



Information Services for Smart Grids

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Motivation: *What do we need?*

- ❑ Making data available timely
 - ❖ required for emergency response tasks.
- ❑ Better categorization / aggregation of content
 - ❖ formulation of custom products and provision of subsetting tools at spatial and temporal levels.
- ❑ Interoperability between various formats of data.
- ❑ Package products based on
 - ❖ meaning and knowledge about the measurements
 - ❖ context of the information sources.
- ❑ Creation of machine understandable semantic metadata
 - ❖ intelligent search engines / agents can automatically process and index the content.



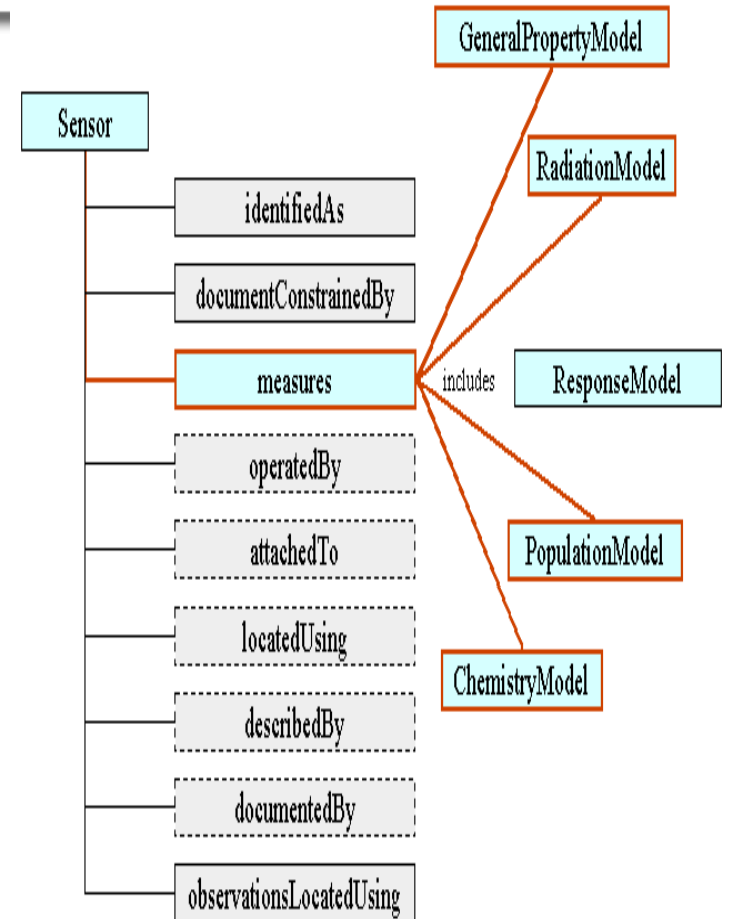
Information Services

- ❑ Focused on providing the right information at the right moment to the right decision maker.
- ❑ The information services required by grid operators could vary from scenario development to estimates of socio-economic impacts of failures to quantitative statistics, trends and forecasts.
- ❑ These services also must be available in a geospatial context and at various temporal scales to support the needs of system operators, planners, and regulatory agencies.
- ❑ Characterized by a strong integration of grid data with ancillary data and information.



