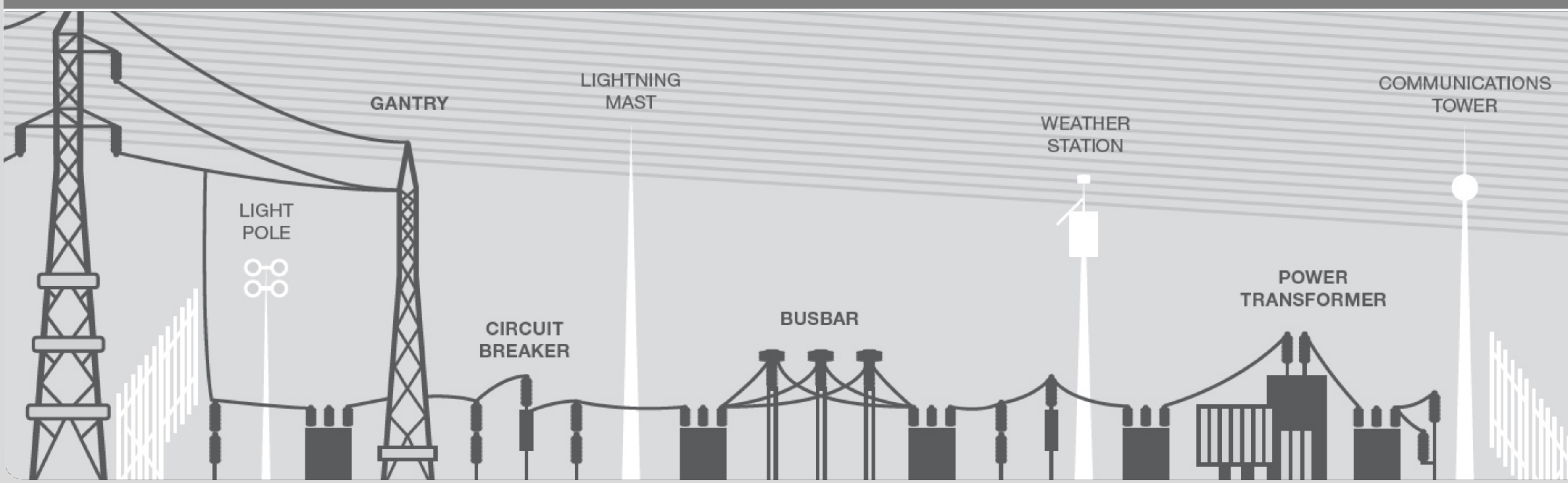
Karlsruher Institut für Technologie

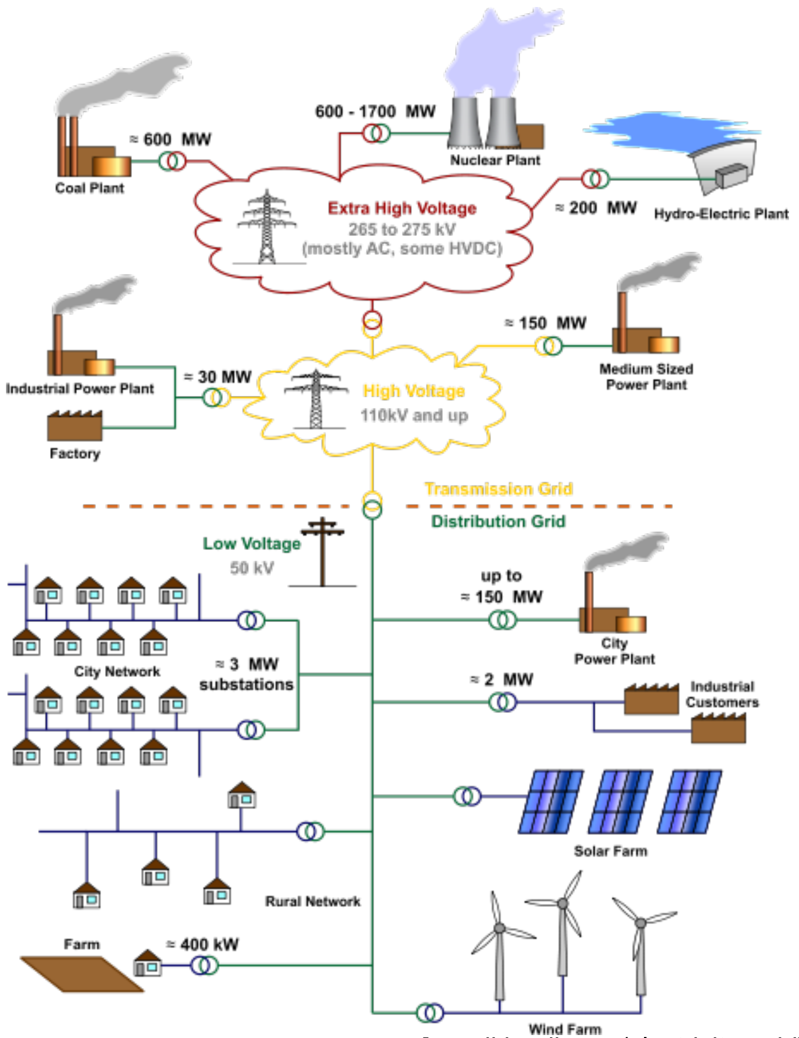
Automated Alignment of Data Models in Energy Informatics

Ilona-Dewi Kusardi

Institute for Applied Computer Science (IAI)



Motivation



[en.wikipedia.org/electricity_grid]

- Different data models for management systems
- Interoperability needs to be ensured
- Currently mapping are carried out manually
- Propose methodology to automate Signal Mapping

Agenda

- International Electrotechnical Commission Data Models
  - IEC 61850
  - IEC Common Information Model
- Problem of Model Alignment
- Proposed Methodology
  - Generate Ontologies
  - Ontology Matching System
  - Processing Alignments
- Experimental Results
- Summary
- Conclusion
- References

International Electrotechnical Commission

- International Electrotechnical Commission (IEC)
  - international standards organization
  - publishes International Standards in the area of electrotechnology
  - IEC 61850
  - IEC Common Information Model

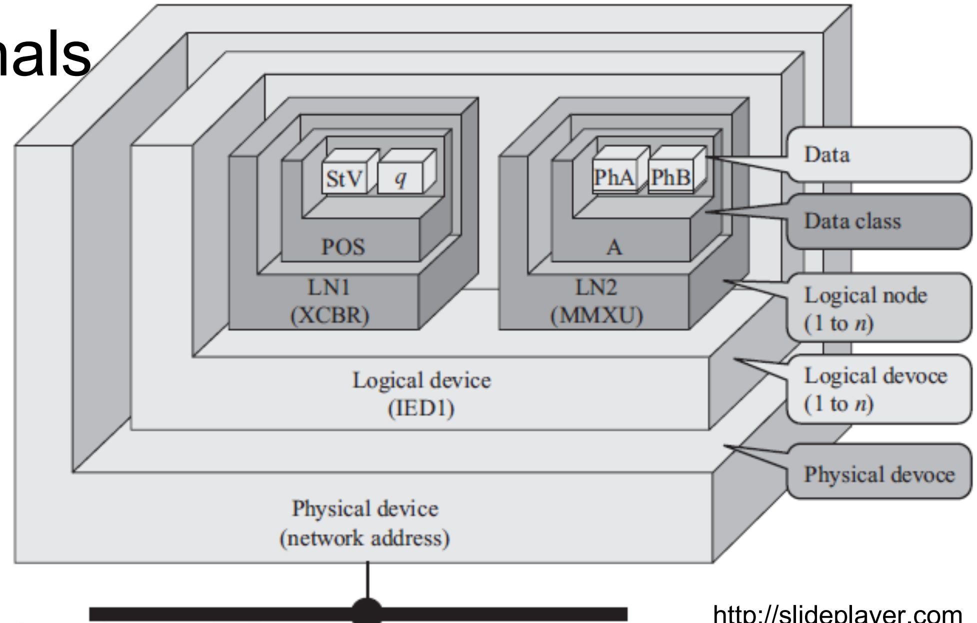
- IEC Technical Committee (IEC TC)
  - Develops and maintains international standards
  - IEC TC 57: Power systems management and associated information exchange

