Scalable, Secure Analysis of Social Sciences Data on Azure

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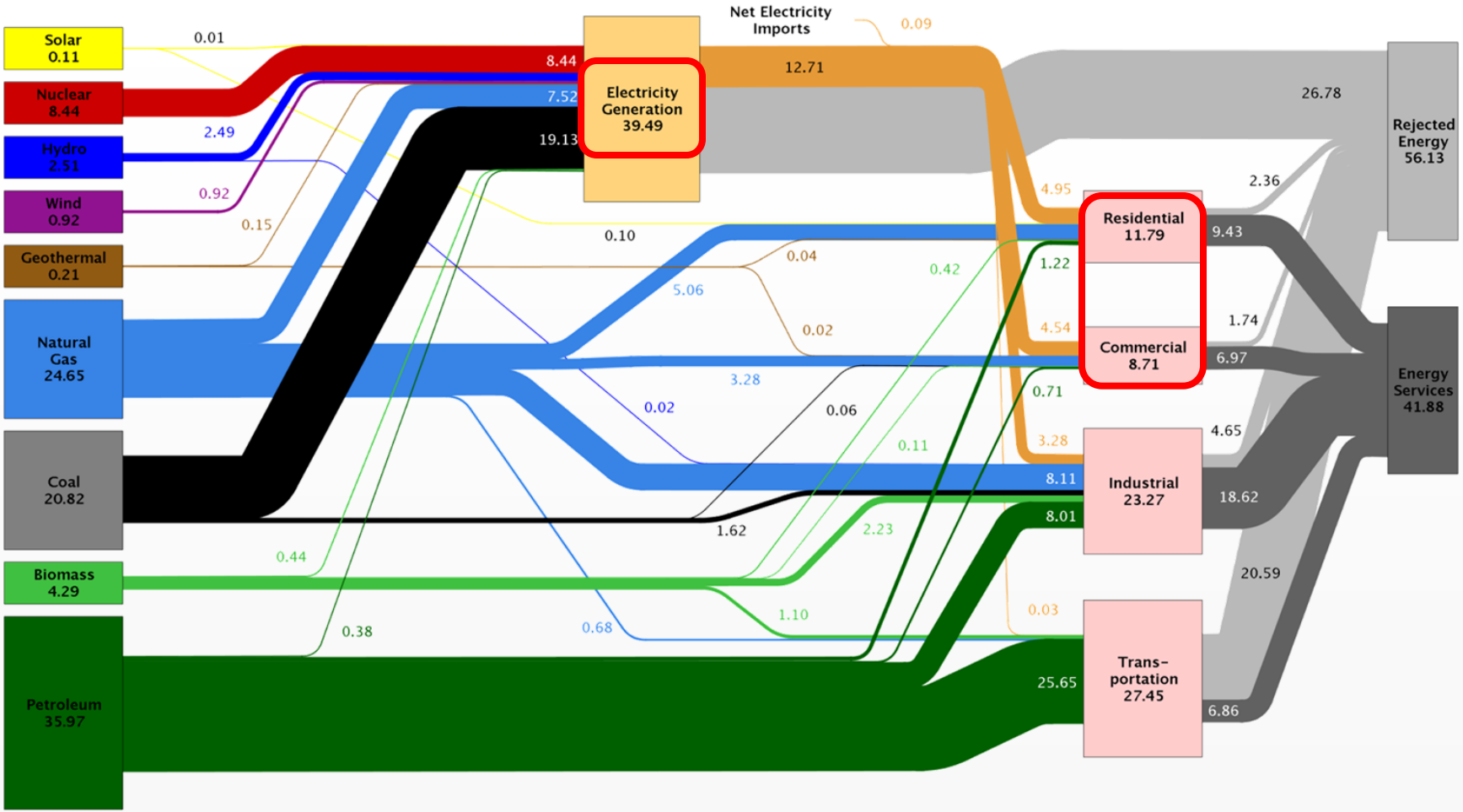
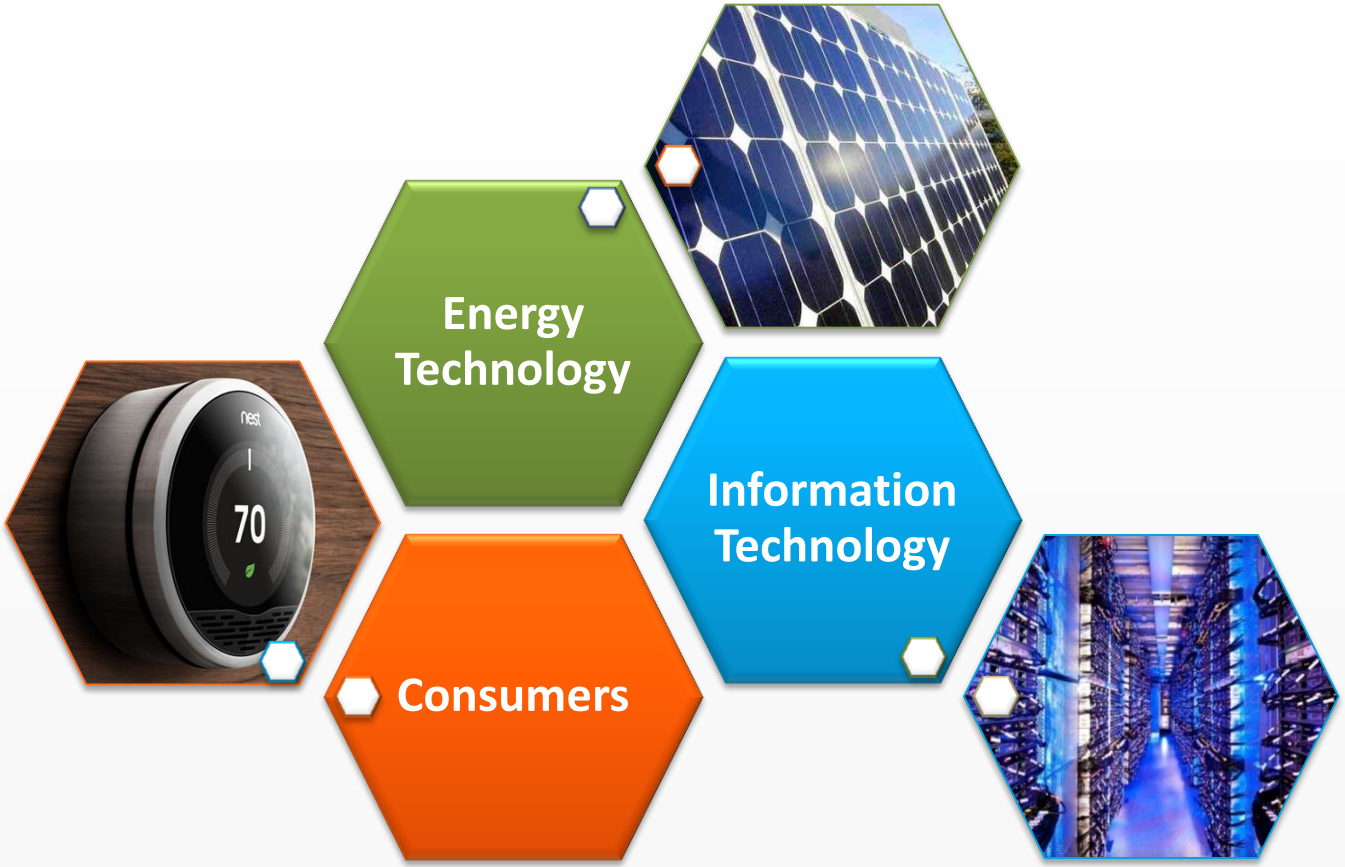
Estimated U.S. Energy Use in 2010: ~98.0 Quads



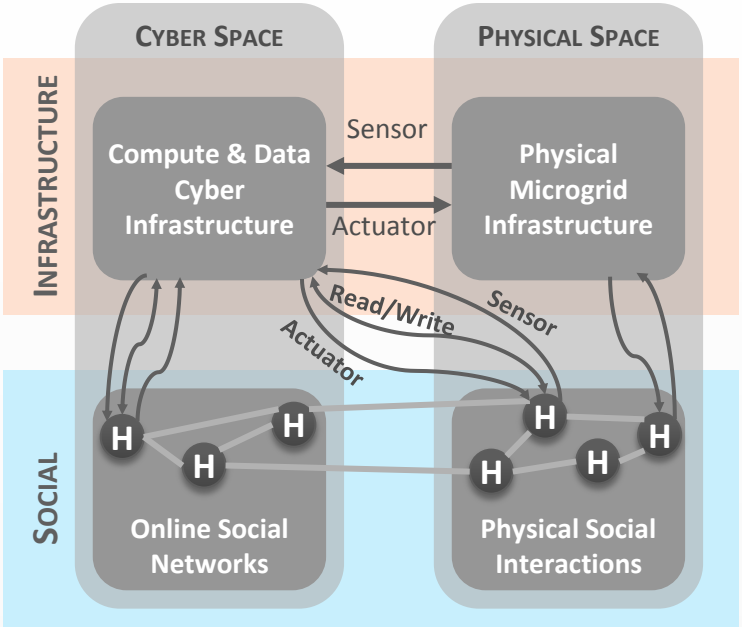
Source: LLNL 2011. Data is based on DOE/EIA-0384(2010), October 2011. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Distributed electricity represents only retail electricity sales and does not include self-generation. EIA

