Preparing for ‘The Web of Things’

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A Brief History of the Web

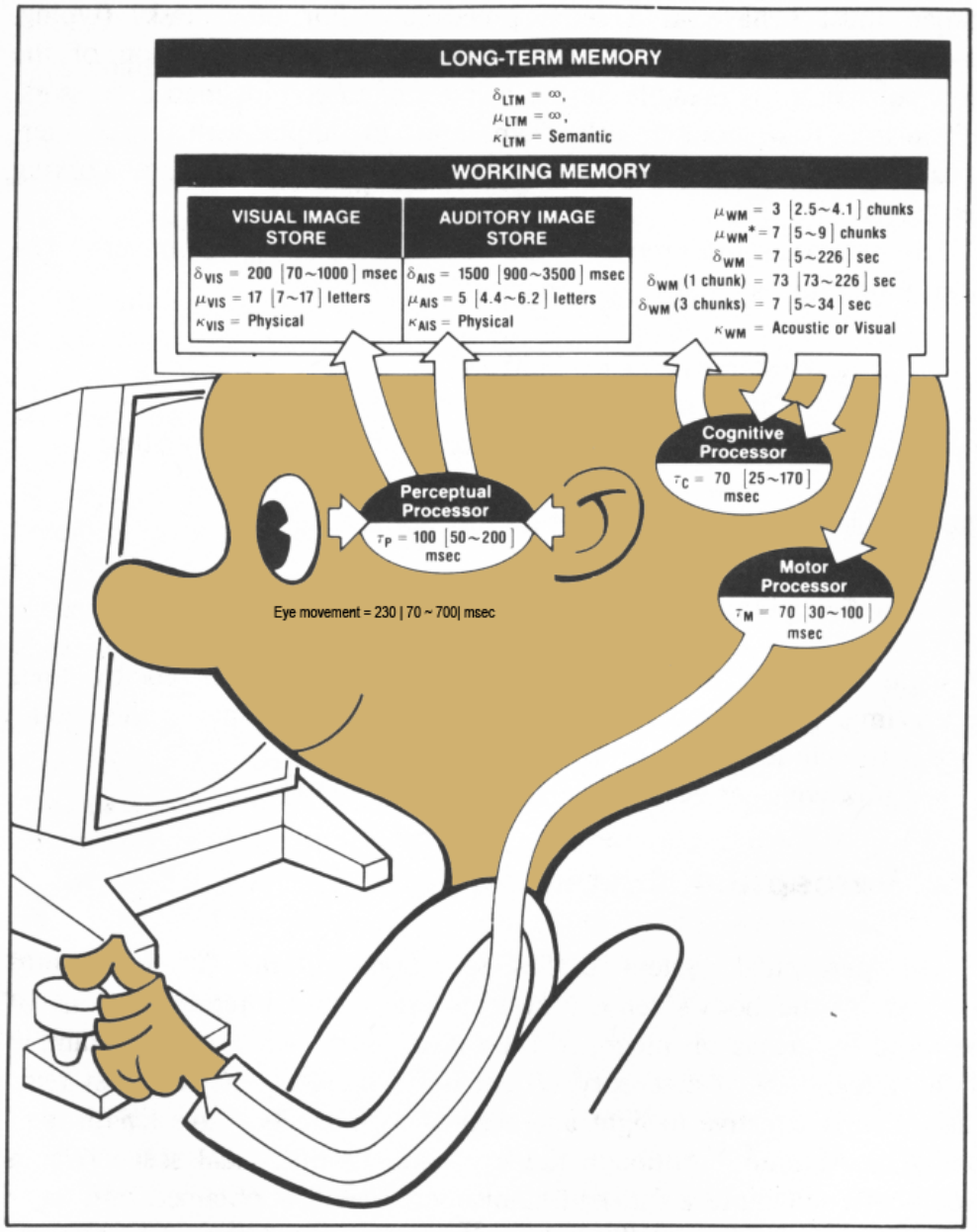
- Web 1.0 – static HTML pages/documents
- Web 1.5 – dynamic HTML pages/documents
- Web 2.0 – the participatory Web
- Web 2.5 – the “Social Web”
- Web 2.6 – the “Multimedia Web”
- Web 2.7 – the “Mobile Web”
- Web 3.0 – the “Semantic Web”
- Web 3.5 – the “Data Web”

So What's Next?

- "The Internet of Things"
- "The Web of Things"
- "The Internet of Objects"
- "The Web of Objects"
- Yada, yada yada…buzz, buzz, buzz

The Important Thing Is

- We have the capability to fully connect and integrate everyday devices and objects into the Web
- And use these devices and objects in ways that we can only imagine


LONG-TERM MEMORY
$\delta_{LTM} = \infty$,
$\mu_{LTM} = \infty$,
κ_{LTM} = Semantic
WORKING MEMORY
VISUAL IMAGE STORE
δ_{VIS} = 200 [70~1000] msec
μ_{VIS} = 17 [7~17] letters
κ_{VIS} = Physical
AUDITORY IMAGE STORE
δ_{AIS} = 1500 [900~3500] msec
μ_{AIS} = 5 [4.4~6.2] letters
κ_{AIS} = Physical
μ_{WM} = 3 [2.5~4.1] chunks
μ_{WM}^* = 7 [5~9] chunks
δ_{WM} = 7 [5~226] sec
δ_{WM} (1 chunk) = 73 [73~226] sec
δ_{WM} (3 chunks) = 7 [5~34] sec
κ_{WM} = Acoustic or Visual
Cognitive Processor
τ_C = 70 [25~170] msec
Perceptual Processor
τ_P = 100 [50~200] msec
Motor Processor
τ_M = 70 [30~100] msec
Eye movement = 230 | 70 ~ 700| msec

The Model Human Computer

- Worked fine
  - When it was just us and a desktop/personal computer
  - When mapping computer I/O to five senses "made sense"
  - When computer architecture was simple
- There is now just one computer (the Internet/Web)
  - We only have a glimpse into it
  - Its processing and data potential is limitless
  - There are more than just five senses
  - Humans are not the only entities using it

Motivations for a ‘Web of Things’

- What is it? What problems can it solve?
- Architectural considerations – How does it look? What are its components?
- The ‘Things’ – What are the ingredients?
- The ‘Glue’ – How do things ‘stick together?’
- Applications and services – What can be built on top of it?