SensorML and Descriptions for Grid Measurement Devices

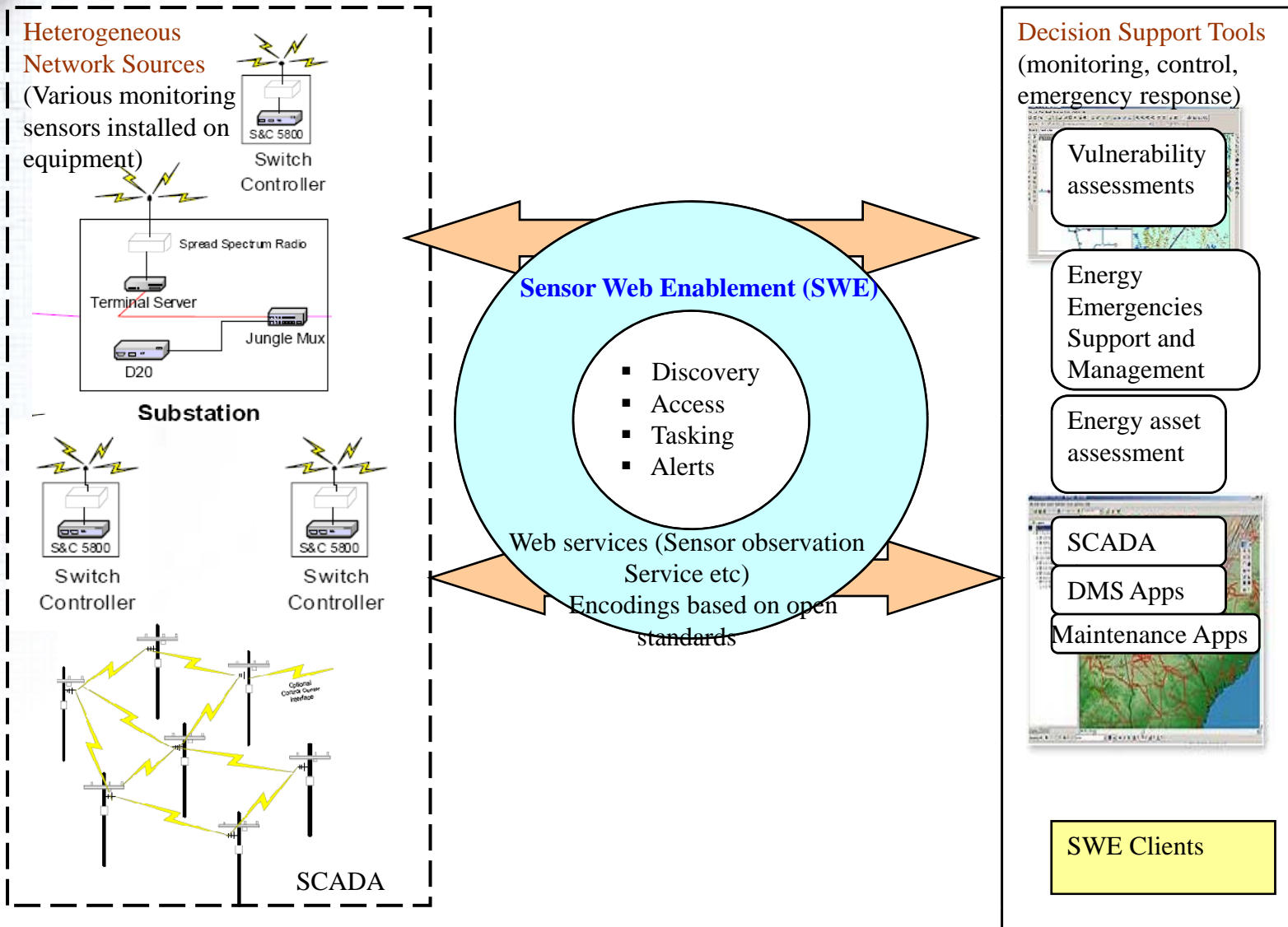
- ❑ The general models and XML encodings for sensors and observation processing.
- ❑ Provides a framework within which the geometric, dynamic, and observational characteristics of sensors and sensor systems can be defined.
- ❑ Provides a **functional model** of the sensor system, rather than a detailed description of its hardware



(Botts and Richard, 2006).



Sensor Web Enablement (SWE) of sensors involved in wide area monitoring of electric power grid





Other services of SWE

❑ Sensor Planning Service (SPS)

❑ Sensor Observation Service (SOS)

- ❖ A service by which a client can obtain observations from one or more sensors/platforms (can be of mixed sensor/platform types). Clients can also obtain information that describes the associated sensors and platforms.

