In-Memory Computing SUMMIT | NORTH AMERICA 2018

In-Memory Computing Brings Operational Intelligence to Business Challenges

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About the Speaker

- Dr. William Bain, Founder & CEO of ScaleOut Software:
  - Email: wbain@scaleoutsoftware.com
  - Ph.D. in Electrical Engineering (Rice University, 1978)
  - Career focused on parallel computing – Bell Labs, Intel, Microsoft
  - 3 prior start-ups, last acquired by Microsoft and product now ships as Network Load Balancing in Windows Server
- ScaleOut Software develops and markets **In-Memory Data Grids**, software for:
  - Scaling application performance with in-memory data storage
  - Analyzing live data in real time with in-memory computing
- Thirteen+ years in the market; 450+ customers, 12,000+ servers

Agenda

The evolution of in-memory computing for operational intelligence:

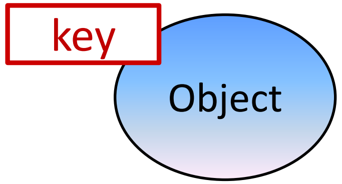
- The foundation: in-memory data grids (IMDGs)
- The challenges: using IMDGs for caching with parallel query
- Data-parallel computing: delivering operational intelligence
  - Examples in financial services
- The next step: data-parallel computing with method invocations
  - Examples in financial services and cable media
- Evolution into stream-processing: the digital twin model
  - Examples in ecommerce, logistics, IOT, medical device tracking, and more
- Combining stream-processing and data-parallel computing with an IMDG

In-Memory Data Grid (IMDG)

IMDGs provide fast, scalable, distributed in-memory data storage.

What is an IMDG?

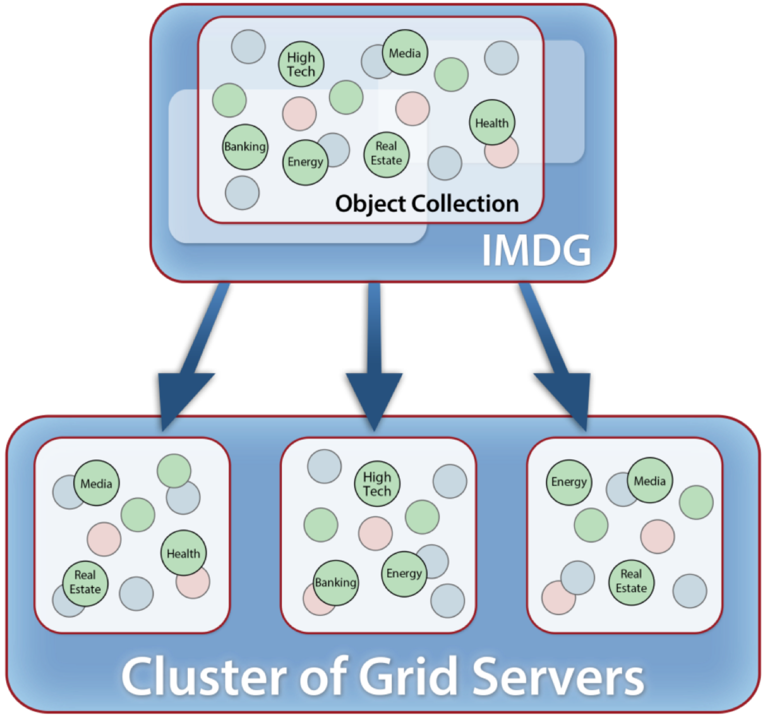
- IMDG stores live, object-oriented data:
  - Uses a key/value storage model for large object collections.



Basic "CRUD" APIs:

- `Create(key, obj, tout)`
- `Read(key)`
- `Update(key, obj)`
- `Delete(key)`

Logical view



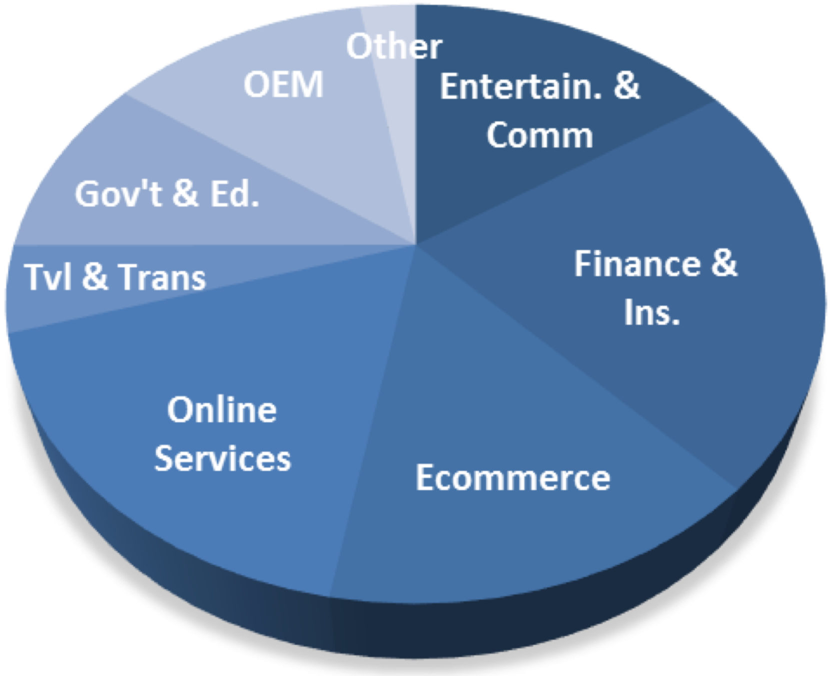
Physical view

IMDG

  - Maps objects to a cluster of commodity servers with location transparency.
  - Has predictably fast (<1 msec.) data access and updates.
  - Designed for *transparent* scaling and high availability

Wide Range of Applications for IMDGs

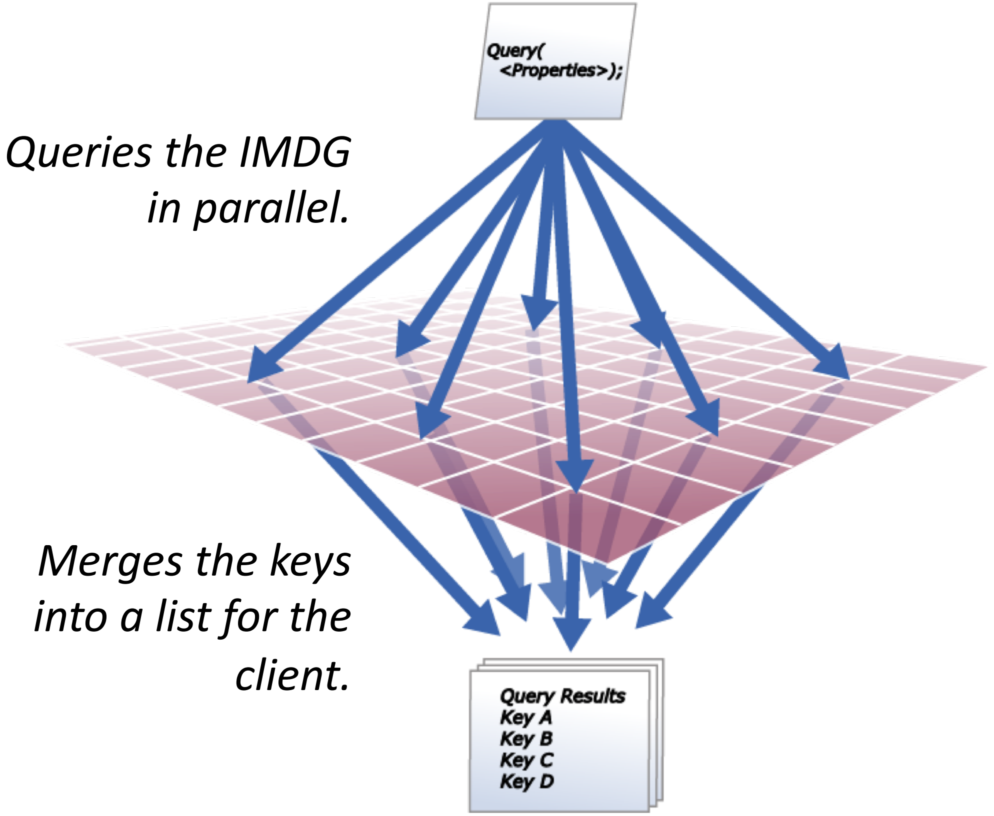
IMDGs are typically used as a distributed cache.



Vertical	Selected Use Cases
Financial & Insurance	• Online banking • Brokerage • Loan apps • Trading • Data services • Portfolio analysis • Risk management • Position updating
Ecommerce	• Shopping carts • User state • Reward programs • Instant offers • Product catalogs • Sale spikes
Online Services	• Patient records • SaaS • User preferences • Service processing • Online education • Internet provisioning • Legal analysis
Entertainment & Communication	• Online game state • Streaming media • Online bill pay • Services catalog • Gambling analysis
Travel & Transportation	• Ticketing system • Reservation system • Reservation analysis

Using IMDG as a Cache: Parallel Query

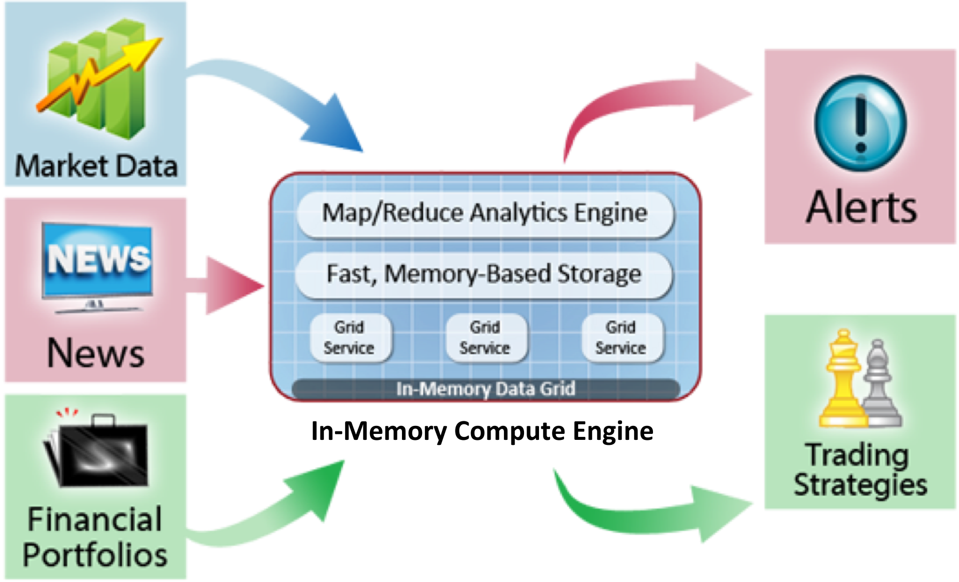
- Users often have a database mindset and rely on query.
- Query retrieves a set of objects with selected properties and/or tags.
  - Uses all grid servers to access queried data.
- Challenges:
  - Cost = O(N) for N servers (vs. O(1) for CRUD)
  - Can create excessive network traffic
- Intermediate solution: filter methods:
  - Run Boolean method on objects to refine search.
  - Example (C#):
    (select stocks where region == NW)
    .Filter(EvalPriceChanges());
  - Reduces number of objects returned to client.
  - Provides a bridge to data-parallel computing.



The Next Step: Operational Intelligence (OI)

Goal: Provide *immediate* (sub-second) feedback to a system handling live data.

- An IMDG hosts live data and can introspect on that data in real time.
- This delivers much greater value that just using the grid as a cache.
- A few example use cases requiring immediate feedback within a live system:
    - **Ecommerce**: personalized, real-time recommendations
    - **Healthcare**: patient monitoring, predictive treatment
    - **Equity trading**: minimize risk during a trading day
    - **Reservations systems**: identify issues, reroute, etc.
    - **Credit cards & wire transfers**: detect fraud in real time
    - **IoT, smart grids**: predictive analytics & optimization



Operational vs Business Intelligence

Operational Intelligence

Real-time

Live data sets

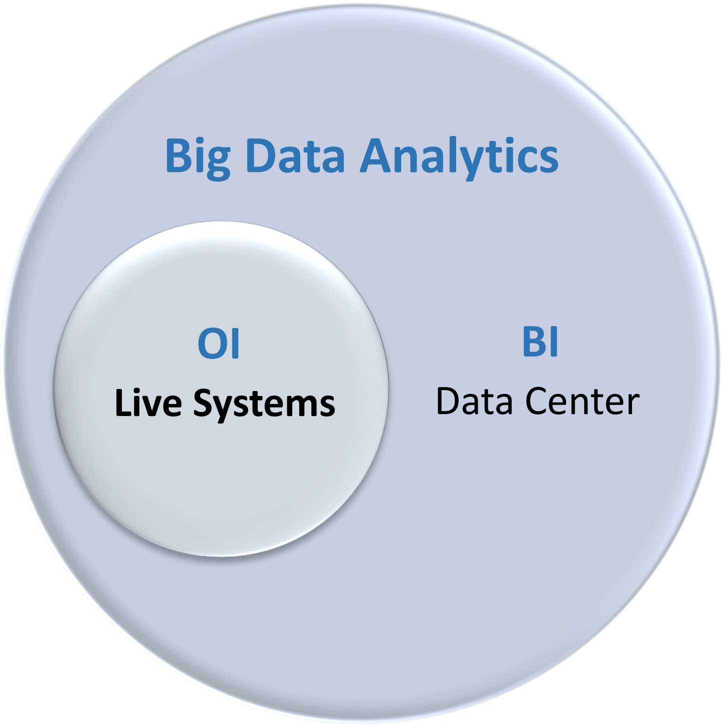
Gigabytes to terabytes

In-memory storage

Sub-seconds to seconds

Best uses:

- Tracking live data
- Immediately identifying trends and capturing opportunities
- Providing immediate feedback



Business Intelligence

Batch

Static data sets

Petabytes to exabytes

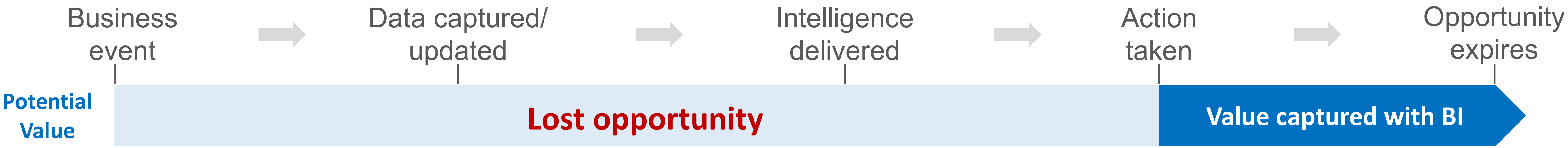
Disk-based storage

Minutes to hours

Best uses:

- Analyzing warehoused data
- Mining for long term trends
- Detecting patterns of strategic importance

Operational Intelligence Reduces Time to Action



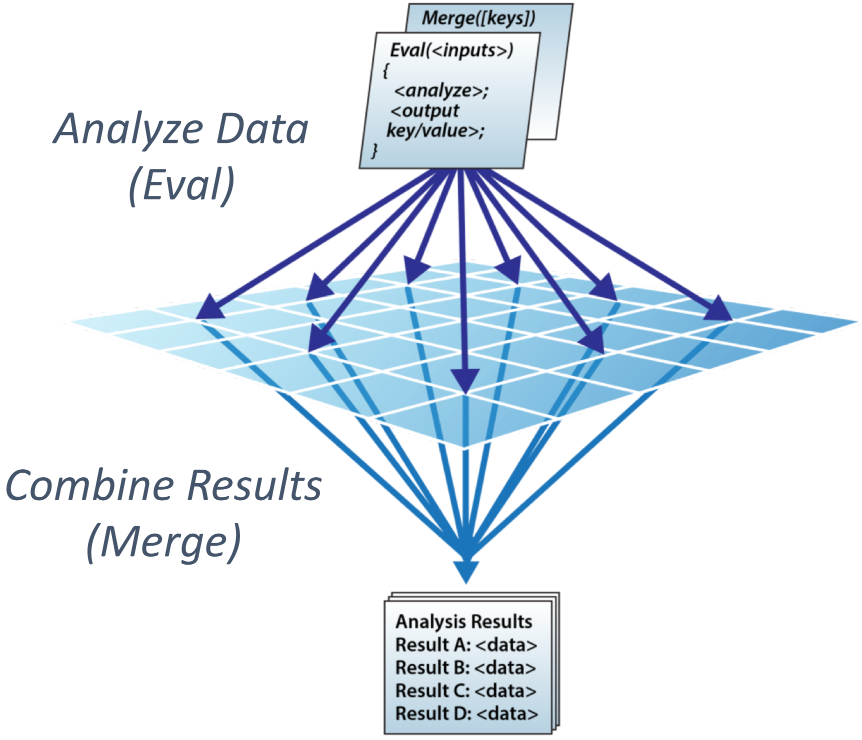
In-Memory Computing Delivers OI in Three Ways:

1. Captures live data with extremely low latency.
2. Continuously analyzes a live system to identify opportunities.
3. Makes automated decisions **before the moment is lost**.

Data-Parallel Computing for OI

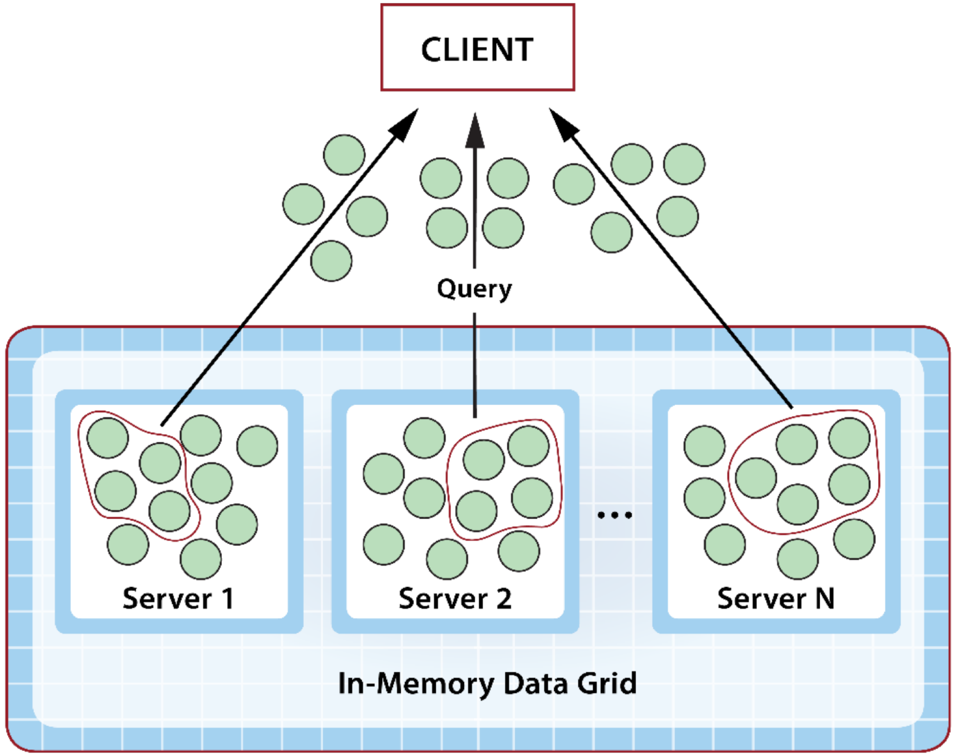
IMDG can have simple, fast APIs for scalable, data-parallel computing:

- "Parallel Method Invocation" (PMI)
  - Follows IMDG's object-oriented storage model.
  - Defines data-parallel tasks as class methods.
  - Runs class methods in parallel across the cluster and performs a distributed merge of results.
- Advantages:
  - Uses standard, well understood "eval/merge" paradigm from parallel supercomputing.
  - Takes advantage of cluster's servers and cores.
  - Moves the code to the data; avoid delays due to data motion.
- Can be used to build more complex data-parallel operators (e.g., MapReduce)

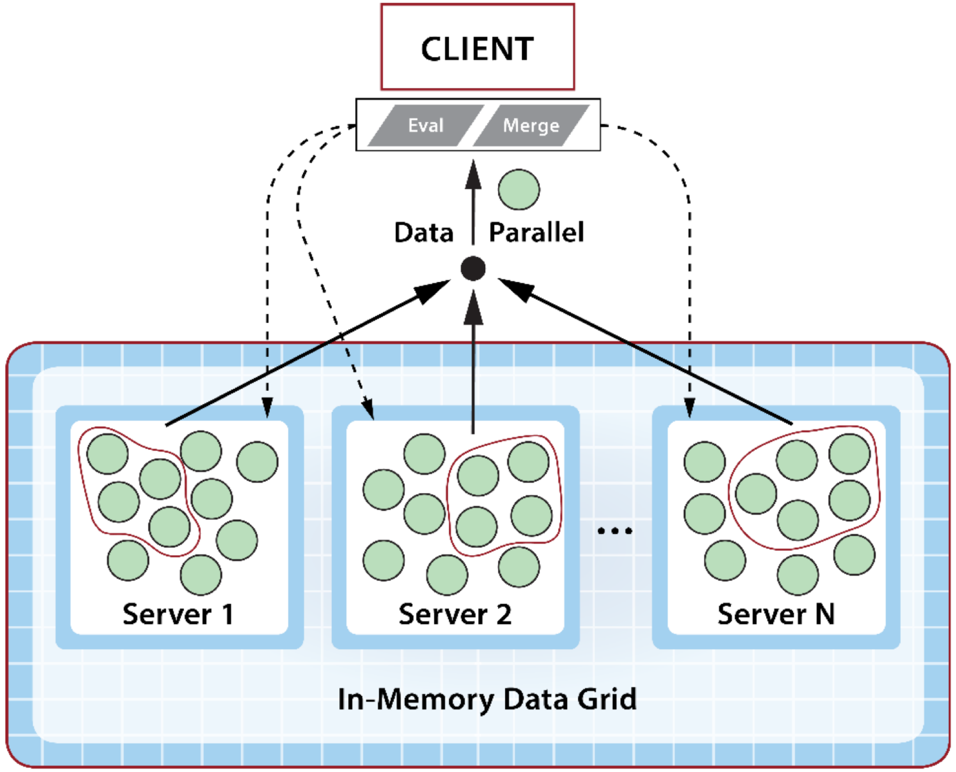


Comparing Query with Data-Parallel Computing

- Data-parallel computing moves the analysis to the IMDG and reduces data motion:



Query

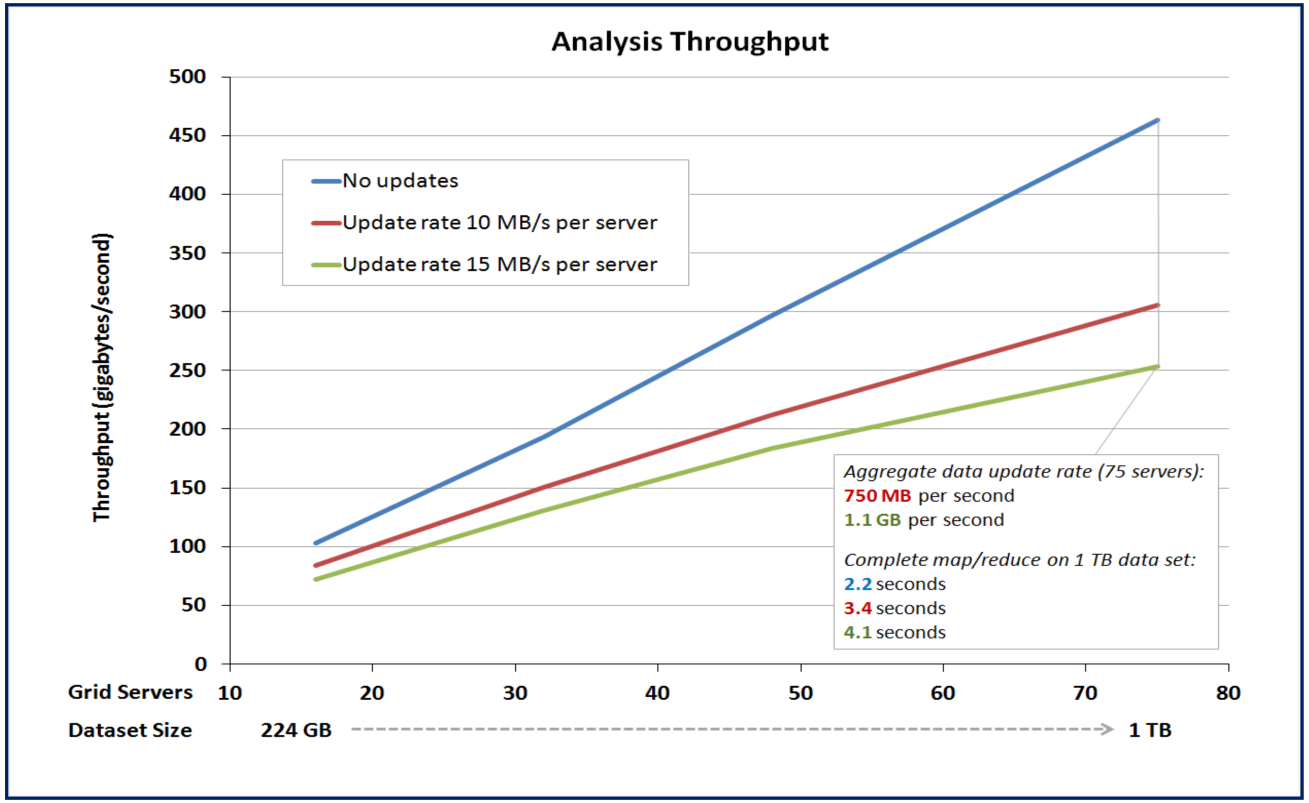


PMI

Example of PMI for OI in Financial Services

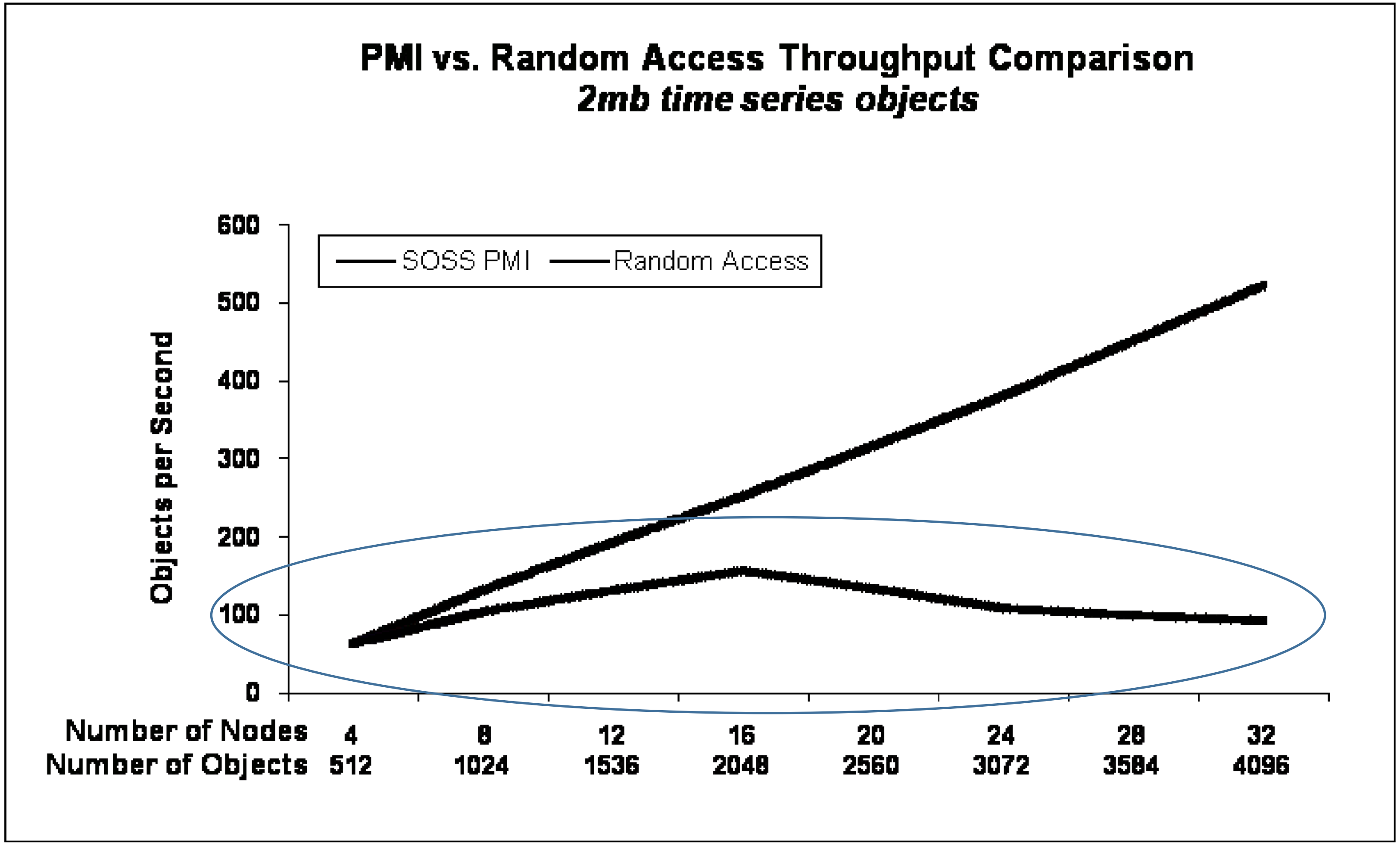
Back-testing stock trading strategies on stock histories:

- A widely used application - “embarrassingly parallel”
- Hosted an IMDG in Amazon EC2 using 75 servers holding **1 TB** of stock history data in memory
- IMDG handled a continuous stream of updates (**1.1 GB/s**)
- Results: analyzed 1 TB in **4.1 seconds** (250 GB/s).
- Observed near-linear scaling as dataset and update rate grew.



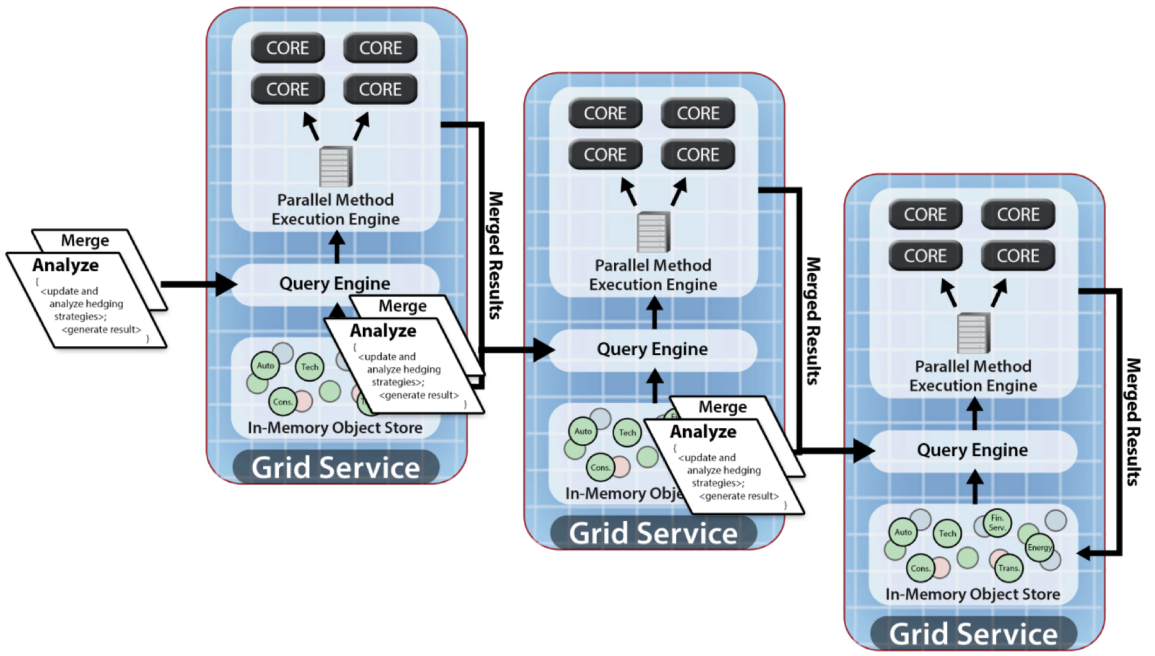
The Benefit of Computing in the IMDG

- Just using IMDG as a cache causes data motion for every operation.
- Network access creates a bottleneck that limits throughput and increases latency.
- Avoiding data motion enables linearly scalable throughput for growing workloads => predictable, low latency.

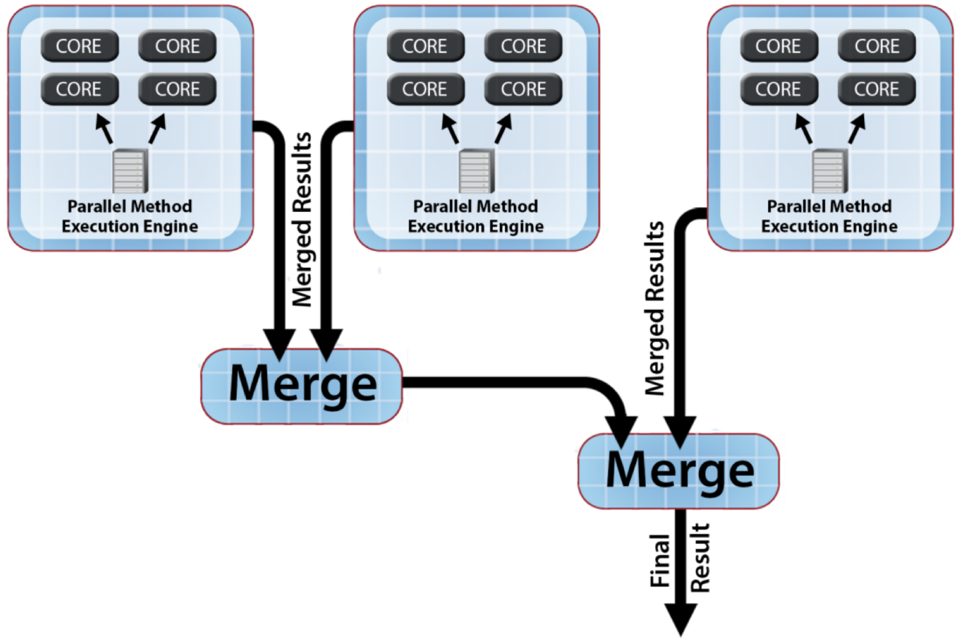


Data-Parallel Execution Steps

- **Eval** phase: each server queries local objects and runs eval and merge methods:
  - Accessing local objects avoids data motion.
  - Completes with one result object per server.

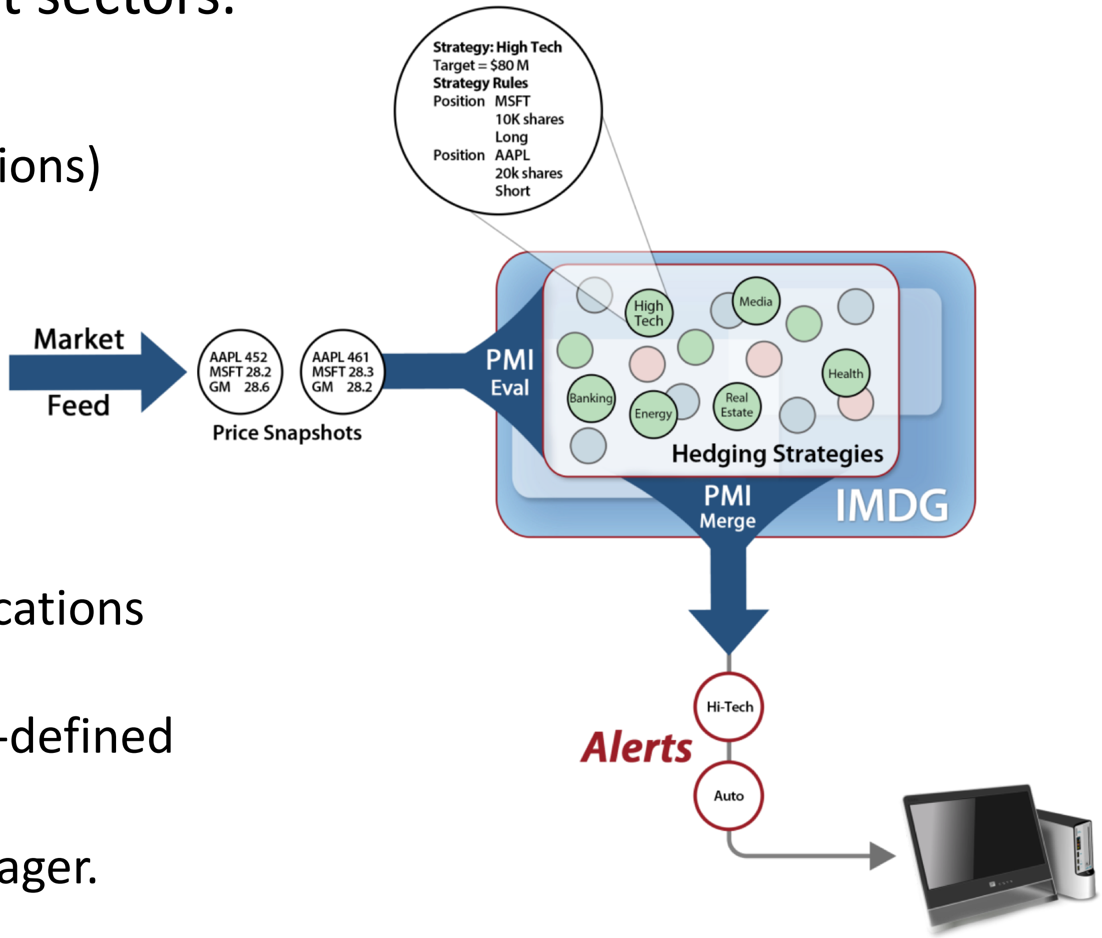


- **Merge** phase: all servers perform binary, distributed merge to create final result:
  - Merge runs in parallel to minimize completion time.
  - Returns final result object to client.



Example in Financial Services

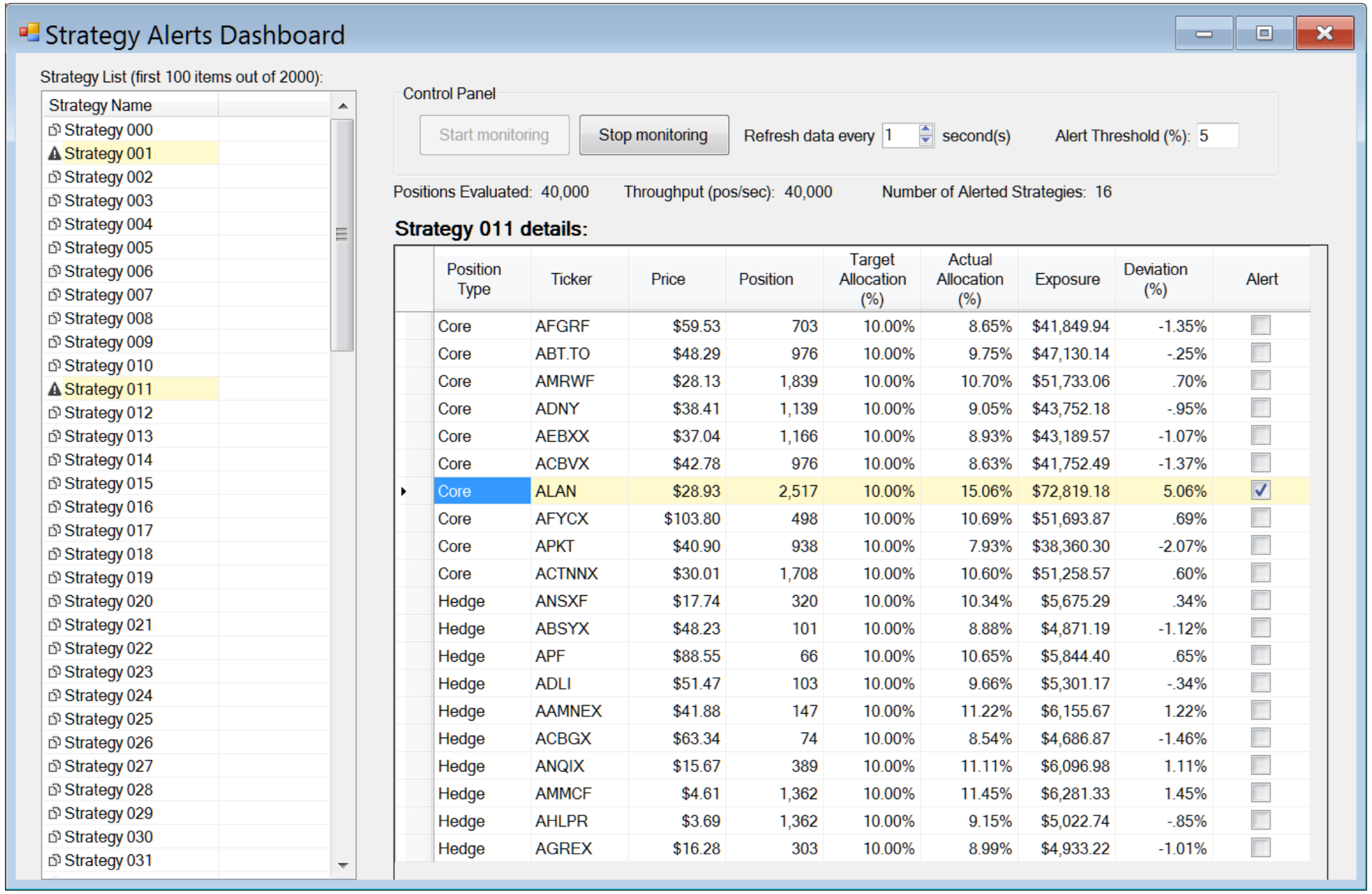
- **Goal**: track market price fluctuations for a hedge fund to keep portfolios in balance across market sectors.
- **Solution**:
  - Keep portfolios of stocks (long and short positions) in an object collection within IMDG.
  - Collect market price changes in one-second snapshots.
  - Define a method which applies a snapshot to each portfolio and optionally generates an alert to rebalance.
  - Perform periodic (1/sec) parallel method invocations on the collection of portfolios.
  - Combine alerts in parallel using a second user-defined merge method.
  - Report alerts to UI every second for fund manager.



