Exploiting Dependencies as Concepts for Parallel Programming

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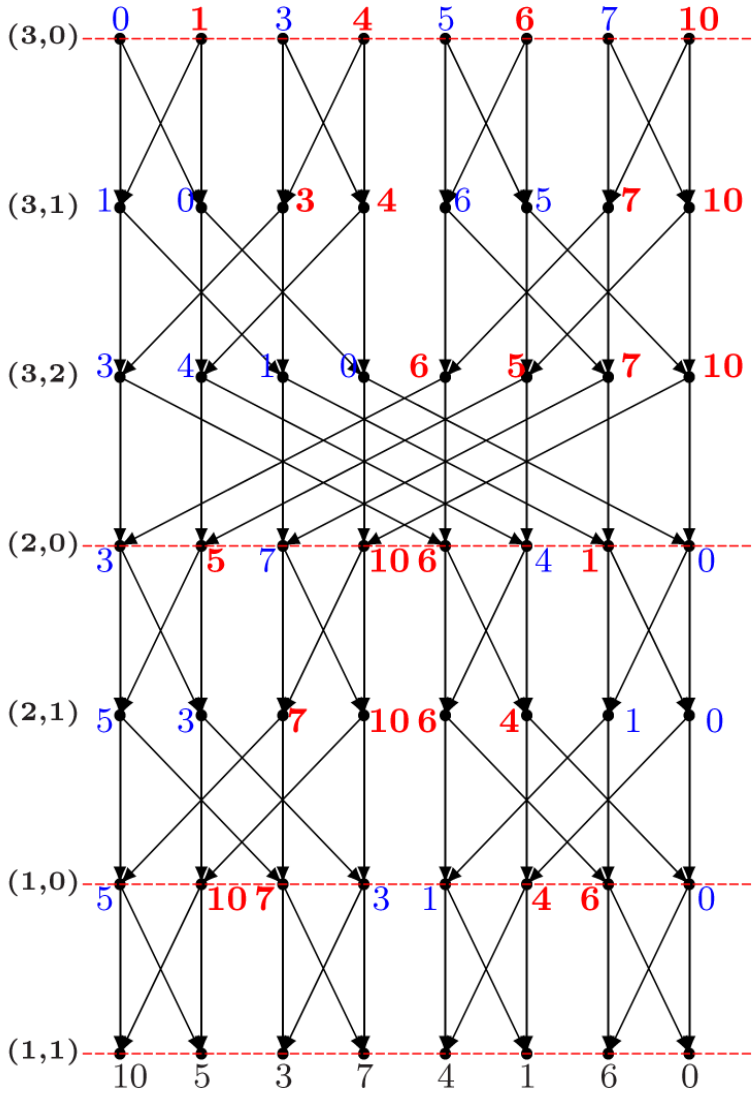
Programming Parallel Architectures

- Traditional: OpenMP and MPI
  - Communication architecture ignored
- Architecture-aware programming
  - Existing codes cannot be ported directly to new architectures
  - New architectures come along with new programming models: one for GPUs, one for Cell and so on.
- Hardware independent programming
  - Map computations to new architectures without rewriting the problem solving code
  - Higher level abstractions needed

