HiHAT: A New Way Forward
for Hierarchical Heterogeneous Asynchronous Tasking
A retargetable interface for tasking & language runtimes

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Distributed and Heterogeneous Programming in
C/C++ Workshop, Toronto, May 16, 2017

MOTIVATION FOR RETARGETABLE INFRASTRUCTURE

Build it right, for lasting impact

- "We haven't agreed on a user-level interface for tasking"
  - It's unlikely that we will anytime soon. But we can agree on infrastructure.
- "We're done with science experiments and want something we can use"
  - Gather usage models and requirements → architect a durable, robust solution
- "We don't want another academic endeavor"
  - Create something driven and supported by vendors

WHAT'S IN IT FOR THE COMMUNITY?

Seeking a win-win-win

- App developers
  - Common SW architecture across multiple targets, with multiple data layouts
- Runtime developers
  - Better performance and robustness, less effort
  - Tasking runtimes and language runtimes that don't necessarily use tasking
- Vendors
  - Expose HW features to a larger market, i.e. SW that spans multiple targets

WHERE DO WE START?

Bottom up

- In order to make life easier for the largest set of people, start at the bottom
  - Extremely performant APIs that span targets, plus an easier-to-use set of APIs
  - Strive for inclusiveness and extensibility
- Progress from low-level plumbing to runtime building blocks
  - Building blocks or anything higher are useless until you have underlying plumbing layer
  - Foster collaboration once we have something to work off of
- Make it easy to create new or improved user interfaces
  - But don’t start by convincing anything to quit using their and use a new user interface

WHAT WOULD IT NEED FOR BROAD ADOPTION?

Top down and bottom up, like a hi-hat cymbal

- Tailor scope to cover what's in common; keep where people innovate out of scope
- Has to meet all provisioning constraints – see list below
- Has to be performant and robust and extensible – see design below
- Has to be the easiest way to get what people want – incremental, meeting needs
- Has to be driven by vendors, who are incentivized to be successful
  - Interest from AMD, ARM, Cray, IBM, Intel, NVIDIA
  - Hosted by **Wilf Pinfold**, Modelado.org, a neutral party funded by vendors and others

IMPLEMENTATION LAYER INTEREST

Some part of each institution has expressed technical interest, not necessarily business commitment.

- **Argobots: Halim Amer, ANL**
- **Qthreads, NoRMa: Stephen Olivier, Sandia**
- **UCX/UCS: Pasha Sharmis, ARM (remote)**
- **SYCL/ComputeCPP: Michael Wong, Codeplay, Khronos, HSA (remote)**

Bold = had material for Mini-Summit

LANGUAGE OR TASKING FRAMEWORKS

Some part of each institution has expressed technical interest, not necessarily business commitment.

- C++ (**CodePlay**, IBM) Michael Wong
- Charm++ (**UIUC**) Ronak Buch, (**Charmworks**) Phil Miller
- Darma (**Sandia**) Janine Bennett
- Exa-Tensor (**ORNL**) Wayne Joubert
- Fortran (IBM)
- Gridtools (**CSCS**, Titech) Mauro Bianco
- HAGGLE (**PNNL/HIVE**) Antonino Tomeo
- HPX (CSCS)
- Kokkos, Task-DAG (**SNL**) Carter Edwards
- Legion (**Stanford/NV**) Mike Bauer
- OmpSs (BSC) Jesus Labarta
- Realm (**Stanford/NV**) Sean Treichler
- OCR (**Intel**, **Rice**, GA Tech) Vincent Cave
- PaRSEC (**UTK**) George Bosilca
- Raja (**LLNL**) Rich Hornung
- Rambutan, UPC++ (LBL) Cy Chan
- R-Stream **(Reservoir Labs)** Rich Lethin
- SyCL (**CodePlay**) Michael Wong
- SWIFT (**Durham**) Matthieu Schaller
- TensorRT (**NVIDIA**) Dilip Sequeira
- VMD (**UIUC**) John Stone

WHAT IS HiHAT?

