Xpress Performance Workshop – The Future of ~~RCRblackboard~~ XpressBlackboard

Allan Porterfield
RENCI, UNC-Chapel Hill

Rob Fowler
RENCI, UNC-Chapel Hill

renci
RESEARCH \ ENGAGEMENT \ INNOVATION

RENCI/UNC's Version of the EXPRESS goal

- Provide a complete slice of a software stack that allows unified approaches to the difficult problems facing Exascale software
  - Massive parallelism
  - Heterogeneous parallelism
  - Resilience
  - Reliability
  - Power management
  - Performance
  - Unified software tools

XPRESS must be a single software stack

- XPRESS must provide a unified software stack
  - Not a set of independent utilities
  - Attack Exascale problems
    - Resilience/Reliability at all levels
    - Billion-way Parallelism
    - Heterogeneity
    - Control Energy Usage
  - Inter-operate smoothly
  - Information flows across boundaries within the stack
    - How is the system performing?
    - How are the other tools responding to the current performance?
- DOE wants the entire X-stack tool chain to be unified
  - Not just XPRESS

renci

XPRESS information

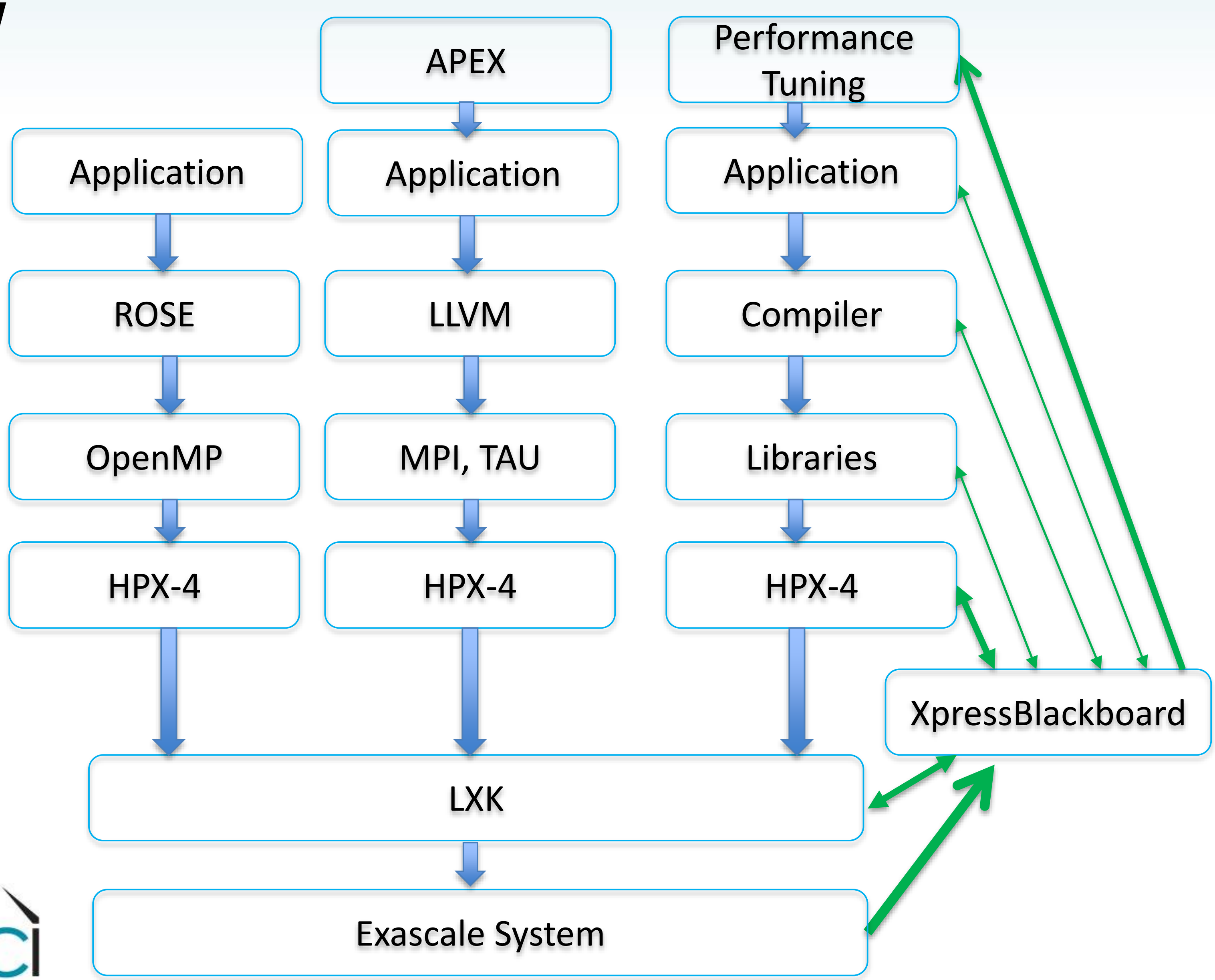
- Passing information between utilities will be critical
  - In current systems information flows one direction
    Application -> Compiler -> Runtime -> OS -> Hardware

