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An Introduction to IEEE P1815.1 – Mapping IEEE 1815 (DNP3) to IEC 61850

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Purpose

- Provide update on the role of the SGIP and PAP12
- Communicate history and background on the protocols
- Provide a rational for migrating from IEEE 1815 to IEC 61850
  - Benefits, Risks, Issues
- Present strategies for migrating from IEEE 1815 to IEC 61850
  - Best practices and guidance on when and how to deploy
- Summarize the key concepts contained in IEEE P1815.1
  - Network topology and conceptual architectures
  - Use cases (3) summaries
  - Logical device and object mapping
  - Mapping of the data structure
  - Mapping of services
  - Mapping using XML
  - Security requirements

Agenda

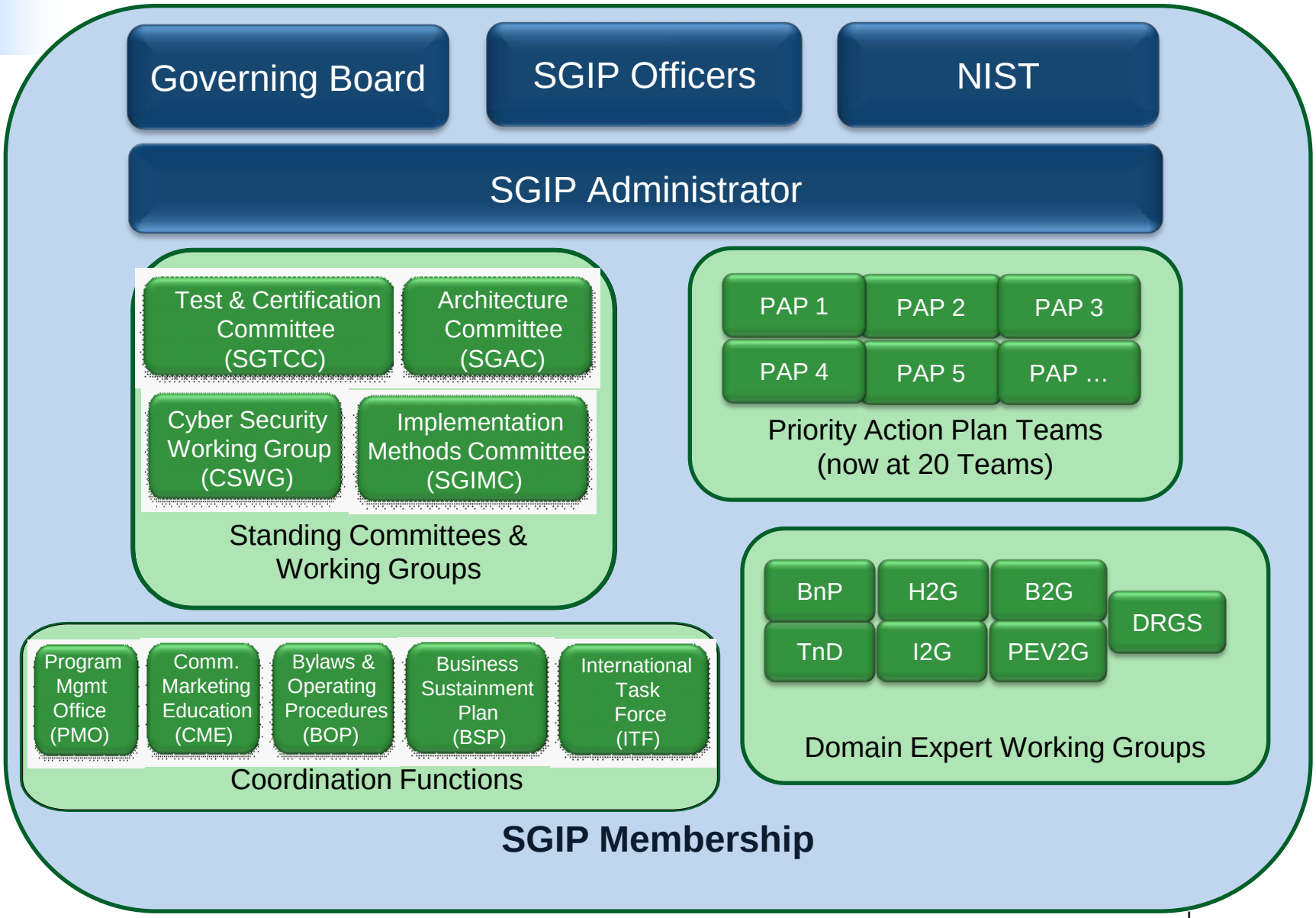
- Introductions
- The SGIP and PAP12
- Background on the Protocols
- Why a Mapping Specification?
- Why Migrate from IEEE 1815 to IEC 61850?
- How and When to Migrate?
- Key Concepts in IEEE P1815.1
- Status of the Standard
- Conclusions

Don't have time to discuss all items – will provide highlights

Smart Grid Interoperability Panel (SGIP)

- Organized by U.S. National Institute of Standards and Technology (NIST)
- Hundreds of member organizations
- International members welcome and active
- Mandate to:
  - Identify standards for “Smart Grid”
  - Identify missing standards and “gaps”
  - Develop “priority action plans” (PAPs) to close gaps
  - Provide deep technical reviews in key areas such as CSWG
  - Coordinate these plans with standards organizations
- New work by the SGTCC and SGIMC

SGIP Organization



SGIP Membership as of 5.10.12

- Total # of Member Organizations: 770
  - # of Participating Member Organizations: 304
  - # of Observing Member Organizations: 466
  - # of Organizations who joined since March 1st: 15
- Total # of Individual Members*: 1,905
- # of Organizations by Country:
  - USA: 675
  - Europe: 23
  - Oceania: 6
  - Africa: 1
  - North America (non-US): 36
  - Asia: 27
  - South America: 2

** Omits non-active Signatory Authorities.*

Priority Action Plans (PAP) – June 2012

0. Meter Upgradability
1. Use of IP in the Smart Grid
2. Wireless Guidelines
3. Pricing Model
4. Scheduling
5. Meter Profiles & Upgrade Std.
6. Common Semantic Model (CIM)
7. Storage Interconnect
8. CIM Distribution Models and Harmonization
9. Standard DR Signals
10. Energy Usage to Customer
11. Common Data Models for Electric Transportation
12. **IEEE 1815 to IEC 61850 Mapping**
13. SynchroPhasor Data Harmonization (C37.118 to IEC 61850) and Time Synchronization
14. Integrate Transmission & Distribution Model Mapping
15. Harmonize Power Line Carrier Standards
16. Wind Plant Communications
17. Facility Smart Grid information
18. SEP 1.x to 2.0 upgrade and coexistence guideline and best practices introduction
19. Wholesale DR
20. Green Button

(Titles are abbreviated)

PAP12 Overview and Tasks

- Develop Use Cases
  - Use case A - IEEE 1815 master communicating with an IEC 61850 substation (two scenarios – retrofit and greenfield)
  - Use case B - IEC 61850 client communicating with an IEEE 1815 substation
- Develop requirements for mapping
- Liaisons with SGIP SGAC and CSWG
- Create and support IEEE working group (C14)
- Help develop IEEE 1815.1 mapping specification
- Propose joint-logo to IEC as IEC 61850-80-2
- Propose any necessary standards changes
  - IEEE 1815: DNP Technical Committee
  - IEC 61850: IEC TC57 WG10
- Develop user guides and examples

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Background – IEEE 1815

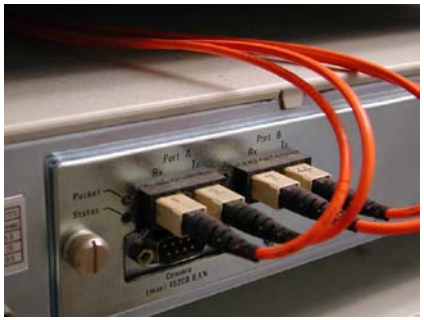
- Distributed Network Protocol (DNP3)
- Originally developed by GE/Harris/Westronic
- Now controlled by DNP Users Group
- Designed for low bandwidth, low reliability links
- Combines best practices from hundreds of earlier protocols
- Most widely used utility protocol in North America (approx 75%)
- Flat, points-based data model
- DNP3-XML Device Profile Document provides configuration info
- Serial and IP profiles

Background – IEC 61850

- Developed in coordination between EPRI, IEEE, IEC
- Widely deployed outside North America
- 4,000 to 5,000 substation installations to date
- Only a few installations in North America so far
- Advanced features
- Growing list of IEC 61850 companion standards (and technical reports addressing: communications outside of substations, between substations and control centers, equipment condition monitoring, DER, phasor data, hydro power plants, network engineering guidelines
- Application of “IT” type features to the power industry
- Strong support by the UCA-IUG

BENEFITS OF MIGRATING FROM SERIAL TO IP(*)

- Reduced wiring and equipment costs
- Replacing aging equipment
- Improved performance
- Improved reliability
- Multiple simultaneous services
- Additional types of data
- Centralized configuration management
- Ease of adding security
- Easier to design and deploy redundancy



*EPRI Tech-Update: “Serial to IP-Based SCADA Migration”, April 30, 2012

Why IEC 61850?