❑ Sensor Alert Service (SAS)

- ❖ define how data collection requests are expressed, observations retrieved, and alert or alarm conditions defined.

❑ Web Notification Service (WNS)

- ❖ A service by which a client may conduct asynchronous dialogues (message interchanges) with one or more other services. This service is useful when many collaborating services are required to satisfy a client request, and/or when significant delays are involved in satisfying the request.

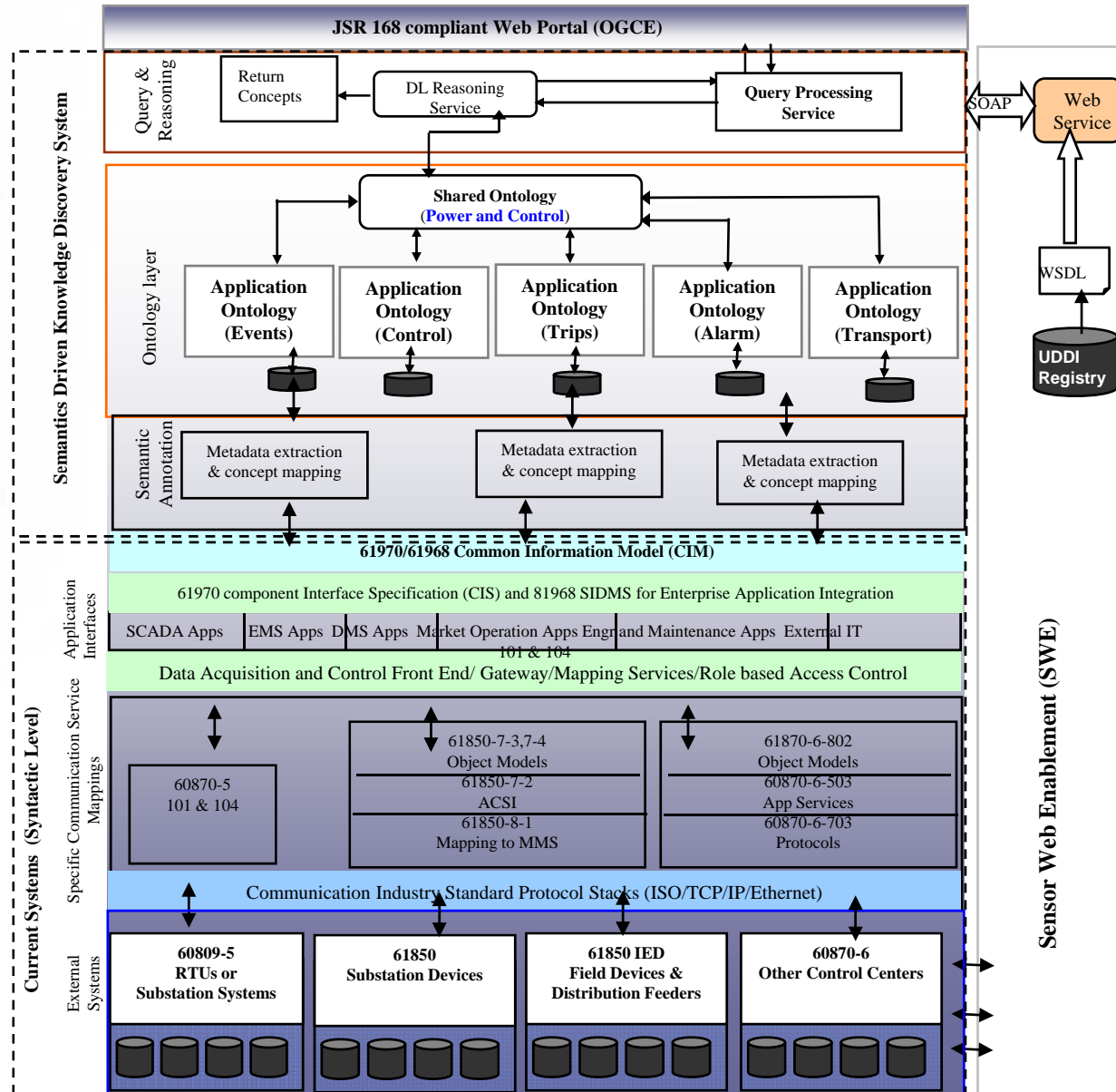


Power Sensor Web Enablement (PSWE)

