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The web of things

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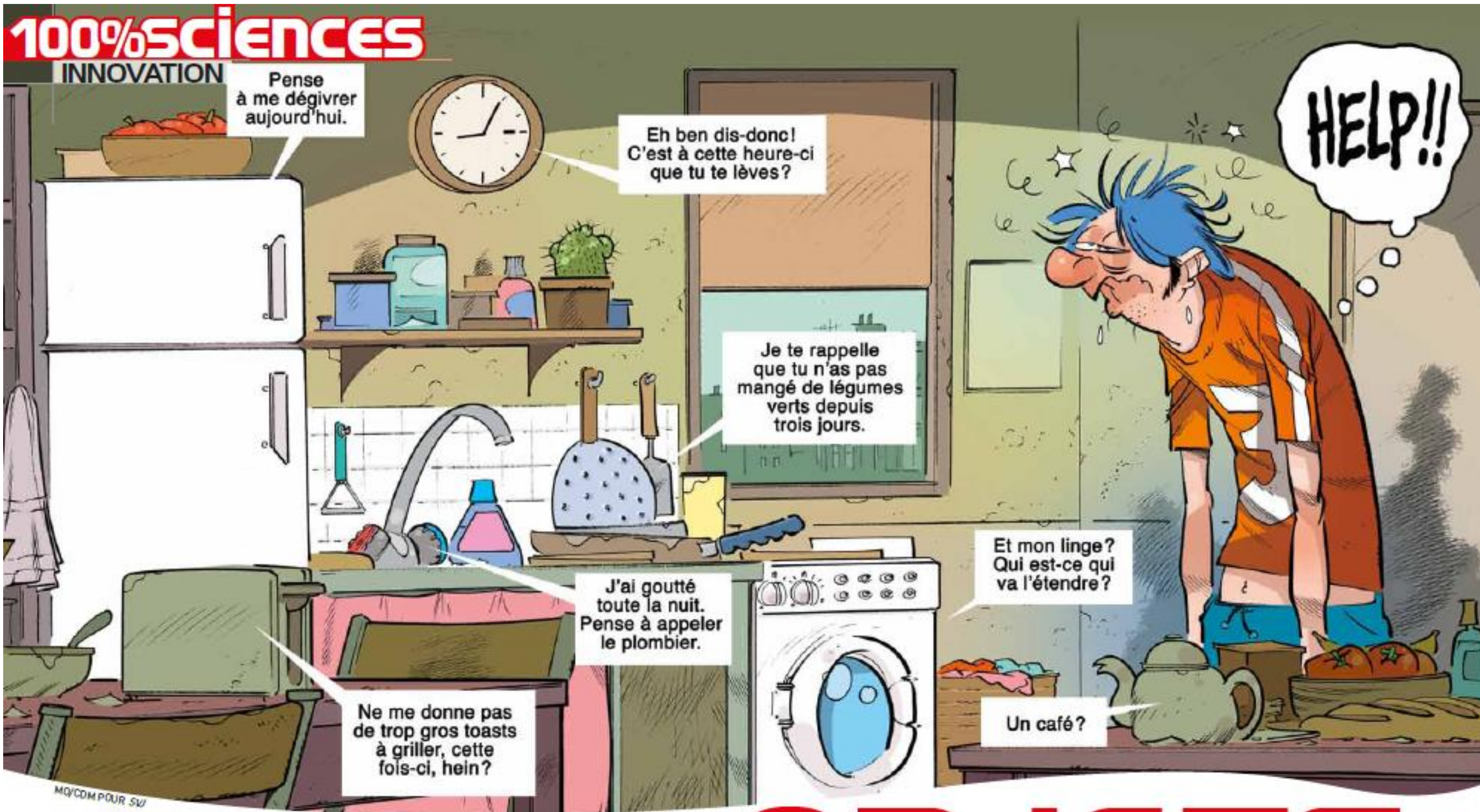
The WoT explained to children

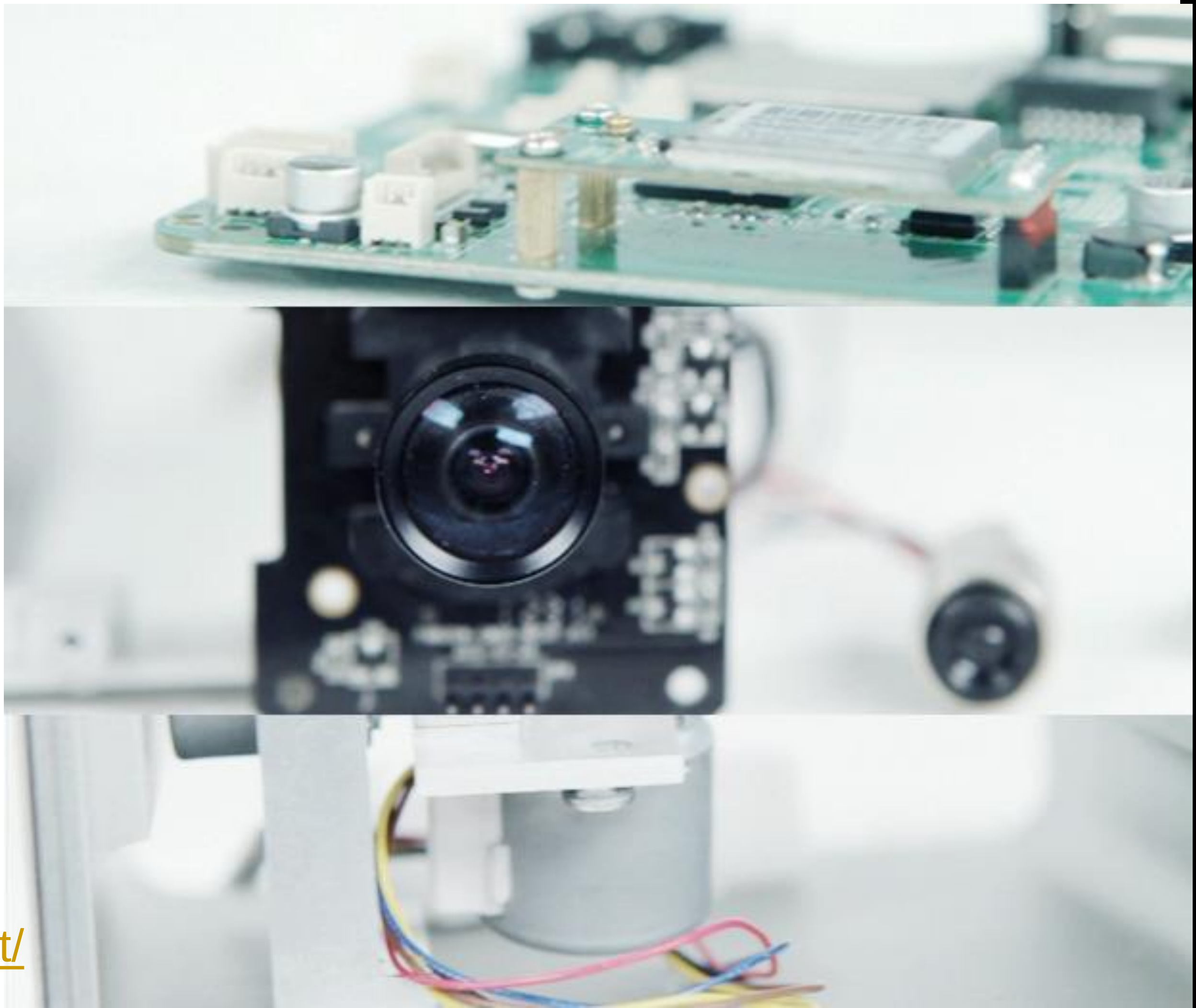


L'Internet des Objets, SVJ 268

Use case: Connected toys (1/2)

- **A start-up produces a device that can be used to remotely:**
  - watch your pet using the embedded camera
  - talk to your cat using the embedded speakers
  - hear your pet using the embedded microphone
  - play with your pet using the embedded laser pointer
  - record and share pictures, etc.
- **The remote interaction is enabled through a smartphone and uses web 2.0 and internet technologies**

Use case: Connected toys (2/2)



Images from http://petcube.net/

Use case: light control

- **Control the lights in your home by**
  - Installing new switches
  - Installing the control app on the smart phone
  - The switched and the phone use wireless to communicate

Control your home from Smartphone.

Images from http://www.pluggxlabs.com/

Use case: disaster monitoring (1/2)

Facts:

- March 11, 2011: Tōhoku earthquake and tsunami in Japan
- Nuclear reactors were affected: explosions and radioactive pollution
- Confusing information about the **levels of radioactivity** from authorities
- **Radiation level maps** based on Geiger counter data started to appear

http://en.wikipedia.org/wiki/2011_Tōhoku_earthquake_and_tsunami

http://wikileaksreputationcrisis.wordpress.com/2011/03/13/fukushima-nuclear-crisis-media-coverage-evolution/

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Use case: disaster monitoring (2/2) – the Radiation level map

http://blog.pachube.com/2011/03/real-time-radiation-monitoring-in-japan.html

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Disclaimer

This is by no means an exhaustive list of use cases …

The main purpose of the list was to show that now, unlike few years ago when we started this tutorial, using Web of Things technologies had been made simple by innovative products.

A nice visualization of the use cases is available at: http://www.beechamresearch.com/article.aspx?id=4

Outline

Part I. Motivation & background

Part II. Technology and tools for exploiting the WoT

Part III. Demos, tools & research directions

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Part I. Motivation & background outline

Web Of Things

- What is it? What problems can it solve?

Architectural considerations

- How it looks like? 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?

Quick start recipes

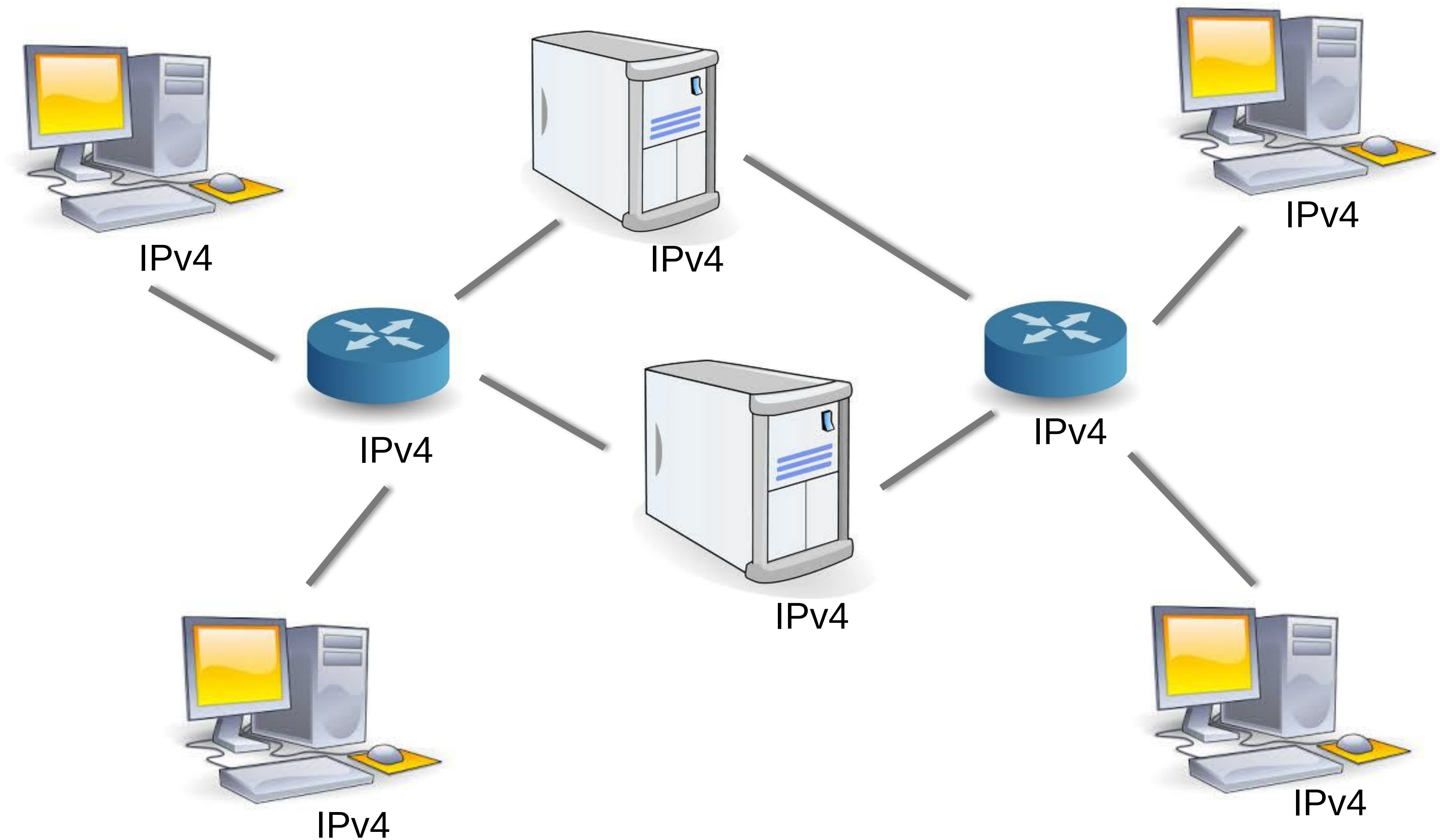
- How does the “Hello World!” look like?

What is the Web of Things?

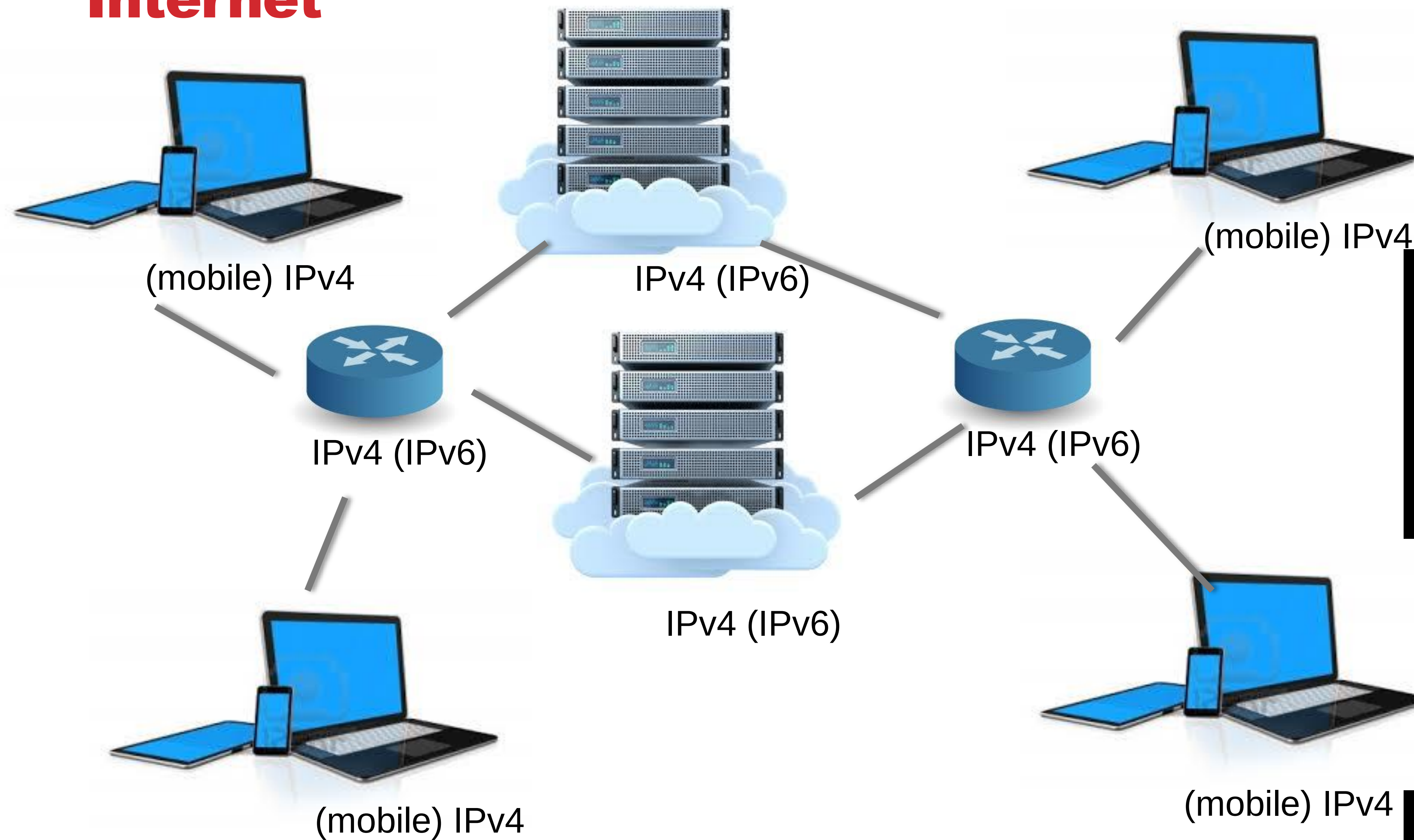
In order to answer the question we will look at the following differences:

- **The Internet vs the Web**
- The Internet of Things vs the Internet
- Web of Things vs the Web
- Web of Things vs the Internet of Things

Quick history: the "old Internet"



Quick history: The "contemporary Internet"



The Internet as we know it

www.facebook.com
www.amazon.com
.....

