Universidad Politécnica de Madrid

Towards a Reference Architecture for Large-Scale Smart Grids System of Systems

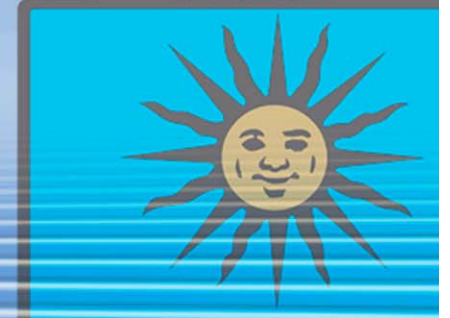*Jennifer Pérez, Jessica Díaz, Juan Garbajosa, Agustín Yagüe*

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Eloy González, Mercedes López-Perea

Indra Software Labs

indra

Content

► **Introduction**

► Large-Scale Smart Grids as a SoS

► A Software Architecture for Large-Scale Smart Grids SoS

► Conclusions & Further Work

Content

► **Introduction**

   ❖ **Context & Motivation**

   ❖ Objective

► Large-Scale Smart Grids as a SoS

► A Software Architecture for Large-Scale Smart Grids SoS

► Conclusions & Further Work

Introduction

> A **System of Systems**

❑ Systems composed by other heterogeneous systems geographically extended and properly integrated

Emergent Behaviour

Emergent Behaviour

Emergent Behaviour

Large-Scale Smart Grids and Cities

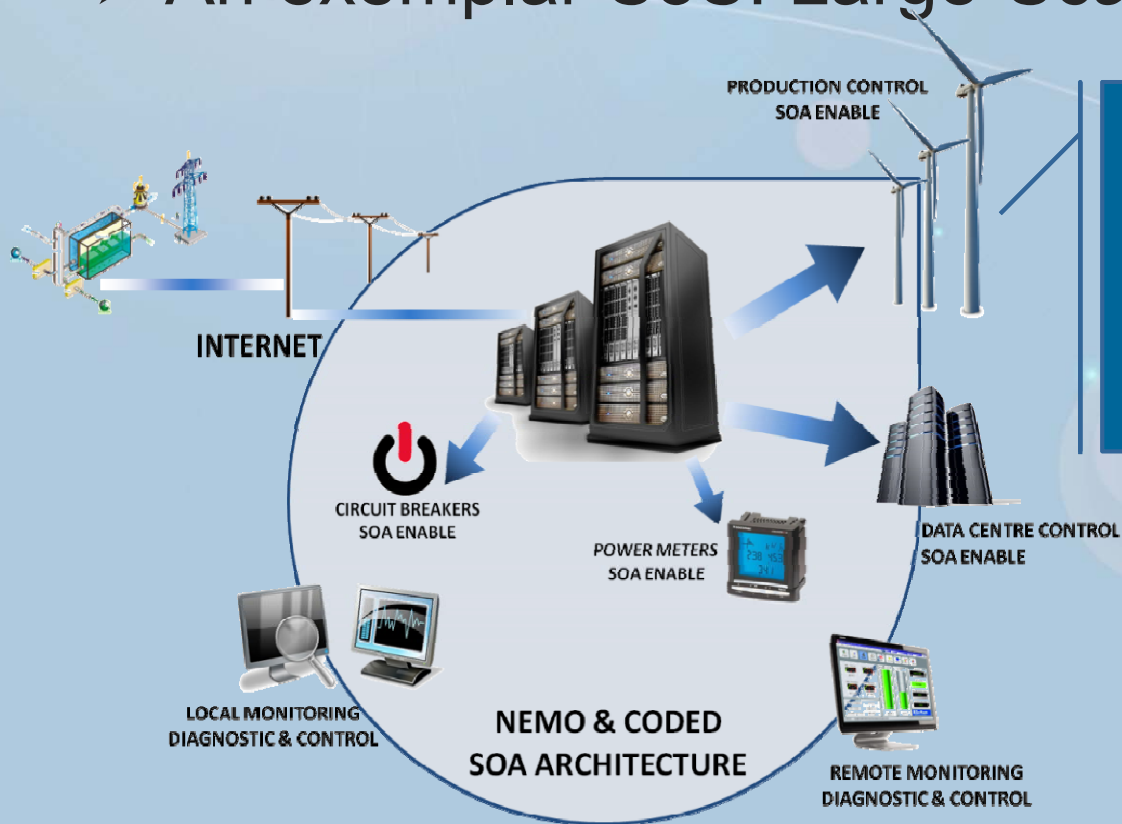**Air Defense Networks**

Intelligent Transport Systems

Introduction

> An exemplar SoS: Large-Scale Smart Grids

Solution to **integrate distributed and intermittent energy generation** and to increase energy efficiency through the introduction of Information and Communication Technologies (ICT).

Smarter and interoperable electricity systems
bidirectional communication, intelligent metering and monitoring systems

Content

► **Introduction**
  ❖ Context & Motivation
  ❖ **Objective**

► Large-Scale Smart Grids as a SoS

► A Software Architecture for Large-Scale Smart Grids SoS

► Conclusions & Further Work

Objective

> ➤ One of the main challenges of engineering SoS

> ❑ The design of their architectural components and interfaces of the SoS guaranteeing interoperability

