New Solutions and Standards for SCADA, EMS, MMS and DMS Systems

Nova Rješenja i Standardi za SCADA, EMS, MMS i DMS Programske Sustave

Stipe Fuštar

May 25, 2009

PowerGrid360
Utility Consulting On-Demand

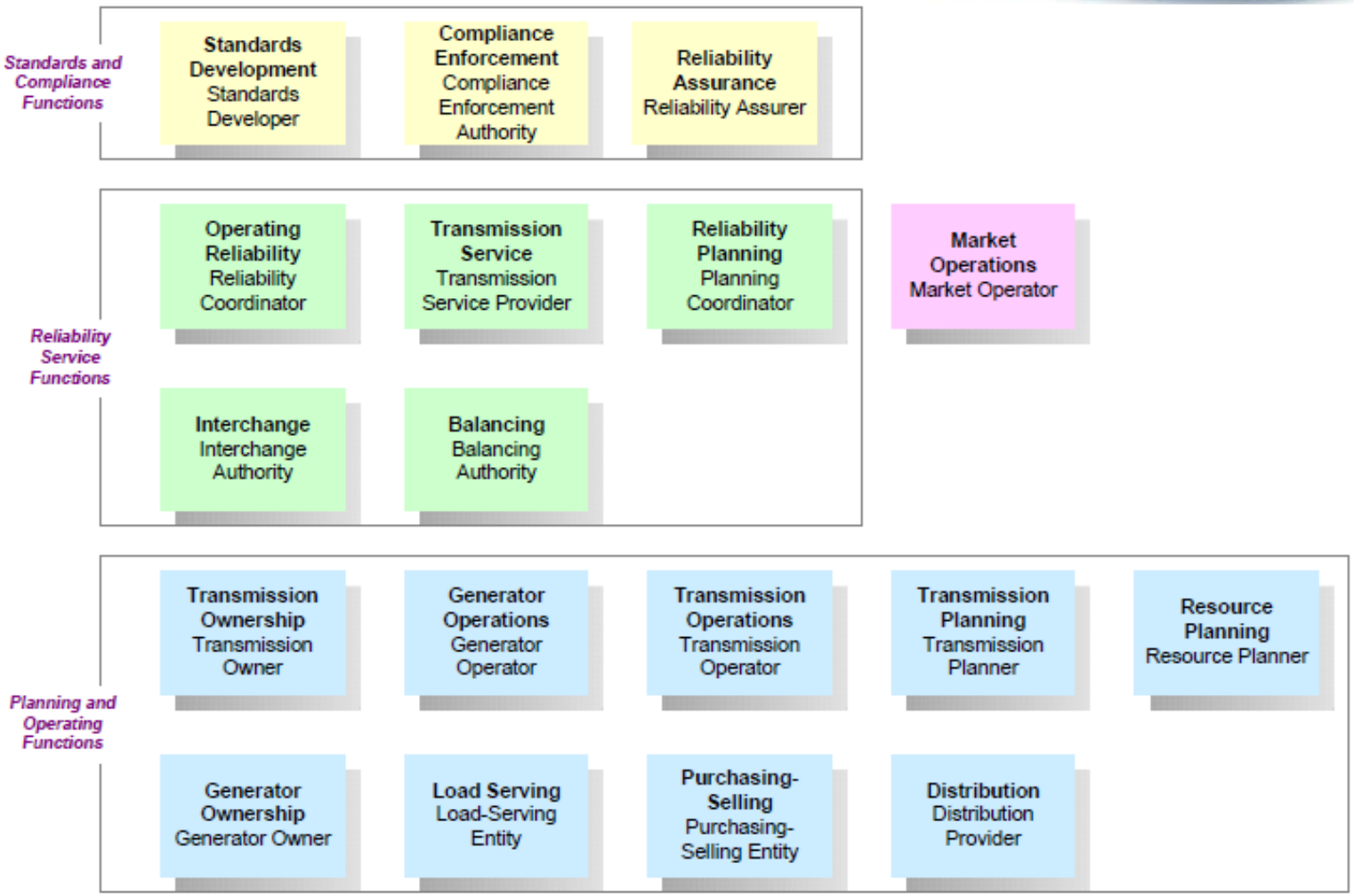
Presentation Outline

- State of Industry
- Utility Real-Estate
  - NERC Functional Model
- Communications Perspective
- Smart Grid
- Role of Interoperability
- Short CIM Tutorial
- Smart Grid Standards
- CIM Usage Perspective
- Message Payload / Service Definition Process
- CIM and Enterprise Semantic Model
- CIM Compliance

State of the Utility Industry

- A lot of Hype around Smart Grid Initiative and Utility Industry in General
- Large Companies are investing in R&D
  - GE
  - IBM
  - Oracle
  - SAP
  - Google
- Different Perception Of Smart Grid and New Trends
- Utilities in US count on Stimulus Package

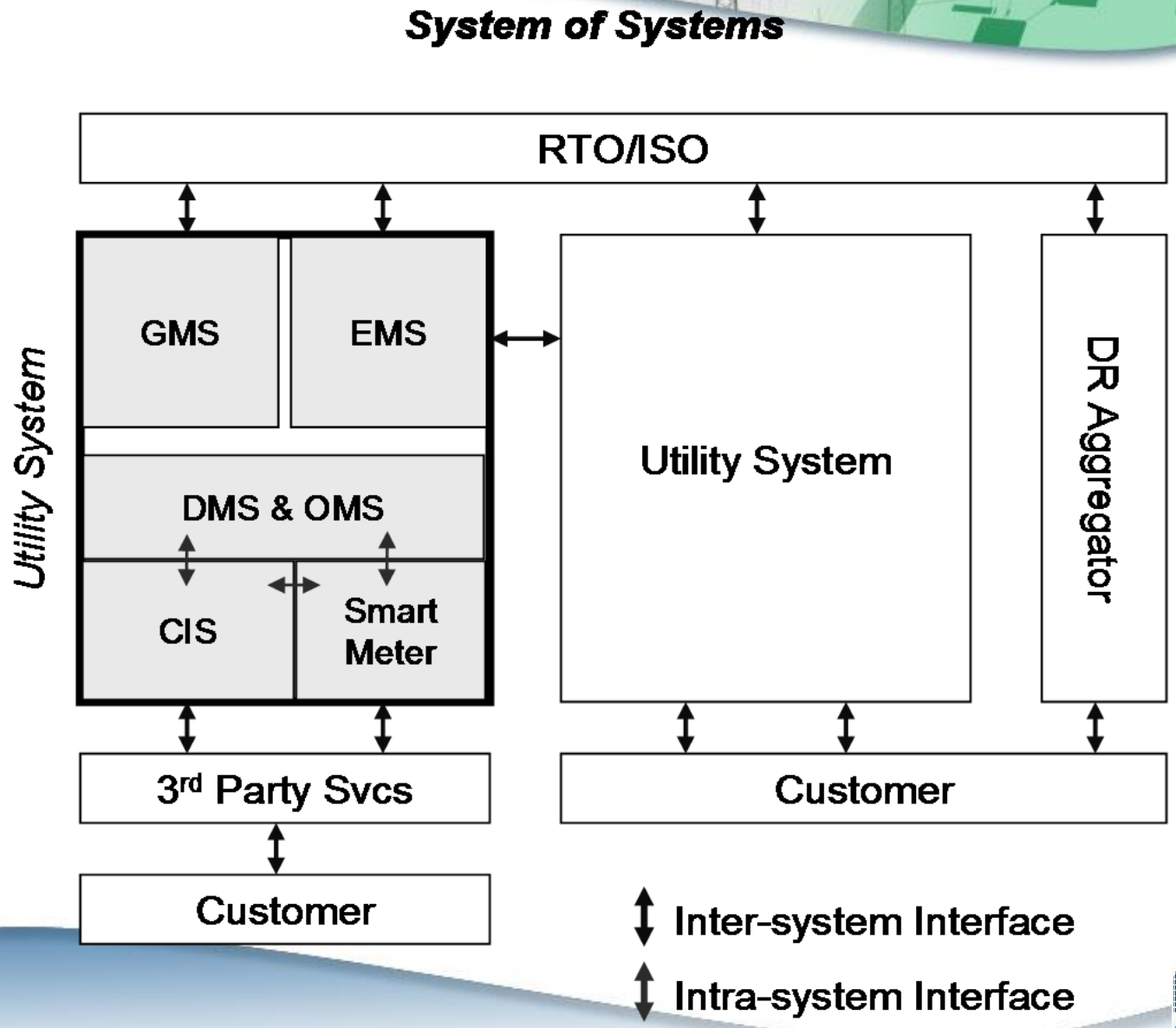
NERC Functional Model (1)



NERC Functional Model (2)

Function Name	*Responsible Entity*
Balancing	Balancing Authority
Compliance Enforcement	Compliance Enforcement Authority
Distribution	Distribution Provider
Generator Operations	Generator Operator
Generator Ownership	Generator Owner
Interchange	Interchange Authority
Load-Serving	Load-Serving Entity
Market Operations	Market Operator (Resource Integrator)
Operating Reliability	Reliability Coordinator
Planning Reliability	Planning Coordinator
Purchasing-Selling	Purchasing-Selling Entity
Reliability Assurance	Reliability Assurer
Resource Planning	Resource Planner
Standards Development	Standards Developer
Transmission Operations	Transmission Operator
Transmission Ownership	Transmission Owner
Transmission Planning	Transmission Planner
Transmission Service	Transmission Service Provider

System of Systems Perspective



Source: Open Smart Grid Users Group

Communications Perspective

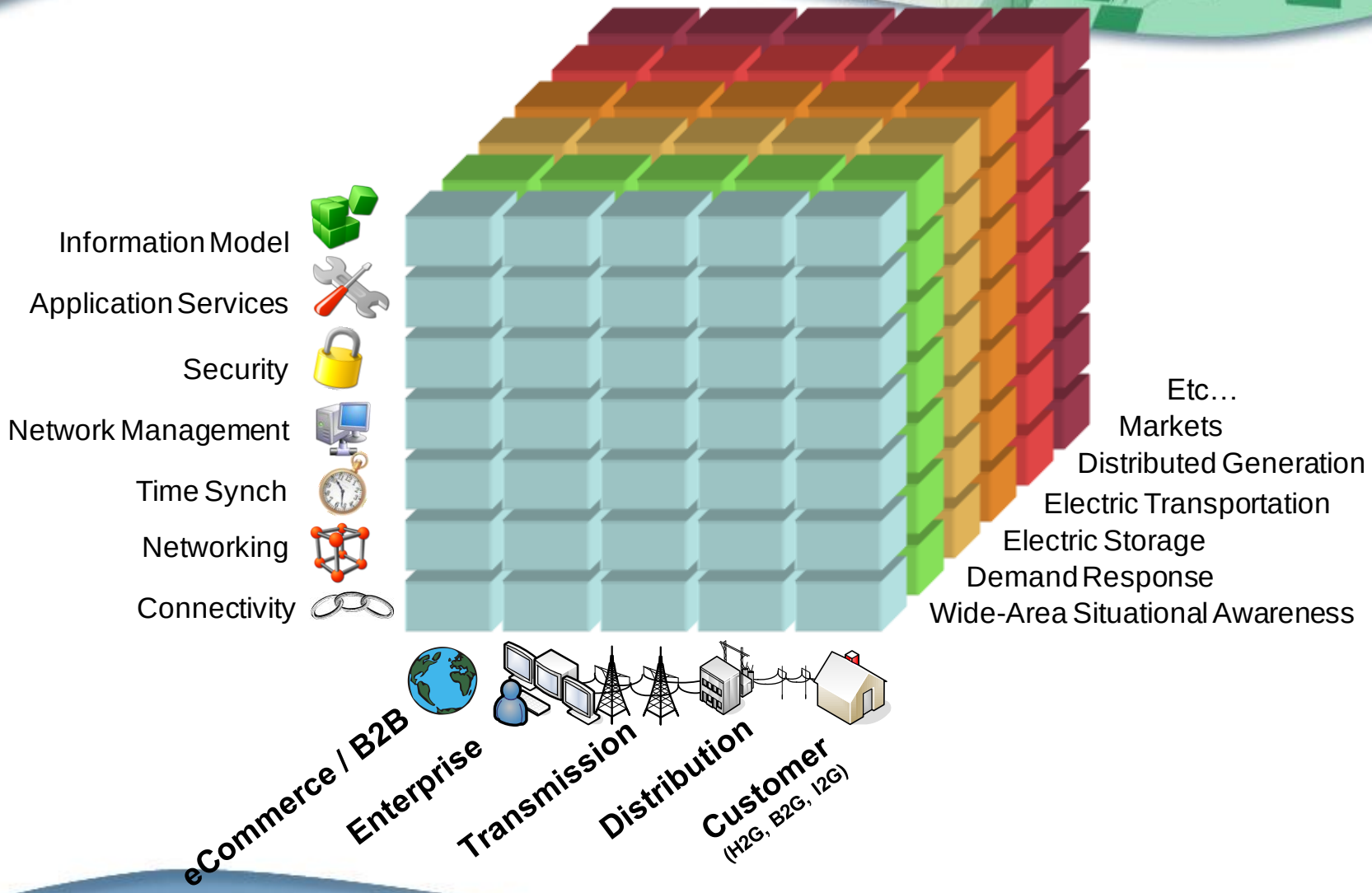
- *The Supervisory Control Data Acquisition (SCADA) network*
- *The marketplace infrastructure: the public Internet for energy transactions and transmission rights information*
- *The regional and inter-regional security data networks, to provide grid information from several utilities to one or more regional or national site(s)*

What is Smart Grid?

- The term “Smart Grid” refers to a modernization of the electricity delivery system so it monitors, protects and automatically optimizes the operation of its interconnected elements – from the central and distributed generator through the high-voltage network and distribution system, to industrial users and building automation systems, to energy storage installations and to end-use consumers and their thermostats, electric vehicles, appliances and other household devices.
- The Smart Grid will be characterized by a two-way flow of electricity and information to create an automated, widely distributed energy delivery network. It incorporates into the grid the benefits of distributed computing and communications to deliver real-time information and enable the near-instantaneous balance of supply and demand at the device level.