Energy Informatics

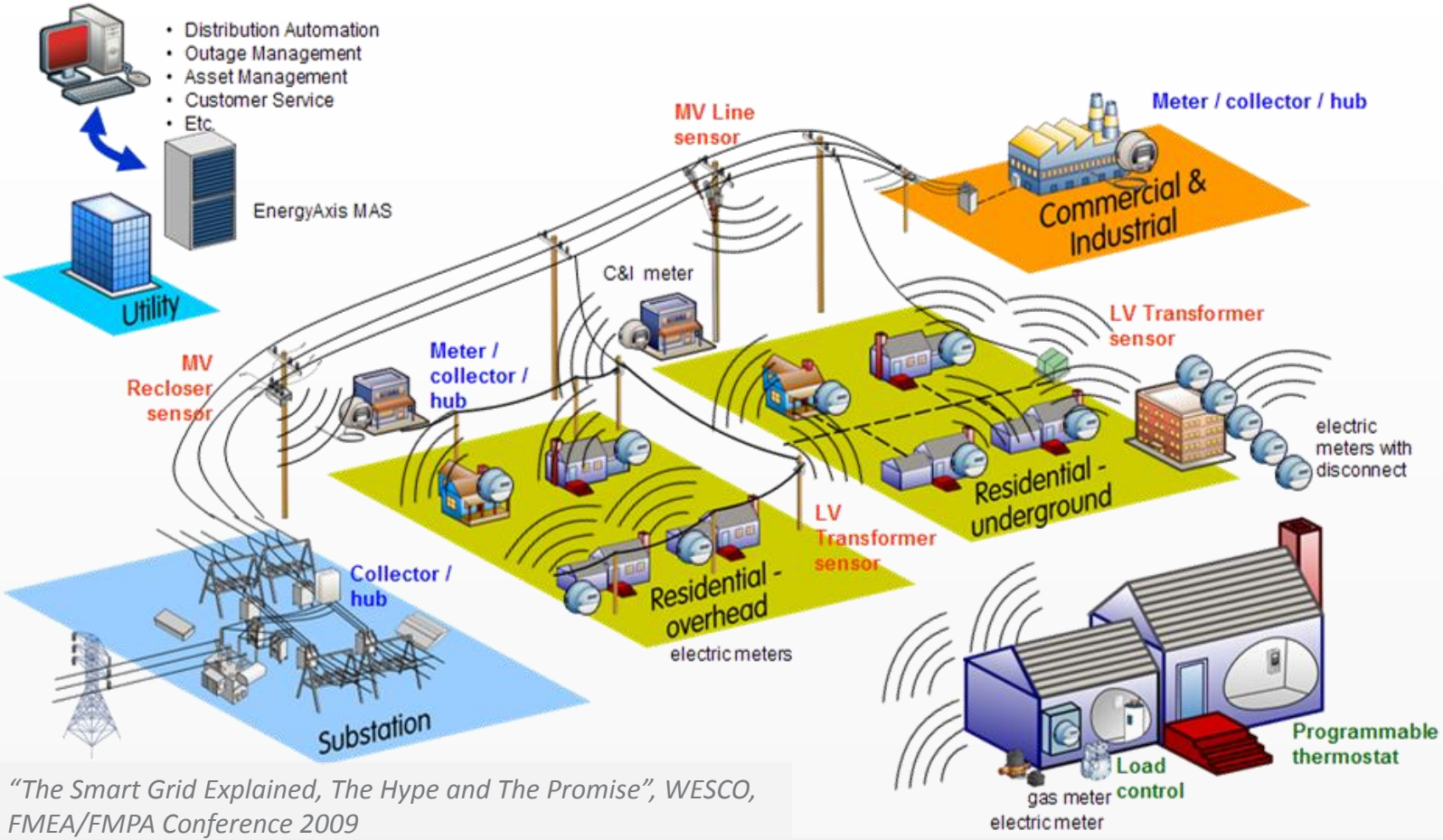


Cyber-Physical-Social Systems

- Physical & Cyber Infrastructure
- Social interactions
- Transportation, Energy, Health, …
- Impact on sustainable living
- *Internet of Things!*



Smart Power Grids



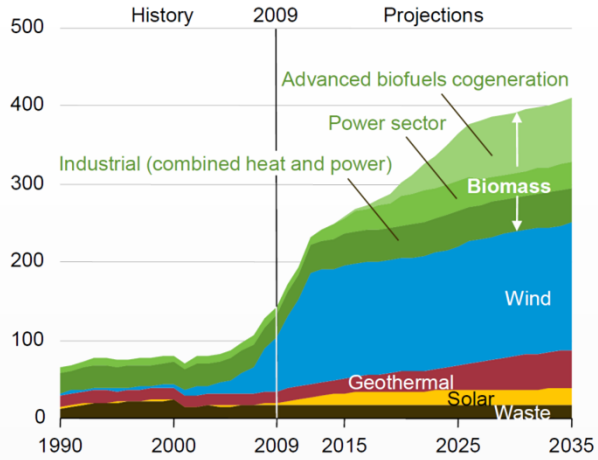
"The Smart Grid Explained, The Hype and The Promise", WESCO, FMEA/FMPA Conference 2009

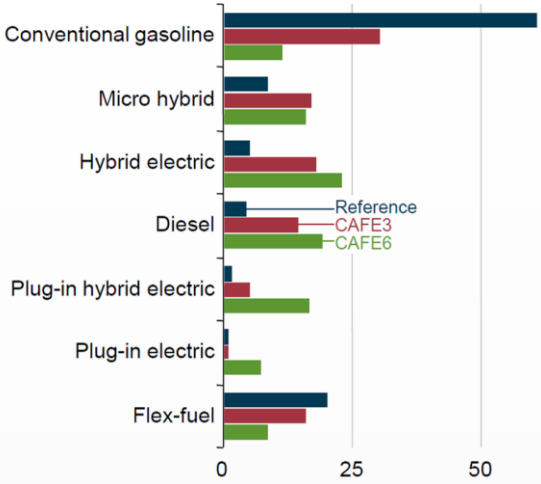
Los Angeles Smart Grid Demo Project

- LA is the largest public utility in US
  - 1% of US power consumed by 1.4M customers
- Collaborative effort
  - USC engaged with DR, CB & EV

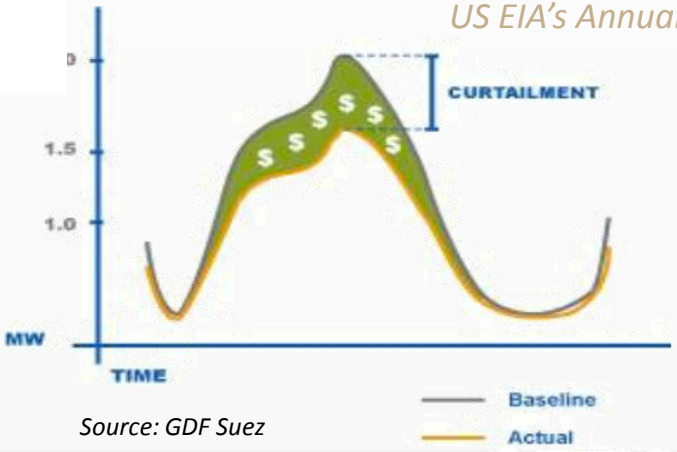
Demand Response Optimization

- More renewables
  - *Intermittent sources*
- More hybrid & electric vehicles
  - *Increase dynamic load on power grid*
- Efficient management of demand & supply
  - *Shift, Shape, Shave power demand*





