Middleware for the Next Generation Power Grid
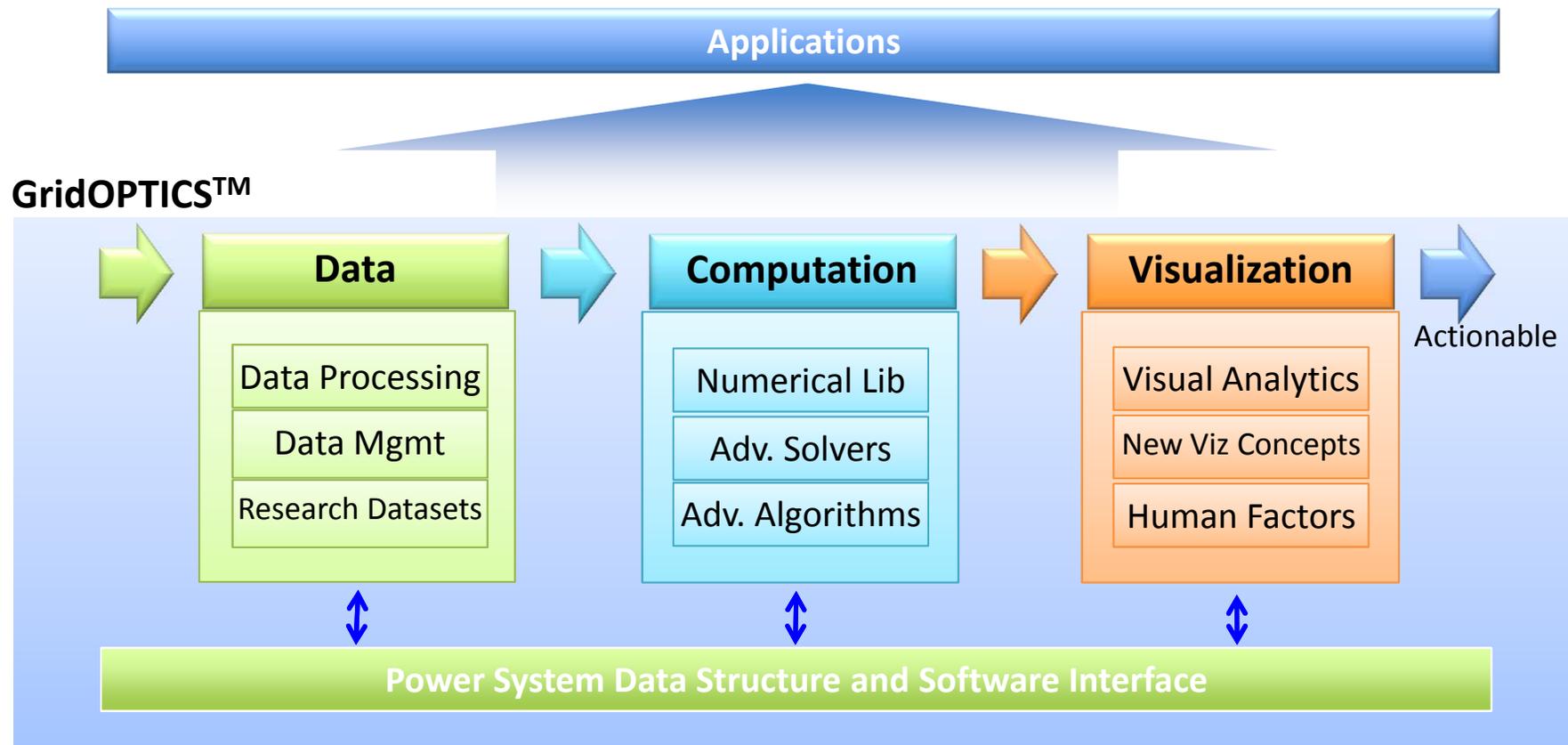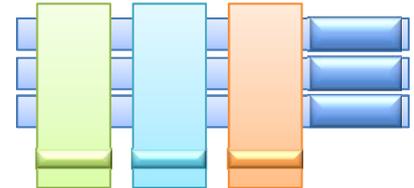
Jason Fuller, Mark Rice, Poorva Sharma, **Adam Wynne**
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Outline