> ➤ Starting from an exemplar SoS could help…
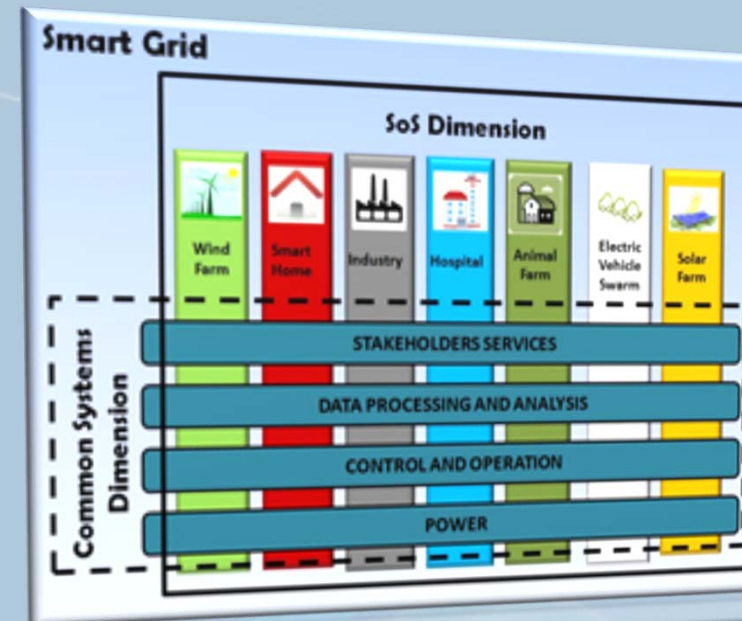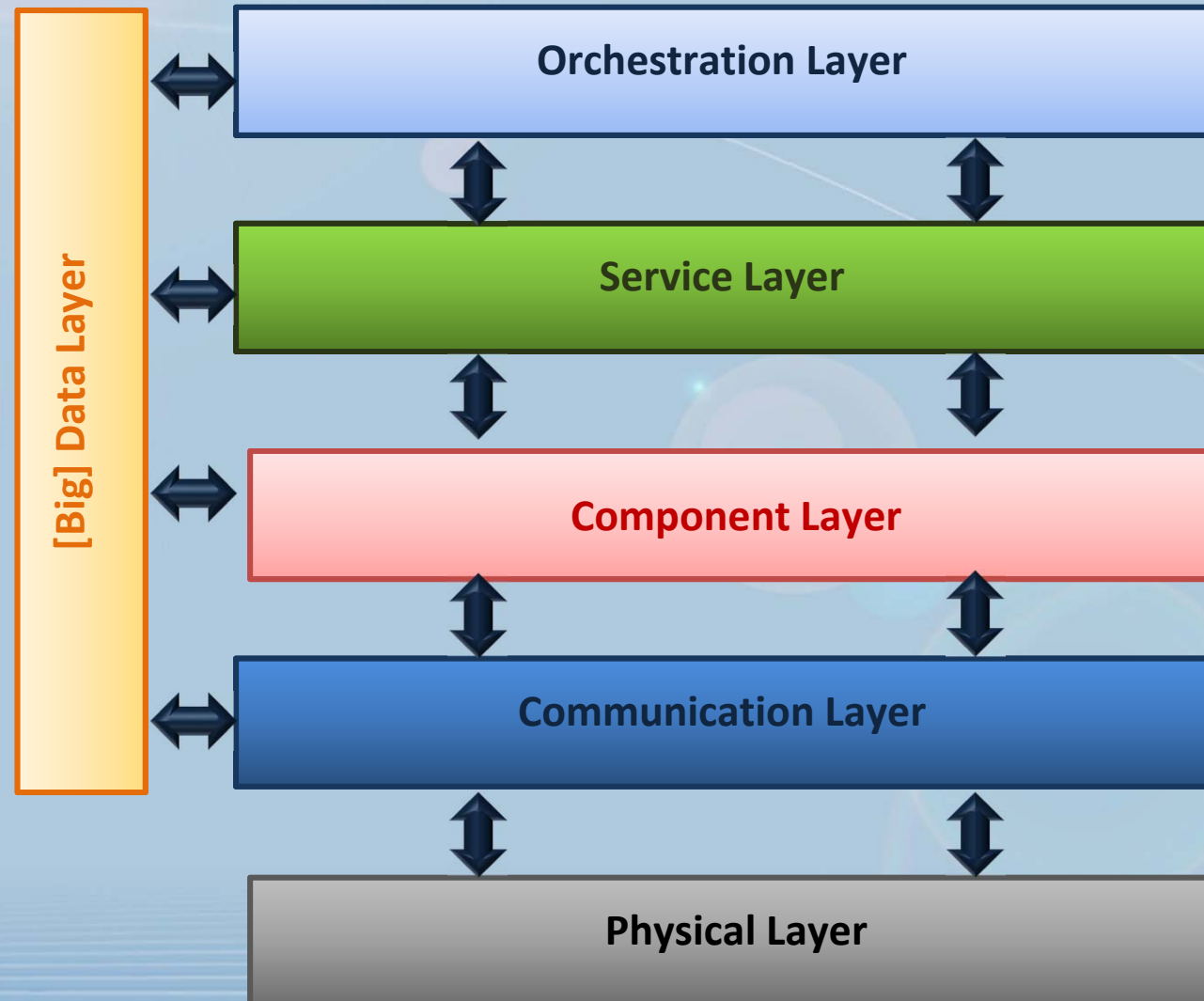
> ➤ From our experience:

Build a first version of a reference architecture for Large-Scale Smart Grids SoS.

Content

Architectural Framework

➢ **Dimensions**

> **Layers**

Content

Architecture for Large-Scale Smart Grids SoS

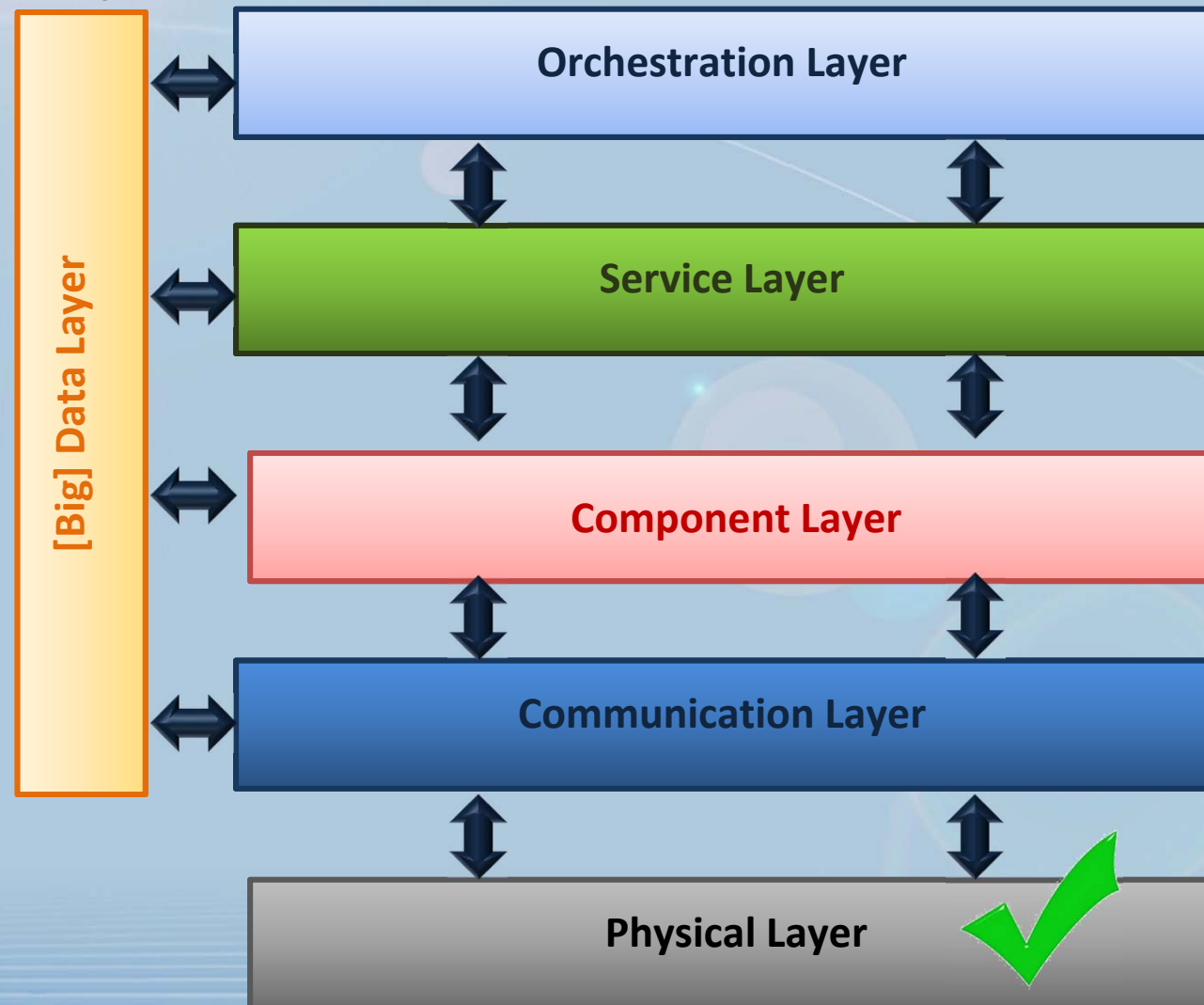➢ Multi-tiered layered architecture:

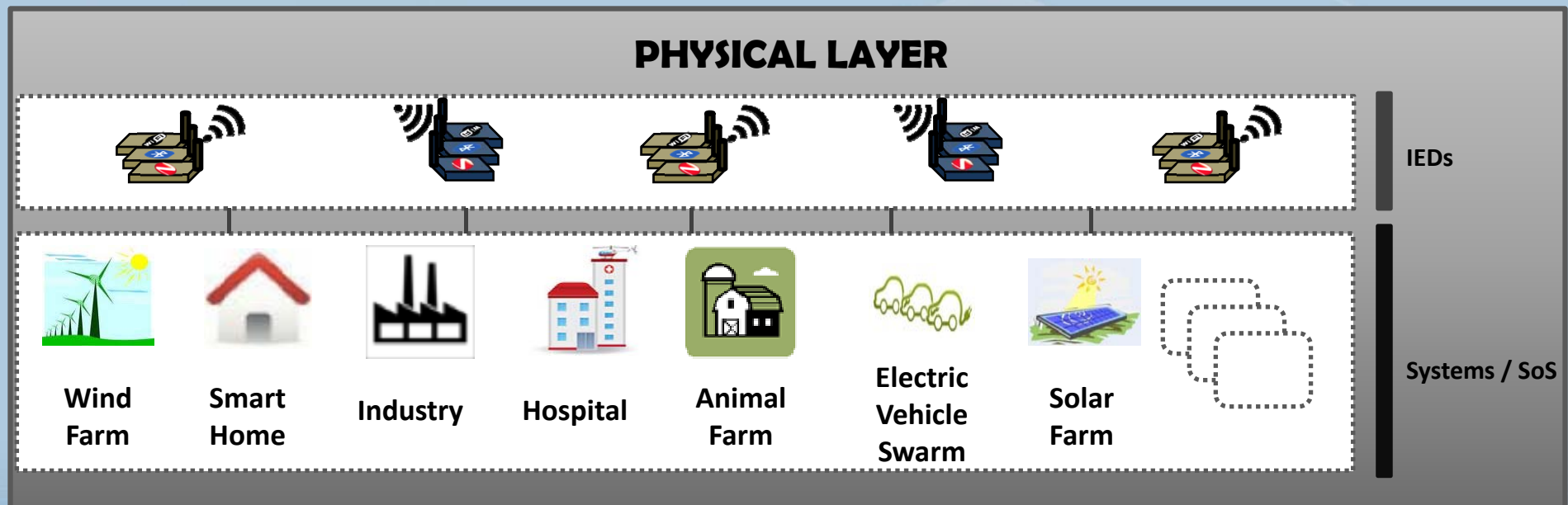# Architecture for Large-Scale Smart Grids SoS

➢ **Physical Layer**

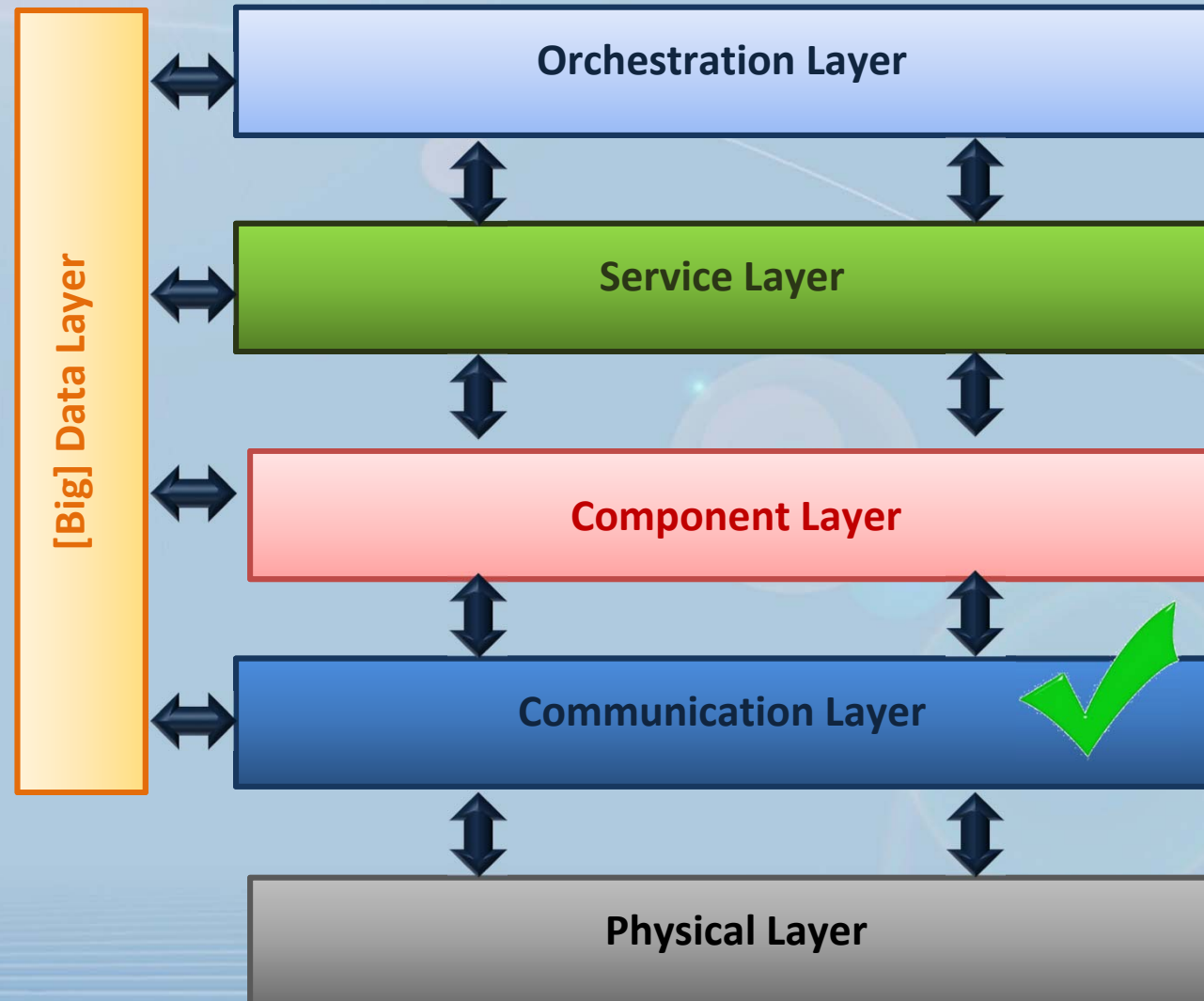# Architecture for Large-Scale Smart Grids SoS