- ❑ Can perform as an extensive monitoring and sensing system that provides timely, comprehensive, continuous, and multi-mode observations for the power systems.
- ❑ A PSWE component could provide the following potential benefits:
 - ❖ Discovery of sensor systems, observations, and observation processes that meet an application or users immediate needs, i.e. acquisition of data from field devices, processing the data in substation, etc.;
 - ❖ Determination of a sensor's capabilities and quality of measurements;
 - ❖ Access to sensor parameters that automatically allow software to process and geo-locate observations (e.g. remotely issue supervisory control commands as needed to field devices.)
 - ❖ Retrieval of real-time or time-series observations and coverages in standard encodings; and
 - ❖ Subscription to and publishing of alerts to be issued by sensors or sensor services based upon certain criteria.



Architecture of Power Grid Sensors integration through Semantics enabled middleware.



COSEMWare – SWE NOAA Buoys

CosemWare - BuoyApplication - Microsoft Internet Explorer

File Edit View Favorites Tools Help

Address http://localhost:8888/edu.msstate.gri.BuoyApplication/BuoyApplication.html

Ontology Edit Help

Class Hierarchy

- owl:Thing
 - Buoy
 - SensorMeasurements
 - Atmospheric
 - Chemical
 - Electromagnetic
 - Oceanographic
 - Current
 - Salinity
 - Water
 - WaterDensity
 - WaterPressure
 - WaterTemperature
 - Waves
 - AveragePeriod
 - BuoyOwnedAndMaintainedBy
 - SignificantWaveHeight
 - SwellDirection
 - SwellHeight
 - SwellPeriod
 - WaveSteepness
 - WindWaveHeight
 - WindWavePeriod
 - WindWaveToDirection
 - Spatial
 - Altitude

Concept Details **Buoy Map** Visualization

Address: Coordinates: (25.17,-94.42)

Enter an address to geocode:

```

<?xml version="1.0" encoding="UTF-8" ?>
<sos:Capabilities
version="0SERVICE_VERSION0"
updateSequence="2005-12-14T10:12:39"
xsi:schemaLocation="http://www.opengis.net/sos http://mars.uni-
erlangen.de/arcxml/trunk/arc/0.0.21/
    
```

Service Info **Sensor Info** **Sensor Query**

SPARQL Query Results(XML) **Table**

osem.erc.msstate.edu/ontologies/cosemont.owl#stationID_41041	ARES	14
osem.erc.msstate.edu/ontologies/cosemont.owl#stationID_42001	VEEP	43
osem.erc.msstate.edu/ontologies/cosemont.owl#stationID_42002	MARS	25
osem.erc.msstate.edu/ontologies/cosemont.owl#stationID_42003	VEEP	61
osem.erc.msstate.edu/ontologies/cosemont.owl#stationID_42004	MVXII	27
osem.erc.msstate.edu/ontologies/cosemont.owl#stationID_42005	MVXII	30

Sensor Web Query Results(XML)

Parameters

Offerings

- windDirection
- windSpeed
- windGust
- waveHeight
- dominantWavePeriod

Stations

- EB53
- 42007
- EB92
- 42016
- 42039

Temporal Subset Duration Comparison Filter Spatial Subset

Temporal Subsetting

- None
- After
- Before
- During
- TEquals

Time period

2007 07 27 15 50 00

XML Query

```

<?xml version="1.0" encoding="UTF-8" ?>
<GetObservation
xmlns="http://www.opengis.net/sos"
xmlns:gml="http://www.opengis.net/gml"
xmlns:ogc="http://www.opengis.net/ogc"
xmlns:ows="http://www.opengis.net/ows"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://www.opengis.net/
    
```