Bitonic Sort Dependency



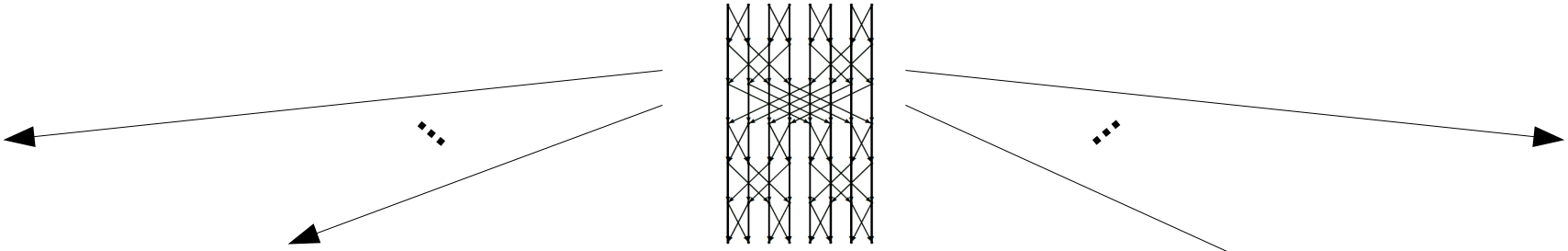
OUTPUT: sorted sequence

1 bitonic sequence of lenght 8

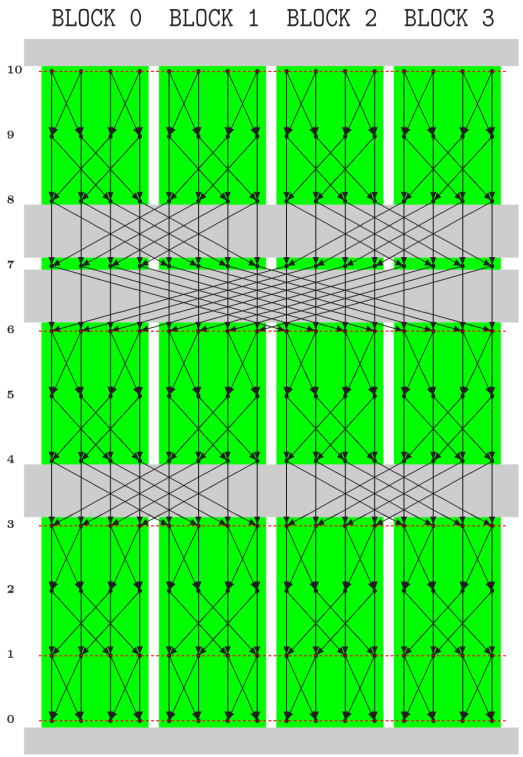
2 bitonic sequences of lenght 4

INPUT: viewed as 4 bitonic sequences of lenght 2

Embedding BS DDA onto Various Hardware

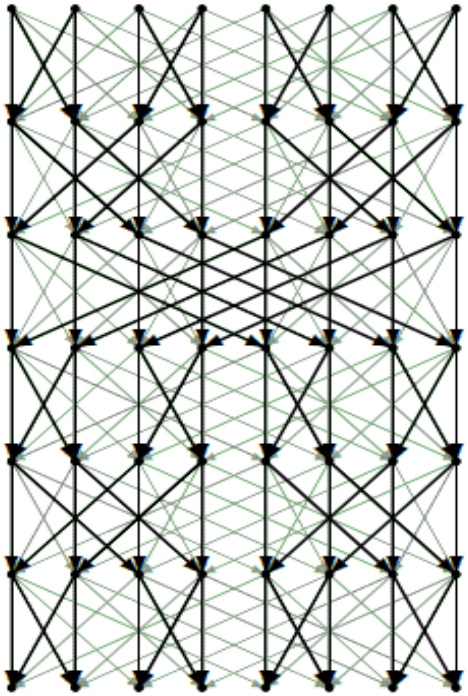


Bitonic Sort DDA



GPU: NVIDIA's CUDA

MPI-code



Hypercube

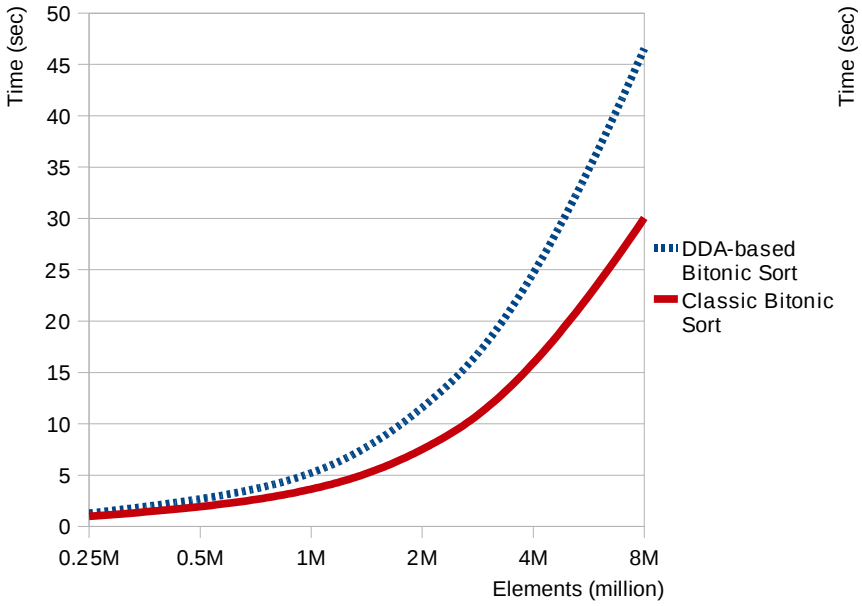
DDA concept (API) definition in Magnolia

```
module DDA
imports Equivalence;

concept DDA<type P, type B> {
requires Substitutable<P>; requires Substitutable<B>;

    /** The signiture */
        predicate rg (P p, B b);
        function P rp (P p, B b) guard rg(p,b);
        function B rb (P p, B b) guard rg(p,b);

        predicate sg (P p, B b);
        function P sp (P p, B b) guard sg(p,b);
        function B sb (P p, B b) guard sg(p,b);

    /** The axioms */
        axiom Receives (P p, B b) {
            assert sg(rp(p,b),rb(p,b));
            assert sp(rp(p,b),rb(p,b)) <-> p;
            assert sb(rp(p,b),rp(p,b)) <-> b;
        }
        axiom Supplies (P p, B b) {