4 faces

Community-wide **requirements** gathering effort

- Leads to solid architecture that's durable, extensible, robust

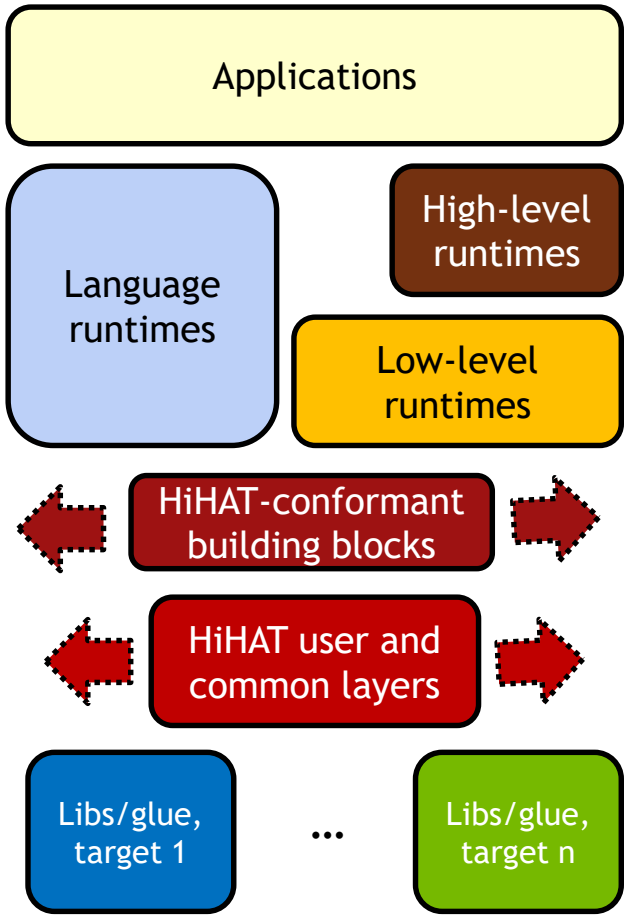
Architect user layer and common layer **API and implementation**

Implementation **beneath** user and common layers

- Vendor-maintained and user-supplemented

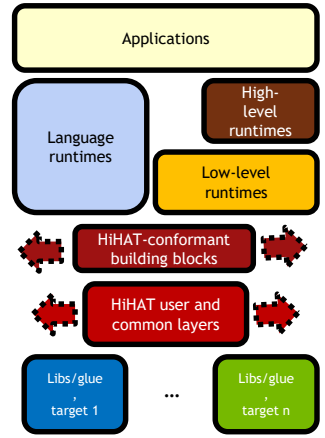
Integrate with OSS project: pluggable, conformant **building blocks**

- Built on user and common layers
- Language and tasking runtimes are built out of these



HiHAT CLIENTS

Start incrementally, build from there

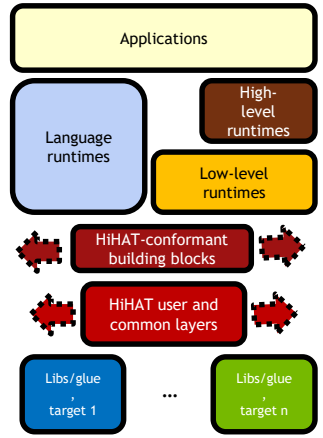


- HiHAT's primary clients are **existing** language and tasking runtimes (e.g. C++, Kokkos)
  - Already have an interface to 1 or more targets, want a better interface/implementation
- HiHAT's secondary clients are runtimes that are **being designed** (e.g. HIVE/HAGGLE)
  - Open to influencing their design to be amenable to integration with/building on HiHAT

- HiHAT provides a **target-neutral** interface, used **whole or in part** by clients
  - Identify what's of greatest value, e.g. for future proofing, ease, robustness
  - **Incrementally adopt** those **parts of HiHAT**, and build up and out from there
- HiHAT does not have a near-term goal of providing a complete user-facing runtime

HiHAT'S OSS BUILDING BLOCKS

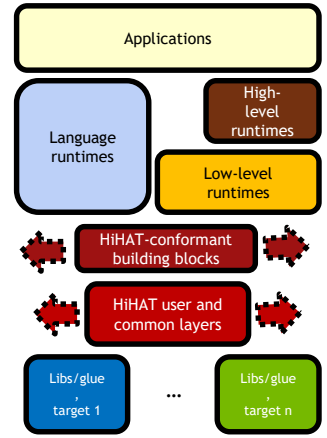
Accelerating communal progress



- The HiHAT interfaces will define types and a machine model
  - This HiHAT definition defines an architecture to which clients built on it conform
- Clients sharing a need for common functionality contribute/use building blocks
  - This would be an open source project
  - Examples: schedulers, cost models, visualization, dependence analysis, transformation
  - Suppose 4 orgs have needs in common; each can contribute a couple, consume others
  - Contributors can share tests (unit, functional, longevity)
  - Consumers can customize and contribute back, beef up testing, etc.