This is actually not the Internet….this is the Web. It’s HTTP (over IP).

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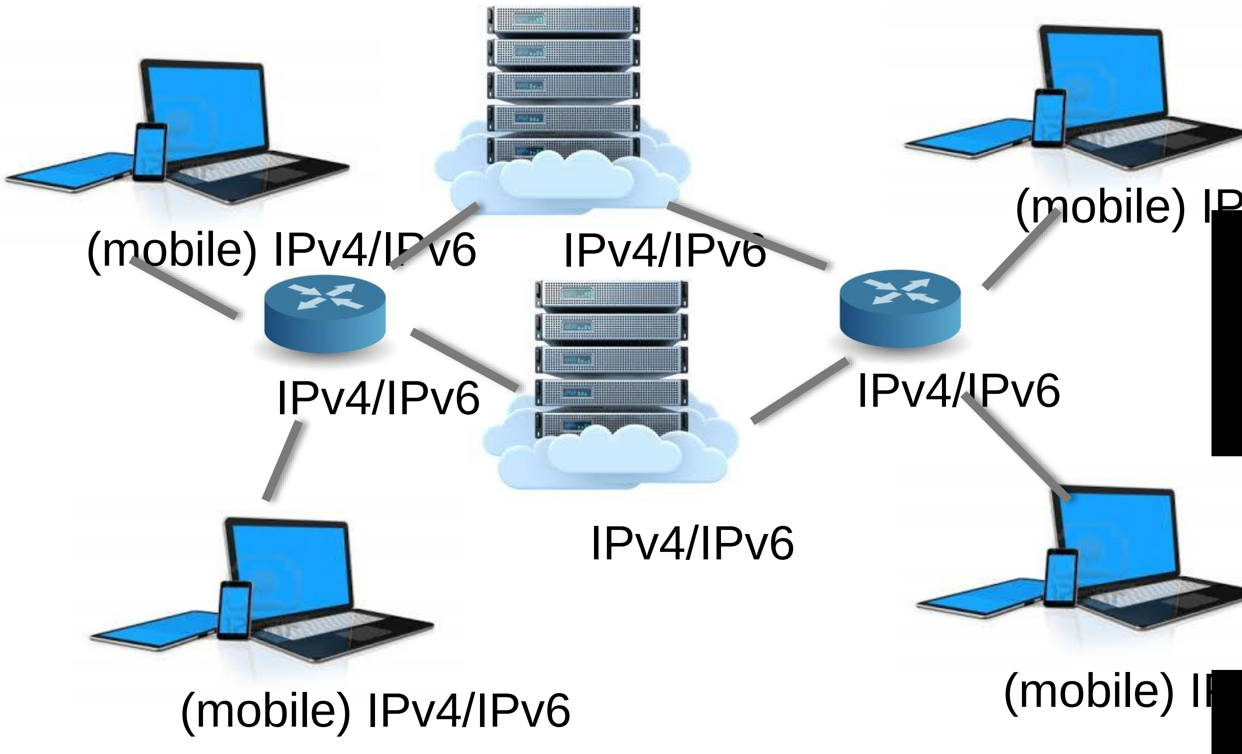
The “next Internet”: IoT/WoT





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Transition towards machine generated information

Past:

"manual input of information by 500 million or a billion users"[1]

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.[1]

[1] Pete Hartwell, How a Physically Aware Internet Will Change the World, Mashable, October 13, 2010.

How Web-of-things fits on the map?

	Description	Technologies
Web 1.0	**Static** HTML pages (web as we first learned it)	HTML, HTTP
Web 1.5	**Dynamic** HTML content (web as we know it)	Client side (JavaScript, DHTML, Flash, …), server side (CGI, PHP, Perl, ASP/.NET, JSP, …)
Web 2.0	**Participatory** information sharing, interoperability, user-centered design, and collaboration on the World Wide Web (web of people)	weblogs, social bookmarking, social tagging, wikis, podcasts, RSS feeds, many-to-many publishing, web services, … URI, XML, RDF, OWL, SparQL, …
Web 3.0	…definitions vary a lot – from Full Semantic Web to AI (web as we would need it)	http://en.wikipedia.org/wiki/Web_3.0#Web_3.0
Web of Things	Everyday devices and objects are connected by fully integrating them to the Web. (web as we would like it)	Well-accepted and understood standards and blueprints (such as URI, HTTP, REST, Atom, etc.) http://en.wikipedia.org/wiki/Web_of_Things

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What is the Web of Things?

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Web of Things vs Internet of Things: what is the difference?

Internet = Interconnected networks

- They are interconnected via IP (Internet Protocol)
- There are IP addresses in the internet, no domain names such as wikipedia.org
- Started around 1950 in a effort to make two computers talk to each other

Web = Linked documents and resources

- Uses HTTP
- The web needs the Internet underneath to function
- Started around 1980 in an effort to help people share data over the Internet

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The web as an enabler

- **the web enabled, among others, large scale behavioral, communication, social and linguistic studies,**

- **the *things* joining the web enable studying the world on far larger scale that ever before**

Analogy humans - WoT

Fortuna et al., Towards Building a Global Oracle: a Physical Mashup Using Artificial Intelligence Technology, International Workshop on the Web of Things, 2012.

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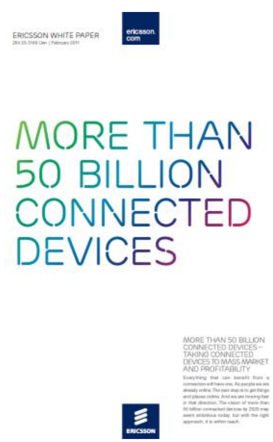
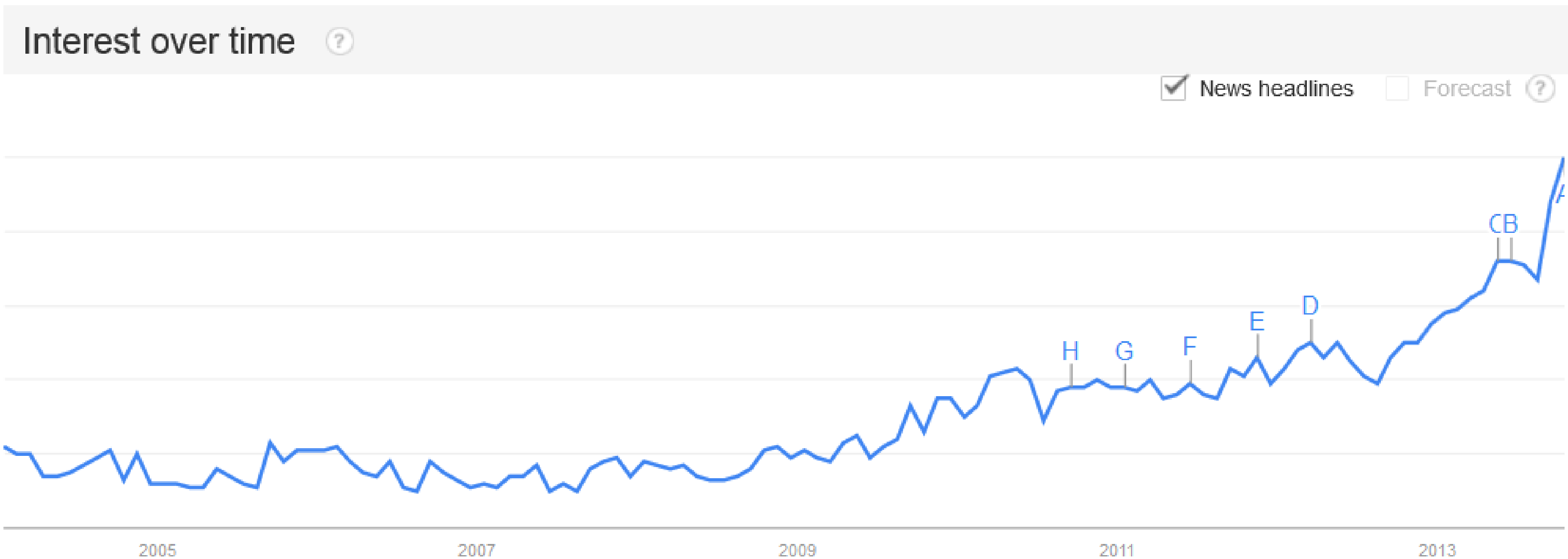
Market Research overview

- **Many consultancy and technology companies offer a range of market research material on “Internet/Web of Things/Everything”**
  - …in the following slides we collected some of the highlights from a number of reports

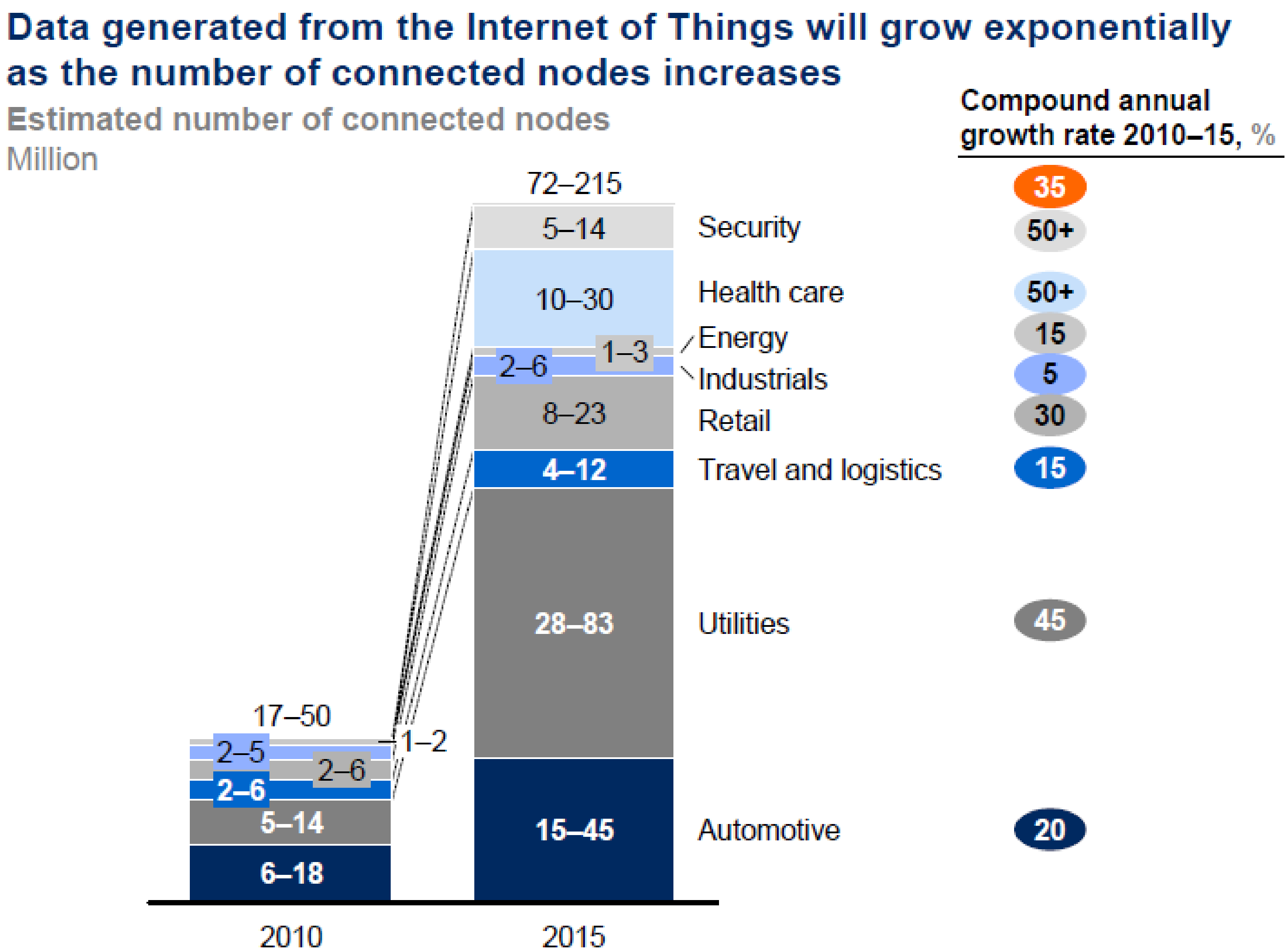


Goggle Trends: popularity of “Internet of Things” keyword



www.google.com/trends/explore?q=internet+of+things

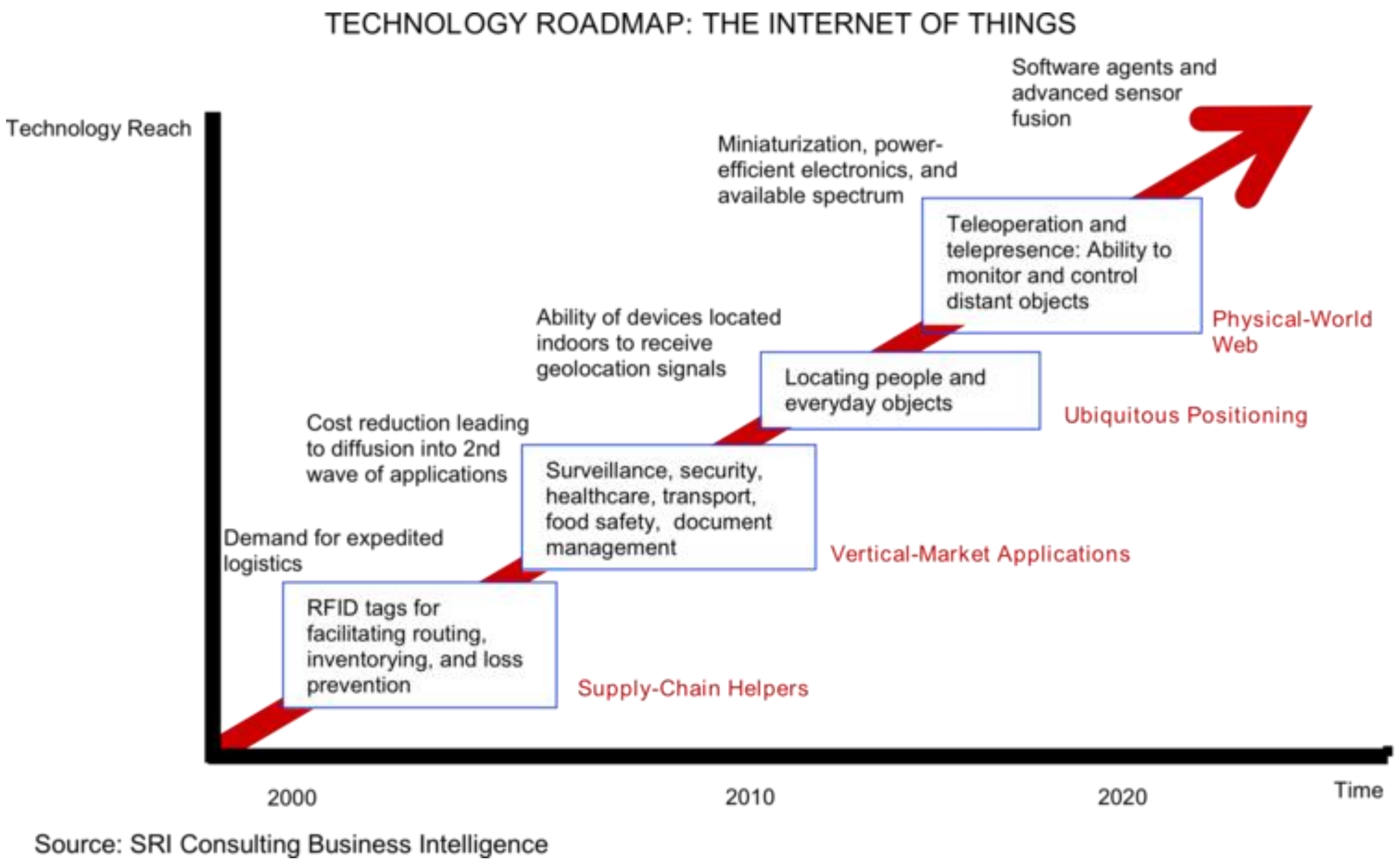
McKinsey: Data from “Internet of Things”



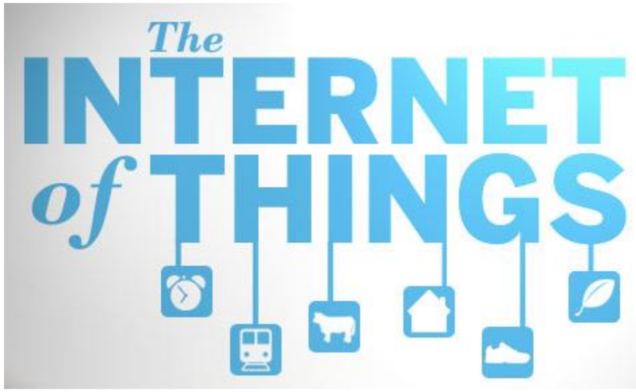
NOTE: Numbers may not sum due to rounding.

