INFO116

Semantics for Sensor Data
Ch. 6

Semantic Sensor Web

- A very large number of sensing devices
  - Billions of devices
  - 2.5 quantillion bytes of data daily
- Very little communication between sensor streams
- Semantic Sensor Web (SSW)
  - Annotation with Semantic Metadata
  - Confusing set of emerging standards

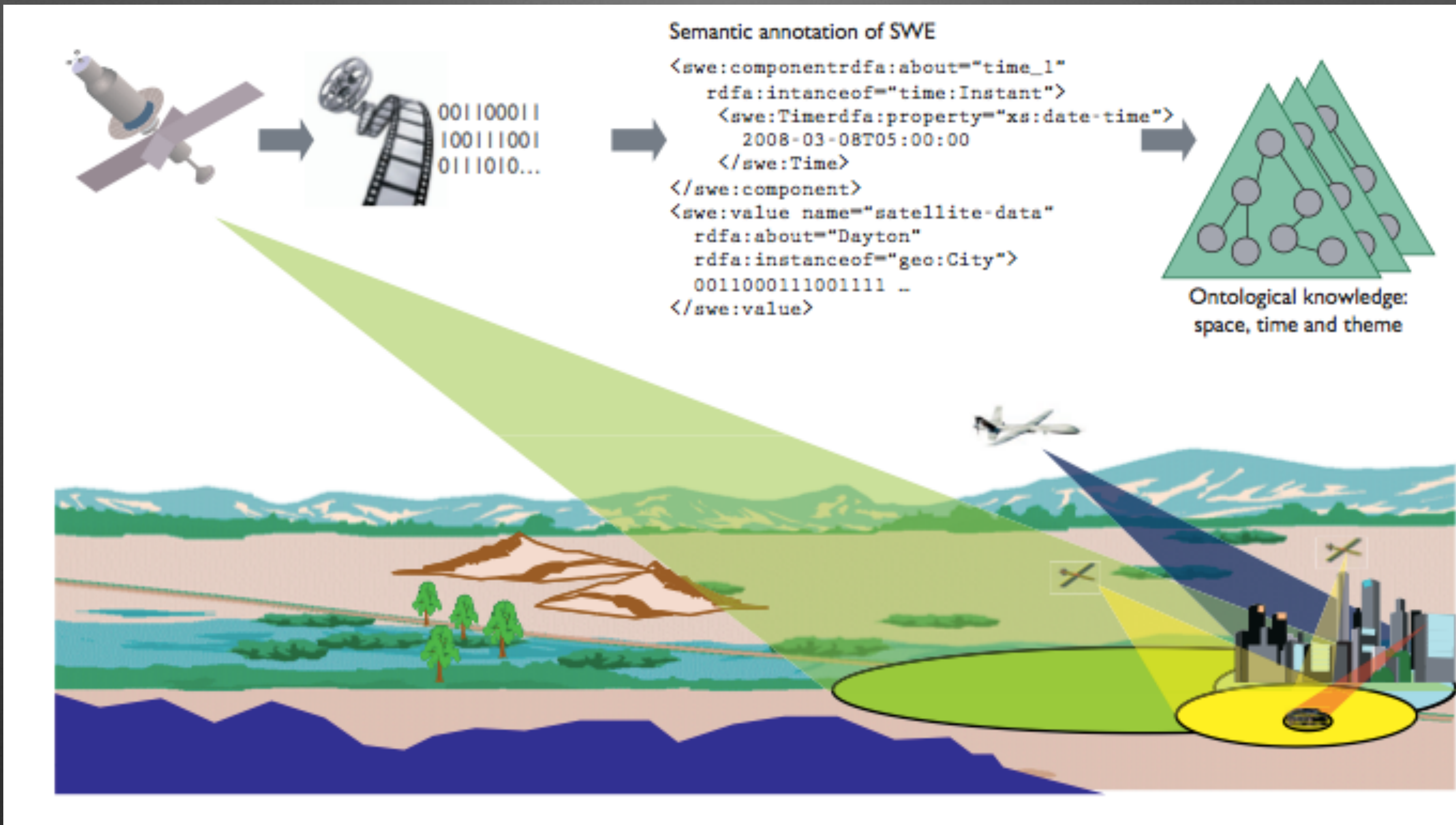
Sensor Data

- Sensors are used for many purposes
  - Meteorology for weather forecasting and wild-fire detection
  - Civic planning for traffic management
  - Satellite imaging for earth and space observation
  - Medical sciences for patient care using biometric sensors
- Generally proprietary, binary data (difficult to quickly look inside data — keyword extraction etc.)

Sensor metadata

- What kind of data?
- Simplest metadata:
  - Magnitude and unit of measurement
  - Location of sensor
  - Time of measurement

Sensor Web Enablement



Some basic issues

- Sensor Web Enablement (SWE) language provides annotations for simple spatial and temporal concepts such as spatial coordinate and timestamp
- More complex spatial concepts need an ontology:
  - spatial region
    - single coordinate location, a spatial region within a bounding-box, or a named location such as a park or school
  - temporal interval
    - within the time interval, contain the time interval, or overlap with the time interval

Some basic questions one might want to ask

- Smart homes and buidlings
  - What is the current average temperature in the building?
  - How many motion detector sensors are present in the 4th floor?
  - What was the average humidity in the areas with temperature > 25C last week?

Sensor fusion

- Multiple sensor data to build evidence for a real-world event
    - Using temperature, humidity, and pressure data to forecast weather
    - Was there an insurgency incident within 30 miles of the Green Zone (in Baghdad) in March 2006?
- Intelligent sensor fusion can cut down unnecessary data by tasking only contextually relevant sensors

