Tiny GPU Cluster for Big Spatial Data: A Preliminary Performance Evaluation

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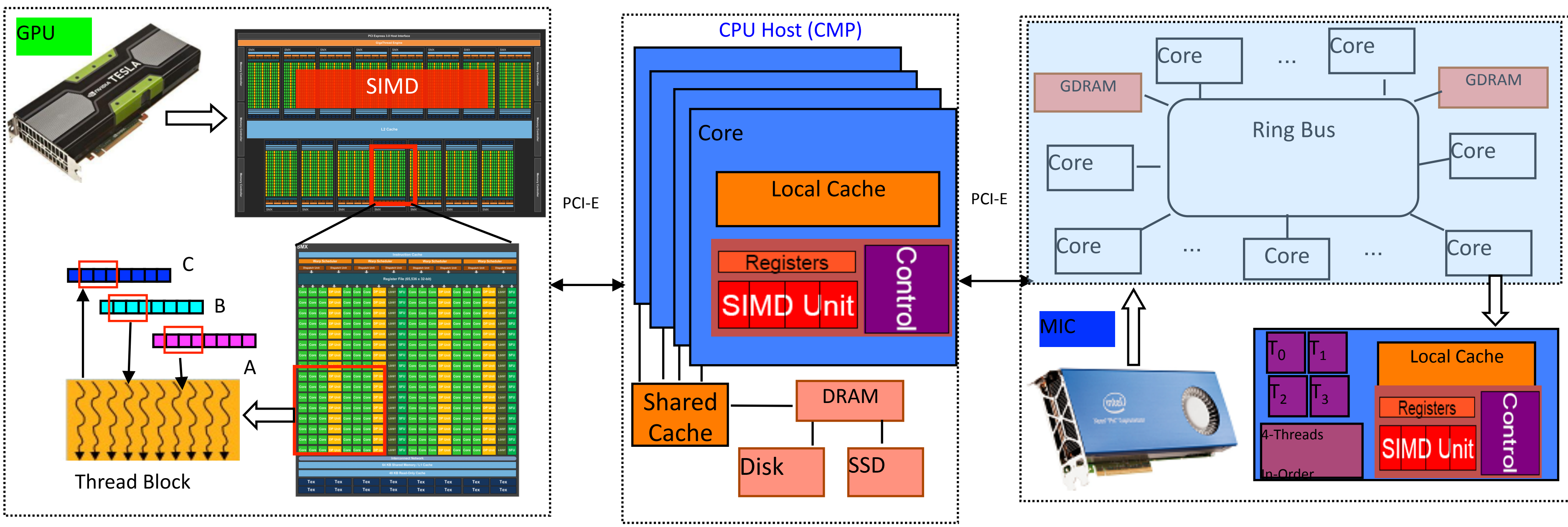
Outline

- Introduction, Background and Motivation
- System Design, Implementation and Application
- Experiments and Results
- Summary and Future Work

Parallel Computing – Hardware



16 Intel Sandy Bridge CPU cores+ 128GB RAM + 8TB disk + GTX TITAN + Xeon Phi 3120A ~ $9994 (Jan. 2014)

Parallel Computing – GPU

ASCI Red: 1997 First 1 Teraflops (sustained) system with 9298 Intel Pentium II Xeon processors (in 72 Cabinets)

Location	Sandia National Laboratories, United States
Power	850 kW
Operating system	Cougaar / Linux
Space	1,600 sq ft (150 m^2)[3]
Memory	1212 gigabytes
Speed	1.3 teraflops (peak)[1]
Ranking	TOP500: 1, June 2000[4]

EVGA GeForce GTX TITAN X 12 GB GDDR5 384bit, PCI-E 3.0 DVI-I, 3 x DP, HDMI, SLI, HDCP, G-SYNC Ready Graphics Card 12G-P4-2990-KR

