Defining Common Information Model (CIM) Compliance

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Keywords: CIM Definition, CIM compliance, CIM profile, interoperability, integration readiness, architecture, utility domain

Abstract

To prosper in a competitive market, utilities are forced to better integrate their systems and processes in order to reduce operating and maintenance costs as much as possible and to improve overall reliability. The Common Information Model (CIM) is designed to achieve easier interoperability between systems. However, the lack of a complete standard semantic model creates a major stumbling block for more effective and efficient integration. Since CIM is the most complete standard semantic model in utility industry, in order to promote and encourage broader use of CIM, explicit and practical rules for CIM compliant interoperability assessment are proposed here.

The idea of leveraging CIM as semantic model has been elaborated and emphasized in [5]. Reference [5] also recognizes a need for explicit CIM compliance rules. The purpose of this paper is to propose a practical and consistent approach for defining the IEC Common Information Model compliance types and levels relative to the different interoperability scenarios where CIM can be leveraged.

Two key types of CIM compliance are elaborated in more details, namely semantic and syntactic compliance at different compliance levels in the context of different interoperability and data usage patterns using several technologies such as Data Management (DM) solutions, Enterprise Service Bus (ESB) and Service-Oriented Architecture (SOA), Enterprise Information Integration (EII), Extract, Transform and Load (ETL), etc.

A formal definition of CIM (a mathematical formulation) is presented as a prelude to explicit CIM compliance rules for each applicable type and level.

1. INTRODUCTION

The Common Information Model (CIM) is a conceptual information model for describing business entities in electrical energy business domain including enterprise and service provider environments. It provides a consistent definition and structure of data, using object-oriented techniques. The CIM includes expressions for common elements that must be clearly presented to management systems and applications like object classes, attributes, properties, and associations to name a few.

The CIM was originally developed as part of the EPRI CCAPI project, and then later adopted by IEC TC57 as a standard, IEC 61970-301. IEC TC57 WG13 specified the use of XML and RDF Schema to represent a set of CIM core objects as the basis for exchanging Transmission Network Model data between applications. At the time, XML Schema (XSD) had not yet been adopted by W3C as a standard. IEC TC57 WG14 later specified the use of XSD to define message standards based on the CIM (the IEC 61968 series of standards).

2. INTEROPERABILITY AND INTEGRATION READINESS

Per Gartner [2] "Integration" is defined as the act or approach of making two of more independently designed things (systems, databases or processes) work together to achieve a common business objective. For practical reasons, integration activities within large enterprises are typically classified as data and application integration. The ultimate result of integration is the fact that all applications work seamlessly together in achieving the same business objective and that typically involves data exchanges and synchronization (data sharing) as well as process and activity coordination.

3. CIM USAGE PERSPECTIVE

The CIM as an information model can be used as a semantic vehicle to achieve full compatibility of data definitions and exchange of data between numerous applications across business areas and corporate boundaries. The CIM defines a standard and a common way of representing a variety of physical and abstract data related to the operation of electric utility organizations. For sometime it's been mostly known for its use in the area of transmission network modeling and simulation, but now with latest extensions, it also contains representations for data related to generation control, scheduling, SCADA, distribution and market functions as well as business objects such as assets and documents. In order to enrich the business context around the existing model, CIM is being envisioned as ontology that defines business concepts, relationships and a set of rules in the utility business domain. It is designed to provide a way to access and manage data from multiple sources, facilitate understanding, and enable rapid use by software applications.

From an integrator perspective, the Common Information Model allows EAI/ESB [1, 3, 4], ETL, EII, BI, Modeling, Process and Data management technology solutions to work together in standard ways. All solutions share the same information model and common vocabulary.

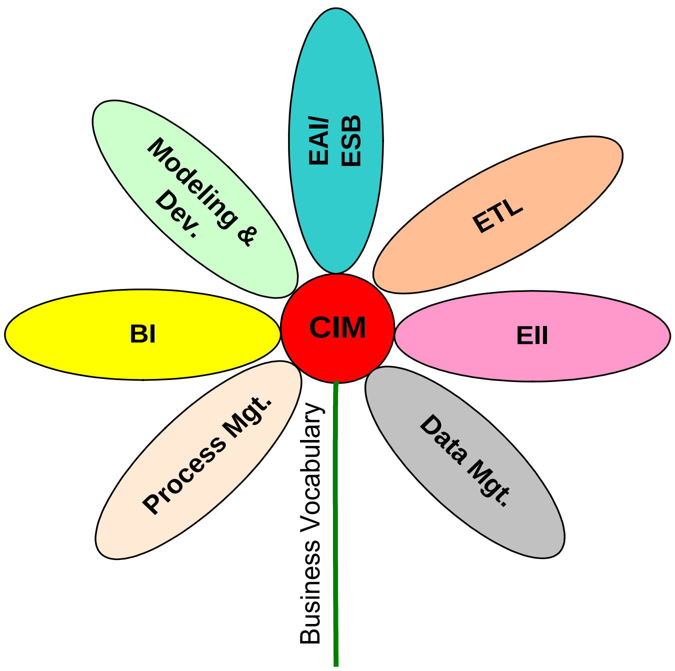

Figure 1: Role of CIM

In general, CIM facilitates common understanding within and beyond corporate boundaries.

