Abelian: A Compiler and Runtime for Graph Analytics on Distributed, Heterogeneous Platforms

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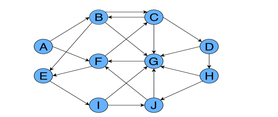
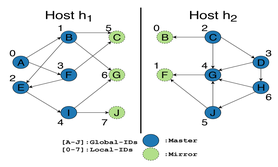
Distributed Heterogeneous Graph Analytics

- **Programming model:**
  - Generalization of vertex programming model
  - Nodes and edges have labels, which are iteratively updated
  - Labels updated by applying ***operator*** to ***active*** *nodes* (***activity***)
  - **Finding *active nodes*:**
    - Topology driven
    - Data driven:
      - Worklist based
      - Filter based
  - Bulk synchronous execution

Graph Partitioning

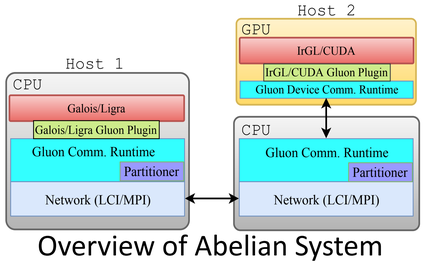
- An example of partitioning a graph for 2 hosts:





- **Communication Patterns:**
  - **Reduce:** values at mirrors are combined on the master using a reduction operation
  - **Broadcast**: value at the master is broadcast to the mirrors

Distributed Heterogeneous Execution Model

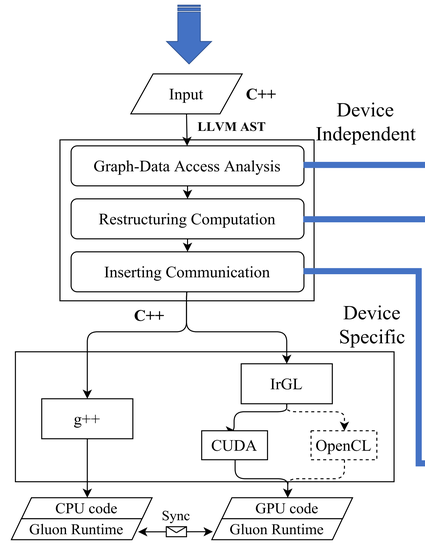


Overview of Abelian System

- **Supports Heterogeneity in Programming model:**
  - D-Galois = Galois + Gluon
  - D-Ligra = Ligra + Gluon
- **Supports Heterogeneity in Architecture:**
  - D-IrGL = IrGL + Gluon (GPU)

Pagerank Source Program

```
struct NodeData {
  uint32_t nout;
  float rank;
  std::atomic<float> res;
}
struct PageRank {
  Graph* g;
  void operator()(GNode src, Worklist& wl){
      auto& sd = g->getData(src);
      auto res_old = sd.res.exchange(0);
      sd.rank += res_old;
      auto delta = res_old*alpha/sd.nout;
      for( auto e : g.getEdges(src)){
        GNode dst = g->getEdgeDst(e);
        auto& dd = g->getData(dst);
        dd.res += delta;
        if(dd.res > tolerance) {
          wl.push(dst);
        }
      }
  }
} ;
Galois:for_each(g, PageRank{g});
```



Overview of the Abelian Compiler

Gluon Sync API

- Compiler generated synchronization structures:
  - Reduce API :

```
struct reduceField {
  static ValTy extract(NodeData& n)
    {/*return field val*/}
  static bool reduce (NodeData& n, ValTy y)
    {/*reduce field with y on master*/}
  static void reset(NodeData& n)
    {/*reset field to identity val*/}
};
```

  - Broadcast API :

```
struct broadcastField {
  static ValTy extract(NodeData& n)
    {/*return field val*/}
  static void setVal(NodeData& n, ValTy y)
    {/*set field to y (received from master)*/}
};
```

  - Sync call :

```
g.sync<reduceDst, readSrc, reduceField,
  broadcastField>(fieldBitVec);
```

Graph-Data Access Analysis

- **Type of field access:**
  - Reduction: Read and updated
  - Read-only
  - Write-only
- **Where is field accessed:**
  - At source of edge
  - At destination of edge
  - At any