by EVGA

51 customer reviews | 22 answered questions

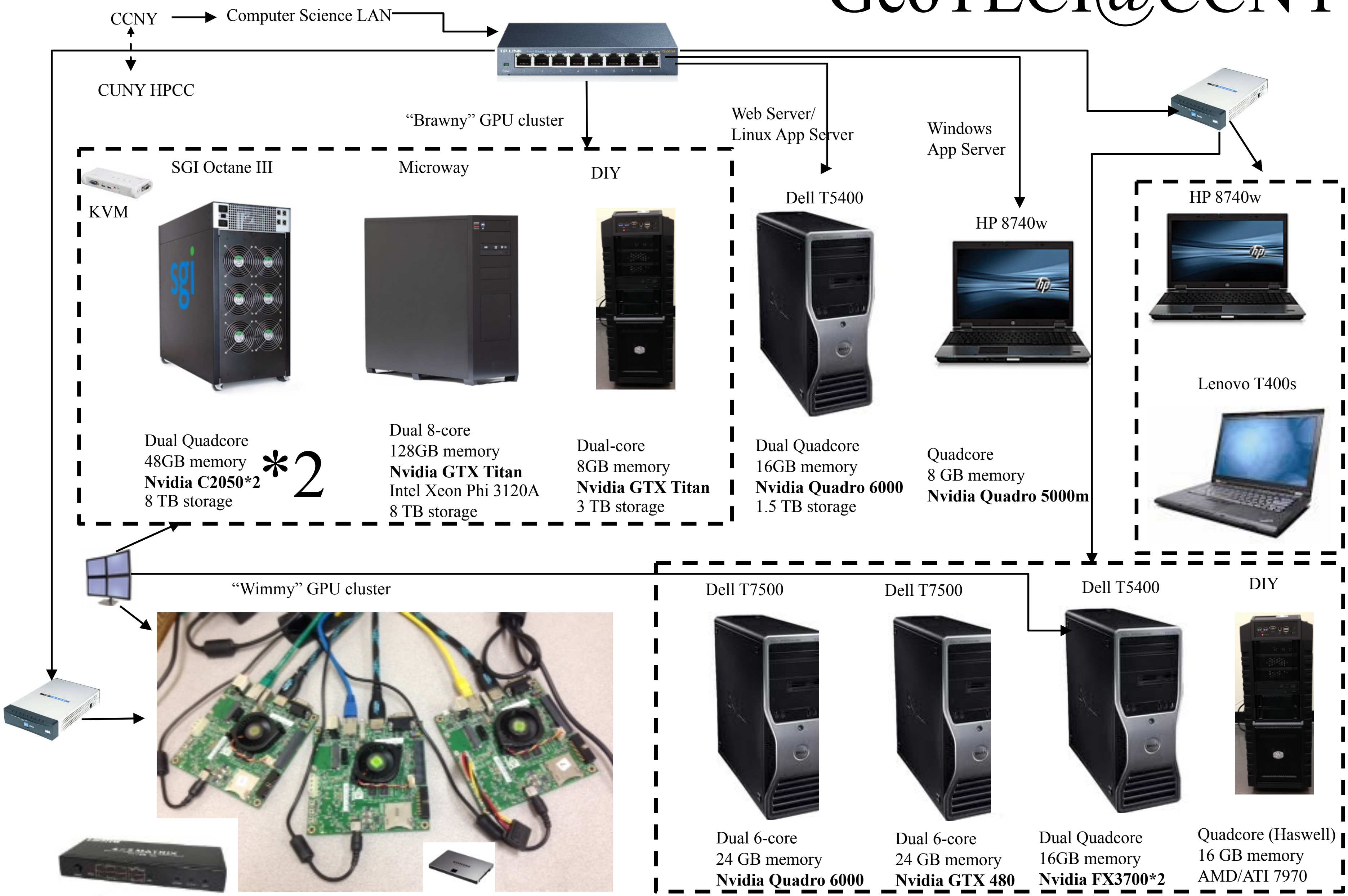
Price: $999.99 Prime

- March 2015
- 8 billion transistors
- 3,072 processors/12 GB mem
- 7 TFLOPS SP (GTX TITAN 1.3 TFLOPS DP)
- Max bandwidth 336.5 GB/s
- PCI-E peripheral device
- 250 W
- Suggested retail price: $999

What can we do today using a device that is more powerful than ASCI Red 19 years ago?

...building a highly-configurable experimental computing environment for innovative BigData technologies…