Map Layout

Enter address Search

Map Satellite Hybrid

Service Info Sensor Info Sensor Query

```
<?xml version="1.0" encoding="UTF-8"?>
<sos:Capabilities
version="0.0.31"
updateSequence="2005-12-14T10:12:39"
```

Sparql Query Results(Table) Results(XML)

```
PREFIX rdf:<http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX cim:<http://iec.ch/TC57/2007/CIM-schema-cim12#>
SELECT ?SensorID?latLon?timeStamp?SensorAccuracy?
DeviceName FROM
<http://www.ece.msstate.edu/~nd54/Measurement-CT.xml>
WHERE
{
?s cim:SensorID ?SensorID.
?s cim:GeographicPosition ?latLon.
?y cim:MeasurementValue.timeStamp ?timeStamp.
?y cim:MeasurementValue.sensorAccuracy ?SensorAccuracy.
?z cim:IdentifiedObject.name "Current Transformer".
?z cim:IdentifiedObject.name ?DeviceName}
```

XSLT style sheet(leave blank for none: xml-to-html.xsl JSON
Run Query

Request Response Table

Offerings

- current
- voltage
- currentAngle
- voltageAngle

Stations

- sensor-1
- sensor-2
- sensor-3
- sensor-4
- sensor-5

Get Capabilities

2007 10 9 10 10 00

Temporal Duration Comparison Filter Spatial Operator

Temporal Subsetting

- None
- After
- Before
- During
- TEquals

```
<?xml version="1.0" encoding="UTF-8"?>
<GetObservation
xmlns="http://www.opengespatial.net/sos"
xmlns:gml="http://www.opengis.net/gml"
xmlns:ogc="http://www.opengis.net/ogc"
xmlns:ows="http://www.opengespatial.net/ows"
xmlns:xsi="http://www.w3.org/2001/
```

Clear Submit

Local intranet | Protected Mode: On

Temporal Operator: The sensor data can be filtered temporally, with the tab highlighted above. When the sensor, offering and temporal filter is selected by the user, the application creates a XML query and sends it to

Map Layout

Enter address

Map | Satellite | Hybrid

Service Info | **Sensor Info** | Sensor Query

```
<?xml version="1.0"
encoding="UTF-8"?>
<sos:Capabilities
version="0.0.31"
updateSequence="2005-12-
14T10:12:39"
```

Map data © 2008 Tele Atlas

Sparql Query | Results(Table) | Results(XML)

```
PREFIX rdf:<http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX cim:<http://iec.ch/TC57/2007/CIM-schema-cim12#>
SELECT ?SensorID?latLon?timeStamp?SensorAccuracy?
DeviceName FROM
<http://www.ece.msstate.edu/~nd54/Measurement-CT.xml>
WHERE
{
?s cim:SensorID ?SensorID.
?s cim:GeographicPosition ?latLon.
?y cim:MeasurementValue.timeStamp ?timeStamp.
?y cim:MeasurementValue.sensorAccuracy ?SensorAccuracy.
?z cim:IdentifiedObject.name "Current Transformer".
?z cim:IdentifiedObject.name ?DeviceName}
```

XSLT style sheet(leave blank for none:
 JSON

Request | **Response** | Table

Offerings

- current
- voltage
- currentAngle
- voltageAngle

Stations

- sensor-1
- sensor-2
- sensor-3
- sensor-4
- sensor-5

2007 | 10 | 9 | 10 | 10 | 00

Temporal | Duration | Comparison Filter | Spatial Operator

Enter number of days

```
<?xml version="1.0" encoding="UTF-8"?>
<GetObservation
xmlns="http://www.opengeospatial.net/sos"
xmlns:gml="http://www.opengis.net/gml"
xmlns:ogc="http://www.opengis.net/ogc"
xmlns:ows="http://www.opengeospatial.net/ows"
xmlns:xsi="http://www.w3.org/2001/
```

Duration Operator: The sensor data can be filtered within certain duration of the date and time given, with the tab highlighted above. When the sensor, offering and duration is entered by the user, the application creates a XML query and sends it to SOS.