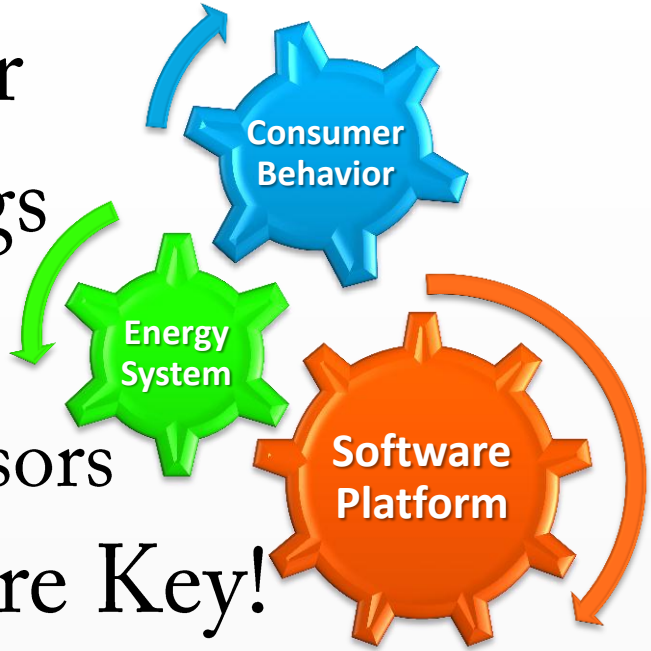
US EIA's Annual Energy Outlook 2011



Source: GDF Suez

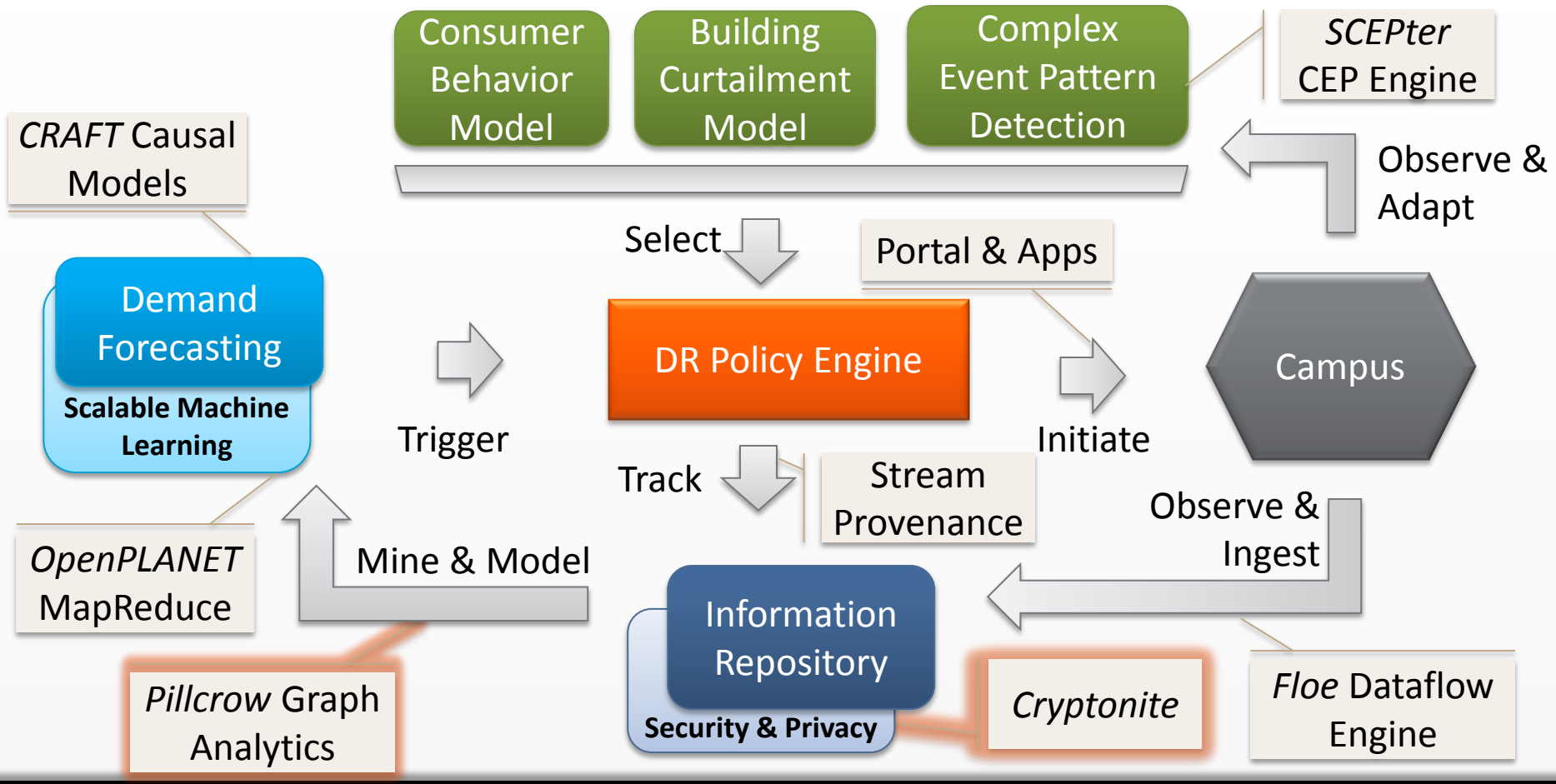
USC Campus MicroGrid

- LA's largest private consumer
- 60,000 people, 100+ buildings
- Well instrumented
  - 50K power, HVAC, temp sensors
- Consumers & Information are Key!
  - CS, Facilities, Sociologists, Psychologists, …



A Living, Learning Laboratory for DR experiments

Platform for Smart Grid Analytics



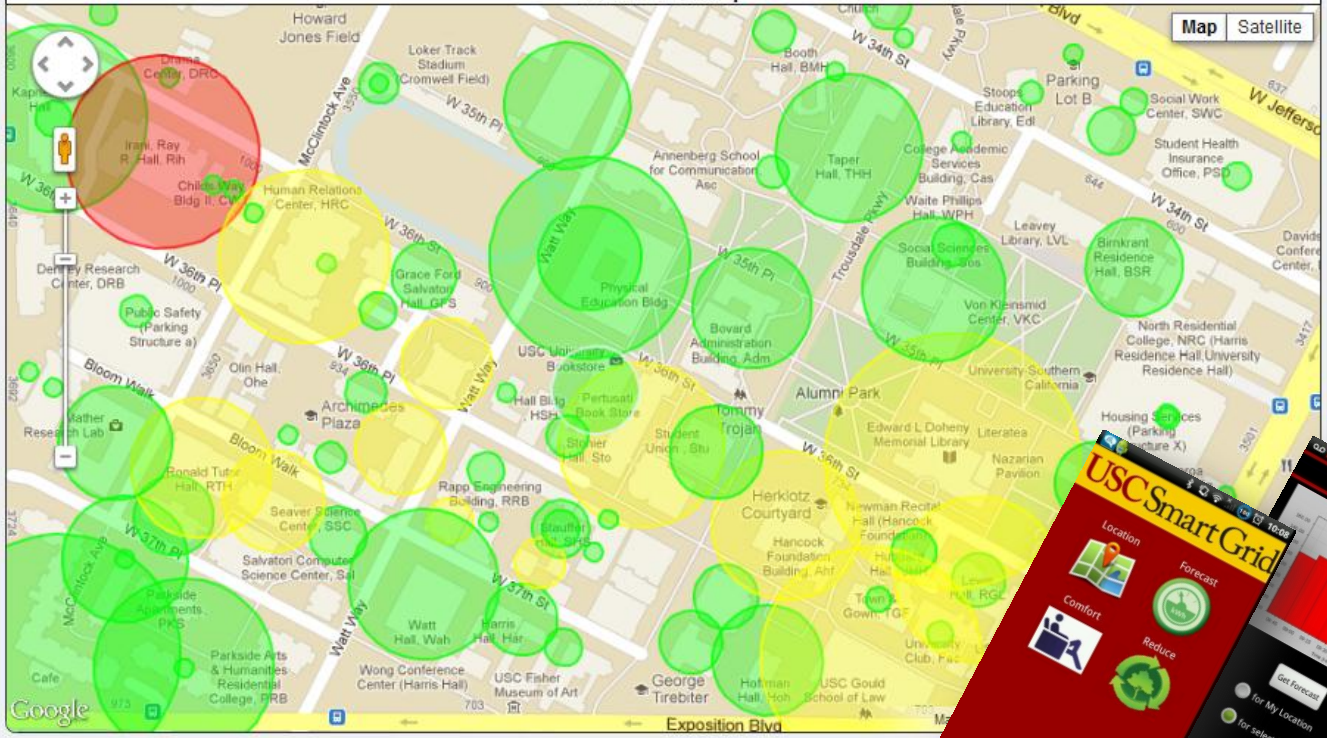
USC Smart Grid

smartgrid.usc.edu

Web Portal | Admin Panel

USC Smart Grid > Web Portal

USC Power Map

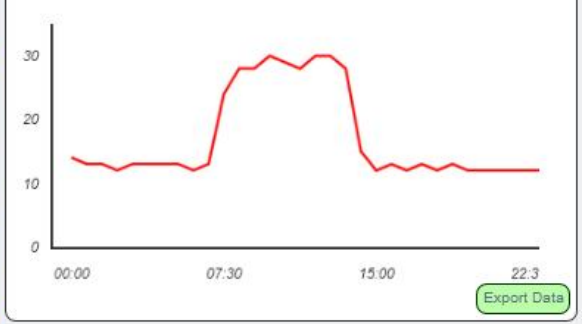


LEGEND: Power Use — Square Feet (Net)

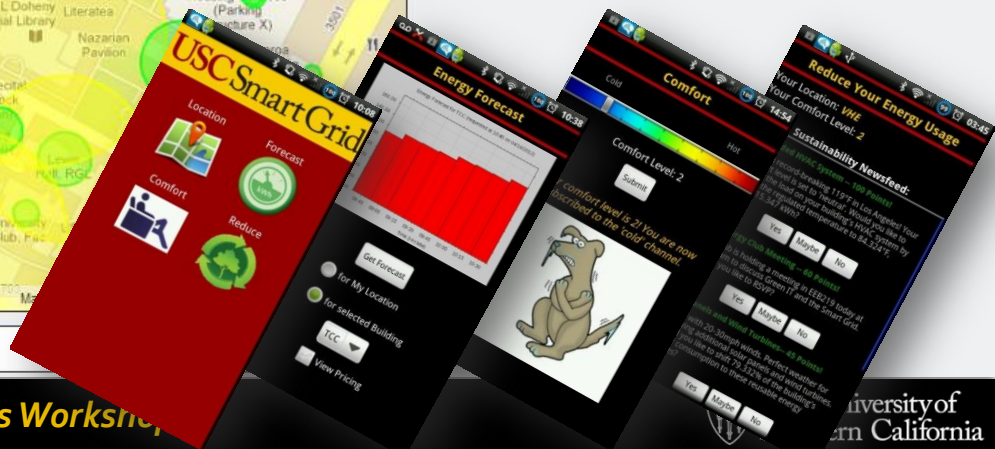
PERTUSATI UNIVERSITY BOOKSTORE (BKS)

Square Foot (Net): 44,218 — 1989

Current kWh: 29.23



Export Data



Social Sciences Challenges on Clouds

1. *How does a multi-disciplinary team **securely share data** and collaborate?*

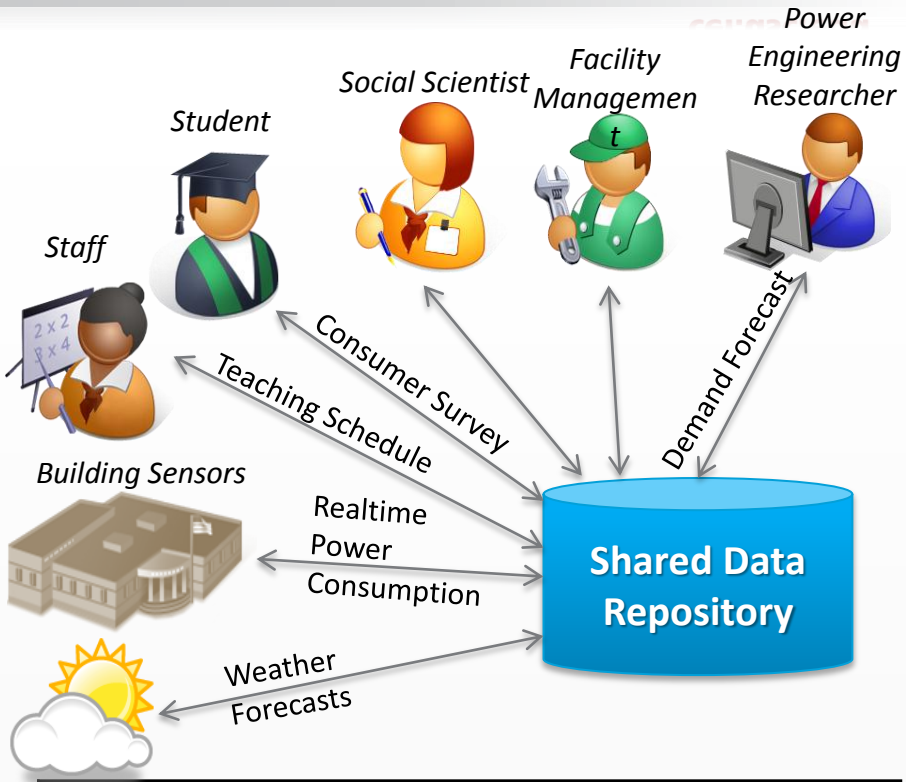
2. *How do we **analyze** social interaction **graphs** at large scales?*

Cryptonite

Secure Data Sharing on Public Clouds

Data Sharing on Clouds

- Ease of management
- Reliability, persistence
- Scalable sharing
- Co-located with Cloud Apps
- *But…*