Creating Sensor Metadata

- Sensor Web Enablement (SWE) Working Group of the Open Geospatial Consortium (OGC) has proposed standards
- These standards provide annotations for the expression of *simple metadata* such as location coordinates, timestamp, sensor specification, and web service interface
  - Observations & Measurements (O&M) - Standard models and XML Schema for encoding observations and measurements from a sensor, both archived and real time.
  - SensorModelLanguage(SensorML)-Standard models and XML Schema for describing sensors systems and processes; provides information needed for discovery of sensors, location of sensor observations, processing of low-level sensor observations, and listing of taskable properties.

- Transducer Model Language (TransducerML or TML) - The conceptual model and XML Schema for describing transducers and supporting real-time streaming of data to and from sensor systems.

- Sensor Observations Service (SOS) - Standard Web service interface for requesting, filtering, and retrieving observations and sensor system information.

- Sensor Planning Service (SPS) - Standard Web service interface for requesting user-driven acquisitions and observations.

- Sensor Alert Service (SAS) - Standard Web service interface for publishing and subscribing to alerts from sensors.

Semantic enhancement

- SSW (Semantic Sensor Web) is a framework for providing enhanced meaning for sensor observations so as to enable situation awareness
- provide more meaningful descriptions and enhanced access to sensor data
- Ontologies and rules for interoperability, analysis, and reasoning over heterogeneous multimodal sensor data

Semantic annotations

- Example of Observations&Measurements annotated with RDFa
- The timestamp's semantic annotation describes an instance of time:Instant

< swe:component rdfa:about=”time_1” rdfa:typeof=”time:Instant”>
< swe:Time rdfa:property=”xs:date-time”>2008-0308T05:00:00</ swe:Time >
< / swe:component >

