AutoShard - Declaratively Managing Hot Spot Data Objects in NoSQL Data Stores

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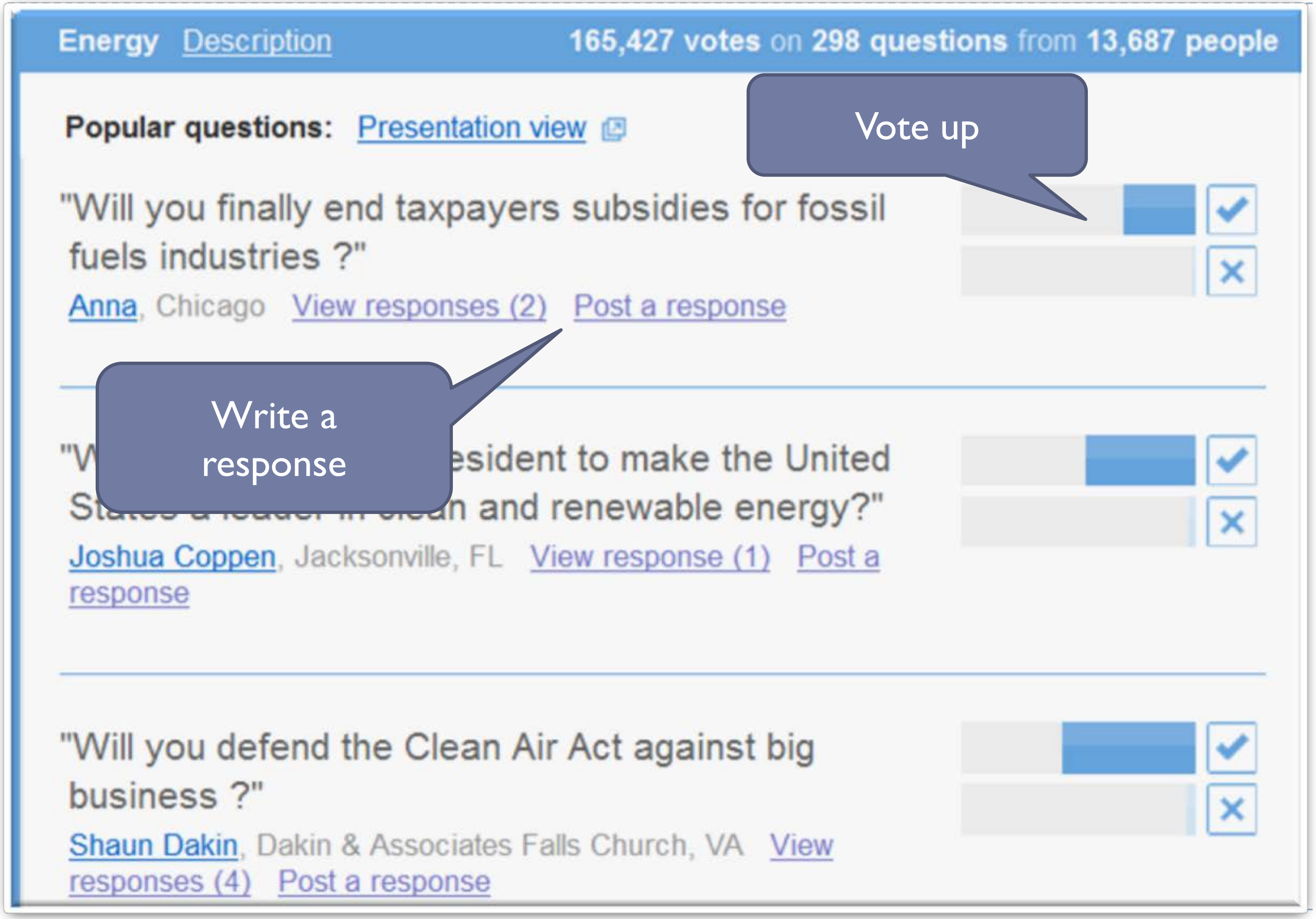
Today's Web Applications



Energy Description 165,427 votes on 298 questions from 13,687 people

Popular questions: Presentation view

"Will you finally end taxpayers subsidies for fossil fuels industries ?"

Anna, Chicago View responses (2) Post a response

"W esident to make the United St n and renewable energy?"