Restructuring Computation

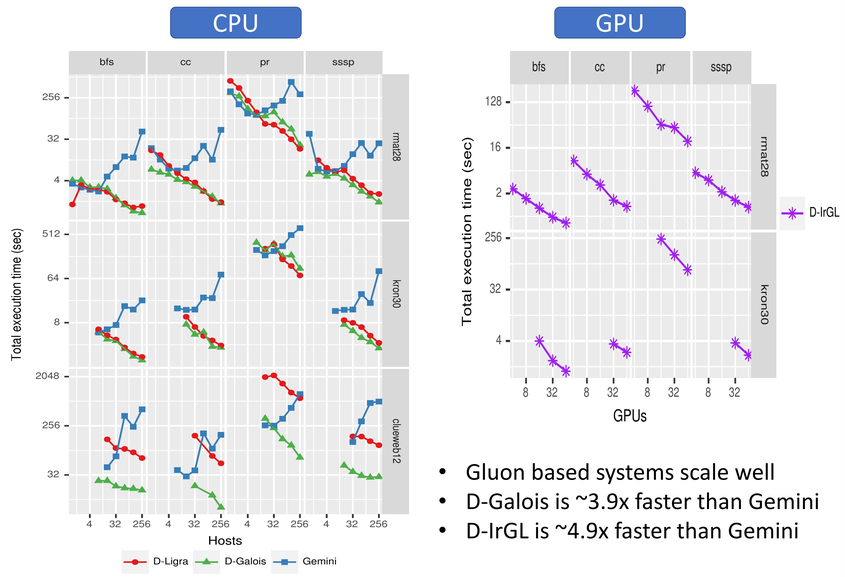
- Fine-grain iteration level parallelism to Bulk synchronous parallelism
  - Operator splitting
  - Worklist elimination

Inserting Communication

- **Fine-grained communication:** Communicate only updated fields using field specific bitVectors
- **On-demand communication:** Precisely specifies the local reads and writes to exploit ***Gluon*** structural optimizations.
  - **Pre-operator:** Sync field if dirty and is being read in the operator
  - **Post-operator:** Mark field dirty if written/updated in the operator

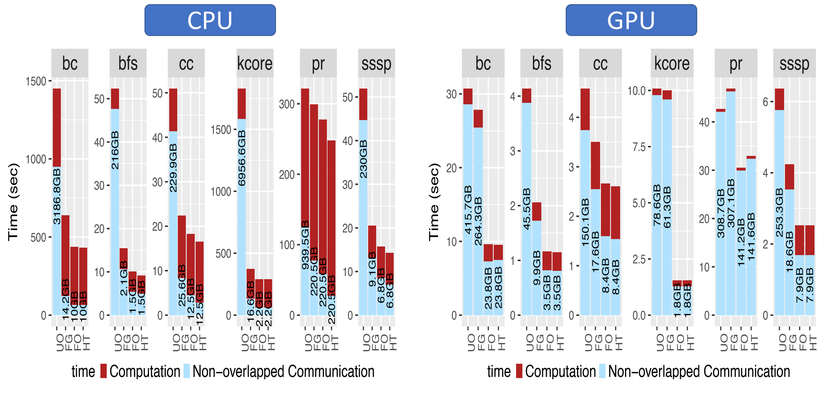
Results

- **Gluon based systems (Hand-Tuned):**



- Gluon based systems scale well
- D-Galois is ~3.9x faster than Gemini
- D-IrGL is ~4.9x faster than Gemini

- **Compiler generated versions:**



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- UO: Unoptimized Code
- FG : Fine-grained Code
- FO : Fine-grained + On-demand (Default of Abelian Compiler)
- HT : Hand-tuned (D-Galois)

- ~23x reduction in communication volume over UO
- FO matches performance HT (within 12%)
- Increased productivity without performance loss

References

- **"Abelian: A compiler and runtime for graph analytics on distributed, heterogeneous platforms" Gurbinder Gill**, Roshan Dathathri, Loc Hoang, Andrew Lenharth, and Keshav Pingali. To appear in Euro-Par 2018, 2018.
- "**Gluon: A communication optimizing framework for distributed heterogeneous graph analytics**" Roshan Dathathri, **Gurbinder Gill**, Loc Hoang, Hoang-Vu Dang, Alex Brooks, Nikoli Dryden, Marc Snir, and Keshav Pingali. To appear in PLDI 2018, 2018.
- **"A lightweight communication runtime for distributed graph analytics"** Hoang-Vu Dang, Roshan Dathathri, **Gurbinder Gill**, Alex Brooks, Nikoli Dryden, Andrew Lenharth, Loc Hoang, Keshav Pingali, and Marc Snir. To appear in IPDPS 2018, 2018.