Source: EPRI Interim Smart Grid Roadmap April 2009

Smart Grid Interface Cube



Source: EPRI Interim Smart Grid Roadmap April 2009

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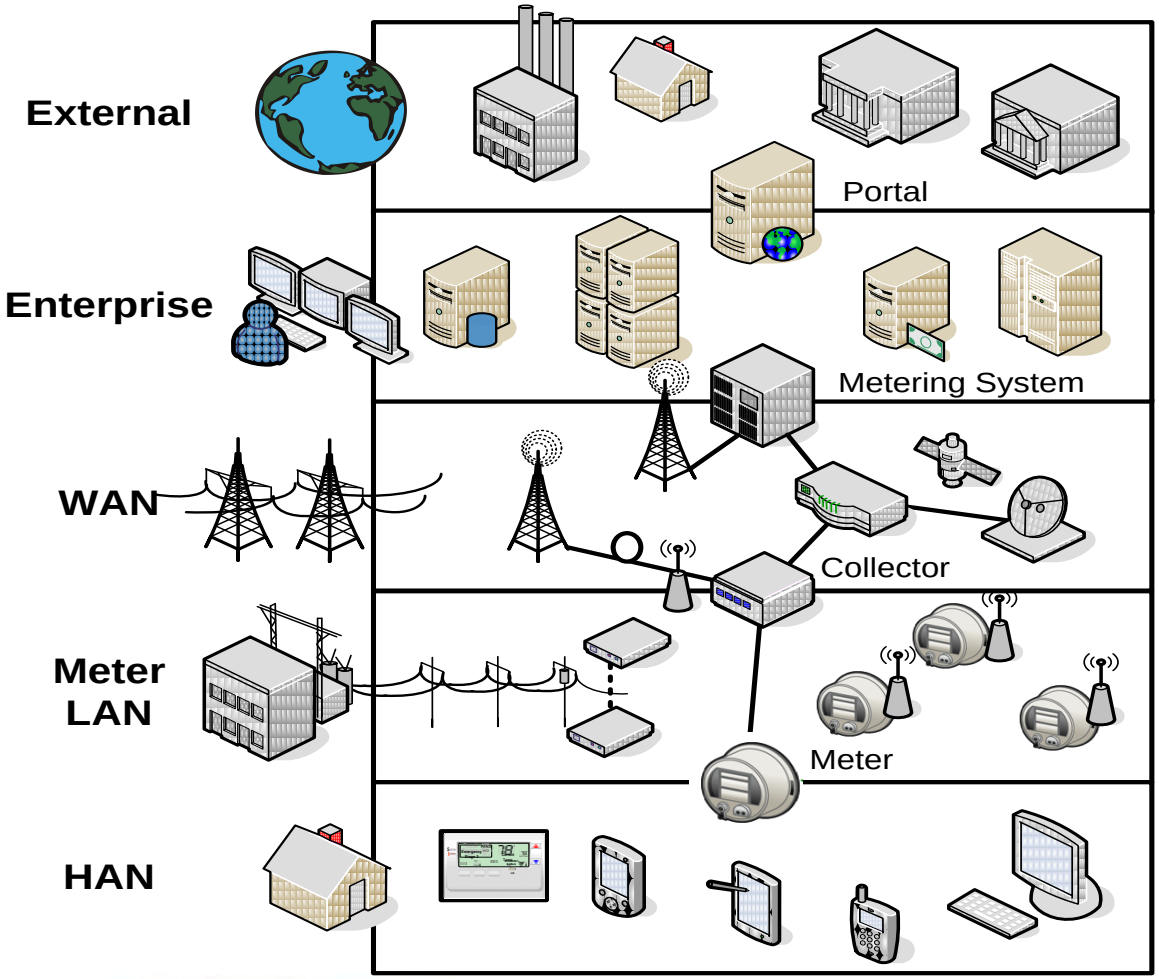
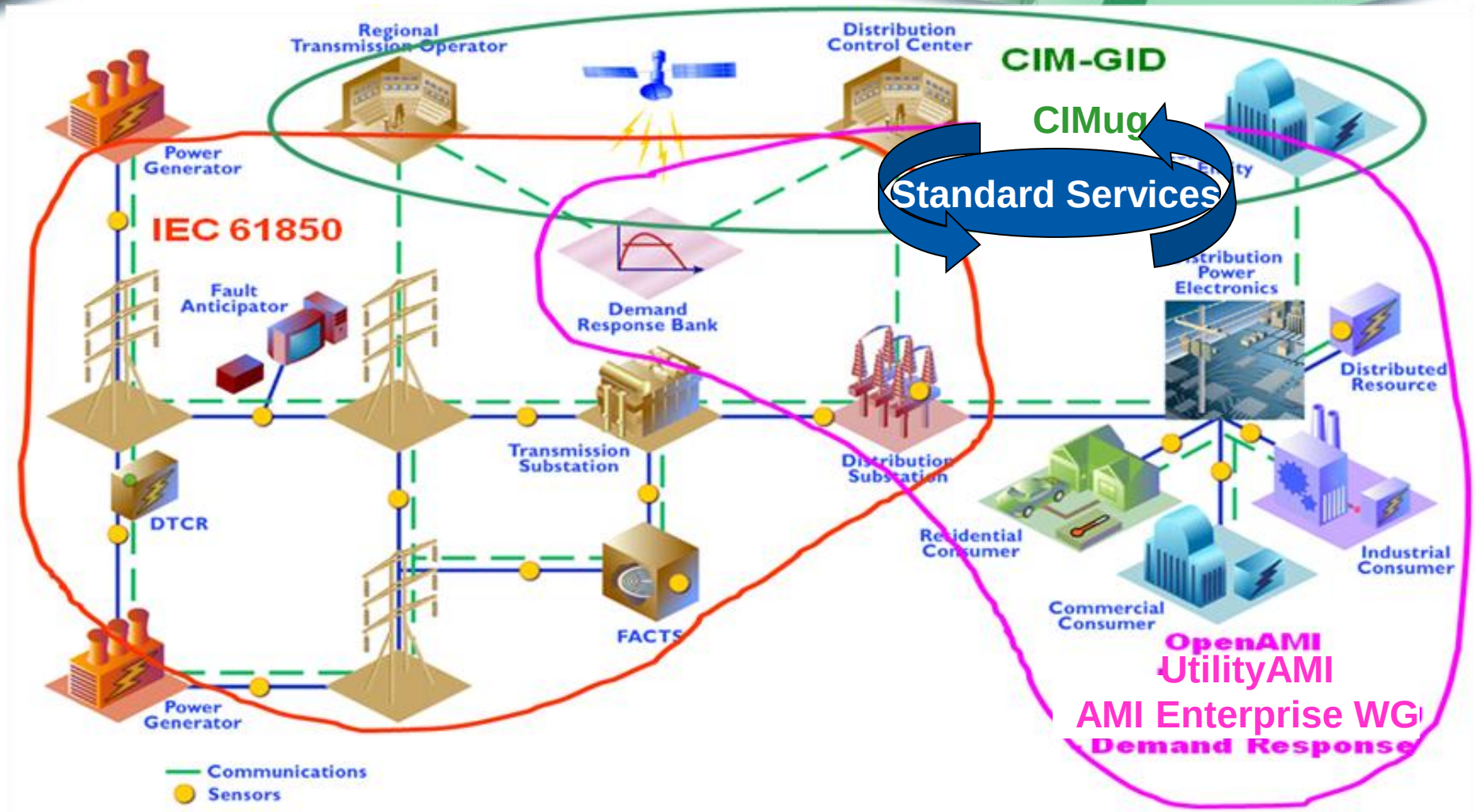
Smart Grid High Level Overview



	Example Members	Example Technologies
External	Retailers Aggregators Regulators Customers Providers	Internet Protocols World-Wide Web ebXML IEC 60870-6 ICCP
Enterprise	MDMS CIS/Billing OMS WMS EMS/DMS	IEC 61970 IEC 61968 Web Services Multispeak Message Buses
WAN	Routers Towers Ground Stations Repeaters Rings	SONET, WDM, ATM MPLS Frame Relay Satellite Microwave IEC 61850 DNP3
Meter LAN	Relays Modems Bridges Access Points Insertion Points	WiMAX BPL / PLC Wireless Mesh ADSL Cellular Cable (DOCSIS)
HAN	Thermostats Pool Pumps Field Tools PCs Building Automation	ZigBee WiFi LonWorks BACnet HomePlug OpenHAN

Source: Erich W. Gunther, Aaron Snyder, Grant Gilchrist, Darren Reece Highfil. "*Smart Grid Standards Assessment and Recommendations for Adoption and Development*" February 2009

Leveraging the Overlap: UCAIug Groups – AMI & CIM



Role of Interoperability (What)

- Exchange of meaningful, actionable information between two or more systems across organizational boundaries,
- A shared meaning of the exchanged information,
- An agreed expectation for the response to the information exchange,
- Requisite quality of service in information exchange: reliability, fidelity, security

Role Of Interoperability (Why)

- Enhance the future grid's reliability, interoperability and extreme event protection for an increasingly complex system operation.
- Increase transmission transfer capabilities and power flow control.
- Use efficient, cost-effective, environmentally sound energy supply and demand.
- Maximize asset use.

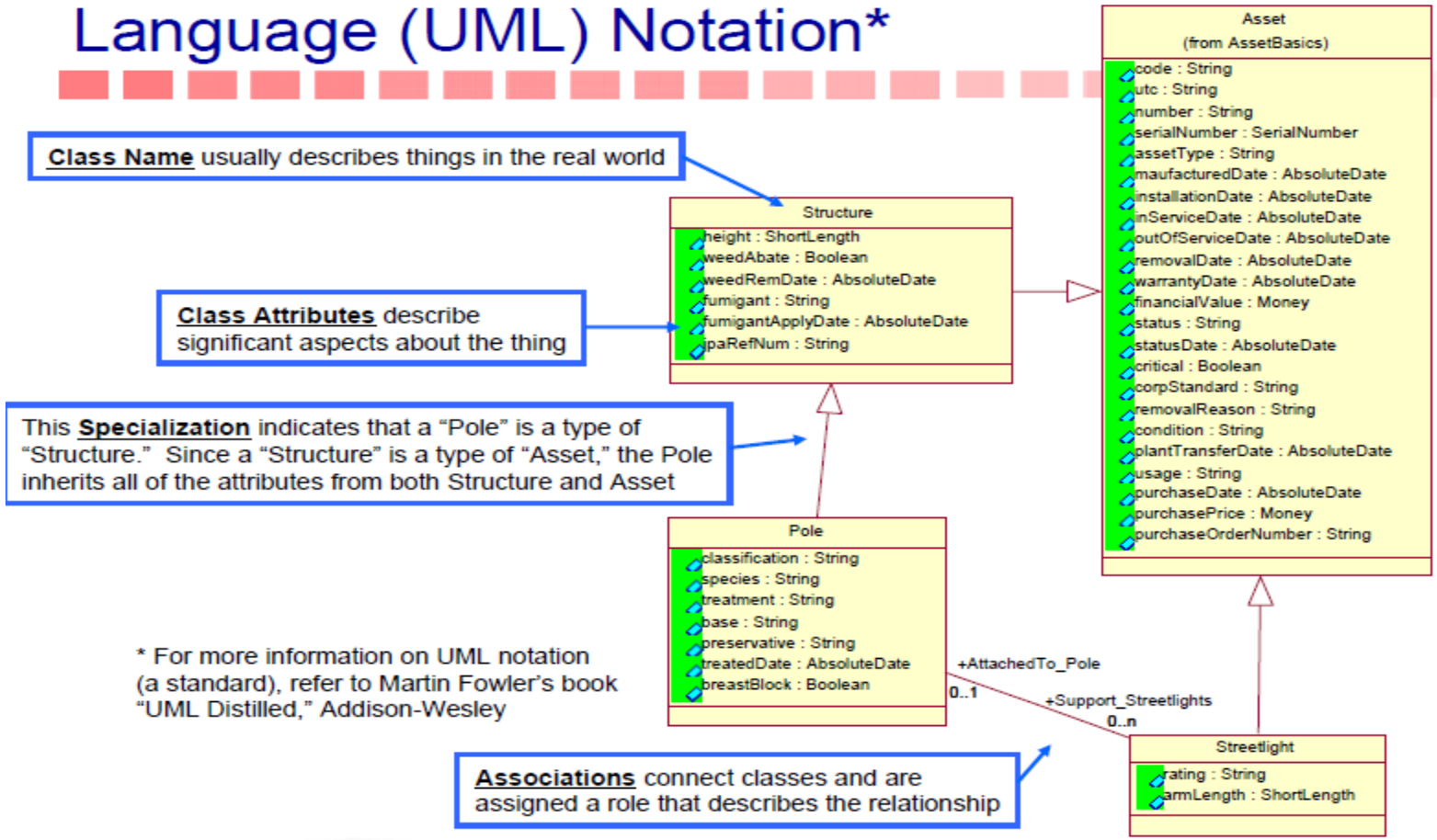
Islands of Information

Short CIM Tutorial?

- CIM = **C**ommon **I**nformation **M**odel
- CIM is:
  - A model defining classes and their relationships to other classes
- CIM is not:
  - A database (object or relational)
  - Defines relationships, not how you implement them

What Is CIM?

The CIM Is Expressed In Unified Modeling Language (UML) Notation*



Courtesy of Xtensible Solutions

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Elements of the Model

Entities

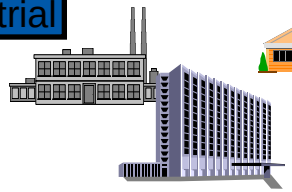
Relationships

Attributes

Data Types

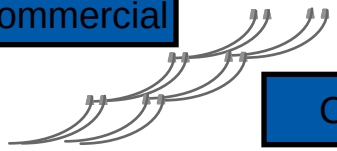
Creation of the model - Define the Entities