CIM can be effectively leveraged in the following technology solutions (Figure 1) and interoperability scenarios:

- Enterprise Application Integrating (EAI) / Enterprise Service Bus (ESB) – provides basis for standard-based message payloads and data transformation (e.g. XSLTs) from and to CIM structures.
- Enterprise Information Integration (EII) – provides platform-independent logical model as well as mappings to underlying systems and federated queries.
- Extract, Transform and Load (ETL) – Generates data transformation workflows to convert data from a source to a target data store using CIM as a logical intermediary.
- Modeling and Development tools – Create / extent / profile models (e.g. interface model) using CIM structures
- Business Intelligence (BI) tools – Using CIM and Business Vocabulary (BV) to generate common business views
- Data Management solutions - provides platform-independent logical model as well as data exchange mappings from CIM-based payloads to underlying systems.
- Process Modeling – More effective process engineering leveraging CIM use cases and standard functional decomposition as well as standard data exchanges and BV.
- Composite Applications Framework – provides standard-based interoperability framework for linking technology and business components into functional assemblies.
- Network Model data exchanges - provides ability for multiple components (within the same organization or B2B) to exchange network models

3.1. Art of Integration

Large scale integration projects require a customized, very often innovative approach designed to achieve major business objectives on time. The key step in each integration project is data exchange analysis.

Data Exchange analysis is designed to identify what data each component would receive from upstream components as well as data it would provide to downstream components. This analysis also identifies all data mappings at data element level as well as all required transformation rules. This is much easier to achieve if all systems' data are mapped to a common information model or in other words if all components "talk" and understand CIM.

Figure 2 illustrates a CIM usage in an integration project where CIM was leveraged extensively. The design time semantic analysis started with CIM. CIM profile as a subset of CIM was created with only data elements required in the project. The CIM profile is then extended with required data elements that were not part of CIM Profile. Note also that those data elements were discovered during data exchange analysis. For Example 1, besides leveraging CIM as integration semantic model, CIM is also used for Web Services and message payloads design.

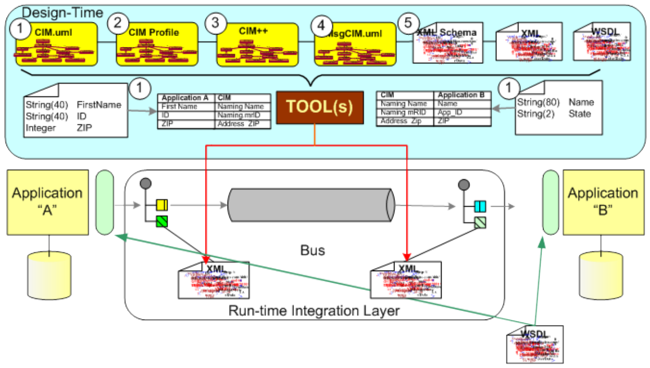

Figure 2: - Example 1 of CIM Usage – Web Service design

Figure 3 example described ETL pattern of data exchanges where CIM is leveraged as semantic intermediary to configure transformation rules.

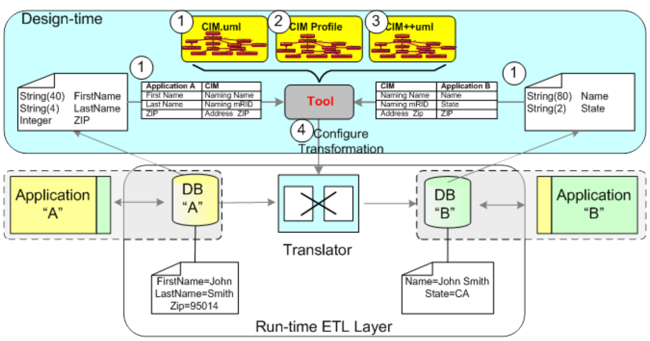

Figure 3: - Example 2 of CIM Usage – ETL

These two examples are presented rather briefly just to illustrate how CIM can be leveraged in integration projects.