- IEC 61850 offers many enhancements that will support important applications and provide significant life cycle savings in the future.
- Leading to an enterprise wide solution addressing communications in many domains and harmonization with CIM
- Industry consensus object modeling for power system devices
- Self-Description
- Structured meta Data
- Publish/subscribe services
- Fast data services for protection and control (eg tripping over the LAN)
- Transmitting Waveform Samples in Real-Time
- LAN-Based Time Synchronization
- Cyber security (IEC 62351)
- Substation Configuration Language
- Automated system engineering tools and processes
- Testing, verification, and quality assurance processes

Comparing IEC 61850 and IEEE 1815

Issue	IEC 61850	DNP3 (IEEE 1815)
Recognized in NIST Interoperability Framework	Yes	Yes
Distribution Feeder Automation	No profile currently exists for low-bandwidth networks	Designed for it
Substation Automation	Yes	Yes
Substation to Control Center	Under development	Yes
High Speed Peer-to-peer	Yes	No
Structured Data and Naming	Yes	Limited. Numbered Points.
Self-Description	Yes	Limited
XML Configuration File	Yes	Yes

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Developing a Strategy for Migrating

- Decision to migrate is based on requirements – IEEE 1815 and IEC 61850 are not in competition
- Require that suppliers provide devices that support both IEEE 1815 and IEC 61850 (end devices and gateways)
- Require that protocol implementations be independently tested
- Build the case for transitioning from serial to IP (LAN and WAN)
- Migrate from DNP serial to DNP/IP
- Widely deploy substation gateways that will support P1815.1
- Build understanding of IEC 61850 including cross functional benefits for your utility (eg reduced capital costs)

Developing a Strategy for Migrating

- Begin lab testing IEC 61850 devices
- Update cross functional requirements and business case
- Identify pilot opportunities and develop detailed implementation agreements with vendors
- Implement 61850 devices coexisting with 1815/IP devices
- Look for candidate sites for full 61850 implementation

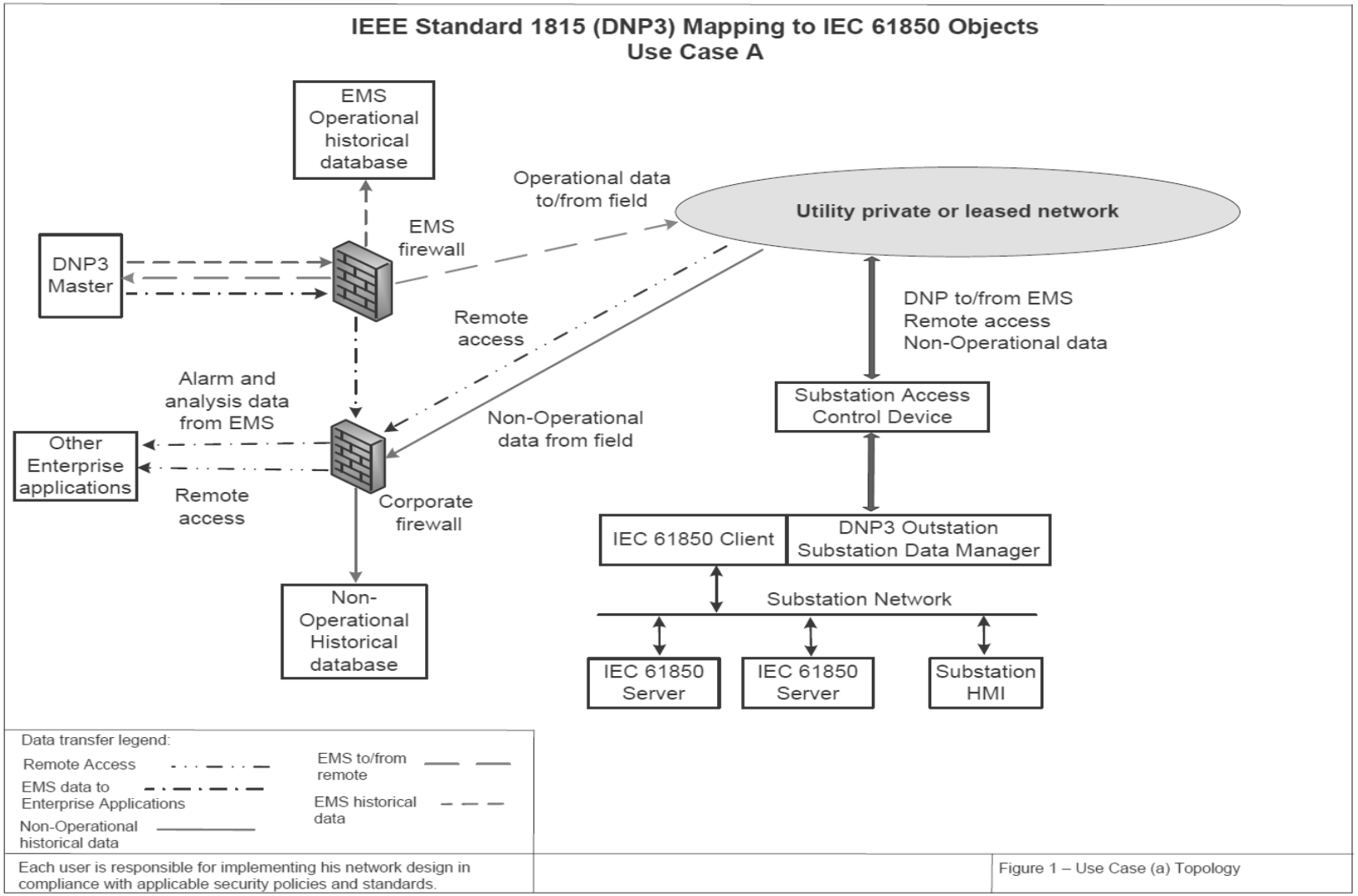
IEEE P1815.1 (Mapping IEEE 1815 (DNP3) to IEC 61850) - Overview

- Key aspects:
  - Conceptual architectures
  - How to map data
  - How to map services
  - Use case descriptions
  - Security considerations
  - Leaf level mapping rules
  - Configuration file formats

Sections of the IEEE 1815.1 Standard

#	Section
1	Overview
2	Normative references
3	Definitions
4	Conceptual architecture
5	Use cases
6	Mapping of information model
7	Mapping of data structure
8	Mapping of services (ACSI)
9	DNP3/IEC 61850 Mapping Using XML
10	Cyber security Requirements
Annex A	Leaf Mapping Table
Annex B	Recommended Implementation Levels
Annex C	Recommended Mapping of IINs to IEC 61850-7-4
Annex D	Time Synchronization Security Considerations
Annex E	Example XML Files

Network Topology – Use Case (a)



Network Topology – Use Case (b)