Industrial



Residential

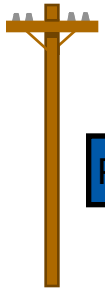
Commercial



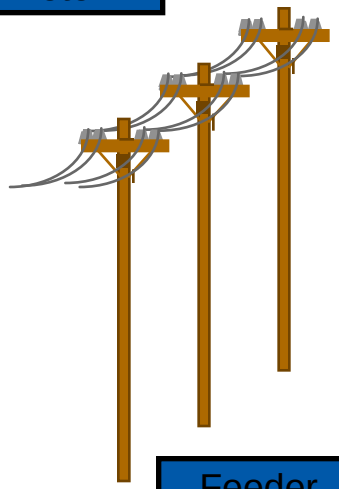
Conductor

Switch

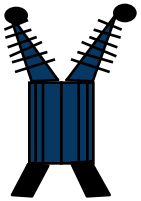
Meter

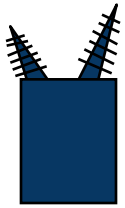


Pole

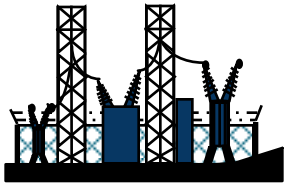


Breaker

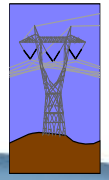




Transformer

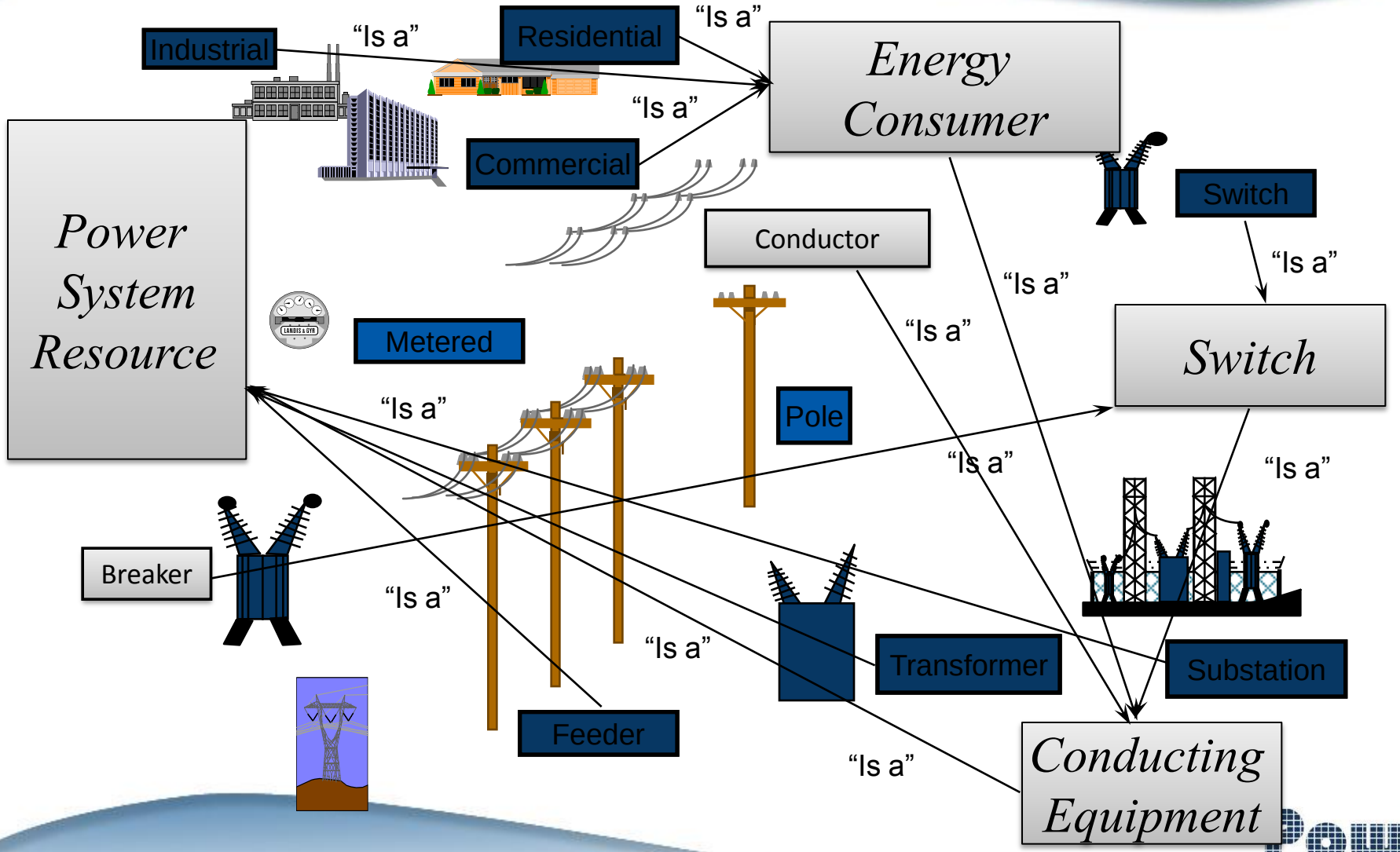


Substation

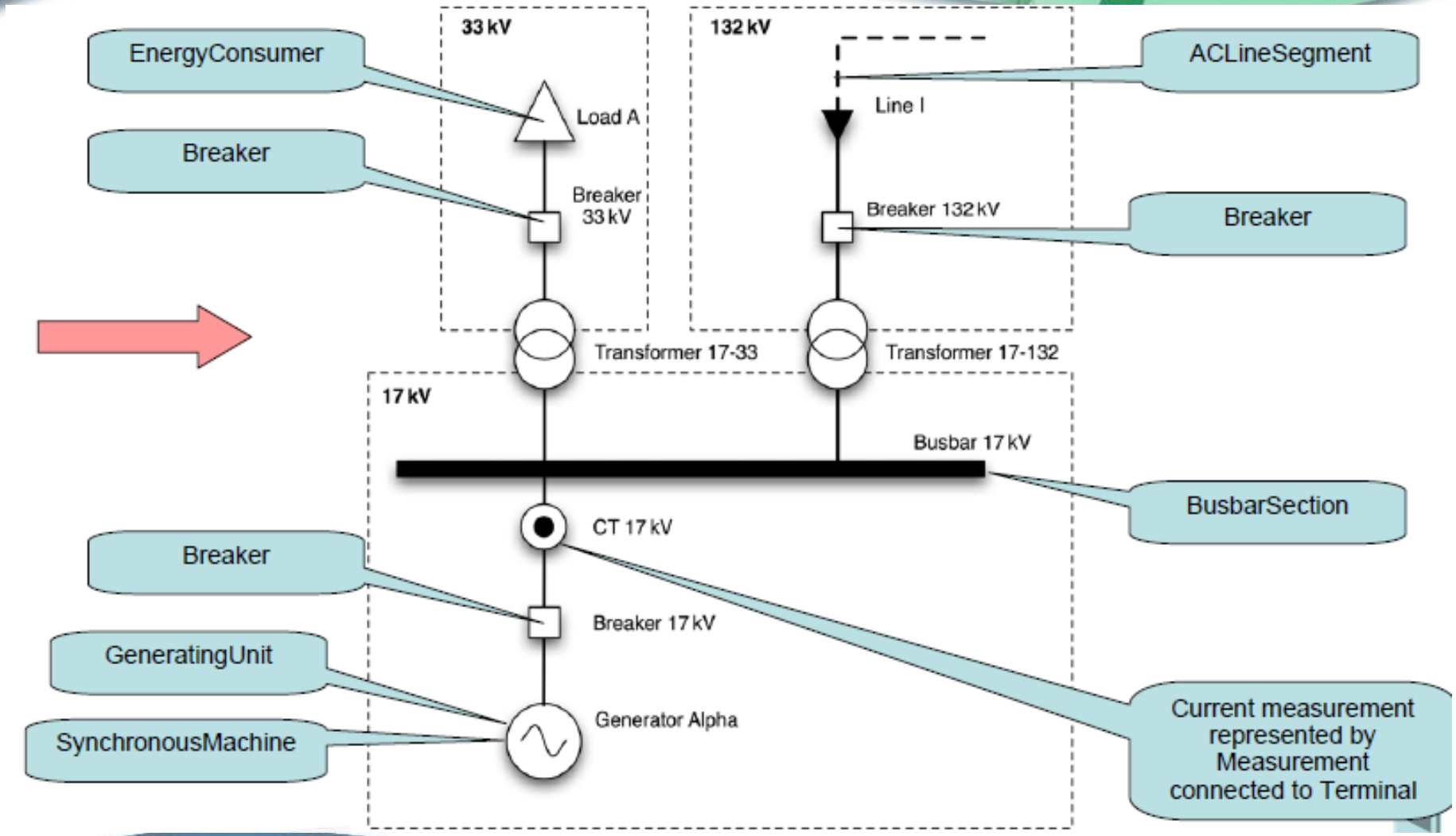


Feeder

Create the model - Define the Relationships

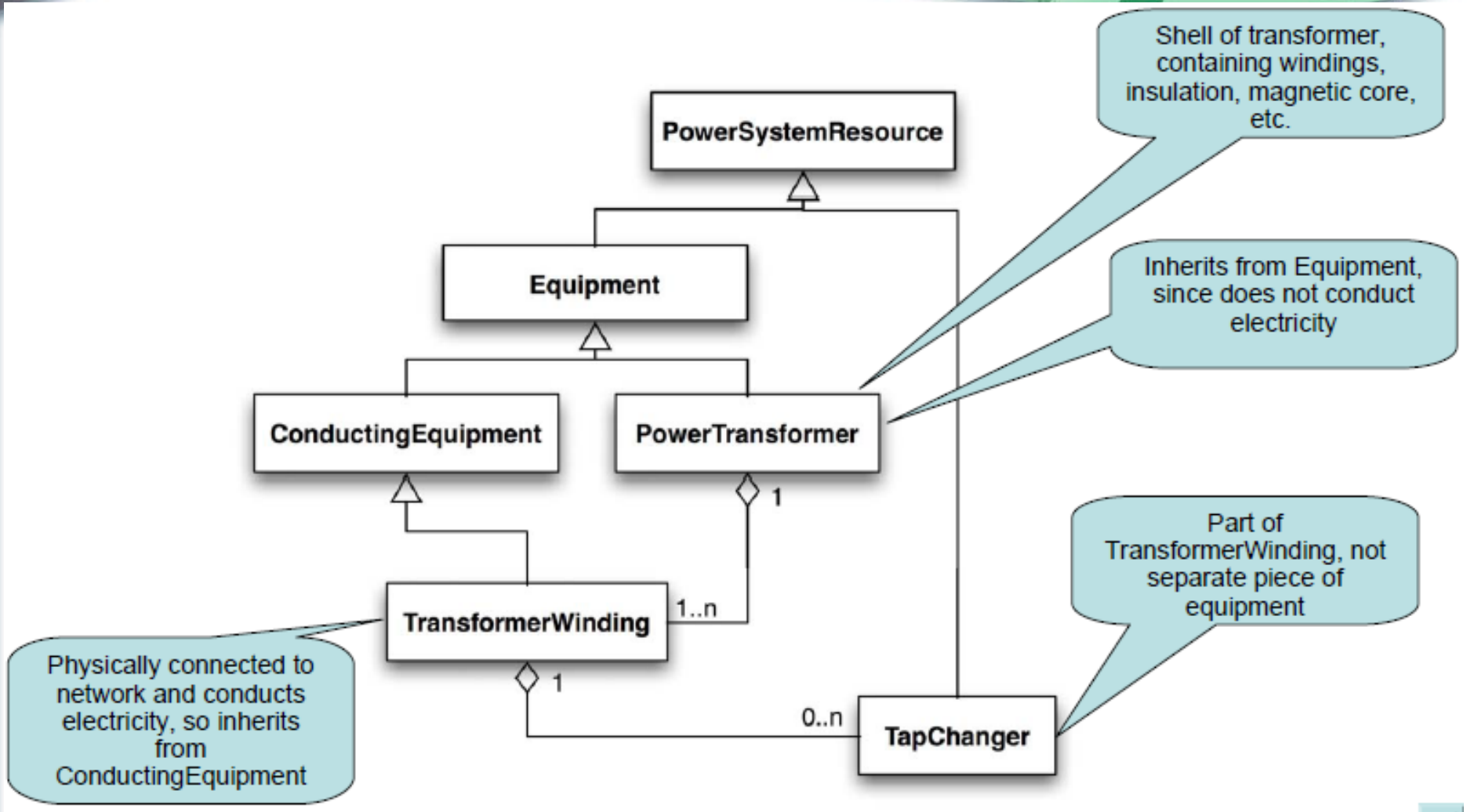


Single Line Diagram Example



Courtesy of Xtensible Solutions

Transformer Class Diagram



Courtesy of Xtensible Solutions

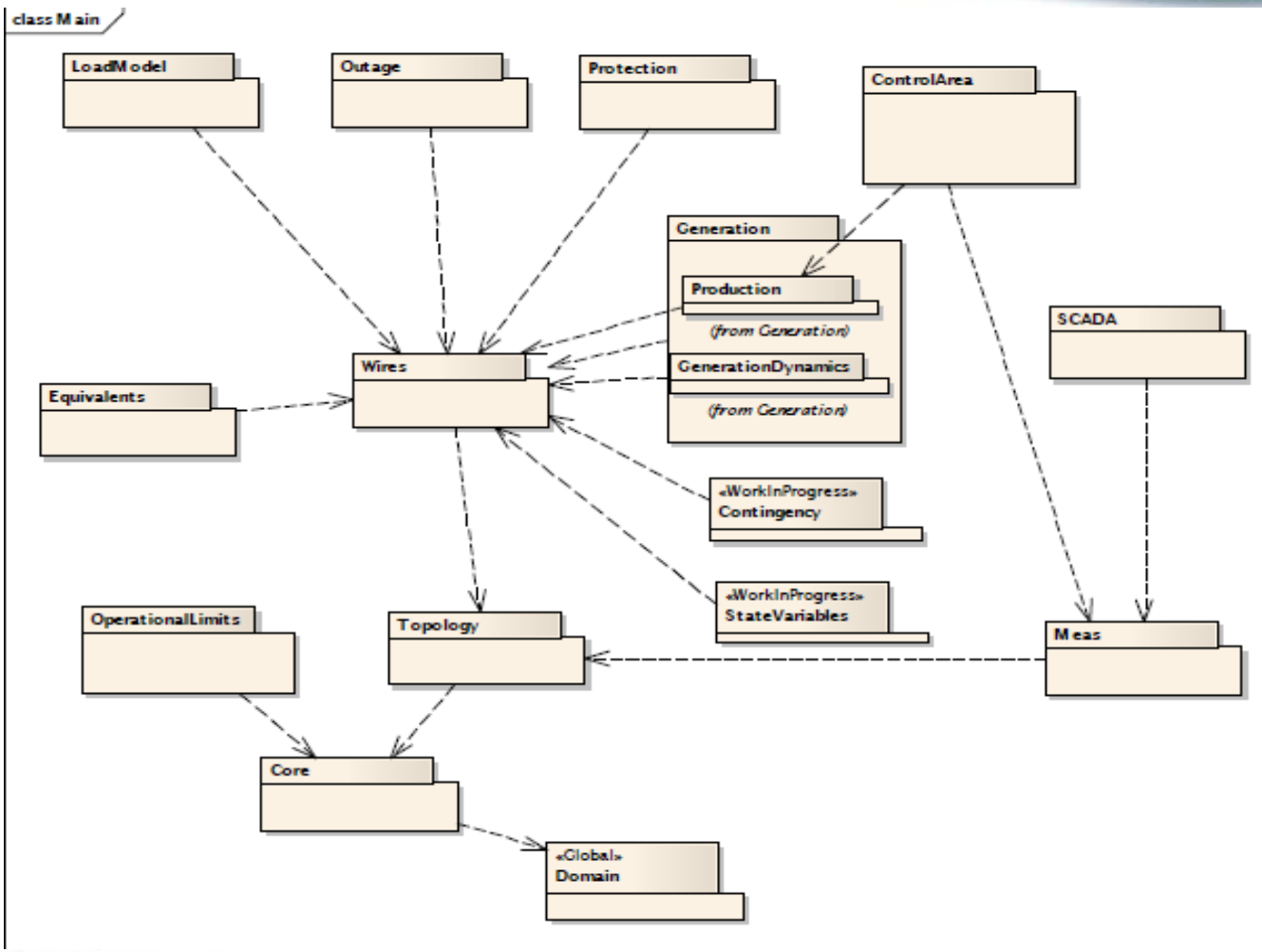
More about CIM

- A Unified Modeling Language (UML) based information model representing real-world objects and information entities exchanged within the value chain of the electric power industry
  - Maintained by IEC in Sparx Enterprise Architect modeling tools
- Enable integration of applications/systems
  - Provides a common model behind all messages exchanged between systems
- Applies primarily to system interfaces
- Enable data access in a standard way
  - Common language to navigate and access complex data structures in any database
    - » Provides a hierarchical view of data for browsing and access with no knowledge of actual logical schema
  - Inspiration for logical data schemas (e.g., for an operational data store)
- Not tied to a particular application's view of the world
  - But permits same model to be used by all applications to facilitate information sharing between applications

