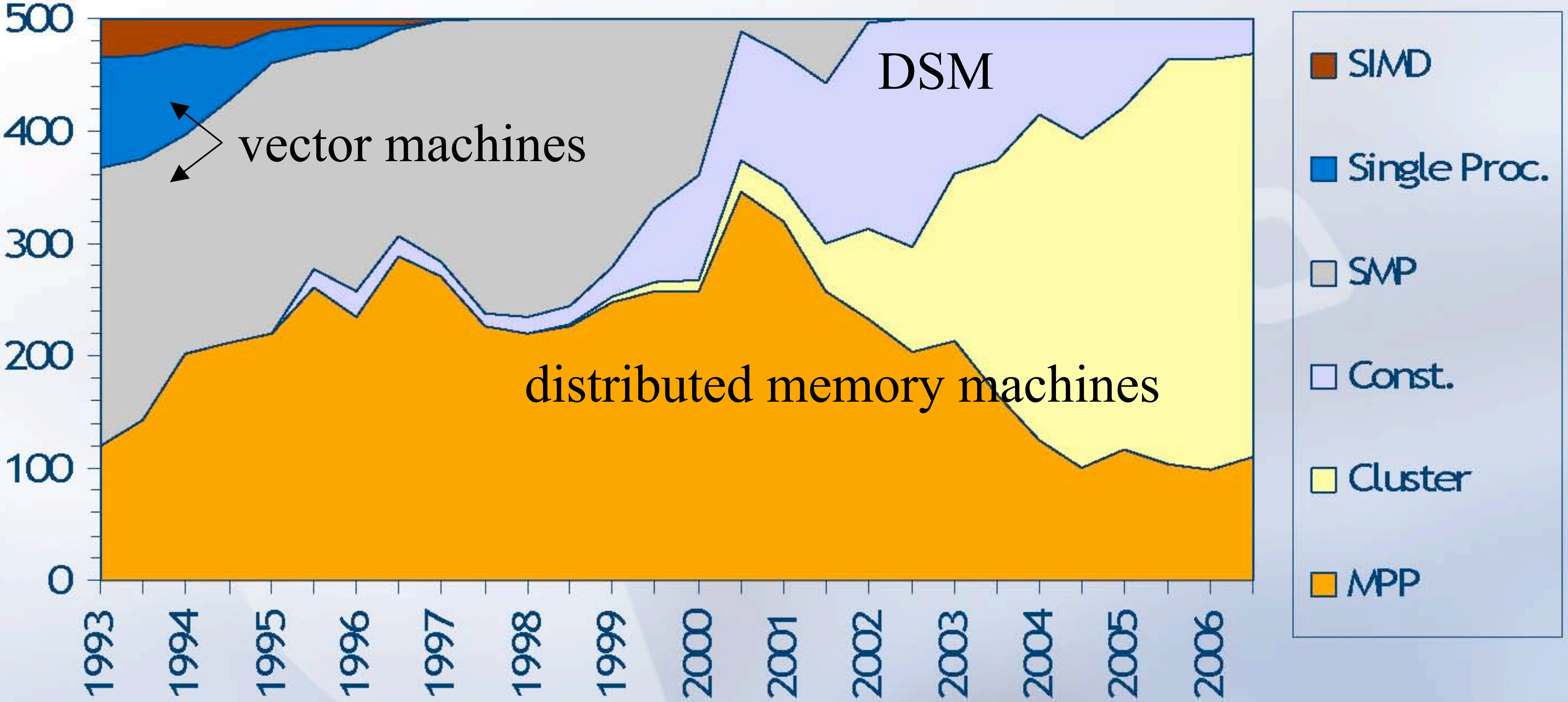
- **What is the model for sharing/communication?**