- For Exascale static scheduling decisions will not work
  - Dynamic environment
    - Billion-way parallelism
    - Resilience
    - Reliability
    - Energy
    - Shared resource contention

Feedback will be required

renci

Exascale Performance Information flow



renci

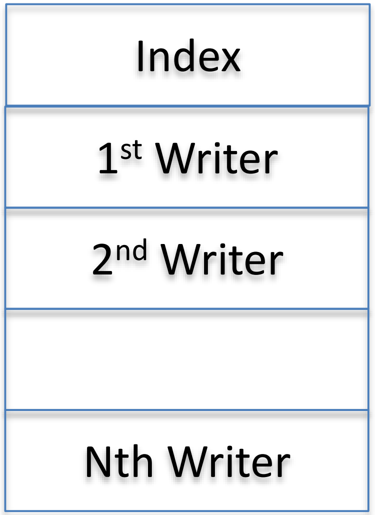
Performance Information as Glue

- Performance information
  - Current – post-execution performance tools
  - Exascale – dynamic application introspection

- For performance and reliability thread/core/node/system knowledge will be critical throughout the software stack
  - Interfaces designed to enable information flow
    - Utilities need to know current system performance
    - Utilities need to know how other utilities are reacting

XpressBlackboard Structure

- Maintain write integrity by only allowing 1 writer per region
  - Multiple readers – Publisher/Reader model
    - Don't have to register – No knowledge of who is currently reading data
  - Structure
    - Each section starts on page boundary
    - 1st page - Index to locate relevant pages
    - 2nd page - first writers data
      - Readers and Writer agree on format
        - » Self-describing – like protobuffer
    - Following pages – more writers



- Local
  - Data specific to a particular locale

renci

XpressBlackboard API

- Register new writer/reader
  - void *AcquireRegion(int Type, int Length);
    - Each writer needs to allocate region
  - int ReleaseRegion(int Type);
    - Only writer can release – returns 0 if successful
  - void *FindRegion(int Type, int *length);
    - Reader locates desired shared memory
- Read/Write
  - Standard memory operations

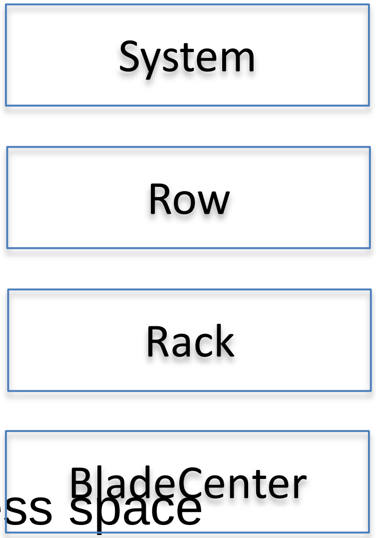
renci

Global XpressBlackboard

- Not all information available locally
  - Global health and energy
  - Dynamic load balance
- Replicating information not practical
  - Million copies too big
  - Uses too much network
  - Global coherence too hard
- Global address space means reachable
  - Single copy possible
  - But are network costs (latency and bandwidth) acceptable?