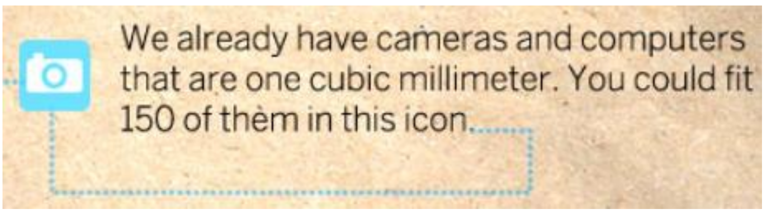
SOURCE: Analyst interviews; McKinsey Global Institute analysis

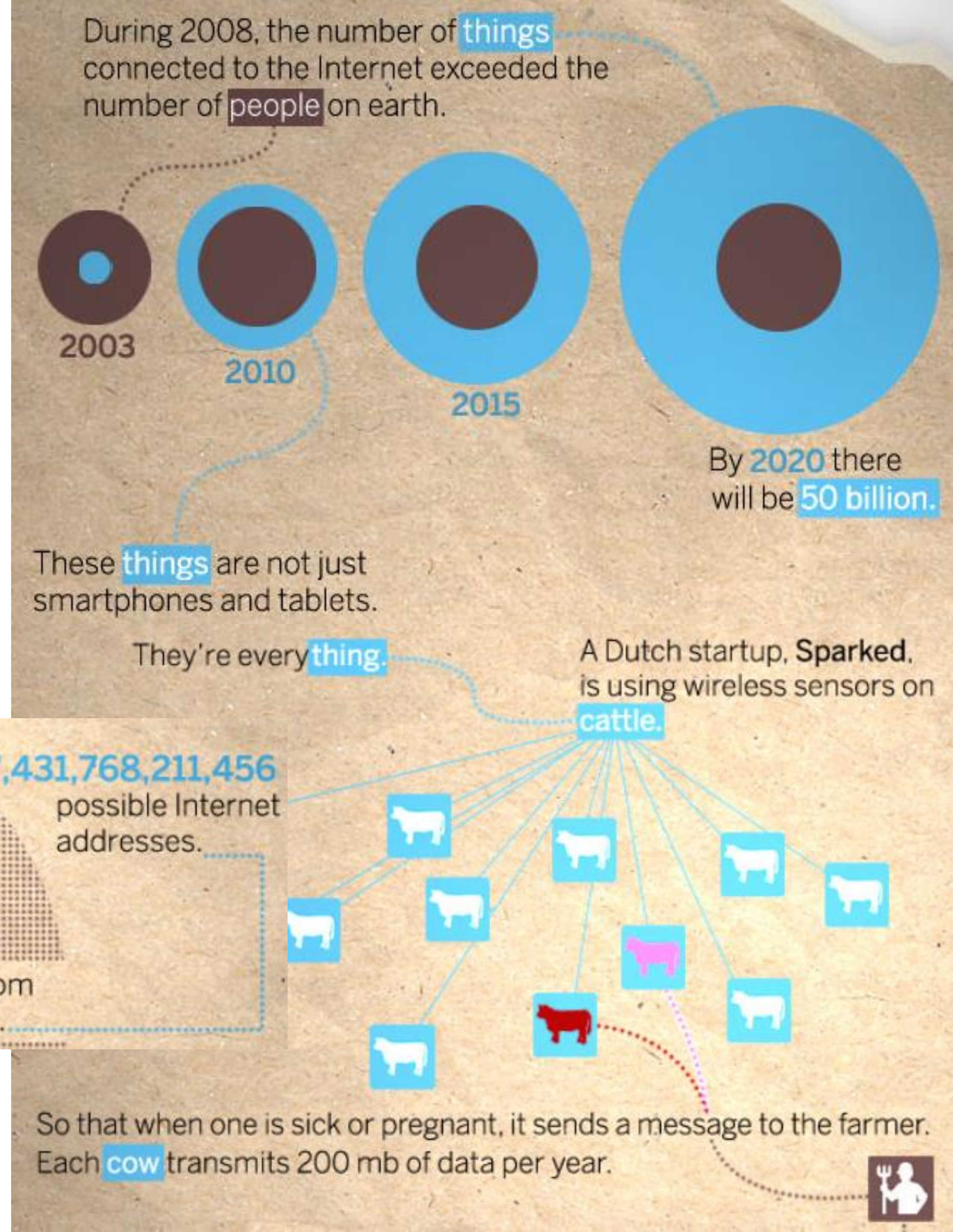
SRI: IoT Technology Roadmap



http://en.wikipedia.org/wiki/Internet_of_Things

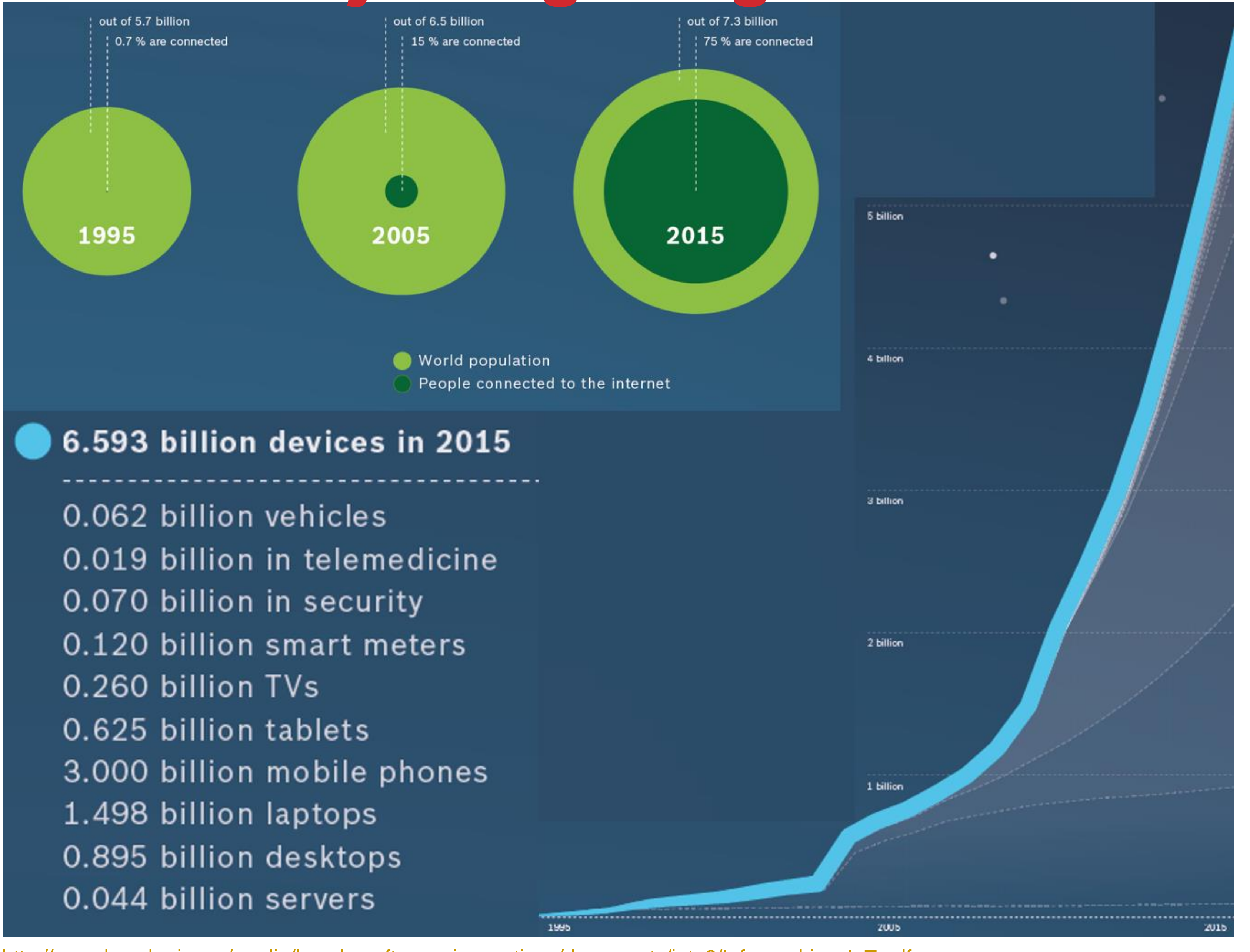




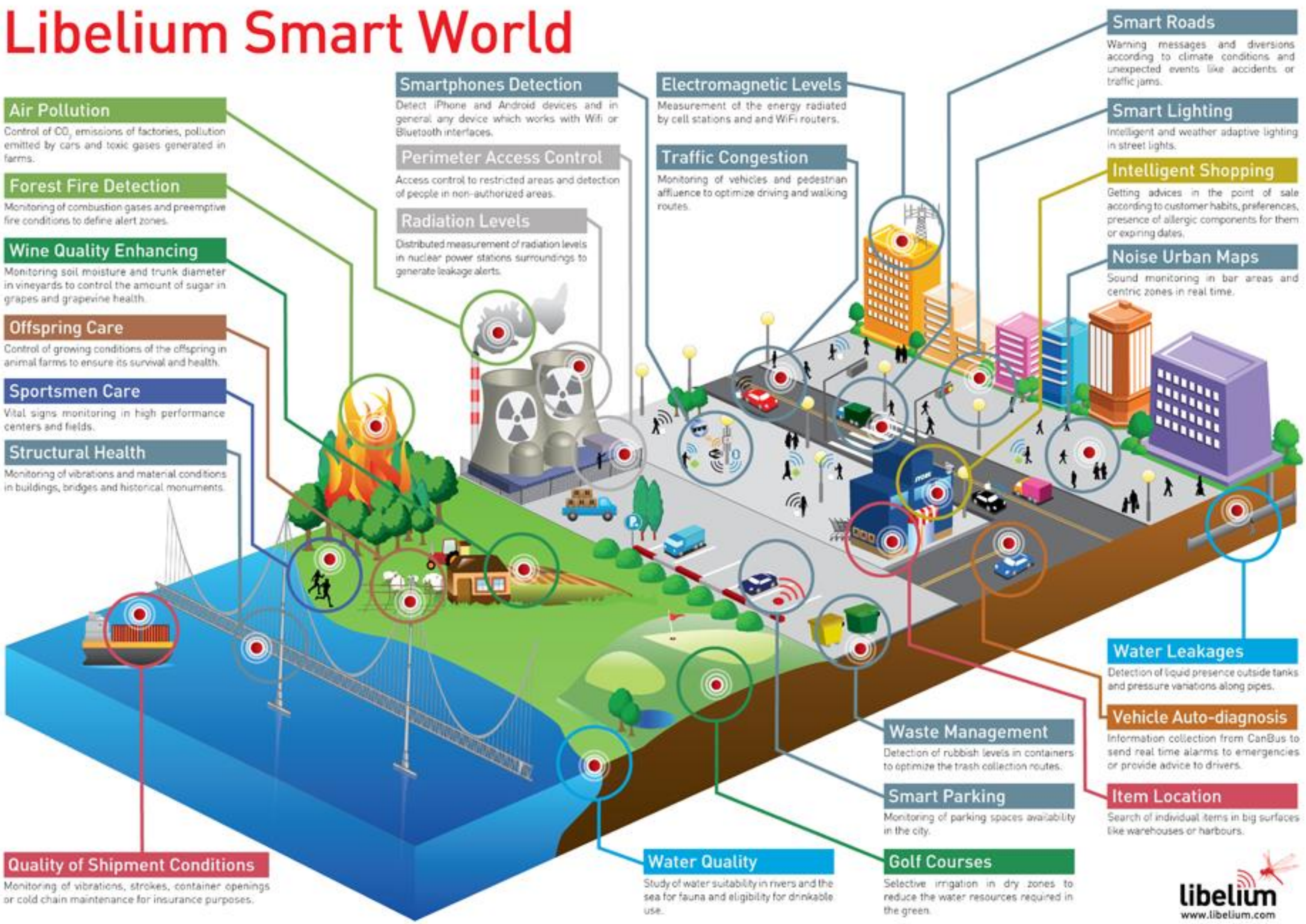


http://blogs.cisco.com/news/the-internet-of-things-infographic/

BOSH: Projecting IoT growth



http://www.bosch-si.com/media/bosch_software_innovations/documents/iot_2/Infographics_IoT.pdf



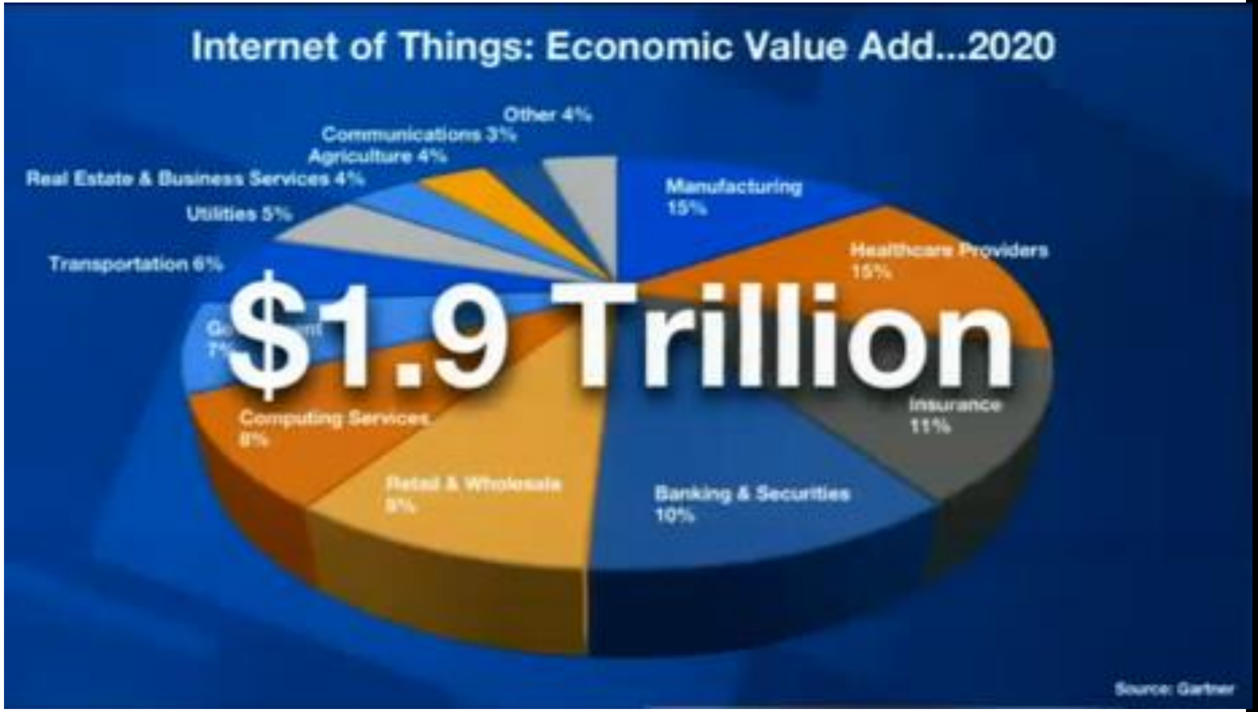
http://www.libelium.com/libelium-smart-world-infographic-smart-cities-internet-of-things/

Gartner: “IoT + Big Data” 2020 projection

“In 2009 there were 0.9 billion sensors and 1.6 billion personal devices …” “[That’s] roughly 2.5 billion things that were connected. By 2020, that will grow to become 30 billion things.