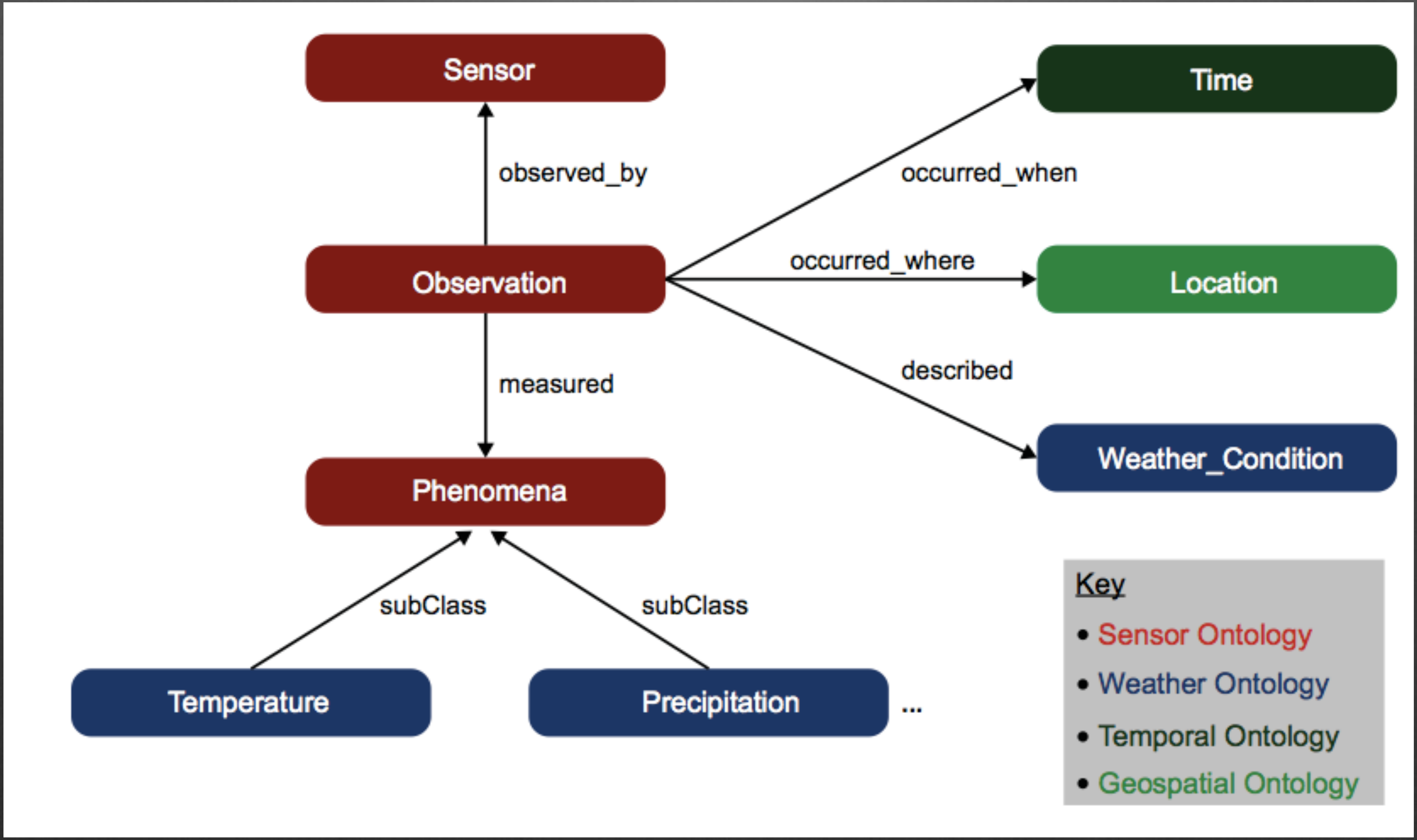
Ontologies

- Domain general and specific ontologies
  - Spacial
  - Temporal
  - Thematic (e.g. weather)
  - Several efforts under way
    - National Institute of Standards and Technology
    - W3C (Geospatial Incubator Group, Geographic Markup Language Ontology)
    - OGC (Open Geospatial Consortium) SWE