IEC 61850

- Communication Networks and Systems for Power Utility Automation
- Developed to standardize substation automation
- Extended to standardize the communication between power system devices
- Two data models: LN model and SCL model

IEC 61850 - LN Model

- Semantics of run-time signals between logical devices
- Described in text tables



http://slideplayer.com /slide/10674295/

- Concept:
  - Physical device represents physical IEDs
  - Logical Devices (LD) virtually represent IEDs
  - Logical Node (LN) represent specific function in LD
  - Data Objects (DO) represent groups of attributes included in LN
  - Data Attributes (DA) are endpoints of LN model

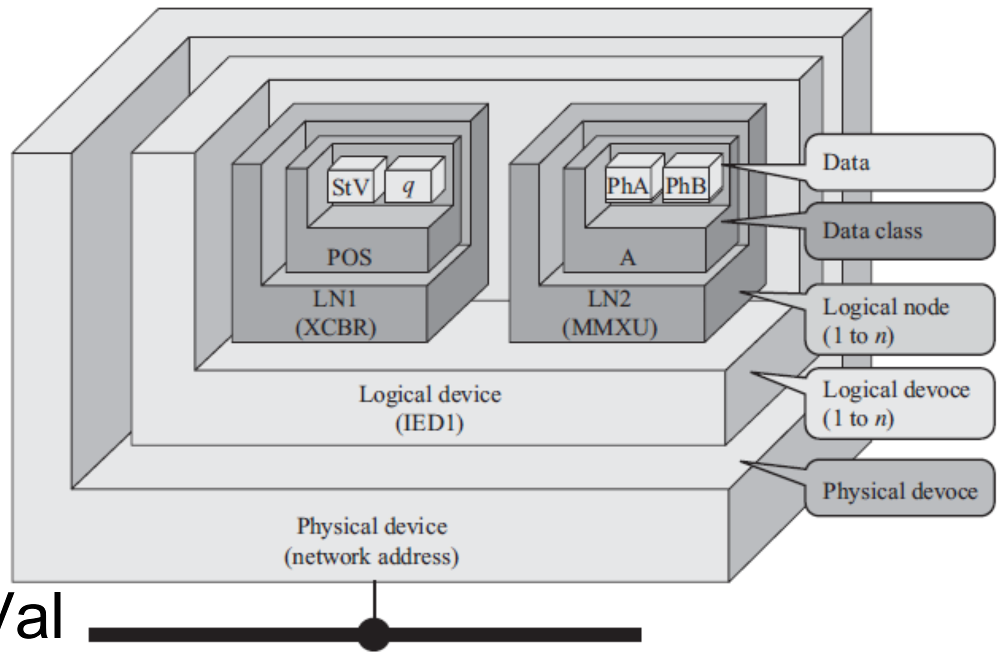
IEC 61850 - LN Model

- Path: Physical Device LD / LN.DO.DA

Physical Device	Logical Device	Logical Node			Data Object	Data Attribute
		prefix	LN class	suffix		

- Example
  - Physical Device = C1
  - Breaker prefix = QA1
  - modelling breaker =XCBR
  - Suffix = 1

C1IED1/QA1XCBR1.Pos.stVal



http://slideplayer.com/slide/10674295/

IEC 61850 - SCL Model

- Substation Configuration Language (SCL)
- Defines concept for configuring automation systems and includes concept to represent LN signals allocated in IEDs
- XML Schema Definition Language (XSD)


```
▶<Header id="None" nameStructure="IEDName">...</Header>
▼<Substation name="S12">
  ▶<PowerTransformer xmlns:sxy="http://www.iec.ch/61850/2003/SCLcoordinates" type="PTR" sxy:x="339" sxy:y="180"
  ▶<VoltageLevel xmlns:sxy="http://www.iec.ch/61850/2003/SCLcoordinates" sxy:x="150" sxy:y="44" name="D1">...</
  ▶<VoltageLevel xmlns:sxy="http://www.iec.ch/61850/2003/SCLcoordinates" sxy:x="148" sxy:y="266" name="E1">...<
 </Substation>
▶<Communication>...</Communication>
▼<IED name="D1Q1SB1">
  ▶<Services>...</Services>
  ▶<AccessPoint name="S1">...</AccessPoint>
 </IED>
▶<IED name="D1Q1SB4">...</IED>
▶<IED name="E1Q2SB1">...</IED>
▶<IED name="E1Q1SB1">...</IED>
▶<IED name="E1Q3SB1">...</IED>
▶<IED name="A1KA1">...</IED>
▶<DataTypeTemplates>...</DataTypeTemplates>
```


https://www.iit.comillas.edu/santodomingo/

IEC Common Information Model

Karlsruher Institut für Technologie

- Common Information Model: "One of the core standards of the future Smart Grid" [UST+12]

- Defined within three IEC Standards
  - IEC 61970 Application integration at electric utilities – Energy management system application program interface (EMS-API)
  - IEC 61968 Application integration at electric utilities – System interfaces for distribution management
  - IEC 62325 Standards related to energy market models & communications

IEC Common Information Model

- Unified Modelling Language (UML)
  cim:Descrete and *cim:Analog* represent measurements,
  cim:Measurement.measurementType represents type