This uber-connectedness combined with the analytics capabilities promised by the big data technology trend will create new value for all organizations, spearheading an economic boom

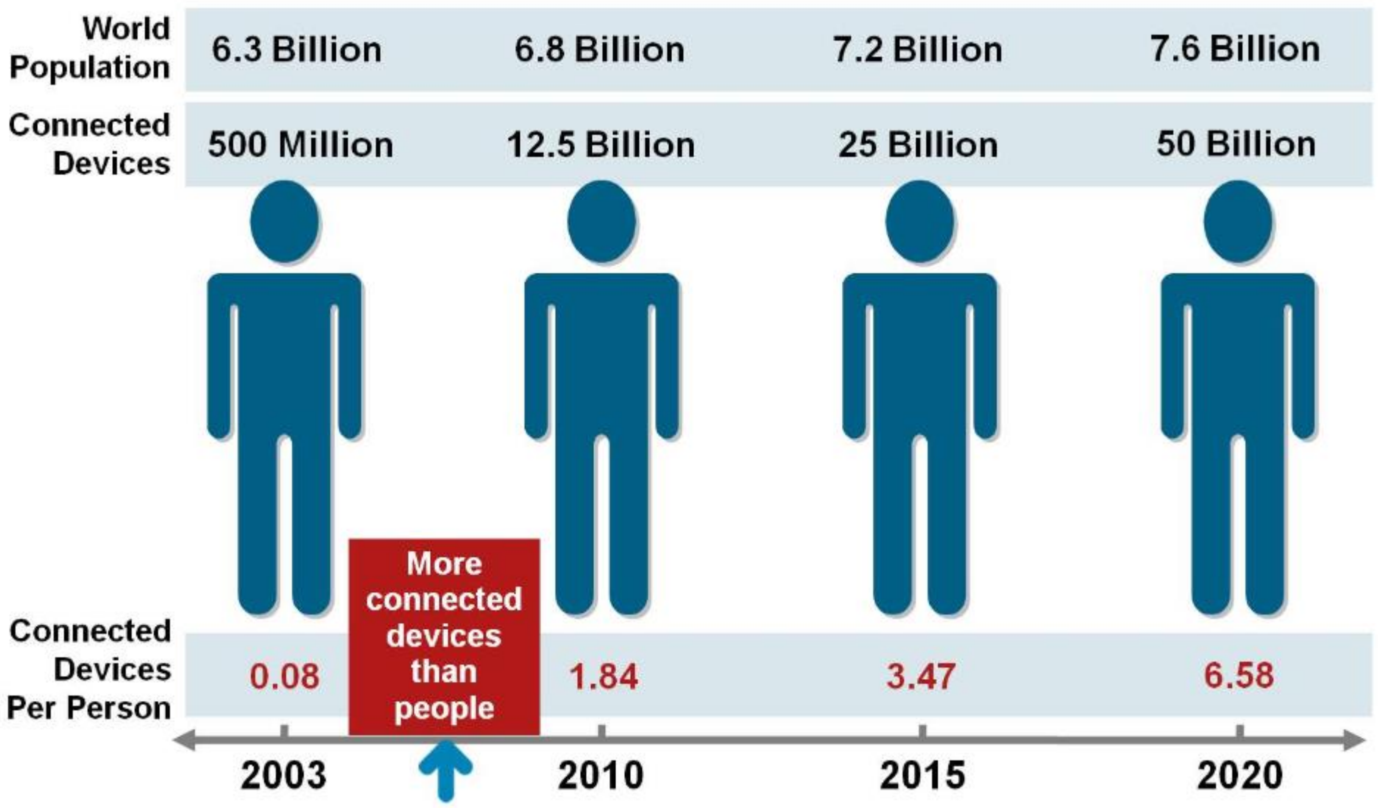
“Gartner projects that the total economic value-add for the Internet of things will be $1.9 trillion dollars by 2020”



http://www.datanami.com/datanami/2013-10-09/gartner:_internet_of_things_plus_big_data_transforming_the_world.html

CISCO: IoT Birth & Growth

Figure 1. The Internet of Things Was "Born" Between 2008 and 2009



Source: Cisco IBSG, April 2011

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CISCO: IoE (Internet of Everything)

The Internet of Everything:

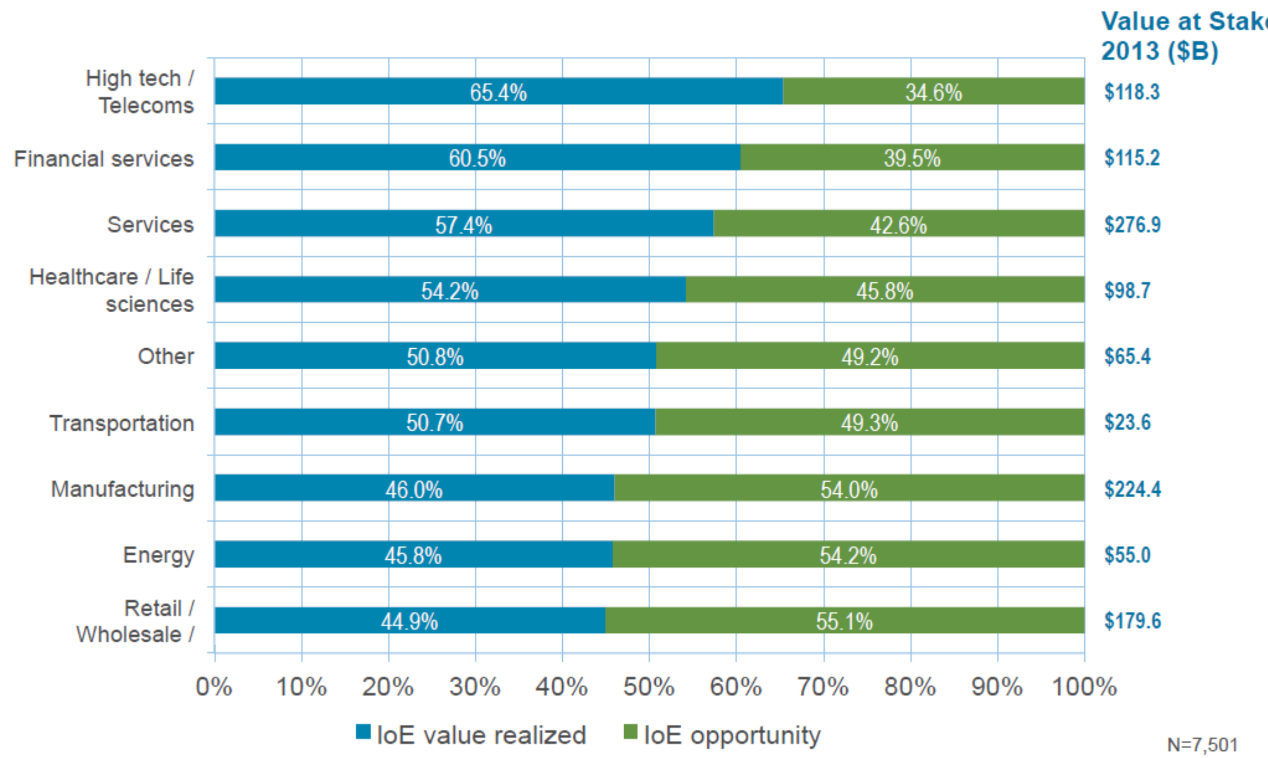
Internet of Everything:

Key Drivers

Key Challenges

Key Challenges

However, IT-Driven Industries Are Capturing the Greatest Share of This Value



http://www.cisco.com/web/about/ac79/docs/innov/IoE-Value-Index_External.pdf

Ericsson: More than 50 billion connected devices by 2020

Development of the networked world is progressing in three major waves

Some high-level, macro-economic trends and statistics. As a few examples, by 2020 there will be:

- 3 billion subscribers with sufficient means to buy information on a 24-hour basis to enhance their lifestyles and improve personal security.
- in mature markets, these customers will typically possess between 5-10 connected devices each.
- 1.5 billion vehicles globally, not counting trams and railways.
- 3 billion utility meters (electricity, water and gas).
- A cumulative 100 billion processors shipped, each capable of processing information and communicating

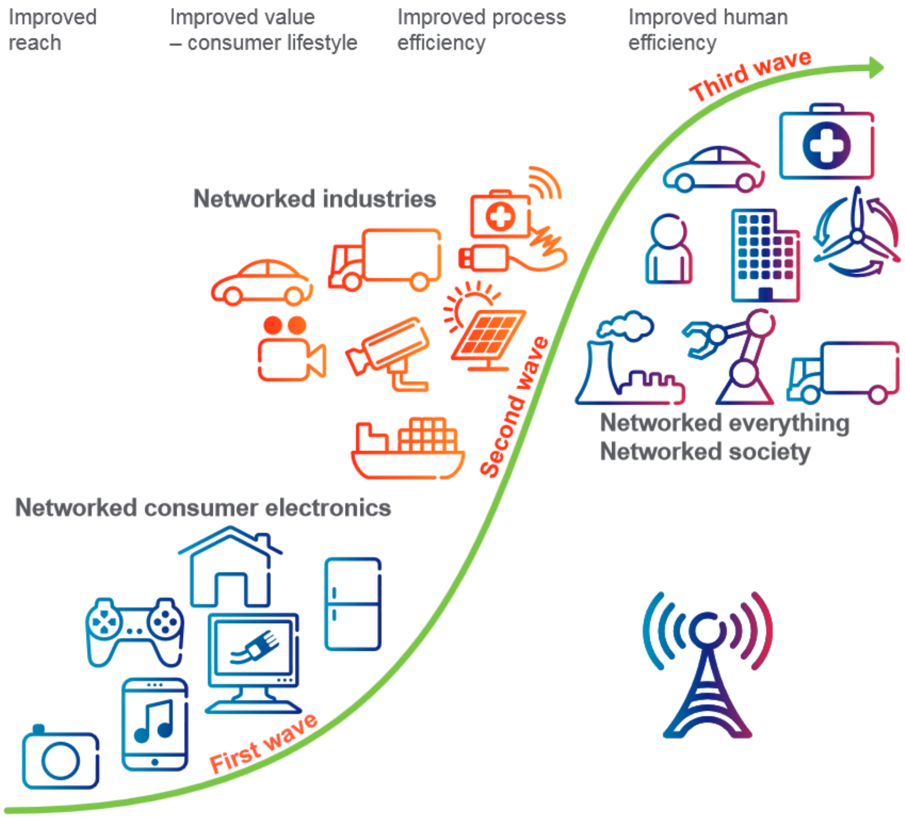


Figure 2. The three waves of connected device development.

http://www.ericsson.com/res/docs/whitepapers/wp-50-billions.pdf

McKinsey: Disruptive technologies

Sized applications of the Internet of Things could have direct economic impact of \$2.7 trillion to \$6.2 trillion per year in 2025

Sized applications	Potential economic impact of sized applications in 2025 (\$ trillion, annually)	Estimated scope in 2025	Estimated potential reach in 2025	Potential productivity or value gains in 2025
Health care	1.1–2.5	▪ \$15.5 trillion cost of treating chronic diseases ▪ \$400 billion cost of counterfeit drugs, 40% addressable with sensors ▪ 50 million nurses for inpatient monitoring – Developed world: \$30 per hour – Developing: \$15 per hour	▪ 70–80% mobile penetration in patients who account for bulk of health-care spending ▪ Counterfeit drug tracking – Developed world: 50–80% – Developing world: 20–50% ▪ Inpatient monitoring – Developed world: 75–100% – Developing: 0–50%	▪ 10–20% cost reduction in chronic disease treatment through remote health monitoring ▪ 80–100% reduction in drug counterfeiting ▪ 0.5–1.0 hour time saved per day by nurses
Manufacturing	0.9–2.3	▪ \$47 trillion in global manufacturing operating costs	▪ 80–100% of all manufacturing	▪ 2.5–5.0% saving in operating costs, including maintenance and input efficiencies
Electricity	0.2–0.5	▪ 27,000–31,000 TWh global electricity consumption ▪ \$200 billion spending on transmission lines ▪ 300 billion consumer minutes outage	▪ 25–50% of consumers could adopt energy management ▪ 25–50% of grid monitored through sensors ▪ 50–100% of consumer meters automated	▪ 2–4% reduction in demand peaks in the grid ▪ Reduction of total load on grid ▪ Operating/maintenance savings; shorter outage time through automated meters
Urban infrastructure	0.1–0.3	▪ 200–300 hours commuting time per urban worker per year ▪ \$200 billion spent on urban water ▪ \$375 billion cost of waste handling	▪ 40–70% of working urban population living in cities with smart infrastructure ▪ 50–70% of large urban regions adopting smart water infrastructure and waste handling	▪ 10–20% reduction in average travel time through traffic and congestion control ▪ 10–20% reduction in water consumption and leaks with smart meters and demand control ▪ 10–20% reduction in cost of waste handling
Security	0.1–0.2	▪ \$6 trillion cost of crime	▪ Adoption of advanced surveillance by countries accounting for 50–70% of global GDP	▪ 4–5% crime reduction through improved surveillance
Resource extraction	0.1–0.2	▪ \$3.7 trillion in global mining operating costs	▪ 80–100% of all resource extraction	▪ 5–10% saving in operating costs from productivity gains
Agriculture	~0.1	▪ \$1.2–1.3 trillion in agricultural production (wheat, maize, rice, soybeans, barley)	▪ 20–40% adoption of advanced irrigation systems and precision farming	▪ 10–20% increase in yields from precision application of fertilizer and irrigation
Retail	0.02–0.10	▪ \$200 billion lost due to stockouts	▪ 30–80% of retail adopting smart logistics	▪ 1.5–2.0% increased sales
Vehicles	~0.05	▪ \$630 billion in automotive insurance premiums[1]	▪ 10–30% of all insured cars equipped with sensors	▪ 25% reduction in cost of vehicle damage from collision avoidance and increased security[1]
Other potential applications (not sized)				
Sum of sized potential economic impacts	**2.7–6.2**			

1 Automotive premiums used as proxy for cost of collisions.

NOTE: Estimates of potential economic impact are for some applications only and are not comprehensive estimates of total potential impact. Estimates include consumer surplus and cannot be related to potential company revenue, market size, or GDP impact. We do not size possible surplus shifts among companies and industries, or between companies and consumers. These estimates are not risk- or probability-adjusted. Numbers may not sum due to rounding.

http://www.mckinsey.com/insights/business_technology/disruptive_technologies

Part I. Motivation & background outline

Web Of Things

- What is it? What problems can it solve?

Architectural considerations

- How it looks like? 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?

Quick start recipes

- How does the “Hello World!” look lilke?

Architectural considerations

Generic vertical	An instance of a vertical
Applications	Traffic today app
Web publishing	RSS feed
Data processing	Real time event detection software
Data storage	Utility company data center
Data collection	Utility company server
Embedded software	Proprietary firmware
Communication technology	6LoWPAN
Embedded device	Microcontroller with sensors
Physical object	Public light pole

Architectural considerations

Generic vertical

Applications
Web publishing
Data collection
Embedded software
Communication technology
Device

An instance of a vertical

MyHome status page
Html
Home computer
RTOS
Bluetooth
Microcontroller with sensors

Main Components of a vertical

Layer	Components	Example
Apps and Services	Applications	Traffic today app
	Web publishing	RSS feed
"Glue"	Data processing	Real time event detection software
	Data storage	Utility company data center
	Data collection	Utility company server
	Embedded software	Proprietary firmware
	Communication technology	6LoWPAN
"Things"	Embedded device	Microcontroller with sensors
	Physical object	Public light pole

From raw measurements to meaningful information: iDiary (1/3)

Apps and Services

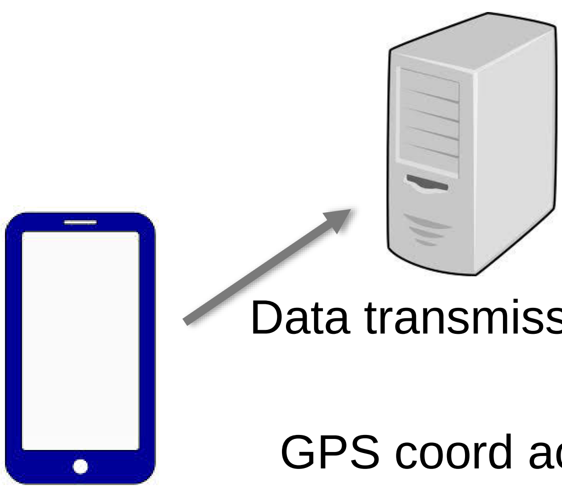
"Glue"