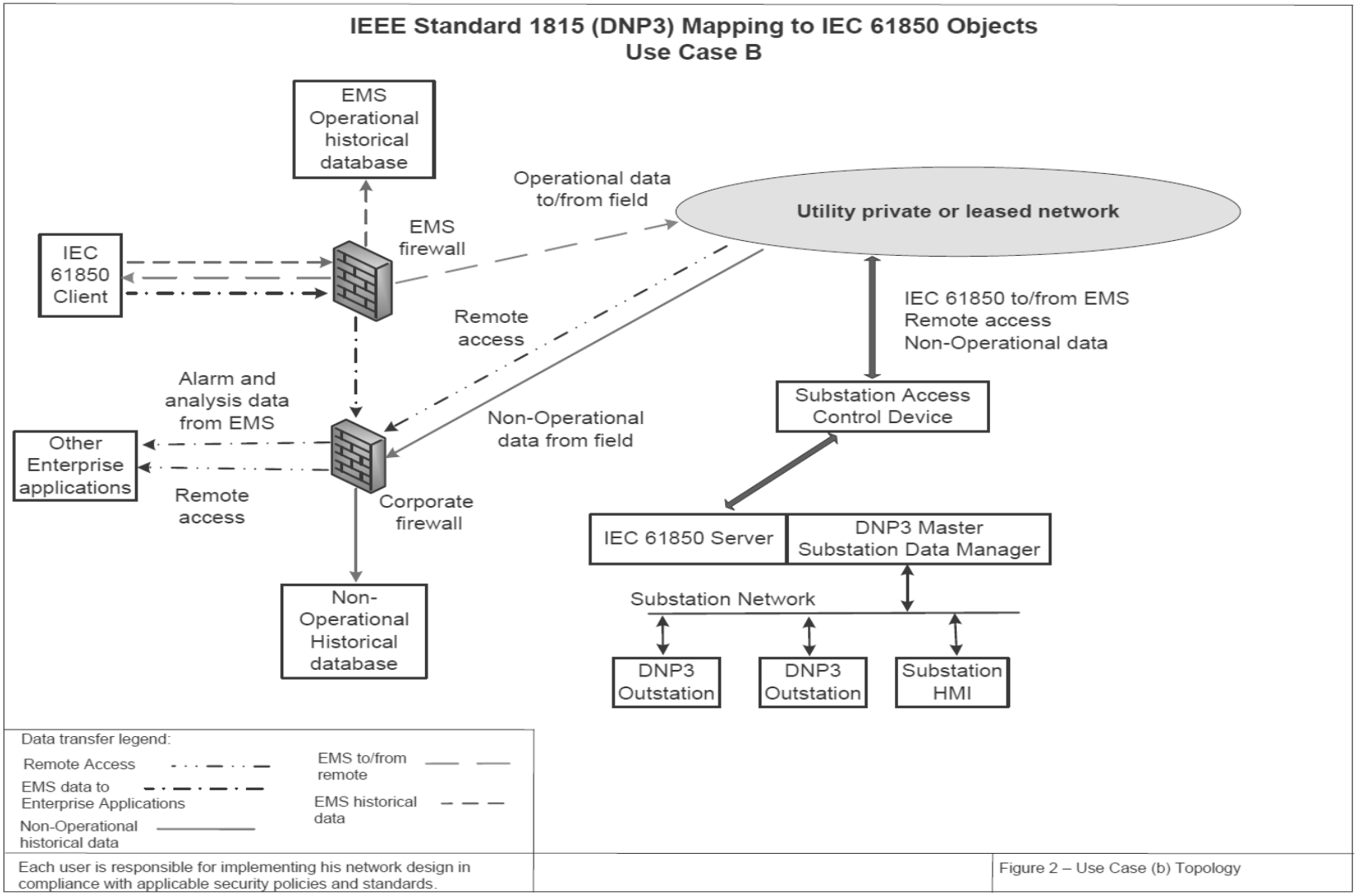
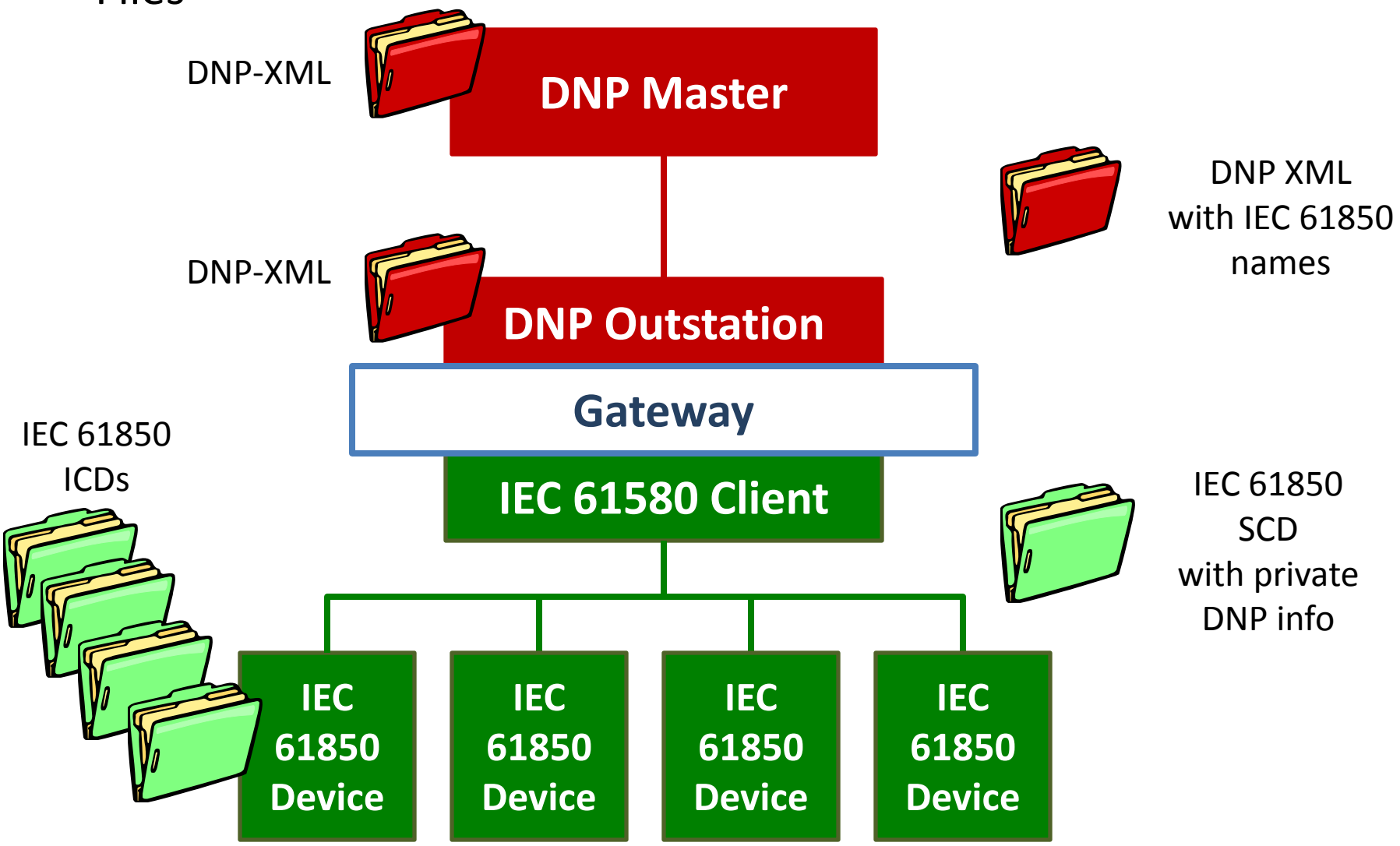


Figure 2 – Use Case (b) Topology

Context - Use Case (a)