➢ **Physical Layer**

❑ SoS are deployed through hundred of IEDs

❑ Information is transmitted through different channels and communications protocols

PHYSICAL LAYER

IEDs

Wind Farm | Smart Home | Industry | Hospital | Animal Farm | Electric Vehicle Swarm | Solar Farm

Systems / SoS

Architecture for Large-Scale Smart Grids SoS

➢ Multi-tiered layered architecture:

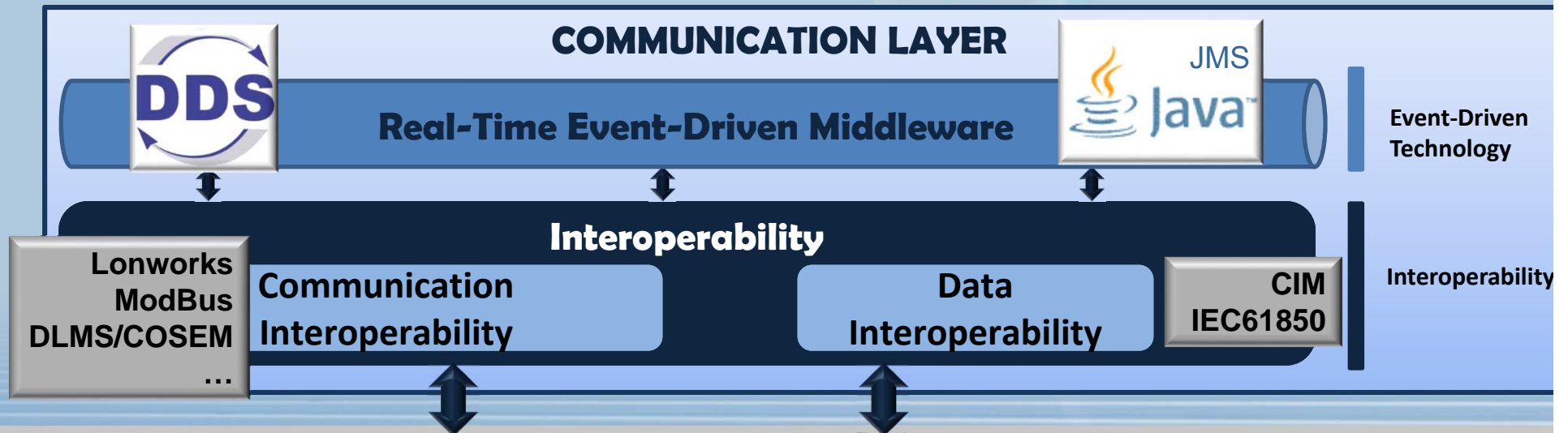# Architecture for Large-Scale Smart Grids SoS

➢ **Communication Layer**

❑ Enable

❖ Interoperability

▪ Communication

▪ Data: Unified Information Model

❖ Quasi real time communication

▪ Data Acquisition and Processing of IEDs

▪ Loosely coupled

▪ Highly distributed

▪ Scalable

EDSOA:
Event-Driven Service-Oriented Architecture

COMMUNICATION LAYER

DDS

Real-Time Event-Driven Middleware

JMS

Java

Event-Driven Technology

Interoperability

Lonworks ModBus DLMS/COSEM ...