Key CIM Related Standards

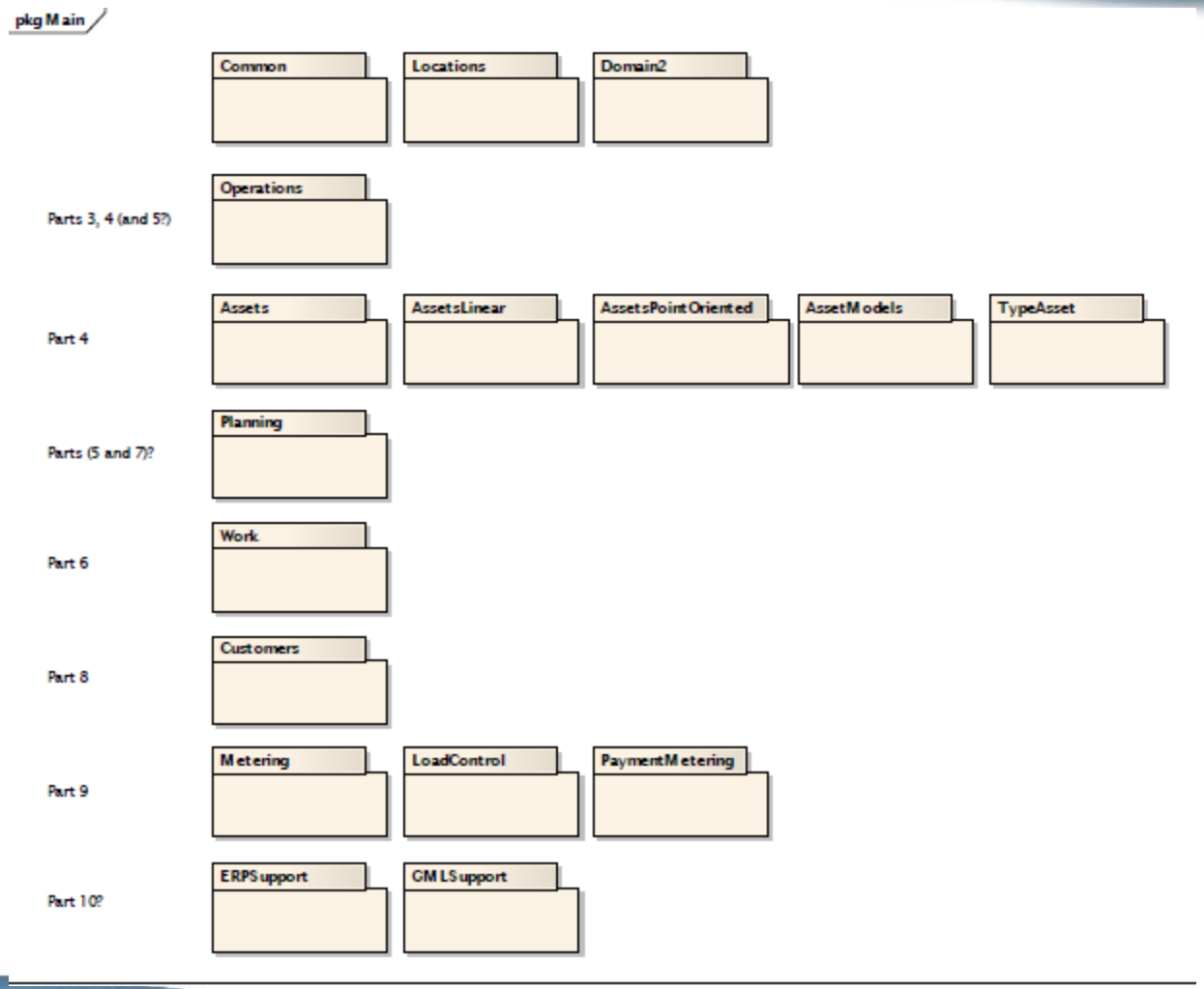
- *IEC 61970-301 (Common Information Model)*
- *IEC 61970-404 (High Speed Data Access)*
- *IEC 61970-405 (Generic Eventing and Subscription)*
- *IEC 61970-407 (Time Series Data Access)*
- *IEC 61970-501 (RDF Model Exchange)*
- *IEC 61968-1 (Integration of Distribution Systems)*
- *IEC 61968-11 (CIM extensions for Distribution Systems)*
- *IEC 62351 (Data and Communication Security Profiles)*
- *IEC 60870-6 (TASE.2, ICCP)*

CIM Packages - 61970



Courtesy of Xtensible Solutions

CIM Packages - 61968



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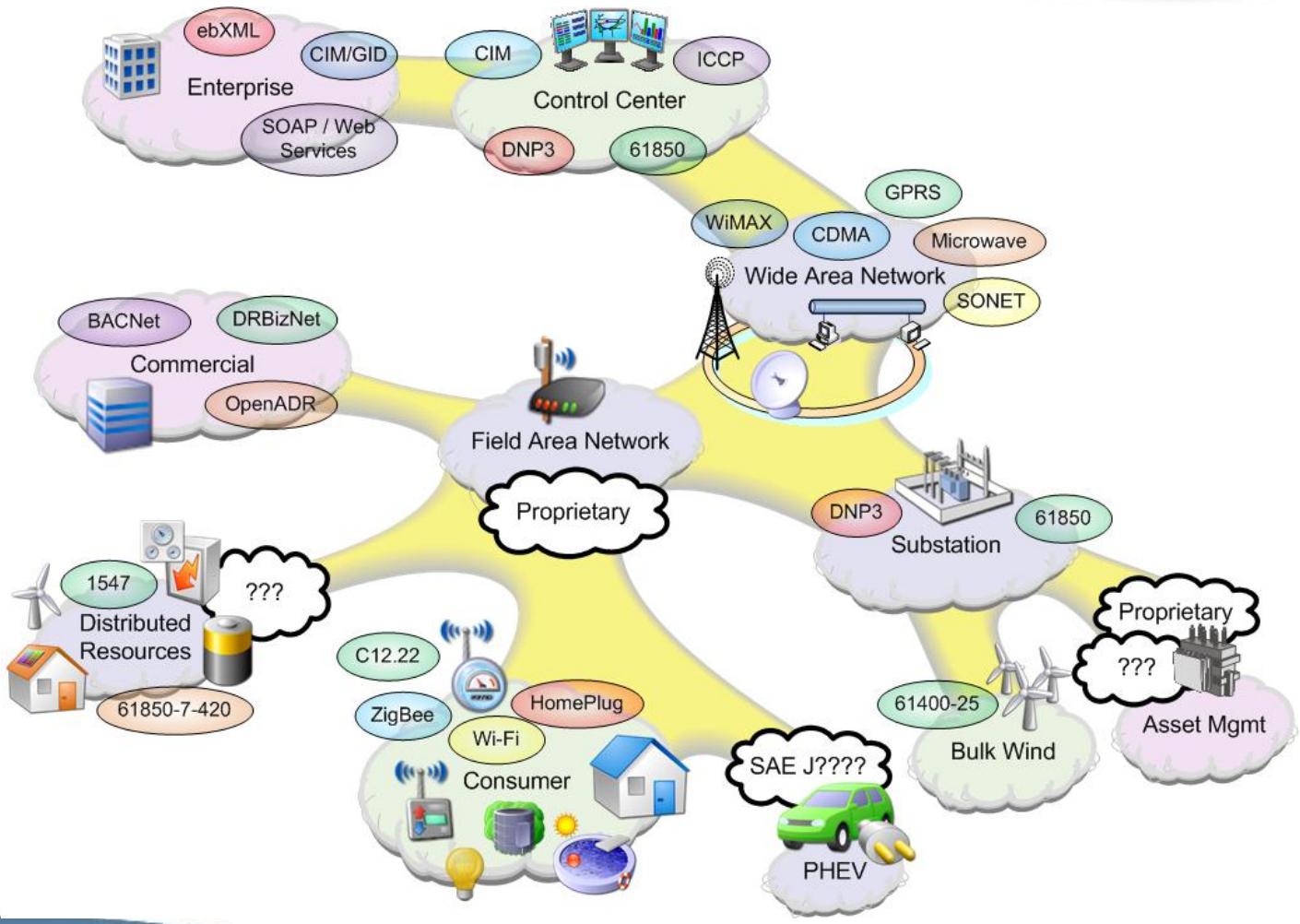
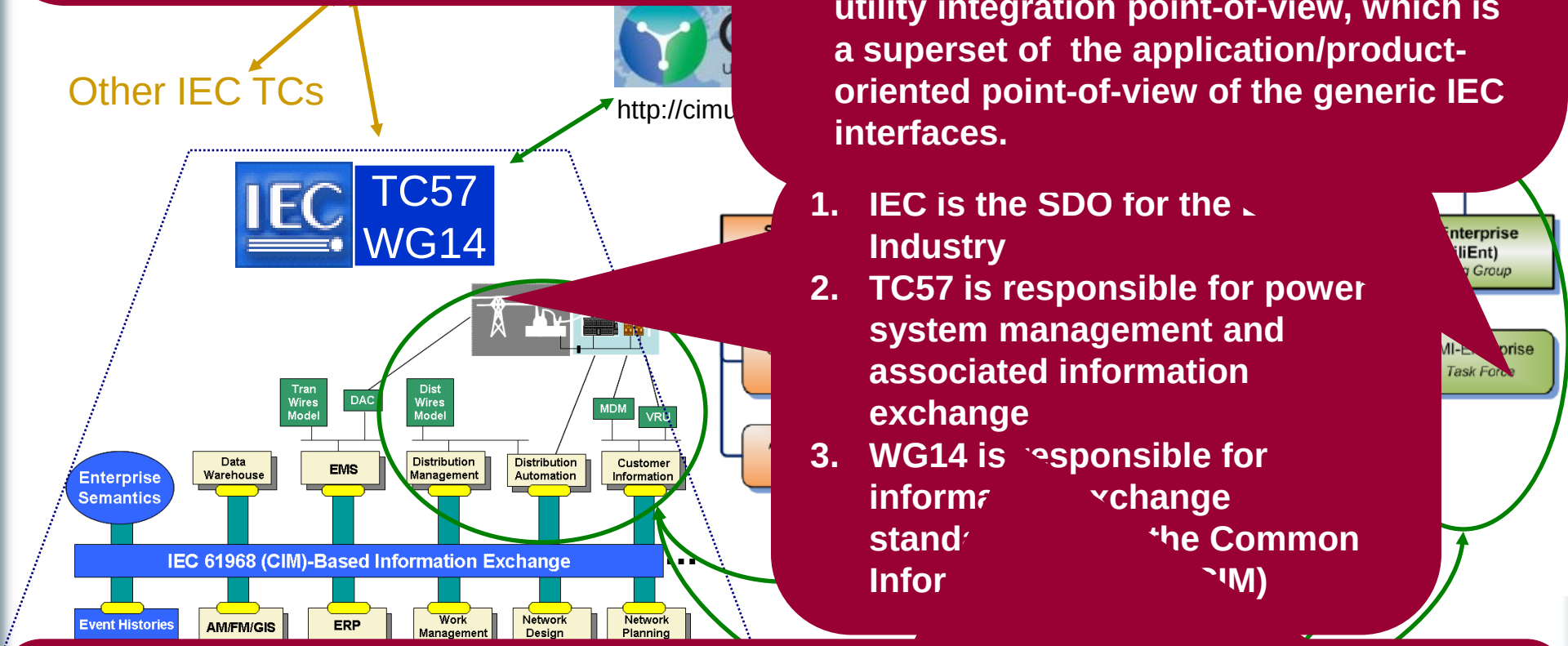
Smart Grid Standards



1. The UCA (Utility Communications Architecture) User Group is the User Community for all TC57 standards and other related users concerns.
2. The CIM User Group is a fast growing organization of CIM users that provide important feedback and suggestions to the SDO.

1. AMI-Ent is a user-driven organization that starts with standards and extends them in an efficient and quick manner to meet current utility project requirements.
2. Appropriate extensions are fed back through the CIM User Group and/or directly to the IEC.
3. Artifacts of this organization are from the utility integration point-of-view, which is a superset of the application/product-oriented point-of-view of the generic IEC interfaces.



1. IEC is the SDO for the ... Industry
2. TC57 is responsible for power system management and associated information exchange
3. WG14 is ...esponsible for inform... ...xchange stand... ...he Common Infor... ...IM)

1. The ZigBee & HomePlug Smart Energy Alliance is currently sponsoring an activity to update its Smart Energy Profile to take advantage of the standard and technology neutral CIM.