GeoTECI@CCNY



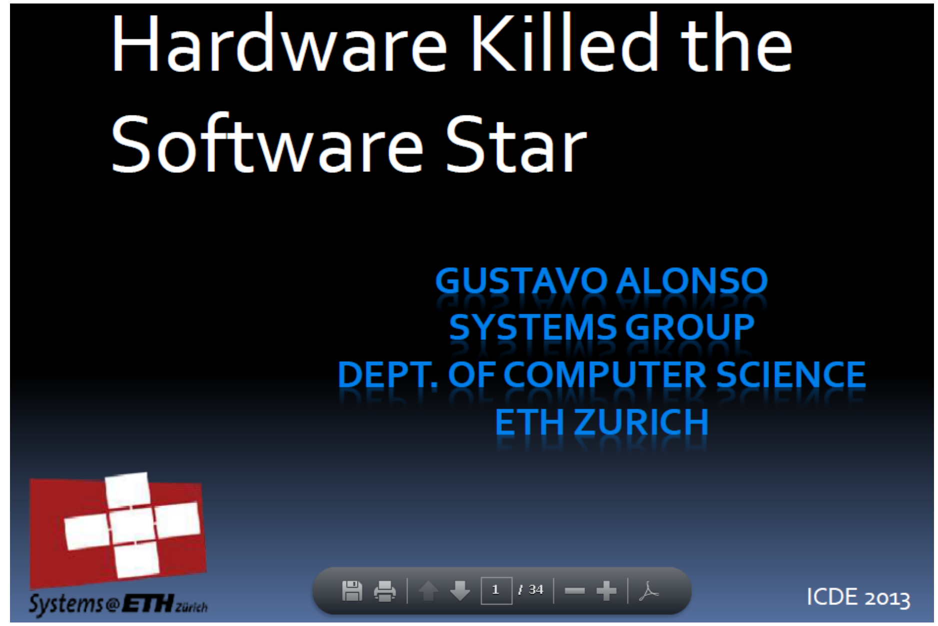
Spatial Data Management

↕

Computer Architecture

How to fill the big gap effectively?

David Wentzlaff, "Computer Architecture", Princeton University Course on Coursea



Heterogeneous Supercomputing in Blue Waters

