Session Advanced System Control,

Modeling & Analytics

Advanced Utility Analytics with Object-Oriented Database Technology

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USA

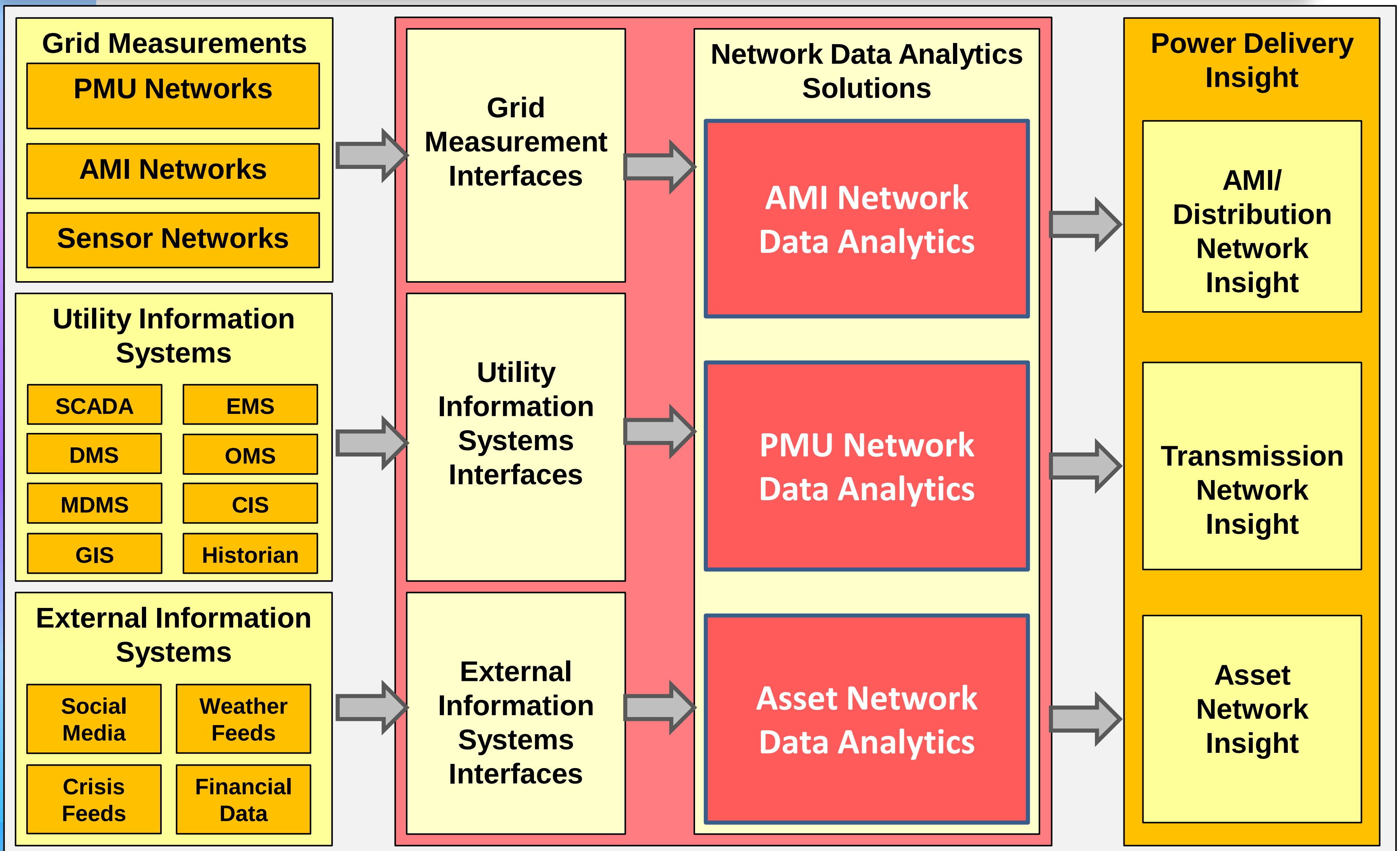
Overview

- Uniqueness of the Big Utility Data context and critical Use Cases requiring Advanced Data Management and Analytics Technologies,
- NoSQL Data Management & Analytics Solution Development Framework for Utilities/ISOs,
- Examples of effective Performance of NoSQL Data Management & Analytics Solutions for Utilities/ISOs:
  - Example 1: NoSQL Solution to create SA in Transmission
  - Example 2: AMI/Asset End Device Event Data Management
  - Example 3: Total Cost of Ownership & Performance (NoSQL/MySQL)

Uniqueness of Big Utility Data Context and Critical Use Cases describing the Need for Advanced Utility Data Management and Analytics

Big Energy Data Features	Energy Data Types	Energy Data Sample Rates
Data Volume (e.g. TBytes per Day)	Telemetric Data (e.g. in SCADA Systems; normally in Historian)	µs – Range (e.g. HF Switching Devices)
Data Velocity (e.g. 300,000 Data Objects/sec)	Oscillographic Data (e.g. in Power Quality Monitor; normally in Historian)	ms – Range (e.g. PMU Devices)
Data Variety (e.g. Large Variety of Data Object Types/Classes)	Usage Data (e.g. in Meter Data Management System; normally in RDBMS)	sec – Range (e.g. DER Output Variations)
Data Validity (e.g. Large Variety in Data Object Shelf Life)	Asynchronous Event Messages (e.g. in Distribution Managem. System; normally in RDBMS)	min – Range (e.g. Service Restoration)
Data Veracity (e.g. Large Variety of Data Objects with different Data Quality)	Meta Data (e.g. in Geospatial Info System; normally in RDBMS)	hour – Range (e.g. Demand Response)
		Day – Range (e.g. Day-ahead Scheduling)
		Year – Range (e.g. Life of IT Asset)
		Decade – Range (e.g. Life of OT Asset)

Utility Data Management & Analytics – Network Data Analytics Use Cases



Integrated NoSQL Data Management & Analytics Solution Development Framework for Utilities/ISOs

RDBMS
(since early 1970s)

DBMS in which information is represented in form of tables with additional relations between the tables.

Object – Relational Impedance Mismatch between OOP and RDBMS

OOP
(since late 1950s/MIT)

Programming paradigm representing concepts as objects with data fields describing the object (attributes) and associated procedures called methods (e.g. C++/Java are OOP languages).
Collection of interacting objects vs. task list

OODBMS
(since early 1980s)

DBMS in which information is represented in form of objects.

OOP and RDBMS are extremely common in software today. OODBMS is less adopted even though much better performance and cost – to – performance ratio.

In OOP, each object is capable of receiving messages, processing data, and sending messages to other objects. Each object can be viewed as an independent "machine" with a distinct role or responsibility.