My Vision for a 'Web of Things/Objects'

- The Web has revolutionized communication
- Everything are objects – it's just knowing how to communicate with them
- The Web becomes an interactive universe of objects, things, data, ideas/concepts and processes both real and virtual
- "By year-end 2012, physical sensors will generate 20% of non-video Internet traffic" (The Gartner Group)
- Any of these entities can be integrated and communicate with one another
- This is one vision of **singularity**

Interactions

- People to people
- Objects to objects
- People to objects
- Without mediaries or with mediaries in the background
- Interactions rely on senses that have a limited range – in the Web of Things, the range is universal
- Things/objects become transmitter and receptors that can initiate and respond to stimuli

Intent

- Objects/things are named entities
- Objects/things have attributes
- Intents are satisfied by presenting objects/things and their attributes

A Lot of This Isn't New…

- Ubiquitous computing
- Pervasive computing
- Captology
- Sensors/RFIDs
- Attempts at a 'Web of Things' was in Web 1.0

Trojan Room Coffee Pot

- Cambridge, 1991
- Inspiration for world's first Webcam
- Clear interaction model to satisfy a clear intent
- But was this coffee pot really "on the Web?" – I say no

A New Vocabulary for the 'Web of Things'

- **Blogjects** – objects that blog (Julian Bleeker, USC)
- **Spimes** – "a location-aware, environment-aware, self-logging, self-documenting, uniquely identified object that flings off data about itself and its environment in great quantities" (Bruce Sterling)
- "The significance of technologies like RFID and 2D barcoding is that they offer a low-impact way to 'import' physical objects into the **datasphere**, to endow them with an **informational shadow**." (Adam Greenfield)

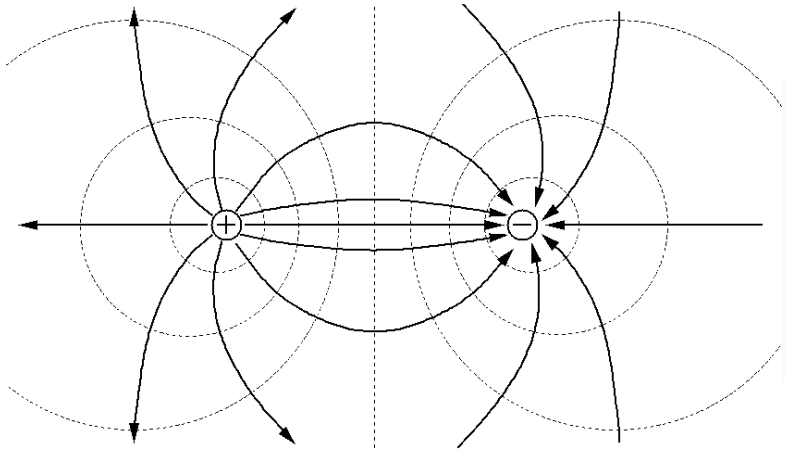
What Does ‘a Person on the Web’ Mean?

- Not
  - Just a home page
  - A Web-accessible database entry
- But
  - A ‘sensory-sensitive,’ complete, unambiguous representation of a person
  - The ultimate example of **The Turing Test**
- Imagine the potential for knowledge capture/ management

How to Do This?

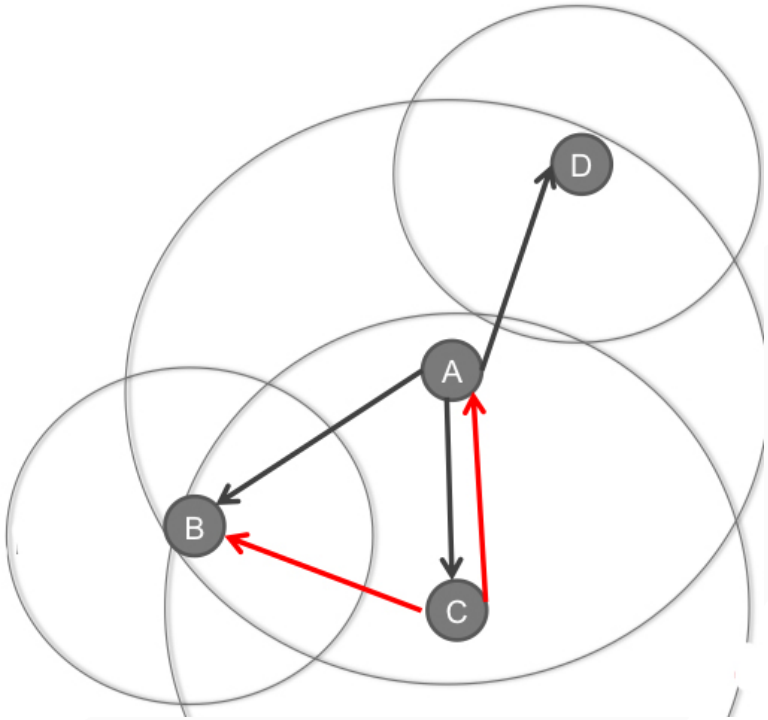
- Premises
  - Nature is a data processing engine
  - The best engineering emulates nature
  - Don’t just start with the human brain – the Internet/ brain comparison is getting tired

Consider Field/Gauge Theory



- Objects/things exchange
  - Hard data (e.g., pheromones)
  - Soft data (e.g., visual cues)
- How do we receive information about objects and/or concepts
- Objects/things obey interaction rules (e.g., only charged particles feel the electromagnetic force)

How Does That Differ From This?



- Wireless and/or wired point-to-point or point-to-multipoint
  - B, C and D in the coverage range of A
    - When A sends a message, B, C and D receive it
  - A, B in the range of C
    - When C sends a message only A and B receive it

Not Only That – We Can Already Become Friends With Things…

Marc Benioff, CEO of Salesforce.com at the Dreamforce conference

Nice Gimmick

TECHNOLOGY

RFID-powered shoes connect wearers to social media

By Olivia Solon | 27 January 11

- But how much is known about the shoe?
- Single use?
  - Social media
  - Supply chain management
  - Web-based inventory management
- Why not **really** put the shoe on the Web? Not just a shoe with a chip.
- The shoe transmits to all who might listen

What? A Shoe on the Web?