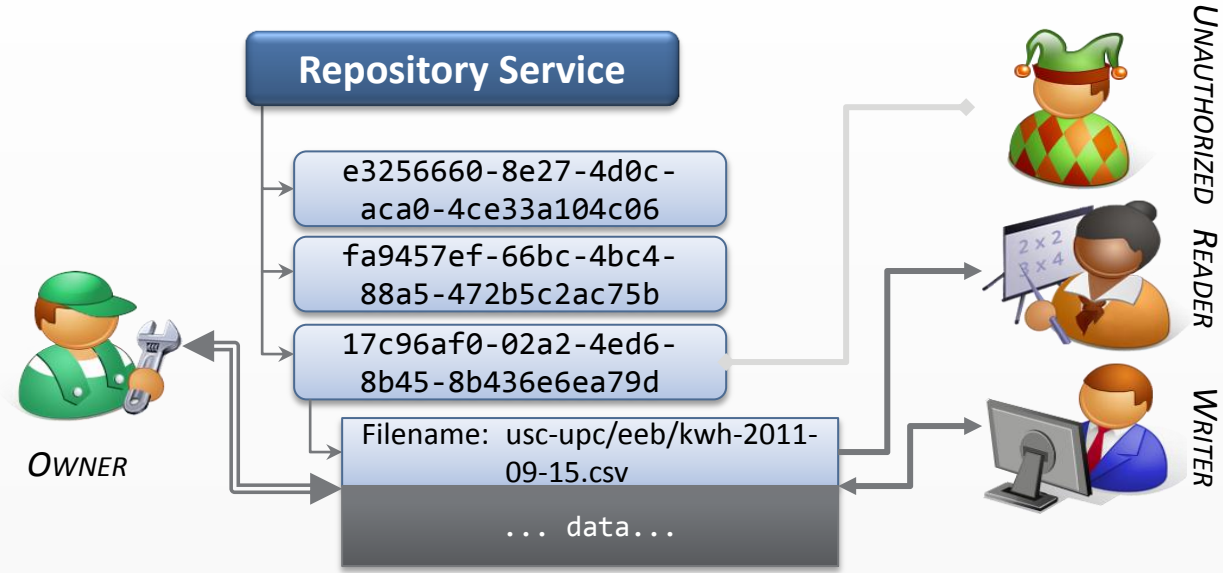
Data	Social Sci.	Power Engr.	Facility Mgmt.	Univ. Staff	Extern
Cons. Survey	O	R*	-	-	-
Staff Schedule	R*	R*	-	O	-
Consumption	R	R	O	-	-
Weather	R	R	O	R	W
Campus Power Forecast	R	W	O	R	-

Storage Concerns on Public Clouds

- Wider attack surface
- Loss of physical control
- Not a major concern for most applications, …
- Use Cloud provider Access Control
  - *Challenge: What if you don't trust Cloud provider?*
- Plain text data may potentially leak
  - Encrypt data before uploading
  - *Challenge: Key management & sharing*

- **Data storage service** which
  - retains the persistence & availability offered by public Cloud storage,
  - but with security & encryption controlled by clients,
  - a low key management overhead,
  - compatibility with existing storage service interfaces,
  - while not sacrificing performance & scalability.

Entities and Roles

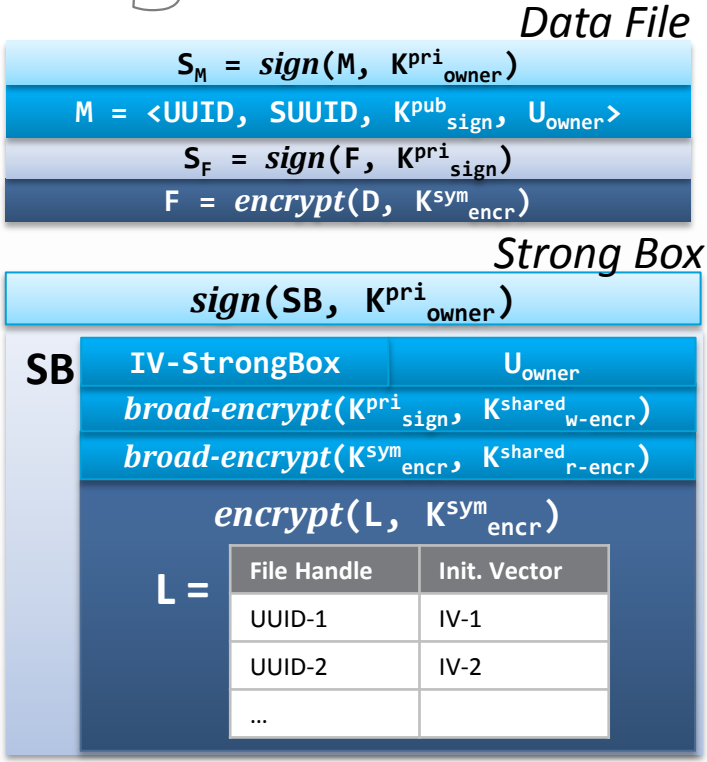


Entities and Roles

- Users *(USC Community)*
  - Community of users who require a secure, shared storage
  - Owners, Readers, Writers
  - Can include 'Malicious' attackers
- Cloud Storage Provider *(Azure)*
  - Provides persistent scalable storage space
  - Trusted with 'availability' (SLA)
  - Not trusted with data security
- Secure, Shared Data Repository Service *(Cryptonite)*
  - Run and Managed by user community on the Cloud
  - Not trusted with plain text data
  - Partial trusted to perform requested operations
  - All operations should be verifiable

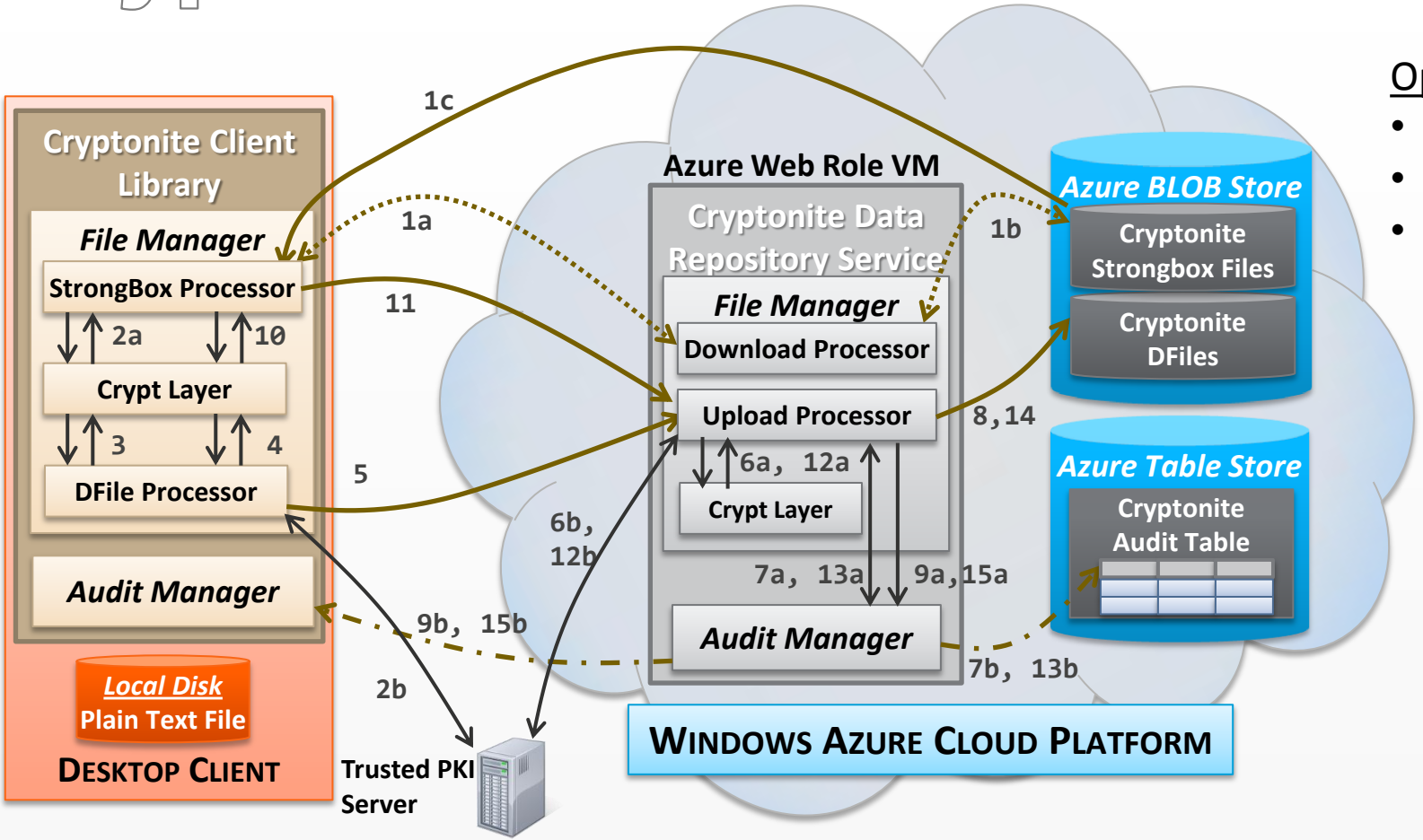
StrongBox for Key Management

- Every user has one global private:public key pair
- File is encrypted using a symmetric key unique to ACL
- File is signed using a key pair unique to ACL
- Symmetric key is **broadcast encr.** using public keys of readers
- Private key of signature is BE using public keys of writers
- StrongBox is signed by owner pvt key



Designing a Secure Storage Repository for Sharing Scientific Datasets using Public Clouds, A. Kumbhare, Y. Simmhan & V. Prasanna , *DataCloud*, 2011