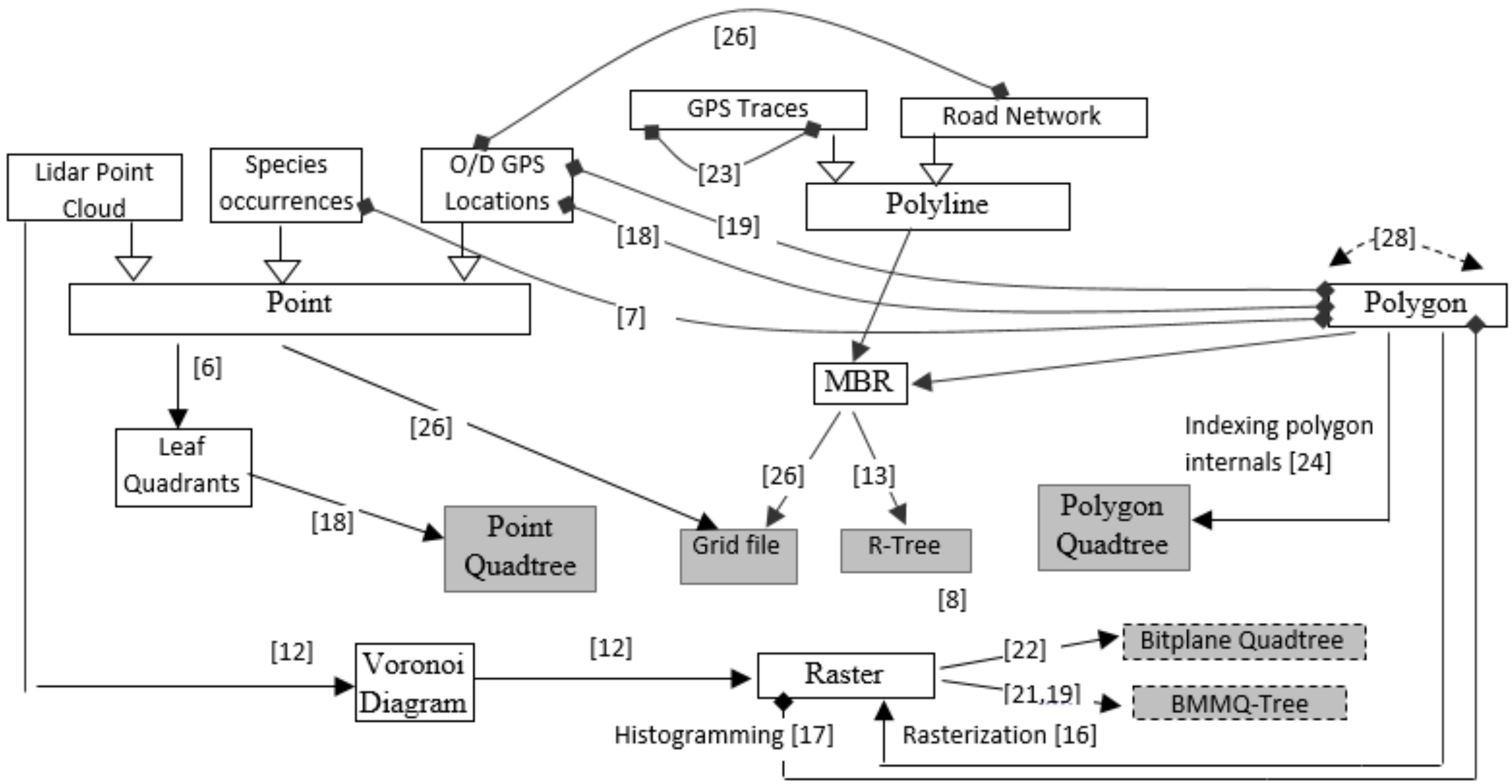
Wen-mei Hwu

University of Illinois at Urbana-Champaign

Scalable and portable software lasts through many hardware generations

Scalable algorithms and libraries can be the best legacy we can leave behind from this era