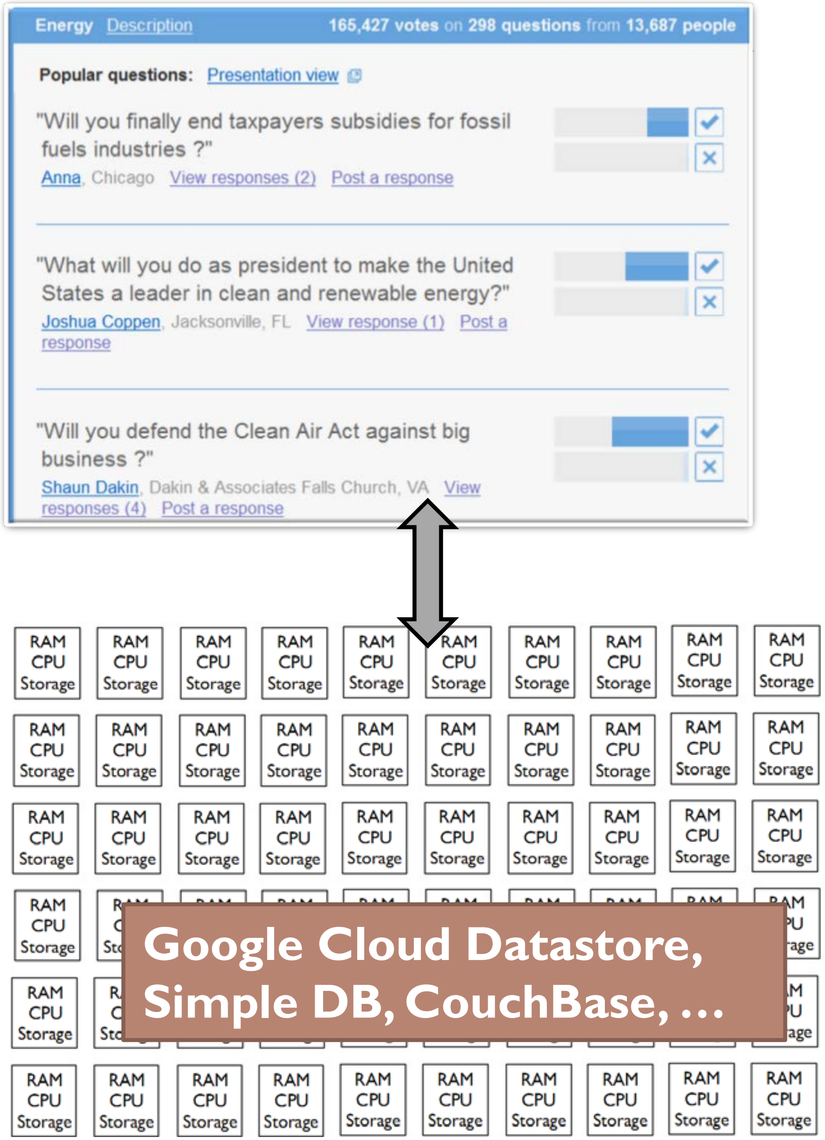
Joshua Coppen, Jacksonville, FL View response (1) Post a response

"Will you defend the Clean Air Act against big business ?"

Shaun Dakin, Dakin & Associates Falls Church, VA View responses (4) Post a response

NoSQL Data Stores

- Flexible data model
  - Query functionality mostly sufficient
- Impressive scalability handles large amounts of data
  - Build for massively parallel reads
- Strongly consistent writes and reads against <u>single</u> entities
  - Appropriate for most web scenarios (#reads >> #writes)