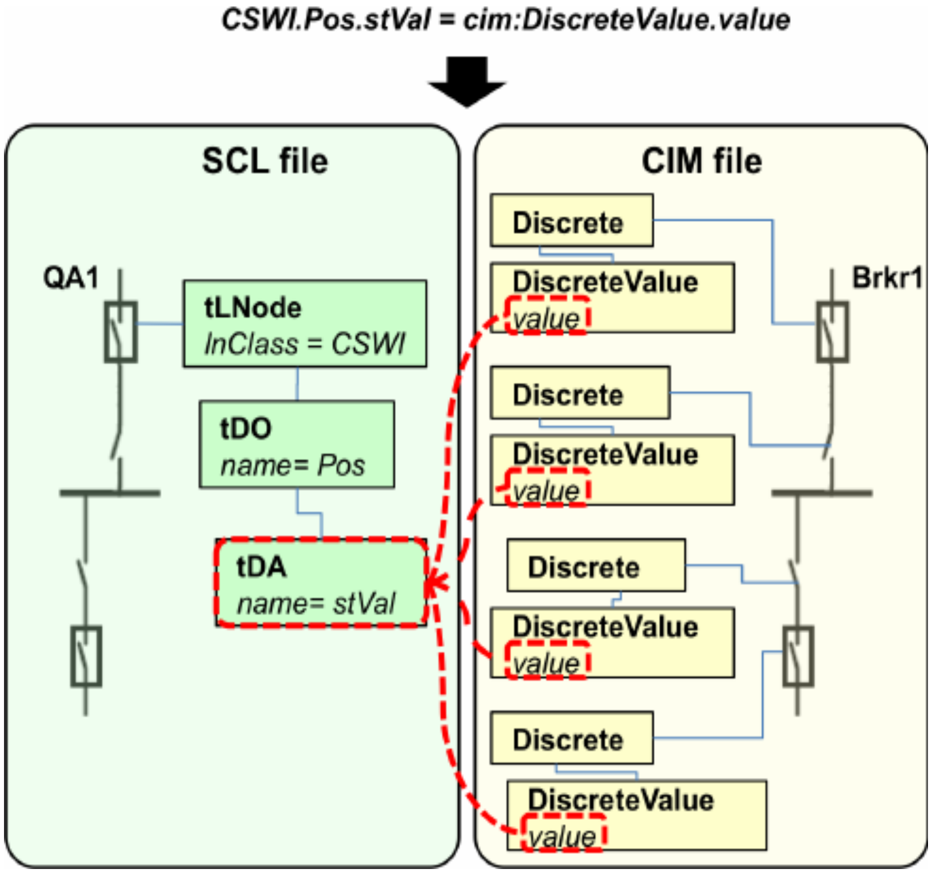
```
<!--BAY D1Q1-->
<cim:Bay rdf:ID="D1Q1">
        <cim:IdentifiedObject.name>Q1</cim:IdentifiedObject.name>
        <cim:Bay.VoltageLevel rdf:resource="#D1"/>
</cim:Bay>
<cim:Breaker rdf:ID="D1Q1QA">
        <cim:IdentifiedObject.name>QA</cim:IdentifiedObject.name>
        <cim:Equipment.EquipmentContainer rdf:resource="#D1Q1"/>
        <cim:Switch.normalOpen rdf:datatype="&xsd;boolean">false</cim:Switch.normalOpen>
</cim:Breaker>
<cim:Terminal rdf:ID="D1Q1QAT1">
        <cim:IdentifiedObject.name>D1Q1QAT1</cim:IdentifiedObject.name>
        <cim:Terminal.sequenceNumber rdf:datatype="&xsd;integer">1</cim:Terminal.sequenceNumber>
        <cim:Terminal.ConductingEquipment rdf:resource="#D1Q1QA"/>
        <cim:Terminal.ConnectivityNode rdf:resource="#D1Q1L1"/>
</cim:Terminal>
```

https://www.iit.comillas.edu/santodomingo/

Problem of Model Alignment

- CIM and SCL developed by groups of IEC TC 57
- Both have ability to exchange configuration information
- CIM based on UML; no limit modelling equipment
- SCL hierarchical described in XSD; limited on exchange of substation equipment related data

Problem of Model Alignment



[San13]

For example:
Physical device C1
Logical device IED1

In SCL file:
C1IED1/QA1CSWI1.Pos.stVal

In CIM file:
cim:DiscreteValue.value
Can lead to many different values

[San13]

Proposed Methodology: Definitions

Karlsruher Institut für Technologie

Ontology

„An ontology is an explicit specification of a conceptualization“ [Gru93]

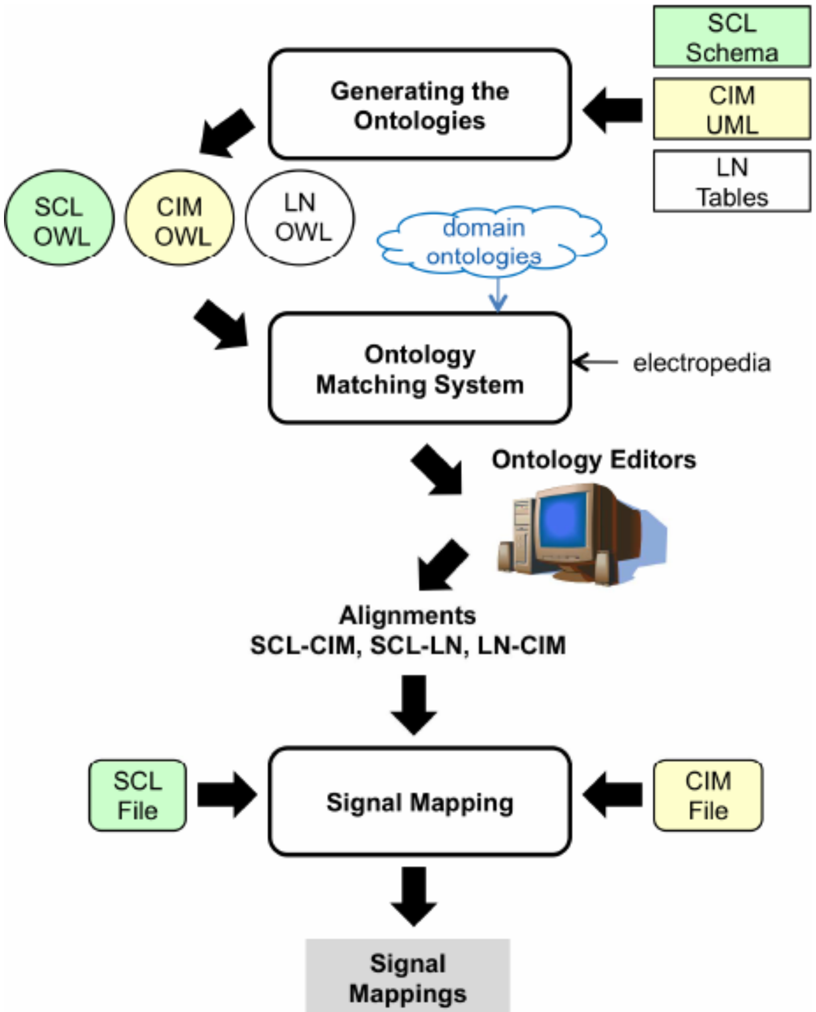
Ontology Matching

„Ontology matching is the process of automatically finding the relationship between the elements [...] of two or more formal ontologies.“ [Hus12]

Jena Rule Language

Language for representing transformation rules

Proposed Methodology



[San13]

3 steps to automate the mapping of LN Signals and CIM Measurements:

1. Generating Ontologies from standard data models

2. Creating alignment between these ontologies

3. Processing alignments to get signal mappings

[San13]

