Collaboration on Legacy Support

HPX - Current State

XPRESS Workshop at LSU, July 10th, 2013

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The 4 Horsemen of the Apocalypse: SLOW

- Starvation
  - Insufficient concurrent work to maintain high utilization of resources
- Latencies
  - Time-distance delay of rem… access and services
- Overheads
  - W… …s and … …e not … …nt
- Wa… …ention resolution
  - D… …e to lack of availability of ov…subscribed shared resource

Impose upper bound on both weak and strong scaling

courtesy of www.albrecht-durer.org

HPX – A General Purpose Runtime System

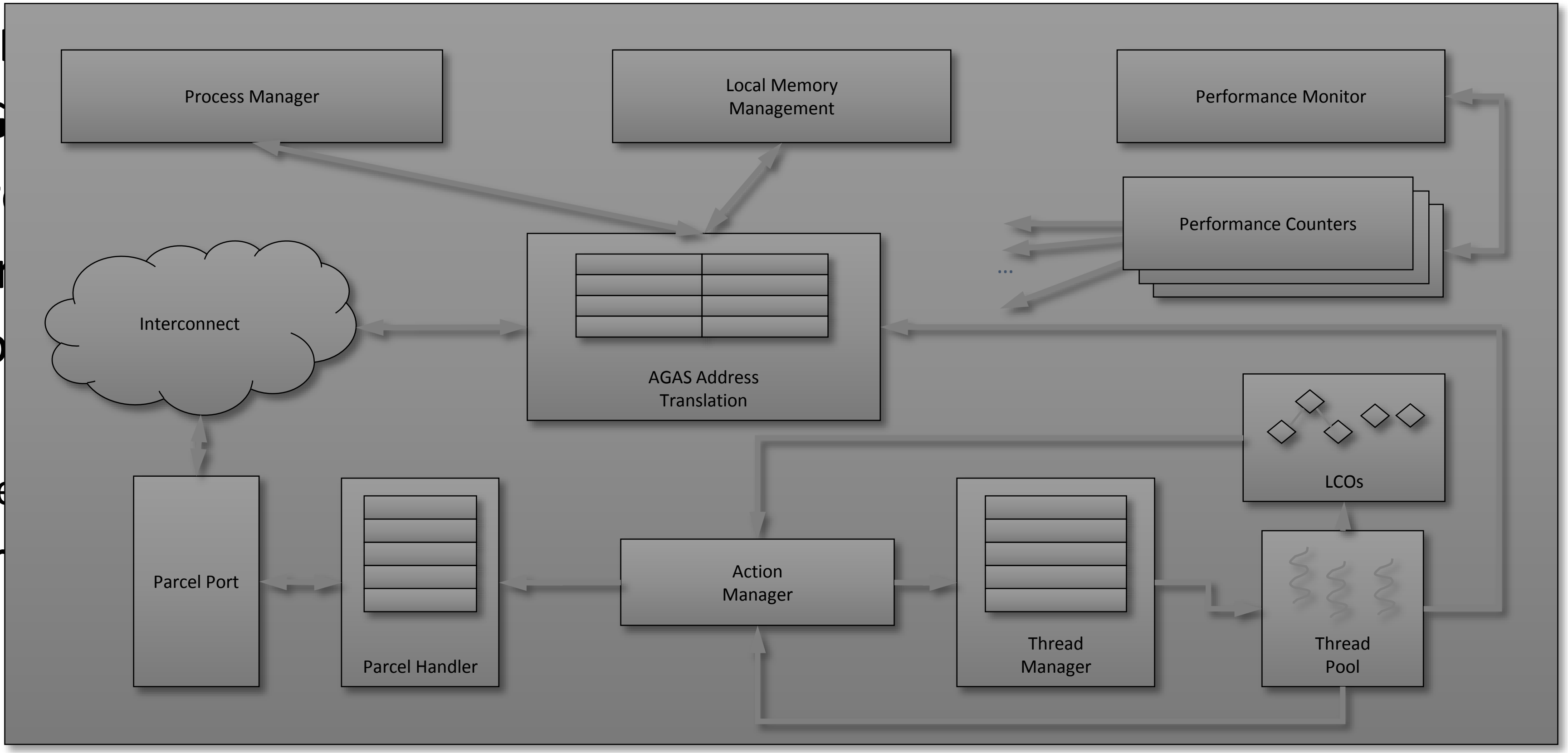
- All examples in this talk are based on HPX
- A general purpose runtime system for applications of any scale
  - http://stellar.cct.lsu.edu/
  - http://github.com/STEllAR-GROUP/hpx/
- Exposes an uniform, standards-oriented API for ease of programming parallel and distributed applications.
- Enables to write fully asynchronous code using hundreds of millions of threads.
- Provides unified syntax and semantics for local and remote operations.
- Is published under Boost license and has an open, active, and thriving developer community.