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"What will you do as president to make the United States a leader in clean and renewable energy?"
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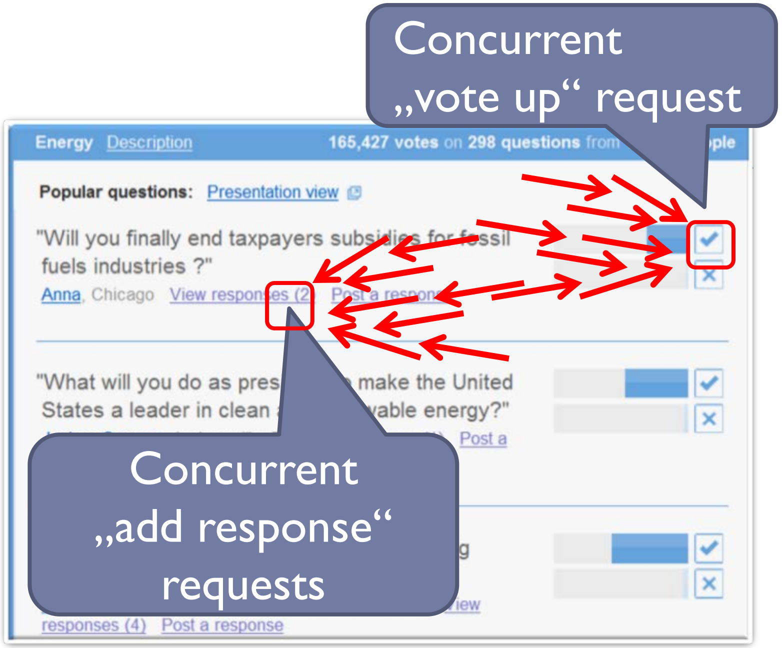
Google Cloud Datastore, Simple DB, CouchBase, …

Hot Spot Data Objects

- Frequently accessed/updated data objects
- Performance vs. scalability
  - Impressive scalability handles large amounts of data
  - Limited write throughput on single data objects (∅ 5-10/sec)
- Frequently updated objects … not entirely new problem ☺
  - Examples: available seats on a plane, overall account balance, …
  - Previous work on hot spot objects for RDBMS
- New aspects for NoSQL data stores



Concurrent „vote up“ request

Concurrent „add response“ requests

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Agenda

- Motivation
- NoSQL Data Stores and Hot Spot Objects
- Sharding
  - Property Sharding
  - Entity Group Sharding
- AutoShard
  - Architecture
  - Dynamic AST modification
- Evaluation
- Summary and Outlook

NoSQL data stores and Hot Spot Objects

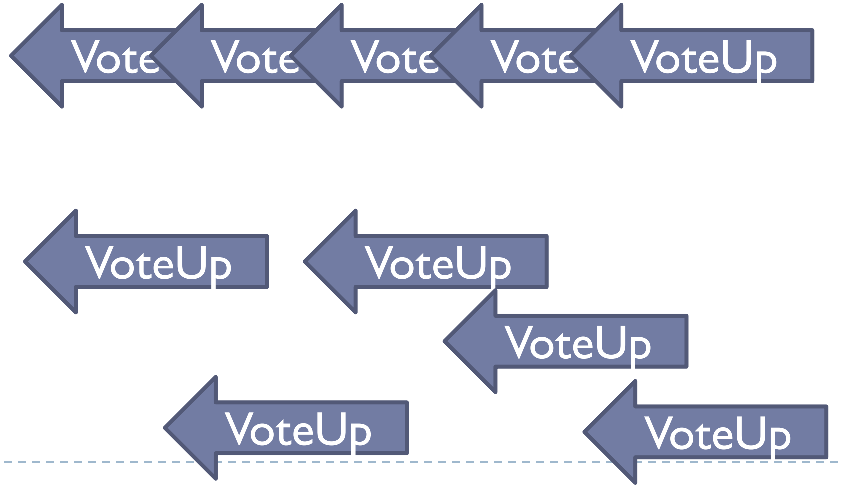
- Optimistic concurrency control
  - „Execute Txs immediately, check at commit for conflicts“
  - No wait locks at the expense of possible aborts → Retry!
  - Appropriate for most web scenarios (#reads >> #writes)
- Database as a Service
  - Developers cannot modify the database in DaaS settings
  - Hot spot objects must be handled on the application level
- No strong consistency
  - Eventual consistency (clients may read stale data)

Property Sharding

- Logical property value is stored using multiple shards (i.e., physical values)
  - Writes are distributed across all shards
  - Aggregated read over all shards
- Example: Vote counter for questions
  - “VoteUp” on any shard; sum all shards to get number of votes

QId	Votes
A	5

QId	Votes
A.1	2
A.2	1
A.3	2



Property Sharding: Implementation

- Initialization
  - Set shard value to **neutral element**
- Write (set specific value)
  - Set one (chosen at random) shard to specific value
  - Set all other shards to neutral element
- Update (based on current value)
  - Update one shard (chosen at random) using **update function**
- Read
  - Read all shards and aggregate using **fold function**
- Manual implementation
  - **Laborious**: complex implementation (and testing)
  - **Unnecessary** (overhead) for many objects / properties