Map Layout
Enter address
Map Satellite Hybrid

Service Info Sensor Info Sensor Query

```
<?xml version="1.0" encoding="UTF-8"?>
<sos:Capabilities
version="0.0.31"
updateSequence="2005-12-14T10:12:39"
```

Request Response Table

Offerings

- current
- voltage
- currentAngle
- voltageAngle

Stations

- sensor-1
- sensor-2
- sensor-3
- sensor-4
- sensor-5

2007 10 9 10 10 00

Temporal Duration **Comparison Filter** **Spatial Operator**

Operators Value Unit:

- None
- Between
- EqualTo
- NotEqualTo
- LessThan

```
<?xml version="1.0" encoding="UTF-8"?>
<GetObservation
xmlns="http://www.opengeospatial.net/sos"
xmlns:gml="http://www.opengis.net/gml"
xmlns:ogc="http://www.opengis.net/ogc"
xmlns:ows="http://www.opengeospatial.net/ows"
xmlns:xsi="http://www.w3.org/2001/
```

Sparql Query Results(Table) Results(XML)

```
PREFIX rdf:<http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX cim:<http://iec.ch/TC57/2007/CIM-schema-cim12#>
SELECT ?SensorID?latLon?timeStamp?SensorAccuracy?
DeviceName FROM
<http://www.ece.msstate.edu/~nd54/Measurement-CT.xml>
WHERE
{
?s cim:SensorID ?SensorID.
?s cim:GeographicPosition ?latLon.
?y cim:MeasurementValue.timeStamp ?timeStamp.
?y cim:MeasurementValue.sensorAccuracy ?SensorAccuracy.
?z cim:IdentifiedObject.name "Current Transformer".
?z cim:IdentifiedObject.name ?DeviceName}
```

XSLT style sheet(leave blank for none:
xml-to-html.xsl JSON

Comparison Operator: The sensor data can be filtered according to the value of the measured offering, with the tab highlighted above. When the sensor, offering and comparison filter is selected by the user, the application creates a XML query and sends it to SOS.

Map Layout

Enter address Search

Map Satellite Hybrid

Remove + 0 - Loc

Offerings

- current
- voltage
- currentAngle
- voltageAngle

Stations

- sensor-1
- sensor-2
- sensor-3
- sensor-4
- sensor-5

Get Capabilities

2007 10 9 10 10 00

Temporal Duration Comparison Filter Spatial Operator

Spatial Subset Points in space

- None
- BBOX**
- Contains
- Intersects
- Overlaps

Upper: 33.03 -87.5
Lower: 34.85 -89.9

```
<?xml version="1.0" encoding="UTF-8"?>
<GetObservation
xmlns="http://www.opengeospatial.net/sos"
xmlns:gml="http://www.opengis.net/gml"
xmlns:ogc="http://www.opengis.net/ogc"
xmlns:ows="http://www.opengeospatial.net/ows"
xmlns:xsi="http://www.w3.org/2001/
```

Clear Submit

Sparql Query Results(Table) Results(XML)