► GridOPTICS Vision

► Middleware Overview

► Middleware Successes in Industry

► Value of open source and use in GridOPTICS

► GridOPTICS Middleware Projects

  ■ GridOPTICS Software System (GOSS)

  ■ Framework for Network Co-Simulation (FNCS)

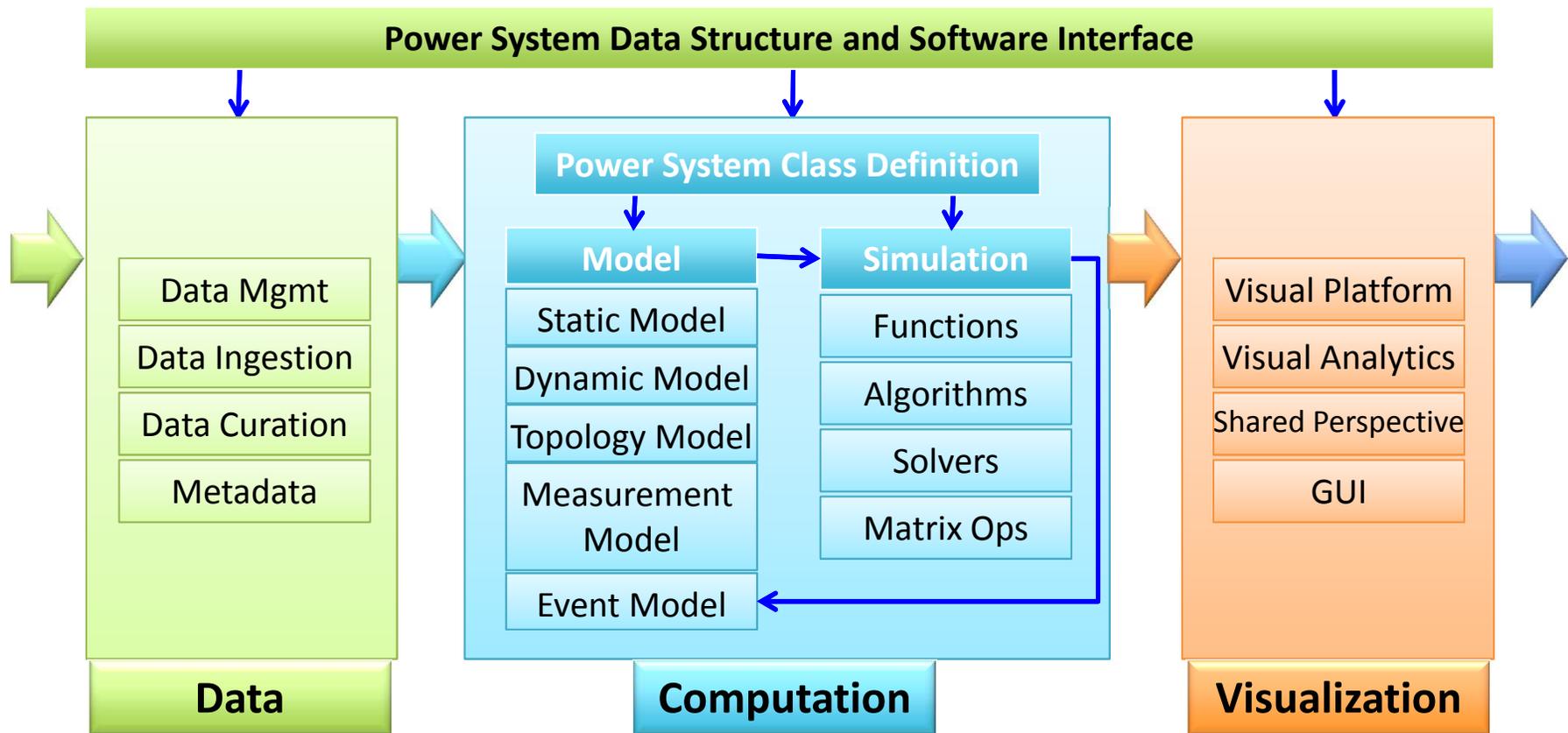 ■ Distributed Systems Architecture (DSA)

GridOPTICS™ Architecture: links data to computation to visualization

▶ Open Source; Open Format; Open Forum
- ■ Enable interoperability and accelerate development of advanced technologies and tools for the future power grid.