Large-Scale Spatial Data Processing on GPUs and GPU-Accelerated Clusters
ACM SIGSPATIAL Special (doi:10.1145/2766196.2766201)



Distributed Spatial Join Techniques

- **SpatialSpark** (CloudDM'15)
- ISP-MC (CloudDM'15), ISP-MC+ and ISP-GPU (HardBD'15)
- LDE-MC+ and **IDE-GPU** (BigData Congress'15)

Background and Motivation

- Issue #1: Limited access to reconfigurable HPC resources for Big Data research

Background and Motivation

- Issue #2: architectural limitations of Hadoop-based systems for large-scale spatial data processing

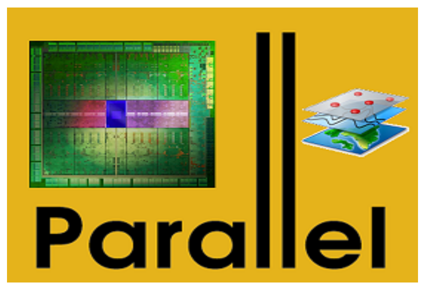
Hadoop-GIS

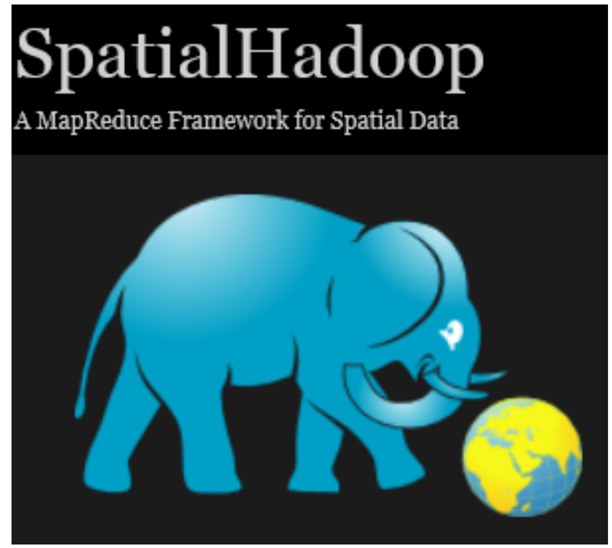
Spatial Big Data Solutions

https://sites.google.com/site/hadoopgis/

SpatialSpark: Big Spatial Data Process using Spark

http://simin.me/projects/spatialspark/





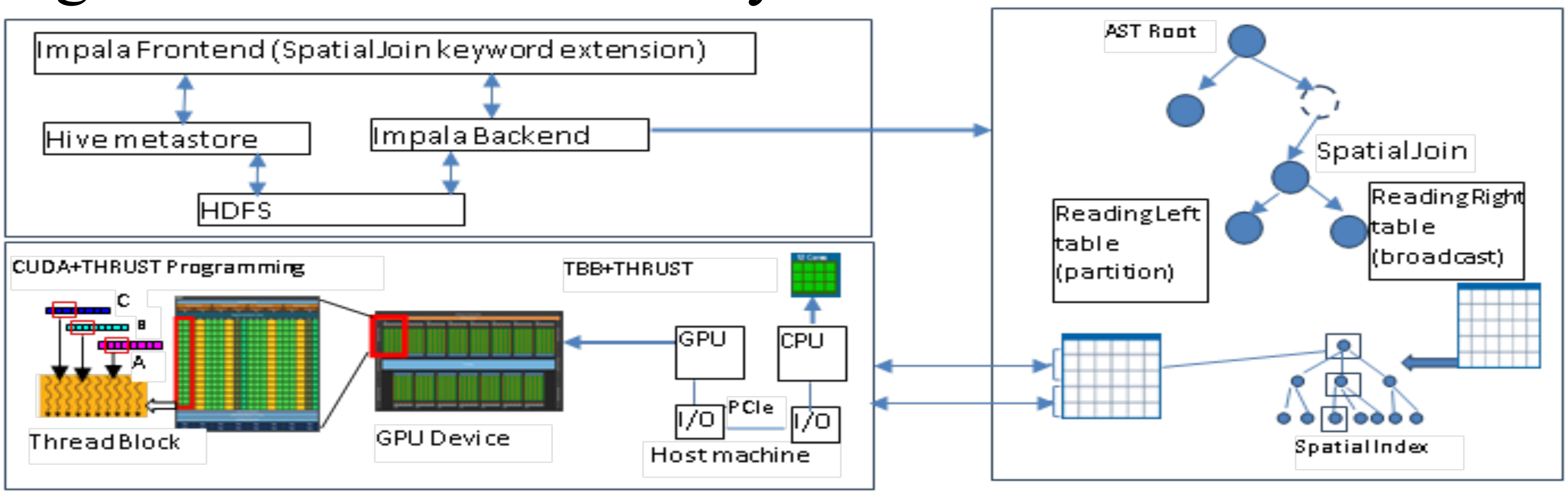