Global XpressBlackboard

- Hierarchical Tree
  - Global data – with well-defined compaction methods defined
- Each level has 1 daemon
  - Keeps table of values from children
  - Communicates single value to parent
  - Receives global value from parent
  - Transmits to children
    - Write into blackboard of child in same address space
    - Trigger event in child to recognize new value
    - Could be message when child not a leaf



Global XpressBlackboard API

- Register New Global Data
  - int RegisterGlobal(Level h, CompactionType t, int freq, int *offset)
    - Setup tree for this global value and return id – done once
      - Level – what region of system is this value visible (system, row, rack)
      - Type – what rule is to be applied for data compaction (max, min, ave.)
      - Freq – how often does the daemon update the global value
      - Offset (?)- offset into the local XpressBlackboard region result
  - int DestroyGlobal(int id, Level h)
    - Remove global no longer required
  - void WriteGlobal(int X, value)
    - Locally produce a new value for global variable X
  - Read using standard memory op returned offset

renci

Global XpressBlackboard API

- Expected Uses
  - Will be used for system data – temperature, energy
    - Setup by LXK – never deleted
  - Will be used for application or workflow specific data – progress, load balance
    - Setup by application or scheduler – deleted on termination
- Concerns
  - Daemon need to be able to add and delete globals
  - Daemon needs strategy for missing (or very old data)
  - Needs to be very light-weight but still allow variable frequencies (maybe fixed set)
  - Data supplied after global removed

XpressBlackboard Use Case – Detect Resource Contention - Hardware Counters/TAU

- First Test – hopefully can prototype this week
- RCRdaemon on SandyBridge (IvyBridge?) systems writes into blackboard ~1000 times a second
  - energy (socket) MSR_PKG_ENERGY_STATUS
  - memory occupancy (core) cX_MSR_PMON_CTL1 – TOR_OCCUPANCY
- Use TAU to identify high/low power regions of the code
  - Looks good in demo – what the programmer will do with this information?
- Use TAU to identify regions where overall occupancy approaches limits
  - Identify memory bottlenecks
    - User rework the application to spread out memory accesses
    - Rework to reduce parallelism with little no effect (improved cache utilization?)

renci

XpressBlackboard Use Case – Load Balance Information – Application to HPX or LXK (1 of 2)

- Detect load imbalance
  - Thread waiting times - PMPI writes wait time into blackboard compute global average – locally check to see if “near” average
    - Much higher – too idle
    - Much lower – too busy
  - Lightweight thread/task queue occupancy – HPX updates blackboard – compute global maximum
    - Max high – local near zero – idle
    - Max high == local value - busy
  - CPU Utilization – global average
    - Global High – local near zero – idle
    - Global Low – local high - busy

renci

XpressBlackboard Use Case – Load Balance Information – Application to HPX or LXK (2 of 2)

- Load imbalance decisions
  - Make sure busy node running at correct power state (LXK/HPX)
  - Set idle node to low power state (LXK/HPX)
  - Rebalance work – move work to idle nodes from busy nodes (App/HPX)
    - Increase amount of work in each thread on idle nodes
    - Move work off busy nodes
    - Increase priority to schedule "slow" threads earlier
- Need to communicate who is doing load balance
  - Don't want to move work in application and HPX and just make a new overloaded node – which LXK has just slowed down too save energy

XpressBlackboard Use Case – Thread Scheduling – Performance Counters to HPX

- Goal: produce answer in same time using less energy
- Detect Resource Contention
  - TOR_OCCUPANCY (summed counters near known max)
  - NIC utilization (above a threshold)
  - Memory allocation (detected either inside app or by LXK)
- Adjust active parallelism to limit resource contention
  - Can limit threads assigned work (adjust duty cycle of idle threads)
- Slow entire node to limit pressure on resource
  - Use DVFS to set node in a lower power state
  - Only works if resource not effected (ie DIMMs speed not effected by processor power state)

XpressBlackboard Use Case – Health Information – IPMI counters to LXK

- Use global counters to detect health anomaly
  - Excessive ECC errors
  - Excessive Temperatures
  - Fan speeds
  - Unusual power requirements (tricky)
- Adjust work
  - Migrate off failing processors
  - Remove processor from allocate list until issue resolved

XpressBlackboard Use Case – Phase Specific Execution Power State – MPI to LXK/HPX

- MPI DVFS research has found many application where energy saving can be accomplished by reducing power for specific phases
- MPI use the blackboard to mark phase boundaries
  - LXK use to control power
  - HPX use to improve scheduling
  - APEX/TAU use to improve program attribution

- Application or Compiler could also identify phases
  - Automation increases usability/may decrease accuracy

renci