Ontology concepts

- W3C recommendation of temporal calculus, provides descriptions of temporal concepts such as instant and interval, which supports defining interval queries such as within, contains, and overlaps
- Domain-specific ontologies that model various sensor-related fields such as weather and oceanography

Mixing ontologies for weather data

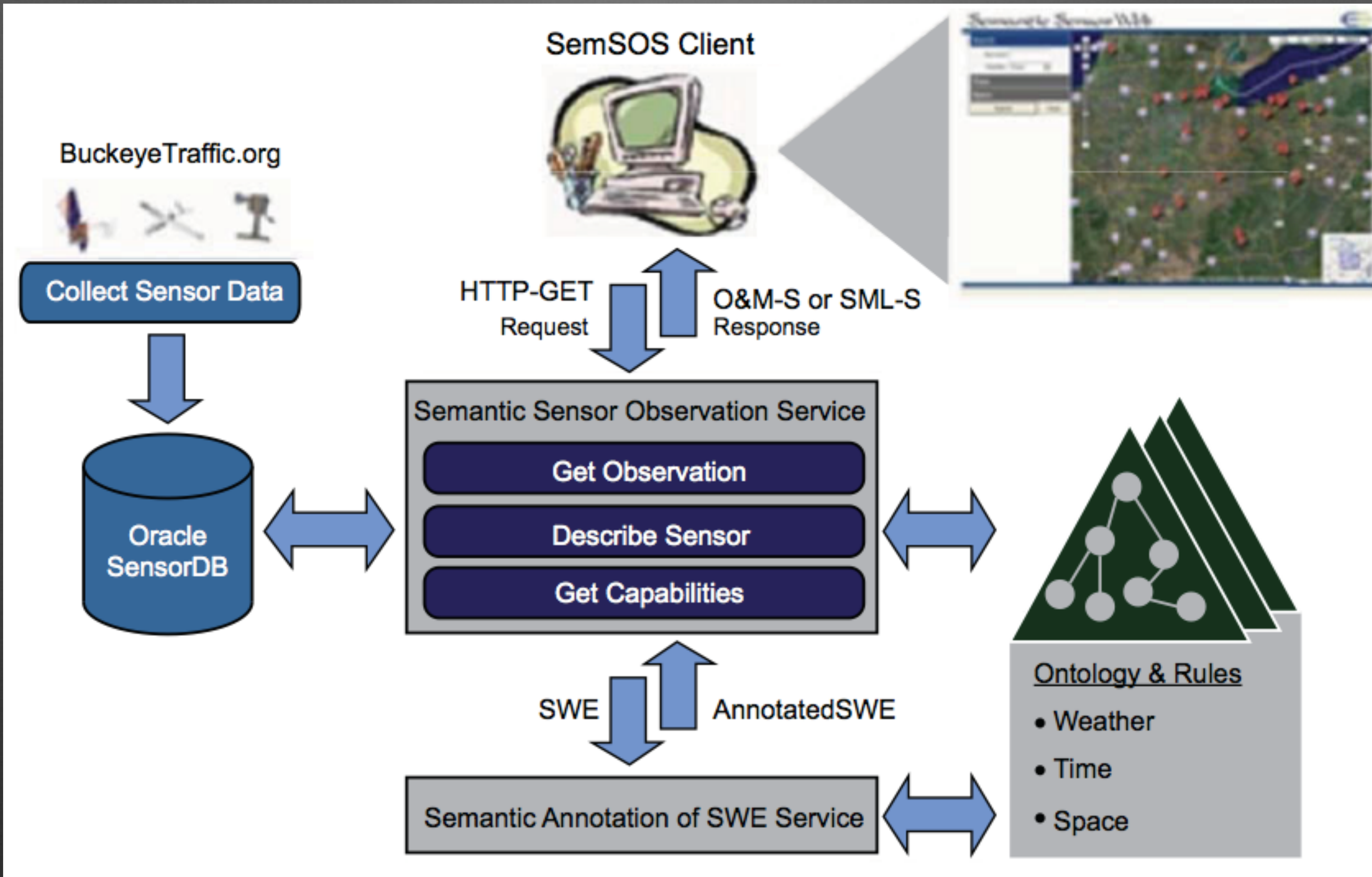


Rule based reasoning

- Ontologies facilitate the use of rules for inference
- Semantic Web Rule Language (SRWL)
- Rule language for semantic web
- antecedent → consequent structure
  - temperature is less than 0 degrees Celsius and it is raining → the roads are potentially icy

Example application

- Semantic Sensor Observation Service (SemSOS)
- Road and weather observations from more than 200 sensors deployed along Ohio interstate highway
- Application collects and uses data including temperatures of the air, surface, subsurface, and dew point, as well as wind speed, wind direction, and precipitation
- semantically annotate these documents with spatial, temporal, and weather ontological concepts


SemSOS Client
BuckeyeTraffic.org
Collect Sensor Data
HTTP-GET
Request
O&M-S or SML-S
Response
Oracle
SensorDB
Semantic Sensor Observation Service
Get Observation
Describe Sensor
Get Capabilities
SWE
AnnotatedSWE
Semantic Annotation of SWE Service
Ontology & Rules
• Weather
• Time
• Space

Semantic queries with weather app

- Supports direct querying for human comprehensible weather features such as **freezing** or **blizzard** conditions at a particular time and place
  - freezing query requires only a temperature sensor and a rule specifying that any temperature less than 32 degrees Fahrenheit constitutes a freezing condition
  - blizzard query requires integrating three sensor types — temperature, wind, and precipitation