Applications

GridOPTICS™

Data	Computation	Visualization
Data Processing	Numerical Lib	Visual Analytics
Data Mgmt	Adv. Solvers	New Viz Concepts
Research Datasets	Adv. Algorithms	Human Factors

Actionable

Power System Data Structure and Software Interface

GridOPTICS™ Vision

► Open Source; Open Format; Open Forum

Power System Data Structure and Software Interface		
Data	**Computation**	**Visualization**

Data
- Data Mgmt
- Data Ingestion
- Data Curation
- Metadata

Computation

Power System Class Definition

Model	Simulation
Static Model	Functions
Dynamic Model	Algorithms
Topology Model	Solvers
Measurement Model	Matrix Ops
Event Model	

Visualization
- Visual Platform
- Visual Analytics
- Shared Perspective
- GUI

GridOPTICS = Grid Operation and Planning Technology Integrated Capabilities Suite

Middleware Overview

► Overview of Middleware

- ■ "Glue" between components in modern software systems
- ■ Frees developers from having to think about challenging communications programming

► Message Oriented Middleware (MOM)

- ■ Decouples system components
- ■ Allows components to operate asynchronously
- ■ Features for routing to component

► Service Oriented Architecture (SOA)

- ■ Components with well-defined interfaces
- ■ Offered over the web

► Enterprise Service Bus (ESB)

- ■ Communications backbone
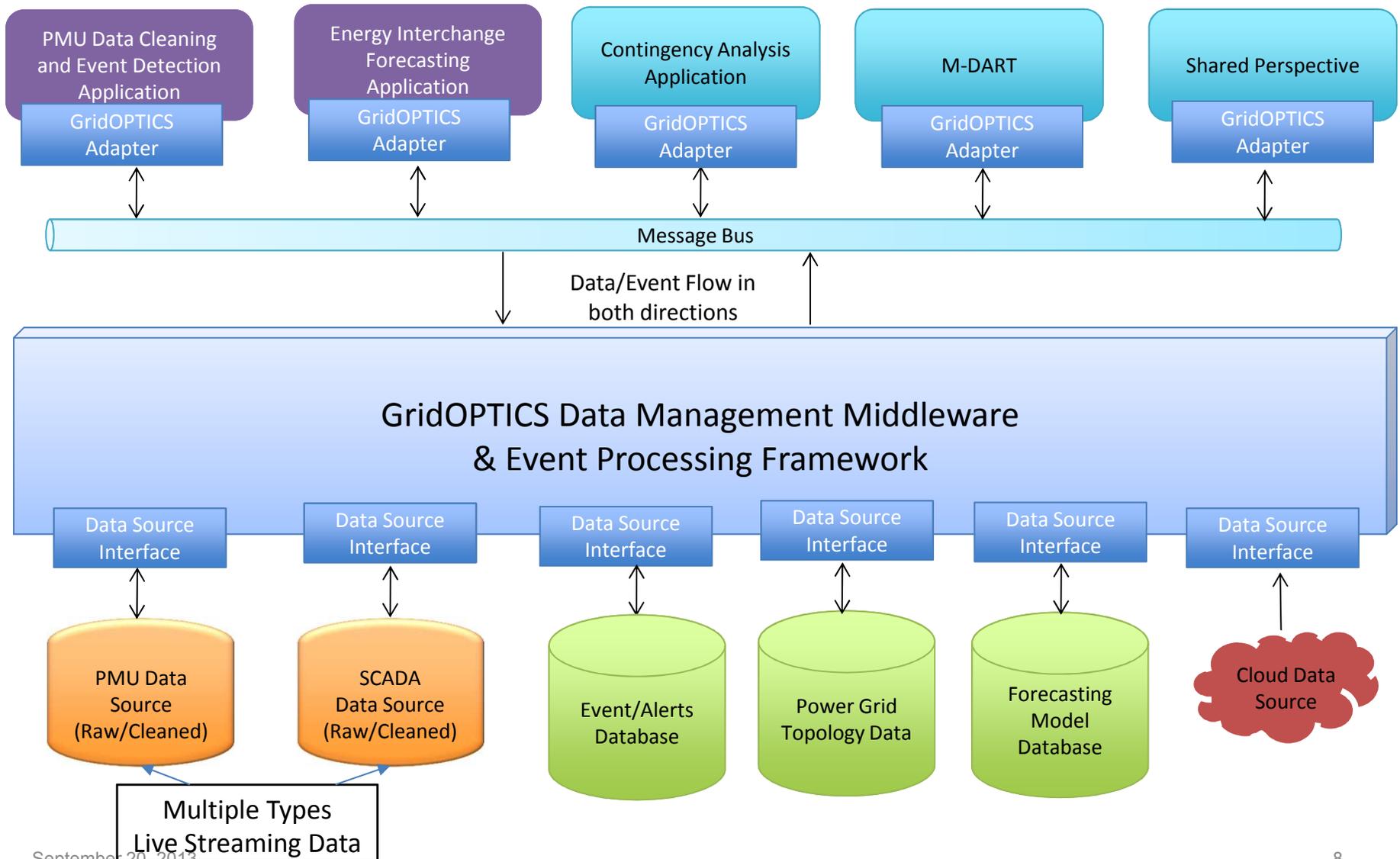- ■ Can connect different components over multiple communication protocols