- With a real embedded server the shoe
  - Could be a ‘first class citizen’ on the Web with
    - Its own IP address
    - The ability to transmit/receive data (e.g., RDF triples)
- Silly you say?
  - Only because we cannot imagine how to use it or the data it contributes…
  - History (especially the history of IT) is littered with ideas that appeared silly at some time

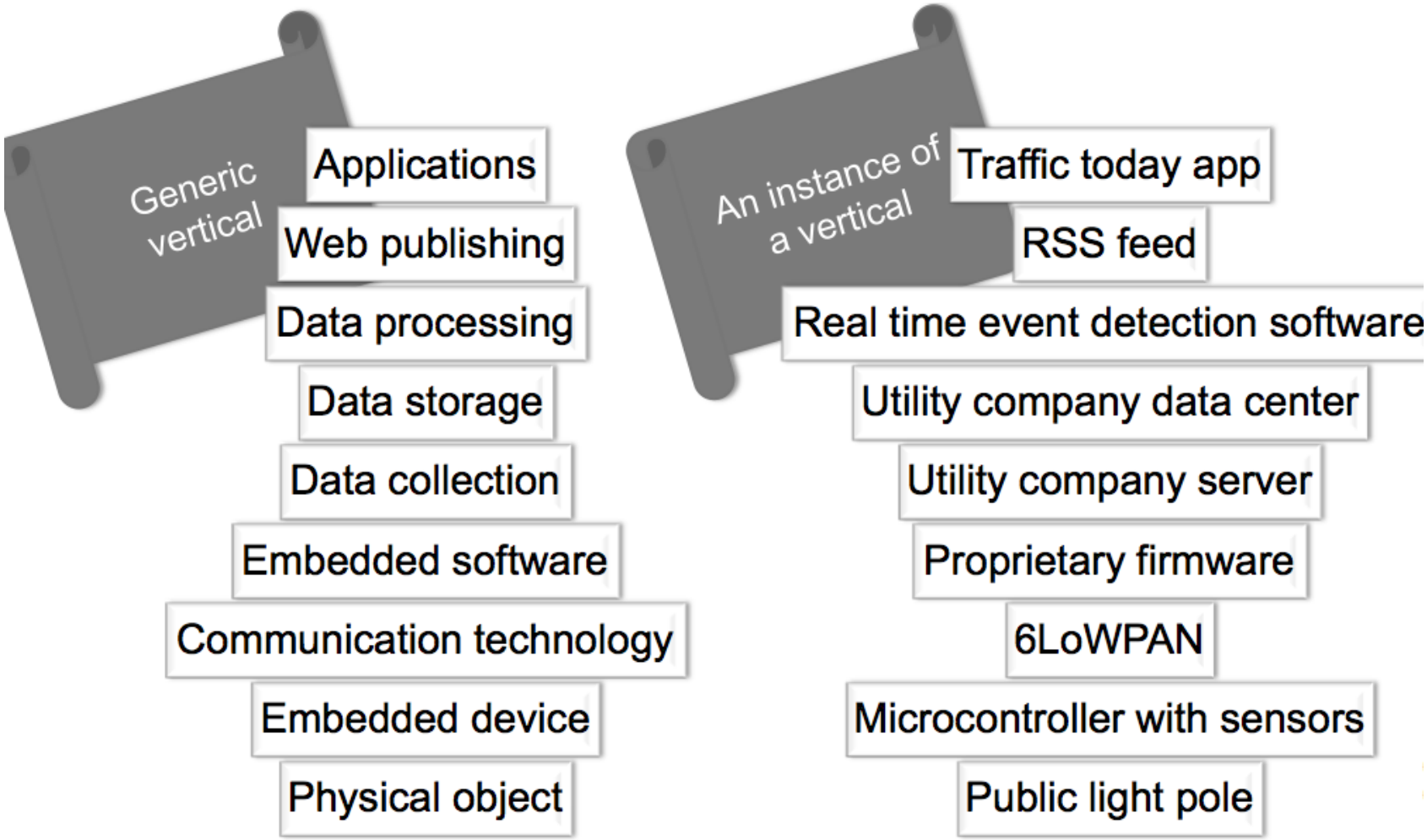
Transition Towards Machine Generated Information

- Past:
  - “manual input of information by 500 million or a billion users”
- Future:
  - “new information can be created automatically without human data entry…the next generation of sensor networks can monitor our environment and deliver relevant information – automatically”

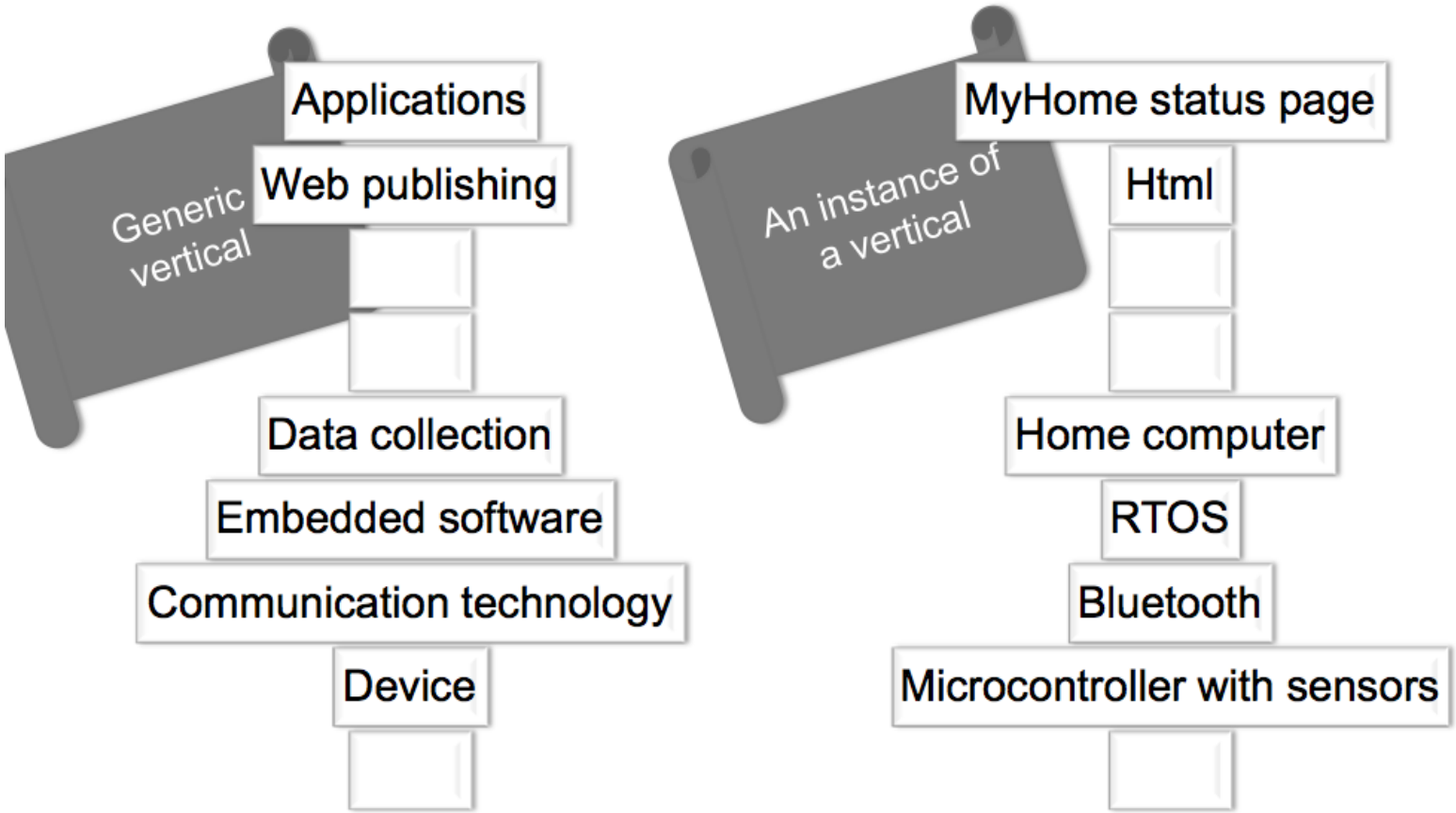
What are Some "Web of Things" Use Cases?