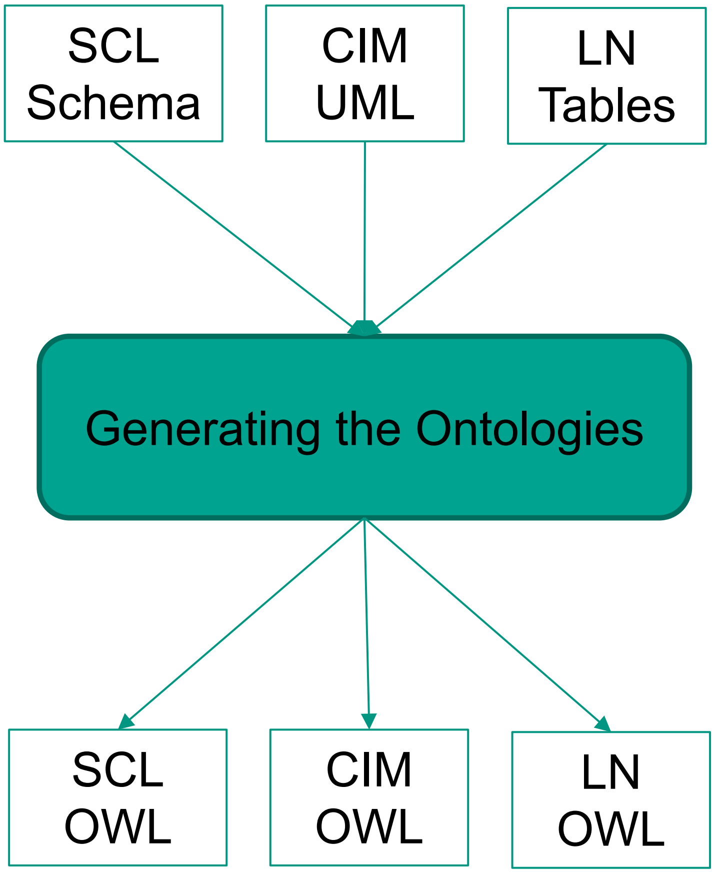
Generating Ontologies

SCL OWL with *xsd2owl*

CIM OWL with *uml2owl*

Simplified LN OWL:

- *ln:Signal61850*
  - *ln:path* and *ln:value*
- *ln:DataTypeMapping*
  - *ln:Equivalence*, *ln:DataConversion* and *ln:ComplexMapping*



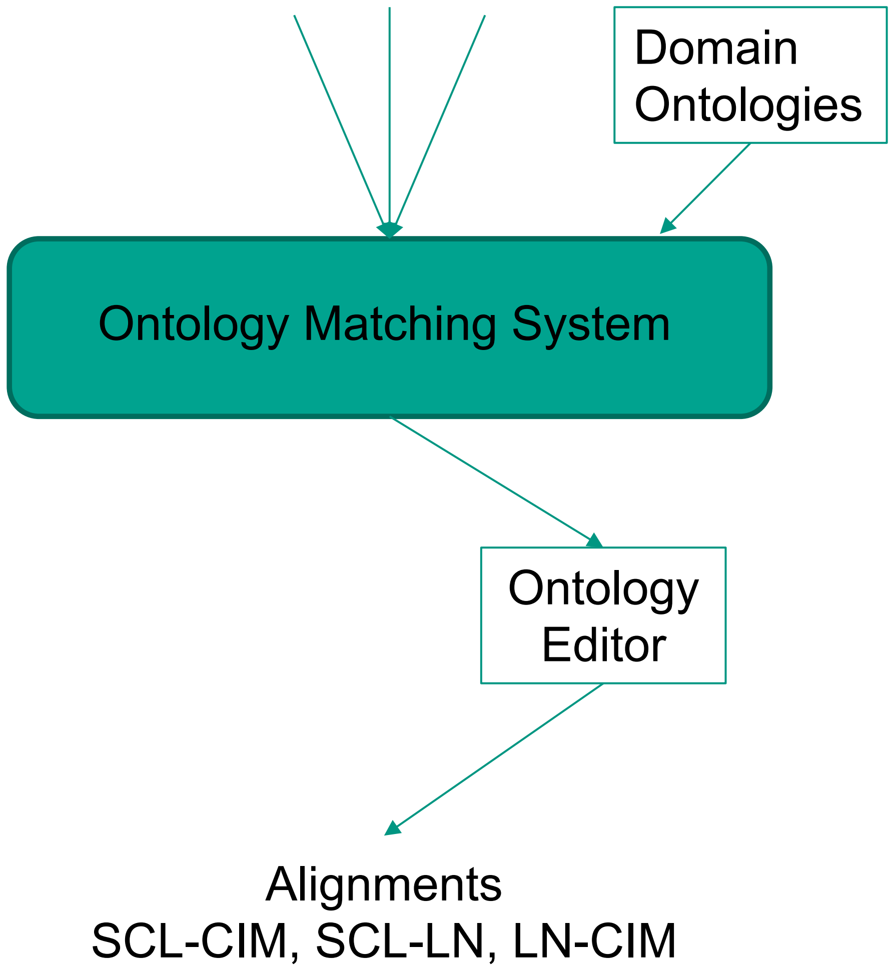
Ontology Matching

CIMMappingBench
schema-based system combining different matching methods

SCL-CIM Alignment
translating files between SCL and CIM

SCL-LN Alignment
get the *ln:Signal61850* instances

LN-CIM Alignment
get the Data Type Conversion



Excursus: Electropedia

- Online version of International Electrothechnical Vocabulary (IEV)

- Global unification of terminologies

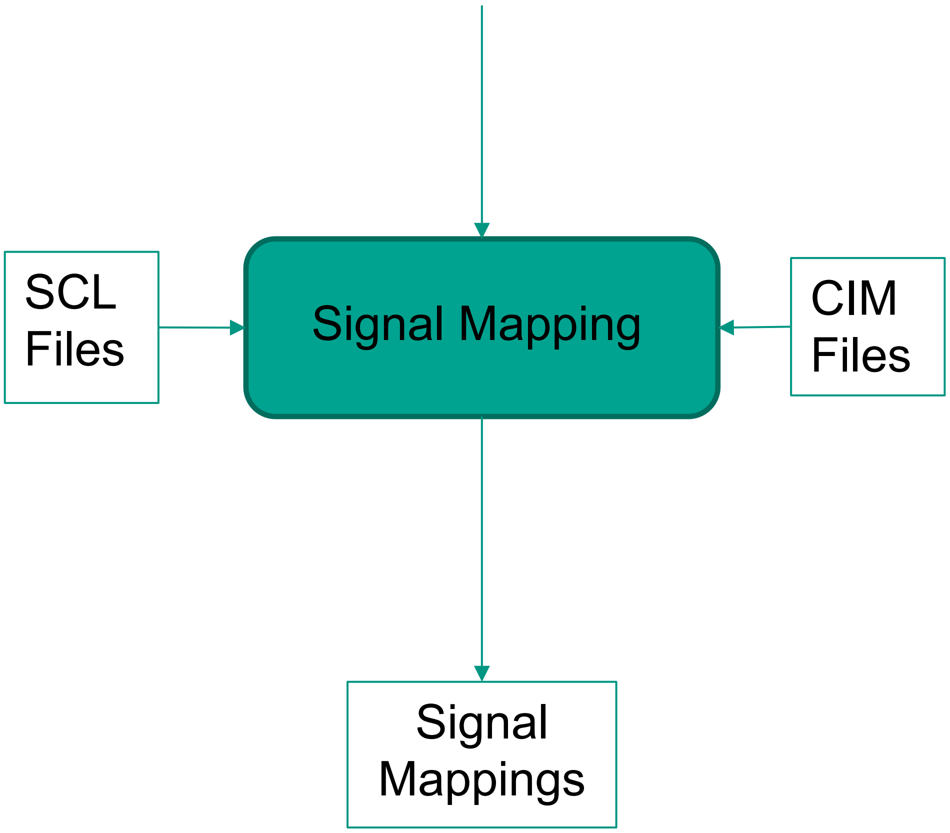
en	circuit-breaker mechanical switching device, capable of making, carrying and breaking currents under normal circuit conditions and also making, carrying for a specified duration and breaking currents under specified abnormal circuit conditions such as those of short circuit
fr	disjoncteur, m appareil mécanique de connexion capable d'établir, de supporter et d'interrompre des courants dans les conditions normales du circuit, ainsi que d'établir, de supporter pendant une durée spécifiée et d'interrompre des courants dans des conditions anormales spécifiées du circuit telles que celles du court-circuit
ar	قاطع دارة
de	Leistungsschalter, m