Utility Data Management & Analytics – NoSQL Solution Development Framework

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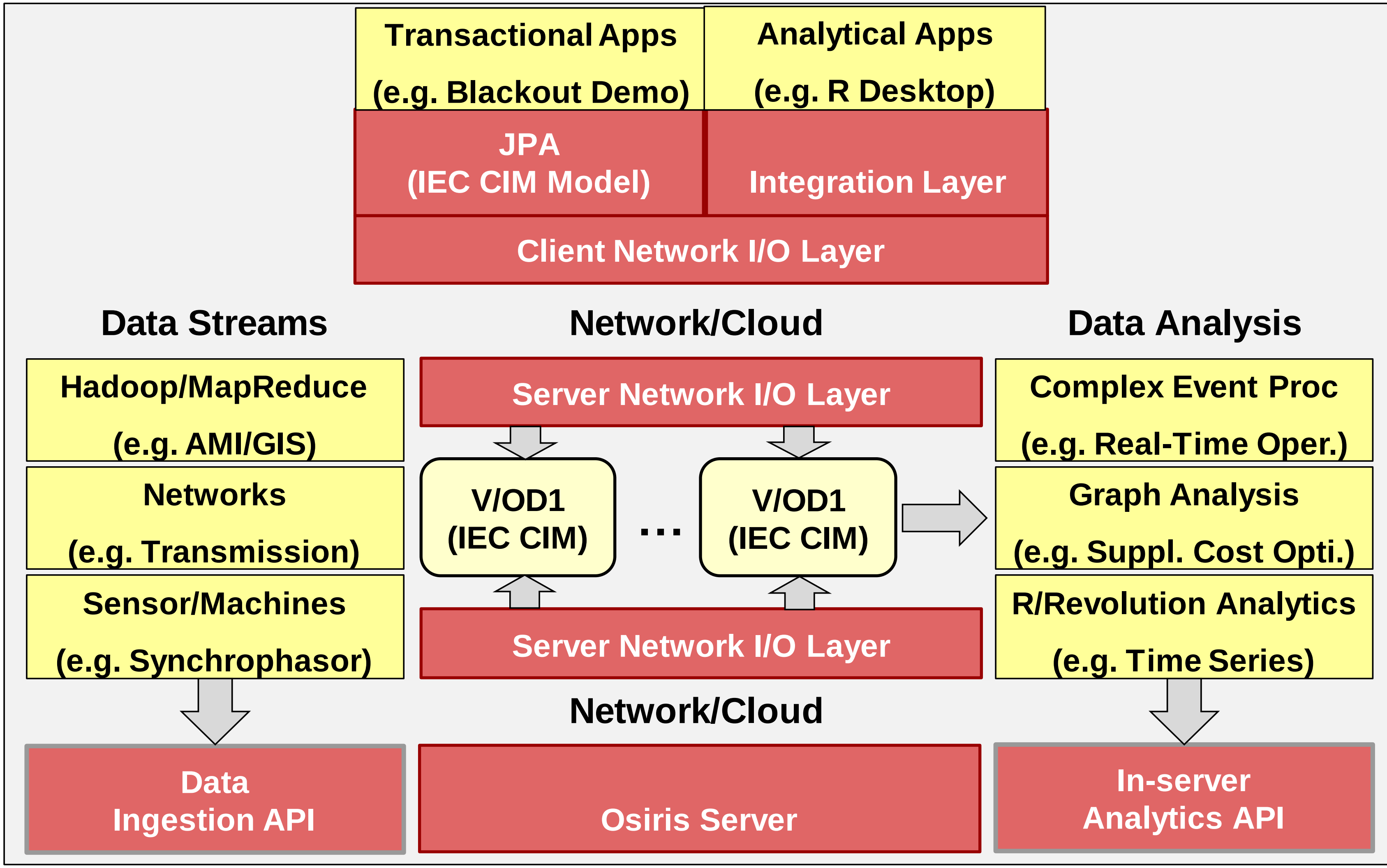

Big Utility Data Management and Analytics – Data Integration

Relational Database

Smart Grid Data Types

- Usage data (MDMS)
- Asynchronous event messages (e.g. DMS)
- Meta data (GIS)

Time Serialized Database (Historian)

Smart Grid Data Types

- Telemetric data
- Oscillographic data

Object-Oriented Database (Integrated Storage Solution)

Smart Grid Data Types:

- Telemetric data
- Oscillographic data
- Usage data
- Asynchronous event message data
- Meta data

Utilities need Object Database Solutions to accommodate Variety of Data Models for effective Utility Data Analytics!

Utility Data Management & Analytics – Network Data Analytics & Visualization

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Grid Measurements
- PMU Networks
- AMI Networks
- Sensor Networks

Utility Information Systems
- SCADA
- EMS
- DMS
- OMS
- MDMS
- CIS
- GIS
- Historian

External Information Systems
- Social Media
- Weather Feeds
- Crisis Feeds
- Financial Data

Data Analytics

Front-End Data Analytics
- Visual Analytics (Input-Output Data Mapping)

Back-End Data Analytics
- Spatial/Temporal/Nodal Analytics
- Correlation and Rules-based Analytics
- Graph-based Analytics
- Statistical and Time Series Analytics

Tuning Parameters for Analytics

Data Visualization
- Control Room Displays
- User Desktop Displays
- Mobile Device Displays
- Geospatial Displays/ Dashboards

Integrated NoSQL Solution Development Framework - Benefits

- Handles complexity of networked data models
- Benchmarks significantly faster than competition
- Designed to Scale with a modern architecture
- Provides high Quality-of-Service (QoS) up time (99.9999 availability)
- Provides extreme operational efficiencies
- Enables new networked data analysis

Examples of
Effective Performance of
NoSQL Data Management &
Analytics Solutions for Utilities/ISOs

PMU Data Analytics:

NoSQL Solution to create Situational Awareness in Power Transmission

Synchrophasor Data Analytics:
NoSQL Solution for SA in Transmission

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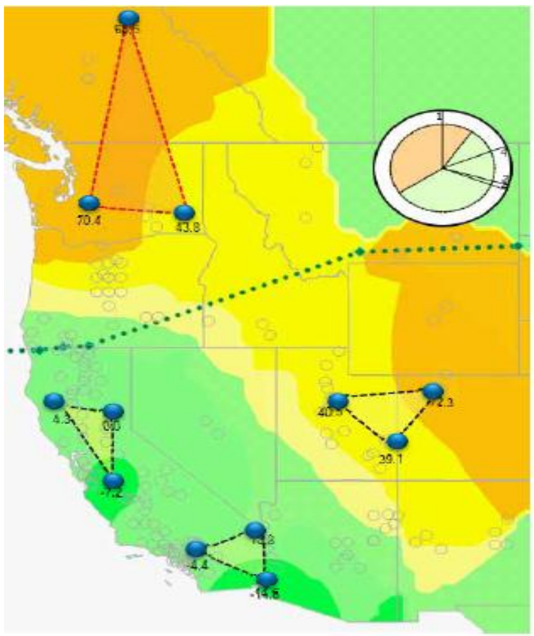
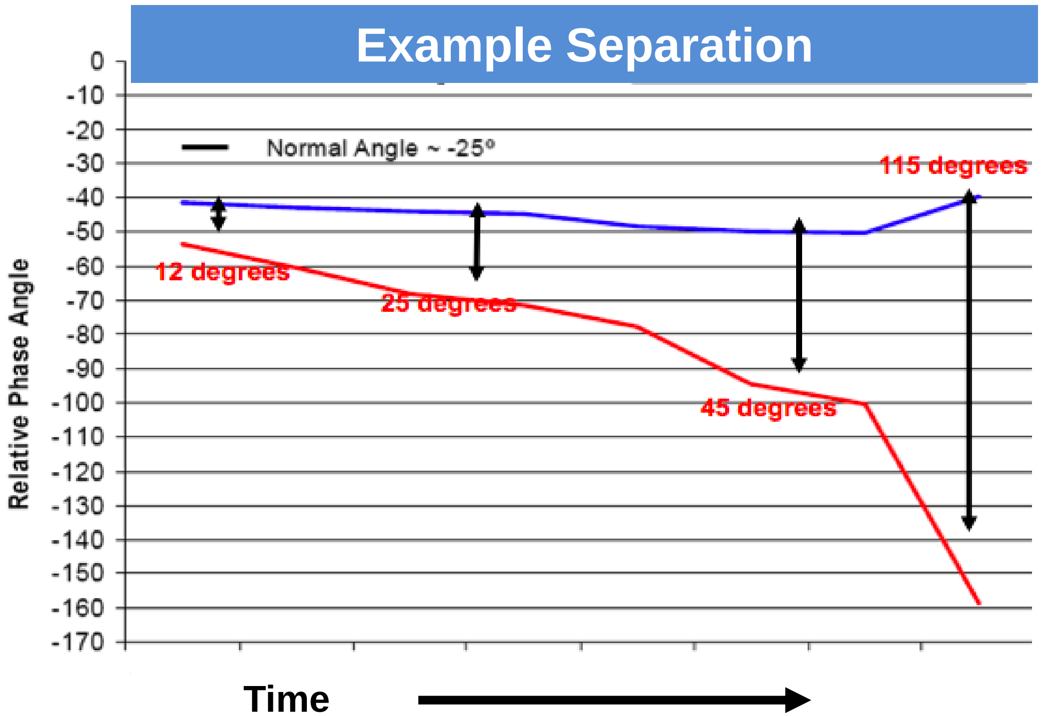
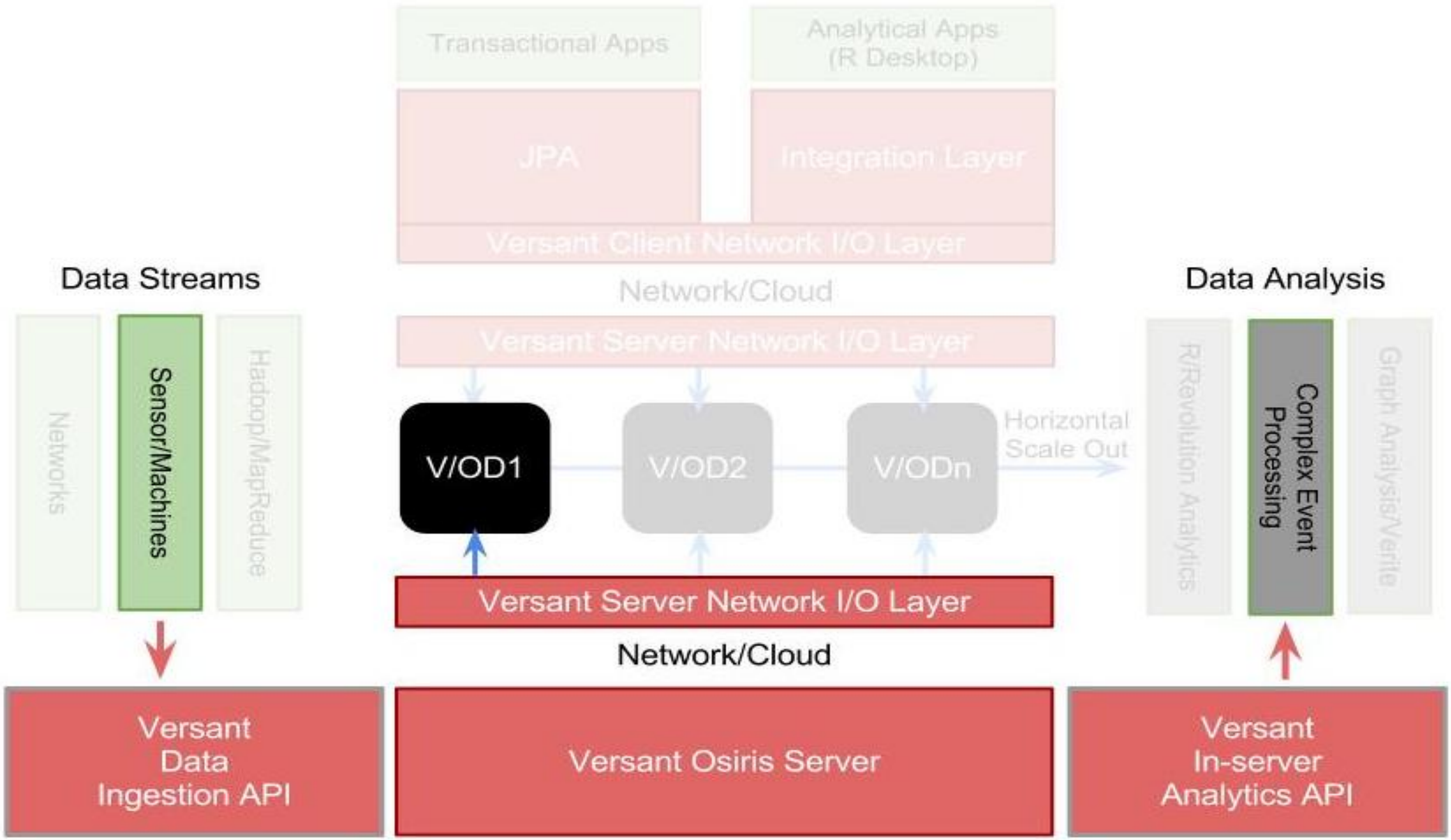




Simulated Wide-Area Phase Angle Divergence between 2 Locations of Transmission Grid, i.e. Seattle WA and Southern CA