- Motivated by an increased interest in automatic management of large systems
  - Commercial use cases
  - Academic use cases
- Alternative solutions
- Ethical issues and abuse

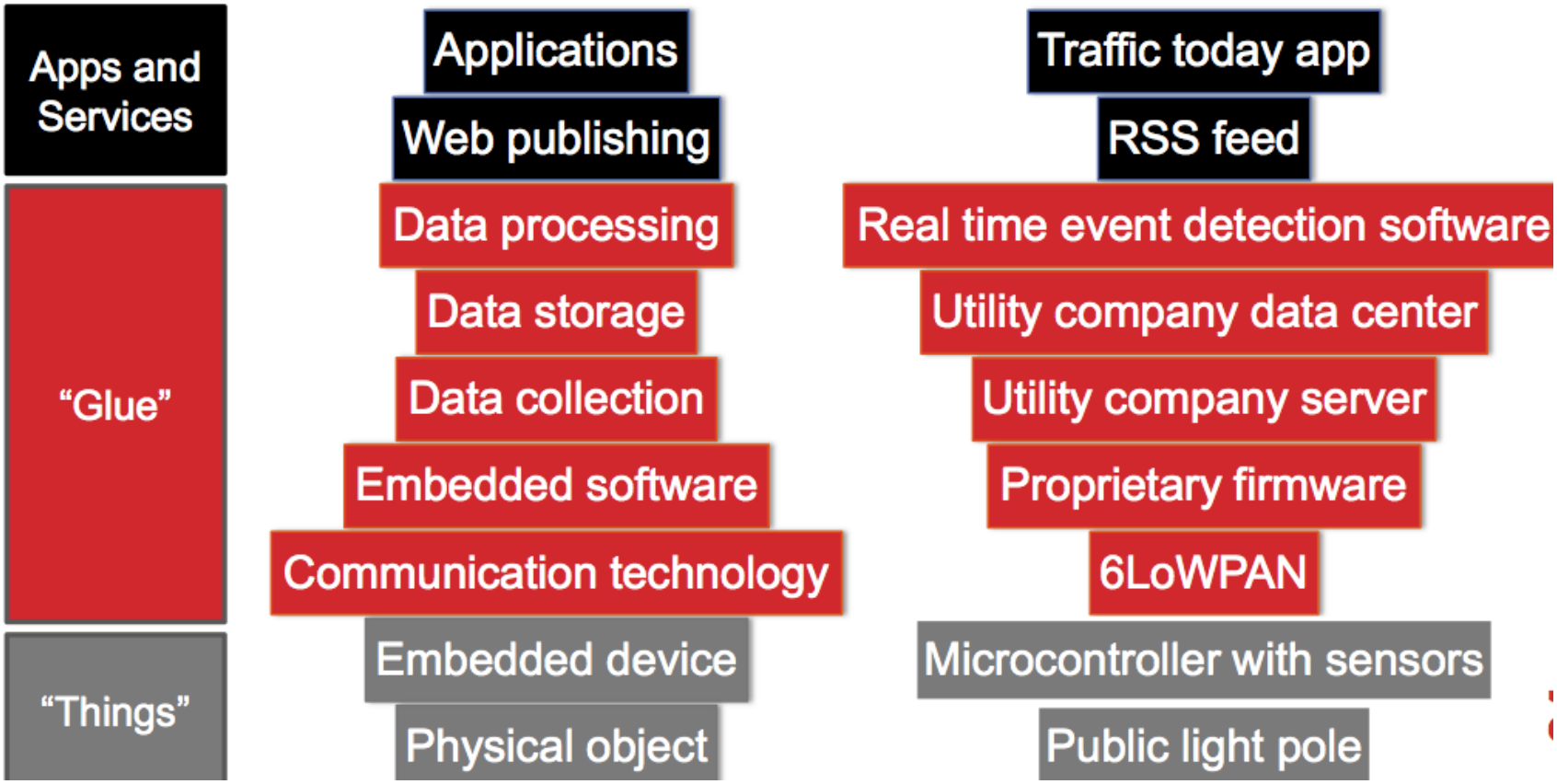
Architectural Considerations (1)



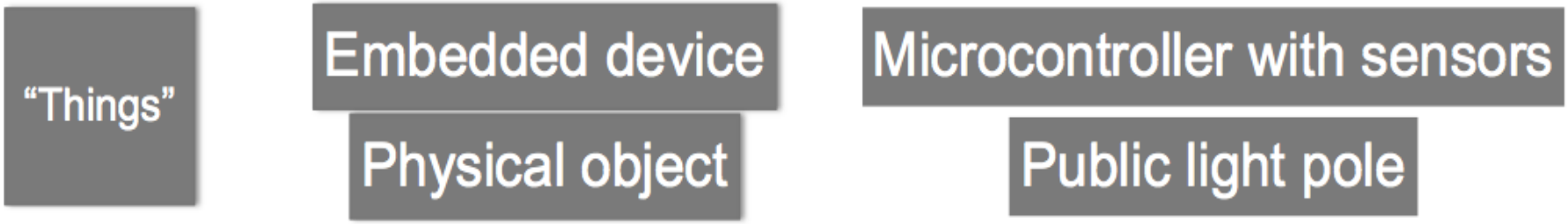
Architectural Considerations (2)