4. CIM FORMAL DEFINITIONS

The CIM is seen as a conceptual information model consisting of entities, attributes (class fields), properties (in this context data type properties) and relationships. The CIM can be formally defined as follows:

Definition 1 – *CIM* Definition

A CIM is a 4-tuple: C = (E, A, P, R), where:

- *E is set of Entities in CIM:*

  $E = \{e_i \mid 1 \leq i \leq n, e_i \in E\}$

- *A is set of Attributes in CIM:*

  $A = \{a_j \mid 1 \leq j \leq m, a_j \in A\}$

- *P is set of Properties in CIM*

  $P = \{p_k \mid 1 \leq k \leq o, p_k \in P\}$

- *R is set of Relationships in CIM*

  $R = \{r_l \mid 1 \leq l \leq q, r_l \in R\}$

- *n – number of entities in CIM*
- *m – number of attributes in CIM*
- *o – number of properties in CIM*
- *q – number of relationships in CIM*

Definition 2 – *CIM Profile* Definition

CIM profile is a subset of CIM and contains only entities, attributes, properties and relationships necessary to achieve required business objectives. CIM profile is defined formally as:

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:*

  $\{e_i \mid 1 \leq i \leq n_{pr}, e_i \subset E\}$

- A_{pr} *is set of Attributes in CIM Profile:*

  $A_{pr} = \{a_j \mid 1 \leq j \leq m_{pr}, a_j \subset A\}$

- P_{pr} *is set of Properties in CIM Profile:*

  $P_{pr} = \{p_k \mid 1 \leq k \leq o_{pr}, p_k \subset P\}$

- R_{pr} *is set of Relationships in CIM Profile:*

  $R_{pr} = \{r_l \mid 1 \leq l \leq q_{pr}, r_l \subset R\}$

- 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 properties in CIM profile* $\{o_{pr} < o\}$
- q_{pr} *– number of relationships in CIM profile* $\{q_{pr} < q\}$

Definition 3 – *Extended CIM* Definition

Extended CIM is either CIM profile or CIM with additional entities, attributes, properties and relationships necessary to achieve required business objectives. Extended CIM is defined formally as:

An Extended CIM is a 4-tuple: $C_{ex} = (E_{ex}, A_{ex}, P_{ex}, R_{ex})$, *where:*

- E_{ex} *is set of Entities in extended CIM:*

  $E_{ex} = \{e_i \mid 1 \leq i \leq n_{ex}, e_i \in E_{ex}, E \subset E_{ex}\}$

- A_{ex} *is set of Attributes in extended CIM:*

  $A_{ex} = \{a_j \mid 1 \leq j \leq m_{ex}, aj \in A_{ex}, A \subset A_{ex}\}$

- P_{ex} *is set of Properties in extended CIM:*

  $P_{ex} = \{p_k \mid 1 \leq k \leq o_{ex}, p_k \in P_{ex}, P \subset P_{ex}\}$

- R_{ex} *is set of Relationships in extended CIM:*

  $R_{ex} = \{r_l \mid 1 \leq l \leq q_{ex}, r_l \in R_{ex}, R \subset R_{ex}\}$

- 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* $\{q_{ex} > q \}$

Definition 4 – CIM Mapping / Transformation Definition

Transformation is defined as an operation / action required for mapping elements of CIM to elements of a model under consideration.

A simple mapping or transformation is defined as 3 - tuple:

$T = (M, O, C)$

where

- *T is set of mappings / transformations*

  $\{t_i \mid 1 \leq i \leq n_t \, t \in T \}$
- *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*

  $O: M \rightarrow C$ *where*

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

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

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

  $\{o_i \mid 1 \leq i \leq n_m, o_i \in O, \ a_m \leq a_c \}$

  - 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*

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*
- a_t *– total number of data elements from model M mapped to CIM*
- a_m *– 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 ($M_1 \rightarrow M_2$) and to CIM.

CIM compliance indicator for multiple m models is defined as

$t_{m\%} = a_t / a_n * 100$

where

- $t_{m\%}$*- percentage of elements mapped to CIM*
- a_t *– total number of data elements from model* $M_1, M_2 \ldots M_n$ *that map to each other and to CIM*
- a_n *– number of applicable attributes in models* $M_1, M_2 \ldots M_n$

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 ($M_1 \rightarrow M_2$) 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* $M_1, M_2 \ldots M_n$

Definition 7 implies that message payloads are derived from CIM.

5. COMPLIANCE DEFINITIONS AND RULES

Interoperability between systems is much easier to achieve if domain models of all integrated components comply with a standard model such as CIM. For this consideration and in this context, two key types of CIM compliance are recognized semantic and syntactic compliance.