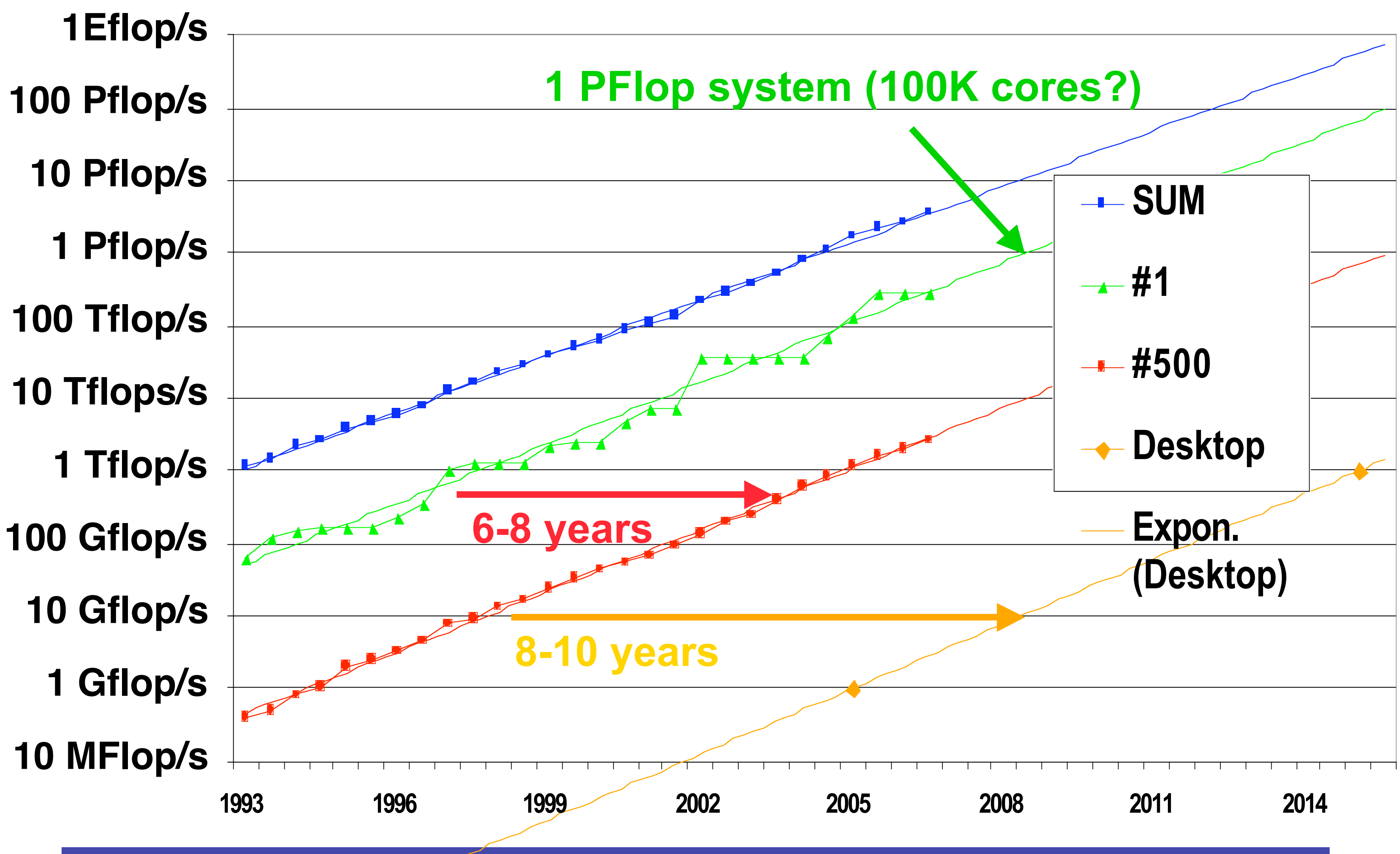
shared memory | **message passing**

implied synchronization for message passing, not shared memory

Architectures / Systems



Petaflop Desktop By 2026 ?



HPC Programming: Where are We?