Synchrophasor Data Analytics: NoSQL Solution Architecture



Phase Angle Divergence – Time Series

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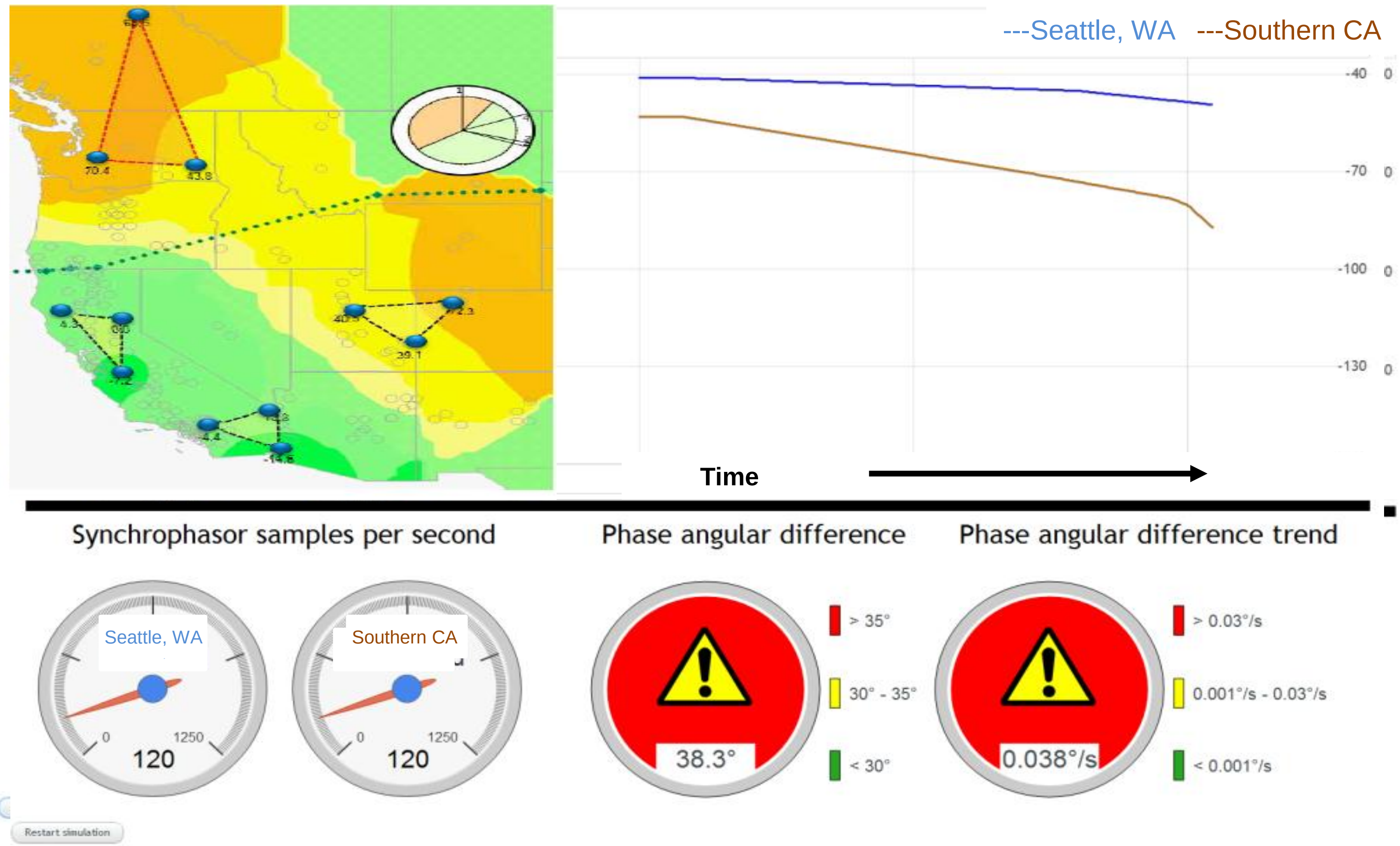
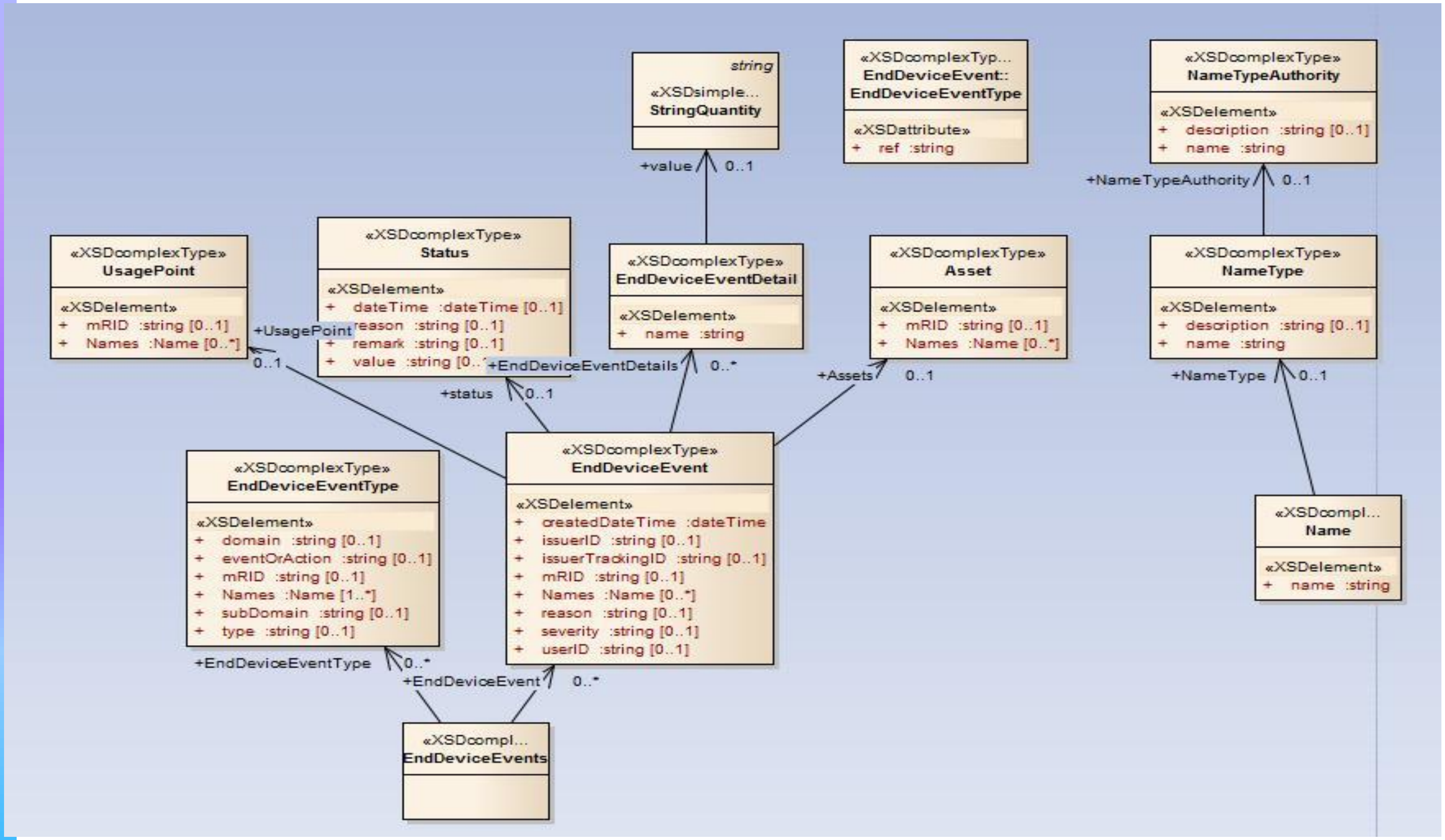


AMI/Asset Event Data Management:

End Device Event Data Ingestion, Analysis and System Correction

Performance Benchmarking

CIM EndDeviceEvent Profile Object Model



AMI/Asset Event Data Management
NoSQL-MySQL Benchmarking

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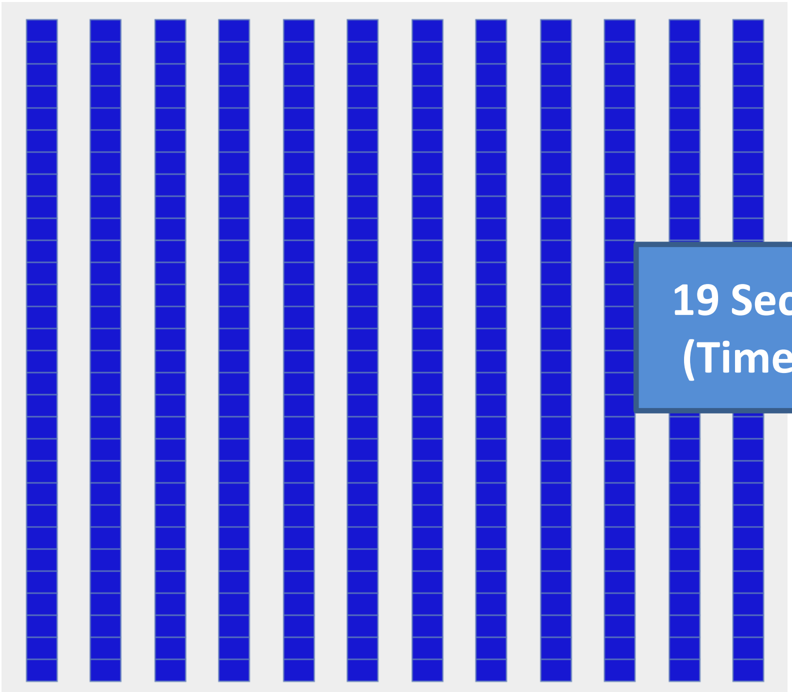
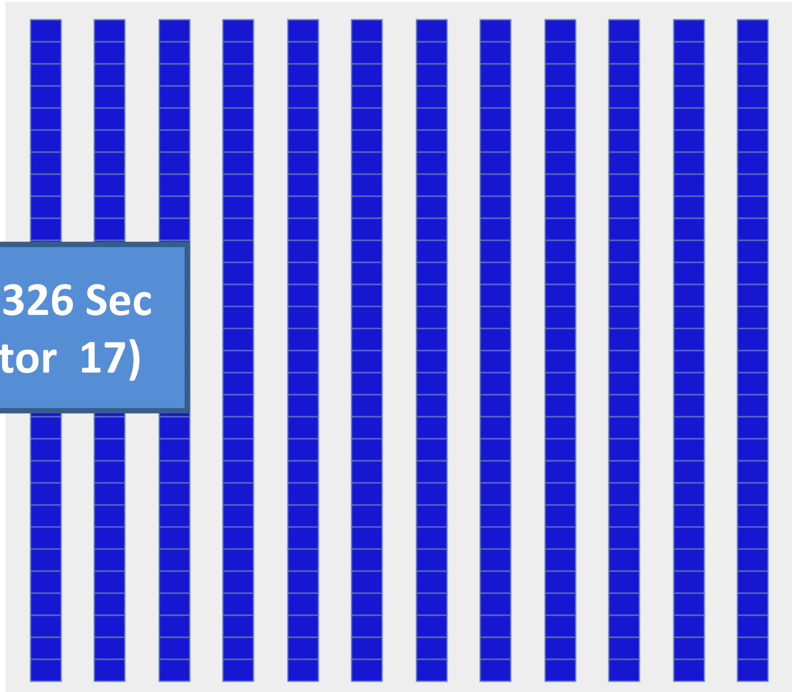
<u>Initial Database Object Population</u>
Versant JPA with NoSQL



<u>Initial Database Object Population</u>
Hibernate JPA with MySQL



19 Sec vs. 326 Sec
(Time Factor 17)

Initial Object Database Population with a Total of 12,000 End Device Event Objects and 384,000 related Objects in 12 parallel Threads. Time consumed equaled 18.935 Seconds.

Initial Object Database Population with a Total of 12,000 End Device Event Objects and 384,000 related Objects in 12 parallel Threads. Time consumed equaled 326.706 Seconds.

AMI/Asset Event Data Management: NoSQL-MySQL Benchmarking

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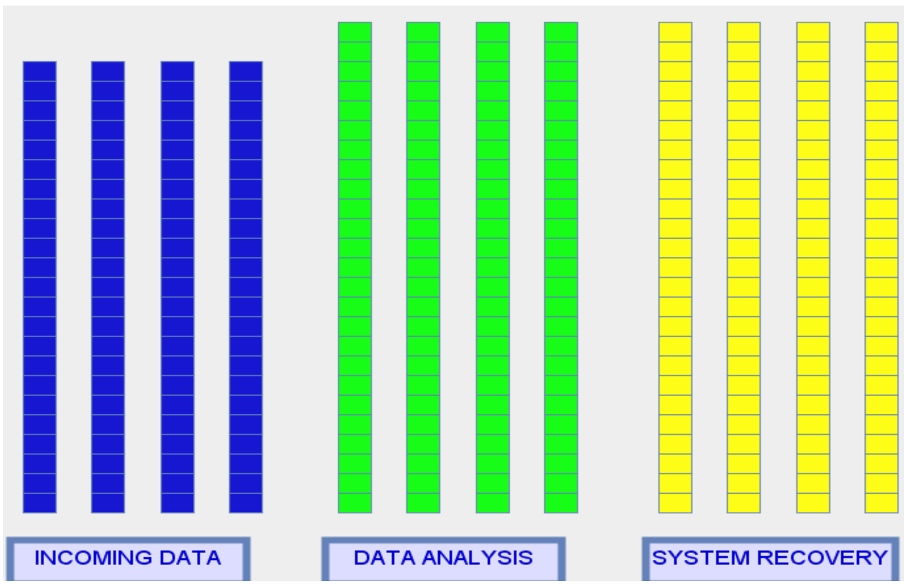
End Device Event Object Ingestion, Data Analysis, System Correction Simulation

Versant JPA with NoSQL



List of Critical/Catastrophic End Device Events during Simulation

Transformer Asset # 37_12398 overloaded (Critical Event)

4 parallel Create Threads processing 132,002 End Device Event Objects

4 parallel Retrieve Threads processing 140,734 End Device Event Objects

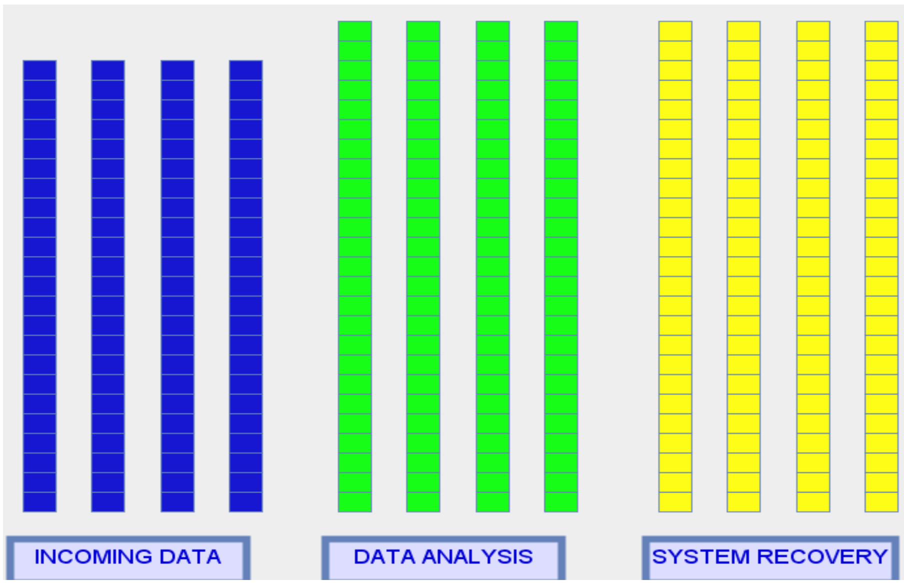
4 parallel Update Threads processing 140,778 End Device Event Objects

End Device Event Simulation has been completed in 34 Seconds processing a Total of 413,000 End Device Event Profile Objects and allowing only 1 critical Failure Event.