Outputs Continuous Alerts to the UI

- PMI runs every second; it completes in **350 msec**. and immediately refreshes UI.

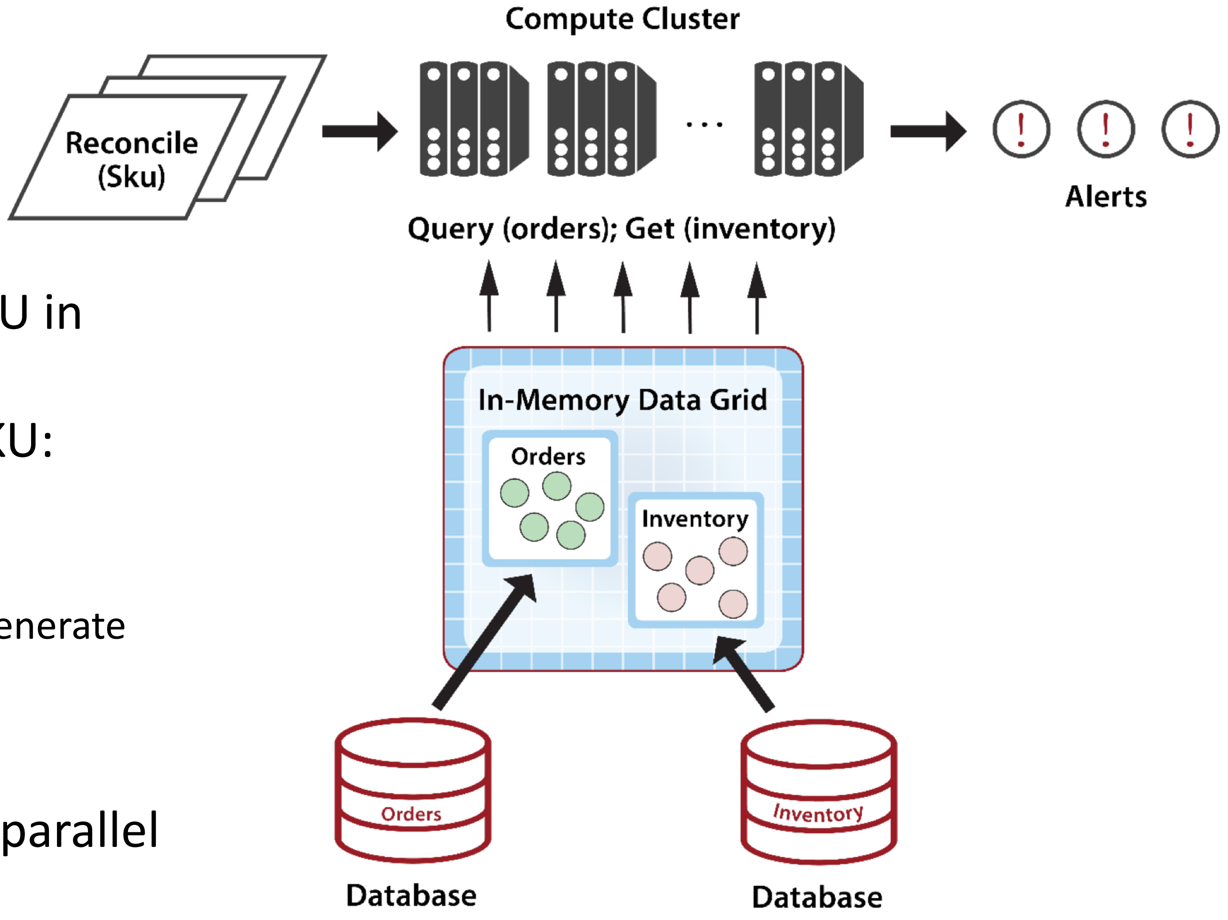
- Encapsulates proprietary analysis algorithm.
- UI alerts trader to portfolios that need rebalancing.
- UI allows trader to examine portfolio details and determine specific positions that are out of balance.



OI Example in Logistics

Goal: Match orders to inventory in real time and report issues before committing orders for perishable goods.

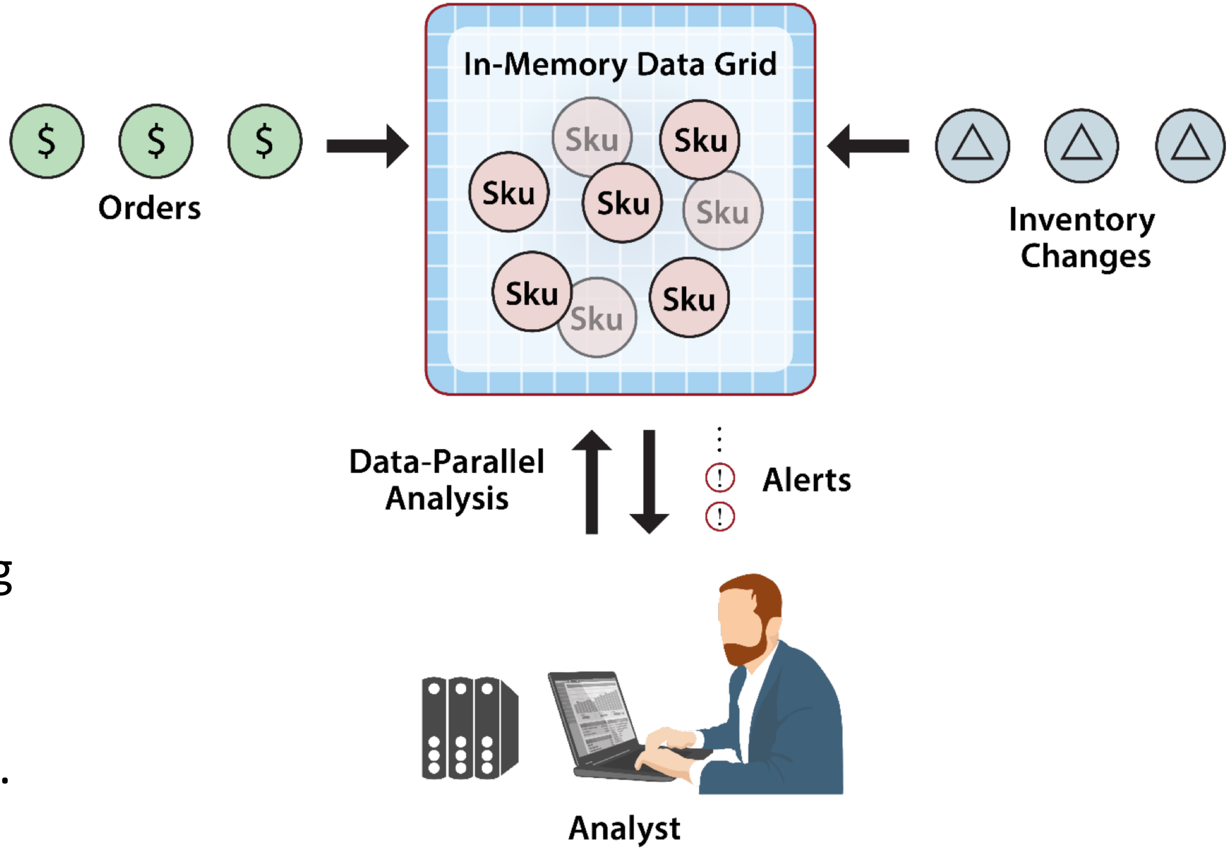
- **Customer's approach**:
  - Use IMDG as a cache with orders and inventory changes stored as objects by SKU in separate name spaces.
  - Perform nightly reconciliation; for each SKU:
    - Query all orders by SKU.
    - Query inventory changes by SKU.
    - Run proprietary reconciliation algorithm and generate alerts.
- **Problems**:
  - Very poor performance (1+ hours) due to parallel queries and data motion
  - Results not available in real time



Data-Parallel Solution

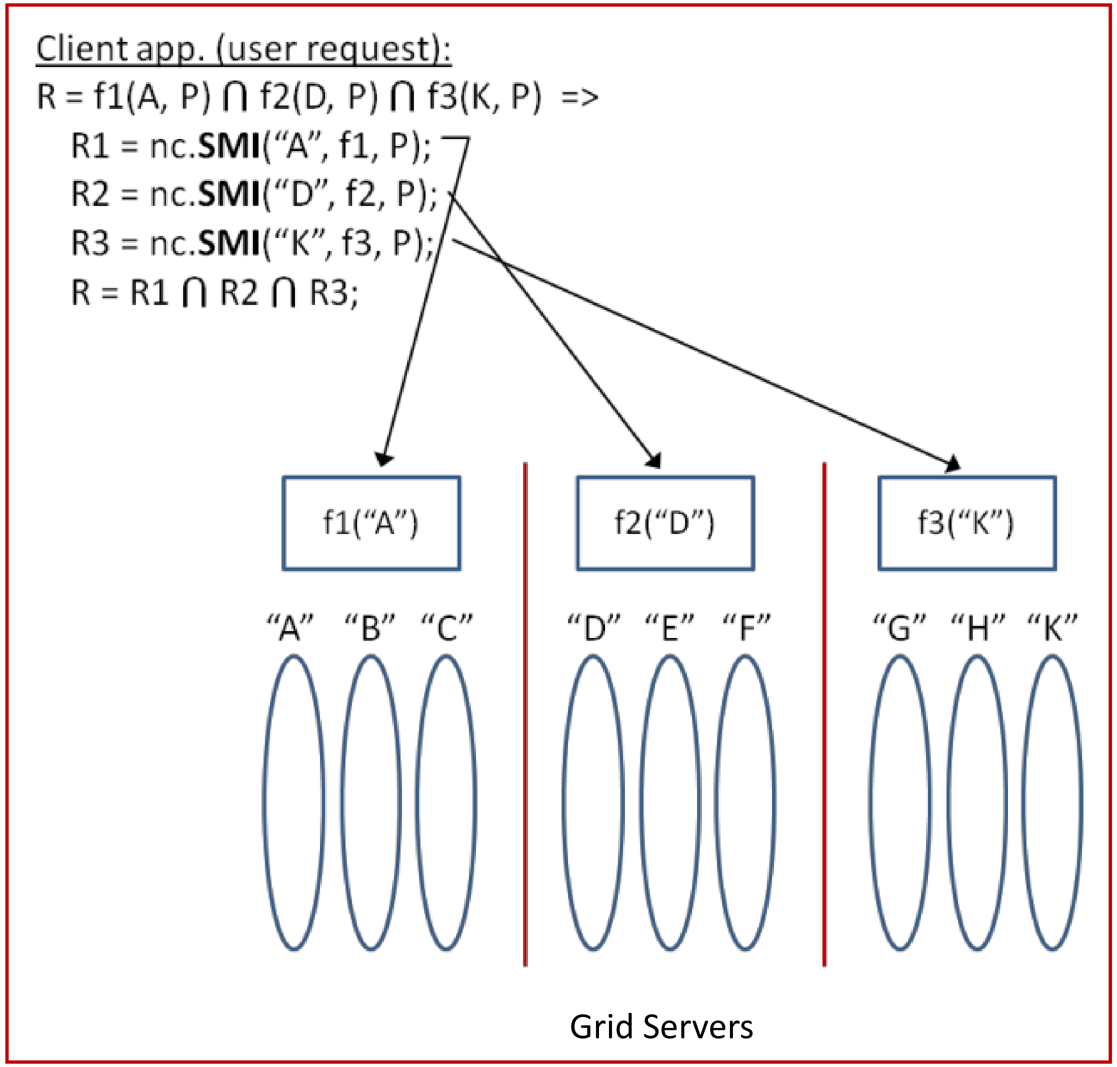
Key challenge for data-parallel computing: choose the right domain

- **Solution**: Store data by SKU in the IMDG and perform data-parallel reconciliation on all SKU objects.
  - Merge operation returns alerts.
- **Advantages**:
  - Pre-joined orders and inventory to avoid queries.
  - Avoided network bottleneck from sending objects to external compute cluster.
  - Eliminated need for a compute cluster.
  - Reduced reconciliation time to <1 minute.
  - Enabled real-time alerting.