Main Components of a Vertical



The “Things”

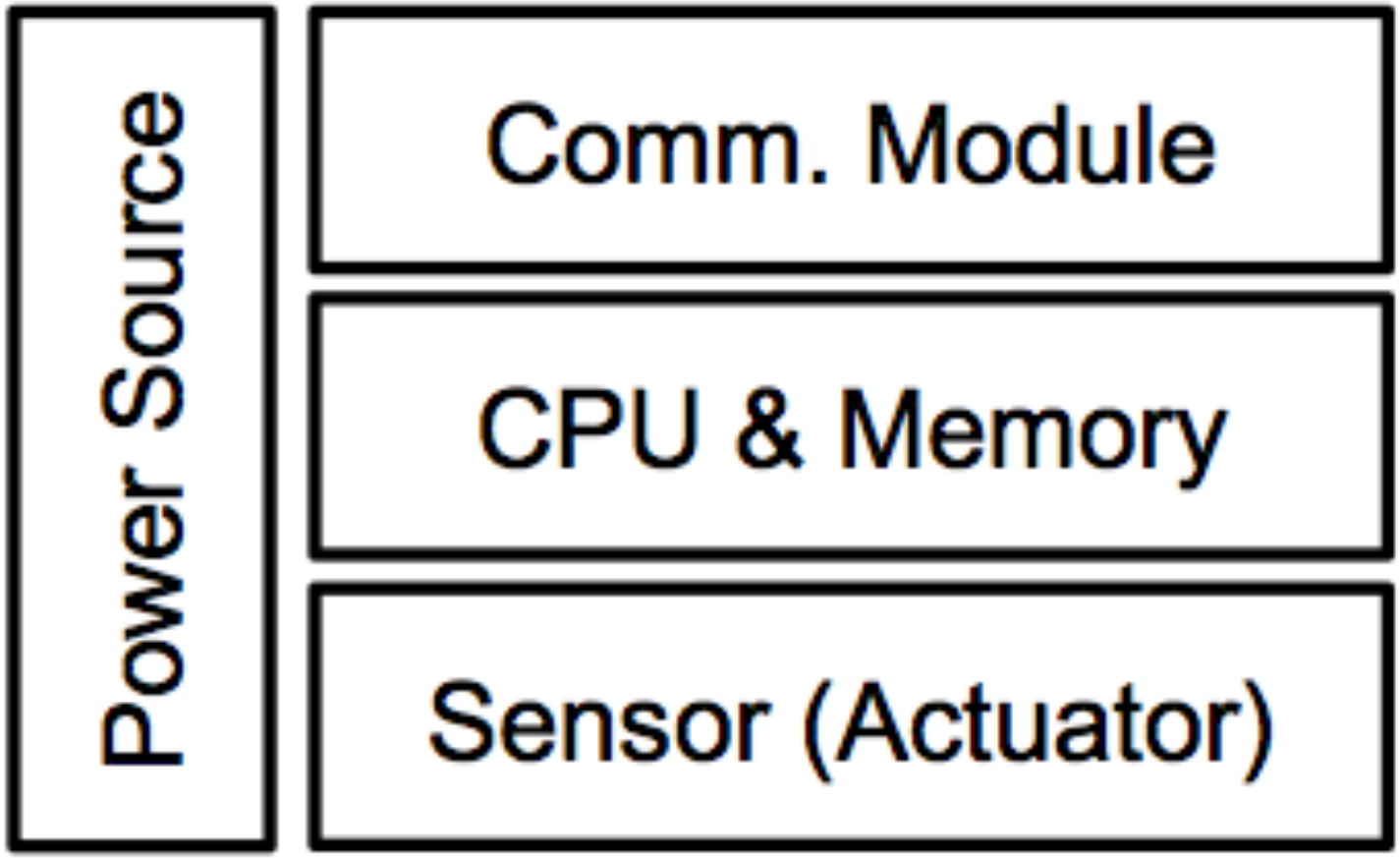


- Embedded device + physical object
- Sensor node
- Mobile phone
- A set of sensor nodes and/or embedded device + physical things that can be abstracted as one “thing”

Some Definitions

- Physical object – an object built for fulfilling other tasks than computing
- Sensor – a material or passive device which changes properties according to some stimulus
- Embedded system – a simple of complex system built into a physical device to perform dedicated functions and enhance the functionality through computation
- Sensor node – a computing and communicating device equipped with sensors

Sensor Nodes and Their Structure

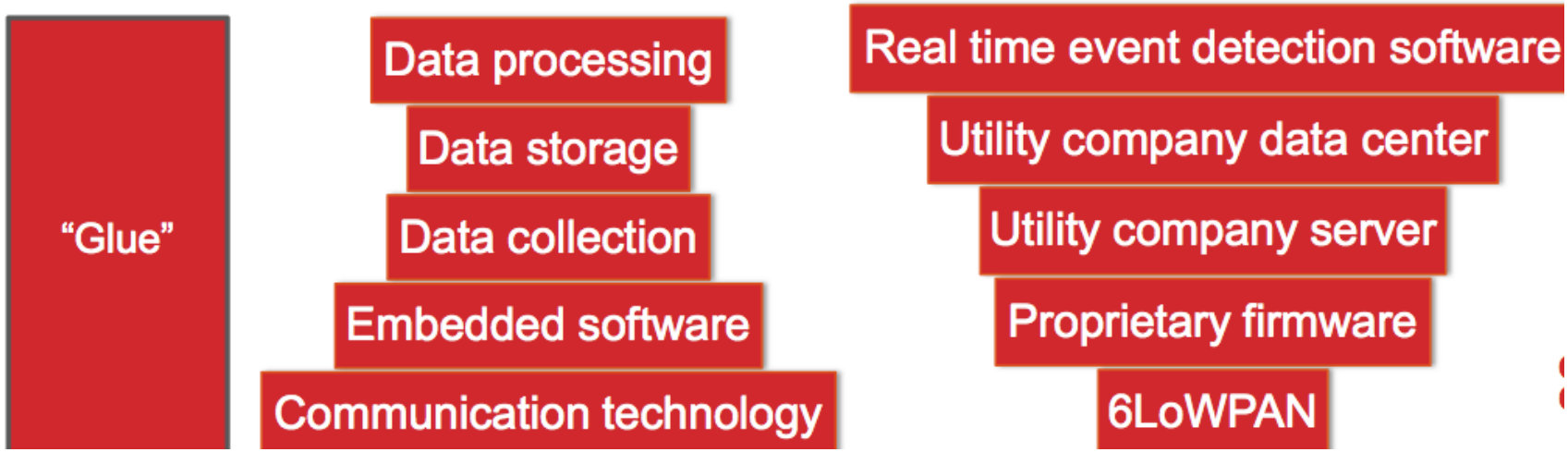


What are some common types of sensors?