"Things"

iDiary:
Searchable diary
Summary of visited places
Summary of activities

Text to activities using Latent Semantic Analysis on Yelp reviews

Reverse geo-coding from GPS coordinates to text using external web services



Trajectory clustering on coresets

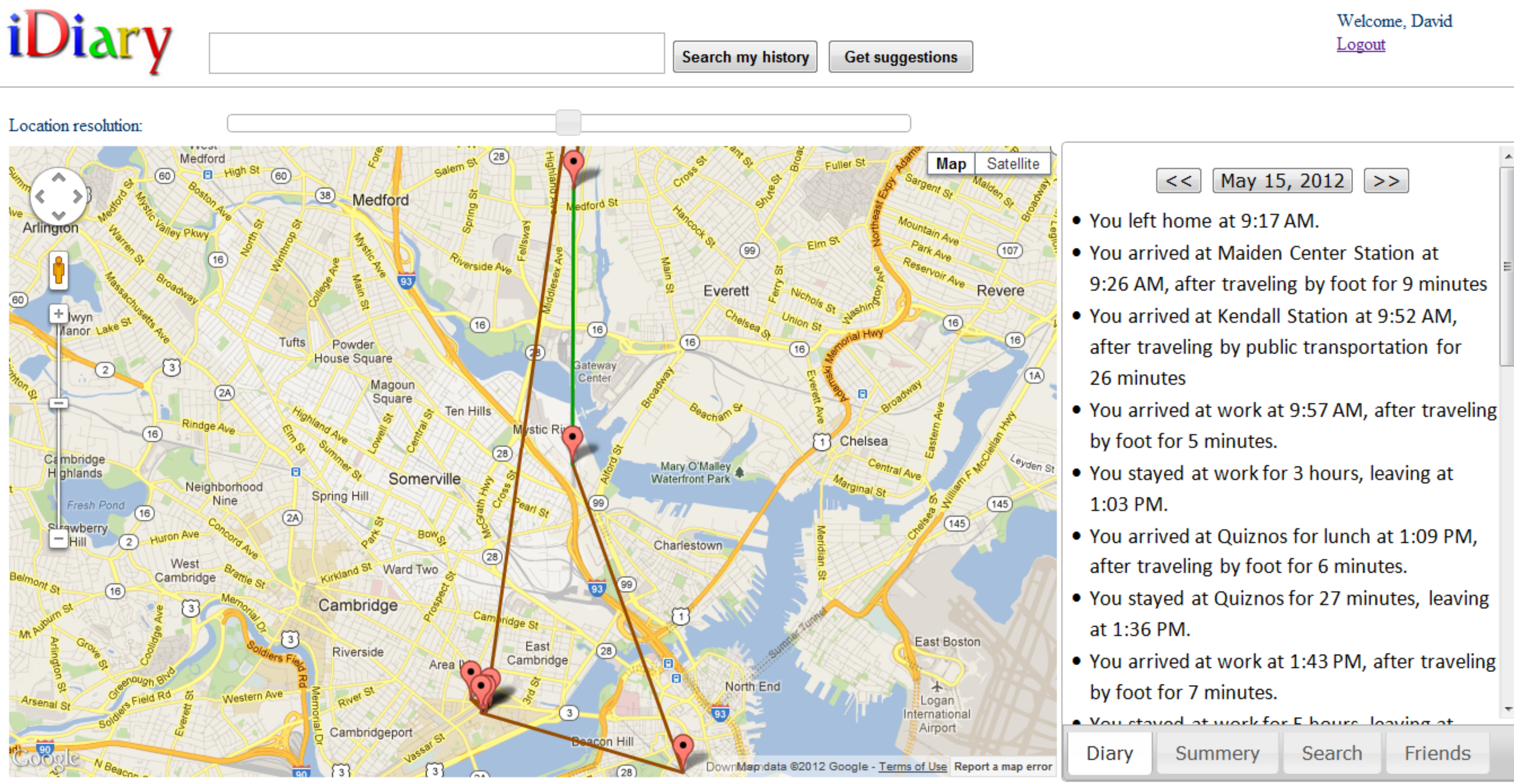
Stream data compression (coresets)

Data transmission

GPS coord acquisition application

D. Feldmann, A. Sugaya, C. Sung, D. Rus, "iDiary:
From GPS Signals to a Text-Searchable Diary", SenSys 2013, Rome, Italy.

From raw measurements to meaningful information: iDiary (2/3)



D. Feldmann, A. Sugaya, C. Sung, D. Rus, “iDiary: From GPS Signals to a Text-Searchable Diary”, SenSys 2013, Rome, Italy.

From raw measurements to meaningful information: iDiary (3/3)

iDiary

restaurants July 11

Search my history | Get suggestions

Welcome, Gary
Logout

Restaurants you visited on July 11th, 2012

1. Anna's Taqueria

   You were here on July 11th from 7:03 PM to 7:31 PM, with John Smith, Foo Bar, and 3 others.

   You have been here 142 other times.

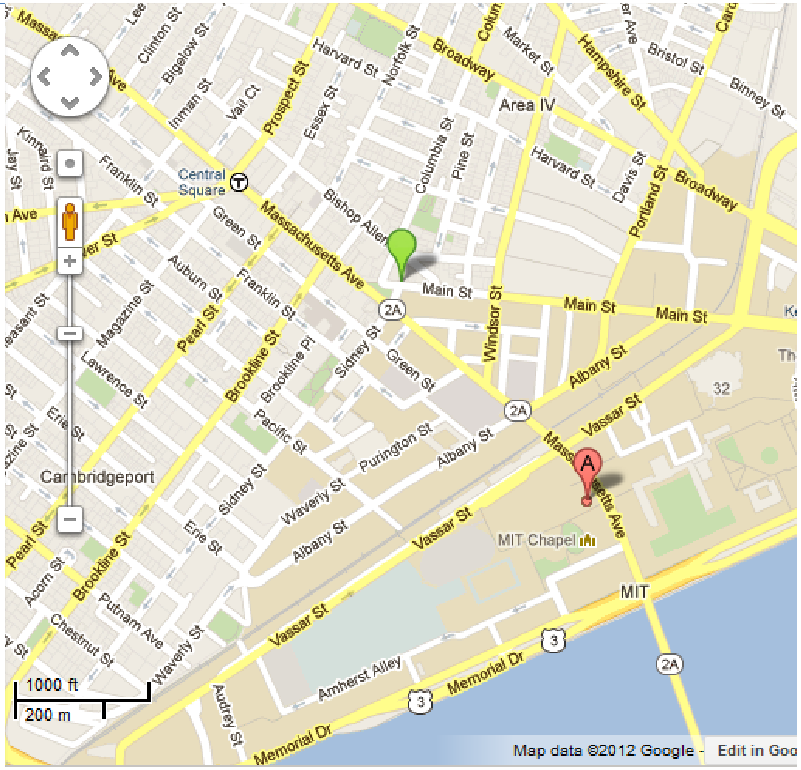
   View similar restaurants

2. Toscanini's Ice Cream

   You were here on July 11th from 7:44 PM to 7:58 PM, with Tim Yang, John Smith, and 4 others.

   You have been here 17 other times.

   View similar restaurants



D. Feldmann, A. Sugaya, C. Sung, D. Rus, "iDiary: From GPS Signals to a Text-Searchable Diary", SenSys 2013, Rome, Italy.

From raw measurements to meaningful information: FixtureFinder (1/3)

fixture discovery system that automatically infers the existence of electrical and water fixtures in the home

(a) Smart Power and Water Meters

(b) In-home Sensors

(c) Ground Truth Sensors

“Things”

V. Srinivasan, J. Stankovic, K. Whitehoue, FixtureFinder: Discovering the Existence of Electrical and Water Fixtures, IPSN April 2013.

From raw measurements to meaningful information: FixtureFinder (2/3)

The goal of the FixtureFinder algorithm is to combine smart meters with in-home sensors to form a fused data stream, and to discover frequently repeating patterns within that stream.

- **it will detect when a 5 liter/minute water flow repeatedly co-occurs with activity in a particular motion sensor**

“Glue”

Step IV - the usage events are clustered into groups that represent the fixtures that have been discovered.

Step III, the edge pairs are matched in rising/falling sequences called usage events

Step II - data streams are fused by finding events in multiple streams That frequently co-occur in time, and combining them to creating edge pairs.

Step I - uses edge detection to compute a sequence of timestamped rising and falling edges in each data stream.

V. Srinivasan, J. Stankovic, K. Whitehoue, FixtureFinder: Discovering the Existence of Electrical and Water Fixtures, IPSN April 2013.

From raw measurements to meaningful information: FixtureFinder (3/3)

Apps and Services

While being an extremely interesting system, presenting the final user with easy to understand information seems to have been outside the scope of the paper.

Since in the case of electricity and water, the space of possible events is rather limited, perhaps manual templates reporting on the events would be sufficient for an app.

Alternatively, events could be manually annotated using for instance Linked Data. These annotations can be used, similar as in iDiary for searching, logging, etc.

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The “things”

“Things”

Embedded device

Physical object

Microcontroller with sensors

Public light pole

= embedded device + physical object (smart public light pole)

= sensor/actuator node

= mobile phone

= a set of sensor nodes and/or embedded device + physical things which are abstracted as one “thing” (large water tank + set of sensor nodes monitoring water level, temperature and purity)

Definitions of components related to things

physical object

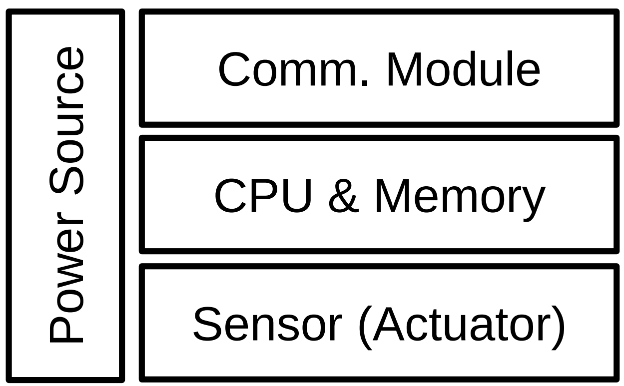
- An object built for fulfilling other tasks than computing
  - Coffee mug, show, light pole, washing machine, electric oven, fruit press, water tank

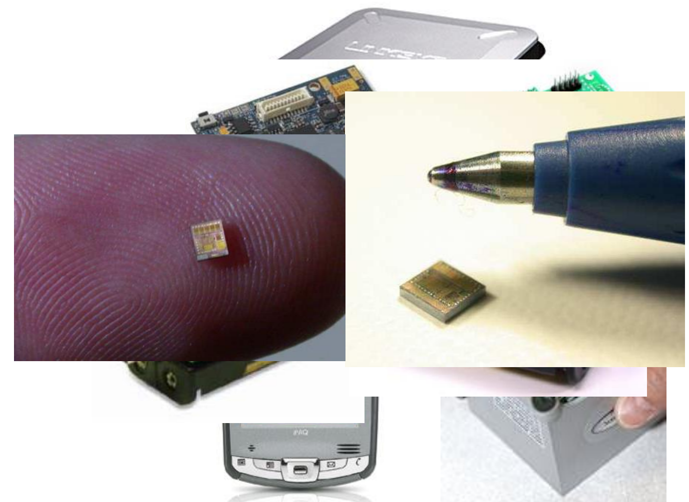
sensor

- a material or passive device which changes its (conductive) properties according to a physical stimulus
  - Thermo couple (temp->voltage), photo resistor (light->resistance variations), etc.

Sensor nodes and their structure

= Sensors + Microcontroller + Communication Module + Power Source

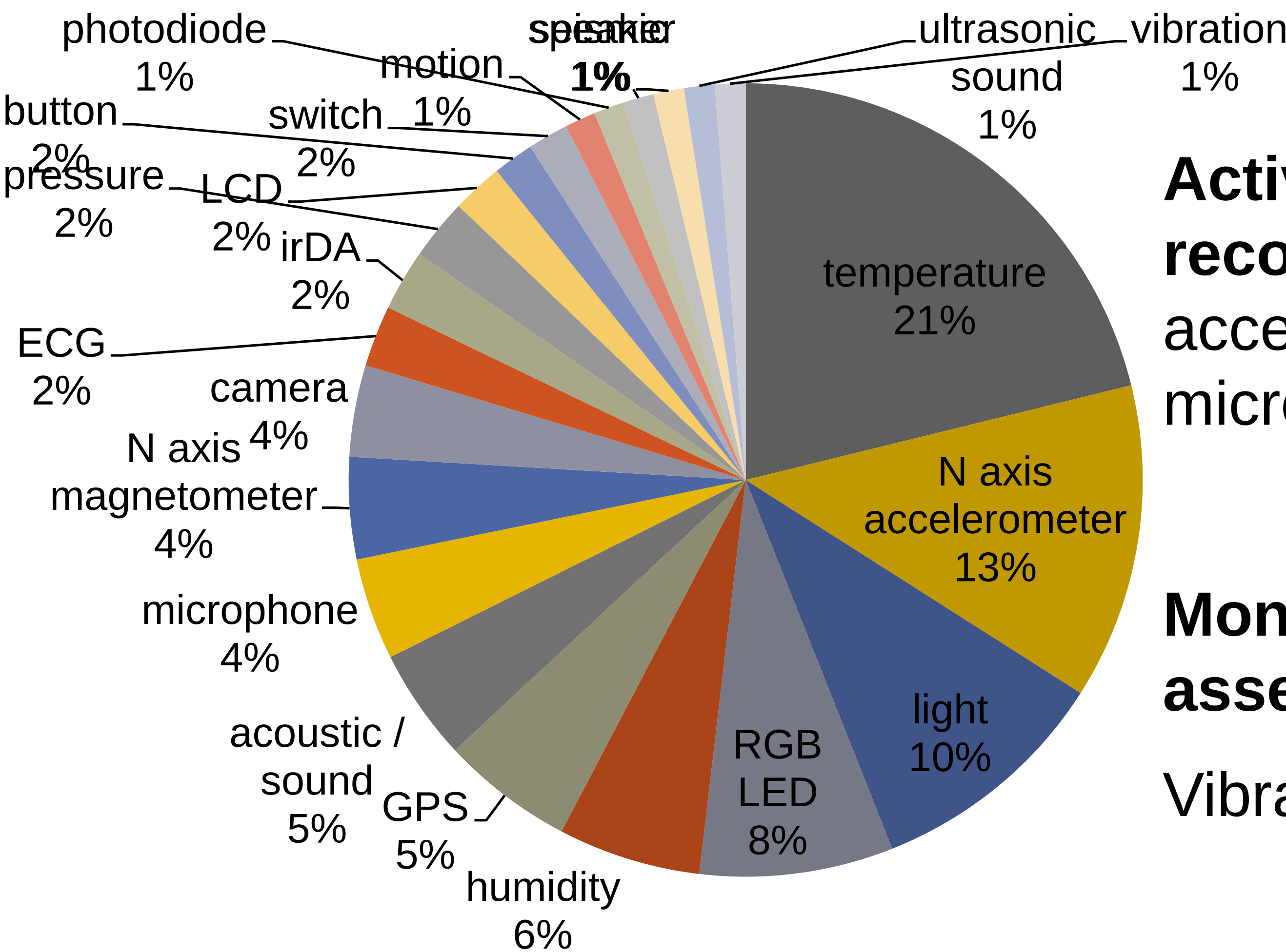




Classification:

- adapted/augmented general-purpose computers
- embedded sensor modules
- system on chip (SoC) solutions

Other types of sensors



Activity recognition: N-axis accelerometer, microphone, camera

Monitoring valuable assets:

Vibration, humidity

…endless combinations

Existing solutions for sensor nodes

Solutions developed in **research community or by groups of enthusiasts**.

- Combine HW components from different produces (for radio, it seems that TI chips are used in vast majority of ‚products‘).
- open-source experimental software such as Contiki OS, TinyOS (& NesC), Nano-RK, FreakZ stack (except for Arduino/Libelium where OEM radio is used whilst crowdsourcing is happening on the level of easy microcontroller programming.
- open source development tools are usually used.

Commercial solutions from particular producers (TI, Atmel, Microchip,…)

- composed of components sold by produces themselves.
- development kits can usually be used with proprietary integrated development environments and allow compiling of certified stacks (most often Zigbee).

Modules assembled by **companies trying to sell software solu**tions

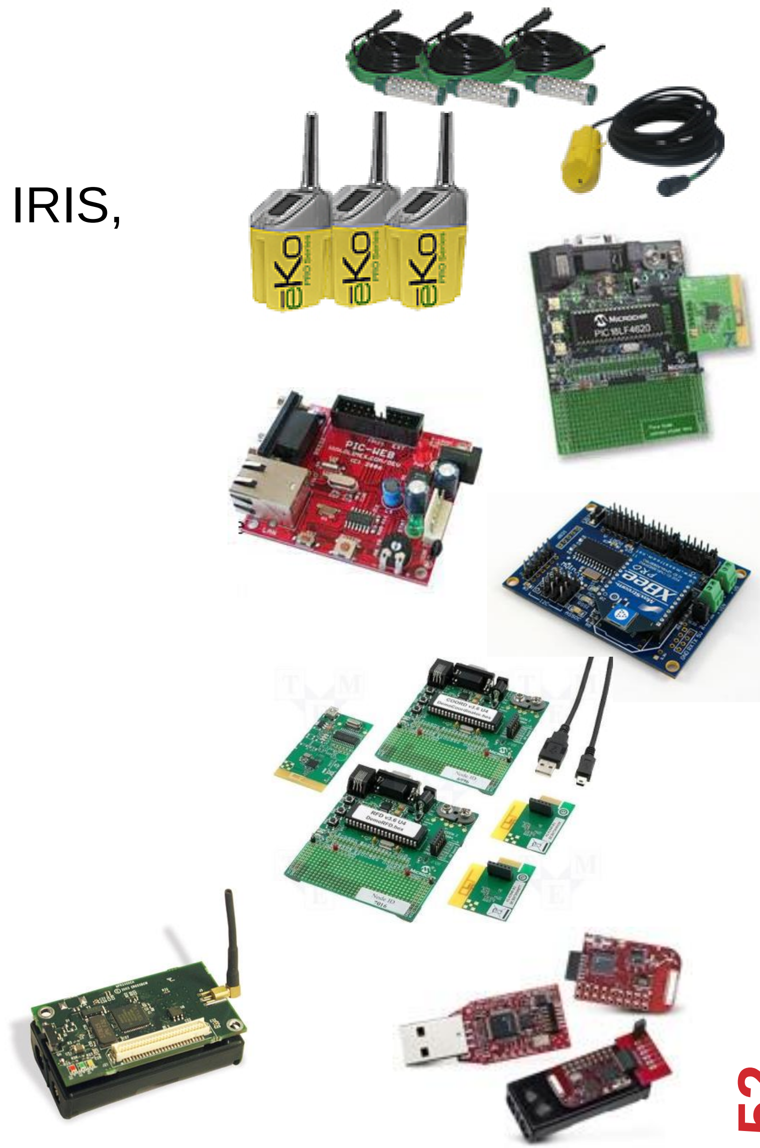
- Sun is in this case promoting the use of Java for sensor networks
- Sensinode is selling one of the 6LoWPAN ports.