AMI/Asset Event Data Management: NoSQL-MySQL Benchmarking

End Device Event Object Ingestion, Data Analysis, System Correction Simulation

Hibernate JPA with MySQL



List of Critical/Catastrophic End Device Events during Simulation

1. Transformer Asset overloaded (1 critical Event),
2. Transformer Asset failed (7 catastrophic Events),
3. Meter Power out (15 critical Events).

4 parallel Create Threads processing 132,200 End Device Event Objects

4 parallel Retrieve Threads processing 140,300 End Device Event Objects

4 parallel Update Threads processing 140,500 End Device Event Objects

End Device Event Simulation has been completed in 278 Seconds processing a Total of 413,000 End Device Event Objects and allowing 16 critical and 7 catastrophic Failure Events.

AMI/Asset Event Data Management NoSQL-MySQL Benchmarking

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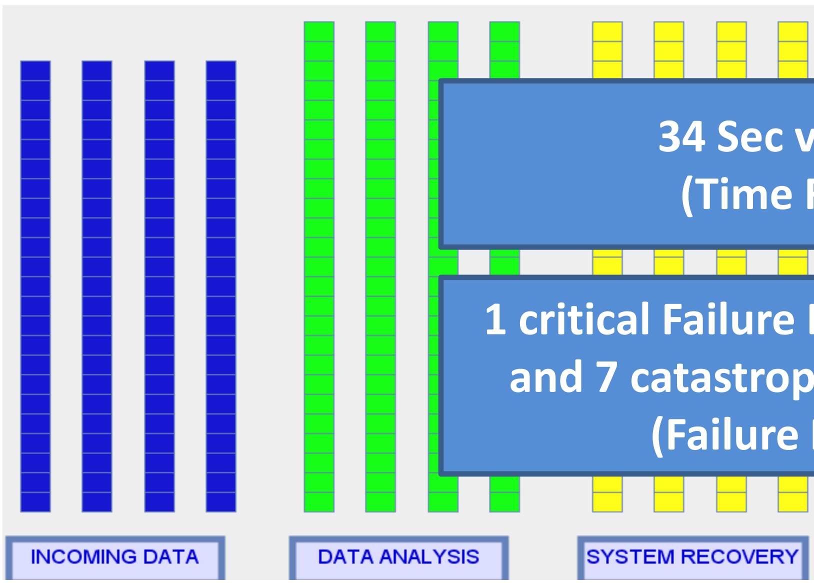
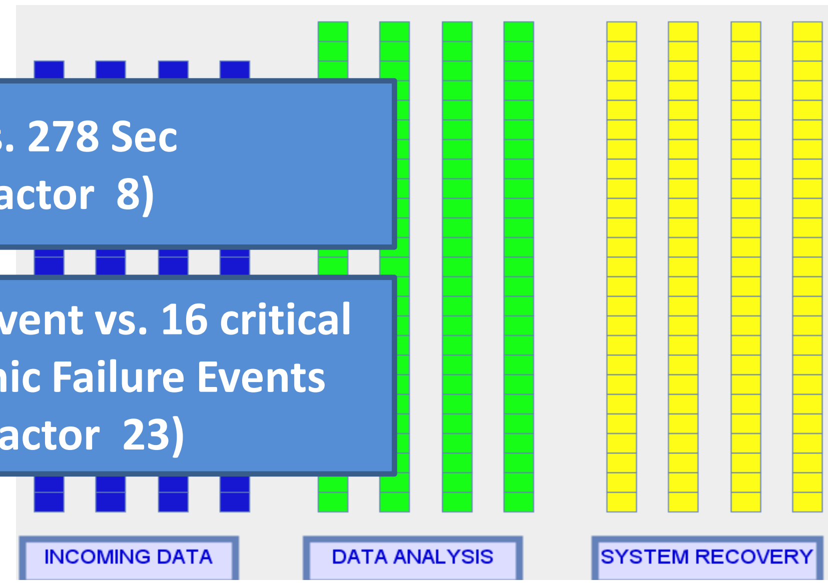
<u>End Device Event Ingestion, Data Analysis, System Correction</u>
Versant JPA with NoSQL

<u>End Device Event Ingestion, Data Analysis, System Correction</u>
Hibernate JPA with MySQL





34 Sec vs. 278 Sec
(Time Factor 8)

1 critical Failure Event vs. 16 critical and 7 catastrophic Failure Events
(Failure Factor 23)

End Device Event Simulation has been completed in 34 Seconds processing a Total of 413,000 End Device Event Objects and allowing only 1 critical Failure Event.

End Device Event Simulation has been completed in 278 Seconds processing a Total of 413,000 End Device Event Objects and allowing 16 critical and 7 catastrophic Failure Events.

Total Cost of Ownership and Performance:

NoSQL vs. MySQL

Total Cost of Ownership & Performance: NoSQL vs. MySQL

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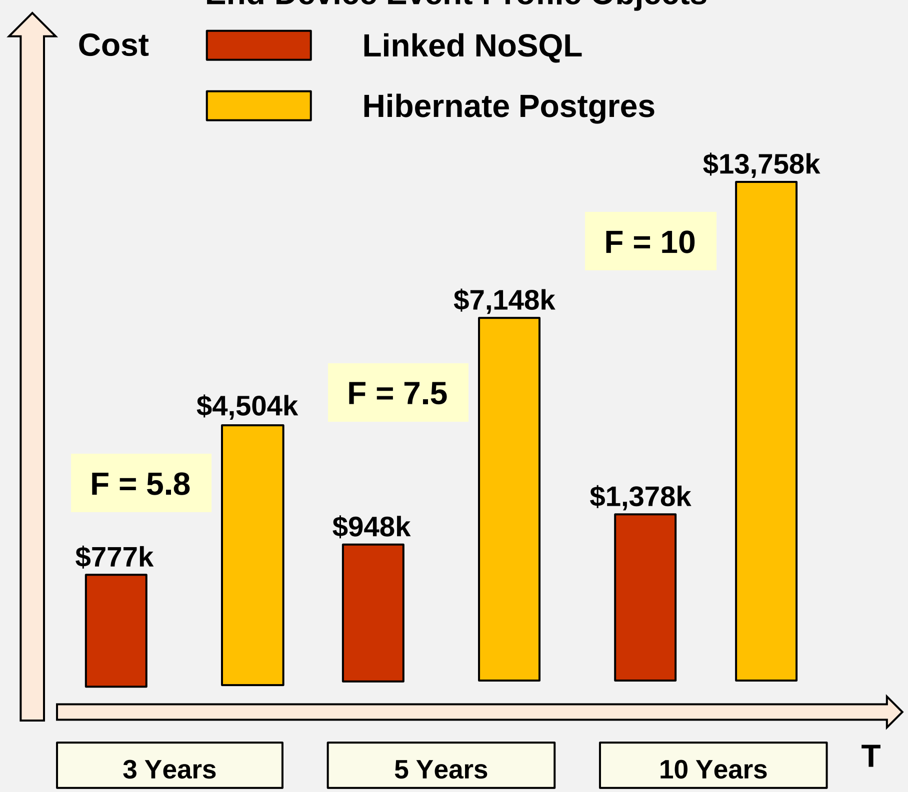
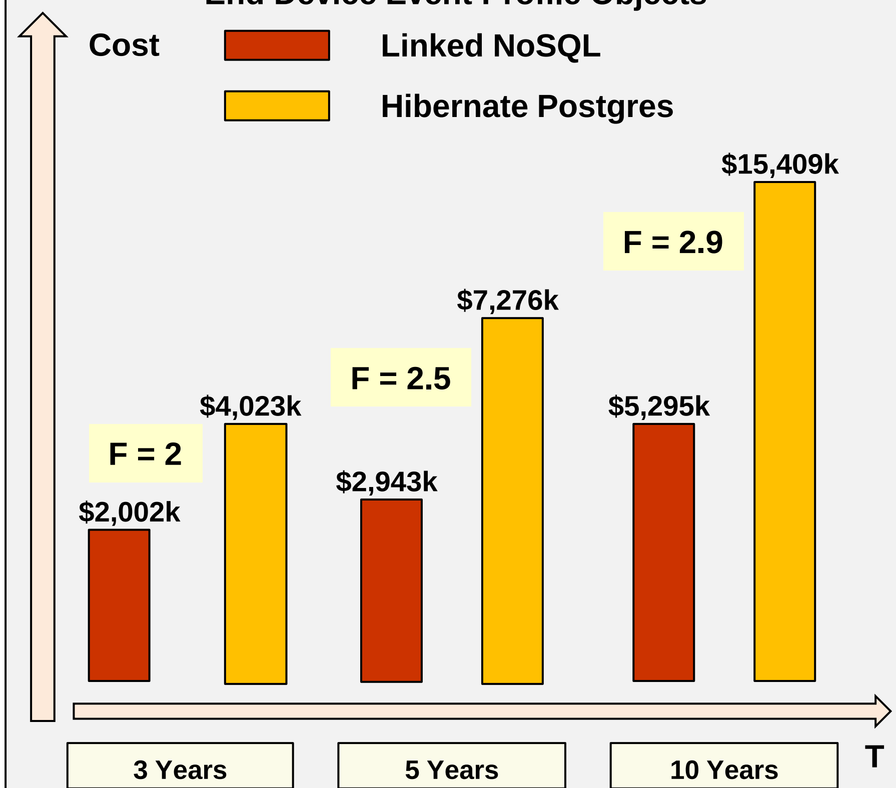
Database Performance Benchmarking: Cost

Data Ingestion Test for IEC CIM End Device Event Profile Objects



In-Database Mixed Workload Test for IEC CIM End Device Event Profile Objects



Assumptions: (i) 1 DB Server requires 2 App Servers (Linked NoSQL) and (ii) 1 DB Server requires 5 App Servers (Hibernate Postgres)

Total Cost of Ownership & Performance: NoSQL vs. MySQL

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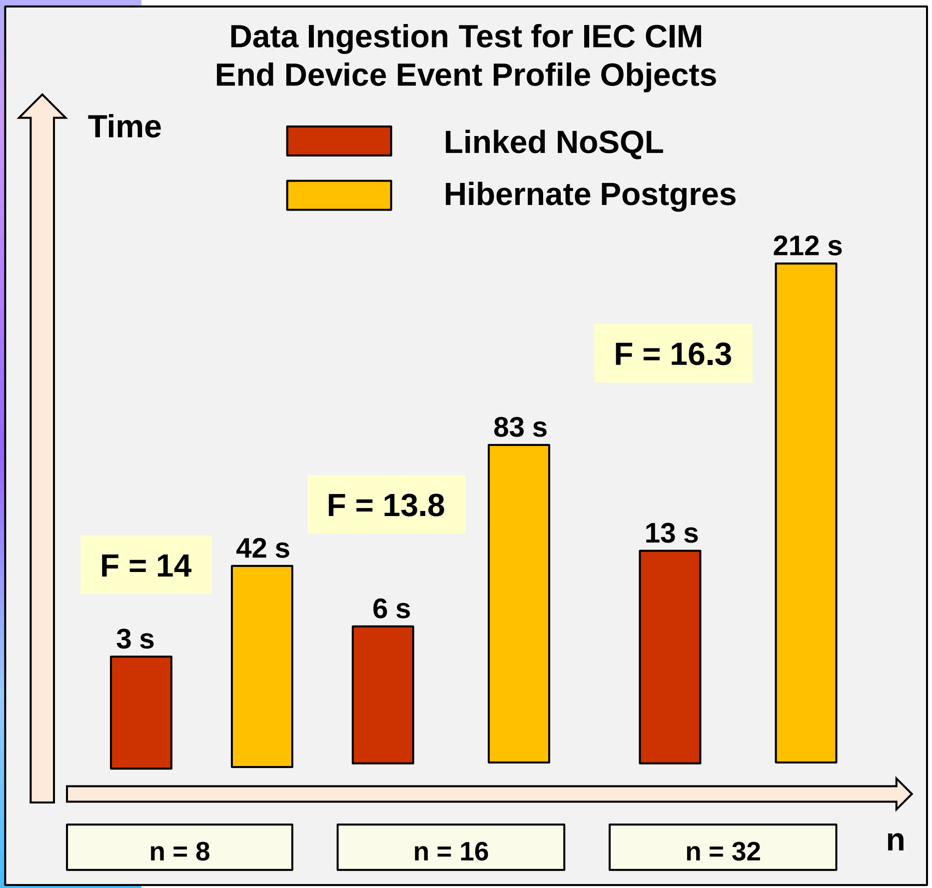
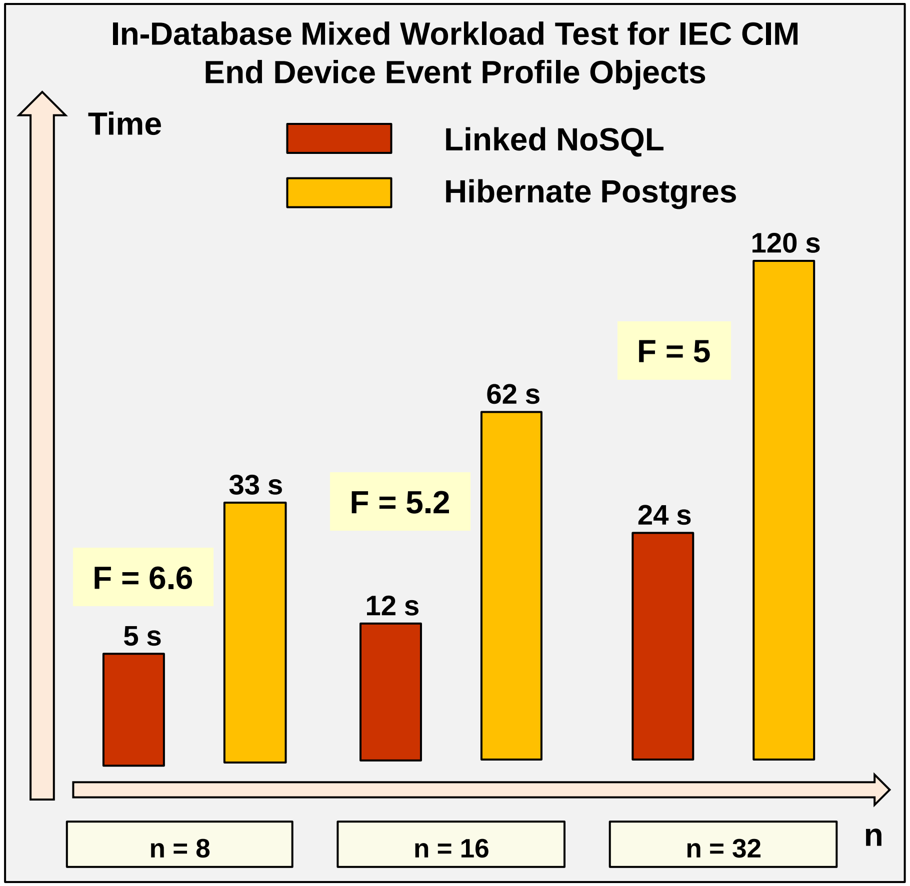
Database Performance Benchmarking: Time