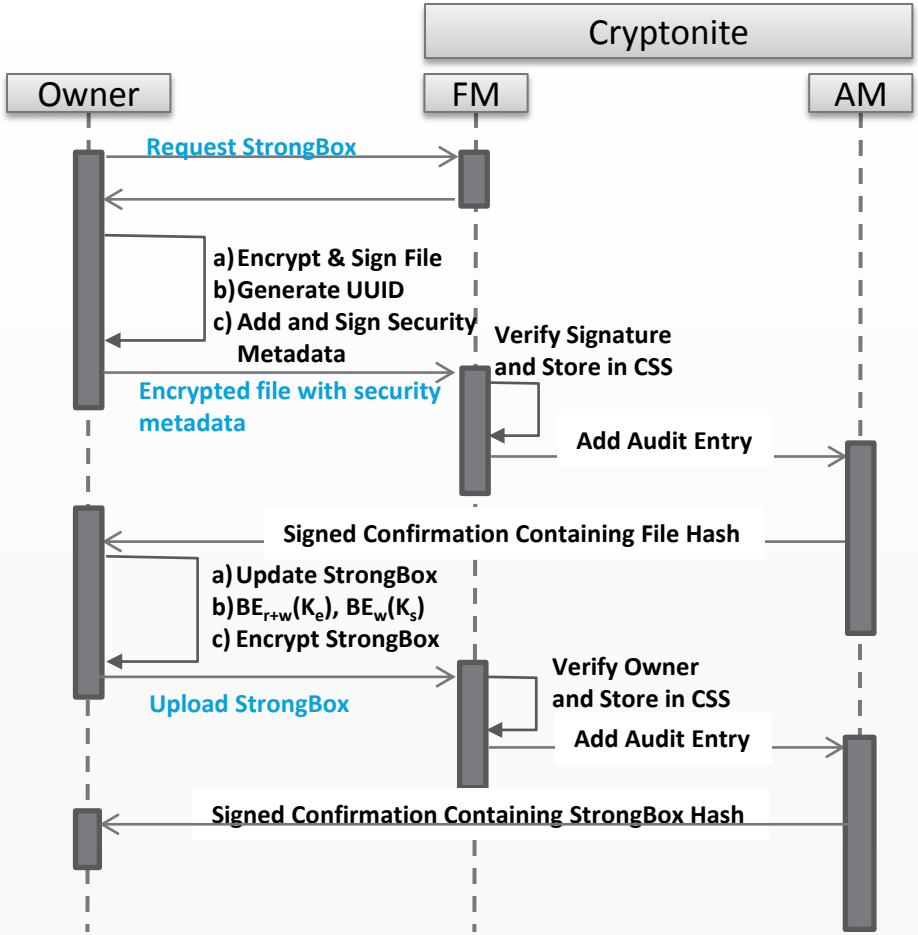
Cryptonite Architecture



Operations

- GET
- PUT
- POST

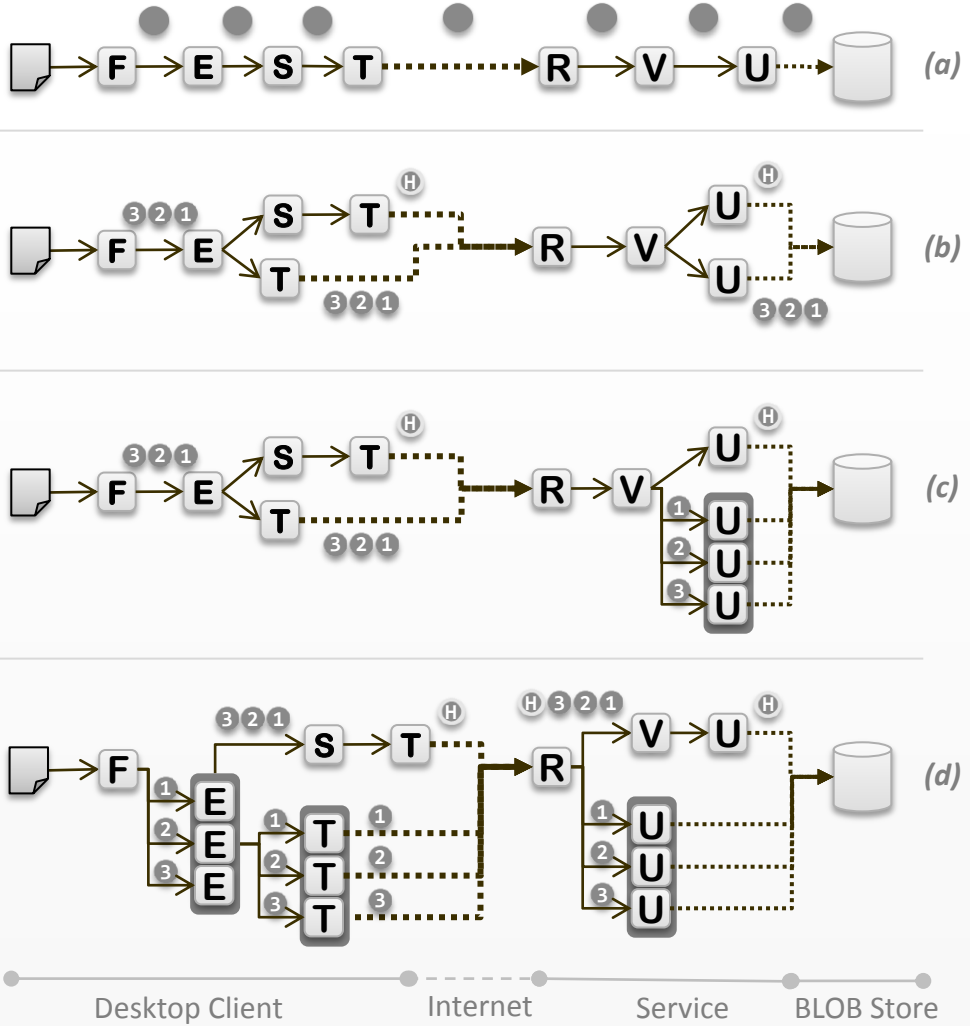
PUT Operation



Optimizations

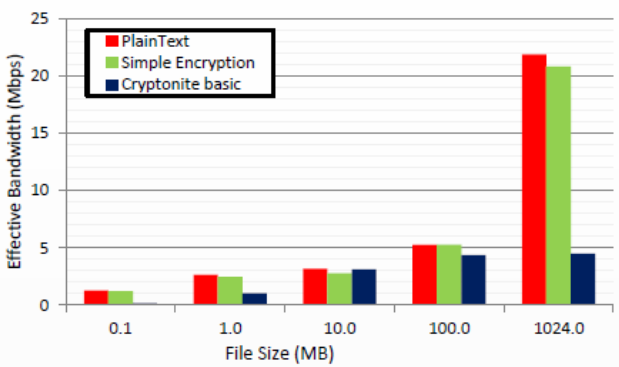
- File read, Encrypt, Strongbox, Transfer
- NW Read, Verify, Blob Upload

- Pipelining
- Data Parallel

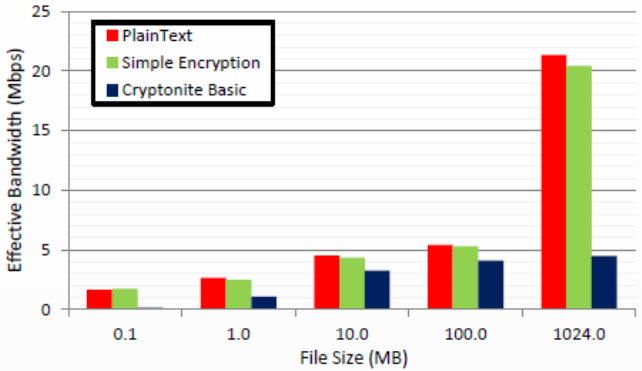


Cryptonite: A Secure and Performant Data Repository on Public Clouds, A. Kumbhare, Y. Simmhan & V. Prasanna , *IEEE CLOUD*, 2012

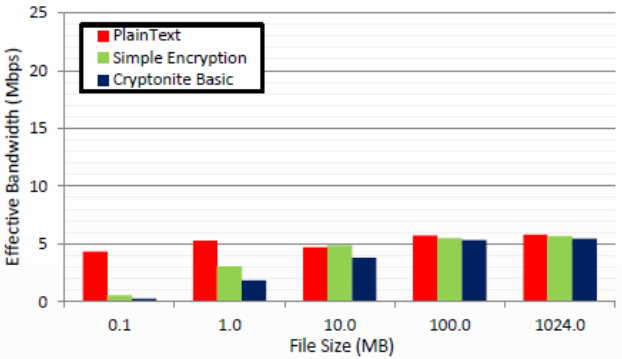
Baseline Performance



(a) POST



(b) PUT

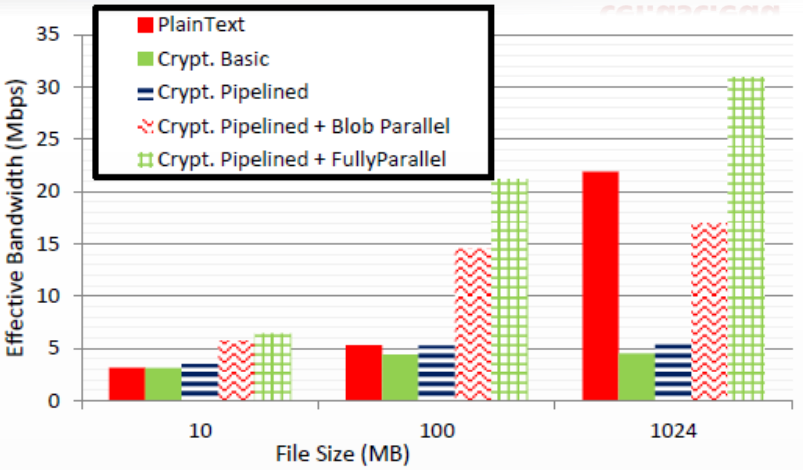


(c) GET

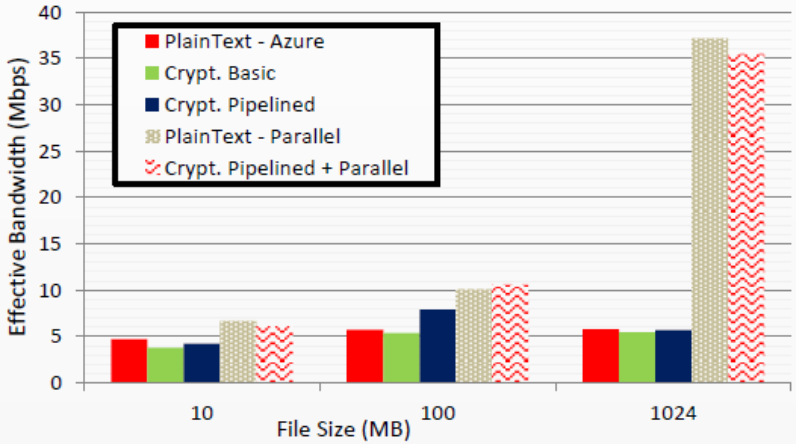
- PUT/POST comparable for medium sized files. Poor for large/small files.
  - Azure Client API does parallel upload >32M
- GET comparable for medium-large files

Optimized Perf.