Middleware in Industry

- ► Used in virtually every modern industry
- ► Accelerates development times, makes systems more manageable
- ► Can Support high performance workloads

- ► Example - Financial Industry
  - ■ Big data problem
  - ■ Need to connect a wide variety of systems with each other: legacy systems, HPC systems, connectivity between organizations
  - ■ These systems are built around middleware (with specialized middleware products for the industry)

Open Source Software

▶ Open source successful in industry,

- RedHat - Over $1B in yearly revenue
- Apache foundation (~200 projects)
- Hadoop – ecosystem of applications appeared "over night"

▶ Open source software in power industry

- Grid Open Source Software Alliance
- Grid Protection Alliance: Projects include OpenPDC, SIEGate, OpenHistorian

▶ Why open source GridOPTICS software?

- Reference architecture
- Open architecture
- Modular middleware – can support any license type

GridOPTICS Software System (GOSS)

PMU Data Cleaning and Event Detection Application — GridOPTICS Adapter

Energy Interchange Forecasting Application — GridOPTICS Adapter

Contingency Analysis Application — GridOPTICS Adapter

M-DART — GridOPTICS Adapter

Shared Perspective — GridOPTICS Adapter

Message Bus

Data/Event Flow in both directions

GridOPTICS Data Management Middleware & Event Processing Framework

Data Source Interface

Data Source Interface

Data Source Interface

Data Source Interface

Data Source Interface

Data Source Interface

PMU Data Source (Raw/Cleaned)

SCADA Data Source (Raw/Cleaned)