http://spatialhadoop.cs.umn.edu/

		WS	EC2-10	EC2-8	EC2-6
taxi-nycb	HadoopGIS	-	-	-	-
	SpatialHadoop	3,327	2,361	2,472	3,349
	SpatialSpark	3,098	813	-	-
edge-linearwater	HadoopGIS	-	-	-	-
	SpatialHadoop	14,135	5,695	8,043	9,678
	SpatialSpark	4,481	1,119	-	-

Spatial Join Query Processing in Cloud: Analyzing Design Choices and Performance Comparisons (HPC4BD'15 –ICPP)

Background and Motivation

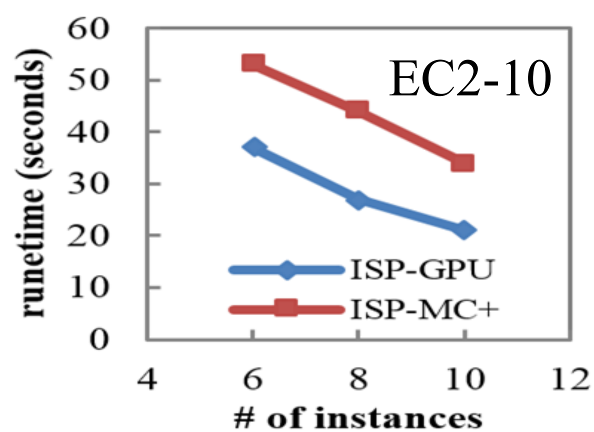
- Issue #3: SIMD computing power is available for free for Big Data –use as much as you can



ISP: Big Spatial Data Processing On Impala Using Multicore CPUs and GPUs (HardBD'15)
Recently open sourced at: http://geoteci.engr.ccny.cuny.edu/isp/

WS	**ISP-GPU**	**GPU-Standalone**
taxi-nycb (s)	96	50

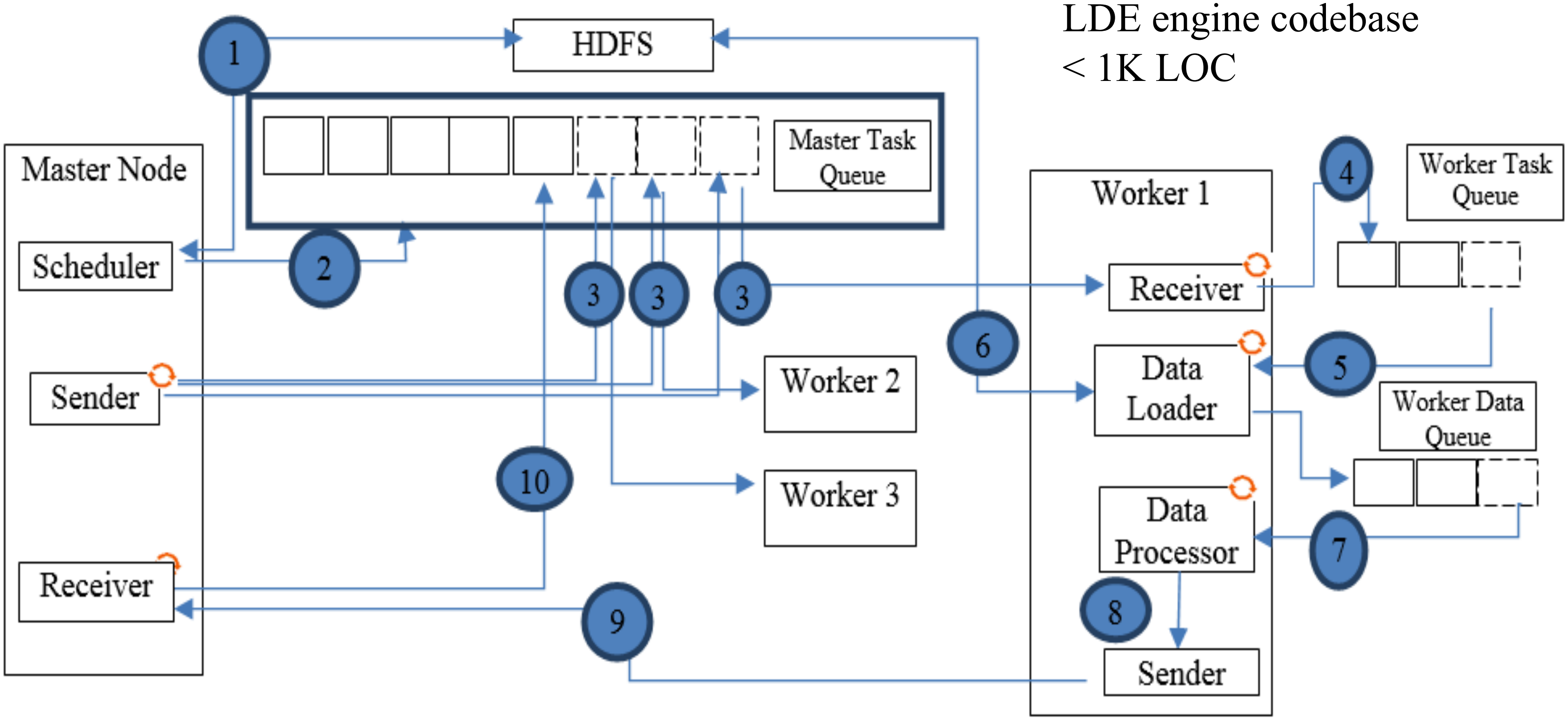
		WS	EC2-10
taxi-nycb	HadoopGIS	-	-
	SpatialHadoop	3,327	2,361
	SpatialSpark	3,098	813