Examples of the three categories of solutions

- FreakLabs Chibi
- Memsic (ex. Crossbow) MICAz/ MICA2, IRIS, TelosB, eKo kit
- CMU FireFly
- GINA
- Arduino/Libelium (XBee)

- TI eZ430-RF2500
- Microchip PICDEM Z
- Atmel RZ600
- Ember InSight
- Jennic JN5148

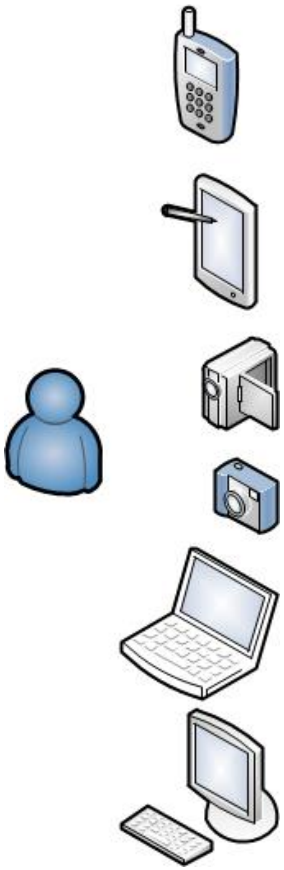
- SunSPOT
- Sensinode
- NanoSensor



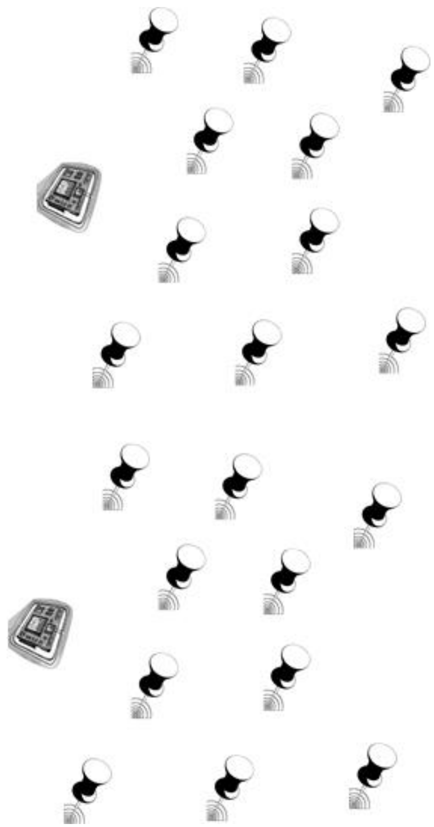
Why are sensor nodes different than other computing devices?

- Most SNs are application specific.
- Asymmetric, highly directional information flow (data fusion).
- Energy is highly constrained.
- Networks of SNs may have huge amount of nodes.
- Application run-time is extremely long.

Sensor nodes vs computing devices



Personal devices



Sensor nodes

Diminishing maintenance costs:

- Integrating sensors into personal computing devices such as phones/laptops
- Efficient remote configuration and management
- Disposable

Part I. Motivation & background outline

- **Web Of Things**
  - What is it? What problems can it solve?
- **Architectural considerations**
  - How it looks like? 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?
- **Quick start recipes**
  - How does the “Hello World!” look lilke?

The “glue”

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

“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

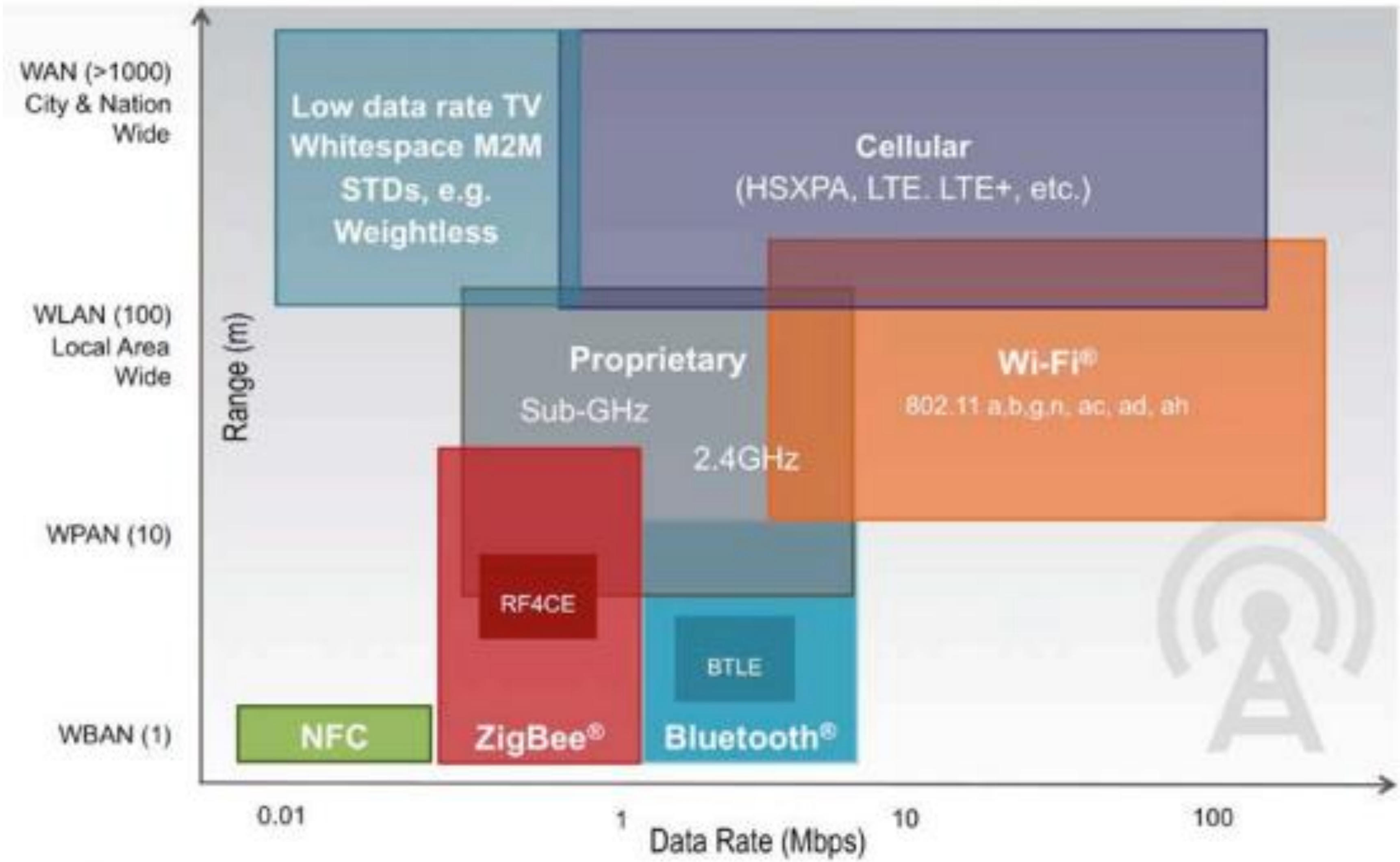
6LoWPAN

Communication technology

Communication medium

- **Wireless and/or Wired point-to-point or point-to-multipoint**
- **Several open and proprietary standards exist, operating in different frequency bands with various rate and range performance**
  - ZigBee, Bluetooth, RFID, WiFi, etc.

Available wireless technologies



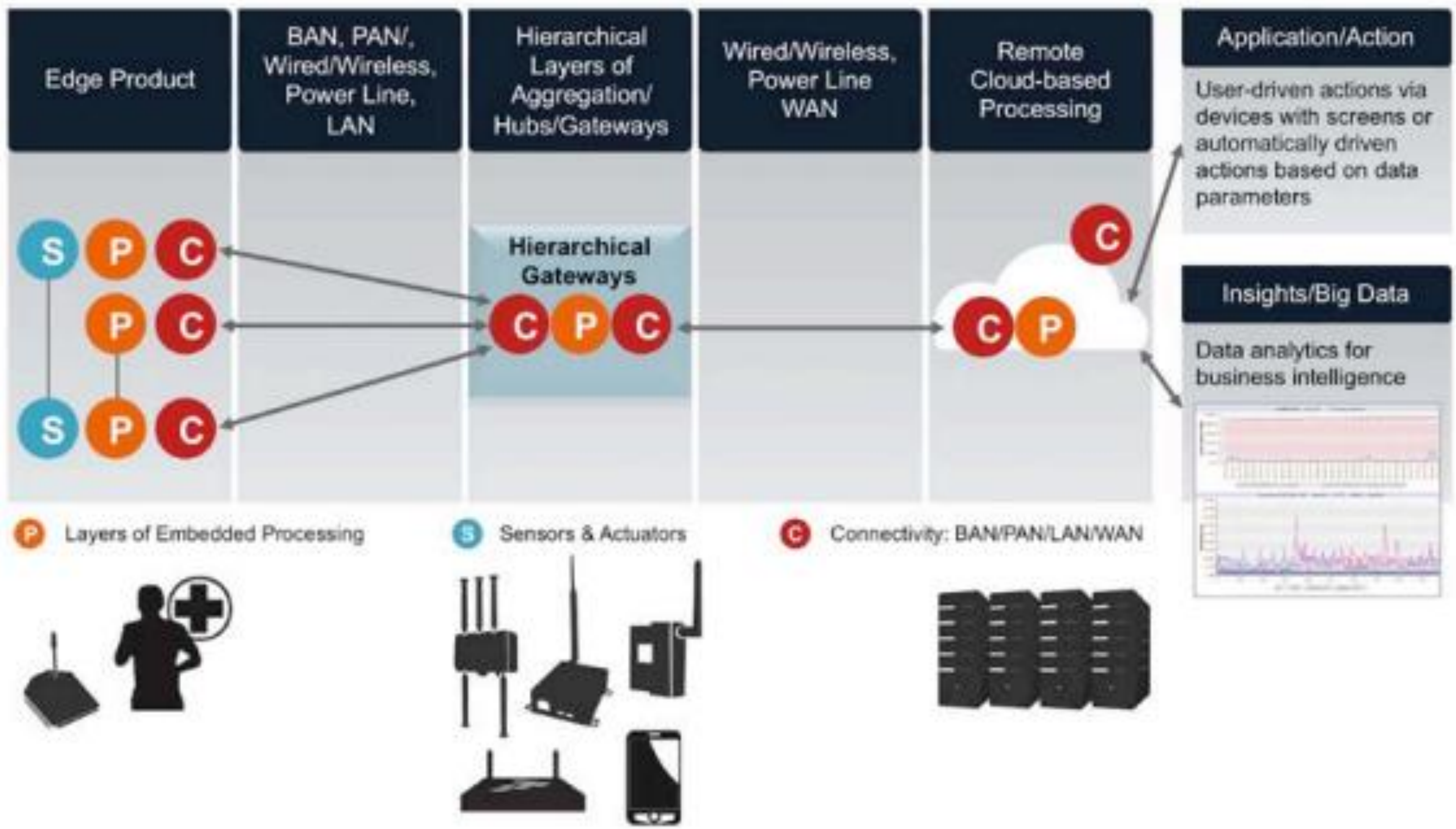
http://www.freescale.com/files/32bit/doc/white_paper/INTOTHNGSWP.pdf

Communication technology

Network

- only the devices and the links between them can be seen, the communication medium is hidden
- it has a hierarchical structure
- The network layer protocols are less standardized as for the internet:
  - IPv4, IPv6 can be used but not available in most commercial products
  - proprietary,
  - other..

The most common sense-process-communicate hierarchy



http://www.freescale.com/files/32bit/doc/white_paper/INTOTHNGSWP.pdf

Making sense of the data

Some examples presented already

Explained in the second part of the tutorial

Part I. Motivation & background outline

- **Web Of Things**
  - What is it? What problems can it solve?
- **Architectural considerations**
  - How it looks like? What are its components?
- **The “Things”**
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  - How do things stick together?
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  - What can be built on top of it?
- **Quick start recipes**
  - How does the “Hello World!” look lilke?

Apps and services

Apps and Services

Applications

Web publishing

Traffic today app

RSS feed

Combine data, presentation or functionality from several sources (mash-up) to create new services.

Things generate only part of the data sources

Selected demos shown throughout the presentation.

Part I. Motivation & background outline

- ✓ **Web Of Things**
  - What is it? What problems can it solve?
- ✓ **Architectural considerations**
  - How it looks like? 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?
- **Quick start recipes**
  - How does the “Hello World!” look like?

SensorLab

Programing the “things”

C… lex and time c… ming n…

- tool… E, co…
- microc… …ode
- re…
- com…
- protocol sta… …a… through AP… …a… …lib…
- operating system (n… …ded fo… …e tasks)
- virtual machine (opt… …)

All this is not necessary anymore unless you want to achieve something rather specific.

Web programmer (rather than embedded programmer) products and do it yourself kits exist.

Some developer friendly hardware solutions for WoT compared

Solution	Pro	Con	Cost
Arduino	big community, open-source hw, documentation	Computational power	25-90 €
Nanode	built-in web connectivity, open-source hw, Arduino compatible	Computational power, documentation	~ 35 €
openPICUS	built-in web connectivity, good documentation, support	Computational power, development windows oriented	~ 70 €
Netduino	open-source hw, documentation, arduino compatible, .NET programming	Computational power, development windows oriented	25-90 €
libelium	documentation, solid, radio boards, sensors boards, over the air programming, libelium support.	Computational power	~ 150 €

Hacking the Internet of Things, Hardware solutions compared, Lelylan Chief, Mar 09, 2012.

Decision process

Before starting, the following questions should be answered:

What is the scope or application?

- Monitoring measurements?

What is the scenario?

- A thing with embedded web service?
- A set of things connected through a gateway?

What programming language?

- Options: C, nesC, Java, C# or ***Javascript***

What is the publishing infrastructure?

- None, custom, third party**.**

How to start?

If you want to get a flavor of what is possible today with existing technologies, a good way to start is:

Ninjablocks , Twine and Sen.se

A good idea is to also have a look at kickstarter for any new gadgets and platforms

Summary

In part one we

- Provided an explanation on the WoT by comparing it to IoT, Internet and Web
- A market study of the area
- Provided an overview of possible verticals of different complexity
- Inspiring examples of what problems can be solved with these verticals

Outline

Part I. Motivation & background

Part II. Technology and tools for exploiting the WoT

Part III. Demos, Tools & Research directions

Outline

Part II. Technology and tools for WoT data

Information infrastructure for “Web of Things”

Conceptualization of sensors domain

Stream Data Processing

Stream Mining

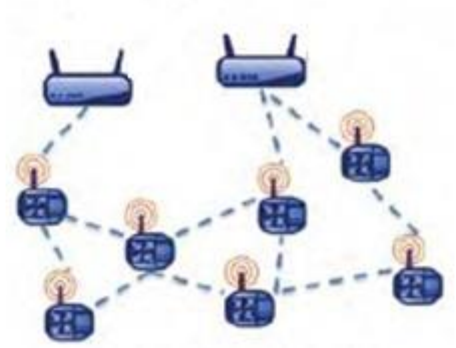
Complex Event Processing

Anomaly Detection

INFORMATION INFRASTRUCTURE FOR “WEB OF THINGS”

Why we need WoT?

…the key objective is to make decision maker more efficient by understanding observed environment



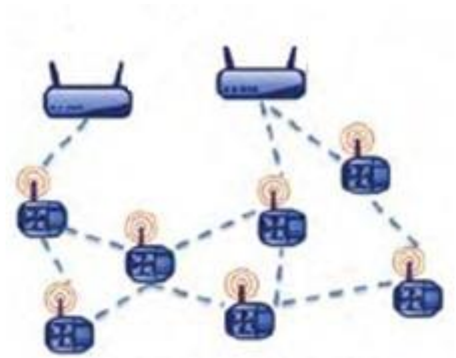
Sensor network

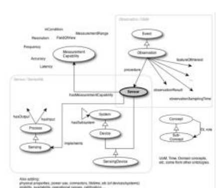
Decision maker

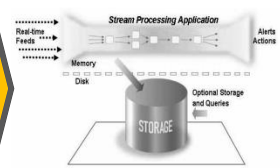
Why we need WoT?