Single Method Invocation (SMI)

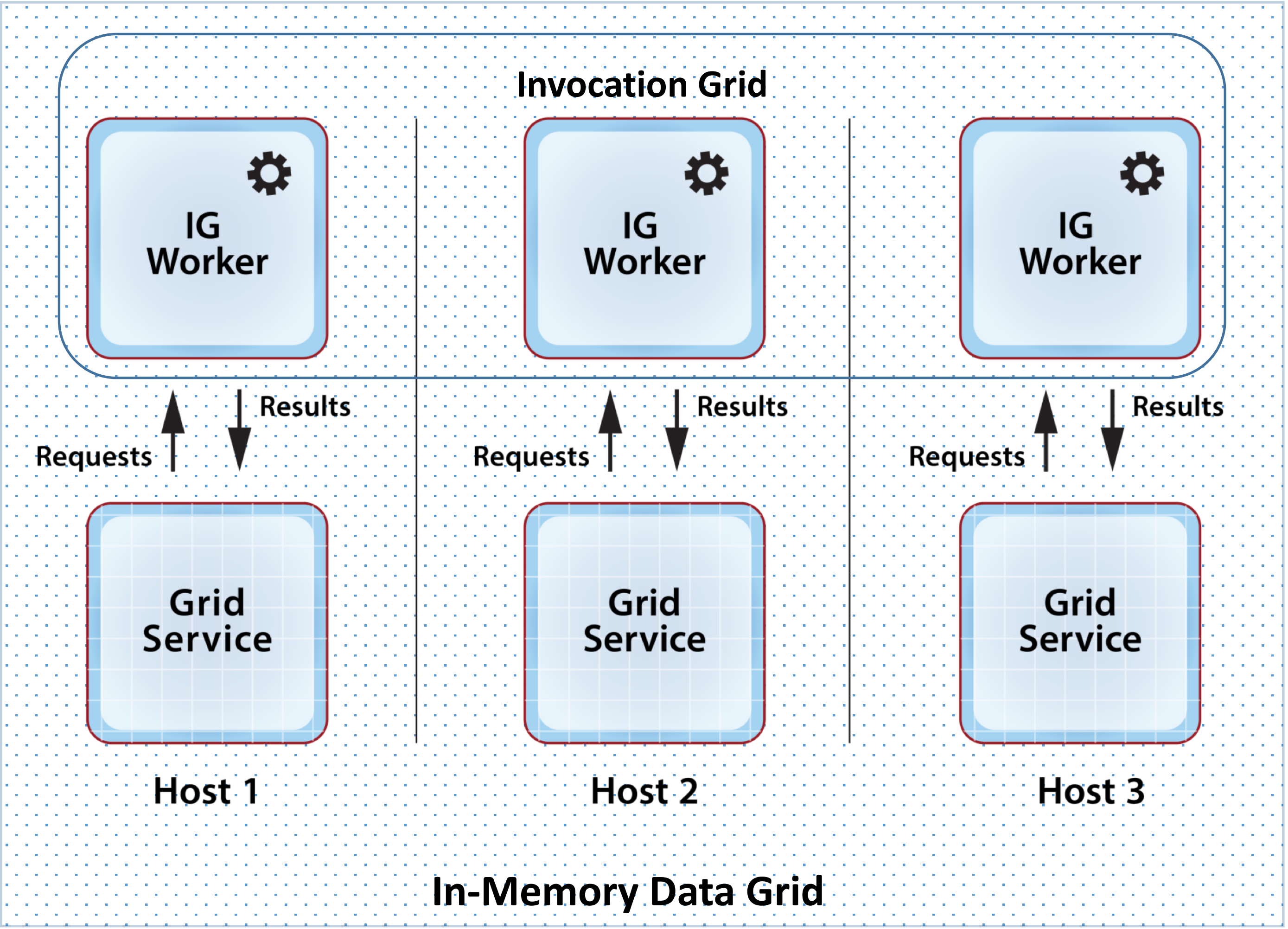
- Another form of data-parallel computation
- Created for a financial services application performing column-oriented computations.
- Invokes user-defined method on a single, selected object:
  - Ships parameters to invoking method.
  - Enables object to be updated.
  - Efficiently returns results to invoking client.
- **Benefits**:
  - Avoids data motion to/from client.
  - Encapsulates application code and stages code in the grid.
  - Minimizes latency to invoke method and return results.



Example of a Column-Oriented Computation with SMI

How an IMDG Runs Computations

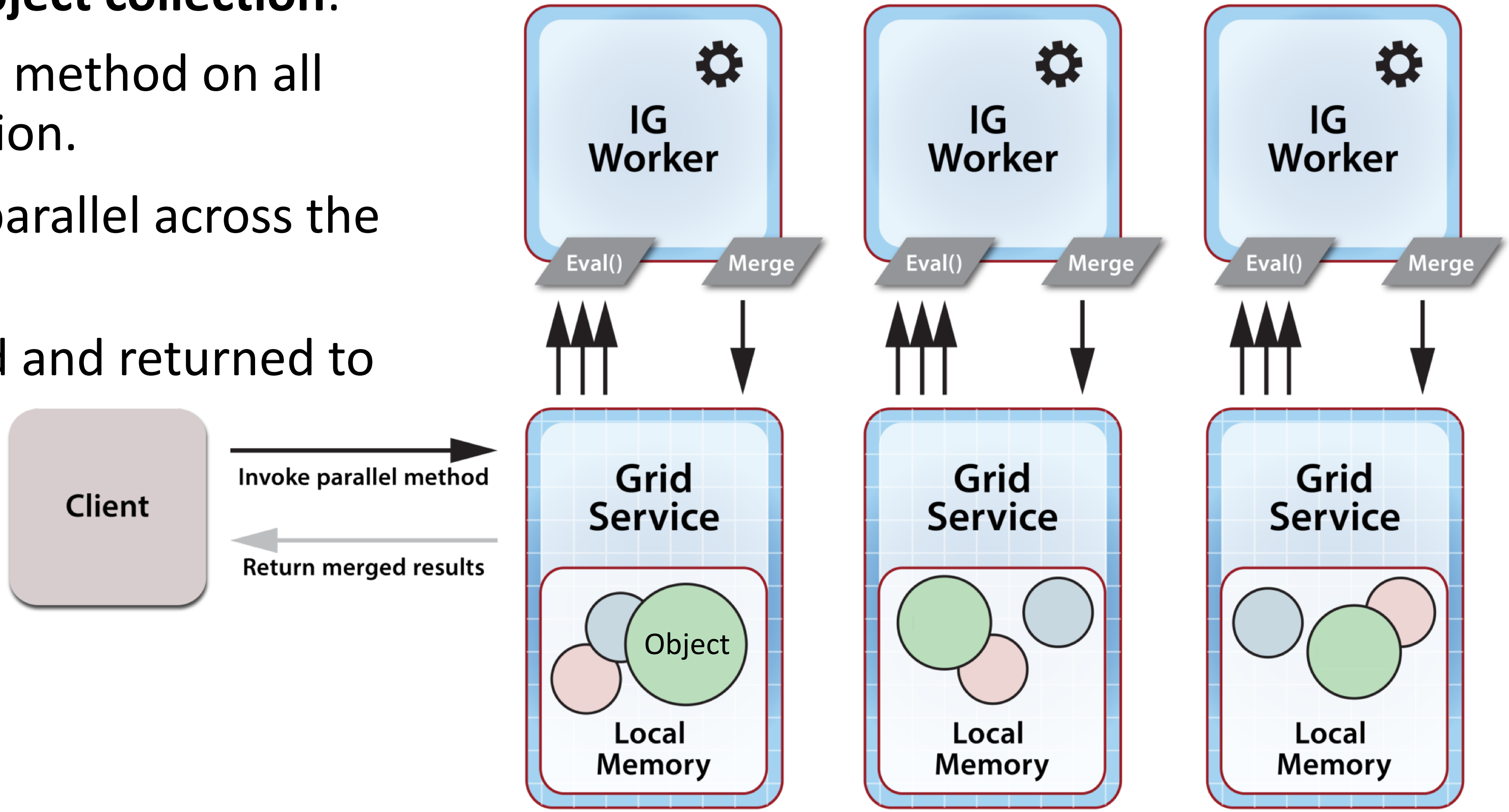
- Each grid host runs a worker process which executes application-defined methods on stored objects.
  - The set of worker processes is called an *invocation grid (IG)*.
  - IG usually runs language-specific runtimes (JVM, .NET).
  - IMDG can ship code to the IG workers.
- Key advantages for IGs:
  - Follows object-oriented model.
  - Avoids network bottlenecks by moving computing to the data.
  - Leverages IMDG's cores & servers.



IMDG Executes Data-Parallel Methods

Method execution implements a parallel op. on an object collection:

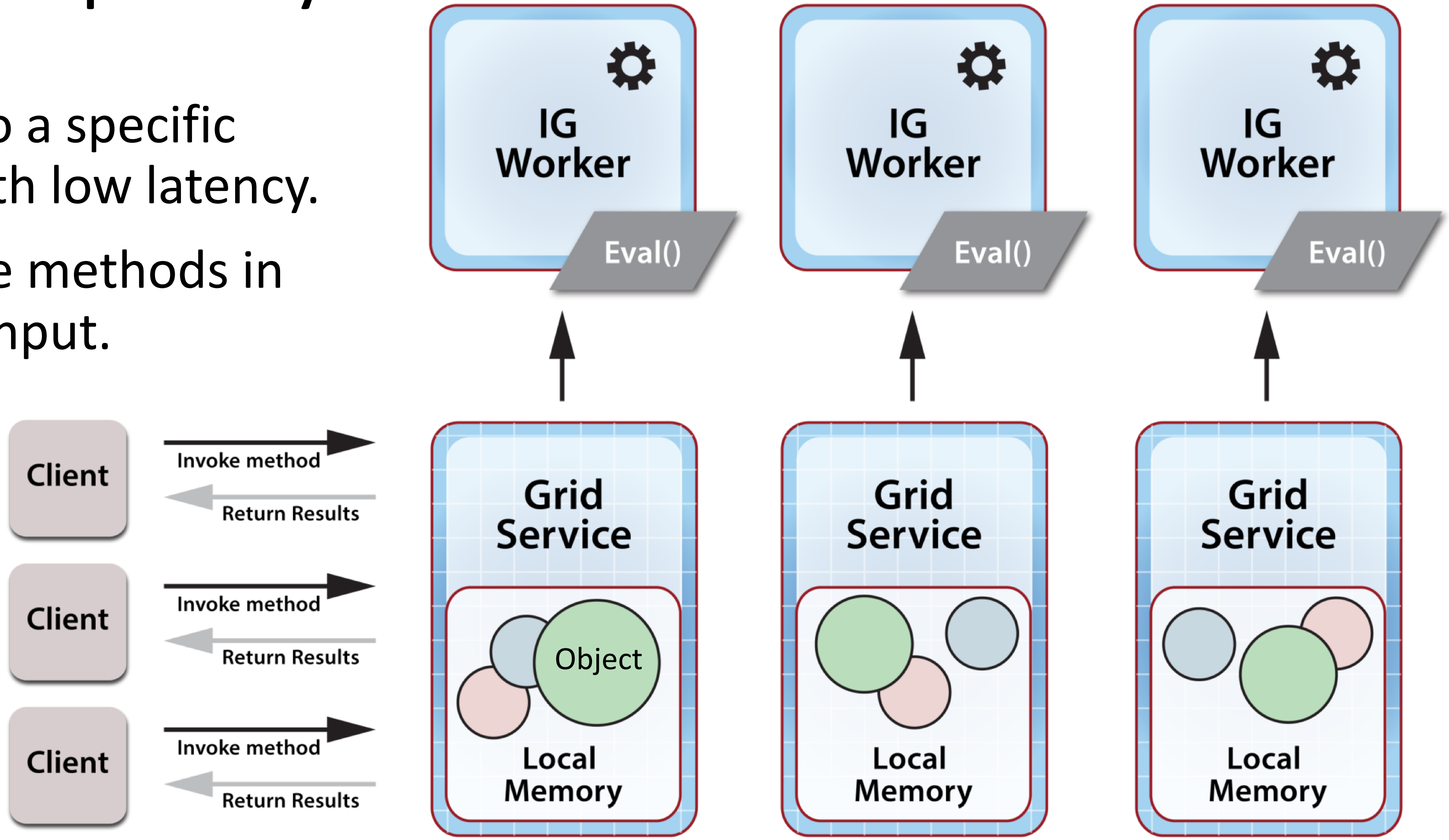
- Client runs a single method on all objects in a collection.
- Execution runs in parallel across the grid.
- Results are merged and returned to the client.



IMDG Executes Methods for Single Objects

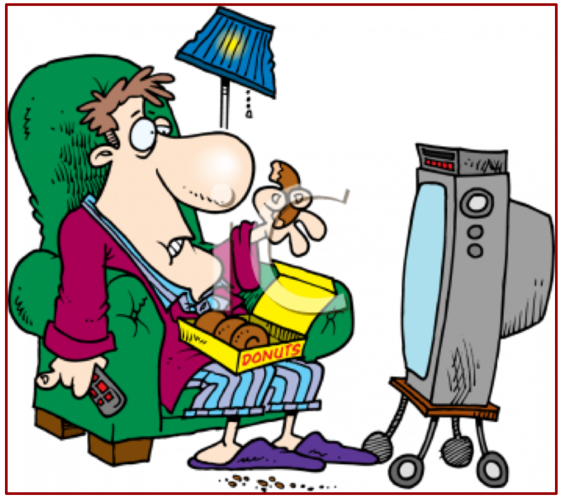
Method execution runs independently for each request:

- IMDG directs request to a specific object for execution with low latency.
- IMDG executes multiple methods in parallel for high throughput.



OI Example: Tracking Cable Viewers

- **Cable Company's Goals:**
  - Make real-time, personalized upsell offers.
  - Immediately respond to service issues & hotspots.
  - Track aggregate behavior to identify patterns, e.g.:
    - Total instantaneous incoming event rate from set-top boxes
    - Most popular programs and # viewers by zip code
- **Requirements:**
  - Track channel-change events from 10M set-top boxes with 25K events/sec (2.2B/day).
  - Correlate, cleanse, and enrich events per rules (e.g. ignore fast channel switches, match channels to programs) within 5 seconds (from current 6+ hours).
  - Refresh aggregate statistics every 10 seconds.