Background and Motivation

- Issue #4: lightweight distributed runtime library for spatial Big Data processing research

LDE engine codebase
< 1K LOC



Lightweight Distributed Execution Engine for Large-Scale Spatial Join Query Processing (IEEE Big Data Congress'15)

System Design and Implementation

Basic Idea:

- Use GPU-accelerated SoCs as down-scaled high-performance Clusters
- The **network bandwidth to compute ratio** is much higher than regular clusters
- Advantages: **low cost and easily configurable**
- Nvida TK1 SoC: 4 ARM CPU cores+192 Kepler GPU cores ($193)

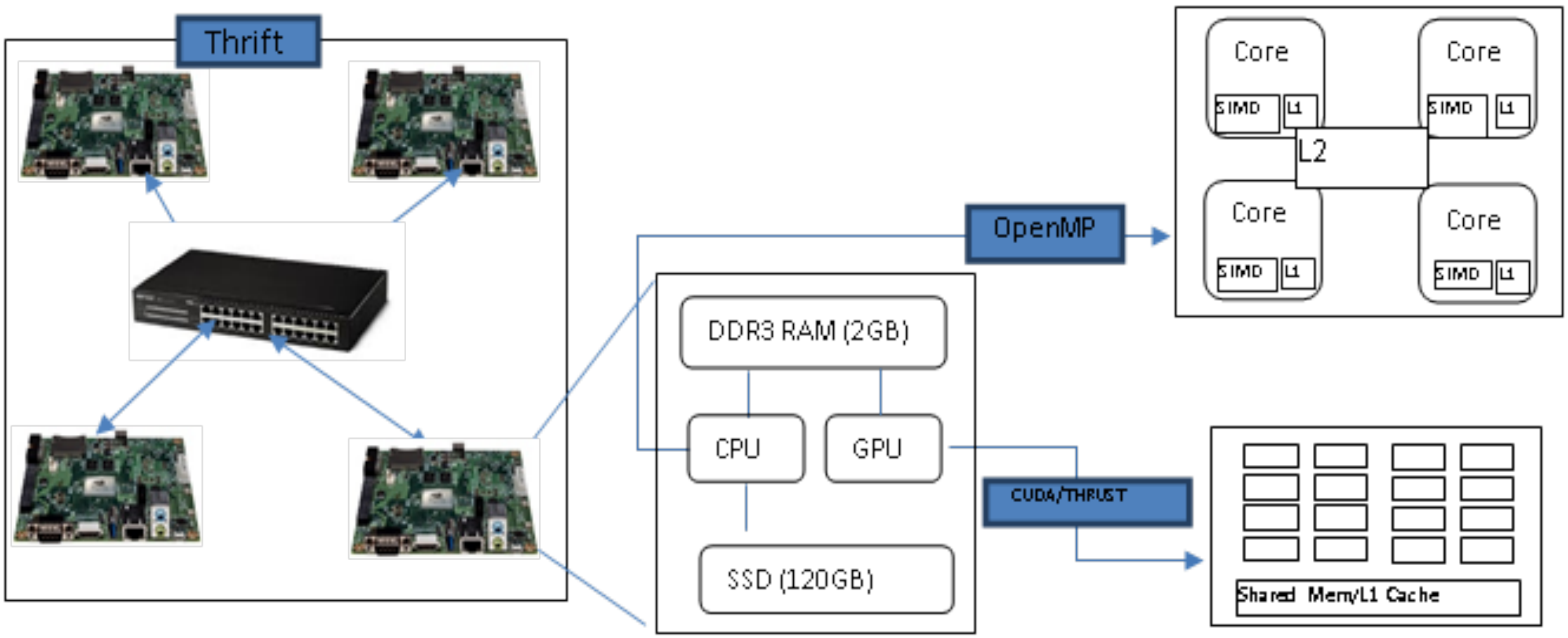
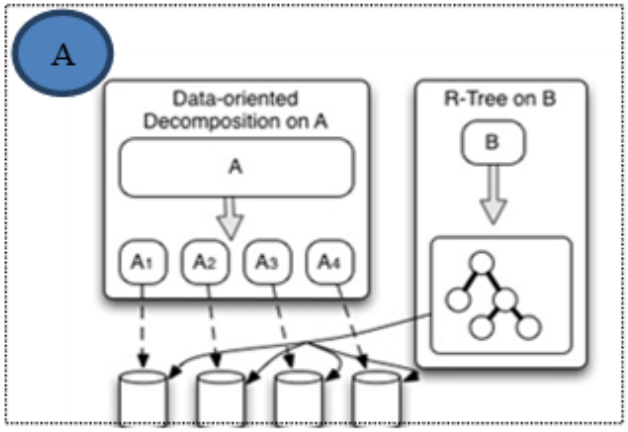
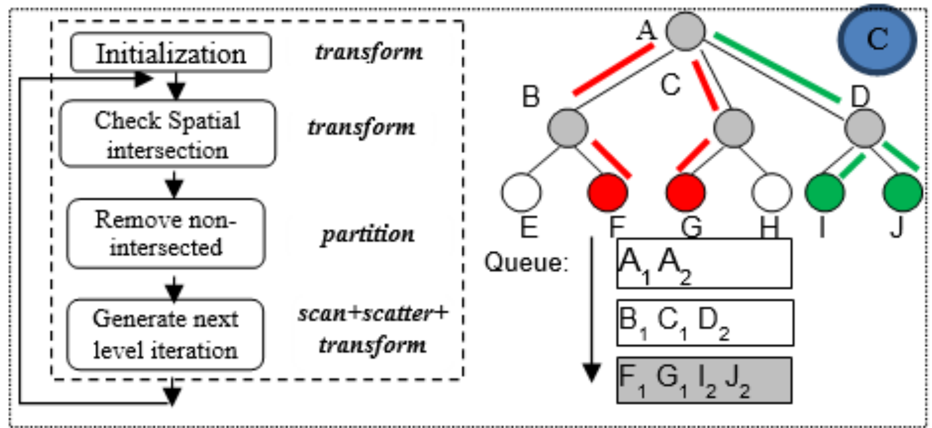