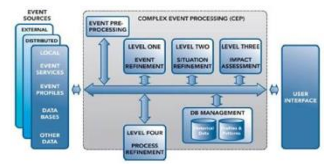
…the key objective is to make decision maker more efficient by understanding observed environment

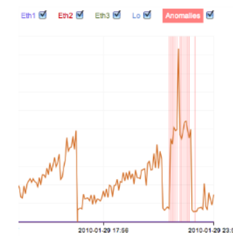
To achieve this, we need to introduce several information layers between sensor setup and decision maker:

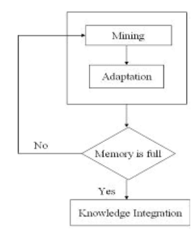












Sensor network

Conceptualization (ontology)

Streaming Storage

Stream Mining; Complex Events; Anomaly Detection

Decision make

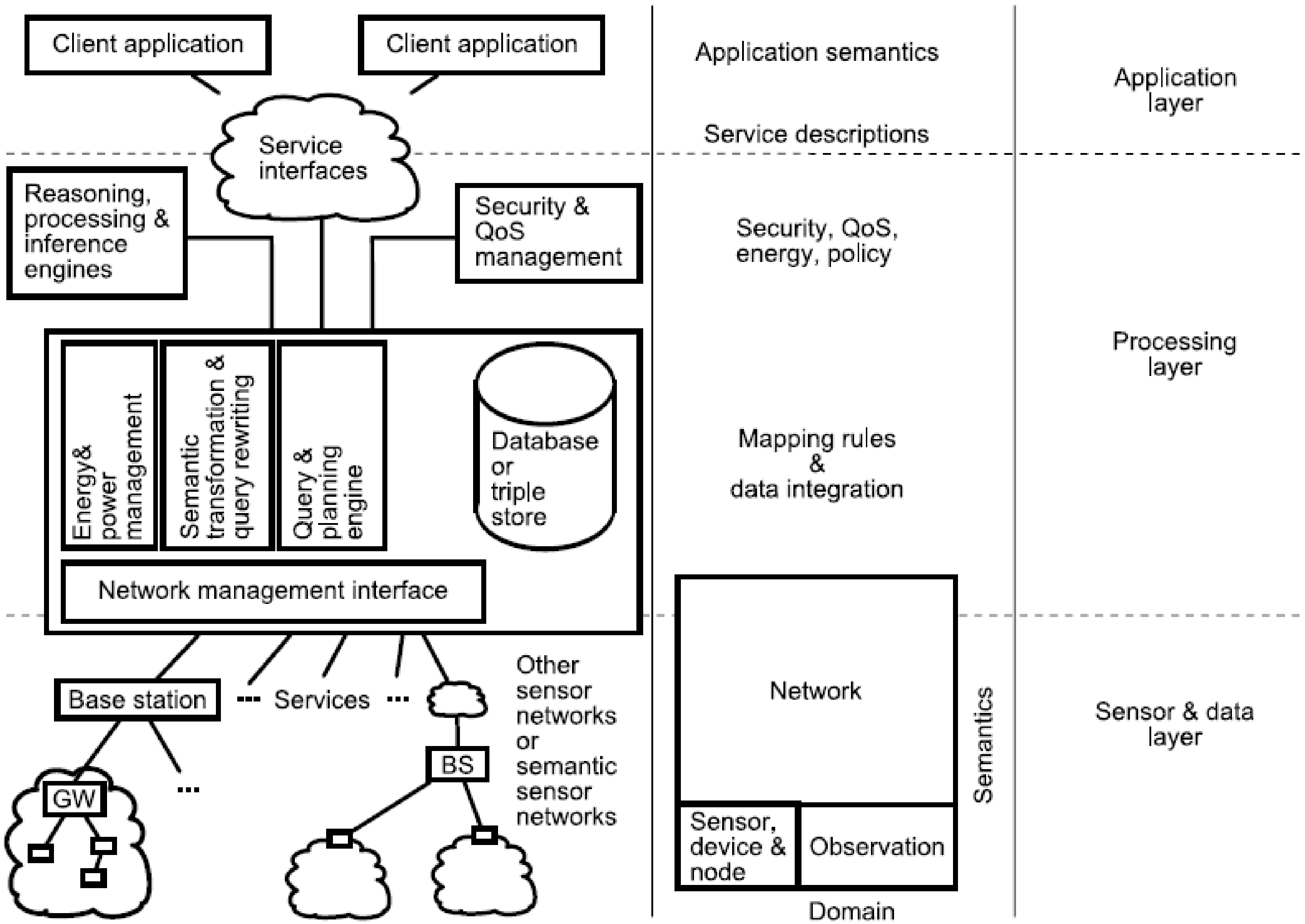
Outline of this part of the talk

In this part we will review approaches on

- How to conceptualize sensor domain?
- How to process streaming data?
    - How to detect complex events?
    - How to perform mining on streaming data?
    - How to detect anomalies?

CONCEPTUALIZATION OF SENSOR DOMAIN

Semantic Sensor Network architecture



http://lists.w3.org/Archives/Public/public-xg-ssn/2009Aug/att-0037/SSN-XG_StateOfArt.pdf

Sensor ontologies

Several ontologies are covering sensor domain

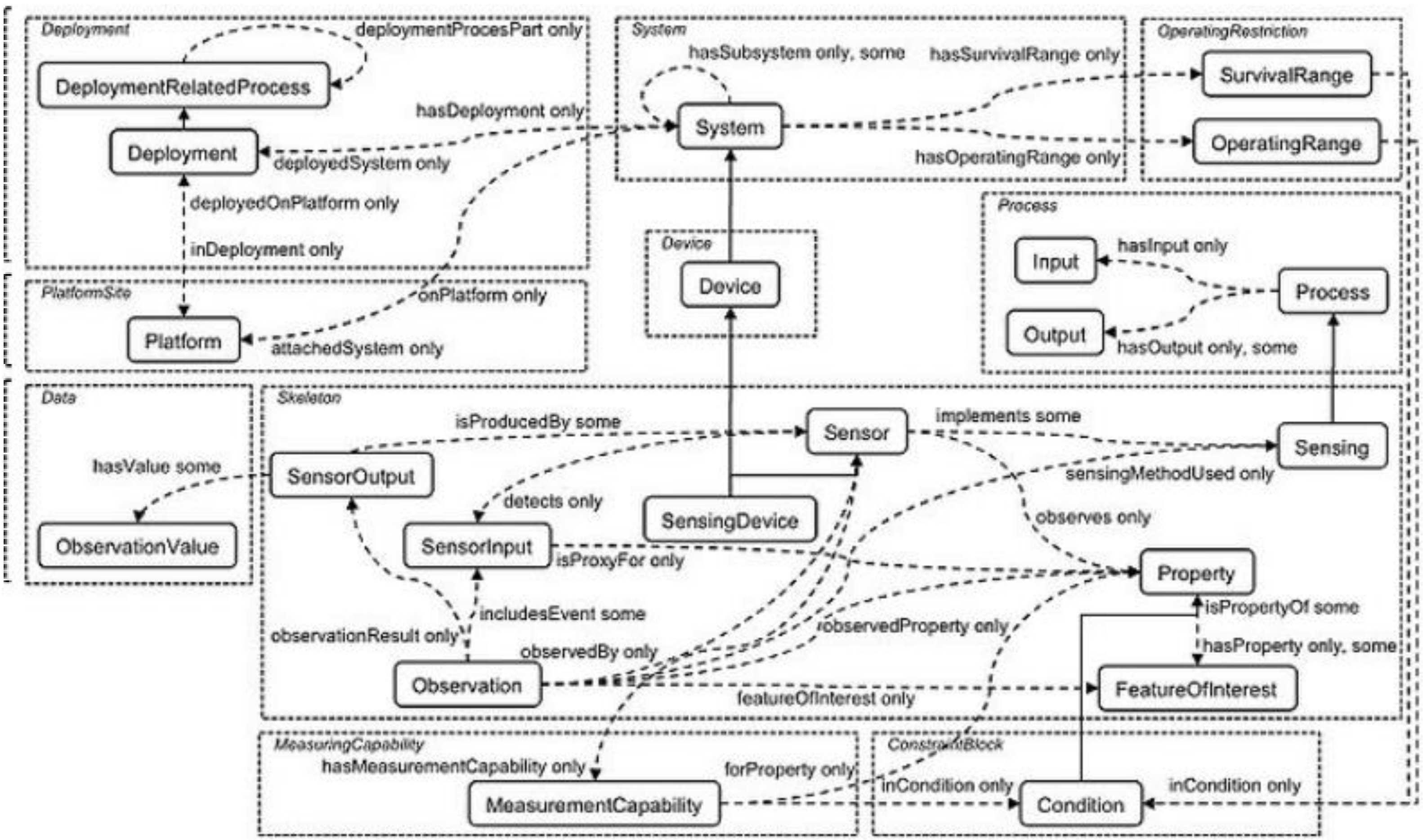
- …most of them only parts

W3C Semantic Sensor Network (SSN) Ontology (next slide) is an attempt to cover complete domain

ontology	base concepts	sensor								physical					observation					domain			
		sensor hierarchy	identity & manufacturing	contacting & software	deployment	configuration	history	components	action & process	location	power supply	platform	dimension, weight, etc.	operating conditions	data/observation	accuracy	frequency	response model	field of view/sensing	units of measurement	feature/quality	sampled medium	time
MMI	sensor (system) & process		✓		✓	✓		✓	✓			✓	✓	✓		✓	✓	✓			✓	✓	
CSIRO	sensor & process	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓		
OOSTethys	component, system & process							✓	✓			✓			✓						✓	✓	
CESN	sensor	✓			✓					✓					✓						✓		✓
SWAMO	agent, process & sensor			✓				✓	✓	✓		✓			✓				✓	✓	✓		✓
Kim	sensor					✓				✓					✓	✓	✓		✓		✓		
OntoSensor	component & sensor	✓				✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓		✓
Eid	sensor		✓			✓				✓	✓				✓	✓	✓	✓	✓				
Matheus	system & sensor	✓		✓					✓	✓					✓		✓						
Avancha	sensor			✓						✓	✓				✓	✓	✓	✓	✓	✓	✓	✓	
ISTAR																							

http://lists.w3.org/Archives/Public/public-xg-ssn/2009Aug/att-0037/SSN-XG_StateOfArt.pdf

W3C Semantic Sensor Network (SSN) ontology structure



http://www.w3.org/2005/Incubator/ssn/wiki/Main_Page

So, how does a value look like?

Having all the semantic infrastructure in place, how an observed value is encoded in SSN?

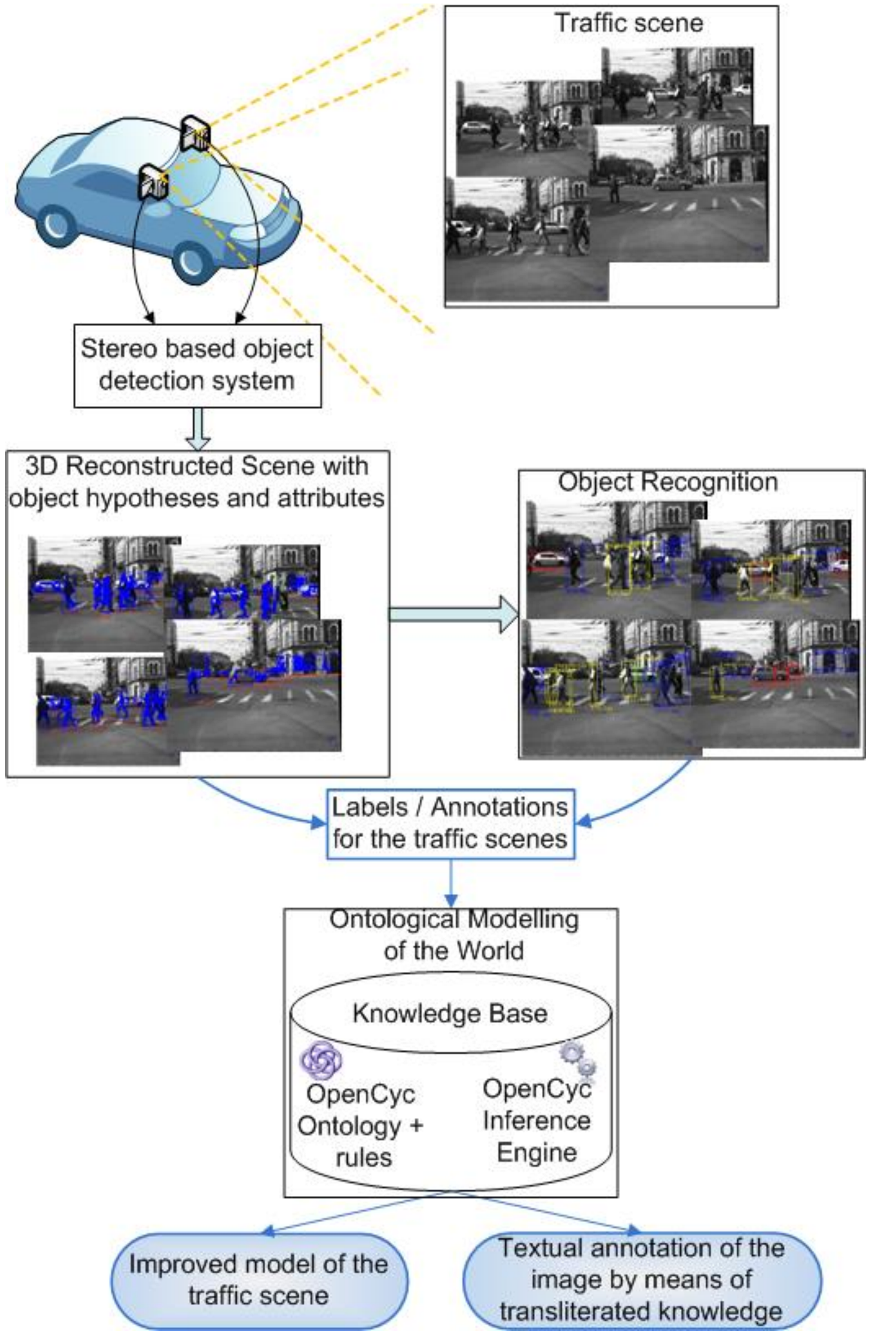
```
<owl:Thing rdf:about="http://purl.oclc.org/NET/ssnx/product/smart-knife#WiTilt30MeasurementRange_3MinValue">
   <rdf:type rdf:resource="http://purl.oclc.org/NET/ssnx/product/smart-knife#AccelerationValue"/>
   <smart-knife:hasQuantityValue rdf:datatype="http://www.w3.org/2001/XMLSchema#float">-4</smart-knife:hasQuantityValue>
</owl:Thing>
```

The observed value

http://www.w3.org/2005/Incubator/ssn/wiki/Main_Page

Spatio-temporal Reasoning for Traffic Scene Understanding

System architecture



Brehar et al, Spatio-temporal reasoning for traffic scene understanding. 2011 IEEE 7th International Conference on Intelligent Computer Communication and Processing.

Traffic Scene Understanding and the WoT vertical

Apps and Services	Enable traffic scene queries and natural language statement generation
"Glue"	Mapping the classes to an ontological model provided by Cyc
	Object classification
	Object tracking using Kalman filter
	Object detection
	Pre-processing: apply undistortion, scaling and rectification
"Things"	Stereo image acquisition by cameras on a vehicle

Brehar et al, Spatio-temporal reasoning for traffic scene understanding. 2011 IEEE 7th International Conference on Intelligent Computer Communication and Processing.

Querying traffic scenes

QUESTION: Image depicts Person?

ANSWER: PEDESTRIAN2A000282 is a person.

QUESTION: Image depicts UtilityPole?

ANSWER: UNCLASSIFIED0A000282 is a utility pole. POLE4A000282 is a utility pole. UNCLASSIFIED6A000282 is a utility pole. UNCLASSIFIED7A000282 is a utility pole. UNCLASSIFIED8A000282 is a utility pole. UNCLASSIFIED9A000282 is a utility pole. UNCLASSIFIED10A000282 is a utility pole.

QUESTION: Image depicts Automobile?

ANSWER: UNCLASSIFIED3A000282 is a car.

QUESTION: Image depicts Person?

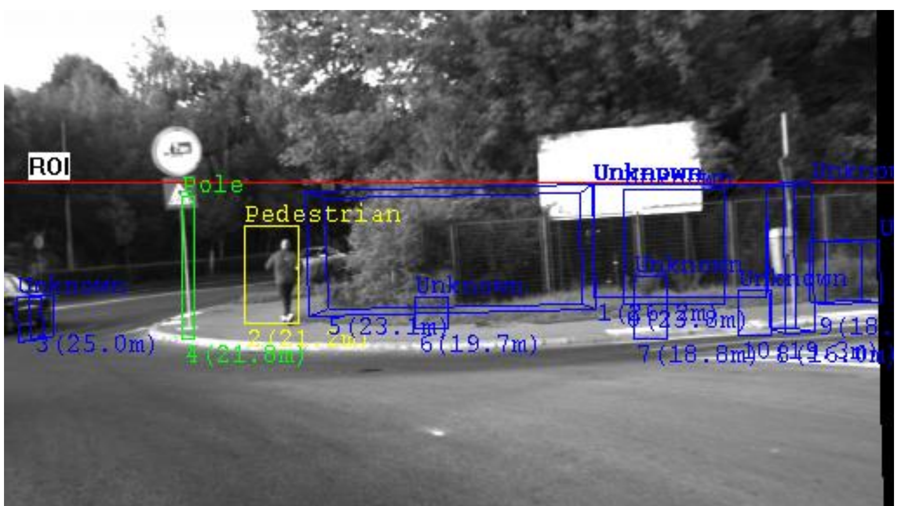
ANSWER: PEDESTRIAN2A000283 is a person.