INPUT
Capabilities Files

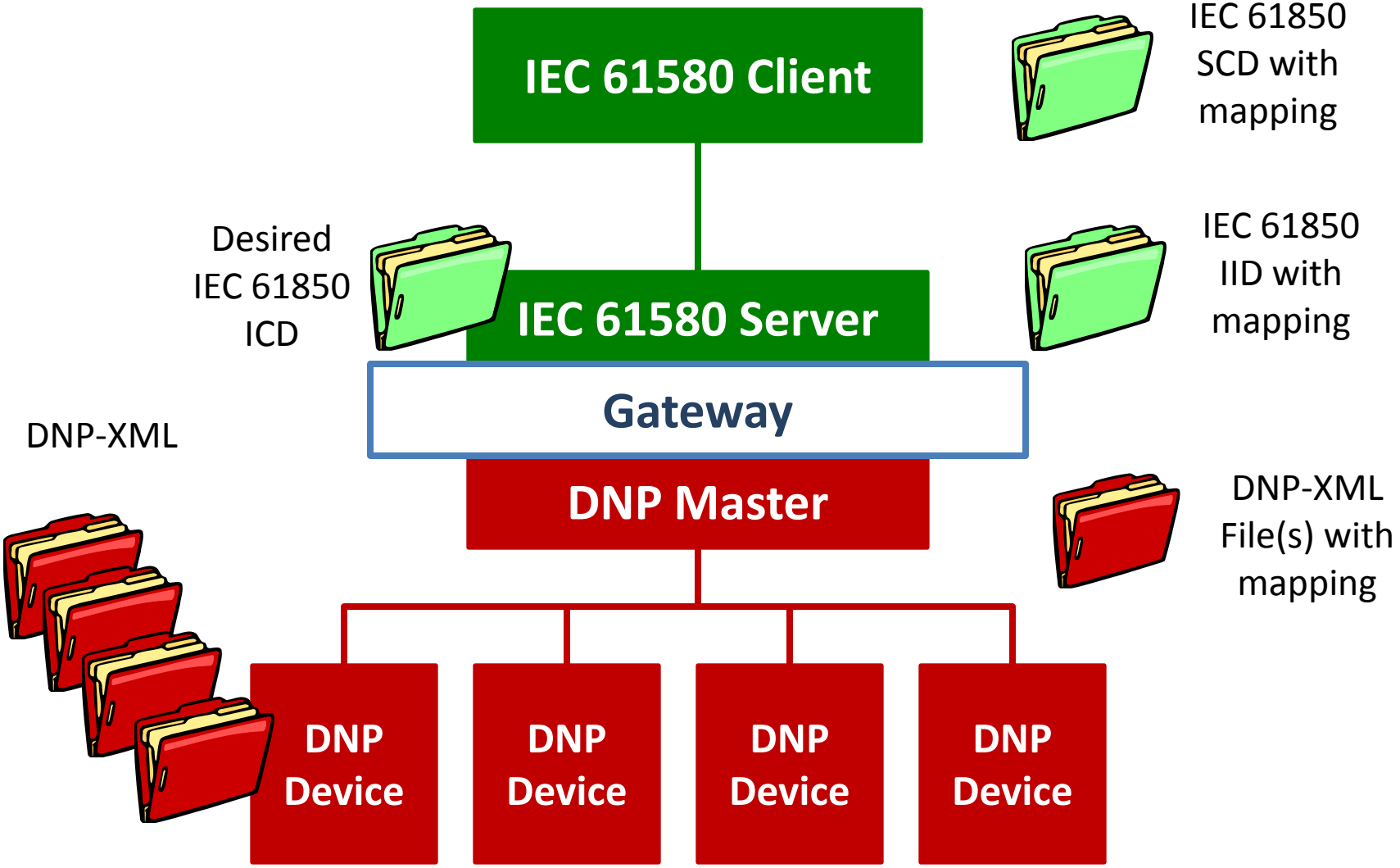
OUTPUT
System Files



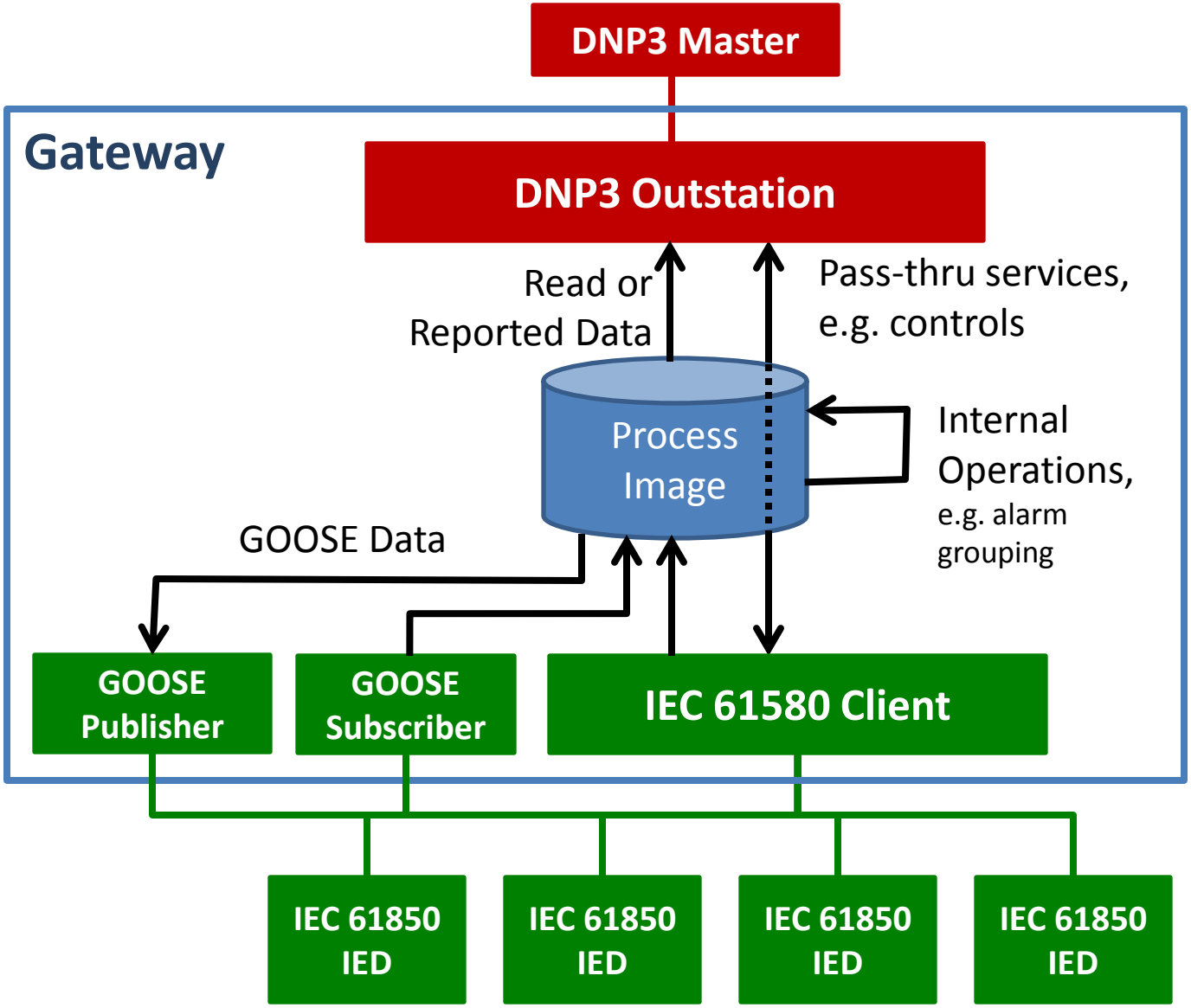
Context -Use Case (b)