Some Characteristics of Next Generation Systems

- Explosion of Data for Processing
  - Frequency
  - Volume
  - Timing
- Data Synchronization
- Requires Greater Communications bandwidth with lower latency
- New generation of applications is expected

Next Generation Energy Systems Platform

- *"The Next Generation energy platform is seen as a high-performance, highly distributed operational data management infrastructure that encompasses hierarchically clustered gateways / agents with distributed memory resident data sources to provide very low-latency, predictable, high-throughput data sharing and event distribution. The platform is envisioned as dynamic massive server networks (dynamic grid), massive distributed and replicated memory spaces, use of event-based internal architecture for intra-systems communications (EDA and CEP inside) and use of an extensible modularity of platform technology (SOA inside)."*
- *(Stipe Fustar CTO, Power Grid 360 and Chief Scientist, Verdeeco Inc.)*

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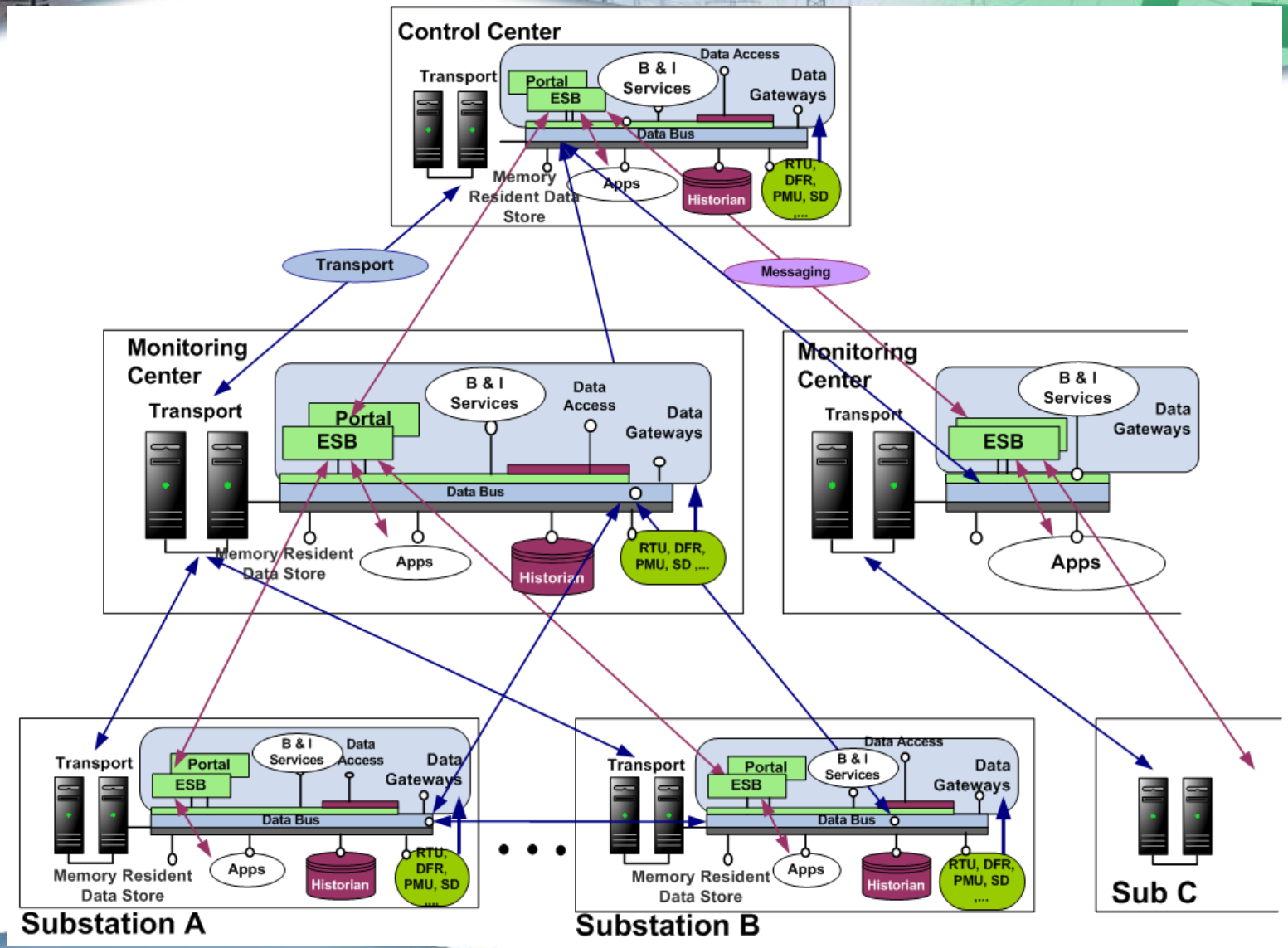
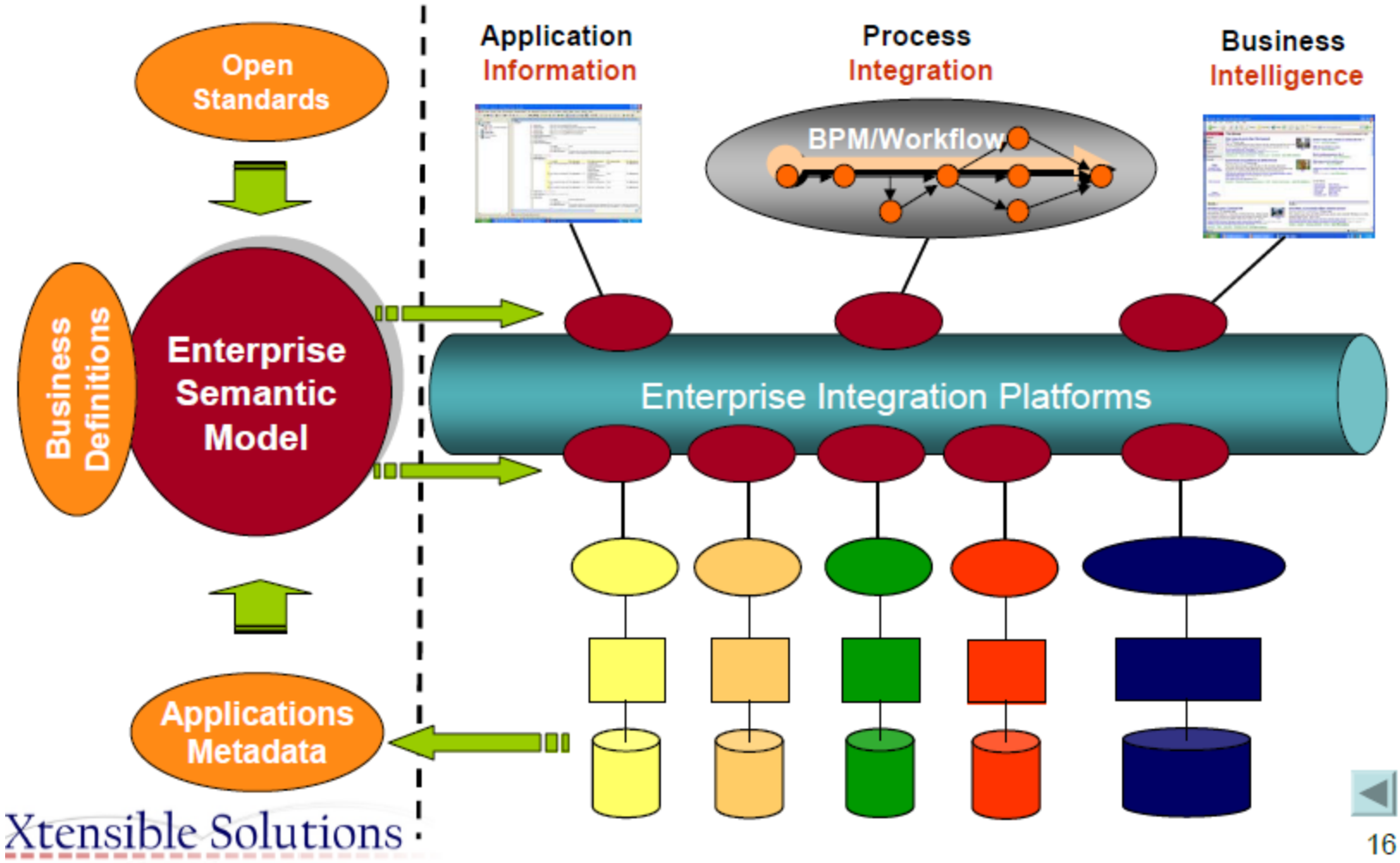
Next Generation Platform