[www.electropedia.com]

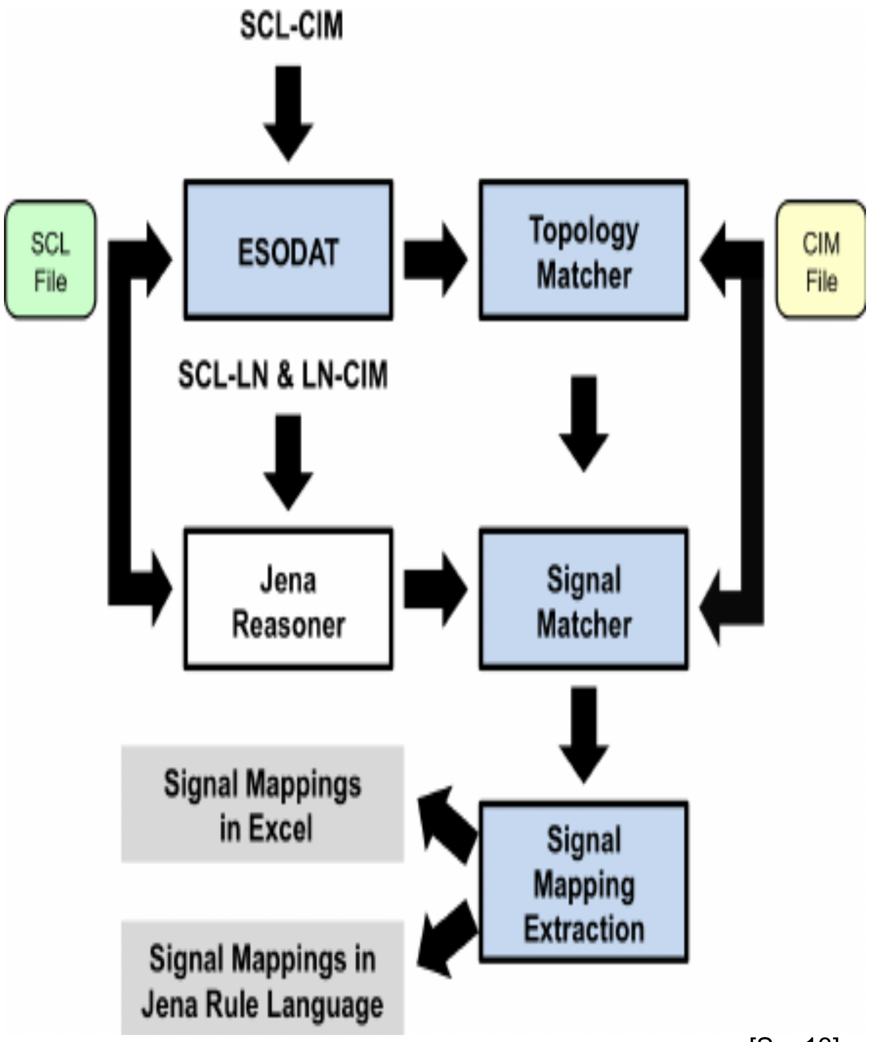
Processing Alignments

Processing Alignments to get signal mappings

Proposed methodology to automatically create signal mapping from 3 alignments and SCL and CIM files



Processing Alignments



[San13]

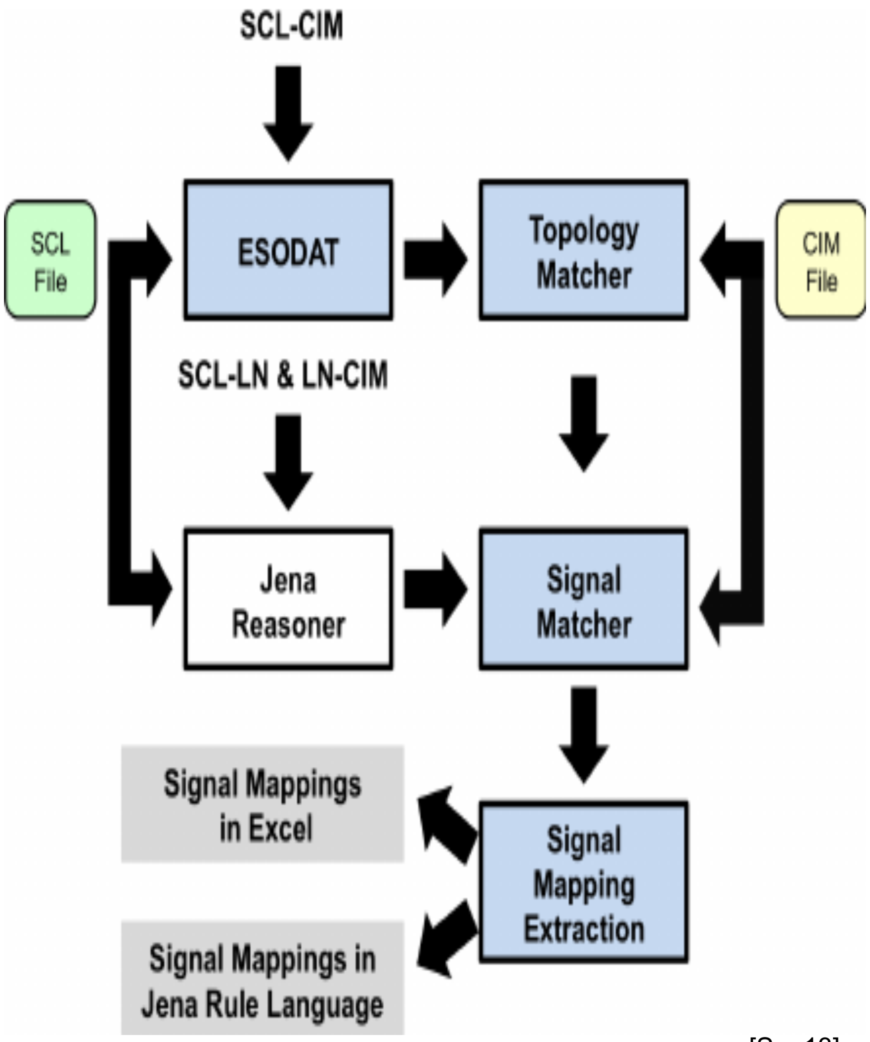
Electronical System Ontologies Data Translator (ESODAT)

- Put in SCL-CIM Alignment
- Put in SCL File

- Translates SCL File into CIM

[San13]

Processing Alignments



[San13]