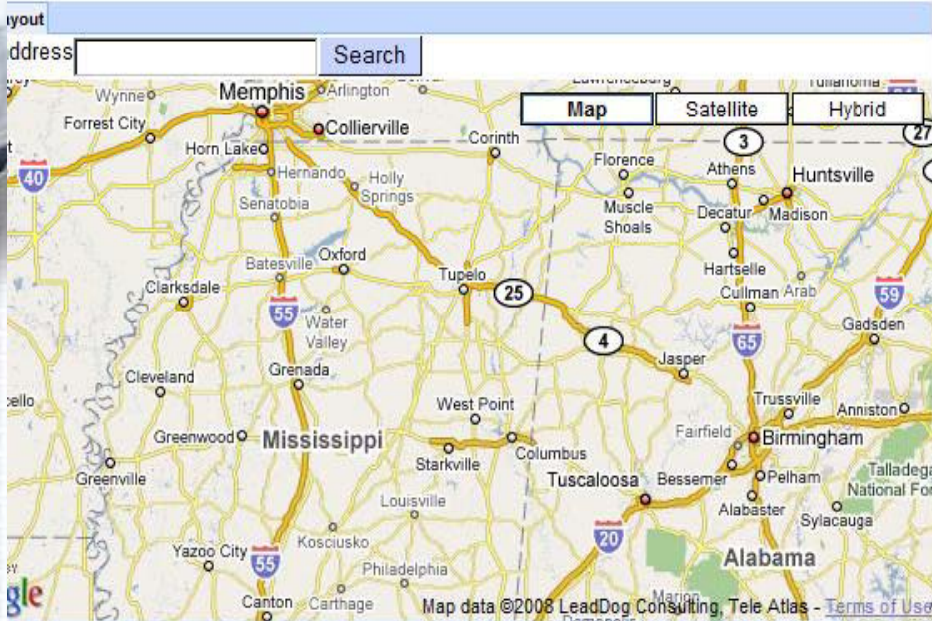
```
PREFIX rdf:<http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX cim:<http://iec.ch/TC57/2007/CIM-schema-cim12#>
SELECT ?SensorID?latLon?timeStamp?SensorAccuracy?
DeviceName FROM
<http://www.ece.msstate.edu/~nd54/Measurement-CT.xml>
WHERE
{
?s cim:SensorID ?SensorID.
?s cim:GeographicPosition ?latLon.
?y cim:MeasurementValue.timeStamp ?timeStamp.
?y cim:MeasurementValue.sensorAccuracy ?SensorAccuracy.
?z cim:IdentifiedObject.name "Current Transformer".
?z cim:IdentifiedObject.name ?DeviceName}
```

XSLT style sheet(leave blank for none):

xml-to-html.xsl JSON

Run Query

Spatial Operator: The sensor data can be filtered spatially, with the tab highlighted above. Whenever spatial operator is selected, a box appears on the map, with coordinates of upper left corner and lower right corner of box recorded. The upper left corner coordinates are used if only one coordinate is needed.



Request Response Table			
BBOX Query			
Station_Id	Lat Lon	Time	current
urn:ogc:def:procedure:CT-sensor-1	33.43 - 88.835	2007-10-05T10:15:00	500
urn:ogc:def:procedure:PMU-sensor-3	34.1915 - 88.72187	2007-10-05T10:15:00	500

```

Query Results(Table) Results(XML)
X rdf:<http://www.w3.org/1999/02/22-rdf-syntax-ns#>
X cim:<http://iec.ch/TC57/2007/CIM-schema-cim12#>
T ?SensorID?latLon?timeStamp?SensorAccuracy?
eName FROM
://www.ece.msstate.edu/~nd54/Measurement-CT.xml>
:
cim:SensorID ?SensorID.
cim:GeographicPosition ?latLon.
cim:MeasurementValue.timeStamp ?timeStamp.
cim:MeasurementValue.sensorAccuracy ?SensorAccuracy.
cim:IdentifiedObject.name "Current Transformer".
cim:IdentifiedObject.name ?DeviceName}

```

style sheet(leave blank for none:
 JSON

Query

Table Format Result: The response of the SOS is displayed in the tabular format.