HiHAT'S IMPLEMENTATION LAYER

Vendor-driven performance and completeness



- HiHAT enables vendors/implementation providers to plug in functionality from below
  - Functionality behind the HiHAT APIs
  - Vendors may have the strongest incentive to provide access to their platform features
  - Others may offer alternate/improvements implementations

STATIC OR DYNAMIC

Both need a common infrastructure

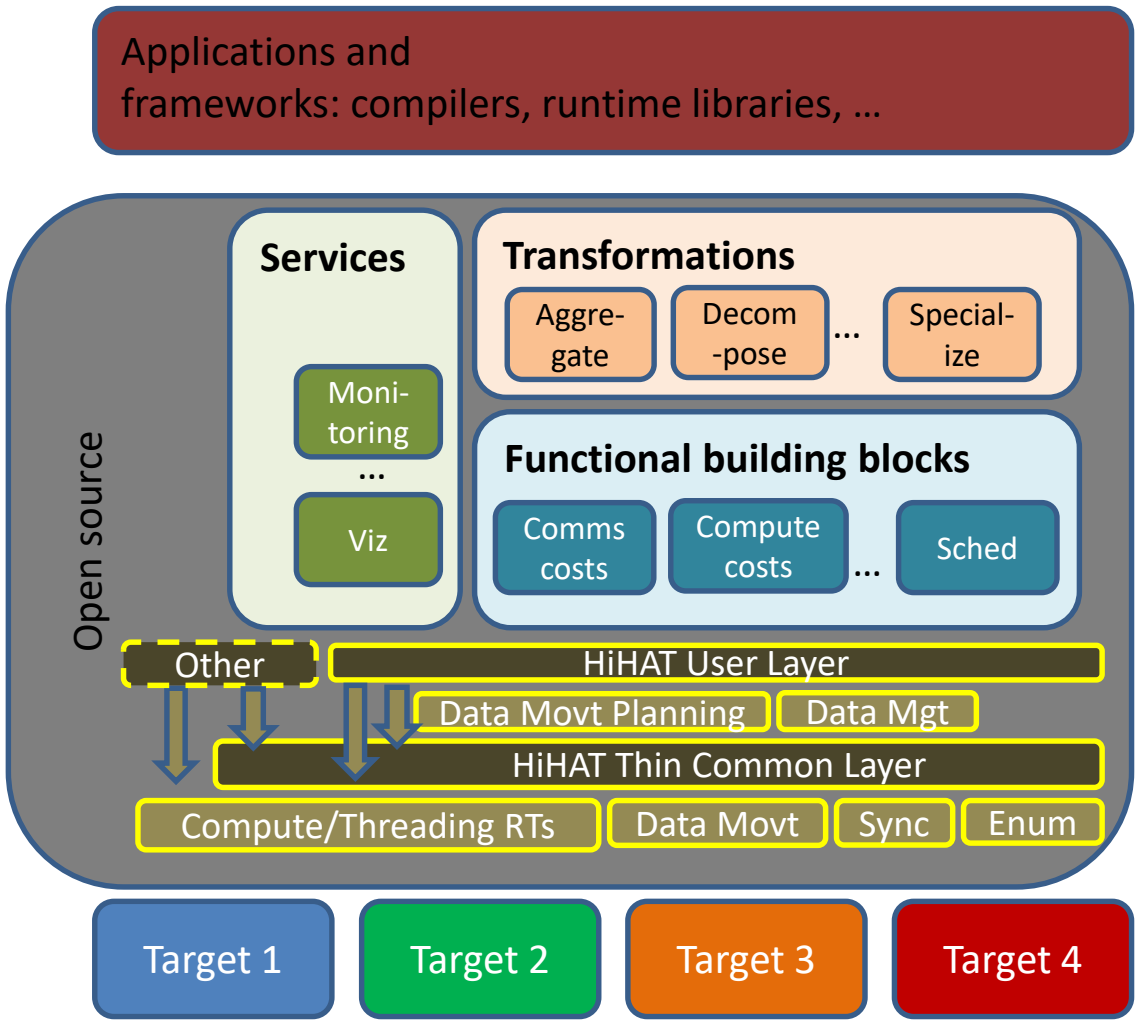
- Commonalities between static and dynamic
  - Same actions: cost models, binding, ordering, allocation, data copies
  - Either can be greedy, look at a limited scope, or buffer to maximize the scope
- Similar principles, slightly different approach
  - Static vs. dynamic: make decisions, either record them for later or execute immediately
- The same (library) primitives are applicable to both
  - In order to be applicable to dynamic runtimes, can't be *only* a compiler
  - But library interfaces need to be vetted to address compiler effectiveness and efficiency
- Inter-mix with compilation