Total Cost of Ownership & Performance:
NoSQL vs. MySQL

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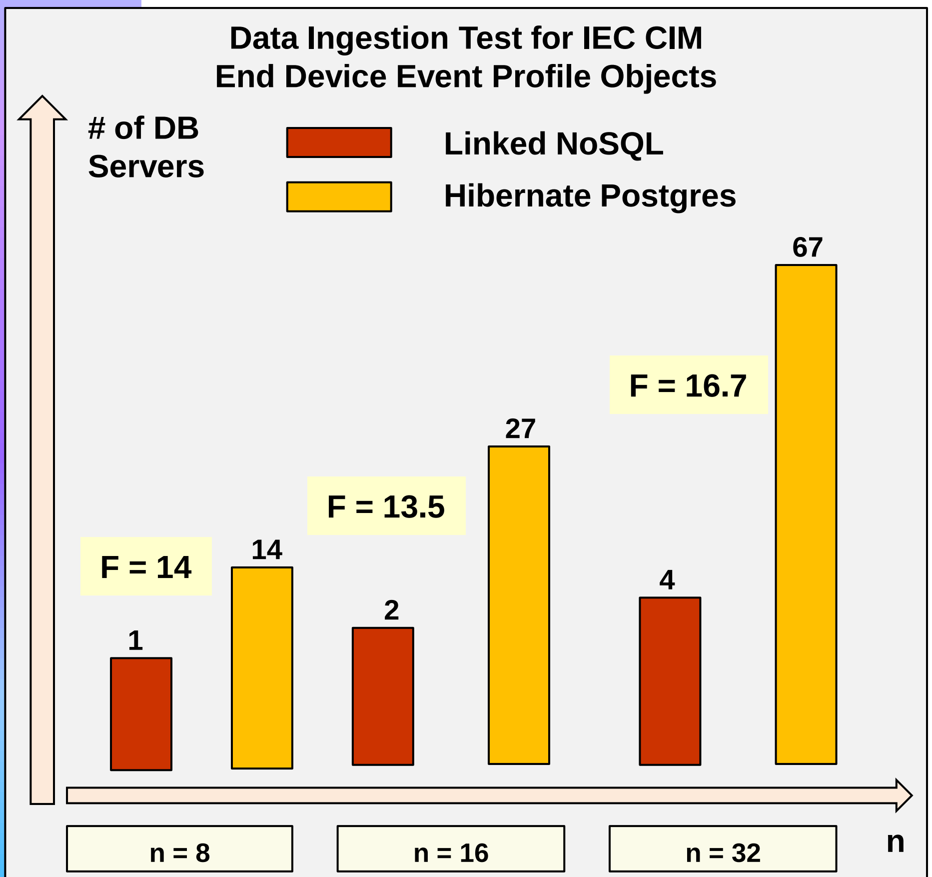
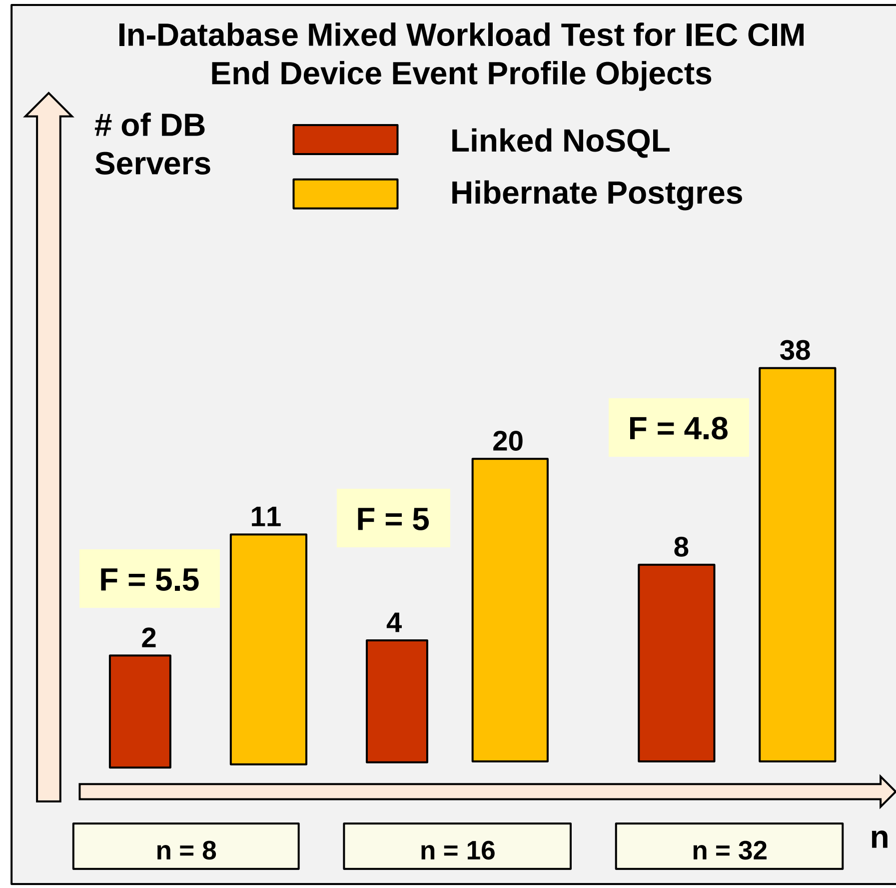
Database Benchmarking: Required Number of DB Servers





Assumption: 20 million Objects per min

THANK YOU!