- PUT outperforms
  - Cryptonite service buffers, stores async
- GET outperforms
  - Azure API does not do parallel download
- Scalability: 400Mb/s B/W Saturation in VM



(a) POST



(b) GET

Future

- Scale out of VMs
- Auditing & verification support
- Leveraging native storage fabric B/W?
- Table oriented data sharing

ganges.usc.edu/wiki/Cryptonite

Pillcrow: Daytona MR, Pregel.NET, …

GRAPH ANALYTICS ON AZURE

Graph Data Analysis

- Understand interconnections between energy consumers, physical space
- Mine for patterns of interesting energy (mis)use activity
- Analyze key influencers of sustainability in peer group

Comparing Prog. Models

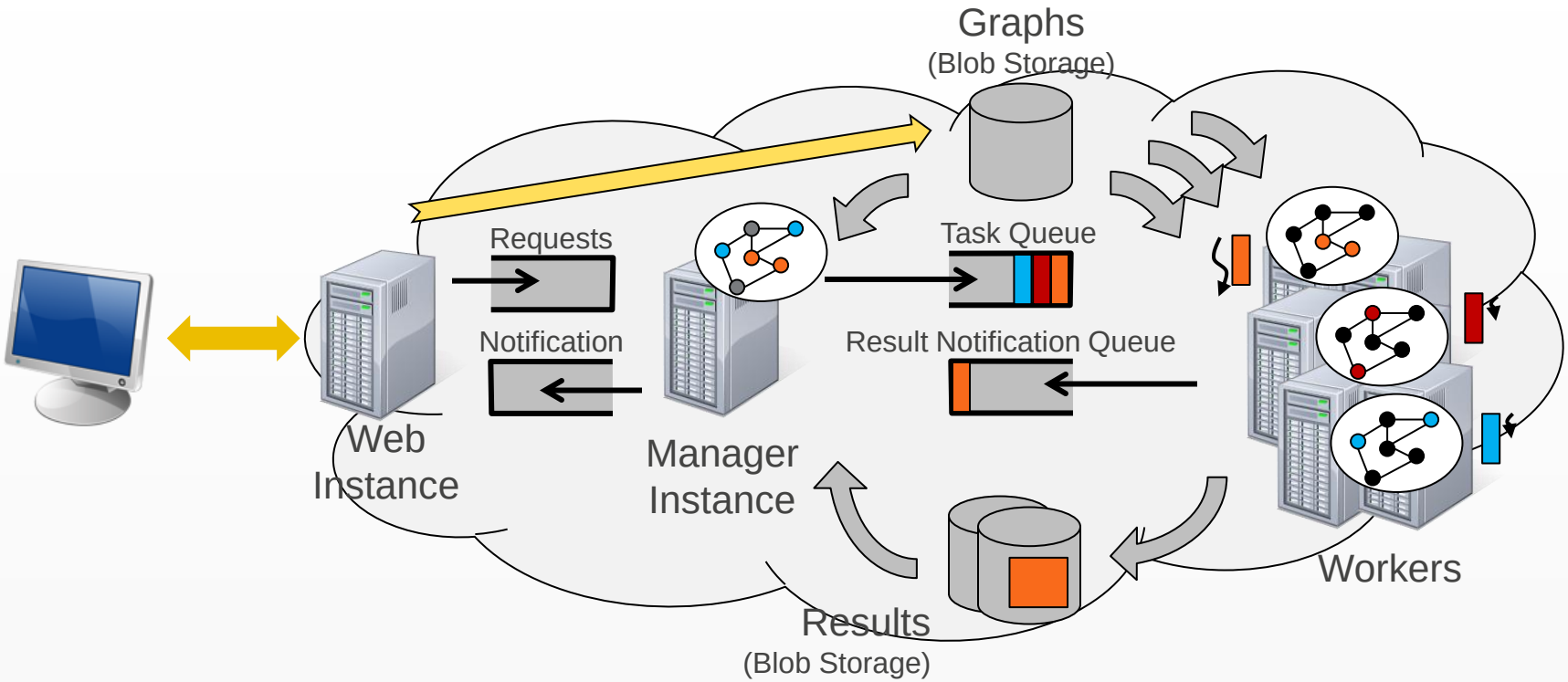
- Loosely-coupled
  - Azure Task queues
- MapReduce
  - MSR Project Daytona
- Pregel
  - Pregel.NET
- Use Betweenness Centrality for evaluation

Betweenness Centrality (BC)

- Determines "centrality" as # of shortest paths from all-pairs on which a vertex lies
- Perform |V| Breadth-first traversals
  - Gives shortest path from root to other vertices
- Reverse traversal from leaf to root, summing % of shortest-paths each vertex belongs to
- Sum vertex's scores across traversals gives BC

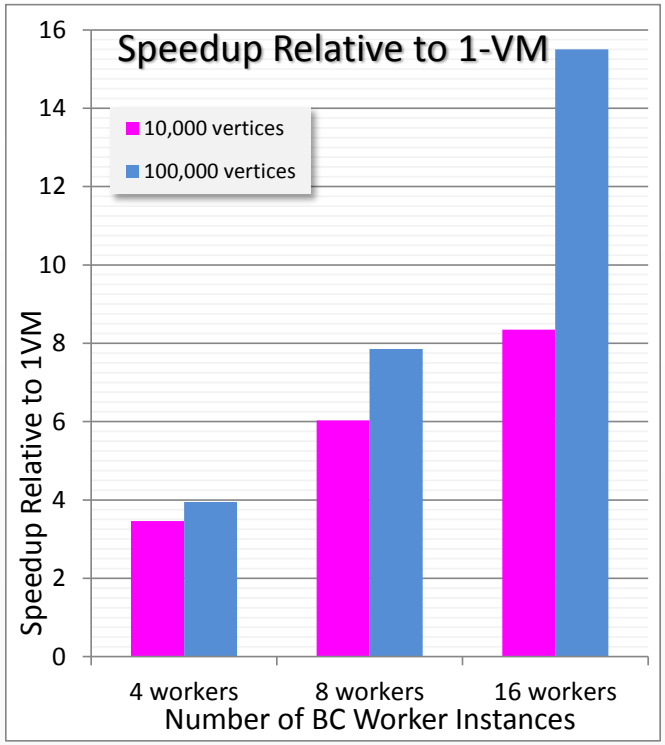
Brandes, U.: **A faster algorithm for betweenness centrality.** *J. Mathematical Sociology*, 25(2), 163–177 (2001)

BC using Loosely Coupled Tasks

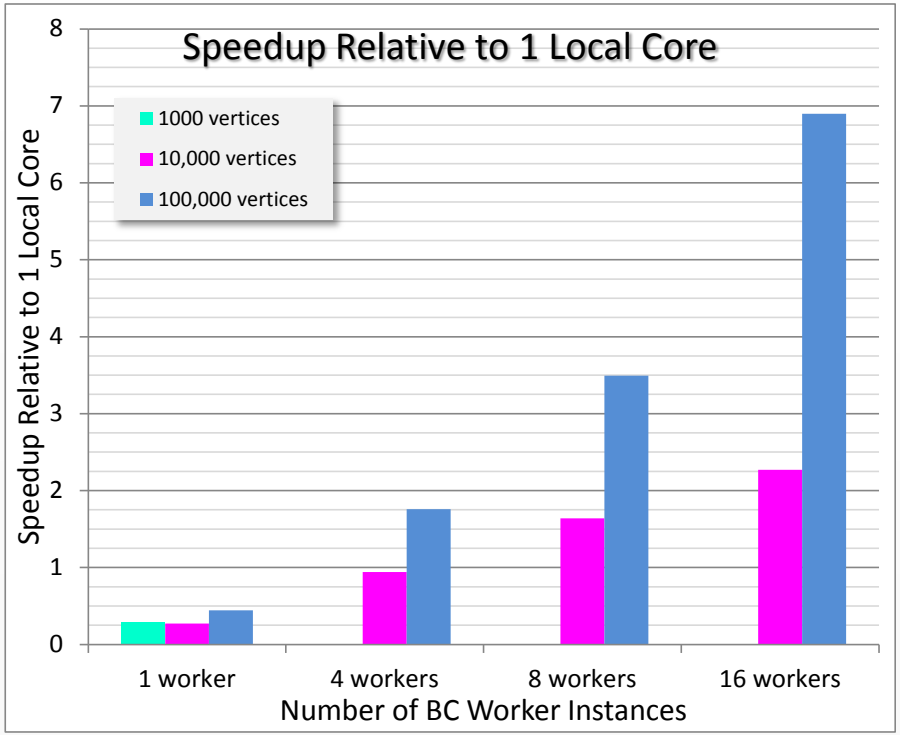


Performance Analysis of Vertex-centric Graph Algorithms on the Azure Cloud Platform, M. Redekopp, Y. Simmhan & V. Prasanna, *ParGraph*, 2011