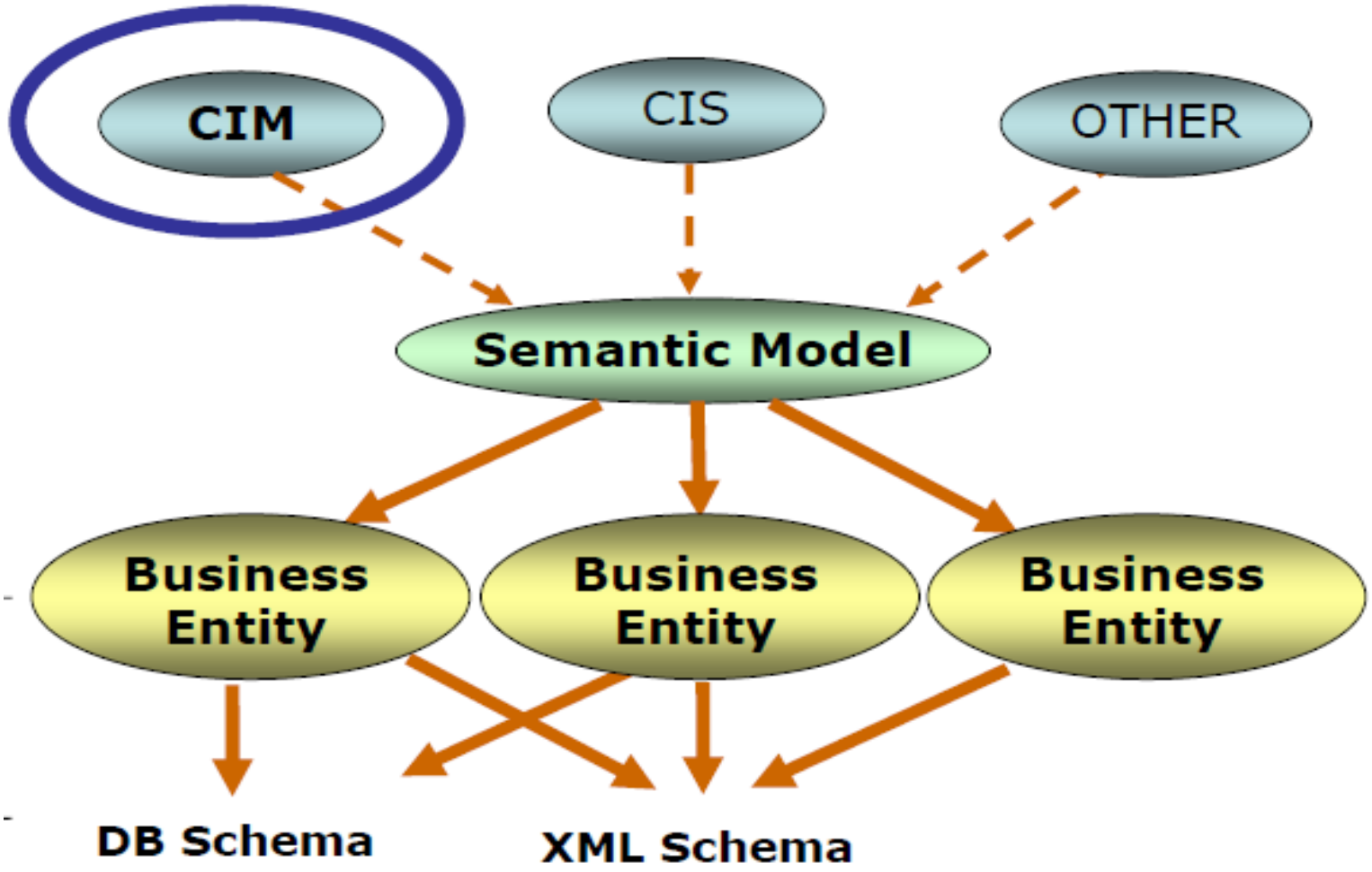


Enterprise Semantic Model Perspective



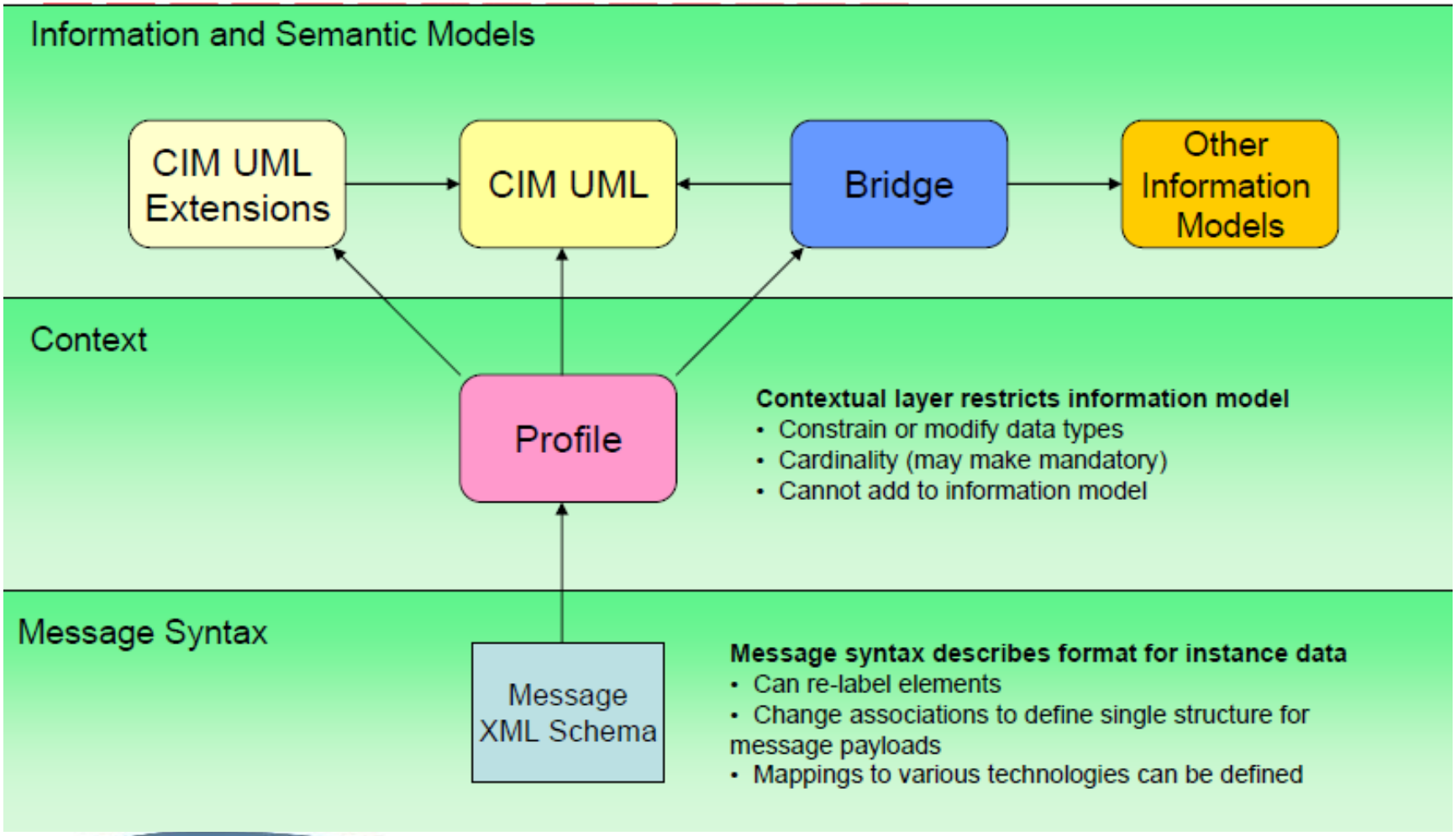
Source: Xtensible Solutions

Enterprise Semantic Model and CIM



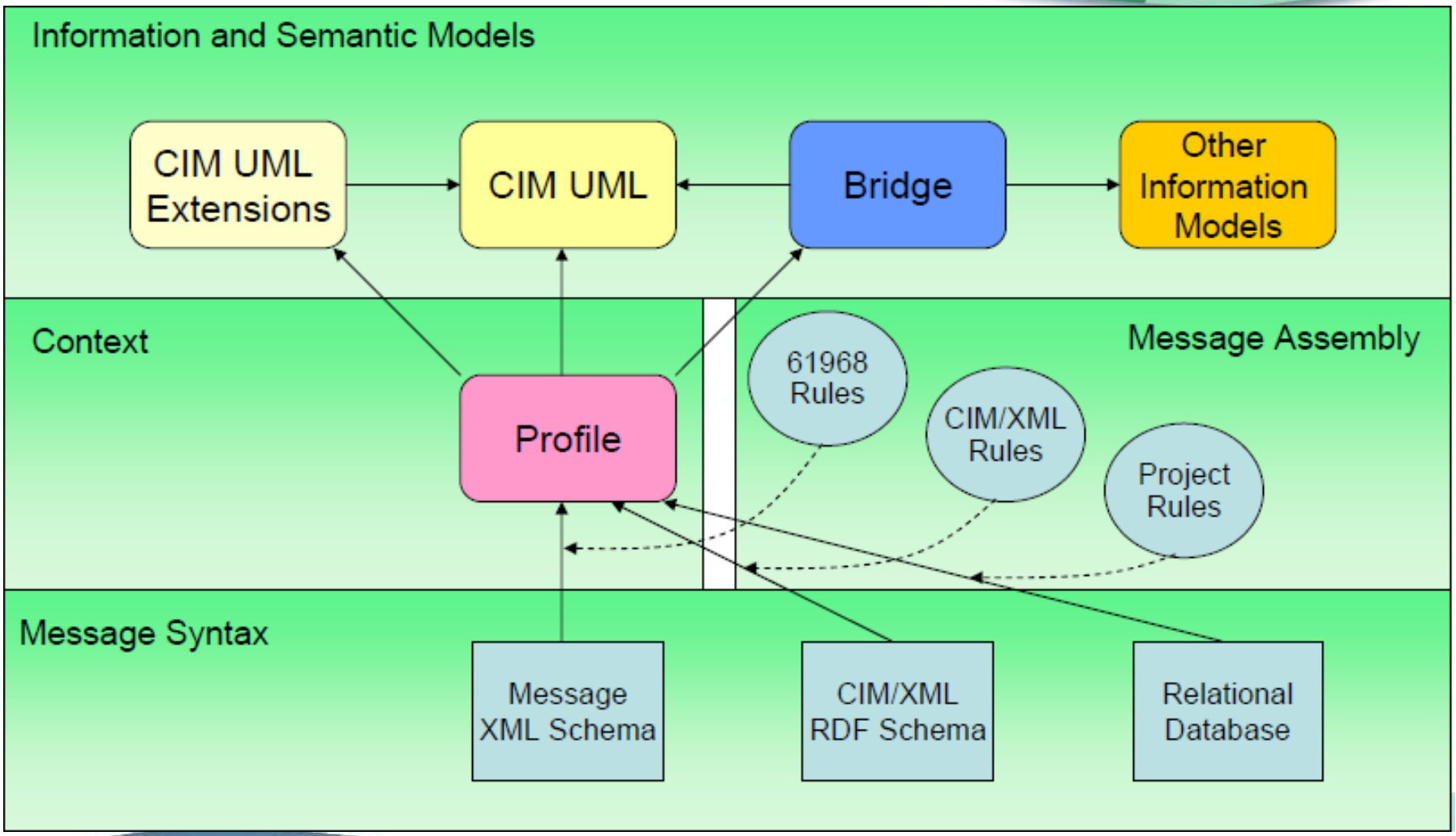
Source: Xtensible Solutions

Semantic Model and Profiles



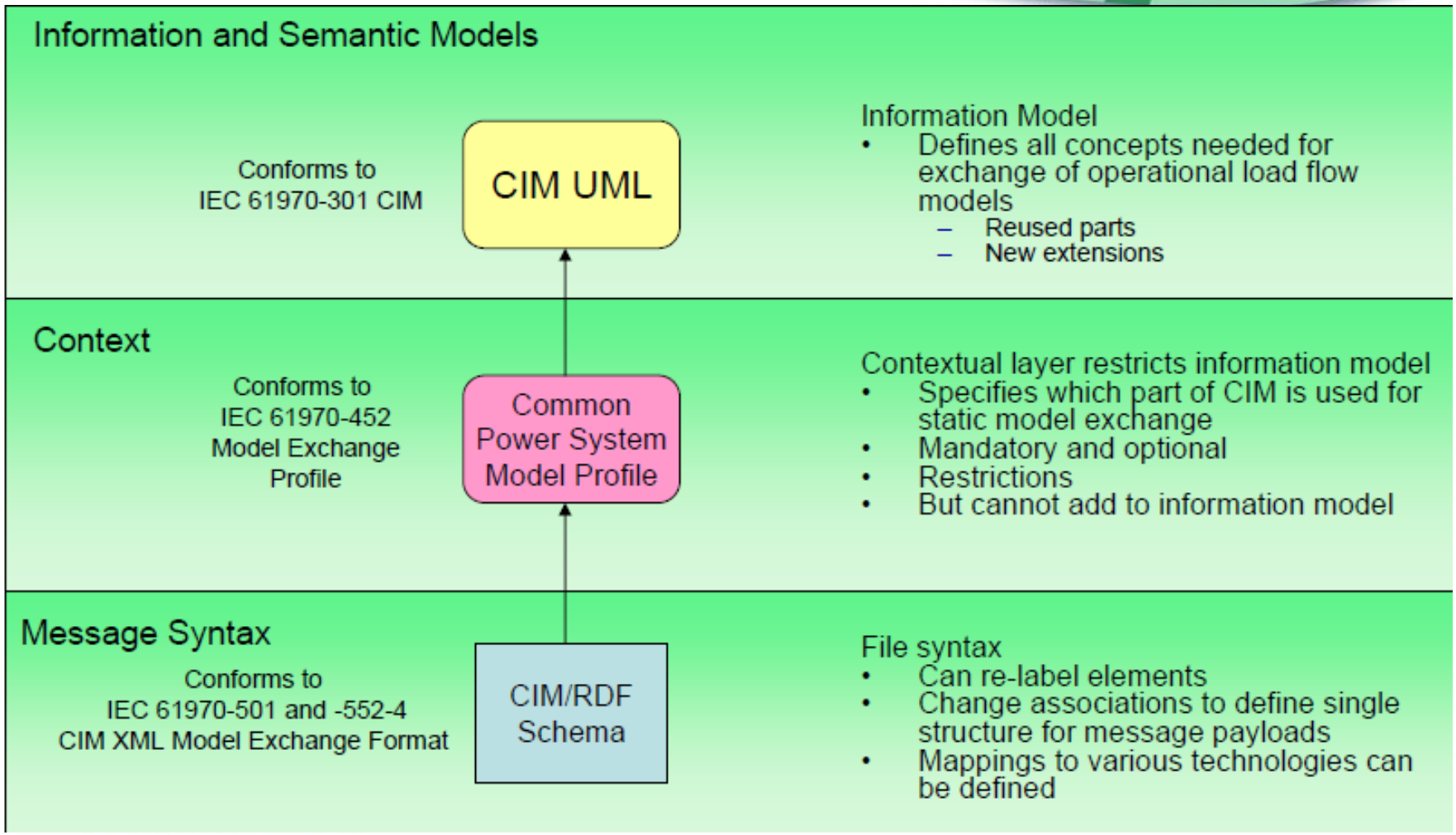
Courtesy of Xtensible Solutions

Semantic Models and Profiles



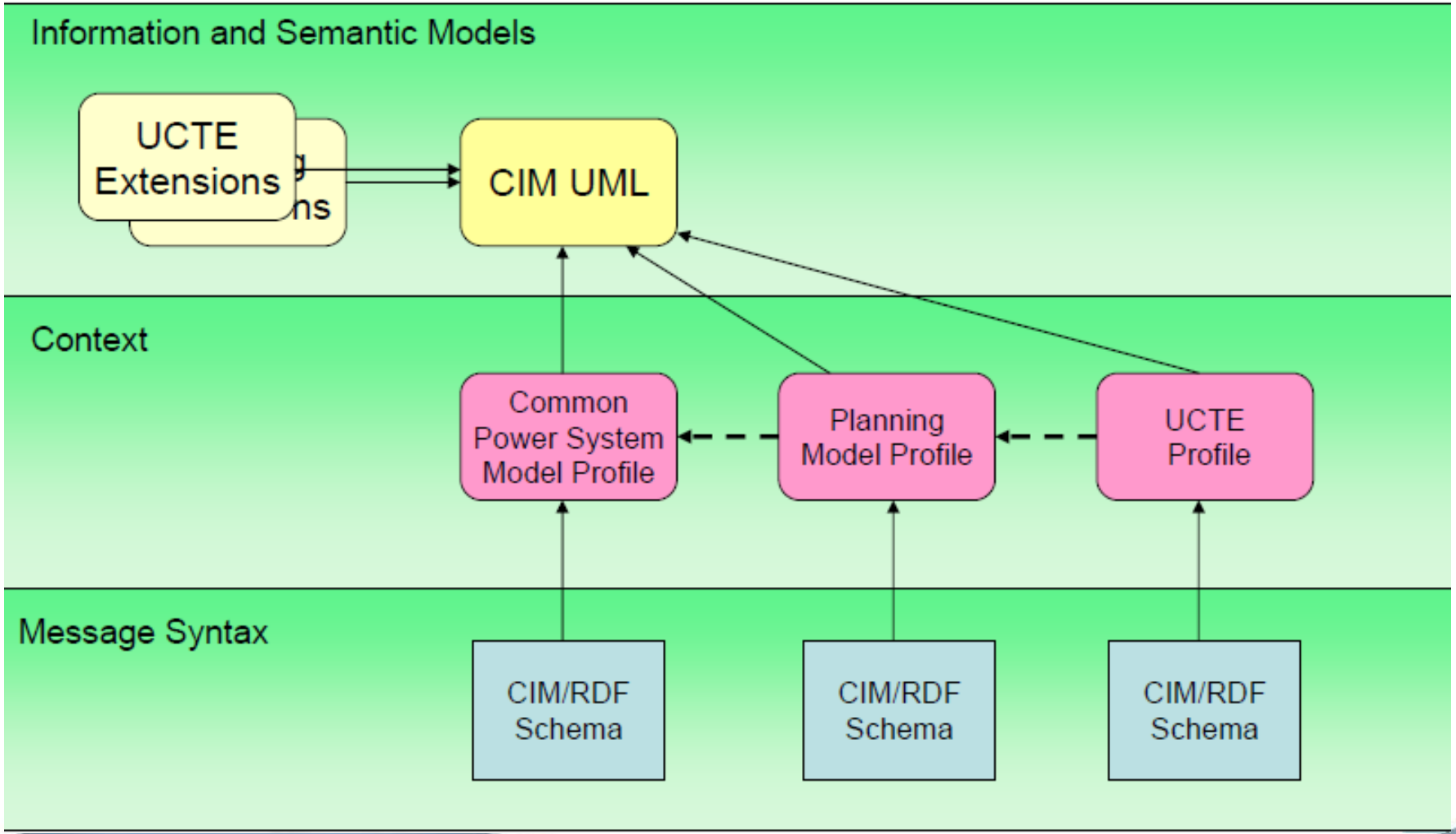
Courtesy of Xtensible Solutions

Power Flow Network Model Exchange



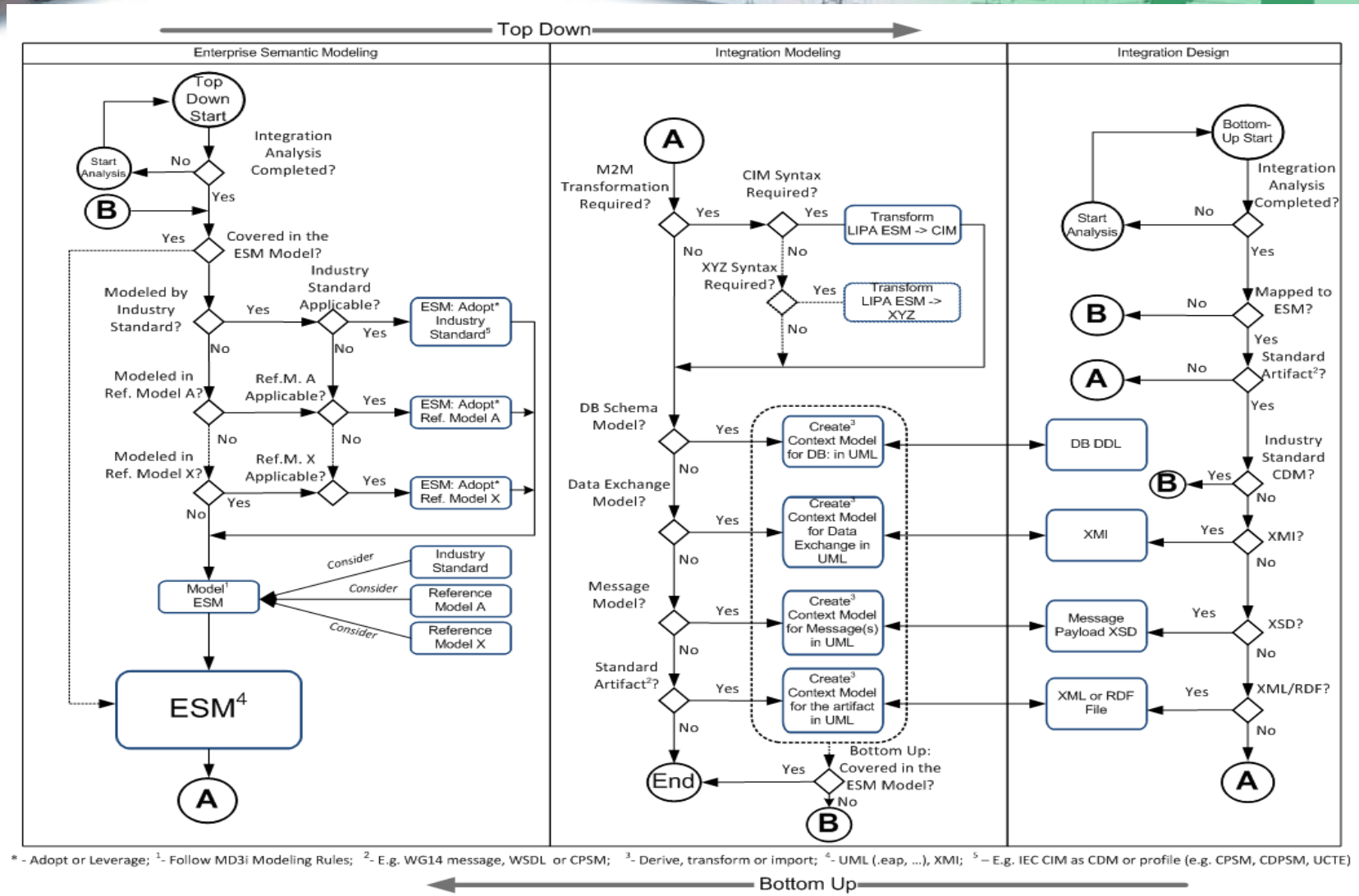
Courtesy of Xtensible Solutions

UCTE Model and Profile



Courtesy of Xtensible Solutions

ESM Dynamics



* - Adopt or Leverage; [1]- Follow MD3i Modeling Rules; [2]- E.g. WG14 message, WSDL or CPSM; [3]- Derive, transform or import; [4]- UML (.eap, ...), XMI; [5] – E.g. IEC CIM as CDM or profile (e.g. CPSM, CDPSM, UCTE)