HPX – A General Purpose Runtime System

- Governing principles
  - Active global address space (AGAS) instead of PGAS
  - Message driven instead of message passing
  - Lightweight control objects instead of global barriers
  - Latency hiding instead of latency avoidance
  - Adaptive locality control instead of static data distribution
  - Moving work to data instead of moving data to work
  - Fine grained parallelism of lightweight threads instead of Communicating Sequential Processes (CSP/MPI)

HPX Runtime System Design

- Current version of HPX provides the following infrastructure on conventio
  - Active G
  - HPX Thr
  - Parcel Tr
  - Local Co
  - HPX Pro
    - Name
  - Monitor



HPX – The API

- Fully asynchronous
  - All possibly remote operations are asynchronous by default
    - ‘Fire & forget’ semantics (result is not available)
    - ‘Pure’ asynchronous semantics (result is available via hpx::future)
  - Composition of asynchronous operations (N3634)
    - hpx::when_all, hpx::when_any, hpx::when_n
    - hpx::future::then(f)
  - Can be used ‘synchronously’, but does not block
    - Thread is suspended while waiting for result
    - Other useful work is performed transparently

HPX – The API

- As close as possible to C++11 standard library, where appropriate, for instance
  - std::thread → hpx::thread
  - std::mutex → hpx::mutex
  - std::future → hpx::future
  - std::async → hpx::async
  - std::bind → hpx::bind
  - std::function → hpx::function
  - std::tuple → hpx::tuple
  - std::any → hpx::any (N3508)
  - std::cout → hpx::cout
  - etc.