5.1. Semantic Compliance

The following semantic compliance rule is proposed to assess CIM compliance level of an information model:

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.*

Rule *– 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 < $t_{\%}$ < 40then 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

where

- *CL – CIM compliance Level*

The Rule1 should be used mainly to assess semantic CIM compliance level. Per rule, a semantic compliance can be achieved at several levels depending on percentage of data elements mapped to CIM (e.g. Level 1 - 5-10%, Level 2 - 10-20%, Level 3 20-30%, Level 4 40-50%, Level 5 - 50-60%, Level 6 60-70%, Level 7 70-80%, Level 8 80-90%, Level 9 90-99% and Level 10 - 100%). Using the Compliance Rule 1, the information model M should be considered as CIM Compliant at some level if sufficient number (e.g. for Level 4 between 40 and 50%) of data elements has corresponding CIM data elements (e.g. entity/data element Organization.type in an EIM can be mapped to entity/data element Company.companyType in CIM). This would ensure that the same logical concepts for data elements in the model under consideration are equivalent to those in CIM.

5.1.1. Interoperability (Message Payloads / Interfaces / Data Streams) CIM Compliance

This section defines compliance rules at data exchange / interface level.

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.*

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

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

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

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

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

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

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

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

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

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

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

where

- *CL – CIM compliance Level*

This ensures that the exchanged information has the same meaning for both systems (sender and receiver). The semantic compliance can be achieved at several levels depending on percentage of data elements mapped to CIM (e.g. Level 1 - 5-10%, Level 2 -10-20%, Level 3 20-30%, Level 4 40-50%, Level 5 - 50-60%, Level 6 60-70%, Level 7 70-80%, Level 8 80-90%, Level 9 90-99% and Level 10 - 100%).

5.2. Syntactic Compliance

Another type of CIM compliant data exchanges deals with syntactic interoperability. The syntactic interoperability is seen as grammar that conveys semantics and structure / format of data exchanges such as messages' payloads or data streams.

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.*

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

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

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

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

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

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

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

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

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

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

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

where

- *CL – CIM compliance Level*

Using message structure/payload derived from CIM, enables so-called direct access to the payload by participating systems while payload just based on CIM requires a clearly defined transformation function / rules. Note that both approaches can be combined in a single payload.

The syntactic compliance can be achieved at several levels depending on percentage of data elements in payload directly derived from CIM or in other words those that facilitate 'direct access' (e.g. Level 1 - 5-10%, Level 2 -10-20%, Level 3 20-30%, Level 4 40-50%, Level 5 - 50-60%, Level 6 60-70%, Level 7 70-80%, Level 8 80-90%, Level 9 90-99% and Level 10 - 100%).

6. INTEGRATION READINESS ASSESSMENT

Integration readiness is seen as a component's ability to interact with other components in an integrated environment. The integration readiness can be assessed by complexity level or effort required to enable a component to exchange information with other components. Experience on large scale integration projects demonstrates that inadequate component' integration readiness results often in significant project delays. Organizations undertaking large scale integration projects are often forced to deal with large number of non-standardized, non-CIM compliant data exchanges resulting in project delays simply because of absence of semantic and syntactic standard compliance rules to assess integration readiness before project starts. Therefore it is extremely important to measure integration readiness of all components at the component selection time. The proposed CIM semantic and syntactic compliance rules are strongly recommended to measure integration readiness of each component.

Table 1: Complexity of Integration vs. Compliance Levels

Integration Complexity	Description	Semantic Compliance Level				Syntactic Compliance Level			
		2	4	7	10	2	4	7	10
High	No SM, No EPs	✓	✓			✓	✓		
Med.High	No SM, Some EPs	✓	✓			✓	✓		
Medium	SM, Some EPs			✓			✓		
Med.Low	SM, EPs			✓				✓	
Low	SM and standard based EPs			✓	✓			✓	✓
Zero Coding Effort*	Plug & Play				✓				✓
Zero effort	True Plug & Play								✓

SM – Semantic Model; EP- End point (e.g Interface, Web Service, input/output staging tables, shared folder)
* - Configuration Effort

The empirically based Table 1 shows strong relationships between complexity of integration and integration readiness expressed in terms of semantic and syntactic compliance levels to a common information model.

Note that higher compliance levels decreases chances of projects' delays and leads to more effective as well as less expensive integration.

7. CONCLUSION

CIM Semantic and Syntactic compliance rules are proposed in this paper. CIM formal definitions are presented as well to provide foundation for clear description of compliance rules. The proposed rules can be used to assess components' integration readiness. Solution providers are strongly encouraged to evaluate integration readiness of their products and use that as a competitive advantage especially for components that would interact with other systems and applications. The proposed rules should encourage non-product suppliers to develop services and tools for CIM compliance level certifications.

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Biography

Dr. Stipe Fustar has over twenty five years of experience in the electric utility industry including architecture and integration technical consulting, project/team management, development, data modeling, system design and quality assurance. He has a deep understanding of all aspects on electric utility industry covering a broad range of energy, distribution and market management services as well as, asset management, smart grid, AMI, AM/FM/GIS technology, data modeling, SCADA, and system integration and design. He provides a unique blend of electric utility industry expertise and strong IT Architecture and

Integration experience. He is President & CEO of Power Grid 360, company that provides consulting services for utilities.