    - blizzard = freezing, high winds, and snowing

Blizzard rules (1/3)

The following set of RDF triples represents data about a wind speed observation at time 1 location 1.

om:windspeed_1 rdf:type w:WindSpeedObservation .
om:windspeed_1 om:samplingTime om:time{_}1 .
om:windspeed_1 om:observationLocation om:location{_}1 .
om:windspeed_1 om:result om:result{_}1 .
om:result_1 om:value “37” .
om:result_1 om:uom w:MPH .

Blizzard rules (2/3)

```
[HighWindSpeedObservationRule:

(?s_obs rdf:type w:WindSpeedObservation)
(?s_obs om:samplingTime ?time)
(?s_obs om:observationLocation ?location)
(?s_obs om:result ?result)
(?result om:uom w:MPH)
(?result om:value ?value)
greaterThan(?value 35)
-→
(?s_obs rdf:type w:HighWindSpeedObservation)]
```

also LowVisibilityObservation and SnowfallObservation

Blizzard rules (3/3)

```
[BlizzardObservationRule:
(?s_obs rdf:type w:HighWindSpeedObservation)
(?s_obs om:samplingTime ?time)
(?s_obs om:observationLocation ?location)
(?v_obs rdf:type w:LowVisibilityObservation)
(?v_obs om:samplingTime ?time)
(?v_obs om:observationLocation ?location)
(?p_obs rdf:type w:SnowfallObservation)
(?p_obs om:samplingTime ?time)
(?p_obs om:observationLocation ?location)
makeTemp(?blizzard)
-→
(?blizzard rdf:type w:Blizzard)
(?blizzard om:eventTime ?time)
(?blizzard om:eventLocation ?location)
(?w_obs om:featureOfInterest ?blizzard)
(?v_obs om:featureOfInterest ?blizzard)
(?p_obs om:featureOfInterest ?blizzard)]
```

Internet of Things

- identify, describe, link, monitor, and effect physical objects and their environment, to create “ambient intelligence” that can assist or relieve people in carrying out everyday tasks
  - techniques and technologies to represent and reason about the state of the objects and their interactions
  - sensing, networking, and communication infrastructure to access and effect the objects