INPUT
Capabilities Files

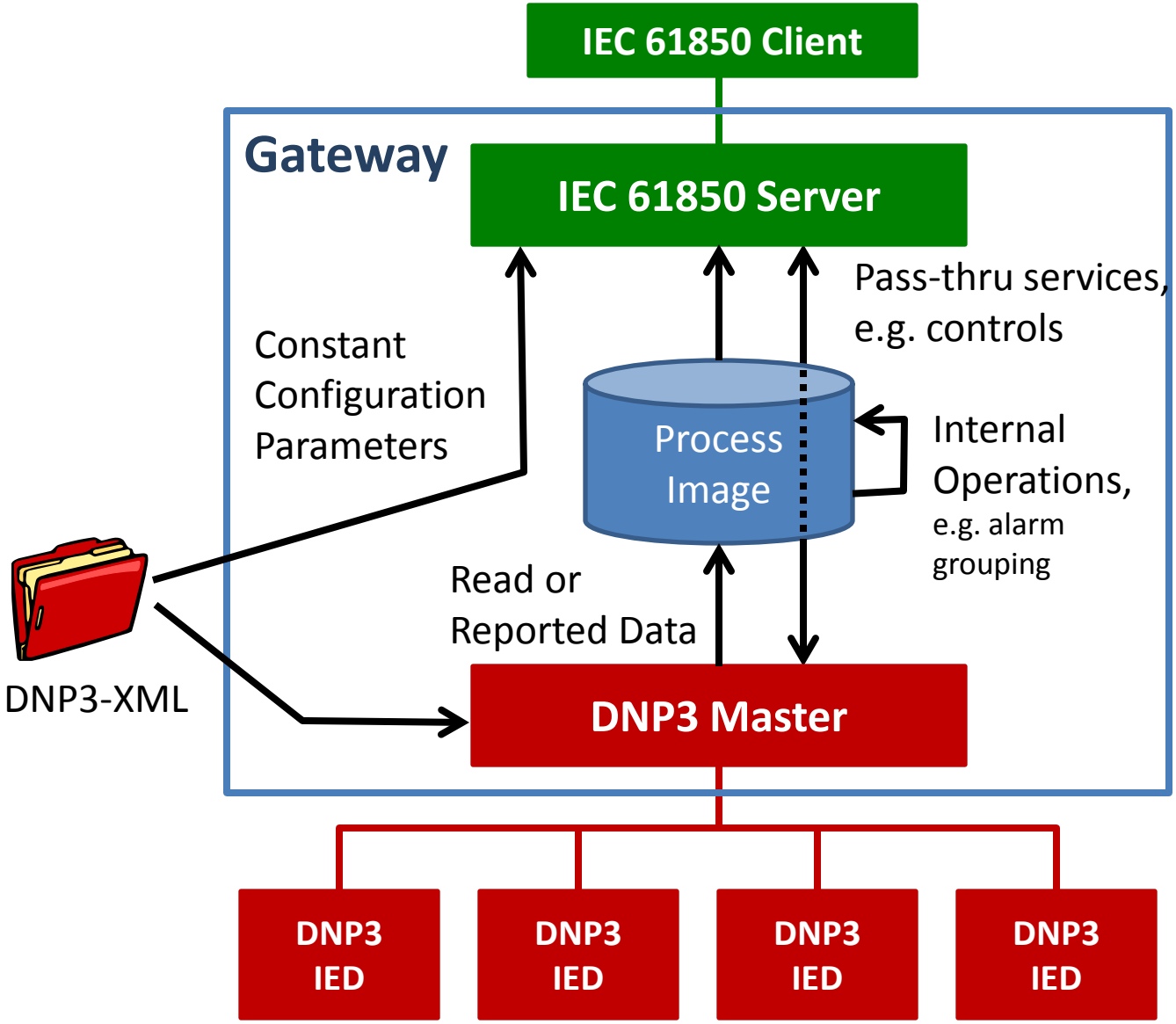
OUTPUT
System Files

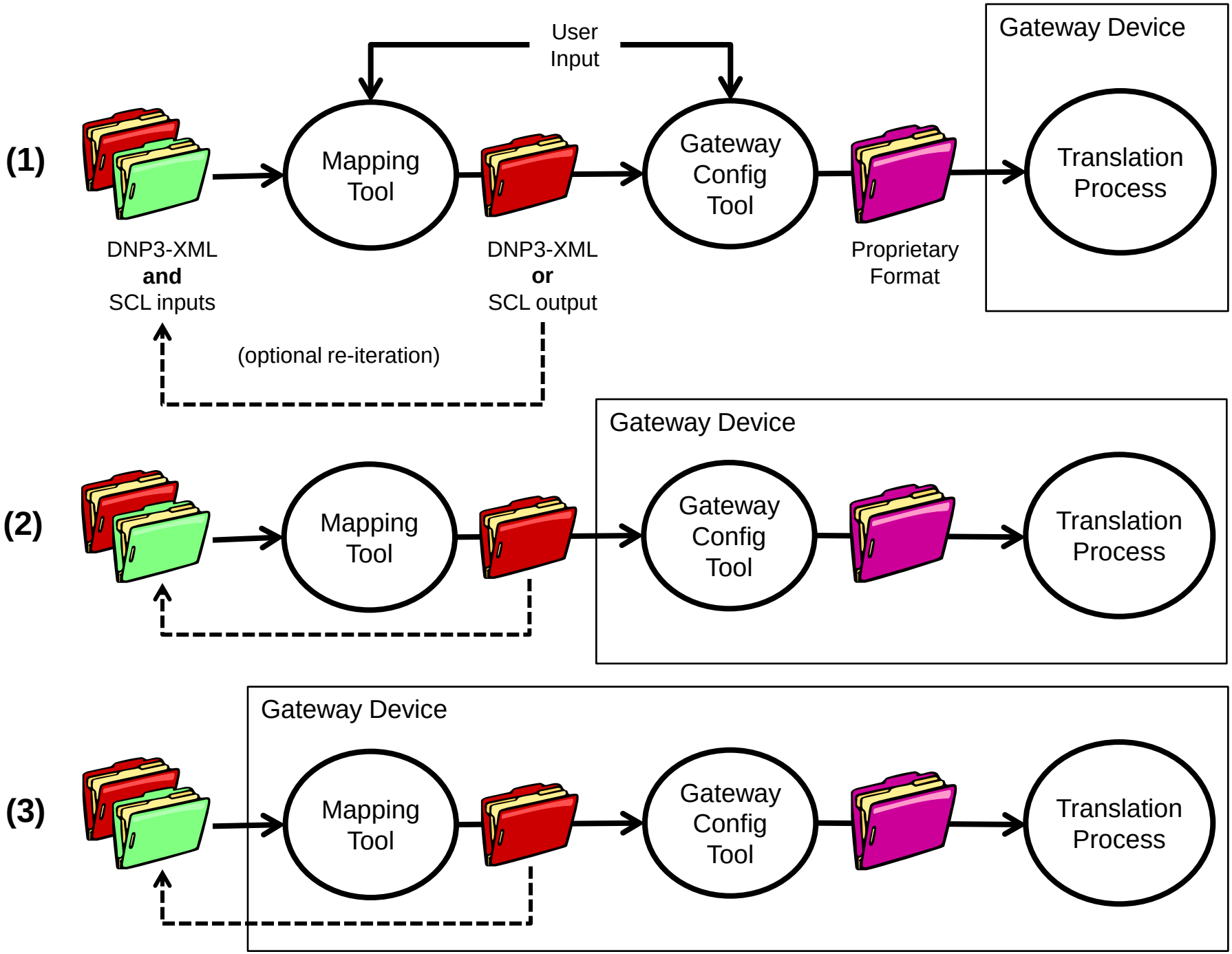


Conceptual Architecture (a)

