Wide Area GOOSE and its Applications to System Integrity Protection Schemes

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Questions

- What are we doing?
- Why are we doing it?
- How are we doing it?
What are we doing?

• Support distributed System Integrity Protection Schemes (SIPS)
Why are we doing it?

- To maintain electric power system stability during wide area disturbances
How are we doing it?

- Using IEC 61850 GOOSE messages
- Based on good understanding of SIPS
- Based on good understanding of the principles of GOOSE within and outside of the substation
- Based on good understanding of the communications technology
- Based on good understanding of cyber security challenges and solutions
GOOSE in IEC 61850

• GOOSE messages are one of the key differentiators of IEC 61850
• Client – Server communications are not suitable for protection applications
• Peer-to-Peer communications can meet the protection performance requirements
• Successful implementation of GOOSE based protection systems requires not only good understanding of the basics, but also planning and motivation
GOOSE History: Chicago, May 1998

• Kay Clinard
  George Schimmel
  Herb Falk
  John Tengdin
  Mark Simon
  Charlie Sufanna
  Alex Apostolov
    Jim Whatley (remotely)
IEC 61850 Services
GSE Messages:

- Max. Repetition Interval
- Fast Repetitions
- Max. Repetition Interval

new Event: Data Change
GOOSE Performance

Physical device PD\[n\]  

Transfer time \( t = t_a + t_b + t_c \)

\( f_i \)  

Communication processor

\( f_k \)

Physical device PD\[m\]
GOOSE WAN Performance

Transfer time $t = t_a + t_b + t_c$

Physical device PD[n]  Communication processor  Physical device PD[m]

$f_i$  Communication processor  $f_k$
Propagation time measurement
Transatlantic latency
Propagation delay Texas - Austria

The diagrams above show the propagation delay between two IP addresses: 172.22.22.22 and 172.22.176.210, and 172.22.22.22 and 172.22.176.210. The data was collected from 2014-09-05 16:35:29 to 2014-09-05 16:35:30.

Key metrics:
- Min: 79.77 ms
- Max: 91.49 ms
- Avg: 82.00 ms
- Std Dev: 677.33 μs
- Packets: 1000
Two way propagation delay Germany - Austria

![Graph showing propagation time vs. packet size]
# GOOSE Control Block

<table>
<thead>
<tr>
<th>Attribute name</th>
<th>Attribute type</th>
<th>r/w</th>
<th>m</th>
<th>Value/value range/explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>GoEna</td>
<td>Boolean</td>
<td>rw</td>
<td>m</td>
<td></td>
</tr>
<tr>
<td>GoID</td>
<td>Visible-string</td>
<td>r</td>
<td>m</td>
<td></td>
</tr>
<tr>
<td>DataSet</td>
<td>Visible-string</td>
<td>r</td>
<td>m</td>
<td></td>
</tr>
<tr>
<td>ConfRev</td>
<td>Unsigned</td>
<td>m</td>
<td>m</td>
<td></td>
</tr>
<tr>
<td>NdsCom</td>
<td>Boolean</td>
<td>m</td>
<td>m</td>
<td></td>
</tr>
<tr>
<td>DstAddress</td>
<td>PHYCOMADDR*</td>
<td>m</td>
<td>m</td>
<td></td>
</tr>
<tr>
<td>MinTime</td>
<td>Unsigned</td>
<td>m</td>
<td>m</td>
<td></td>
</tr>
<tr>
<td>MaxTime</td>
<td>Unsigned</td>
<td>m</td>
<td>m</td>
<td></td>
</tr>
<tr>
<td>FixedOffs</td>
<td>Boolean</td>
<td>m</td>
<td>m</td>
<td></td>
</tr>
<tr>
<td>SecurityEnable**</td>
<td>ENUMERATED</td>
<td>m</td>
<td>m</td>
<td>None, DigitalSignature, DigitalSignatureandEdgeAuthentication</td>
</tr>
</tbody>
</table>

*Revisions to PHYCOMADDR can be found in clause 8.1.1.3.2
**Additional attribute to be added to the control block.
SIPS Functionality

• SIPS can be considered as systems that have three main types of functional elements:
  – System monitoring elements
  – Protection elements
  – Execution elements

• The function of the system monitoring elements is to:
  – Detect a change in power system topology
  – Detect a change in system load
  – Detect a change in generation
Analog GOOSE Applications
Adaptive Load-shedding
MPLS for Wide Area GOOSE

CE - customer edge
PE - provider edge
LER – label edge router
LSR – label switch router
Wide Area R-GOOSE

Diagram showing substation network connected through IP.
IEC 61850 90-5 Session Protocol

- Session Identifier (SI)
- Session Header
  - Session Header Length
  - Security Information
    - Signature domain
    - SPDU Length
      - Payload Length (32 bit)
        - Padding (0x0F)
        - Padding (m bytes)
        - Signature (size of signature + 2 bytes)

- Security Information
  - SPDU Length (32 bits)
  - SPDU Number (32 bits)
  - Version = 2 (8 bit)
  - Time of Current Key (32 bits)
  - Time of Next Key (16 bits)
  - Key ID (32 bits)
  - Initialization Vector (9 1-233 bytes)

- SPDU Number (32 bits)
- Time of Current Key (32 bits)
- Time of Next Key (16 bits)
- Key ID (32 bits)
- Initialization Vector (9 1-233 bytes)

- Session User Information
  - Session Identifier (SI) = 0xA0 (8 bit) - Tunnelled
  - Session Identifier (SI) = 0xA1 (8 bit) - GOOSE
  - Session Identifier (SI) = 0xA2 (8 bit) - Sample value
  - Session Identifier (SI) = 0xA3 (8 bit) - Management

- Header Content Indicator [PC] = 0x80 (8 bit)
- LI (8 bit)
- APDU Length (32 bits)
- APDU Number (32 bits)
- APPID
- GOOSE APDU
- SV APDU
- MNGT APDU
- IPv6
- De MAC
- VLAN
- IEEE 802.1p
- Frame Length
- GOOSE or SV Ethernet packets + Ethernet Pad Bytes

- PDUs
  - GOOSE PDUs
  - SV PDUs
  - MNGT PDUs

- PaddingLength (8 bits)
  - Padding (m bytes)
  - m

- Payload
  - PayloadLength (8 bits)
  - PayloadLength (m bytes)

- Signature domain
  - Signature (size of signature + 2 bytes)

- Header Content Indicator [PC] = 0x80 (8 bit)
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<td>Boolean</td>
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<td>m</td>
<td></td>
</tr>
<tr>
<td>DstAddress</td>
<td>UDPCOMADDR*</td>
<td>r</td>
<td>m</td>
<td></td>
</tr>
<tr>
<td>MinTime</td>
<td>Unsigned</td>
<td>r</td>
<td>o</td>
<td></td>
</tr>
<tr>
<td>MaxTime</td>
<td>Unsigned</td>
<td>r</td>
<td>o</td>
<td></td>
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<tr>
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<td>o</td>
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<td>o</td>
<td>None, Signature, SignatureAndEncryption</td>
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* The definition of UDPCOMADDR can be found in Table 5.
** Additional attribute to be added to the control block.
E2E Cryptographic Integrity
Conclusions

- Wide-Area-GOOSE is a new powerful tool for different SIPS related applications
- It requires good understanding of the propagation delay
- It can be implemented using 2.5 or 7 layer communications
- Cyber security has to be considered and implemented