Entity Group Sharding

- Entity group (set of entities) is stored using multiple shards (i.e., physical values)
  - Writes are distributed across all shards
  - Aggregated union over all shards
- Example: Responses for questions
  - "AddResponse" on any shard (subset of responses)
  - Unify all shards to get the complete list of reponses

AutoShard

- Object mapper with **automatic** and **adaptive** sharding
  - Java objects ↔ NoSQL entities (in BigTable-like DS)
  - Automatic sharding on logical schema avoids scalability bottlenecks / write contention
  - Adaptive, i.e., automatic identification of hot spots
- Two kinds of sharding
  - Property sharding: distribute atomic values
  - Entity Group sharding: distribute sets of entities
- Easy-to-use
  - Definition using Java annotations
  - Implementation by automatic AST transformation

Example Annotations: Class question

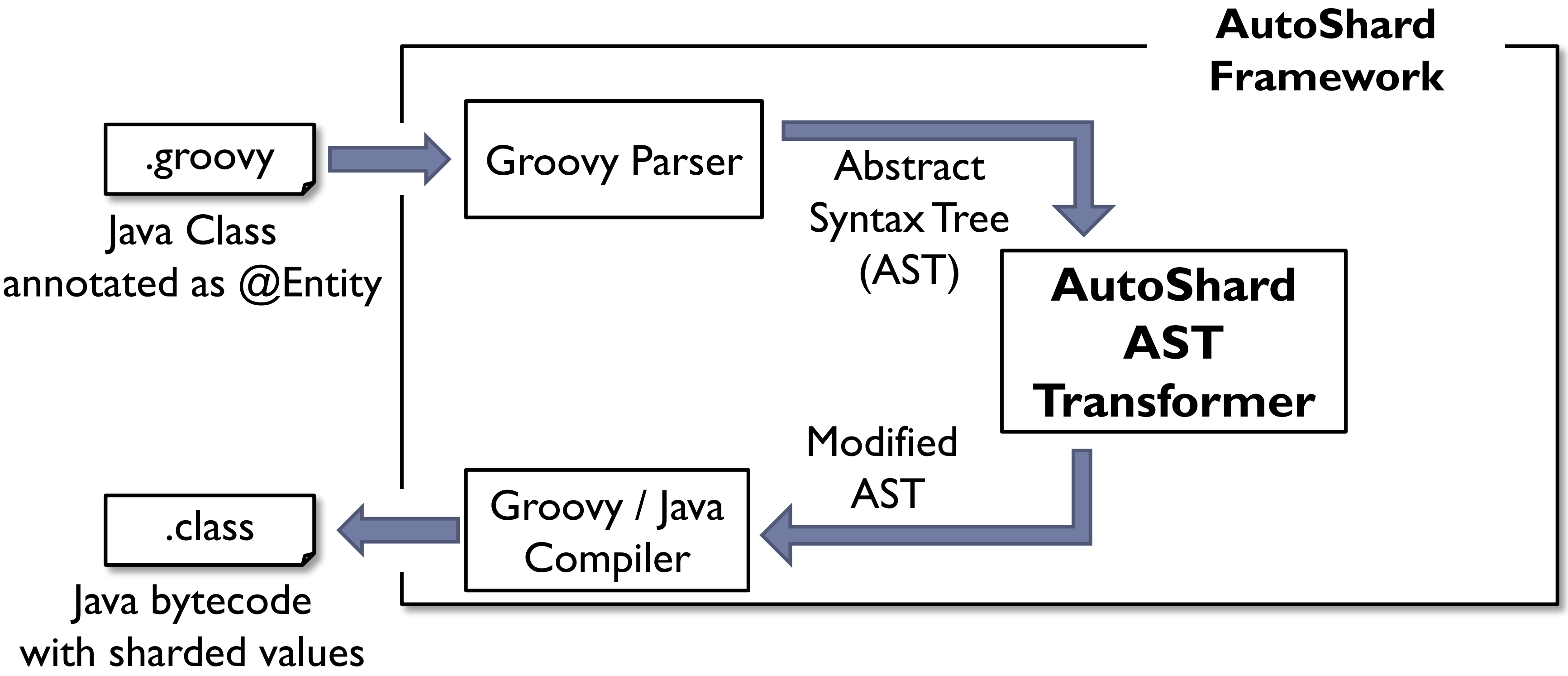
```
@Entity
class Question {
   @Id private int id;
   private String question;
   private String author;
   private List<Response> responses;
   @Shardable (neutral=0)
   private int votes = 0;

   @ShardMethod
   public void voteUp() {
      this.votes++;
   }

   @ShardFold
   public static int foldVotes(int x, int y) {
      return x + y;
   }
   ...
}
```