To Summarize

- The CIM is an abstract information model standard expressed in UML.
- Profiles specifying a subset of the CIM classes and attributes for specific business context
- Implementation models, such as use of XML to create serialized files and message
  - Standards for power system models
- Standards for information message payloads
- Also, the CIM UML can be extended
  - Standard extensions for new functional areas
- Private extensions for specific utility requirements

Message Payload Definition and Management Process

Initiate
- Kickoff
- Plan
- Gather & Review
- Analyze
- Architect
- Fact Modeling

Model
- Business Process
- Use Cases
- CIM Extensions
- Class Diagrams
- Sequence Diagrams
- Semantic Mappings and Business Rules

Design
- XML Schema (XSD)
- XML Instance
- WSDL
- Business Rules
- Design Document

Manage
- Release
- Review
- Update
- Approve
- Manage Versions
- Change Request

Initiate

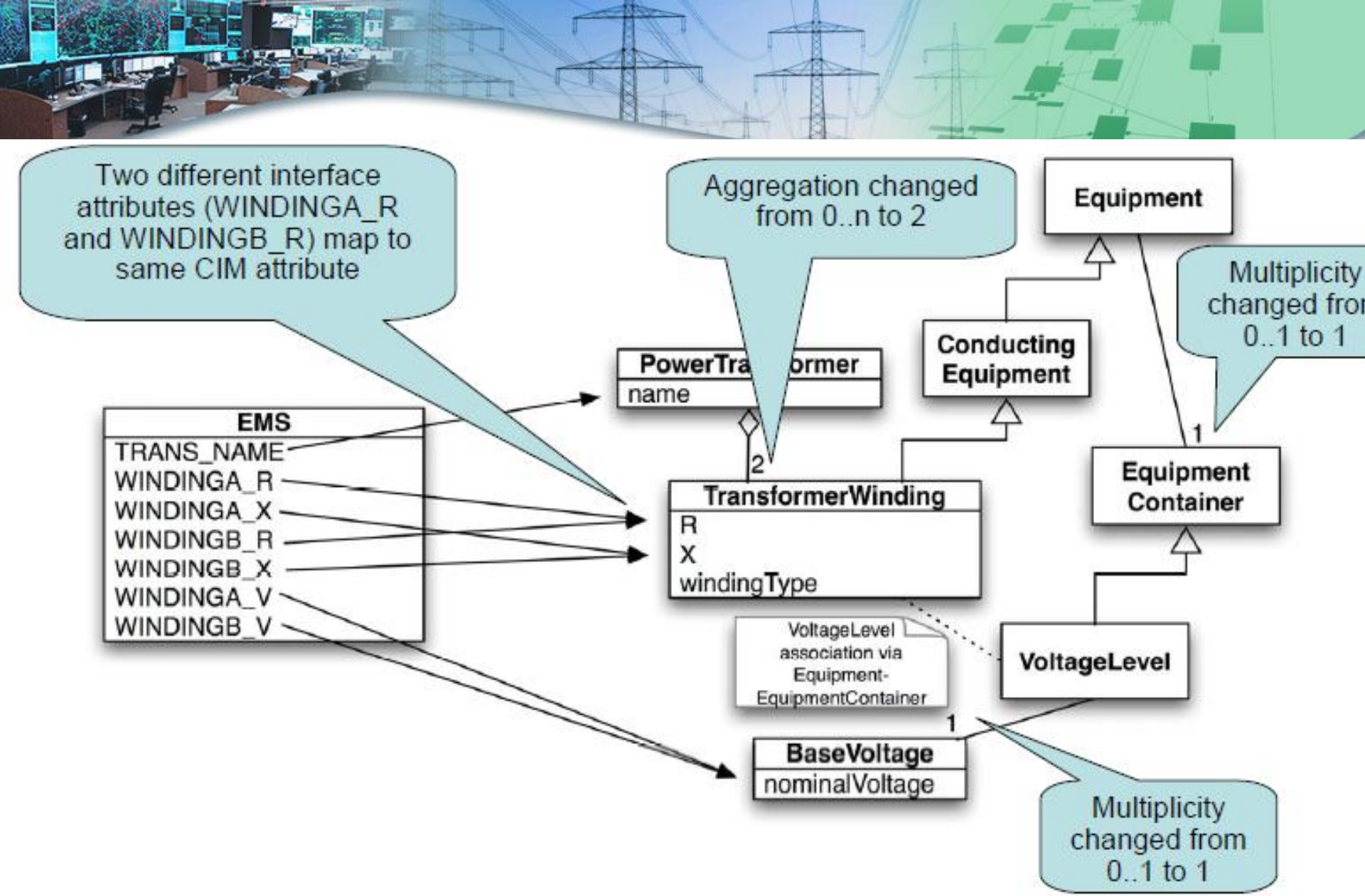
Model

Design

Implement

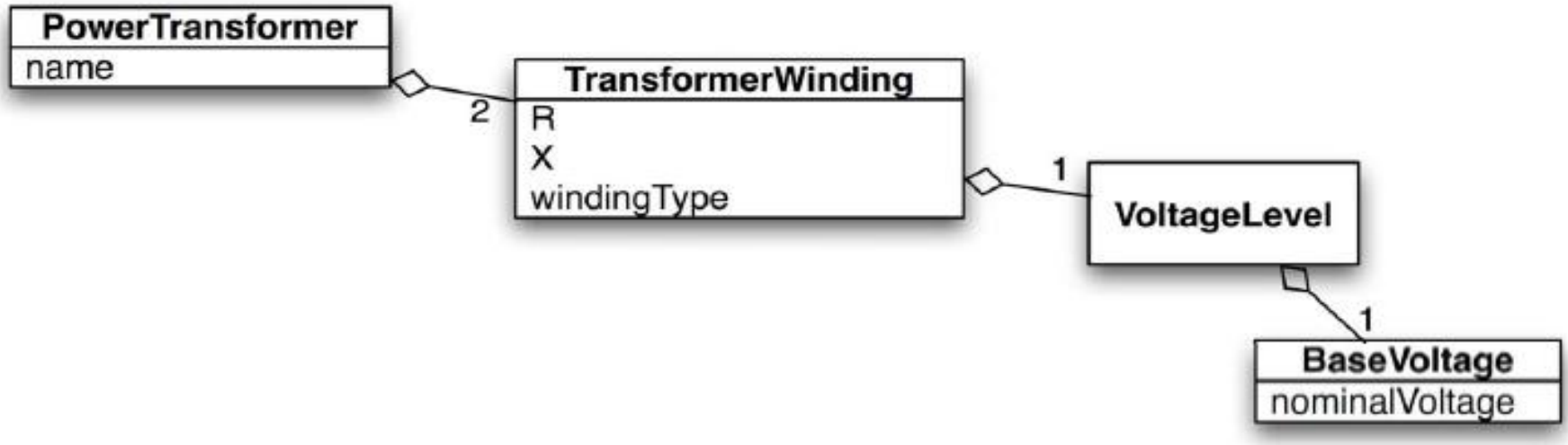
Test

Manage



Courtesy of Xtensible Solutions

Message Payload Model in UML



Courtesy of Xtensible Solutions

XML Schema for The Message

```
<xs:schema xmlns:cim="cimBase" xmlns:xs="http://www.w3.org/2001/XMLSchema">

<xs:element minOccurs="1" maxOccurs="1" name="PowerTransformer">
 <xs:complexType>
  <xs:complexContent>
   <xs:extension base="cim:PowerTransformer">
    <xs:sequence>
     <xs:element minOccurs="1" maxOccurs="1"
         name="Naming.name" type="xs:string"/>
     <xs:element minOccurs="2" maxOccurs="2"
         name="PowerTransformer.Contains_TransformerWindings">
      <xs:complexType>
       <xs:complexContent>
        <xs:extension base="cim:TransformerWinding">
         <xs:sequence>
          <xs:element minOccurs="1" maxOccurs="1"
              name="TransformerWinding.r" type="xs:float"/>
          <xs:element minOccurs="1" maxOccurs="1"
              name="TransformerWinding.x" type="xs:float"/>
          <xs:element minOccurs="1" maxOccurs="1"
              name="TransformerWinding.windingType" type="cim:WindingType"/>
          <xs:element minOccurs="1" maxOccurs="1"
              name="TransformerWinding.MemberOf_EquipmentContainer">
           <xs:complexType>
            <xs:complexContent>
             <xs:extension base="cim:VoltageLevel">
              <xs:sequence>
               <xs:element minOccurs="1" maxOccurs="1"
                   name="VoltageLevel.BaseVoltage">
                <xs:complexType>
                 <xs:complexContent>
                  <xs:extension base="cim:BaseVoltage">
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                   </xs:sequence>
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```
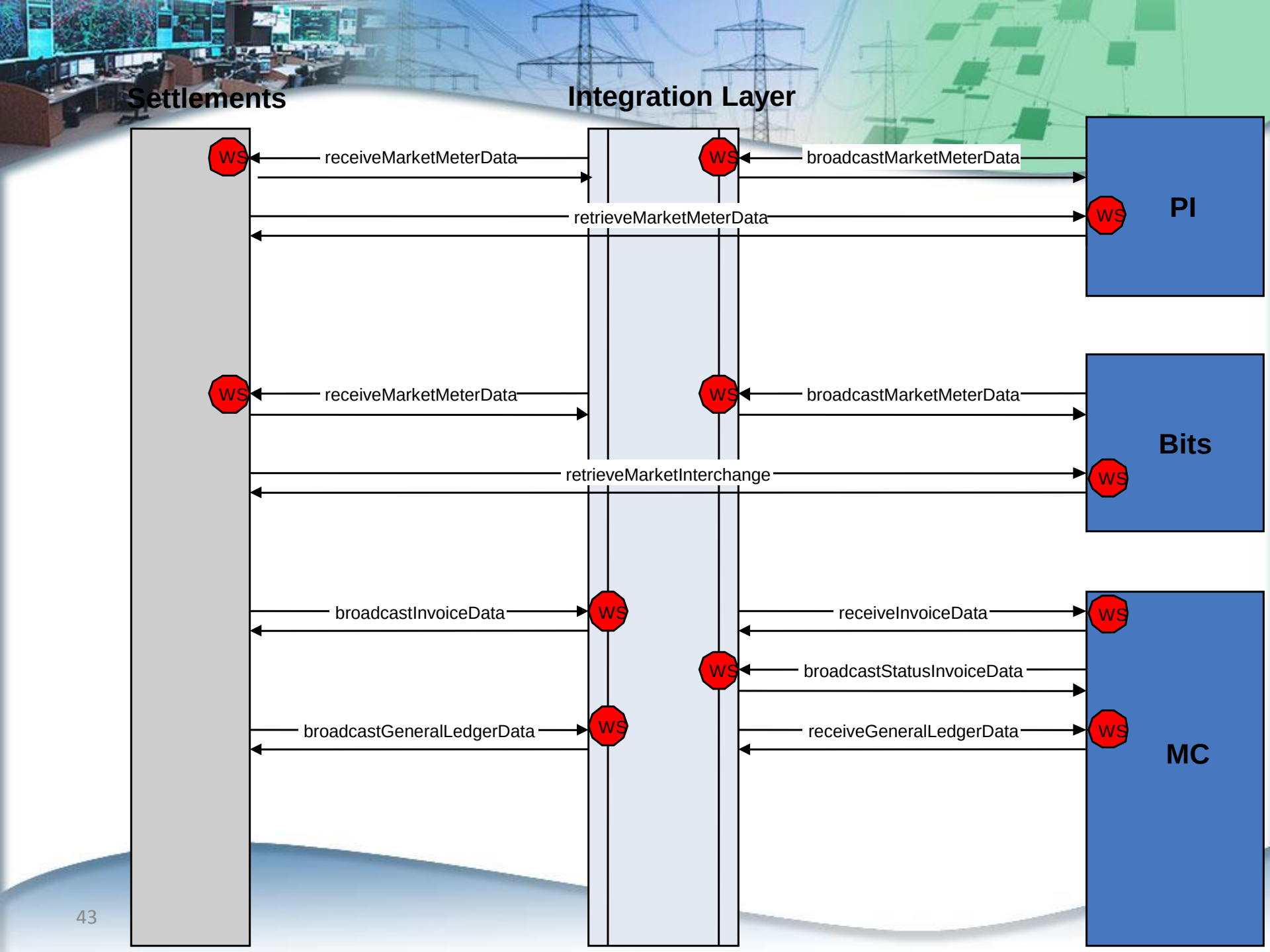

Courtesy of Xtensible Solutions


Settlements
Integration Layer
WS
receiveMarketMeterData
broadcastMarketMeterData
retrieveMarketMeterData
PI
receiveMarketMeterData
broadcastMarketMeterData
retrieveMarketInterchange
Bits
broadcastInvoiceData
receiveInvoiceData
broadcastStatusInvoiceData
broadcastGeneralLedgerData
receiveGeneralLedgerData
MC

CIM Compliance Realities

- Lack of consistent and clear compliance rules
- CIM is not consistently leveraged on large scale integration projects
- Misperception of CIM Usage and compliance makes vendors hesitant to address compliance
- They all “smoke” CIM however most of them don’t “inhale” it.
- A fair amount of ambiguities at the different levels
- A need to promote CIM usage beyond network model exchange

CIM Formal Definitions (1)

- **Definition 1** - CIM Definition
  - *A CIM is a 4-tuple:* ***C = (E, A, P, R)***
    - ***where***
      - E *is set of Entities in CIM:* $E = \{e_i \mid 1 \leq i \leq n, e_i \subset E\}$
      - A *is set of Attributes in CIM:* $A = \{a_j \mid 1 \leq j \leq m, a_j \subset A\}$
      - P *is set of attribute data Properties in CIM* $P = \{p_k \mid 1 \leq k \leq o, p_k \subset P\}$
      - R *is set of Relationships in CIM* $R = \{r_l \mid 1 \leq l \leq q, r_l \subset R\}$
      - n *– number of entities in CIM*
      - m *– number of attributes in CIM*
      - o *– number of attribute data properties in CIM*
      - q *– number of relationships in CIM*

There is nothing more practical than a good theory

CIM Formal Definitions (2)

- **Definition 2** – CIM profile Definition
  - *A CIM Profile is a 4-tuple:* $C_{pr} = (E_{pr}, A_{pr}, P_{pr}, R_{pr})$
    - Where
      - E_{pr} *is set of Entities in CIM Profile:* $\{e_i \mid 1 \; i \; n_{pr}, e_i \subset E\}$
      - A_{pr} *is set of Attributes in CIM Profile:* $A_{pr} = \{a_j \mid 1 \le j \le m_{pr}, a_j \subset A\}$
      - P_{pr} *is set of attribute Data Properties in CIM Profile:* $P_{pr} = \{p_k \mid 1 \le k \le o_{pr}, p_k \subset P\}$
      - R_{pr} *is set of Relationships in CIM Profile:* $R_{pr} = \{r_l \mid 1 \le l \le q_{pr}, r_l \subset R\}$
      - n_{pr} *– number of entities in CIM profile* $\{n_{pr} < n\}$
      - m_{pr} *– number of attributes in CIM profile* $\{m_{pr} < m\}$
      - o_{pr} *– number of data properties in CIM profile* $\{o_{pr} < o\}$
      - q_{pr} *– number of relationships in CIM profile* $\{q_{pr} < q\}$

CIM Formal Definitions (3)

- **Definition 3** – *Extended CIM* Definition
  - *An Extended CIM is a 4-tuple:* $\boldsymbol{C_{ex} = (E_{ex}, A_{ex}, P_{ex}, R_{ex})}$
    - Where
      - E_{ex} *is set of Entities in extended CIM:* $E_{ex} = \{e_i \mid 1 \le i \le n_{ex},\ e_i \in E_{ex},\ E \subset E_{ex}\}$
      - A_{ex} *is set of Attributes in extended CIM:* $A_{ex} = \{a_j \mid 1 \le j \le m_{ex},\ a_j \in A_{ex},\ A \subset A_{ex}\}$
      - P_{ex} *is set of Properties in extended CIM:* $P_{ex} = \{p_k \mid 1 \le k \le o_{ex},\ p_k \in P_{ex},\ P \subset P_{ex}\}$
      - R_{ex} *is set of Relationships in extended CIM:* $R_{ex} = \{r_l \mid 1 \le l \le q_{ex},\ r_l \in R_{ex},\ R \subset R_{ex}\}$
      - n_{ex} *– number of entities in extended CIM* $\{\ n_{ex} > n\ \}$
      - m_{ex} *– number of attributes in extended CIM* $\{\ m_{ex} > m\ \}$
      - o_{ex} *– number of properties in extended CIM* $\{\ o_{ex} > o\ \}$
      - q_{ex} *– number of relationships in extended CIM* $\{q_{ex} > q\ \}$

CIM Formal Definitions (4)

- **Definition 4** – CIM Mapping / Transformation Definition
  - *A simple mapping or transformation is defined as 3 - tuple:* ***T = (M, O, C)*** *where*

    - *T is set of mappings / transformations* $\{t_i \mid 1 \ i \ n_t \ t \ T\}$
    - *C is set of CIM elements*
    - *M is set of Model elements*
    - *O – set of operations (simple transformation / function or direct mapping) that maps elements of set M to elements of set C*

      O: M -> C where

      $\{ m_j = o_i (c_k) \}$