Event/Alerts Database

Power Grid Topology Data

Forecasting Model Database

Cloud Data Source

Multiple Types Live Streaming Data
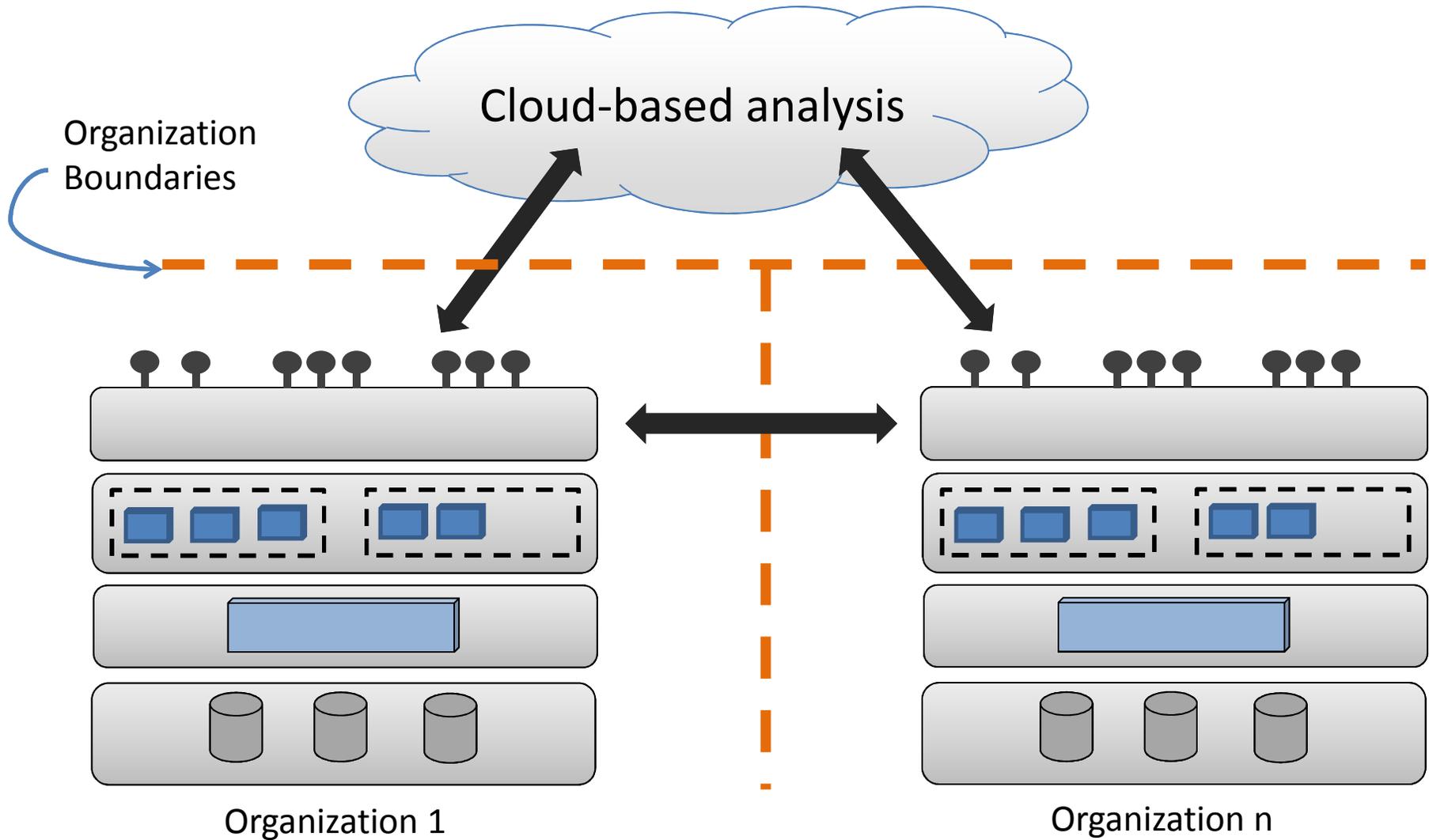
FNCS - Next Generation Network Simulator