AutoShard Architecture: Deploy Time

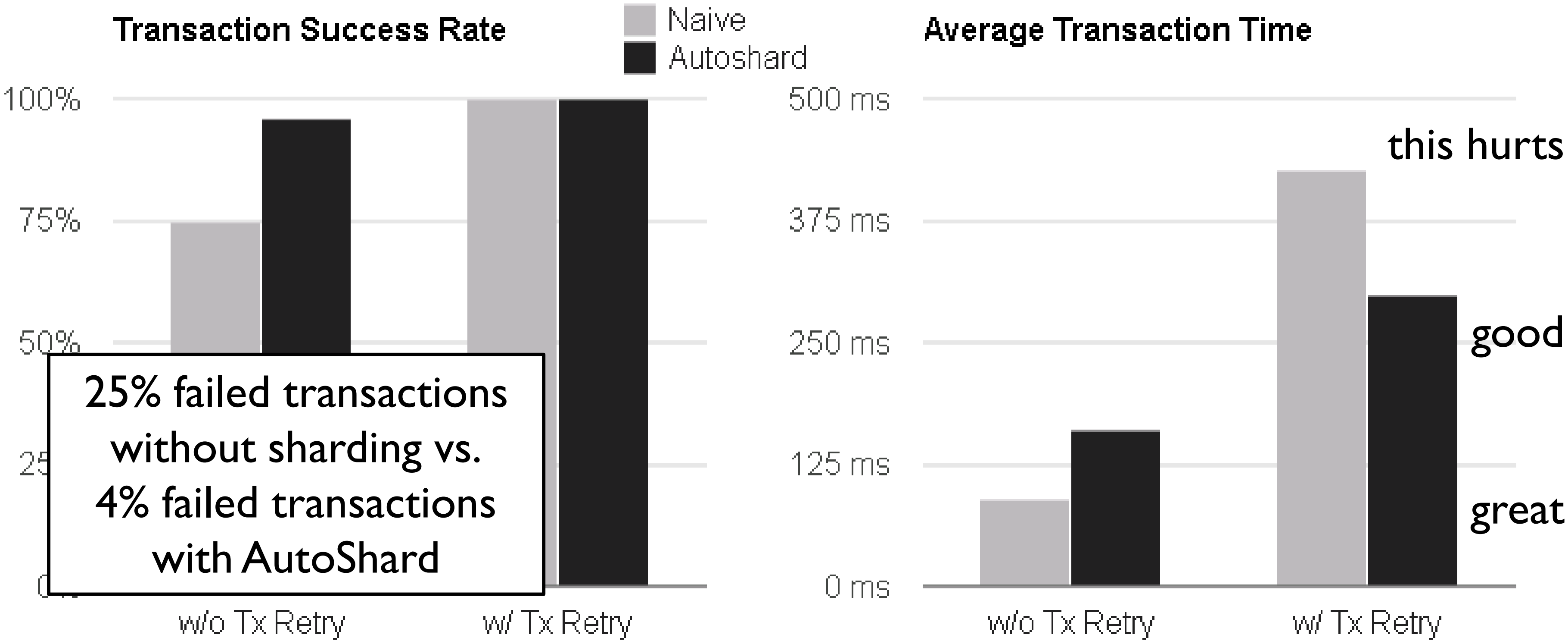
- „Injection“ of sharding functionality during compile time
- Automatic program modification based on annotations



AutoShard Framework
.groovy
Java Class annotated as @Entity
Groovy Parser
Abstract Syntax Tree (AST)
AutoShard AST Transformer
Modified AST
Groovy / Java Compiler
.class
Java bytecode with sharded values

Evaluation

- 2,000 users, 75 voting requests per sec across 16 questions
  - w/ Tx retry: re-start failed transactions (exception handling)