The screenshot displays a web application interface for a sensor service. At the top, there is a search bar with the text "Enter address" and a "Search" button. Below the search bar is a map showing a region in Mississippi. A red location pin is placed on the map, and a "Service Info" popup window is open over it. The popup contains the following XML data:

```
<?xml version="1.0" encoding="UTF-8"?>
<sos:Capabilities version="0.0.31" updateSequence="2005-12-14T10:12:39">
```

Below the map, there is a "Sparql Query" section with three tabs: "Sparql Query", "Results(Table)", and "Results(XML)". The "Results(Table)" tab is selected and shows a table with the following data:

"SensorID"	"LatLon"	"timeStamp"	"sensorAccuracy"
urn:ogc:def:procedure:CT-sensor-1	33.43 -88.835	6/26/2008 12:03:12 PM	0.6

On the right side of the interface, there are several sections: "Offerings" with a dropdown menu showing "current", "voltage", "currentAngle", and "voltageAngle"; "Stations" with a dropdown menu showing "sensor-1" through "sensor-5"; a "Get Capabilities" button; a date/time selector showing "2005 10 10 10 15 00"; a "Temporal" section with a dropdown menu showing "None", "After", "Before", "During", and "TEquals"; and a large text area containing XML code for a "GetObservation" request. At the bottom of this section are "Clear" and "Submit" buttons.

GetCapabilities Response: The tabular format of the result of SPARQL query is shown in the highlighted tab. The user has to query for the Geographic position or SensorID in order to enable the marking of the Sensor location in the Map as shown in the figure. When the user clicks on the marker of the sensor, the SensorML and GetCapabilities response are displayed. The GetCapabilities response is shown in the figure above

The screenshot shows a web application interface for sensor discovery. At the top, there is a search bar with the text "Enter address" and a "Search" button. Below the search bar is a map of Tennessee and Georgia. A red pin is placed on the map near Columbus, Mississippi. A callout box from the map displays a snippet of XML: `<?xml version="1.0" encoding="ISO-8859-1" standalone="no"?><SensorML xmlns="http://www.opengis.net/sensorML" xmlns:swe="http://www.opengis.net/swe" />`. Below the map is a table with the following data:

"SensorID"	"LatLon"	"timeStamp"	"sensorAccuracy"
urn:ogc:def:procedure:CT-sensor-1	33.43 -88.835	6/26/2008 12:03:12 PM	0.6

To the right of the map is a large window titled "Request Response Table" showing the full XML response for the selected sensor:

```
<?xml version="1.0" encoding="ISO-8859-1"
standalone="no"?><SensorML
xmlns="http://www.opengis.net/sensorML"
xmlns:swe="http://www.opengis.net/swe"
xmlns:xlink="http://www.w3.org/1999/xlink"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-
instance" version="1.0"
xsi:schemaLocation="http://www.opengis.net/s
ensorML http://mars.uni-
muenster.de/swerep/trunk/sensorML/1.0.30/bas
e/sensorML.xsd">
  <System id="system.ifgi-sensor-1">
    <identification>
      <IdentifierList>
        <identifier name="longName">
          <Term>ifgi water gage</Term>
        </identifier>
        <identifier name="shortName">
          <Term>ifgi water gage</Term>
        </identifier>
        <identifier name="modelName">
          <Term
            qualifier="urn:ogc:identifier:modelNumber">1
            234</Term>
          </identifier>
        <identifier name="manufacturer">
          <Term
```

At the bottom of the window are "Clear" and "Map it!" buttons. The browser's status bar at the very bottom shows "Done", "Local intranet | Protected Mode: On", and "100%" zoom.

Sensor Discovery Response: As described in the previous slide the SensorML of the sensor selected in the table is shown in the figure above.



Conclusions

- ❑ The electric power grid is part of this country's critical infrastructure.
- ❑ An architecture has been developed for using a sensor web enablement to provide information services for wide area monitoring and power system protection and control.
- ❑ To facilitate these services it will be incumbent upon the power research community to develop tools to facilitate operational data acquisition and handling in interoperable formats and to create information products through a coordinated process chain.
- ❑ The successful conversion of power sensor data into actionable intelligence requires the integration of power system expertise in modeling, data management and service delivery to describe the state of the grid and to predict responses to actual and potential change.