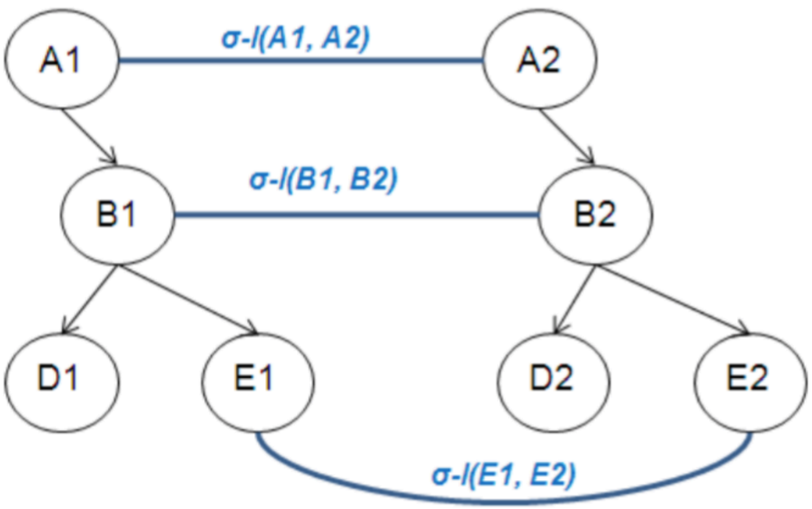
Topology Matcher:

- Creates graphs from SCL-to-CIM translation and CIM File
- Uses graph-based method
  - Descendant's Similarity Inheritance (DSI)
  - Siblings' Similarity Contribution (SSC)

[San13]

Excursus: Descendant's Similarity Inheritance

$$\sigma - g(n1, n2) = MCP * \sigma - l(n1, n2) + \frac{2 * (1 - MCP)}{m * (m + 1)} * \sum_{i=1}^{m} (m + 1 - i) * \sigma - l(parenti(n1), parenti(n2))$$



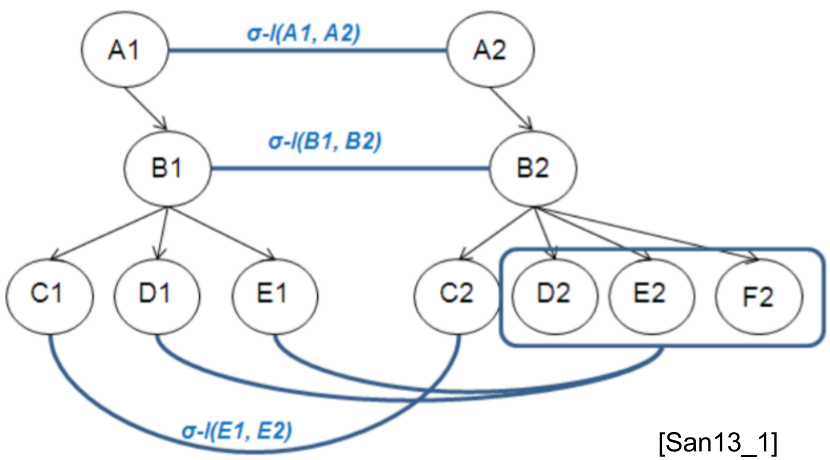
[San13_1]

$\sigma - g(n1, n2)$ = global similarity
$\sigma - l(n1, n2)$ = local similarity
Main Contribution percentage (MCP)
MCP = 0,75
path_len_root(n) = number of arcs between a node *n* and it's root
m= minimum value from *path_len_root(n1) and th_len_root(n2)*
parenti(n) = i-th parent node of a node n

$$\sigma - g(E1, E2) = 0{,}75 * \sigma - l(E1, E2) + 0{,}167 * \sigma - l(B1, B2) + 0{,}083 * \sigma - l(A1, A2)$$

Excursus: Sibling's Similarity Contribution

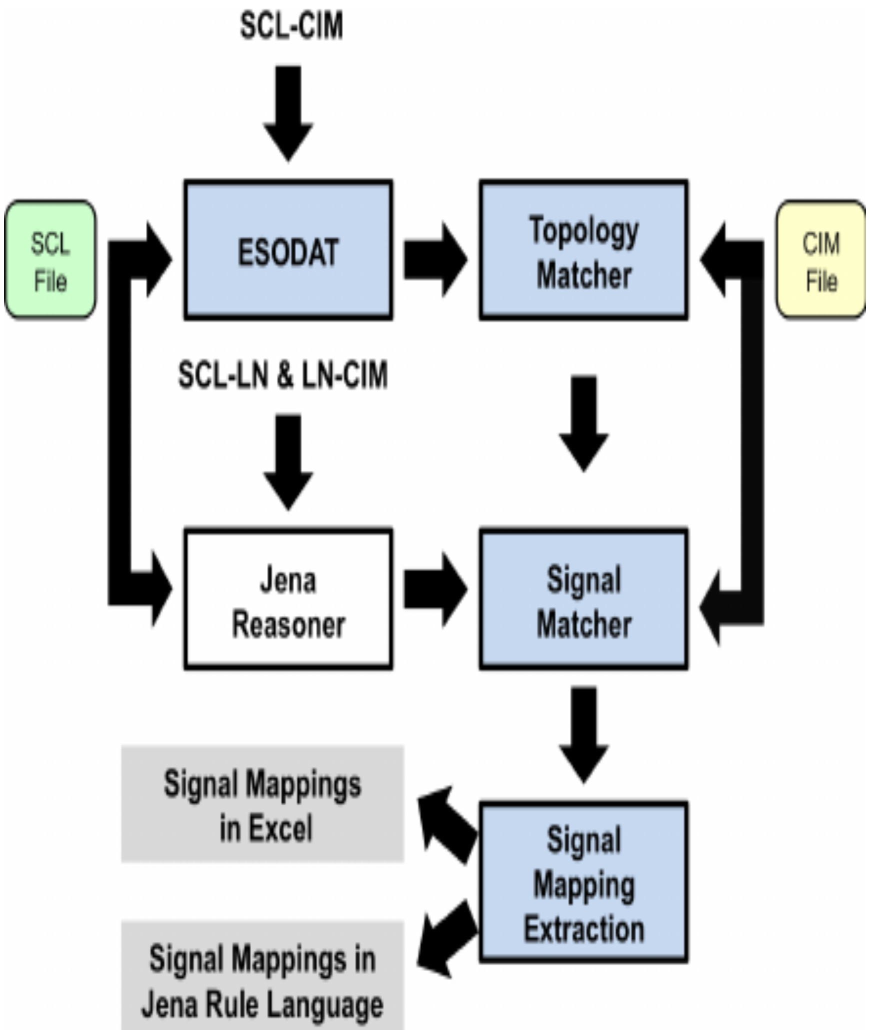
$$\sigma - g(n1, n2) = MCP * \sigma - l(n1, n2) + \frac{1 - MCP}{m1} * \sum_{i=1}^{m1} \max(\sigma - l(Si(n1), Si(n2)), \ldots, (\sigma - l(Si(n1), Sm2(n2))$$



[San13_1]

$\sigma - g(n1, n2)$ = global similarity
$\sigma - l(n1, n2)$ = local similarity
Main Contribution percentage (MCP)
MCP = *0,75*
$Si(n1)$ = i-th sibling of n1
$m1$ = number of siblings of node n1