            assert rg(sp(p,b),sb(p,b));
            assert rp(sp(p,b),sb(p,b)) <-> p;
            assert rb(sp(p,b),sb(p,b)) <-> b;
        }
}
```

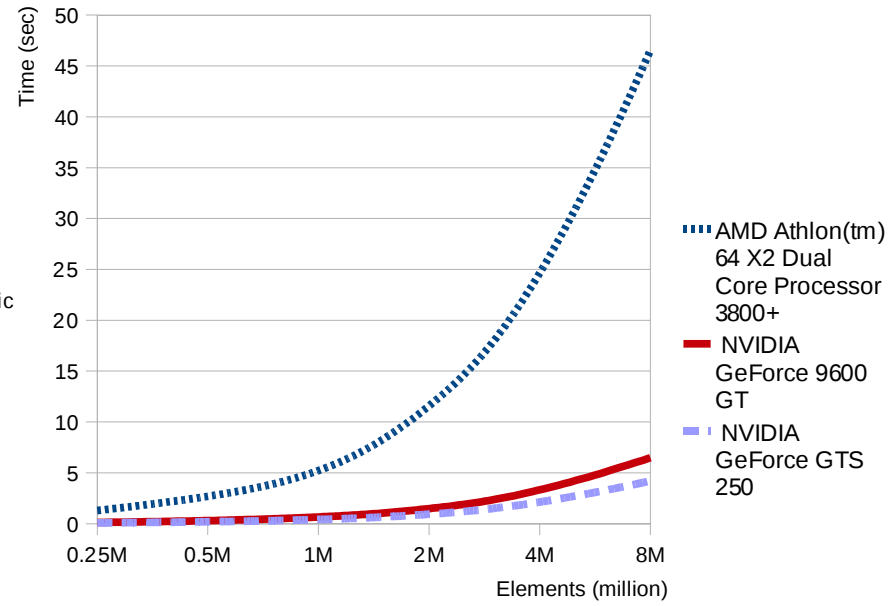
DDA Concepts and Compilation Schemes

- Plain DDA concept
  - Hashmap based implementation
    - Time control, no space control
- DDA with space-time projections concept
  - Sequential implementation
    - Time and space (memory layout) control
  - Parallel execution model using MPI
    - Time and space (parallel distribution) control
    - No communication structure control (limitation of MPI)
  - CUDA / OpenCL execution model using threads
    - Time and space (kernel/block/thread/memory) control
    - Communication structure control

Run Times for DDA-based Bitonic Sort



a)



b)

DDA-concept implementations are portable across platforms.

DDAs as Concepts

- Application domain – compiler construction
- DDA concept – API for the user
- Predefined collection of concepts with associated computational mechanism:
  - CUDA-execution model
  - MPI
  - Hypercube
  - FPGA,
  - etc
- Portability
- User benefits from axiom-based testing tools.