Fig. 1 Hardware Configuration and Software Stacks of a 4-node Tiny GPU Cluster

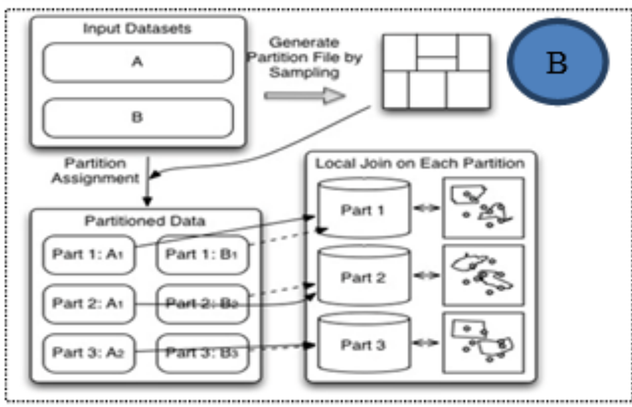
System Design and Implementation



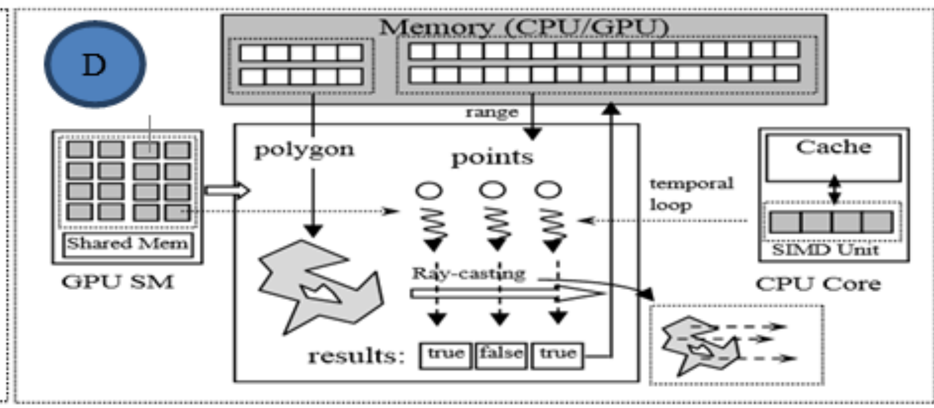
Broadcast based Spatial Join



Data Parallel Batched R-Tree Query for Spatial Filtering



Spatial Partition based Spatial Join



Data Parallel Point-in-polygon based spatial Refinement

Light Weight Distributed Execution Engine

•**Asynchronous** network communication, disk I/O and computing

•Using **native parallel programming tools** for local processing

Experiments and Results

Taxi-NYCB experiment
•170 million taxi trips in NYC in 2013 (pickup locations as points)
•38,794 census blocks (as polygons); average # of vertices per polygon ~9

g10m-wwf experiment
•~10 million global species occurrence records (locations as points)
•14,458 ecoregions (as polygons) ; average # of vertices per polygon 279

g50m-wwf experiment

"Brawny" configurations for Comparisons

- Dual 8-core Sandy Bridge CPU (2.60G)
- 128GB memory
- Nvidia GTX Titan (6GB, 2688 cores)

http://aws.amazon.com/ec2/instance-types/

GPU

G2

Model	GPUs	vCPU	Mem (GiB)	SSD Storage (GB)
g2.2xlarge	1	8	15	1 x 60
g2.8xlarge	4	32	60	2 x 120

Experiments and Results

Experiment	Setting	standalone	1-node	2-node	4-node
taxi-nycb	LDE-MC	18.6	27.1	15.0	11.7
	LDE-GPU	18.5	26.3	17.7	10.2
	SpatialSpark	-	179.3	95.0	70.5
g10m-wwf	LDE-MC	1029.5	1290.2	653.6	412.9
	LDE-GPU	941.9	765.9	568.6	309.7

Experiments and Results

g50m-wwf (more computing bound**)**

	TK1-Standalone	TK1-4 Node	Workstation-Standalone	EC2-4 Node
CPU Spec. (per node)	ARM A15 2.34 GHZ 4 Cores 2 GB DDR3		Intel SB 2.6 GHZ 16 cores 128 GB DDR3	Intel SB 2.6 GHZ 8 cores (virtual) 15 GB DDR3
GPU Spec. (per node)	192 Cores 2GB DDR3		2,688 cores 6 GB GDDR5	1,536 cores 4 GB GDDR5
Runtime (s) – MC	4478	1908	350	334
Runtime (s) – GPU	4199	1523	174	105

Experiments and Results

CPU computing:

- TK1 SoC~10W, 8-core CPU ~95W
- Workstation Standalone vs. TK1-standalone: 12.8X faster; consumes 19X more power
- EC2-4 nodes vs. TK1-4 nodes: 5.7X faster; consumes 9.5X more power

•GPU computing:

- Workstation Standalone vs. TK1-standalone: 24X faster; 14X more CUDA cores
- EC2-4 nodes vs. TK1-4 nodes: 14X faster; 8X more CUDA cores

Summary and Future Work

- We propose to develop a low-cost prototype research cluster made of Nvidia TK1 SoC boards and we evaluate the performance of the tiny GPU cluster for spatial join query processing on large-scale geospatial data.
- Using a simplified model, the results seem to suggest that the ARM CPU of the TK1 board is likely to achieve better energy efficiency while the Nvidia GPU of the TK1 board is less performant when compared with desktop/server grade GPUs, in both the standalone setting and the 4-node cluster setting for the two particular applications.

- Develop a formal method to model the scaling effect between SoC-based clusters and regular clusters, not only including processors but also memory, disk and network components.
- Evaluate the performance of SpatialSpark and the LDE engine using more real world geospatial datasets and applications ➔ Spatial Data Benchmark?

National Science Foundation
WHERE DISCOVERIES BEGIN

CISE/IIS Medium Collaborative Research Grants 1302423/1302439: “Spatial Data and Trajectory Data Management on GPUs”

Q&A

http://www-cs.ccny.cuny.edu/~jzhang/

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