Processing Alignments



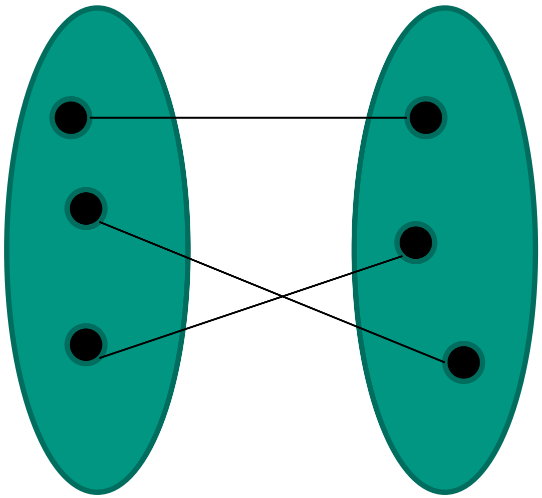
[San13]

Topology Matcher:

- Graph-based method: Descendant's Similarity Inheritance (DSI) and Siblings' Similarity Contribution (SSC)
- Get matrix with similarities
- Mapping Algorithm: Maximum Weight Bipartite Graph

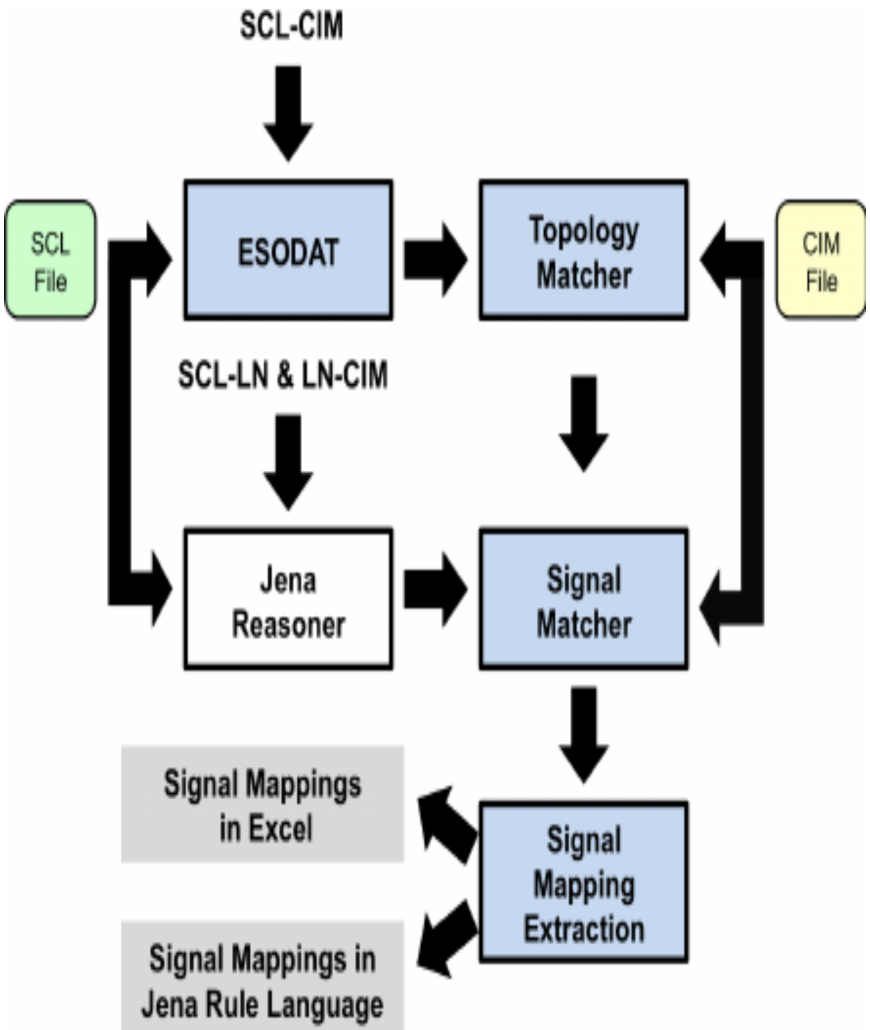
[San13]

Excursus: Maximum Weight Bipartite Graph



- Get column minimum
- Subtract it from every element of that column
  ⇒ at least one 0 in every column
- Get row minimum
- Subtract it from every element of that row
- Get combination, so that there is exactly one 0 in every row and column

Processing Alignments



[San13]

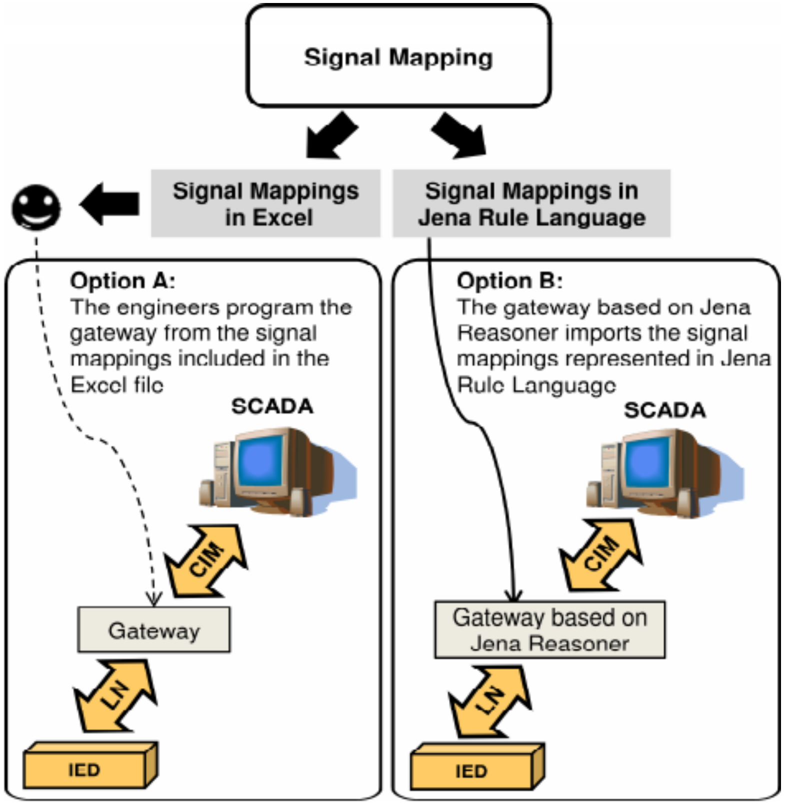
Jena Reasoner

Signal Matcher:
Compares the two CIM Measurement from SCL file and CIM file

Signal Mapping Extraction

[San13]

Processing Alignments



[San13]

Excel:
Signal Mapping has to be carried out manually

Jena Rule Language:
Jena Reasoner could carry out bi-directional translations between LN signals and CIM measurements