HPX – The API

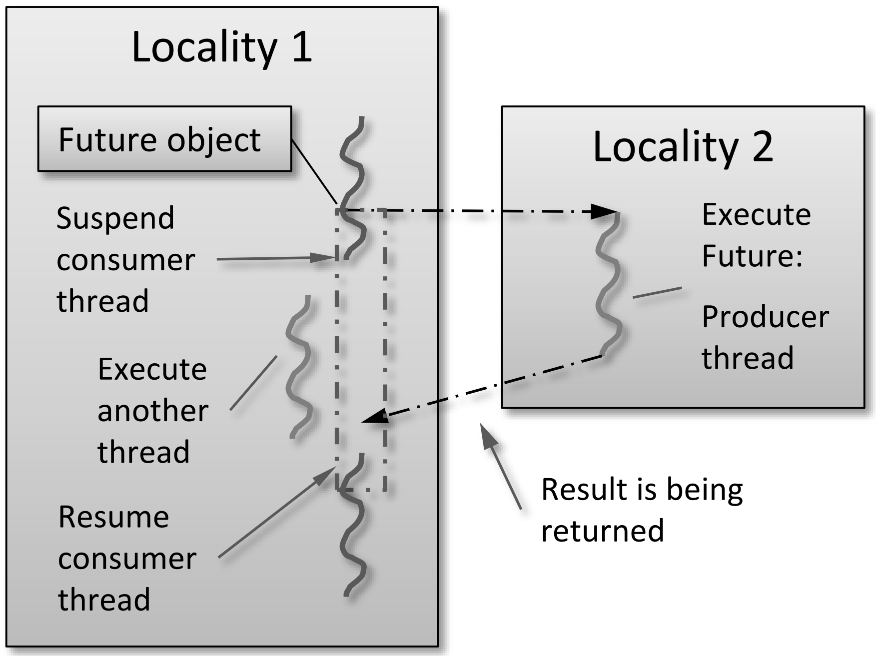
- Fully move enabled (using Boost.Move)
  - hpx::bind, hpx::function, hpx::tuple, hpx::any
- Fully type safe remote operation
  - Extends the notion of a ‘callable’ to remote case (actions)
  - Everything you can do with functions is possible with actions as well
- Data types are usable in remote contexts
  - Can be sent over the wire (hpx::bind, hpx::function, hpx::any)
  - Can be used with actions (hpx::async, hpx::bind, hpx::function)
- Fully asynchronous
  - All possibly remote operations are asynchronous by default
    - ‘Fire & forget’ semantics (result is not available)
    - ‘Pure’ asynchronous semantics (result is available via hpx::future)
  - Composition of asynchronous operations (N3428)
    - hpx::when_all, hpx::when_any, hpx::when_n
    - hpx::future::then(f)
  - Can be used ‘synchronously’, but do not block
    - Thread is suspended while waiting for result

HPX – The API

`R f(p...)`	**Synchronous (return R)**	**Asynchronous (return future<R>)**	**Fire & Forget (return void)**
Functions (direct)	`f(p…)` C++	`async(f, p…)`	`apply(f, p…)`
Functions (lazy)	`bind(f, p…)(…)`	`async(bind(f, p…), …)` C++ Library	`apply(bind(f, p…), …)`
Actions (direct)	`HPX_ACTION(f, a)` `a(id, p…)`	`HPX_ACTION(f, a)` `async(a, id, p…)`	`HPX_ACTION(f, a)` `apply(f, id, p…)`
Actions (lazy)	`HPX_ACTION(f, a)` `bind(a, id, p…)(…)`	`HPX_ACTION(f, a)` `async(bind(a, id, p…), …)`	`HPX_ACTION(f, a)` `apply(bind(a, id, p…), …)` HPX

What is a (the) future

- A (std) future is an object representing a result which has not been calculated yet



- Enables transparent synchronization with producer
- Hides notion of dealing with threads
- Makes asynchrony manageable
- Allows for composition of several asynchronous operations
- Turns concurrency into parallelism

What is a (the) Future?

- Many ways to get hold of a future, simplest way is to use (std) async:

```
int universal_answer() { return 42; }

void deep_thought()
{
    future<int> promised_answer = async(&universal_answer);

    // do other things for 7.5 million years

    cout << promised_answer.get() << endl;   // prints 42
}
```

Example of using Futures

- Calculate Fibonacci numbers in parallel

```
uint64_t fibonacci(uint64_t n)
{
    // if we know the answer, we return the value
    if (n < 2) return n;

    // asynchronously delay-calculate one of the sub-terms
    future<uint64_t> f = async(&fibonacci, n-1);

    // synchronously calculate the other sub-term
    uint64_t r = fibonacci(n-2);

    // wait for the future and calculate the result
    return f.get() + r;
}
```

HPX & OpenMP

- HPX makes a perfect backbone for an OpenMP implementation
  - Most of OpenMP functionality maps directly onto HPX concepts (threads, tasks, etc.)

HPX & MPI

- MPI is two things
  - Highly efficient and widely supported communication platform (send, receive, isend, ireceive)
  - Programming model (broadcast, all_reduce, data types, etc.)
- We should reuse communication layer
  - New parcelport for HPX
- We should re-implement higher level MPI functions on top of HPX