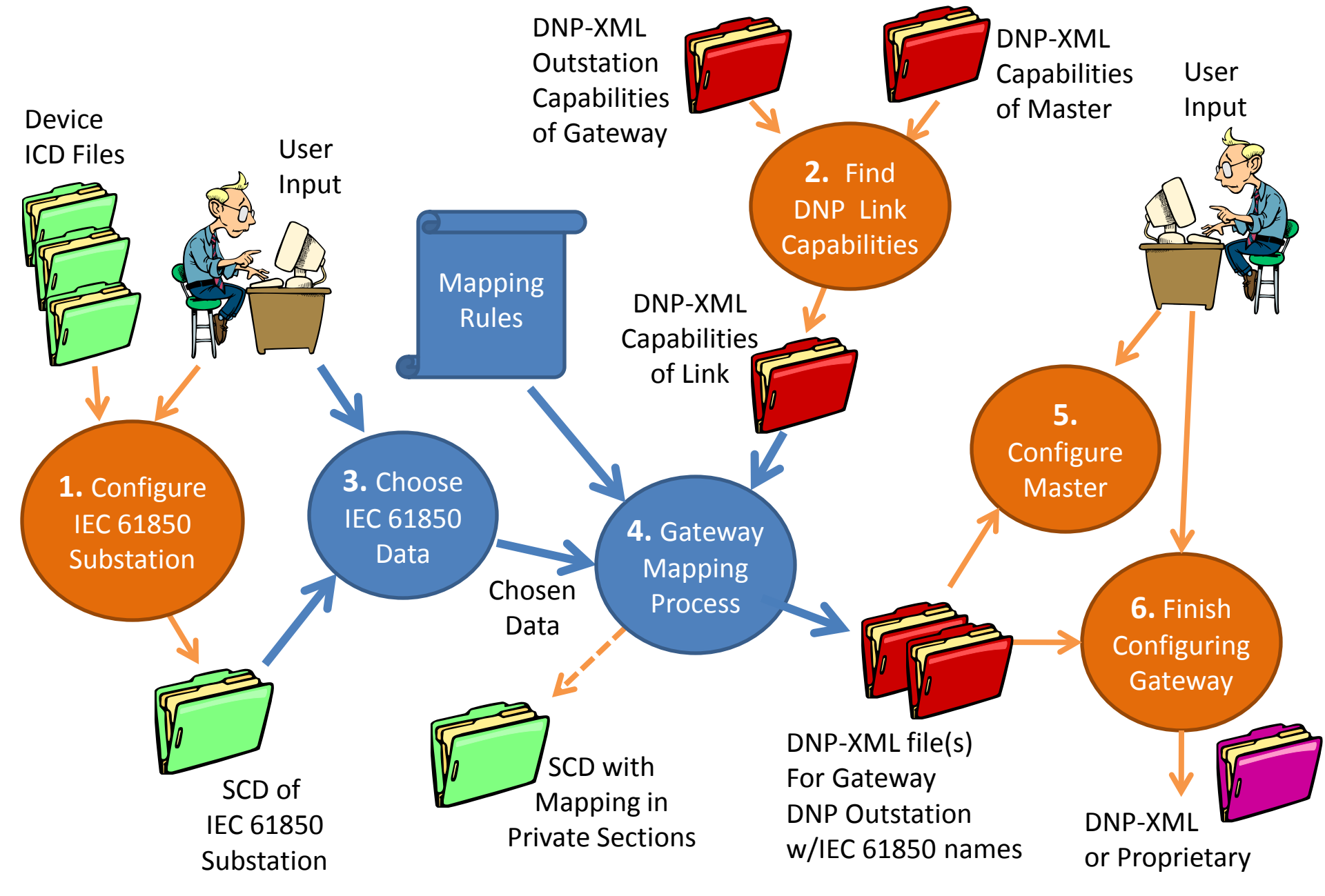


Conceptual Architecture (b)




(1)
User Input
Gateway Device
Mapping Tool
Gateway Config Tool
Translation Process
DNP3-XML **and** SCL inputs
DNP3-XML **or** SCL output
Proprietary Format
(optional re-iteration)
(2)
Gateway Device
Mapping Tool
Gateway Config Tool
Translation Process
(3)
Gateway Device
Mapping Tool
Gateway Config Tool
Translation Process