25% failed transactions without sharding vs. 4% failed transactions with AutoShard

this hurts

good

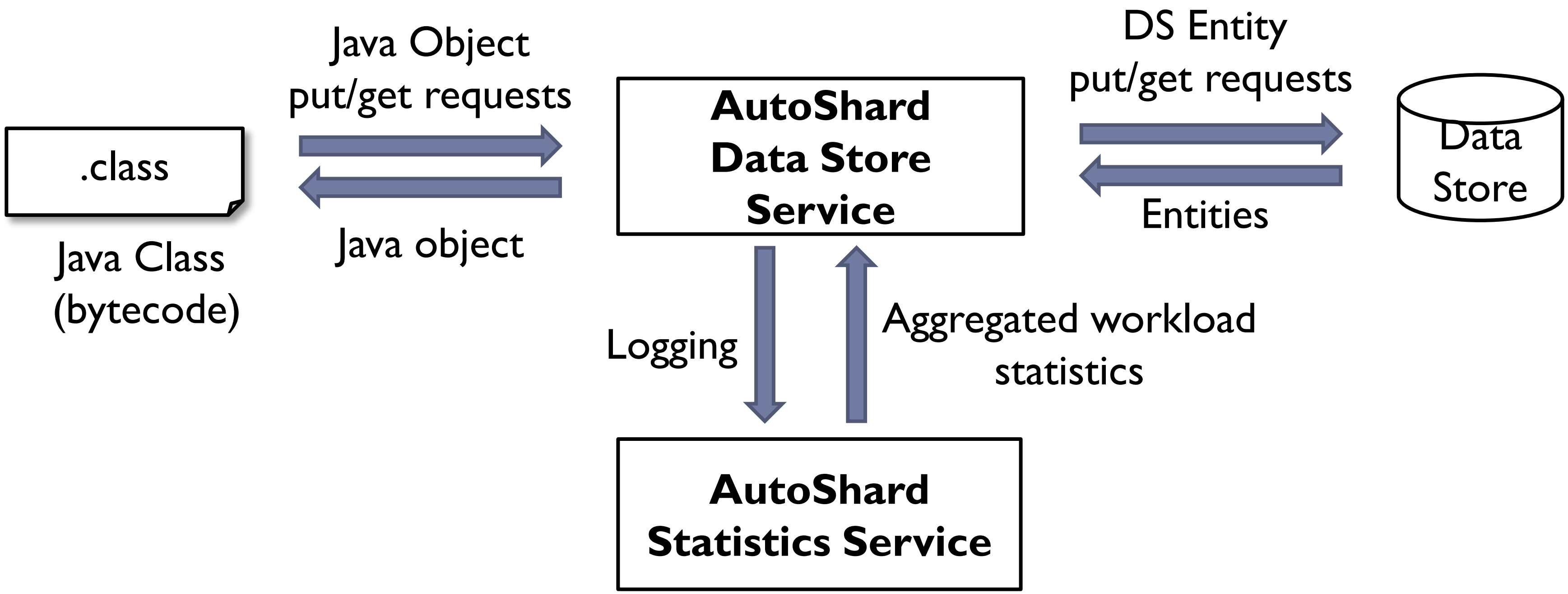
great

Current Work: Adaptive Sharding

- Automatic identification of …
  - Properties / entities that should be sharded
  - Sharding parameters, e.g., number of shards
- Statistics
  - Time-based: Number of put requests per time and per entity
  - Exception-based: Number of raised exceptions
- Implementation
  - Add logging statements during AST transformation
  - Store all / aggregated statistics in MemCache
  - Rule-based decision

AutoShard Architecture: Run Time

- Put/get requests are logged into MemCache
  - Fast, distributed in-memory cache
- Workload statistics used to apply sharding on-demand



Java Object put/get requests
DS Entity put/get requests
.class
AutoShard Data Store Service
Data Store
Java Class (bytecode)
Java object
Entities
Logging
Aggregated workload statistics
AutoShard Statistics Service

Summary / Outlook

- AutoShard = A novel object mapper that can declaratively manage hot spot data objects
  - Avoids schema-inherant performance bottlenecks in NoSQL-based web applications
- Implements database techniques (sharding) using programming techniques (annotation + AST transformation)

- Adaptive Sharding
  - When is sharding required (80/20 rule)?
  - What is good number of shards?
  - Background processes for compaction, ...

Thank you!