Experimental Results

Karlsruher Institut für Technologie

Comparison between mappings from implementation and reference mappings

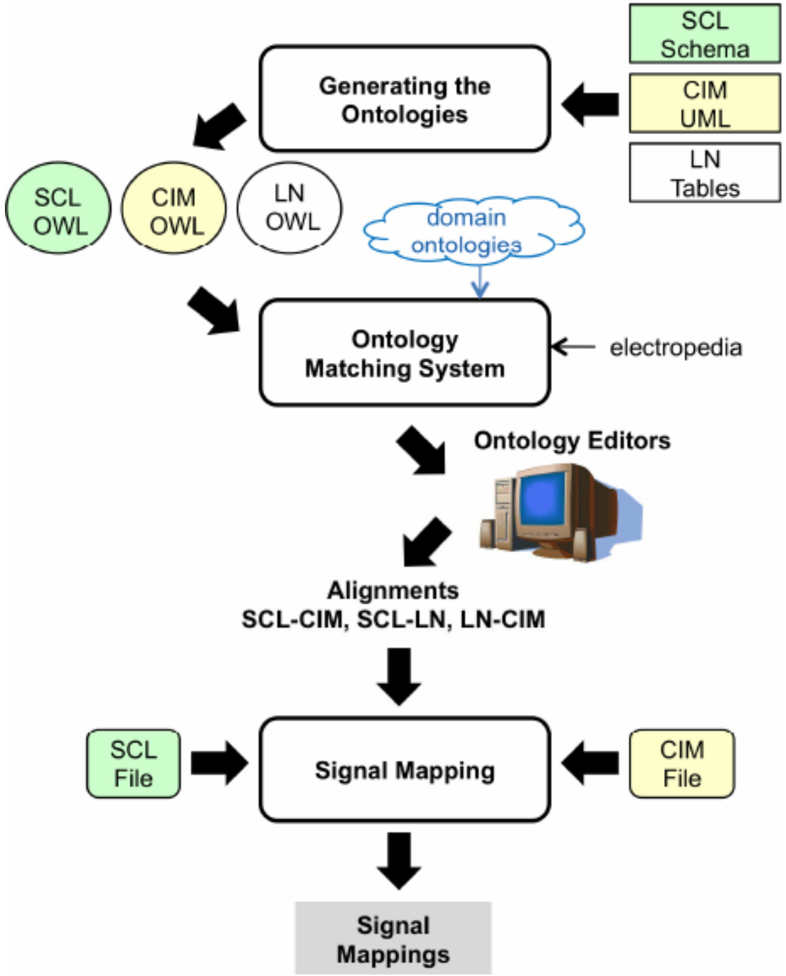
Recall = ratio of correct mappings to reference mappings
Precision = ratio of correct mappings to total mappings from implementation
Accuracy = Recall*(2- 1/Precision)

	Recall	Precision	Accuracy
Radial	1	1	1
Type_1	0.628	0.700	0.359
Type_2	0.604	0.577	0.161
Type_3	0.693	0.700	0.396
Average	0.731	0.744	0.479

Values: [San13_2]

Summary

- Generating Ontologies
- Creating Alignments by using CIMMappingBench
- Obtaining Signal Mappings from SCL and CIM Files by processing the Alignments



[San13]

Conclusion

- Interoperability of the different systems need to be ensured
- Reduces integration effort
- No manual mapping needed anymore

References

[San13] Santodomingo, Rafael. „Facilitating the Automatic Mapping of IEC 61850 Signals and CIM Measurements“, IEEE Transactions on power systems. November 2013

[NBVS14] Naumann, Bielchev, Voropai, Styczynski. „Smart grids automation using IEC 61850 and CIM standards“. 22 January 2014

[San13_1] Santodomingo, Rafael. „Using Semantic Web Resources to achieve metadata interoperability in the scope of future smart grids“ . April 2013

[Gru93] Gruber, T.R. „A Translation Approach to Portable Ontology Specifications“ . April 1993

[Hus12] Hussain, M.M. „A Study of Different Ontology Matching System“ . April 2012

[SRS+11] Santodomingo/Rodriguez-Mondéjar/Sanz-Bobi/Rohjans/Uslar, “Towards the automatic alignment of CIM and SCL ontologies”, Proc. IEEE SmartGridComm, 2011.

References

[IEC04] International Standard IEC 61850-6. "Communication networks and systems in substations- Part 6". 2004

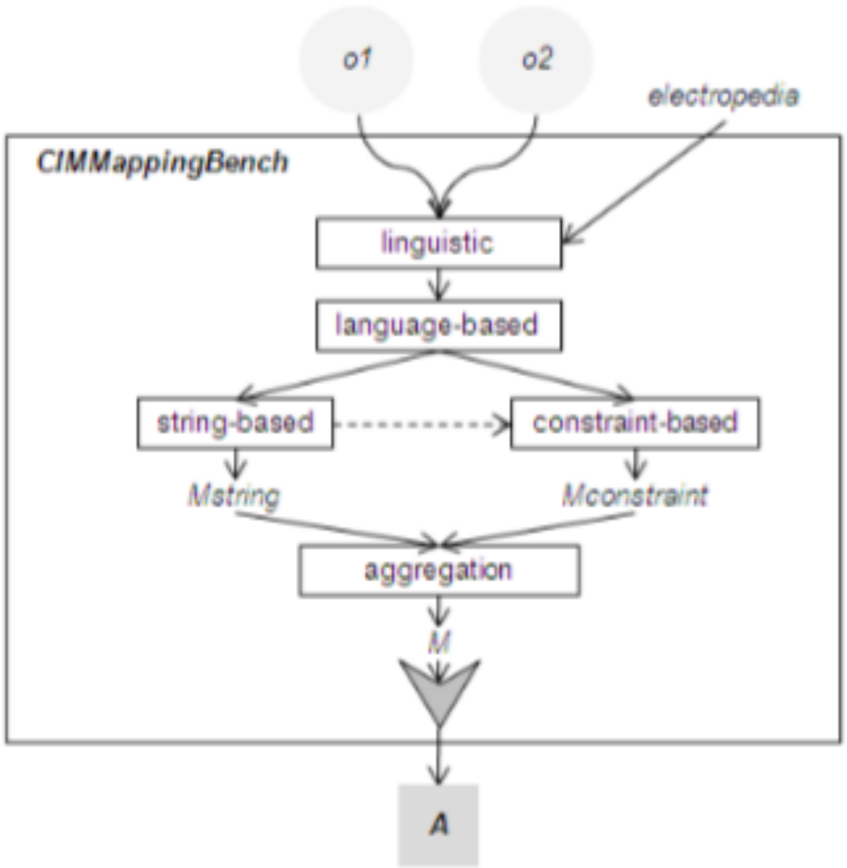
[CS08] Sunna/Cruz.„Structure-based Methods to Enhance Geospatial Ontology Alignment".

[McM07] McMorran, Dr Alan W. „An Introduction to IEC 61970-301 & 61968-11: The Common Information Model". Januar 2007.

[UST+12] Uslar/Specht/Rohjans/Trefke/González „The Common Information Model CIM".2012.

[San13_2] Santodomingo, Rafael. „Ontologies, Alignments and Configuration Files for Evaluation" .2013.

BackUp: CIMMappingBench



[San13_1]

Combining different matching methods:

-linguistic-based method
-language-based method
-string-based method
-constraint-based method

BackUp: Ontology Matching System Case

Recall	CIMMappingBench	Agreement Maker
Simple	0,893	0,385
Radial	0,589	0,222
Type_1	0,492	0,203
Type_2	0,59	0,203
Type_3	0,639	0,203
Average	0,641	0,243

[Values:San13]

AgreementMaker
"one of the best generic ontology matchers" -Ontology Alignment Evaluation Initiative (OAEI)

Type_1-Type_3
Defines by a spanish electricity company