The “Glue” (1)

- The communication
  - The communication medium
  - The network
- Node centric programming
  - Operating system
  - Virtual machine
- System level programming (macro-programming)
  - Distributed/centralized storage and retrieval
  - Content management

The “Glue” (2)


“Glue”
Data processing
Data storage
Data collection
Embedded software
Communication technology
Real time event detection software
Utility company data center
Utility company server
Proprietary firmware
6LoWPAN

Applications and Services

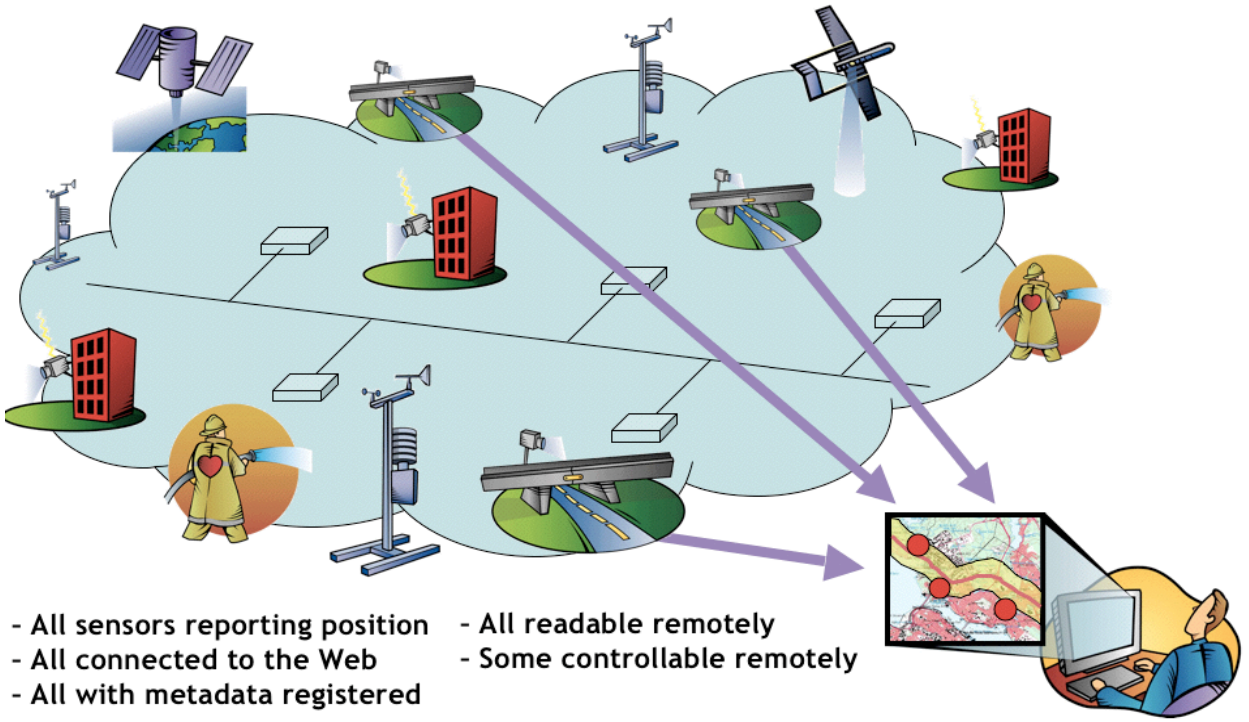
- Combine data, presentation or functionality from several sources (mashup) to create new services
- Things generate only part of the data source

The Need for Sensor Standards

- Sensors are already prevalent today, but they will become even more necessary and prevalent in WoT-enabled devices and applications
- Sensors are developed by a variety of manufacturers, using many different protocols and formats, making the interoperability and large scale sensor integration required by the WoT difficult without standards
- Effective use of sensors to enable and drive the WoT requires standards for discovering sensors, retrieving sensor data, tasking sensors, and subscribing to and receiving sensor alerts

**From: "Vision and Challenges for Realising the Internet of Things", March 2010*
http://www.internet-of-things-research.eu/pdf/IoT_Clusterbook_March_2010.pdf