Communication Interoperability

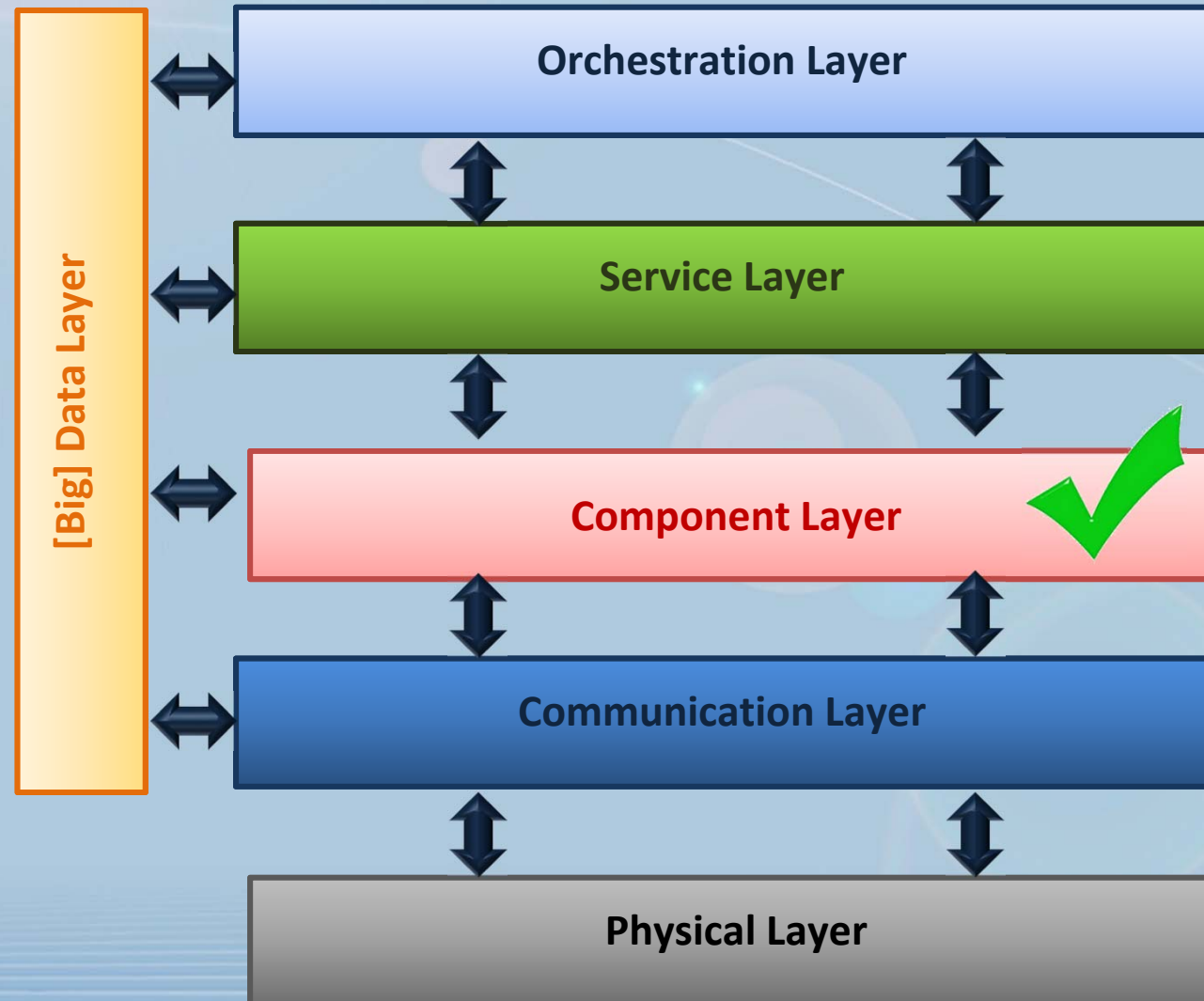**Data Interoperability**

CIM IEC61850

Interoperability

Architecture for Large-Scale Smart Grids SoS
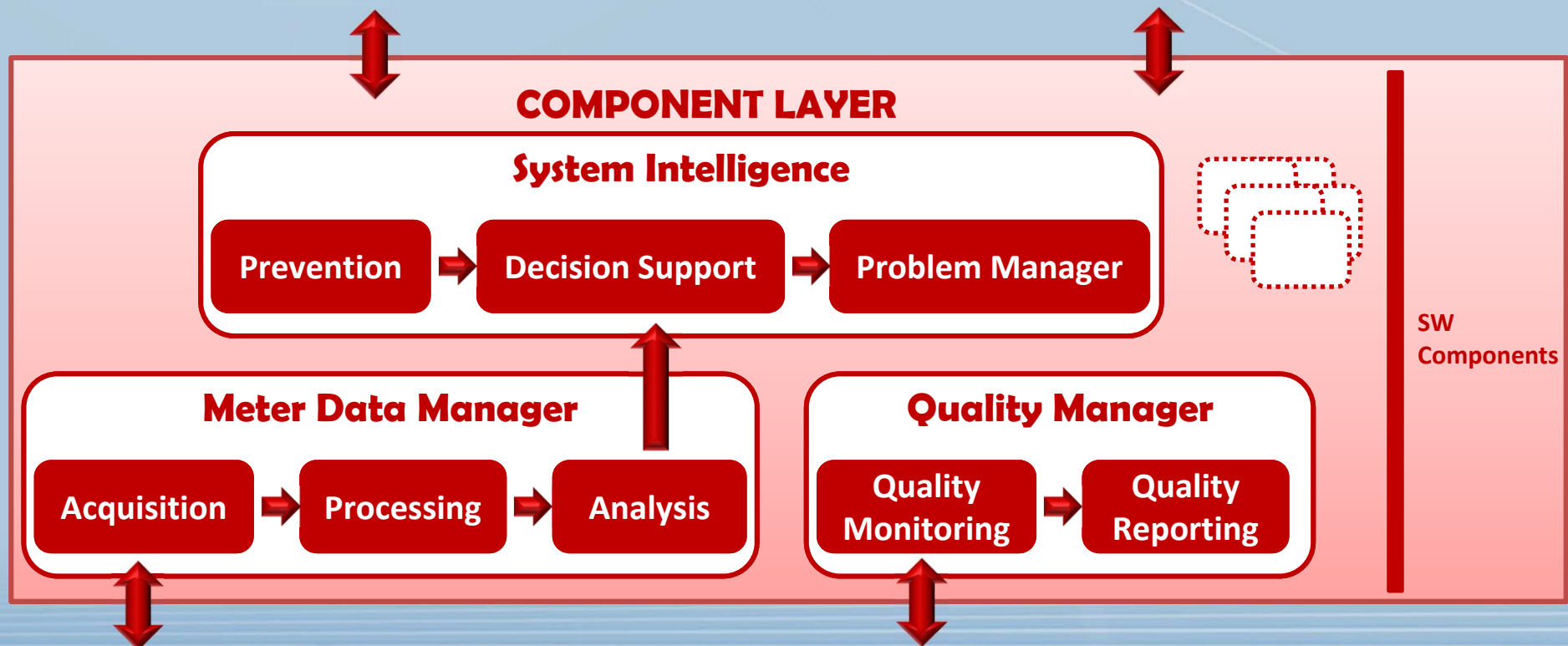
➢ Multi-tiered layered architecture:

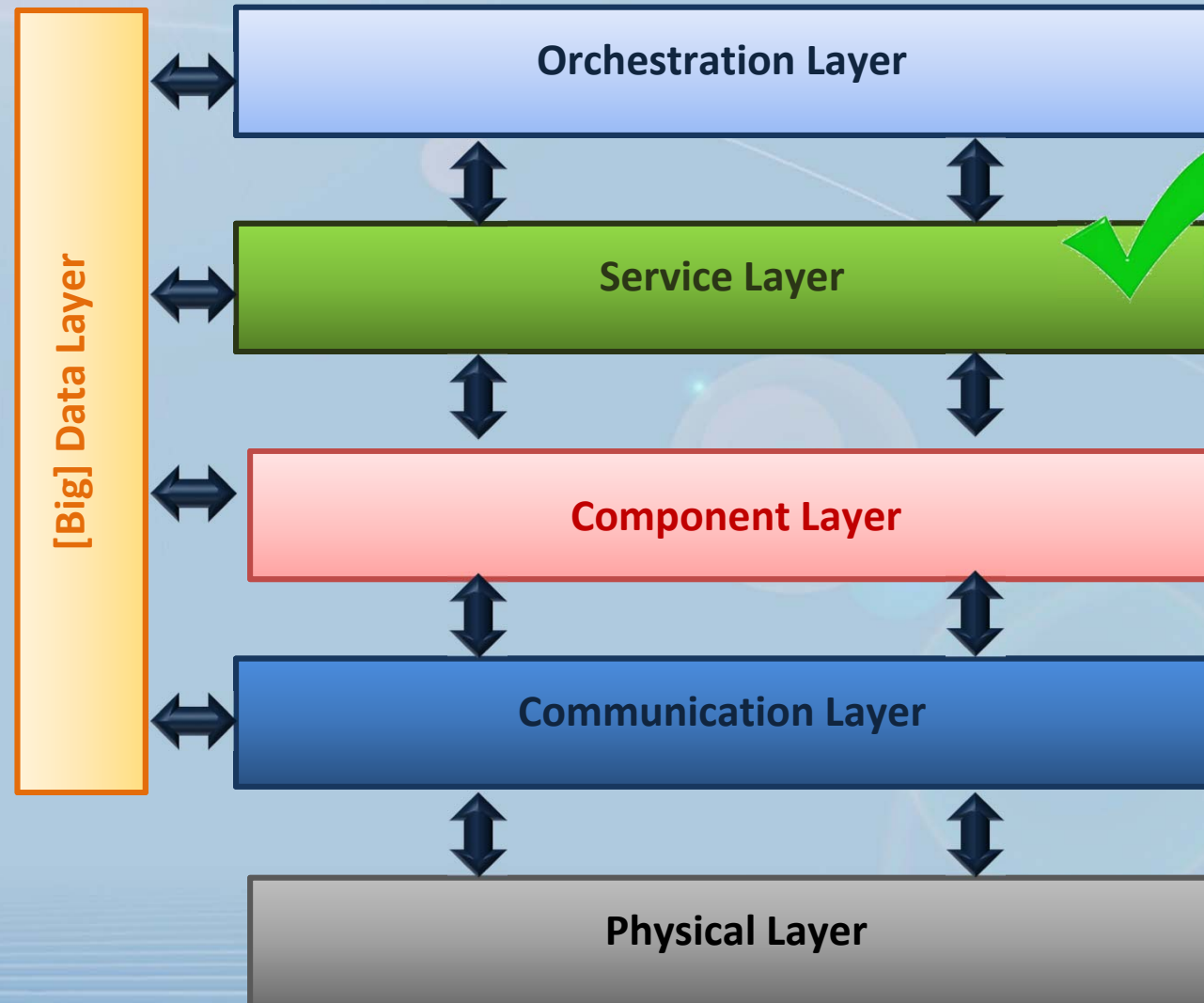# Architecture for Large-Scale Smart Grids SoS

➢ **Component Layer**

❑ Provides services to upper layers

❑ Analyzes data and behaviour

❑ Provides intelligence to the networks

COMPONENT LAYER

System Intelligence

| Prevention | → | Decision Support | → | Problem Manager |

SW Components

Meter Data Manager

| Acquisition | → | Processing | → | Analysis |

Quality Manager

| Quality Monitoring | → | Quality Reporting |

Architecture for Large-Scale Smart Grids SoS

➢ Multi-tiered layered architecture:

Architecture for Large-Scale Smart Grids SoS

➢ **Service Layer**

❑ Publishes software components behaviour

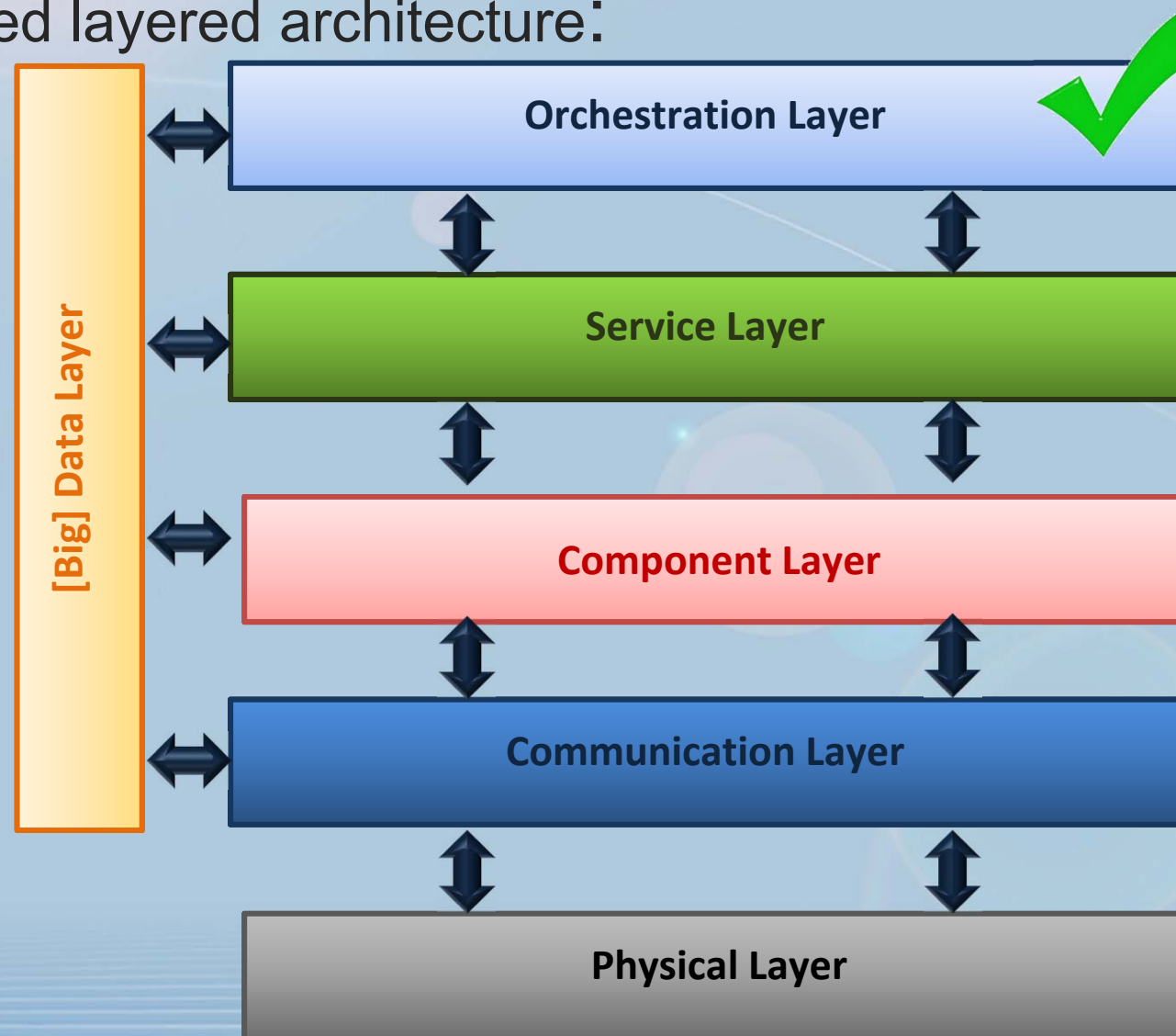❑ Provides services to stakeholders

❑ Parametrizes goals and purposes

SERVICE LAYER

Enterprise Service Bus

System's Stakeholders

Systems Behavior

Architecture for Large-Scale Smart Grids SoS

➢ Multi-tiered layered architecture:

Architecture for Large-Scale Smart Grids SoS

➢ **Orchestration Layer**

- ❑ Implements the behavior that a SoS leverages
- ❑ Complex services → Crosscutting of systems
  - ❖ SLAS
- ❑ Flexible and adaptive
  - ❖ handle continuous and dynamic change

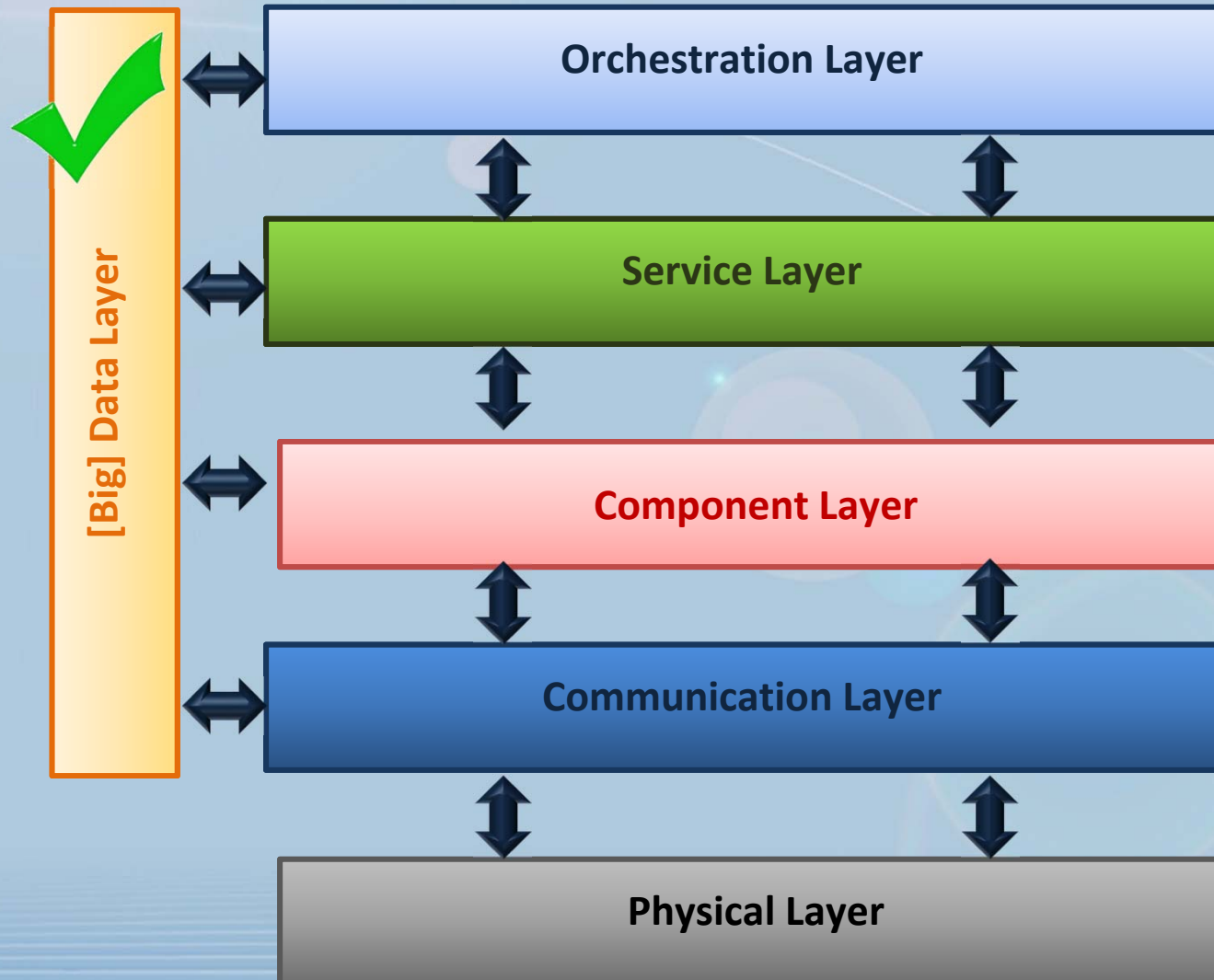# Architecture for Large-Scale Smart Grids SoS
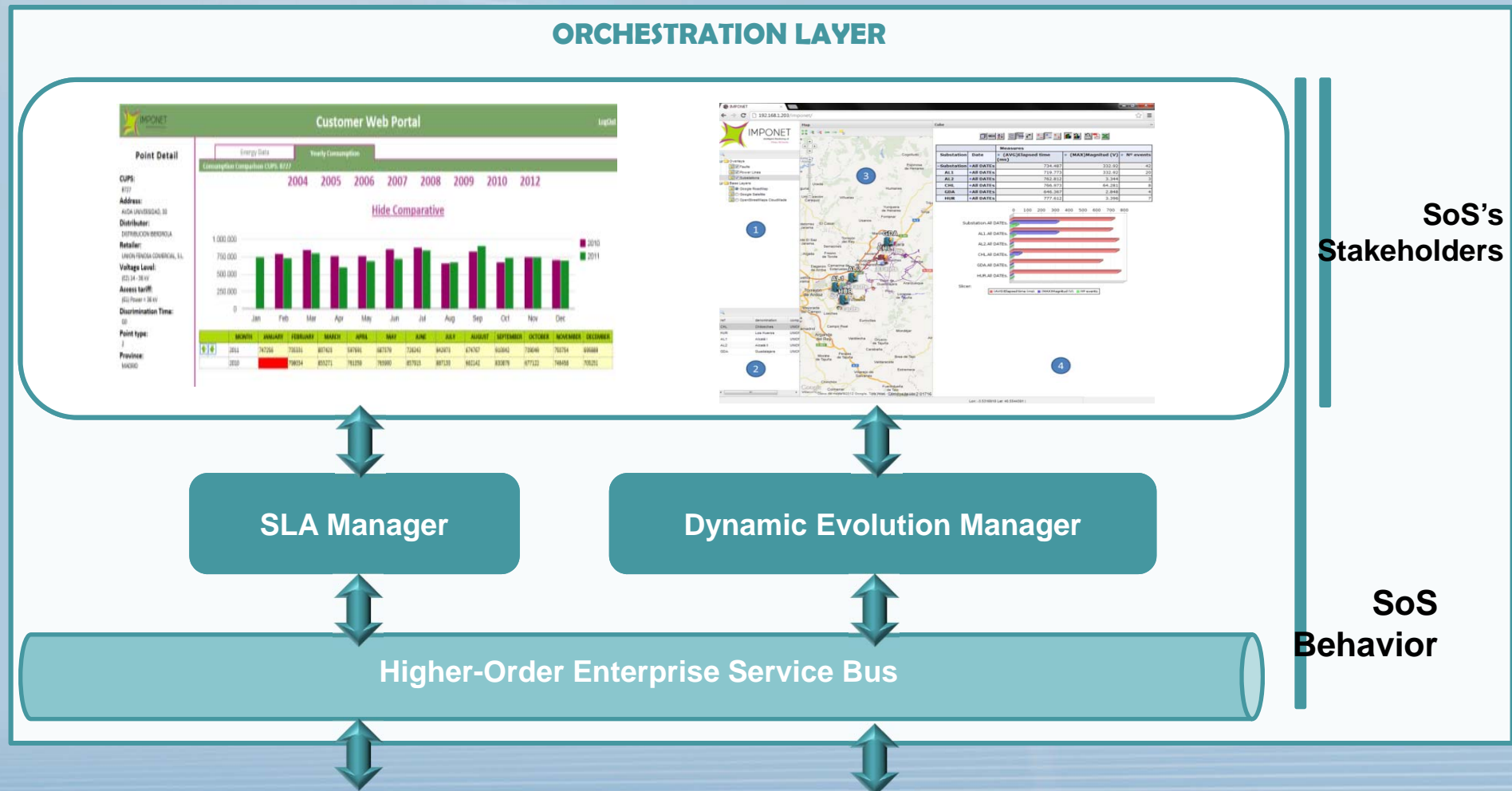
➢ **Orchestration Layer**