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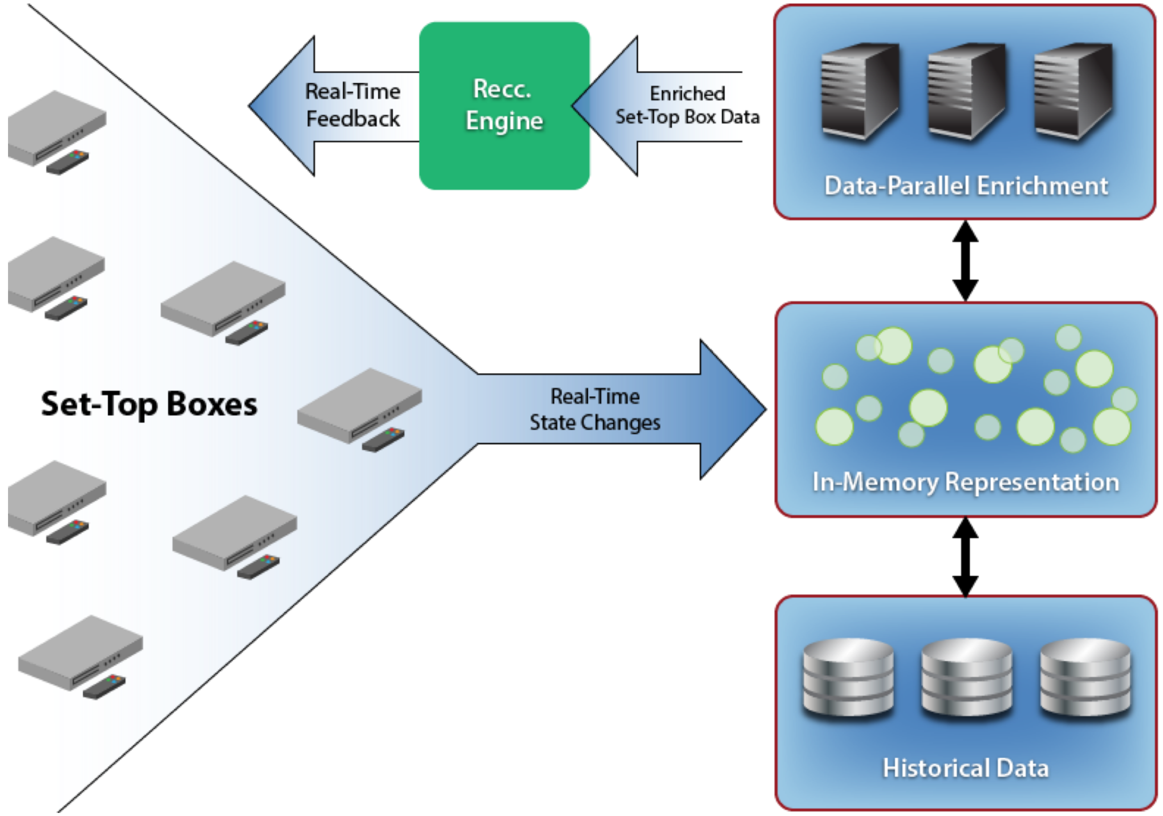
Implementation with both SMI and PMI

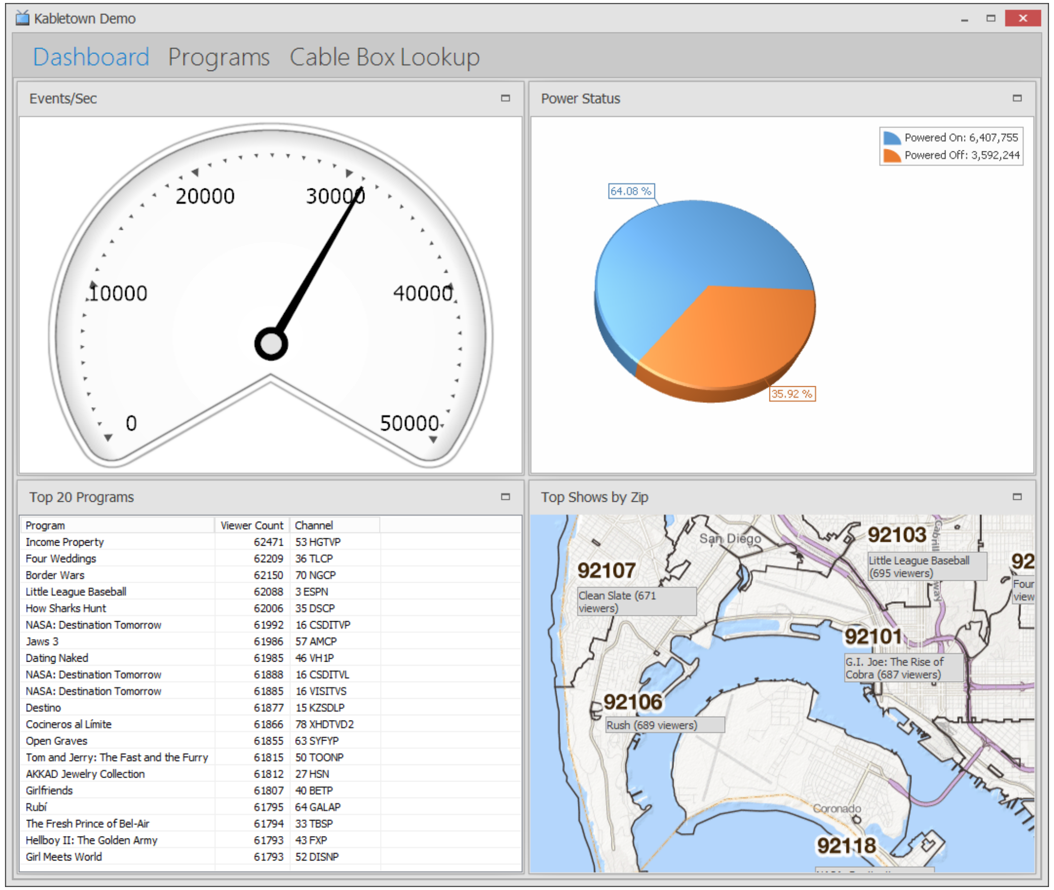
- Each set-top box is represented as an object in the IMDG
- Object holds raw & enriched event streams, viewer parameters, and statistics
- IMDG captures incoming events by updating objects
- IMDG uses both forms of data-parallel computation to:
  - immediately update box objects to generate alerts to recommendation engine using SMI, and
  - continuously collect and report global statistics using PMI across box objects
- Demonstrates the use of an IMDG for stream processing.



Synthetic Workload Demonstration

Built a POC to demonstrate performance and scalability for cable vendor:

- Based on a simulated workload for San Diego metropolitan area
- Continuously correlated and cleansed telemetry from 10M simulated set-top boxes (using a synthetic load generator)
- Processed more than 30K events/second
- Enriched events with program information every second
- Tracked aggregate statistics (e.g., top 10 programs by zip code) every 10 seconds

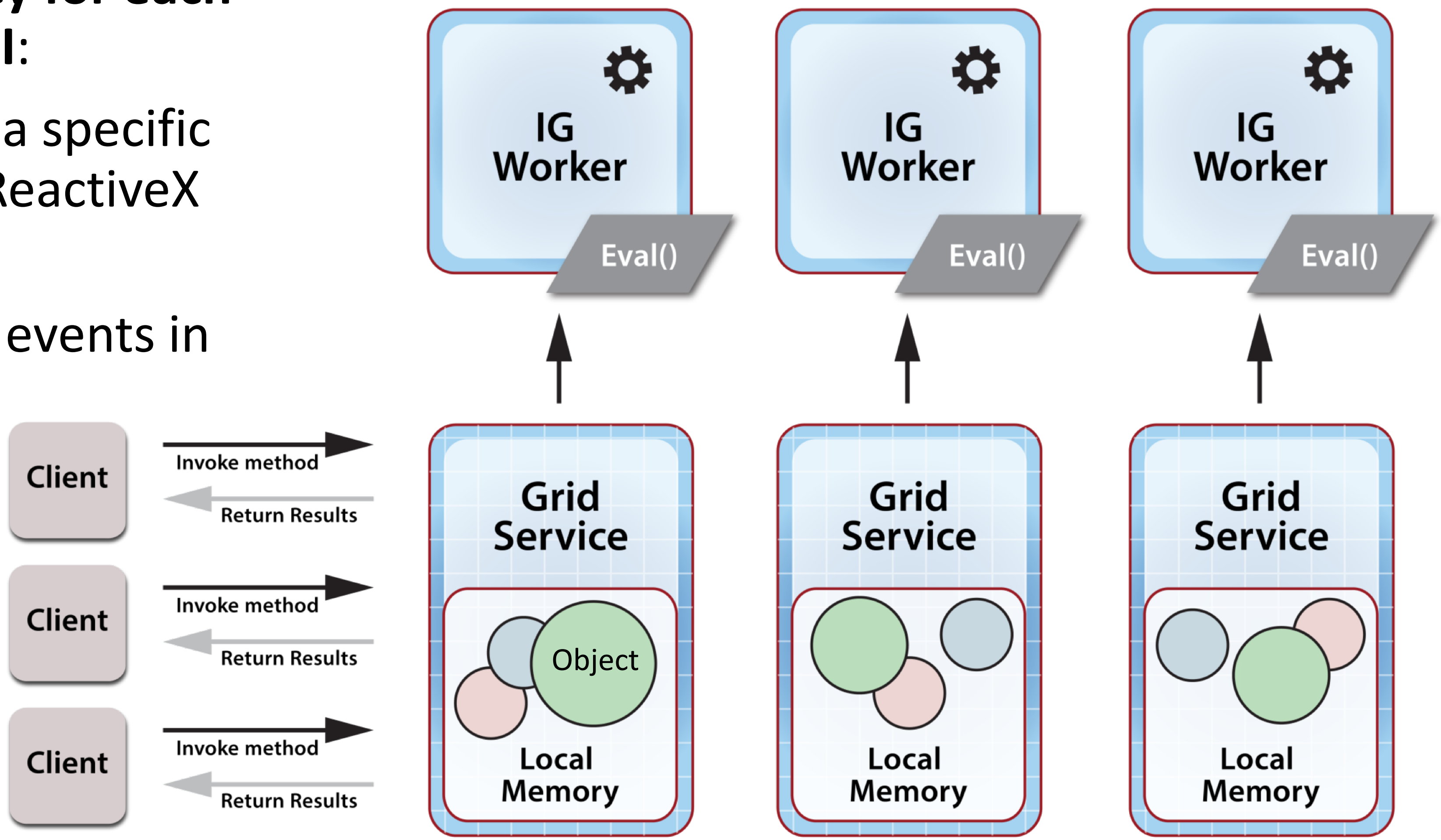


Real-Time Dashboard

IMDG Processes Events with ReactiveX

ReactiveX reduces latency for each request compared to SMI:

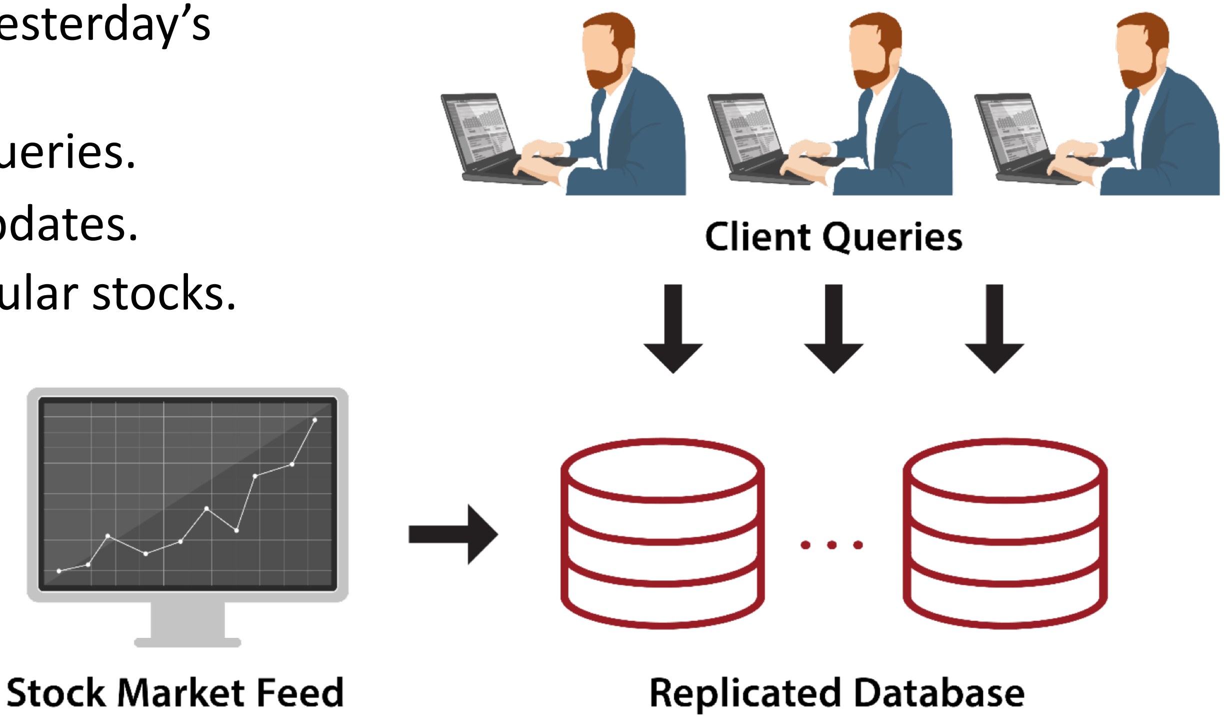
- IMDG directs events to a specific object for handling by ReactiveX observers.
- IMDG handles multiple events in parallel for high throughput.