      $\{m_j \mid 1 \ j \ a_m, \ m_j \in M \}$

      $\{c_k \mid 1 \ k \ a_c, \ c_k \in C, \ \}$

      $\{o_i \mid 1 \ i \ n_m, \ o_i \in O, \ a_m \leq a_c \}$
    - a_m *– number of attributes in M*
    - a_c *– number of attributes in CIM*
    - *o – number of operations that transform / map model data elements to CIM*

CIM Formal Definitions (5)

- **Definition 5** – CIM compliance indicator for a model is defined as percentage of model data elements mapped to CIM
  - *CIM compliance indicator is defined as*

    $t_{\%} = a_t / a_m * 100$ *where*
    - *t% - percentage of elements mapped to CIM*
    - *at – total number of data elements from model M mapped to CIM*
    - *am – number of applicable attributes in model M*

- **Definition 6** – CIM compliance indicator for multiple models (e.g. sender/source and receiver/target) is defined as percentage of model data elements that map to each other (M_1 -> M_2) and to CIM.
  - *A simple mapping or transformation is defined as 3 - tuple:*

    T = (M, O, C) where
    - $t_{m\%}$*- percentage of elements mapped to CIM*
    - a_t *– total number of data elements from model* M_1, M_2…M_n *that map to each other and to CIM*
    - a_n *– number of applicable attributes in models* M_1, M_2…M_n

CIM Formal Definitions (6)

- **Definition 7** – CIM compliance indicator for multiple models (e.g. sender/source and receiver/target) is defined as percentage of model data elements that map to each other (M_1 -> M_2) and to CIM.
  - CIM compliance indicator s for multiple ***m*** models is defined as

$$s_m\% = a_t / a_n * 100$$

where

- $s_{m\%}$ *- percentage of elements mapped to CIM*
- a_s *– total number of data elements from model* M_1, $M_2 \ldots M_n$ *that map to each other and to CIM at entity, attribute, property and relationship level.*
- a_n *– number of applicable attributes in models* M_1, $M_2 \ldots M_n$

CIM Compliance Assessment Rules (1)

- Semantic Compliance
  - Rule 1 - A necessary condition for CIM semantic compliance is the ability to map directly or using a simple translation, data elements of an information model to the respective attributes of the CIM.

    Supposing Definition 4 and according to Definition 5, CIM Compliance Levels are

If $10 < t_{\%} < 20$ *then CL = 1*

Else if $20 < t_{\%} < 30$ *then CL = 2*

Else if $30 < t_{\%} < 40$ *then CL = 3*

Else if $40 < t_{\%} < 50$ *then CL = 4*

Else if $50 < t_{\%} < 60$ *then CL = 5*

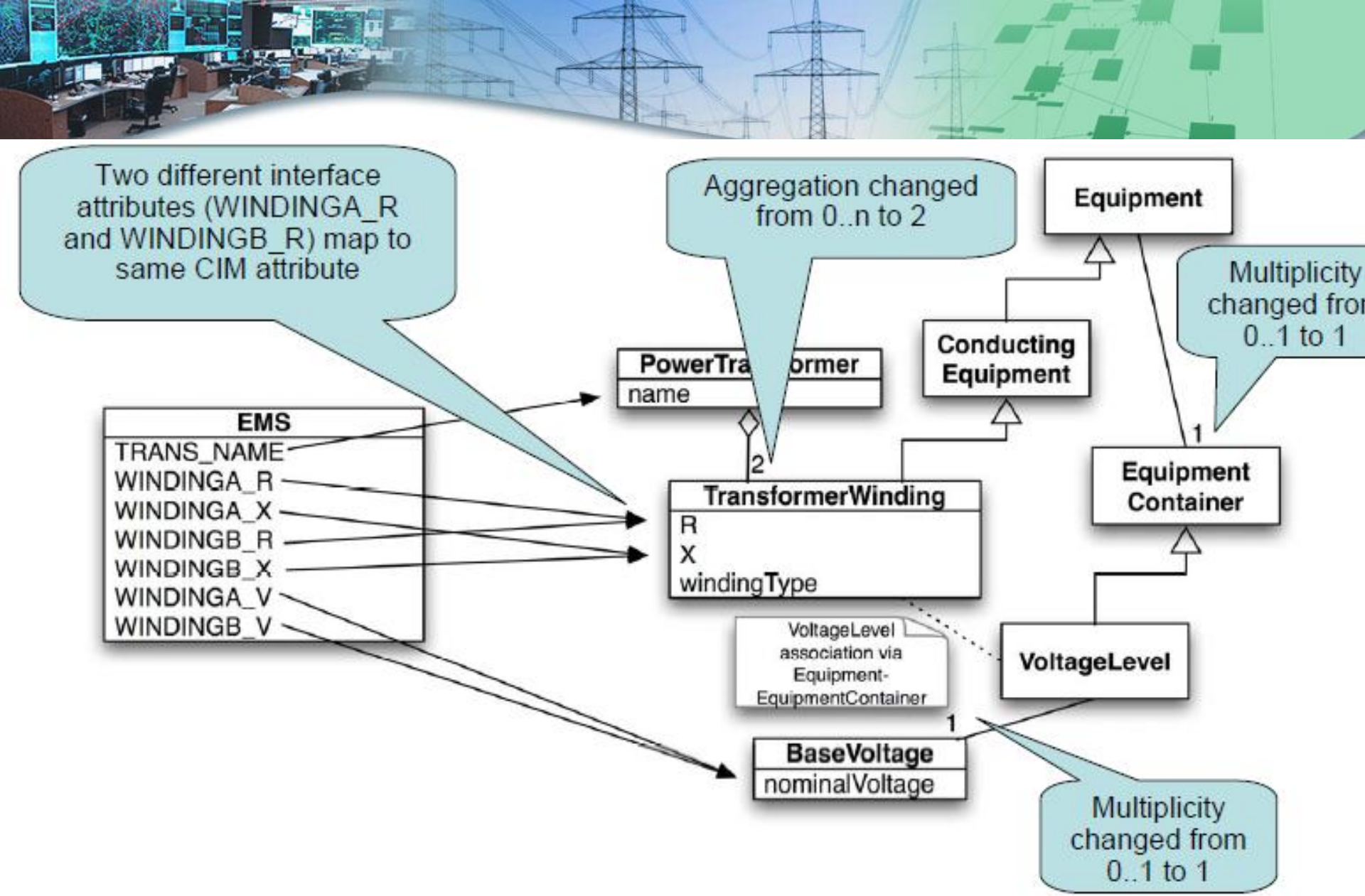
Else if $60 < t_{\%} < 70$ *then CL = 6*

Else if $70 < t_{\%} < 80$ *then CL = 7*

Else if $80 < t_{\%} < 90$ *then CL = 8*

Else if $90 < t_{\%} < 99$ *then CL = 9*

Else if $t_{\%} = 100\%$ *then CL = 10*



Courtesy of Xtensible Solutions

CIM Compliance Assessment Rules (2)

- Interoperability (Message Payloads / Interfaces / Data Streams) CIM Compliance
  - ***Rule 2 -*** *A necessary condition for CIM compliant semantic interoperability between two systems is the existence of mapping schema or translation function that maps data elements of the domain models of both systems (sender/source and receiver/target) to the respective attributes of CIM.*

    Supposing Definition 4 and according to Definition 6, CIM Compliance Levels are

If $10 < t_{\%} < 20$ then CL = 1

Else if $20 < t_{\%} < 30$ then CL = 2

Else if $30 < t_{\%} < 40$then CL = 3

Else if $40 < t_{\%} < 50$ then CL = 4

Else if $50 < t_{\%} < 60$ then CL = 5

Else if $60 < t_{\%} < 70$ then CL = 6

Else if $70 < t_{\%} < 80$ then CL = 7

Else if $80 < t_{\%} < 90$ then CL = 8

Else if $90 < t_{\%} < 99$ then CL = 9

Else if $t_{\%} = 100\%$ then CL = 10

CIM Compliance Assessment Rules (3)

- Syntactic Compliance
  - ***Rule 3*** *- A necessary condition for CIM compliant syntactic interoperability between two systems is the existence of semantically compliant sender and receiver as well as when both systems (sender and receiver) can process message structure/payload derived from CIM*

Supposing Definition 4 and according to Definition 7, CIM Compliance Levels are

If $10 < t_{\%} < 20$ *then CL = 1*

Else if $20 < t_{\%} < 30$ *then CL = 2*

Else if $30 < t_{\%} < 40$ *then CL = 3*

Else if $40 < t_{\%} < 50$ *then CL = 4*

Else if $50 < t_{\%} < 60$ *then CL = 5*

Else if $60 < t_{\%} < 70$ *then CL = 6*

Else if $70 < t_{\%} < 80$ *then CL = 7*

Else if $80 < t_{\%} < 90$ *then CL = 8*

Else if $90 < t_{\%} < 99$ *then CL = 9*

Else if $t_{\%} = 100\%$ *then CL = 10*

Integration Readiness Assessment

Complexity of Integration vs. Compliance Levels (Traditional Integration Tools)

Integration Complexity	Description	Semantic Compliance Levels				Syntactic Compliance Levels			
		2	4	7	10	2	4	7	10
High	No Semantic Model, No Endpoints	✓	✓			✓	✓		
Med/High	No Semantic Model, Some Endpoints	✓	✓			✓	✓		
Medium	Semantic Model, Some Endpoints			✓			✓		
Med/Low	Semantic Model, Endpoints			✓				✓	
Low	Semantic Model and standard based Endpoints			✓	✓			✓	✓
Zero Coding Effort*	Plug & Play				✓				✓
Zero effort	True Plug & Play								✓

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Integration Readiness Assessment

Complexity of Integration vs. Compliance Levels (Next Generation Tools)

Integration Complexity	Description	Semantic Compliance Levels				Syntactic Compliance Levels*			
		2	4	7	10	2	4	7	10
High	No Semantic Model, No Endpoints	✓	✓			✓	✓		
Med/High	No Semantic Model, Some Endpoints	✓	✓			✓	✓		
Low	**Semantic Model,** Some Endpoints			✓	✓		✓		
Configuration Effort	**Semantic Model**, Endpoints				✓			✓	
Configuration Effort	**Semantic Model** and standard based Endpoints				✓			✓	✓
Configuration Effort	Plug & Play				✓				✓
Zero effort	True Plug & Play				✓				✓

***Semantic Model will be imported in Integration Tools and used as an Intermediary where all mapping and transformations will be defined for run-time. Therefore, semantic compliance will become more important in the future.**

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Conclusions

- *Next generation of SCADA, EMS, MMS, DMS is expected in the near future*
- *Next Generation Systems are seen as a flavor of XTP*
- *Smart Grid initiative is becoming mainstream*
- *New Standards are expected*
- *CIM Semantic and Syntactic compliance rules are proposed*
  - *This is an attempt to demystify CIM usage and simplify CIM compliance assessment*
  - *Proposed rules can be used to assess components' integration readiness*
  - *Proposed rules can be leveraged by 3-parties for CIM compliance certifications*
  - *Higher compliance levels decreases chances of projects' delays and leads to more effective and less expensive integration*

Questions

- Contact Information

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