Layer

Value

Many frameworks

Many hats



Shared,
contributed
utilities

Accelerate coding
Share technology
Increase robustness

Target agnostic
Target specific

Increase robustness
More portable, tunable

Targets

Future proofing

https://wiki.modelado.org/HiHAT_SW_Stack

VALUE

Providing the easiest path toward what you already want

- Common interface to vendor-specific features
  - Modular design, separation of concerns
    - What's above user/common layer can use target-agnostic heuristics on target-specific parameters
  - Future proofing
    - Retargetable across vendors, implementations, generations
    - Underlying implementations can chase changes and improvements
- Performance and robustness
  - Vendors are incentivized to provide 1st-class support; others can supplement

STATUS

Gradual start, but on firm footing

- Gather
  - Usage models, applications, user requirements – modestly-broad participation, need more
- Architect
  - Design principles – good progress, much more to come; need more concrete requirements
- Implement
  - Implementation plan – POC this summer, anticipating partial implementation end of 2017
- Integrate
  - Proof of concept → early adopters → broaden

Opt Timing	2016 | 2017 | 2018
Gather	Community input Community review Community feedback
Architect	Design principles API proposal Refined API Updated API
Implement	Proof of concept Initial subset More complete
Integrate	Proof of concept First/partial clients Broader, more complete

MOMENTUM

Building interest, firming up investment

- Modelado.org – neutral zone, posting of usages, requirements, apps; monthly mtgs
- Active bottom-up discussions with vendors → initial POC with glue code
- Existence proofs and past learning: hetero streams, REALM, ~OCR, CodePlay
- ECP – ATDM funding, PathForward2 SW, CORAL/APEX/ECP app owners from ORNL, ANL, LBL, LANL
- PASC – interest from Platform for Advanced Scientific Computing, Switzerland
- Workshop on Exascale SW Technologies (WEST) – panelist, Feb. 22
- Workshop at GPU Tech Conference – May 9 am, share progress, deepen investment
- Talk @ IWOCL workshop, Distributed and Hetero Programming for C/C++17, May 16
- Performance portability workshop – August 21