Sensor Webs



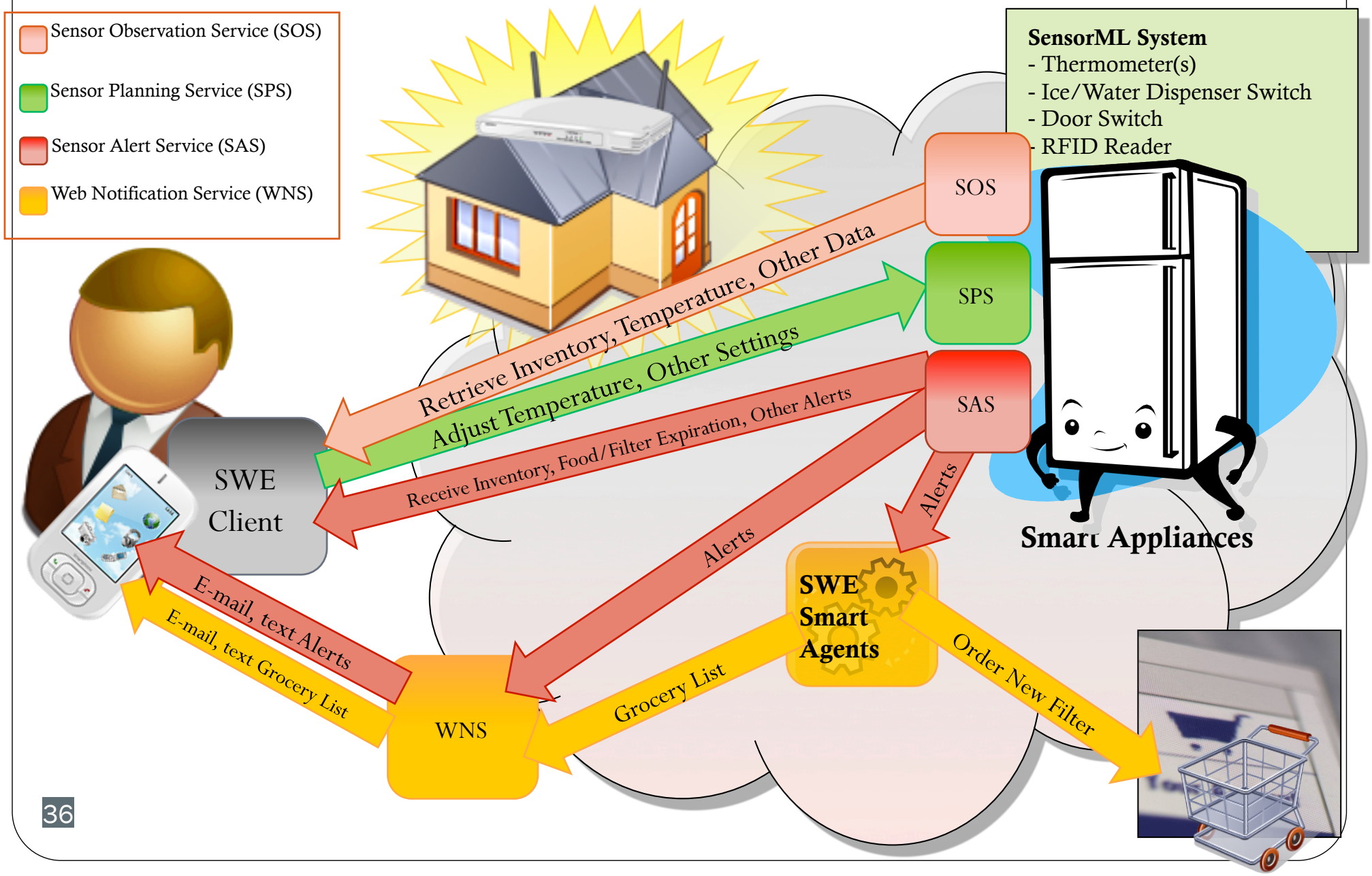
"… Web accessible sensor networks and archived sensor data that can be discovered and accessed using standard protocols and application program interfaces (APIs)"

From OGC 07-0165 - OGC Sensor Web Enablement: Overview and High Level Architecture

Sensor Web Enablement (SWE) Standards

- Help to enable the vision of the Sensor Web by eliminating barriers to sensor interoperability
- Include XML-based messaging formats and web service interfaces for discovering, accessing, and controlling all types of sensors
- Include built-in support for location and a variety of coordinate reference systems that should address both outdoor and indoor location
- Sensors, measured phenomena, geographic features, and other items are all identified using Uniform Resource Identifiers (URIs)
- Built with the Semantic Web and shared vocabularies/ontologies in mind
  - Semantic interoperability is seen as a key building block of the WoT
- The 1.0 versions have been around for a few years, with the 2.0 versions being adopted now. The 2.0 versions include:
  - Better support for asynchronous messaging
  - Improved consistency across standards
- OGC has formed a Pub/Sub Standards Working Group (SWG) to address broader support for pub/sub technologies across its standards
  - Should help with real-time /event-driven WoT use cases