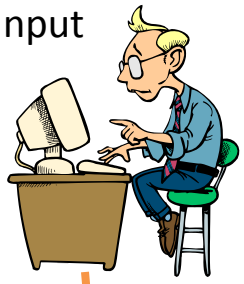
Use Case (a) Steps



Use Case (b) Steps

Choose database points

Mapping Rules



2. Create IEC 61850 Model

ICD of Gateway IEC61850 Server

4. Configure Client

1. Configure Gateway DNP Master

Gateway Database Point Map

3. Gateway Mapping Process

SCD with mapping

5. Finish Configuring Gateway

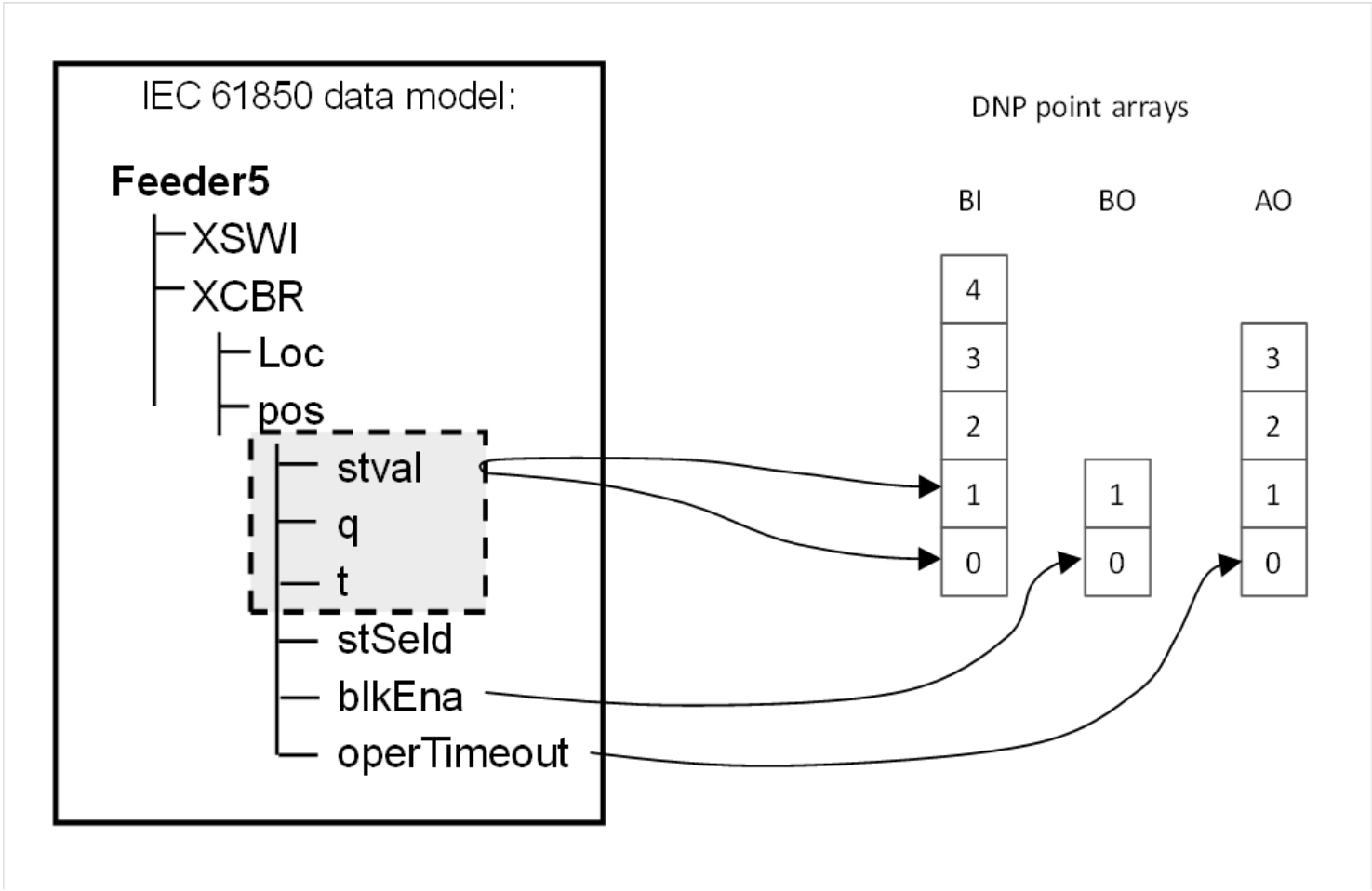
IID with mapping in private sections

DNP-XML for each DNP device

DNP-XML files with mapping

CID or Proprietary

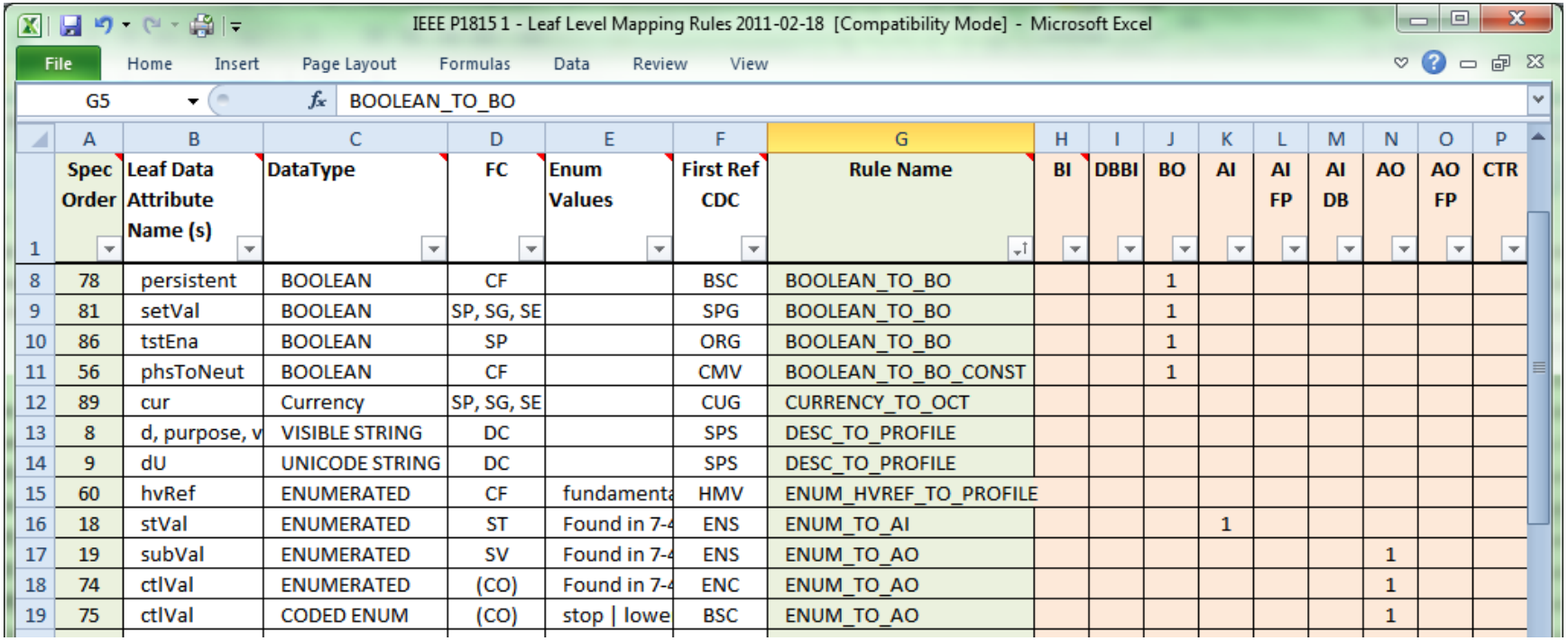
Object Mapping



Data Structure Mapping (SPS)

Preferred DNP3 Implementation						
Data Attribute Name	First Choice		Second Choice		Notes	
	Point Type	Point Count or Note	Point Type	Point Count or Note	Use Case (a) Mapping IEC 61850 Substation to DNP3 Master	Use Case (b) Mapping DNP3 Substation to IEC 61850 Client
stVal	BI	1				
q	BI	quality - stVal				
t	BI	time - stVal				
subEna	BO	1				
subVal	BO	1				
subQ	OCT	1			Order of bits as defined in IEC 61850	Order of bits as defined in IEC 61850
subID	OCT	1				
blkEna	BO	1				
d		PROFILE			Not available at run-time in DNP3	Fixed IEC 61850 value from DNP Device Profile
dU		PROFILE			Not available at run-time in DNP3	Fixed IEC 61850 value from DNP Device Profile
cdcNs						
cdcName						
dataNs						

Data Structure Mapping: "Leaf" Mapping Rules



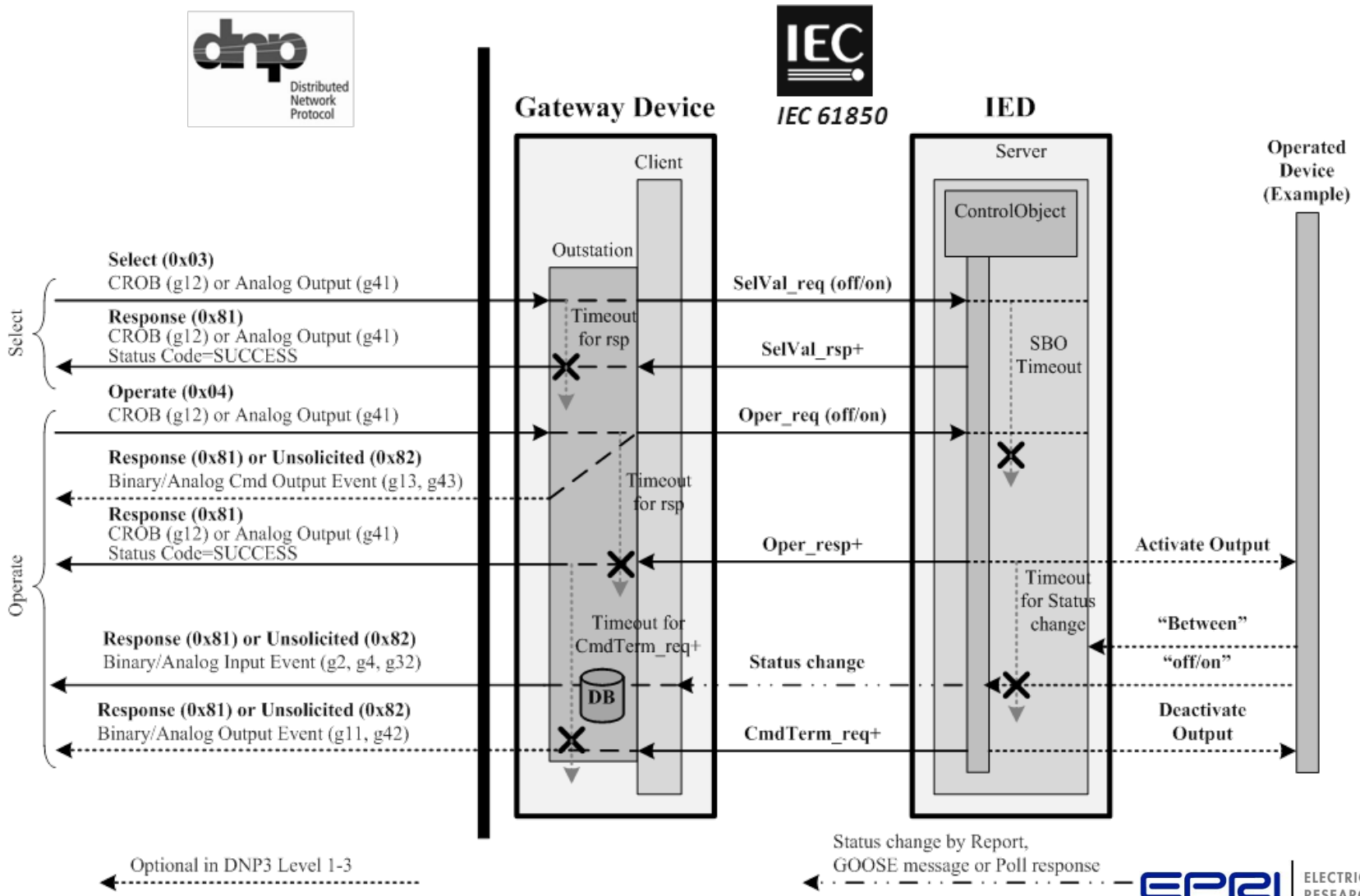
IEEE P1815 1 - Leaf Level Mapping Rules 2011-02-18 [Compatibility Mode] - Microsoft Excel