SCOPE OF FUNCTIONALITY

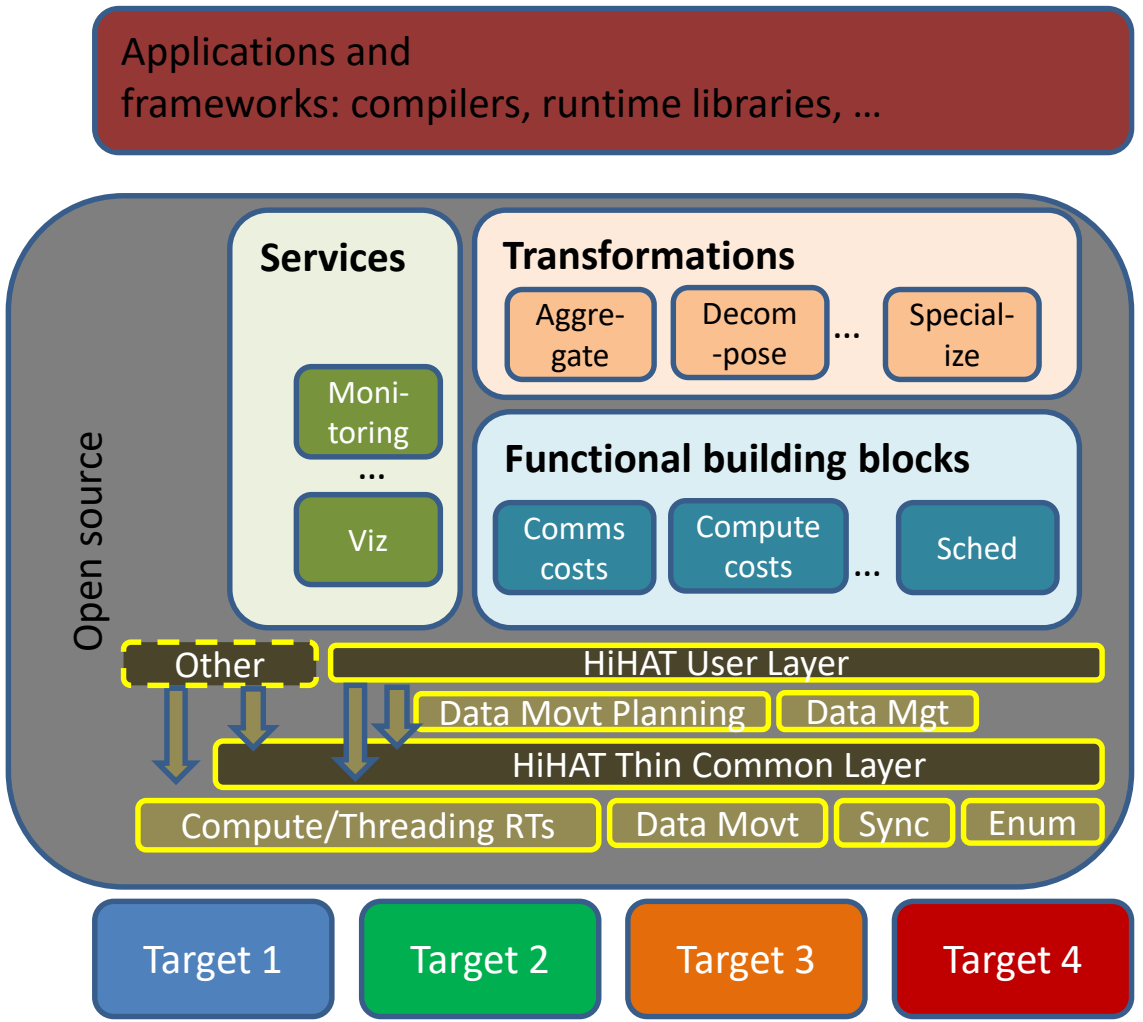
- Cover key platform-specific actions and services
  - Data movement – target-optimized copies, DMA, networking
  - Data management – support many kinds and layers of memory, specialized pools
  - Coordination – completion events, locks, queues, collectives, iterative patterns
  - Compute – target-optimized tasks, including remote invocation
  - Enumeration – kinds and number of resources (compute, memory), topologies
  - Feedback – profiling, load
  - Tools – tracing, callbacks, pausing, … {debugging}

Layer

Value

Many frameworks

Many hats



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TABULATED RESULTS FROM MINI-SUMMIT

Strong interest, modestly amenable; focus on data first

Type of functionality	Level of interest			Amenability to refactoring		
	H	M	L	H	M	L
Data movement – target-optimized copies, DMA, networking	14	0	1	7	3	1
Data management – kinds and layers of memory, specialized pools	10	3	2	7	2	2
Coordination – completion events, locks, queues, collectives, iteration	8	7	0	5	4	1
Compute – local or remote invocation	7	1	4	4	4	3
Enumeration – kinds/# of resources, topologies	11	3	1	4	3	2
Feedback – profiling, utilization	6	5	2	4	5	1
Tools – tracing, callbacks, pausing, debugging	3	10	2	2	5	2

CALL TO ACTION

Join the momentum, keep us grounded in reality

- Join the community in providing input
  - Provisioning constraints, usage models, user stories @ hihat.modelado.org
  - Leverage real-world experience to influence API design
- Consider reviewing, contributing code
  - Implementation layer for new targets
  - Building blocks
- Detailed compare/contrast between HiHAT and OpenCL