Stream Processing for Fast Queries

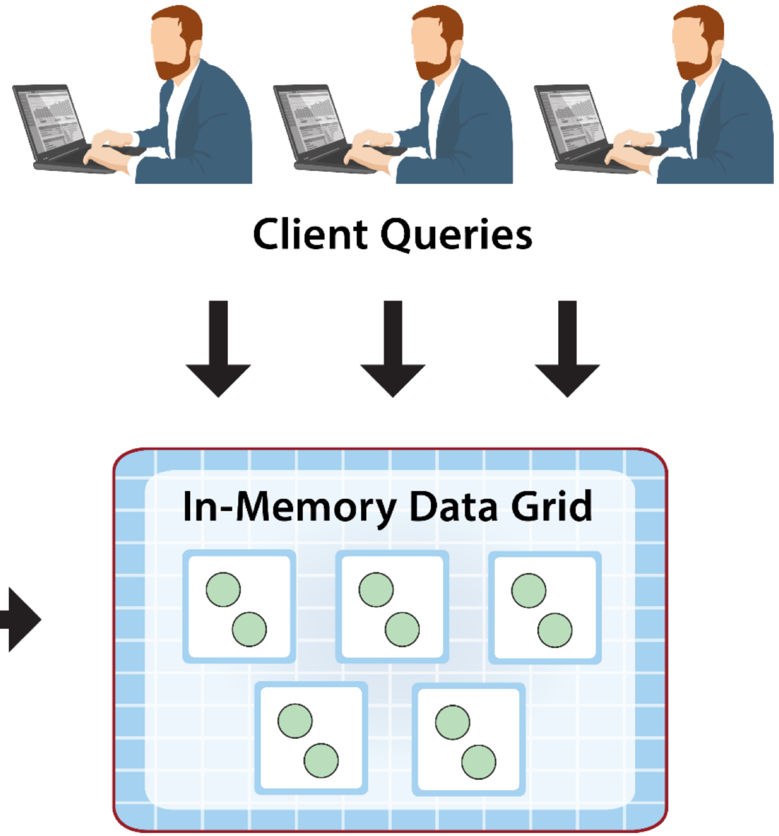
Challenge: How to query stock histories that are being continuously updated from a ticker feed?

- Requirements:
  - Must hold all prices from today's and yesterday's ticker feed.
  - Must support 1000s of simultaneous queries.
  - Each query must see the latest price updates.
  - Queries may have hotspots due to popular stocks.
- Current solution:
  - Replicate all stock price data across 12+ databases for simultaneous access.
  - Use a compute cluster.
  - Not clear how to keep databases coherent; expensive



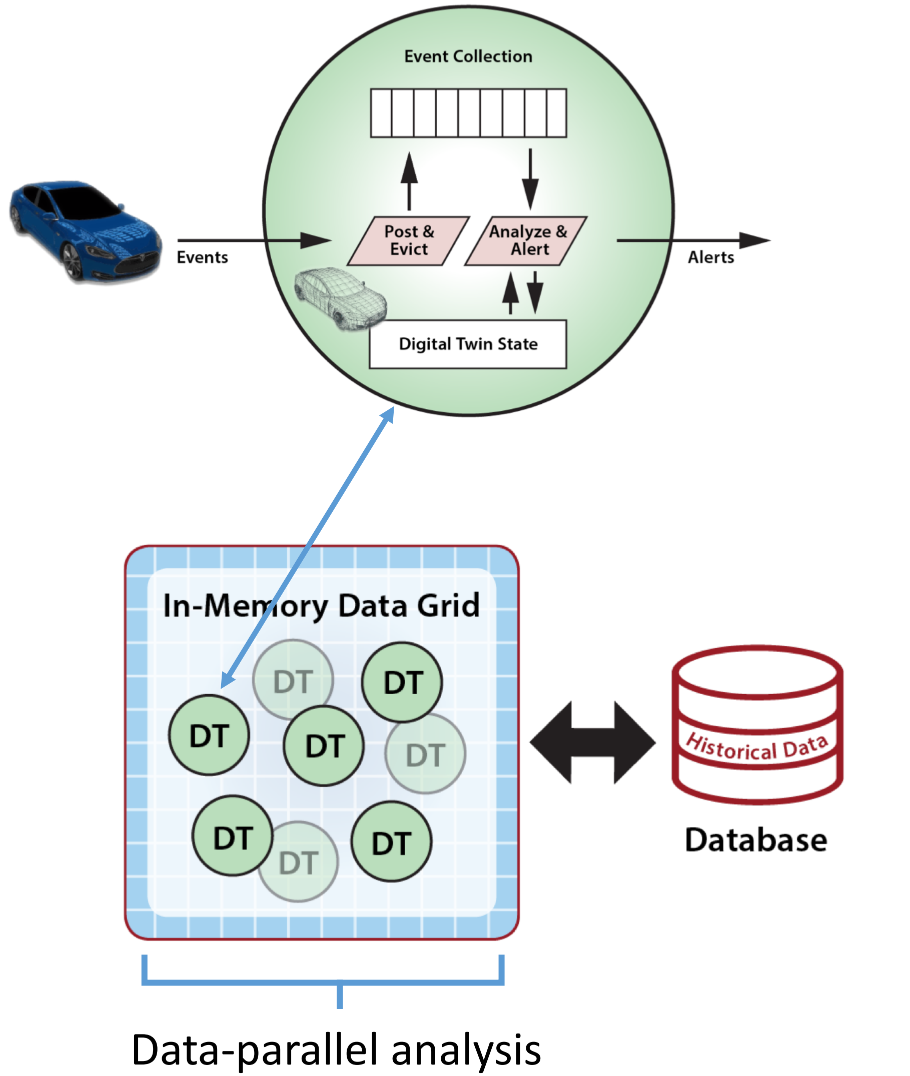
Solution Using an IMDG

- Store each stock's price history as a pair of objects (today's and yesterday's prices).
- Apply updates to today's stock prices as streaming events.
- Query stock prices with fast key/value reads.
- Client caches host latest values for objects using 2+ objects per stock minimizes data motion.
- Implement a special read mode that always reads cache and asynchronously applies updates to refresh.
- Advantages:
    - All queries have fast, predictable latency.
    - Hotspots do not affect latency.



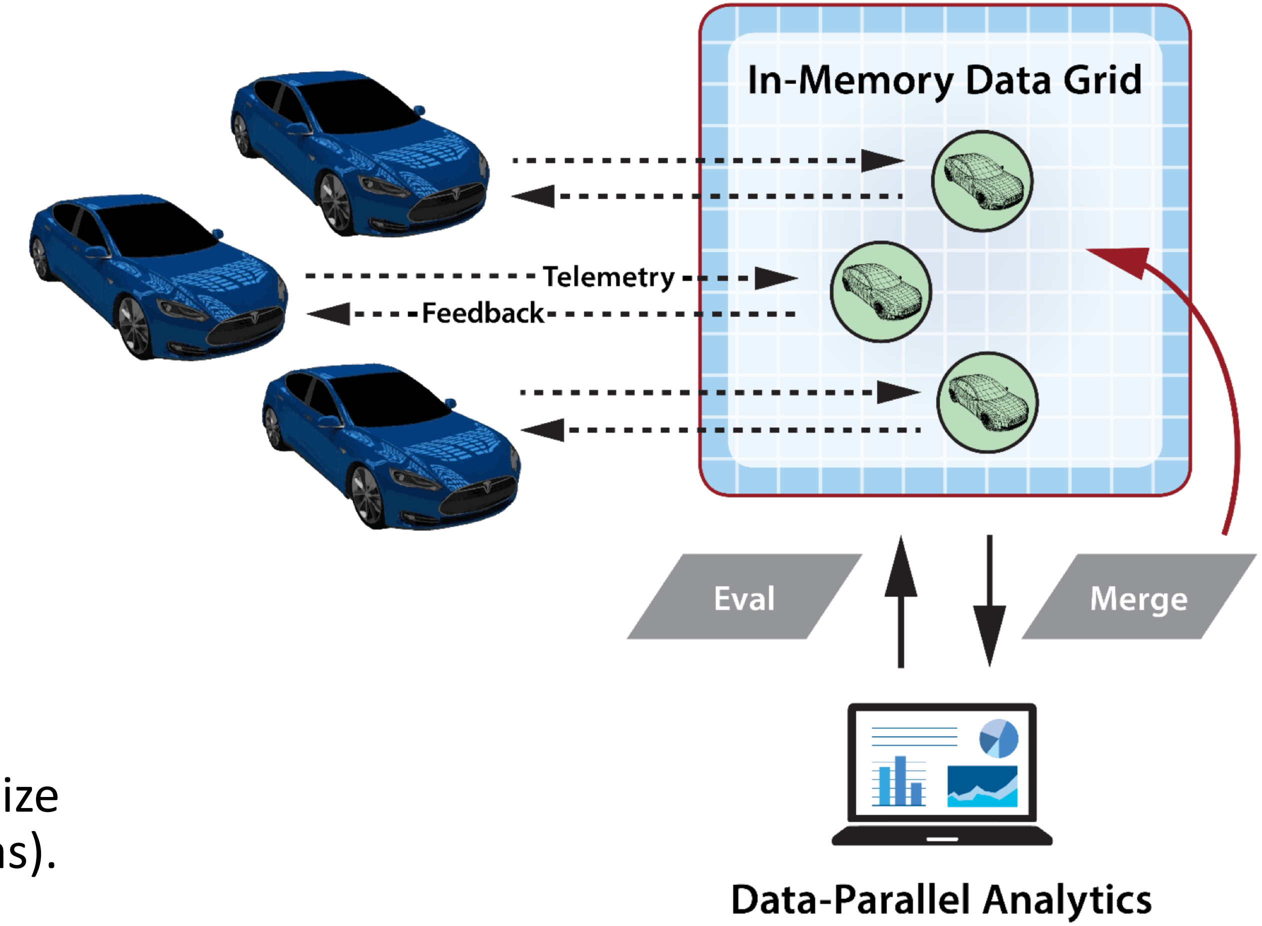
Stateful Stream-Processing on an IMDG

- IMDG is well suited to use the “digital twin” model created by Michael Grieves; popularized by Gartner.
- This model represents each data source with a grid object that holds:
  - An event collection
  - State information about the data source
  - Logic for analyzing events, updating state, and generating alerts
- Benefits:
  - Offers a structured approach to stateful stream processing.
  - Automatically correlates incoming events by data source.
  - Integrates all relevant context (events & state).
  - Enables easy deployment of application-specific logic (e.g., ML, rules engine, etc.) for analysis and alerting.
  - Provides domain for aggregate analysis and feedback.



Example: Tracking a Fleet of Vehicles

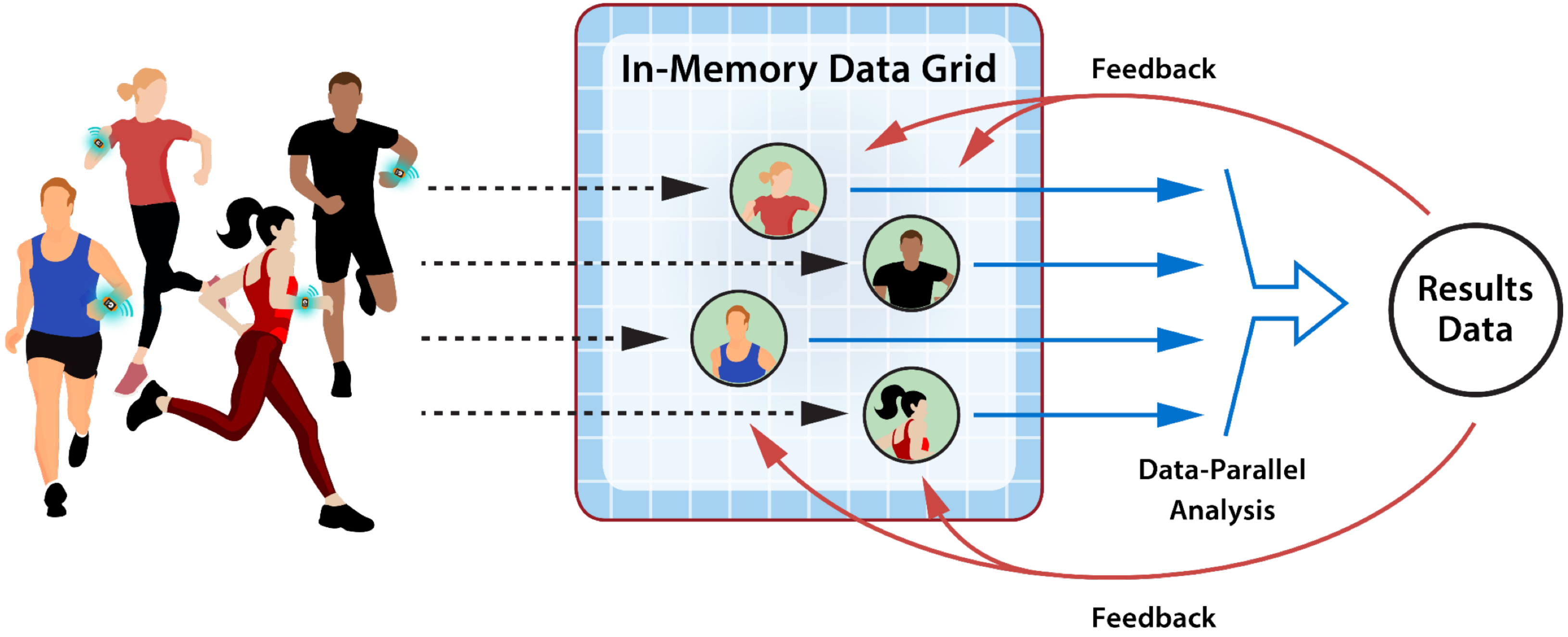
- **Goal:** Track telemetry from a fleet of cars or trucks.
  - Events indicate speed, position, and other parameters.
  - Digital twin object stores information about vehicle, driver, and destination.
  - Event handler alerts on exceptional conditions (speeding, lost vehicle).
- Periodic data-parallel analytics determines aggregate fleet performance:
  - Computes overall fuel efficiency, driver performance, vehicle availability, etc.
  - Can provide feedback to drivers to optimize operations (e.g., avoiding congested areas).