Perf. Of Loosely Coupled



For large graphs performance is scalable over number of workers

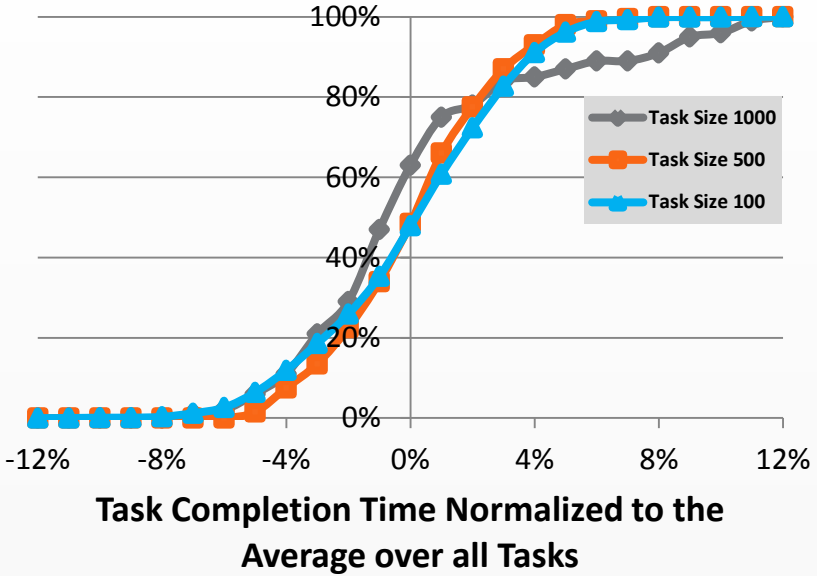


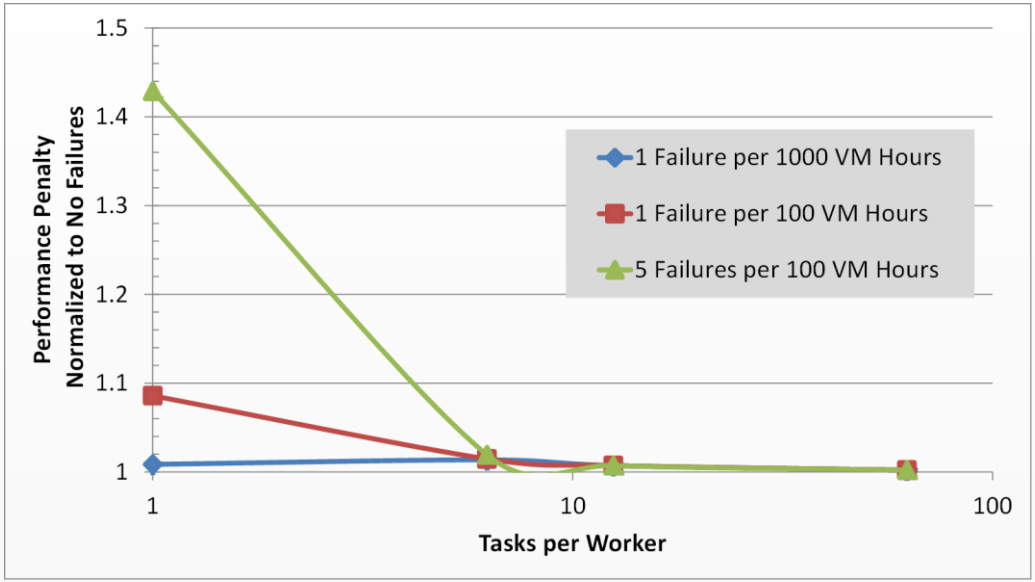
For large graphs and 16 workers we get about 8x speedup compared to a single local core

Task Sizes and Resilience

Set timeout to average task time+12%

Analyze performance penalties for different MTBF



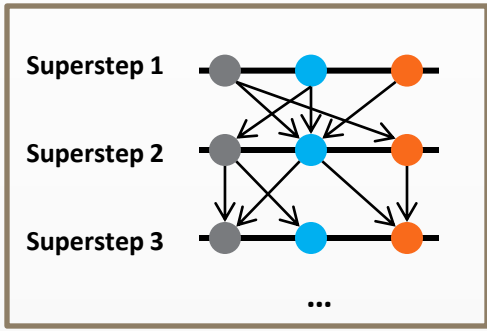


For 10^5 vertex graph, all tasks finish with in 12% variation from the average

More tasks per worker (smaller task size) helps to mitigate performance impact of failures

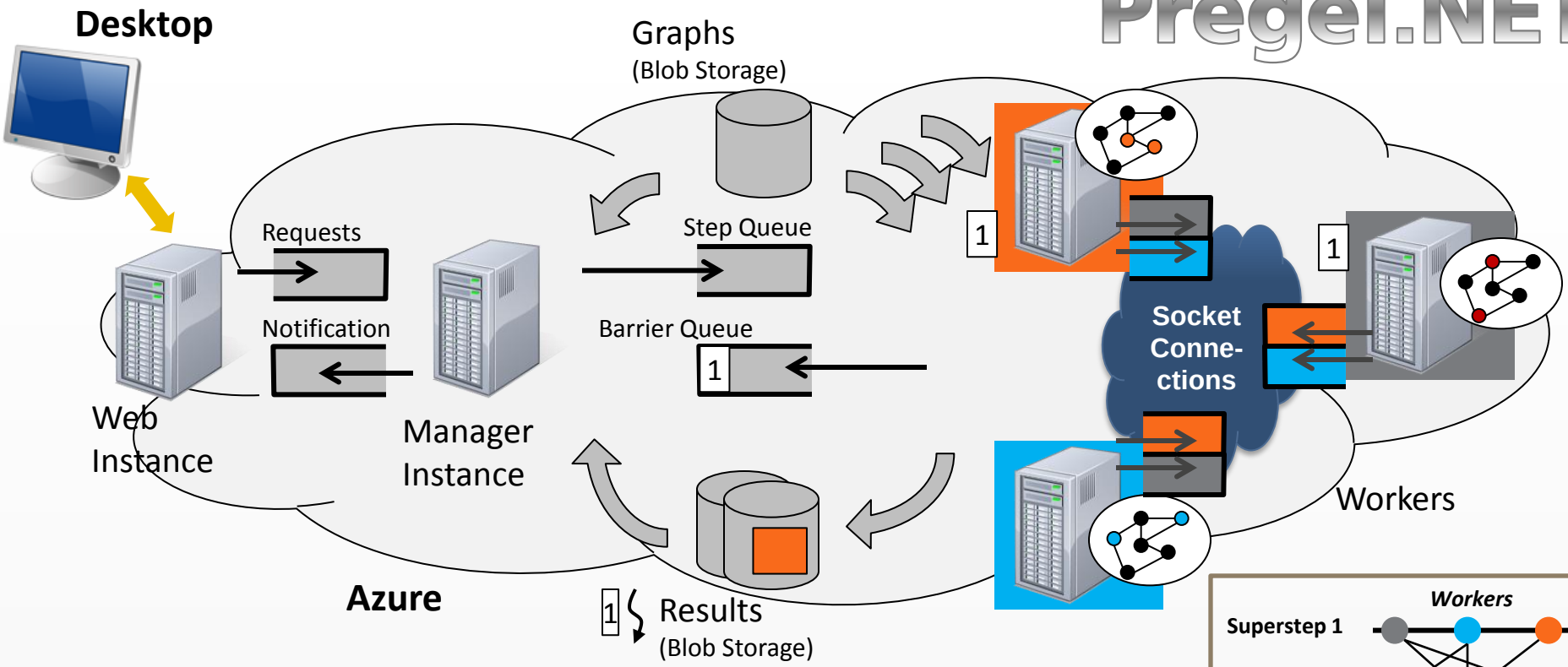
Pregel

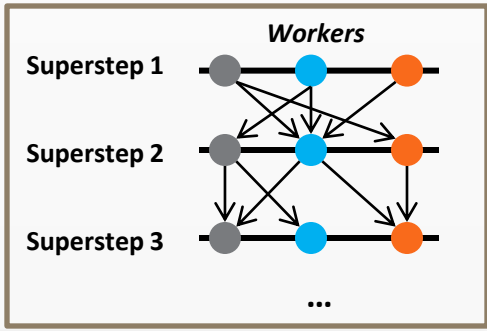
- Graph vertices distributed among workers
- Computation in synchronized supersteps
  - Bulk Synchronous Parallel model
- In each superstep
  - Vertex accepts messages in edges,
  - Processes messages, and
  - Emits messages to neighbors
- Stops when all "vote" to halt…M-R-R-R…



Pregel: a system for large-scale graph processing, G. Malewicz, et al., *SIGMOD* 2010