Architecture for Large-Scale Smart Grids SoS
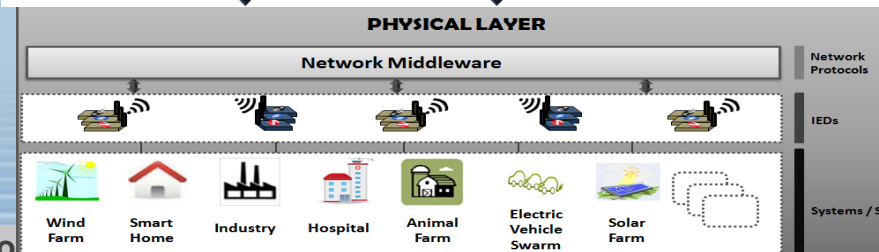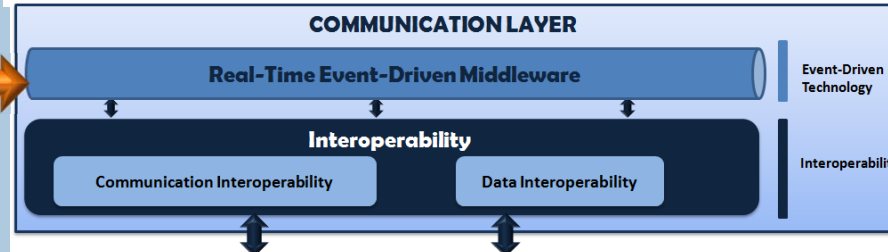
➤ Multi-tiered layered architecture:
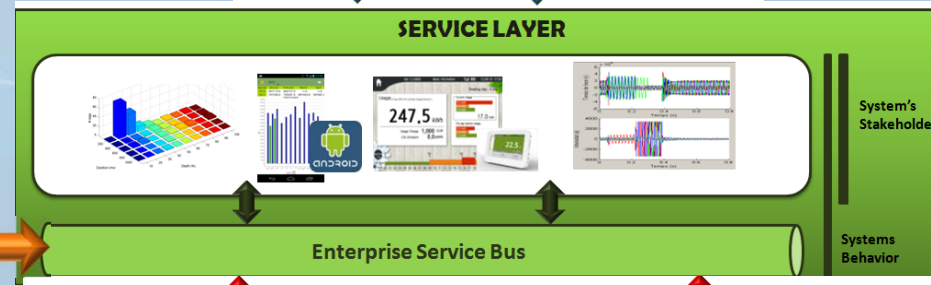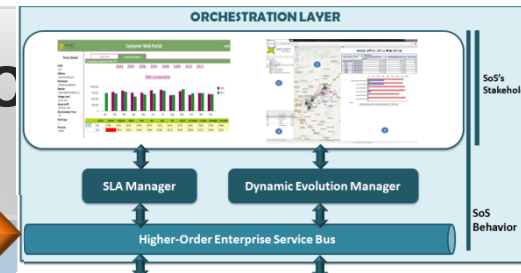
tecture for Smart SoS

► Introduction

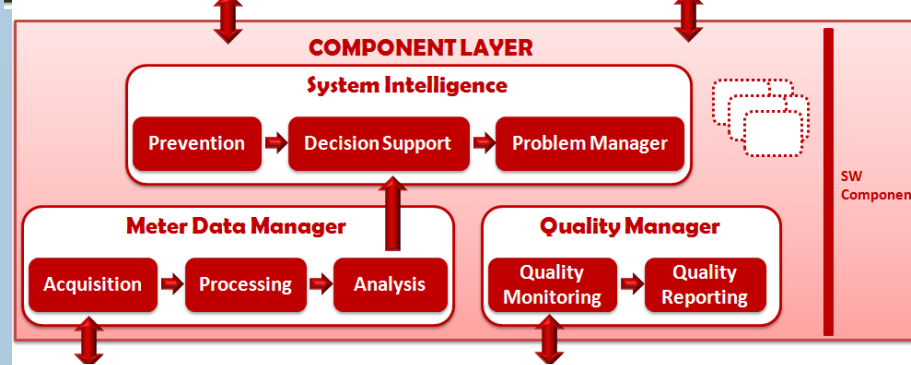► Large-Scale Smart Grids
as a SoS

► A Software Architecture for
Large-Scale Smart Grids SoS

► **Conclusions & Further Work**

Conclusions

➢ First definition of a reference architecture for Large-Scale Smart Grids SoS

❑ Multi-tiered architecture

❑ Based on the Event-Driven SOA paradigm

❑ Main properties: scalable, lowly coupled, open to new functionalities, use of dynamic reconfiguration and standards

Further Research

➢ Mechanisms for the management of goals, plans, and variability

➢ Behavior patterns could be studied and identified to address this variability

➢ Implement a recommender decision support system for configuring the architecture taking into account the needs of each specific SoS.

➢ Abstracting the architecture to construct a reference architecture for SoS

Thank you very much for your attention

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