File Home Insert Page Layout Formulas Data Review View

G5 fx BOOLEAN_TO_BO

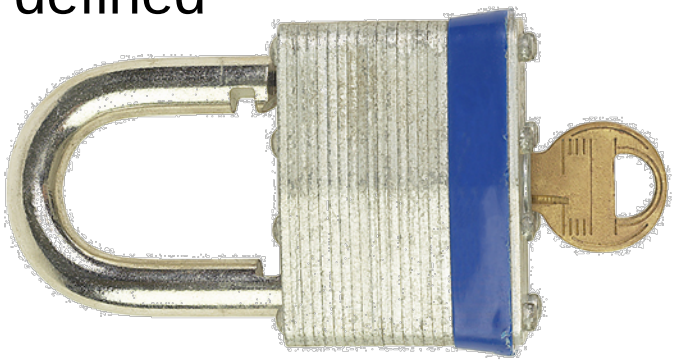
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	Spec Order	Leaf Data Attribute Name (s)	DataType	FC	Enum Values	First Ref CDC	Rule Name	BI	DBBI	BO	AI	AI FP	AI DB	AO	AO FP	CTR
8	78	persistent	BOOLEAN	CF		BSC	BOOLEAN_TO_BO			1						
9	81	setVal	BOOLEAN	SP, SG, SE		SPG	BOOLEAN_TO_BO			1						
10	86	tstEna	BOOLEAN	SP		ORG	BOOLEAN_TO_BO			1						
11	56	phsToNeut	BOOLEAN	CF		CMV	BOOLEAN_TO_BO_CONST			1						
12	89	cur	Currency	SP, SG, SE		CUG	CURRENCY_TO_OCT									
13	8	d, purpose, v	VISIBLE STRING	DC		SPS	DESC_TO_PROFILE									
14	9	dU	UNICODE STRING	DC		SPS	DESC_TO_PROFILE									
15	60	hvRef	ENUMERATED	CF	fundamenta	HMV	ENUM_HVREF_TO_PROFILE									
16	18	stVal	ENUMERATED	ST	Found in 7-4	ENS	ENUM_TO_AI				1					
17	19	subVal	ENUMERATED	SV	Found in 7-4	ENS	ENUM_TO_AO							1		
18	74	ctlVal	ENUMERATED	(CO)	Found in 7-4	ENC	ENUM_TO_AO							1		
19	75	ctlVal	CODED ENUM	(CO)	stop | lowe	BSC	ENUM_TO_AO							1		

Service Mapping - SBO Enhanced



Security Requirements

- Both protocol suites have security features defined
  - Authentication and message integrity
  - Encryption in some cases
  - Not the concern of this specification
- Primary security goals
  - An equivalent level of security controls are applied on both sides of the gateway, so that communications on one side does not present a vulnerability to the other.
  - Data and services received on one side of the gateway are not modified in transit through the gateway, unless the gateway is specifically requested to do so by an authenticated and authorized user



Example Security Requirements (simplified)

- Shall use the security features of both protocols
- A function that is critical on one side must be critical on the other
- Shall use comparable security algorithms and key lengths on both sides
- Programmable arithmetic or logic functions cannot be changed without authentication and authorization
- Must log all critical functions performed by either protocol suite
- Shall maintain IEEE 1815 security statistics
- Shall use a time source protected against attacks
- Shall verify the integrity of the translation software on restart
- Shall use role definitions from IEC 62351 and respective stds

XML Mapping

- Captured in DNP3-XML Device Profile Document
- Profile definition already lists all the DNP3 points in a device
- IEEE 1815.1 specifies additional elements for mapping
- Each mapping contains
  - Path within the Profile to one or more DNP3 points
  - Fully qualified name of corresponding IEC 61850 object(s)
  - Leaf-level mapping rule to apply OR an equation to apply
- The entire profile can be embedded in an SCL file
- IEEE 1815.1 specifies where it is embedded

Structure of DNP-XML Device Profile Doc

```
<?xml version="1.0" encoding="utf-8"?>
<DNP3DeviceProfileDocument
 xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
 xmlns:xsd="http://www.w3.org/2001/XMLSchema"
 xmlns="http://www.dnp3.org/DNP3/DeviceProfile/Nov2011"
 schemaVersion="2.08.00">
  <documentHeader>
    <!-- Document Header Information -->
  </documentHeader>
  <referenceDevice>
    <configuration>
      <!-- DNP3 Device Configuration Parameters-->
    </configuration>
    <iec61850DeviceMapping>
      <!-- Mapping to/from IEC 61850 -->
    </iec61850DeviceMapping>
    <database>
      <!-- DNP3 Device Database Parameters -->
    </database>
    <implementationTable>
      <!-- DNP3 Device Implementation Table -->
    </implementationTable>
    <dataPointsList>
      <!-- DNP3 Device Data Points-->
    </dataPointsList>
  </referenceDevice>
</DNP3DeviceProfileDocument>
```

XML Mapping Element

```
<iec61850DeviceMapping>
 <!-- Mapping to/from IEC 61850 -->

 <iec61850RuleMapping>
  <note>This is an example of a rule based mapping</note>
  <rule>FLOAT_TO_AI</rule>
  <dnp3XPath>
       dnp:dataPointsList/dnp:analogInputPoints/dnp:dataPoints/dnp:analogInput[dnp:index=0]/dnp:dn
       pData/dnp:value
  </dnp3XPath>
  <iec61850Path fc="MX" dataType="FLOAT32" cdc="MV">
       IED_0006PROT/LLN0.Beh.stVal
  </iec61850Path>
 </iec61850RuleMapping>


 <iec61850EquationMapping>
  <note>Custom equation (DNP3 to IEC 61850)</note>
  <equation>celsius = ((value * scale) - 32) / 1.8</equation>
  <dnp3XPath varname="scale">
       dnp:dataPointsList/dnp:analogInputPoints/dnp:dataPoints/dnp:analogInput[dnp:index=0]/dnp:sc
       aleFactor
  </dnp3XPath>
  <dnp3XPath varname="value">
       dnp:dataPointsList/dnp:analogInputPoints/dnp:dataPoints/dnp:analogInput[dnp:index=0]/dnp:dn
       pData/dnp:value
  </dnp3XPath>
  <iec61850Path varname="celsius" fc="MX" dataType="FLOAT32" cdc="MV">
       IED_0006PROT/LLN0.Beh.stVal
  </iec61850Path>
 </iec61850EquationMapping>

</iec61850DeviceMapping>
```

XML Mapping Example – in Annex

- Use Case (a) simulation
- Includes the following files:
  - IEC 61850 IED Capability Description (ICD) of a real device
  - List of Data Attributes chosen
  - Resulting DNP3-XML Mapping
- Not a comprehensive example
- Many mappings not described
- Intended to show the context

Status of Standard – IEEE P1815.1

- Strong IEEE WG participation – WG C14 (Substations Committee)
- PAP12 support and liaisons with SGIP SGAC and CSWG
- Sponsor ballot that ends on July 27th
- Expecting a lot of comments
- Publication in December or January
- IEC participation leading to dual logo – IEC 61850-80-2

Conclusions

- Many people see 1815/DNP3 and 61850 as competing – but base decision on requirements
- IEEE P1815.1 – the Mapping Spec allows them to co-exist and facilitates a migration path
- Most vendors offer migration path from IEEE 1815 to IEC 61850
- The jump to IP from serial comes first and is higher capital cost
- IEEE 1815 serial to IP to IEC 61850
- 61850 includes features and services that 1815 will never include
- Mapping standard includes the leaf mapping tables and the actual XML file so enables a standardized gateway and saves time for implementer. Previous mappings such as IEC 61850-80-1 (IEC 870-5 to IEC 61850 just had CDC tables)
- IEC 61850 does not include a low bandwidth profile
- IEEE 1815 will be used at EMS/DMS for many years

Applicable EPRI Reports and Updates

- EPRI Tech-Update: “Serial to IP-Based SCADA Migration”, April 30, 2012
- EPRI Report – “Implementation of IEC 61850; A Coherent Approach to Substation Automation and the Smart Grid” - 1021609
- EPRI Report – “Utility Standards & Technology Adoption Roadmap” - 1023041

Together…Shaping the Future of Electricity

Back Up Material

SGIP TWiki Overview

- Twiki is a “brand” of Wiki – wiki:
  - A wiki (pronounced /'w?ki/ WIK-ee) is a website that allows the easy creation and editing of any number of interlinked web pages via a web browser using a simplified markup language or a WYSIWYG text editor.
- SGIP / NIST TWiki has major sections for:
  - SGIP Overview and Introduction:
    - http://collaborate.nist.gov/twiki-sggrid/bin/view/SmartGrid/SGIP
  - Priority Action Plans
    - http://collaborate.nist.gov/twiki-sggrid/bin/view/SmartGrid/PriorityActionPlans
  - Working Groups and Committees
    - http://collaborate.nist.gov/twiki-sggrid/bin/view/SmartGrid/SGIPWorkingGroupsAndCommittees
  - Interoperability Knowledge Base
    - http://collaborate.nist.gov/twiki-sggrid/bin/view/SmartGrid/InteroperabilityKnowledgeBase