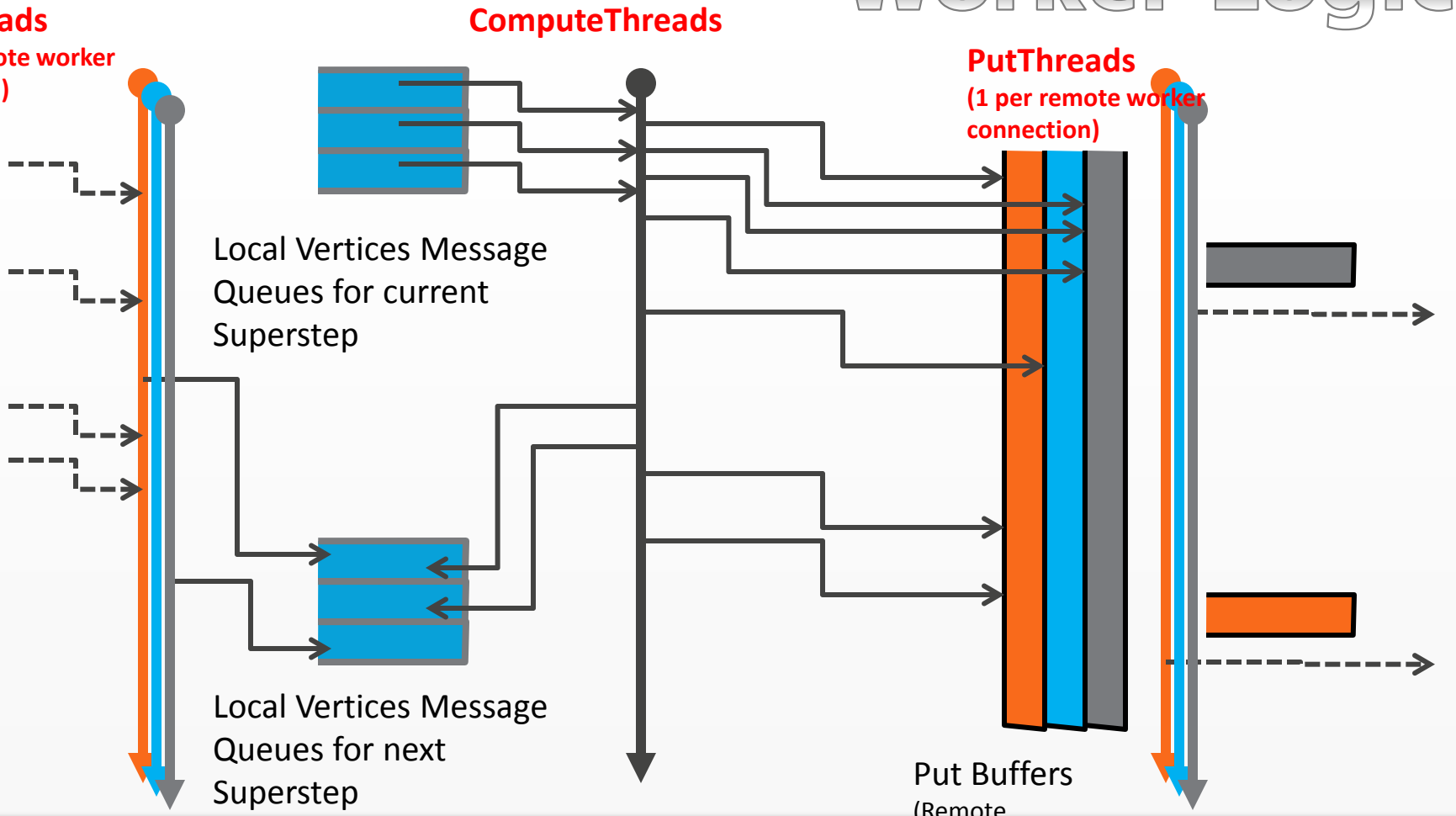
Pregel.NET





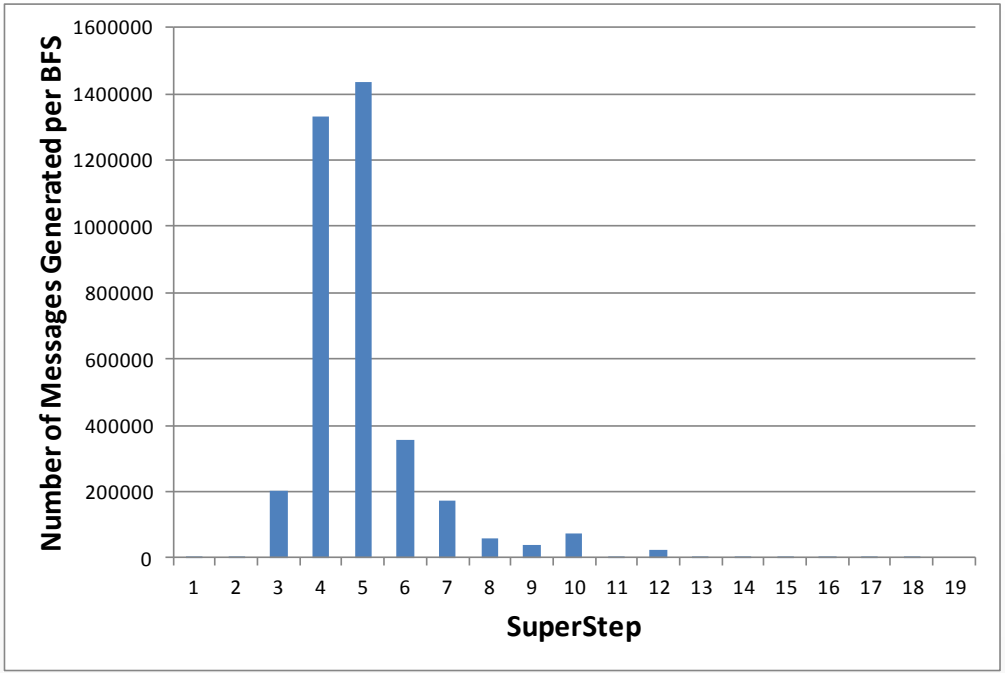
Pregel.NET Worker Role Implementation on Azure

Worker Logic



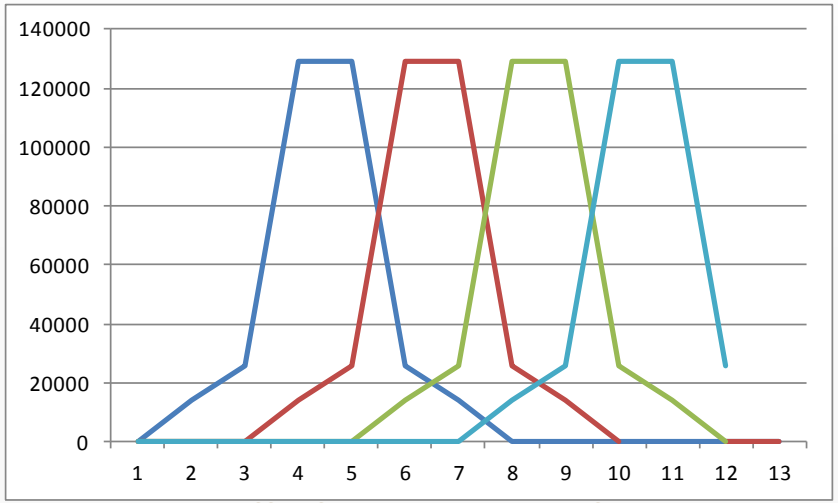
Pregel Characteristics

- Communication Latency
  - Messages flow between workers on internal endpoints (sockets)
- Memory Pressure
  - Typical Pregel model does |V| BFS traversals in parallel
  - Large memory buffering for input messages
- Variability of message traffic & memory across supersteps … long tail

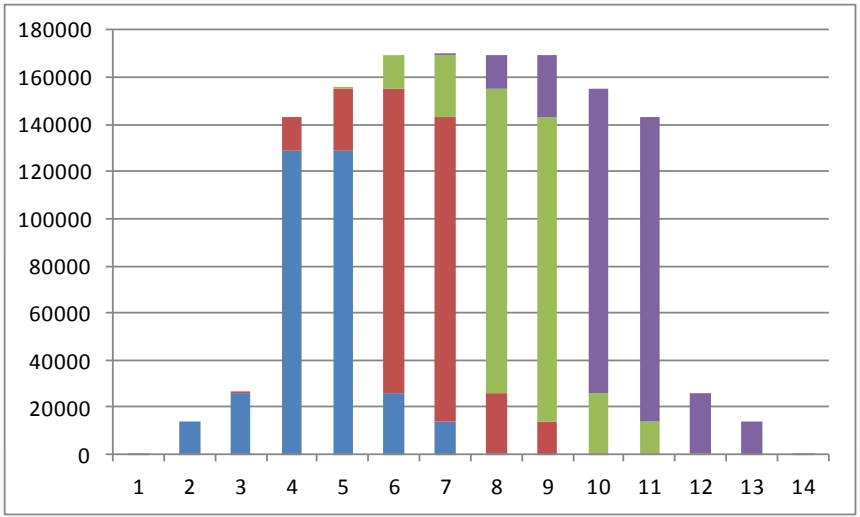


Pregel Optimizations

- Launch a swath of *k* BFSs at a time (k < |V|)
  - *k* based on predicted peak memory requirements (How?)
- Launch swaths at intervals for constant message traffic, memory
  - Heuristics for selecting initiation interval

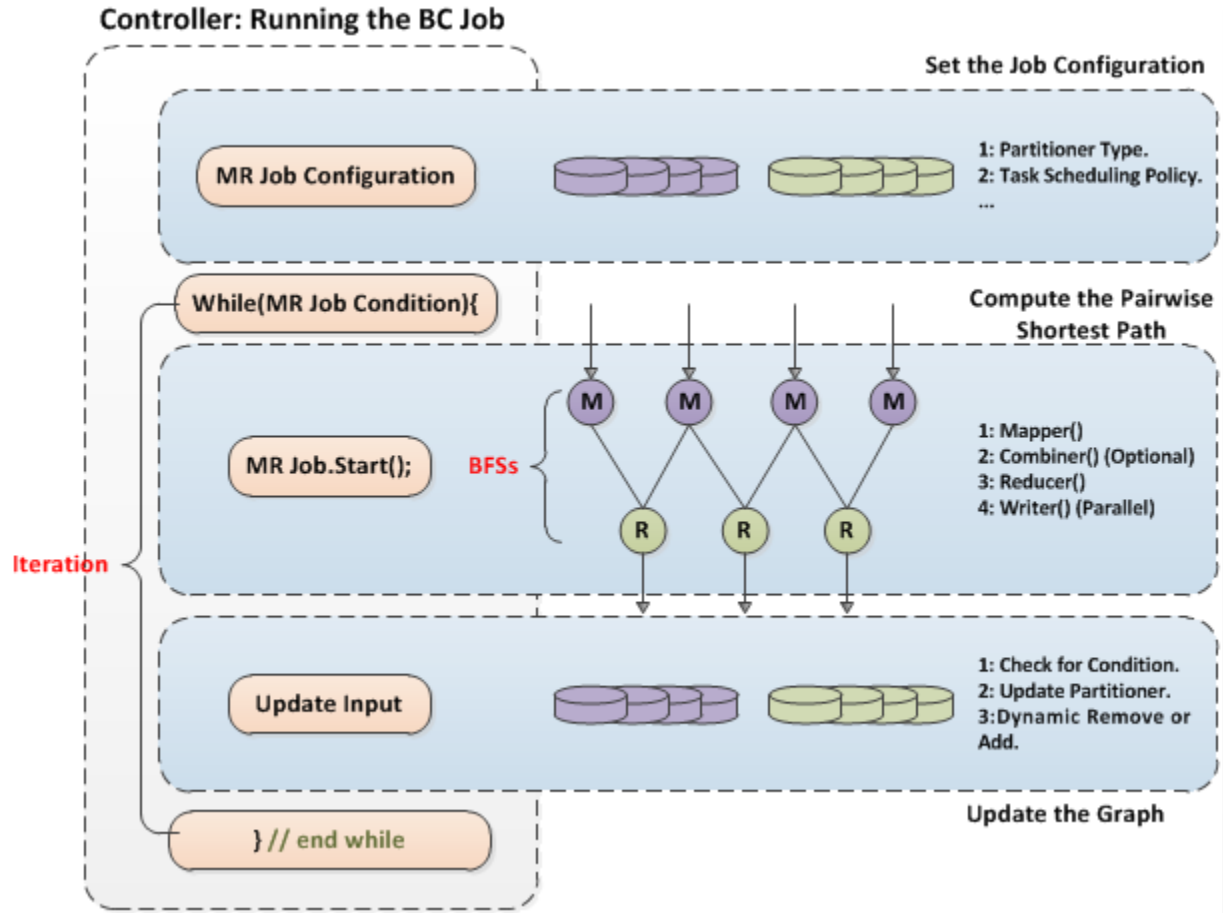


Message traffic from 4 swaths of BFS launched at an interval of 2 supersteps



Cumulative message traffic for the 4 swaths

BC on Daytona's iMapReduce



Future work

- Comprehensive evaluation
- Initiate parallel swaths in "waves"
  - Analytical model
- Dynamic graphs, incremental updates
- Other graph applications

Plugs…

- Workshop on Massive Data Analytics on Scalable Systems (DataMASS)
  - Co-located with the 19th IEEE International Conference on High Performance Computing (HiPC), *December 18 - 21, 2012, Pune, India* ***(TBA)***
- Call for Articles: Cloud Computing for Data-driven Science and Engineering
  - Concurrency and Computation: Practice and Experience Journal, *Deadline: August 15, 2012*

*This material is based upon work supported by the **National Science Foundation** and **Microsoft** under Award Number CCF-1048311 of the Computing in the Cloud initiative, and by the **Department of Energy** under Award Number DEOE0000192.*

The views and opinions expressed herein do not necessarily state or reflect those of the US Government or any agency thereof.

THANK YOU!

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