Objective

► Interface existing power grid and communication simulators
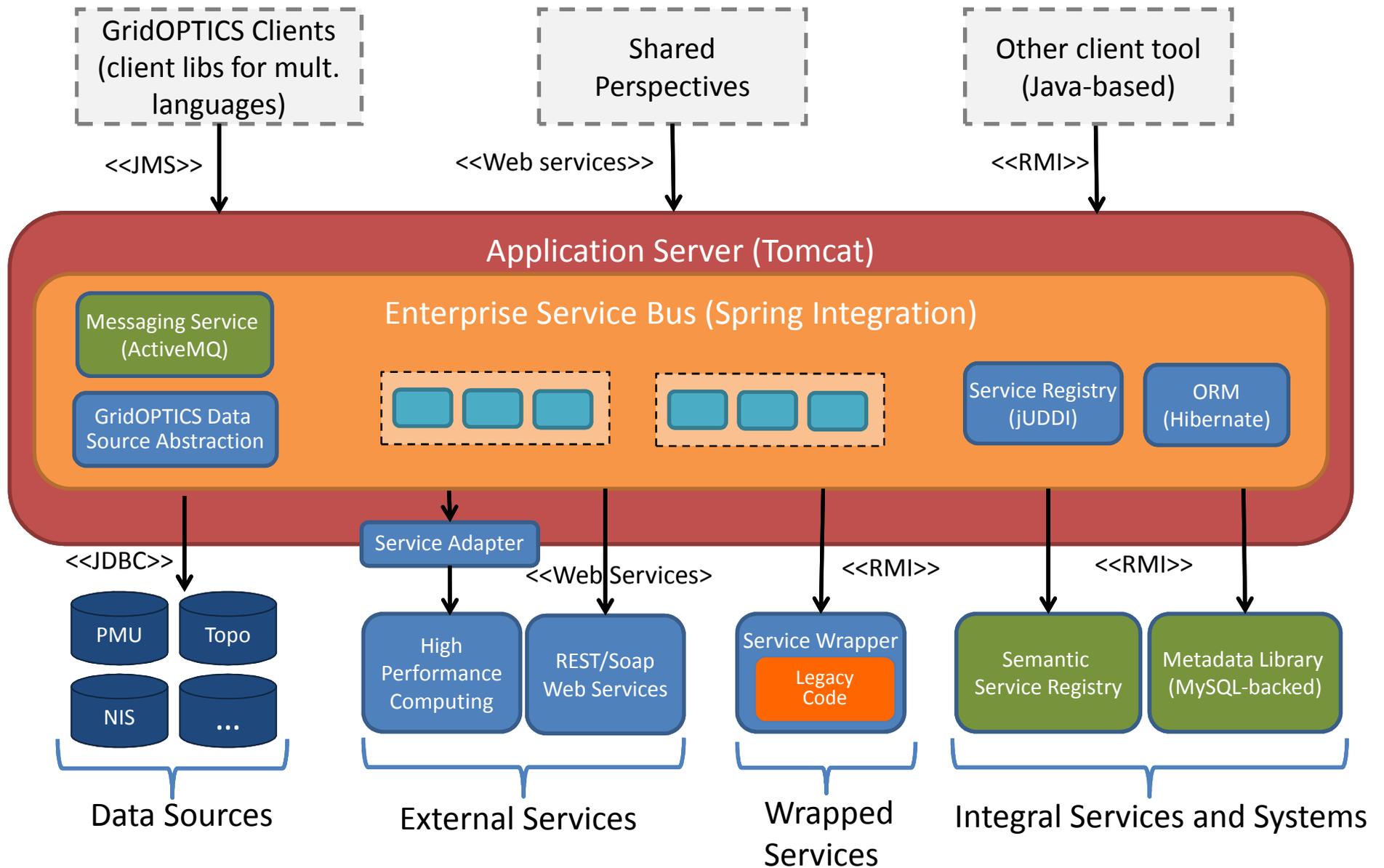
► Develop optimized HPC simulation platform

Approach

► Coordinate interaction of ns-3 with GridLAB-D and transmission simulators

► Modular framework links simulators via ZeroMQ

► Dynamically adjusts synchronization requirements among simulations

Distributed Systems Architecture Project

Cloud-based analysis

Organization
Boundaries

Organization 1

Organization n

Expanded GOSS Architecture

GridOPTICS Clients
(client libs for mult.
languages)

Shared
Perspectives

Other client tool
(Java-based)

<<JMS>>

<<Web services>>

<<RMI>>

Application Server (Tomcat)

Enterprise Service Bus (Spring Integration)

Messaging Service
(ActiveMQ)

GridOPTICS Data
Source Abstraction

Service Registry
(jUDDI)

ORM
(Hibernate)

<<JDBC>>

Service Adapter

<<Web Services>

<<RMI>>

<<RMI>>

PMU

Topo

NIS

...

High
Performance
Computing

REST/Soap
Web Services

Service Wrapper

Legacy
Code

Semantic
Service Registry

Metadata Library
(MySQL-backed)

Data Sources

External Services

Wrapped
Services

Integral Services and Systems

Accomplishments / Impact of GOSS

► Use cases
  - Contingency Analysis – sharing between 2 SOA infrastructures
  - PMU Data Cleaning and Event Detection
  - NIS Load Forecasting Tool
  - Shared Perspective

► API Support
  - Platforms: Windows/Linux
  - Native client languages: Java, C#, R
  - Communication format: Java Object, XML, JSON, REST, SOAP

► Databases
  - Multiple MySQL servers (Grid topology, Contingencies, Events/Alerts)
  - GridMW (PMU measurements)

► Line of Code / Development time/effort:
  - Reduced significantly due to redundancy control