- BG/L at LLNL has 64K processor cores
  - **There were 68K transistors in the MC68000**
- A BG/Q system with 1.5M processors may have more processors than there are logic gates per processor
  - **Trend towards simpler cores, but more of them**

- HPC Applications developers write programs that are as complex as describing where every single bit must move between the transistors in the MC68000
- We need to *at least* get to "assembly language" level

Slide source: Horst Simon and John Shalf, LBNL/NERSC

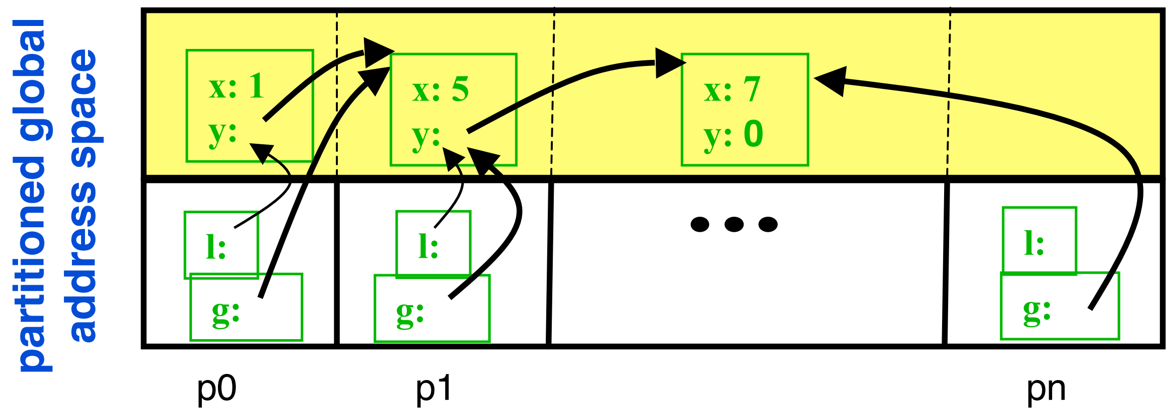
A Brief History of Languages

- **When vector machines were king**
  - Parallel "languages" were loop annotations (IVDEP)
  - Performance was fragile, but there was good user support
- **When SIMD machines were king**
  - Data parallel languages popular and successful (CMF, *Lisp, C*, …)
  - Quite powerful: can handle irregular data (sparse mat-vec multiply)
  - Irregular computation is less clear (multi-physics, adaptive meshes, backtracking search, sparse matrix factorization)
- **When shared memory multiprocessors (SMPs) were king**
  - Shared memory models, e.g., OpenMP, Posix Threads, are popular
- **When clusters took over**
  - Message Passing (MPI) became dominant

We are at the mercy of hardware, but we'll take the blame.

Partitioned Global Address Space Languages

- ***Global address space:*** **any thread may directly read/write data allocated by another → shared memory semantics**
- ***Partitioned:*** **data is designated local/remote →message passing performance model**



- ***3 older languages:*** **UPC, CAF, and Titanium**
  - All three use an SPMD execution model
  - Success: in current NSF PetaApps RFP, procurements, etc
  - Why: **Portable** (multiple compilers, including source-to-source); **Simple** compiler / runtime; **Performance** sometimes better than MPI
- ***3 newer HPCS languages:*** **X10, Fortress, and Chapel**
  - All three use a dynamic parallelism model with data parallel constructs

Challenge: improvement over past models that are just large enough

Open Problems

- **Can load balance if we don't care about locality (Cilk)**
  - Can we mix in locality?
  - If user places the work explicitly can we move it? They can unknowingly overload resources at the "place" because of an execution schedule chosen by the runtime
- **Can generate SPMD from data parallel (ZPL, NESL, HPF)**
  - But those performance results depend on pinning
  - E.g., compiled a program and run it on P processors, what happens if task needs to use some of them?
- **Can multicore support better programming models?**
  - A multicore chip is not an SMP (and certainly not a cluster)
    - **10-100x higher bandwidth on chip**
    - **10-100x lower latency on chip**
  - Are transactions a panacea?

Predictions

- **Parallelism will explode**
  - Number of cores will double every 12-24 months
  - Petaflop (million processor) machines will be common in HPC by 2015 (all top 500 machines will have this)
- **Performance will become a software problem**
  - Parallelism and locality are key will be concerns for many programmers – not just an HPC problem
- **A new programming model will emerge for multicore programming**
  - Can one language cover laptop to top500 space?
- **Locality will continue to be important**
  - On-chip to off-chip as well as node to node