User Applications - The SWE-Enabled Home



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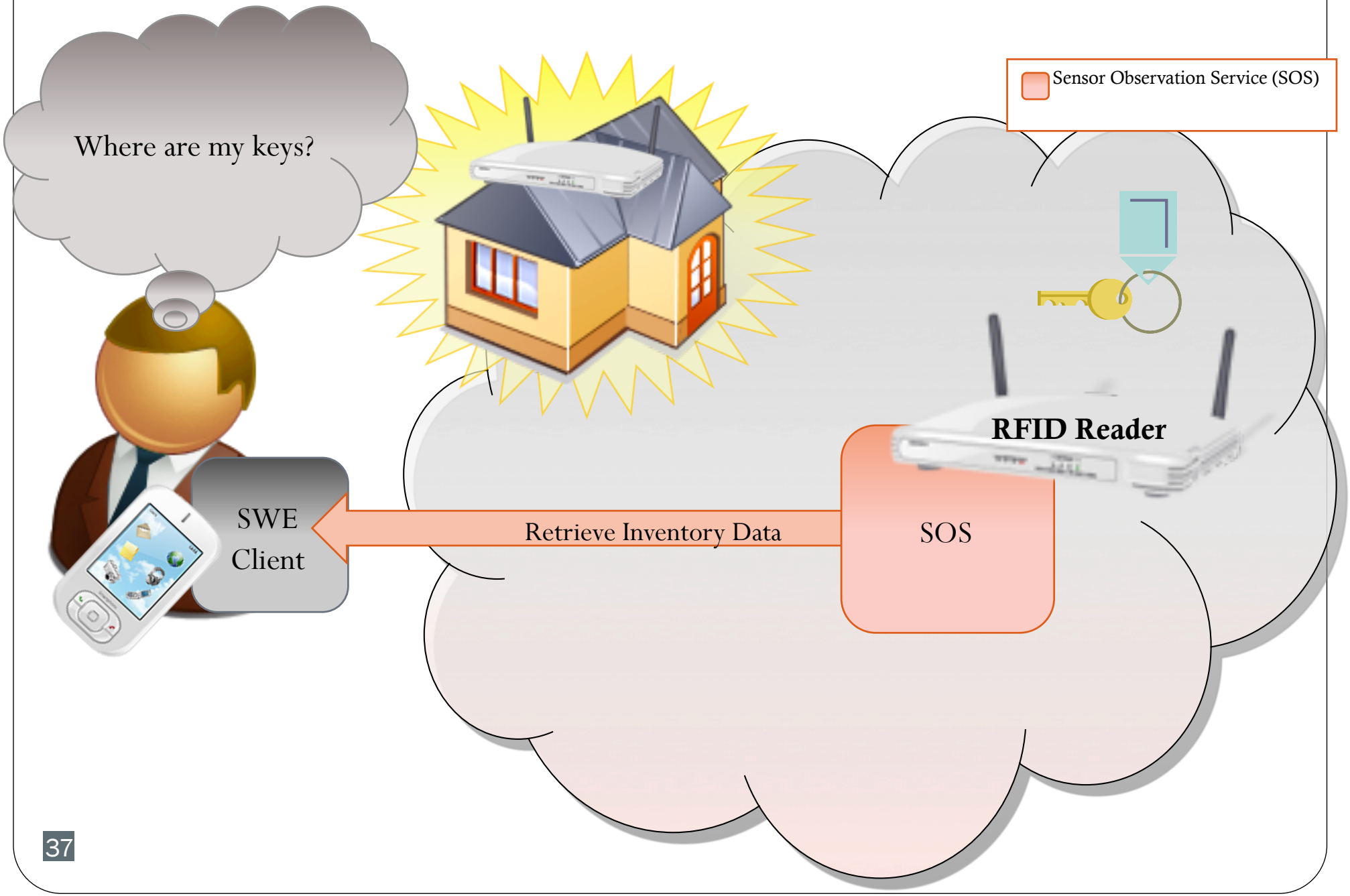
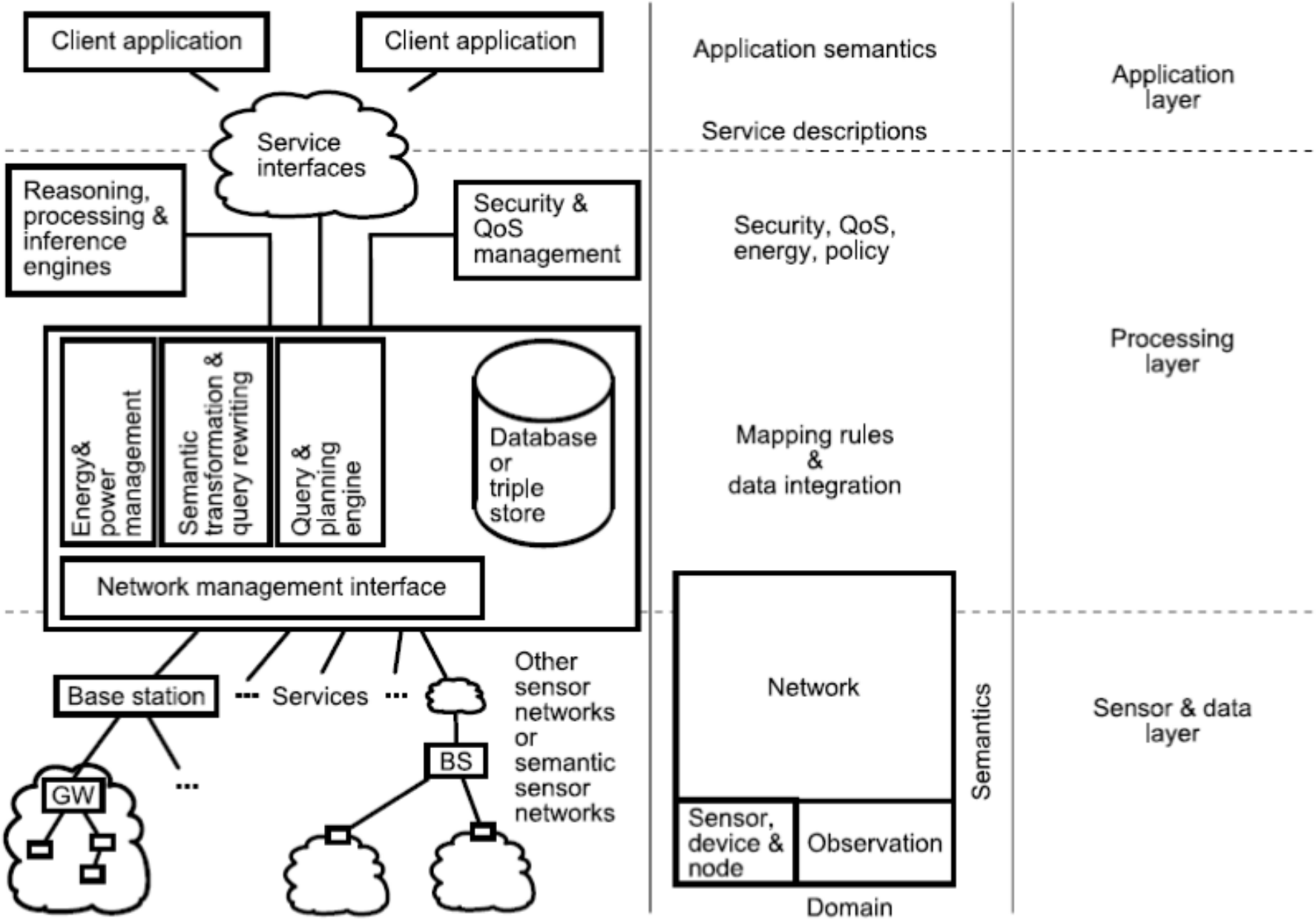


Challenges

- Scaling
  - Can/how do the SWE standards work in an WoT environment on a large scale – billions/trillions or more sensors/"things"?
- Discovery
  - How do I find sensor services? How do I make my sensors discoverable? Is there a central catalog or set of catalogs or a search engine for the sensor web where I go to find services, or is there some peer-to-peer mechanism where sensors/services notify me of their availability?
- Performance
  - Moving towards event-driven, publish/subscribe, CEP mechanisms to optimize the flow of information → information can be stored as needed, filtered and sent to the appropriate recipients/applications
- Standards Harmonization
  - Multiple sensor and WoT standards need to be harmonized in order to realize interoperability across sensor systems
- Big Data
  - Sensors and the WoT add to the growing amount of monitoring data that is available to a wide range of users. How do we effectively analyze all of this data and ensure that meaningful and relevant data and decisions are made?


Client application
Client application
Service interfaces
Reasoning, processing & inference engines
Security & QoS management
Energy& power management
Semantic transformation & query rewriting
Query & planning engine
Database or triple store
Network management interface
Base station
Services
Other sensor networks or semantic sensor networks
GW
BS
Application semantics
Service descriptions
Security, QoS, energy, policy
Mapping rules & data integration
Network
Sensor, device & node
Observation
Domain
Semantics
Application layer
Processing layer
Sensor & data layer

Information Infrastructure for the "Web of Things"

- Data is the key commodity
- It all begins with the "Web of Data"
- Demonstrated by Linked Open Data (LOD) and Semantic Web concepts and standards
- SWE standards recommend use of Semantic Web technologies

Thank You!
Questions?
Comments?

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