Example: Heart-Rate Watch Monitoring

Tracks heart-rate for a large population of runners:

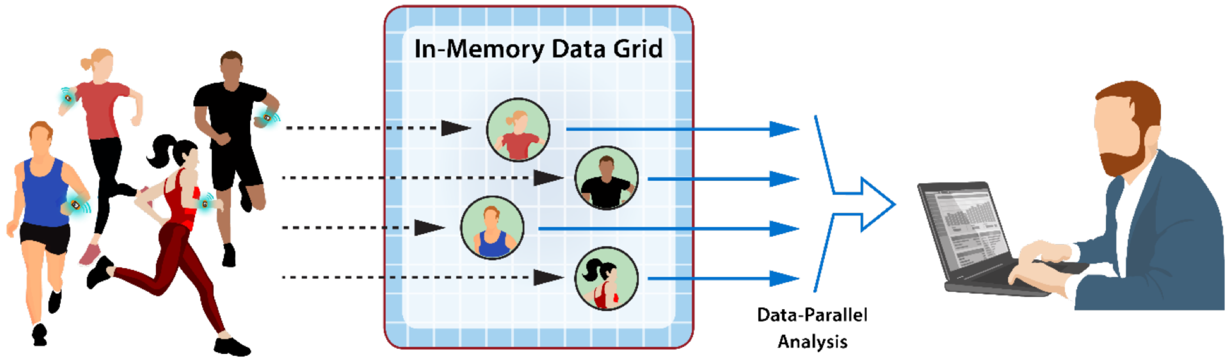
- Heart-rate events flow from smart watches to their respective digital twin objects for analysis.
- The analysis uses wearer's history, activity, and aggregate statistics to determine feedback and alerts.



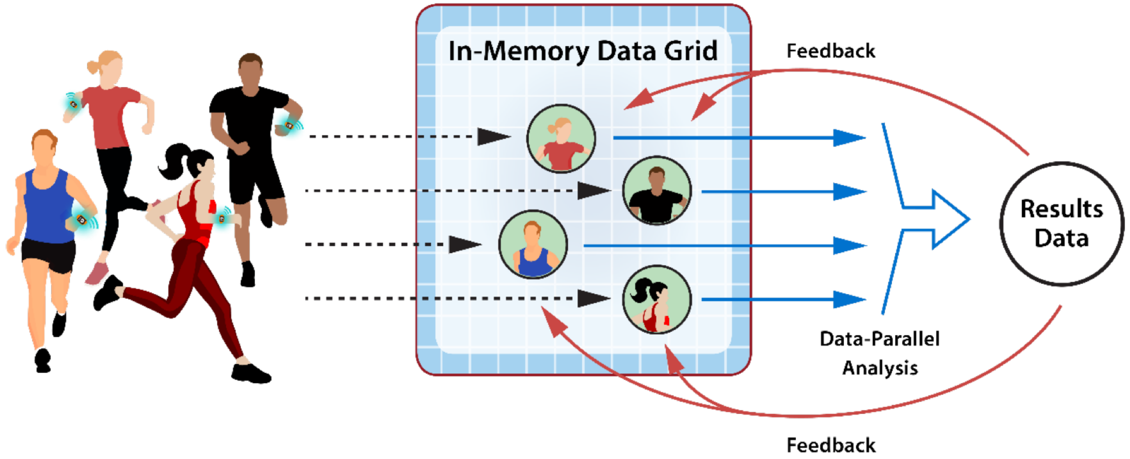
Data Parallel Analysis Across all Digital Twins

- Uses IMDG's in-memory compute engine to create aggregate statistics in real time.

- Results can be reported to analysts and updated every few seconds.



- Results can be used as feedback for event analysis in digital twin objects and/or reported to users.



Example: Ecommerce Recommendations

Goal: Deliver real-time recommendations to 1000s of online shoppers.

- Each shopper generates a clickstream of products searched.
- Stream-processing system must:
  - Correlate clicks for each shopper and associate with shopper's preferences.
  - Maintain a history of clicks during a shopping session.
  - Analyze clicks to create new recommendations within 100 msec.
- Analysis must:
  - Take into account the shopper's preferences and demographics.
  - Create and use aggregate feedback on collaborative shopping behavior.

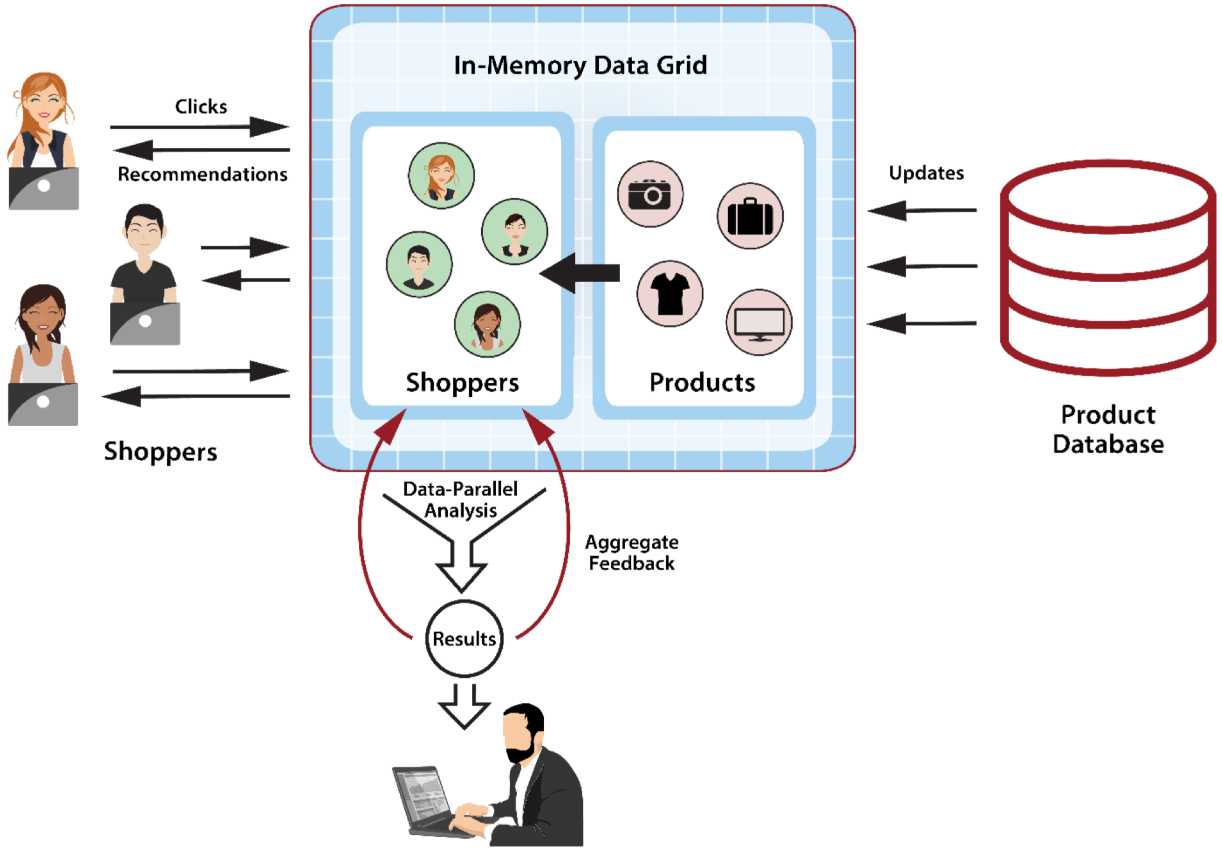
Providing Recommendations in Real Time

- Requires scalable stream-processing to analyze each click and respond in <100ms:
  - Accept input with each event on shopper’s preferences.
  - Provide aggregate feedback on best-selling products.

Implementation Using Digital Twin Objects

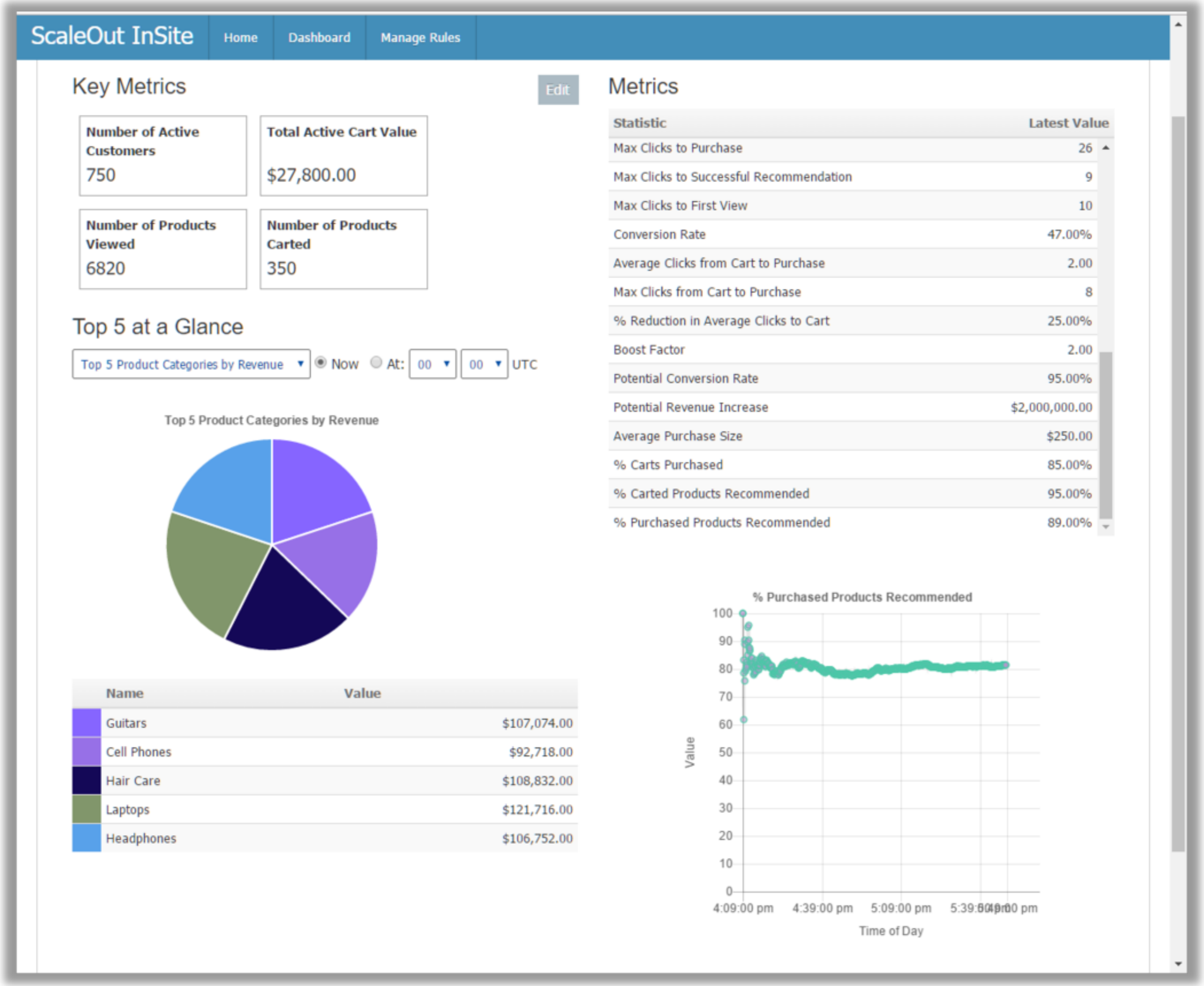
Tracks shoppers as digital twins and makes real-time recommendations:

- Each DT object holds clickstream of browsed products, preferences, and demographics.
- Event handler analyzes this data and immediately updates recommendations.
  - Product descriptions are kept in second object collection in the IMDG.
  - These descriptions are uploaded from the product database.
- Periodic data-parallel, batch analytics across all shoppers determine aggregate trends:
  - Examples include best selling products, average basket size, etc.
  - Used for analysis and real-time feedback



Providing Key Aggregate Metrics

- Periodic data-parallel computation generates aggregate statistics across DT objects for all shoppers.
  - Tracks real-time shopping behavior.
  - Charts key purchasing trends.
  - Enables merchandizer to create promotions dynamically.
- Aggregate statistics can be shared with shoppers:
  - Allows shoppers to obtain collaborative feedback.
  - Examples include most viewed and best selling products.



Wrap-Up

In-memory computing enables *operational* intelligence.

- **Challenge**: using an IMDG solely as a cache does not take advantage of its ability to introspect on live data and return results in real time.
  - Users tend to view IMDGs as in-memory databases and rely heavily on queries.
- **Operational intelligence can capture new opportunities** that boost competitive value.
- **Data-parallel computing for OI in an IMDG** offers several key benefits:
  - It boosts application performance by moving code to the data, avoiding network bottlenecks.
  - It can be implemented using object-oriented constructs, which cleanly separate application code from the IMDG's orchestration mechanisms.
  - It delivers results in real time for live data.
- **Stream processing in an IMDG** allows deeper introspection than previously possible:
  - IMDGs provide an excellent platform for the digital twin model, which has many applications.

In-Memory Computing for Operational Intelligence

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