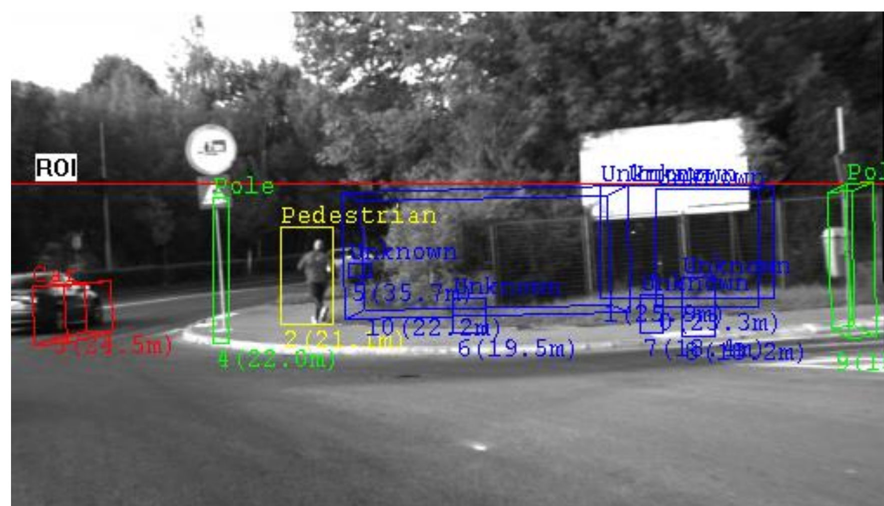
QUESTION: Image depicts UtilityPole?

ANSWER: UNCLASSIFIED0A000283 is a utility pole. POLE4A000283 is a utility pole. UNCLASSIFIED6A000283 is a utility pole. UNCLASSIFIED7A000283 is a utility pole. UNCLASSIFIED8A000283 is a utility pole. POLE9A000283 is a utility pole.

QUESTION: Image depicts Automobile?

ANSWER: UNCLASSIFIED3A000282 is a car.





Natural language traffic scene description generation

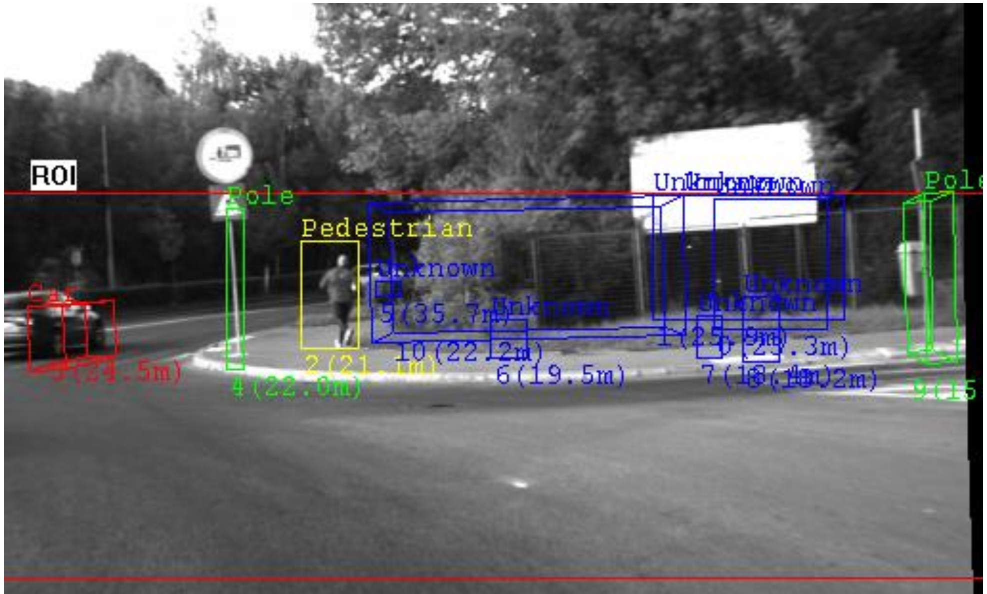
QUESTION: Image depicts ObjectWithUse?

ANSWER:

UNCLASSIFIED0A000283 is a utility pole, every utility pole is a post, every post is a shaft, every shaft is a rod, every rod is an implement, every implement is a device, every device is an object with uses.

CAR3A000283 is a car, every car is a device that is not a weapon, every device that is not a weapon is a device, every device is an object with uses.

POLE4A000283 is a utility pole, every utility pole is a post, every post is a shaft, every shaft is a rod, every rod is an implement, every implement is a device, every device is an object with uses.



Brehar et al, Spatio-temporal reasoning for traffic scene understanding. 2011 IEEE 7th International Conference on Intelligent Computer Communication and Processing.

STREAM DATA PROCESSING

SensorLab

Stream data processing

Applications that require real-time processing of high-volume data steams are pushing the limits of traditional data processing infrastructures

In the following slides we present the requirements of that system…

- …based on the paper "**The 8 Requirements of Real-Time Stream Processing**" by Stonebraker, Çetintemel, Zdonik; ACM SIGMOD Record Volume 34 Issue 4

Eight rules for stream processing (1/2)

Rule 1: Keep the Data Moving

- *Processing messages "in-stream", without requirements to store them; ideally the system should also use an active (i.e., non-polling)*

Rule 2: Query using SQL on Streams

- *High-level SQL like language with built-in extensible stream oriented primitives and operators*

Rule 3: Handle Stream Imperfections

- *Dealing with stream "imperfections", including missing and out-of-order data, which are commonly present in real-world data streams*

Rule 4: Generate Predictable Outcomes

http://www.complexevents.com/2006/06/30/the-eight-rules-of-real-time-stream-processing/

Eight rules for stream processing (2/2)

Rule 5: Integrate Stored and Streaming Data

- Combining stored with *live streaming data*

Rule 6: Guarantee Data Safety and Availability

- *Integrity of the data maintained at all times, despite failures*

Rule 7: Partition and Scale Applications Automatically

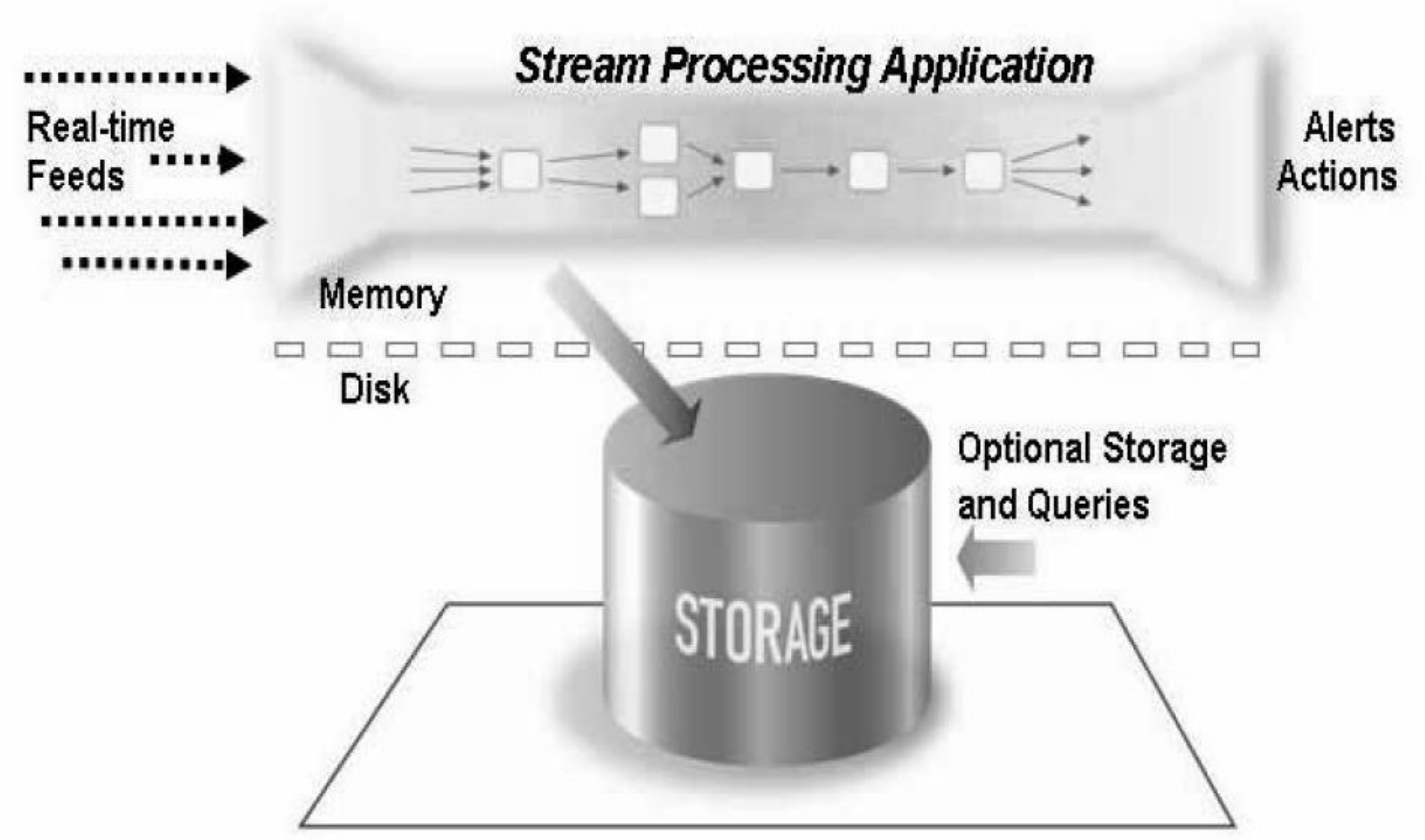
- *Distribute its processing across multiple processors and machines to achieve incremental scalability*

Rule 8: Process and Respond Instantaneously

- *Minimal-overhead execution engine to deliver real-time response*

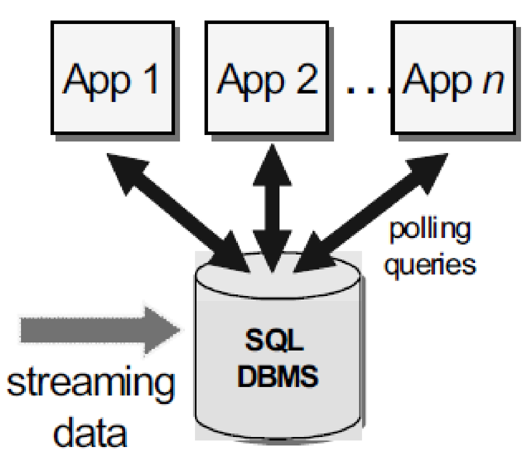
http://www.complexevents.com/2006/06/30/the-eight-rules-of-real-time-stream-processing/

"Straight-through" processing of messages with optional storage

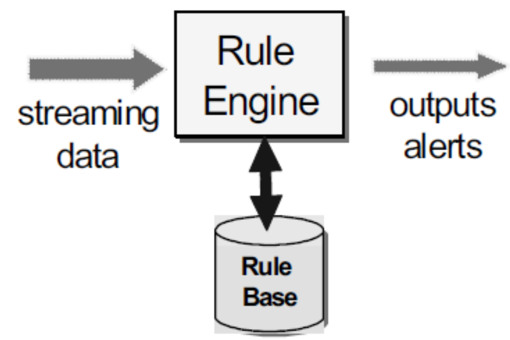


http://www.complexevents.com/2006/06/30/the-eight-rules-of-real-time-stream-processing/

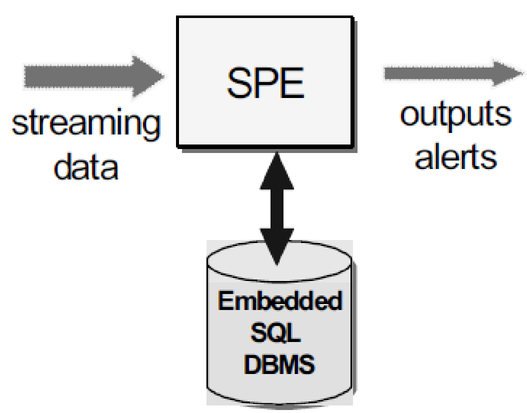
Basic architectures for stream processing databases



Traditional DBMS system



Rule engine



Stream processing engine

http://www.complexevents.com/2006/06/30/the-eight-rules-of-real-time-stream-processing/

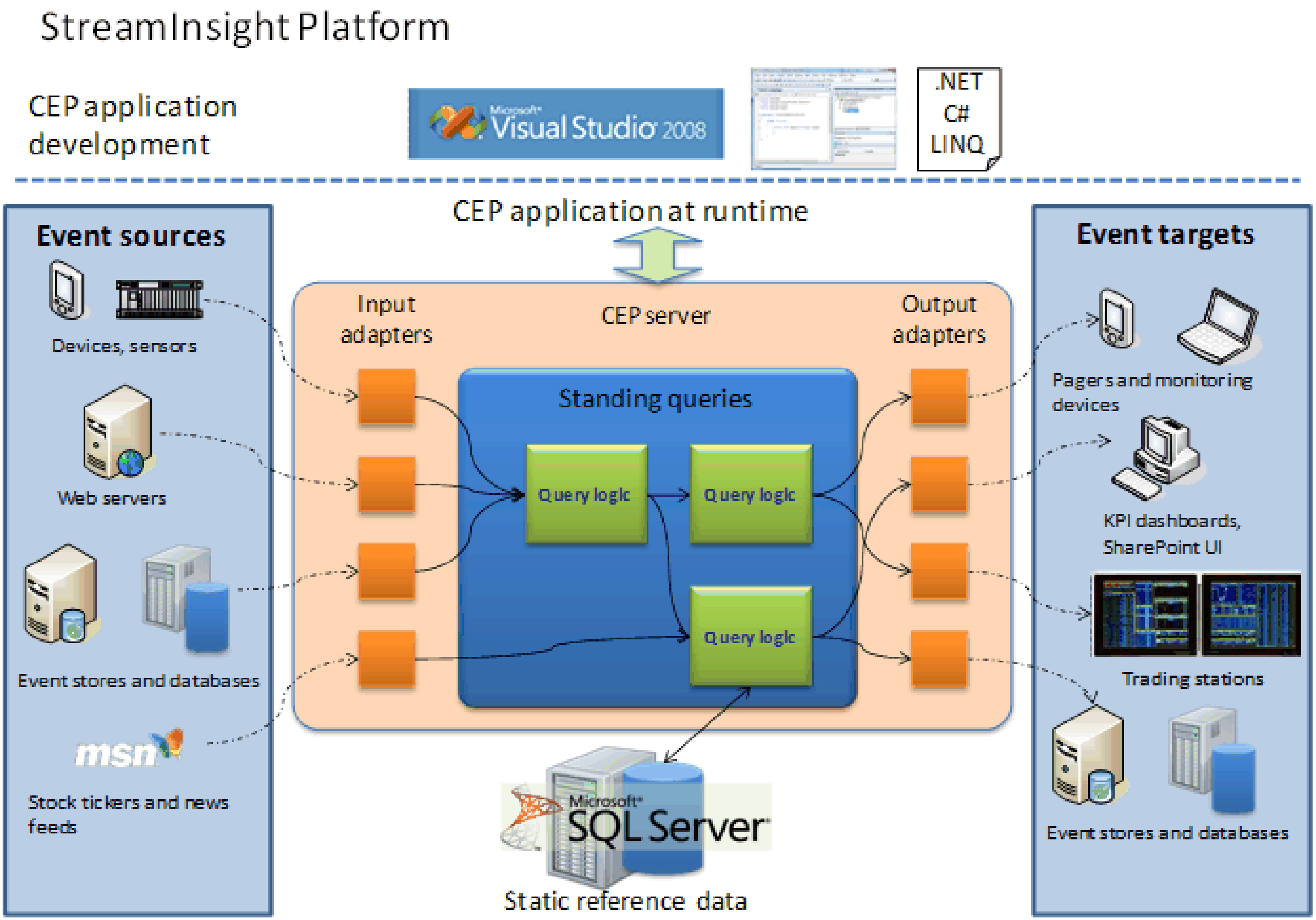
The capabilities of various systems software

	DBMS	Rule engine	SPE
Keep the data moving	No	Yes	Yes
SQL on streams	No	No	Yes
Handle stream imperfections	Difficult	Possible	Possible
Predictable outcome	Difficult	Possible	Possible
High availability	Possible	Possible	Possible
Stored and streamed data	No	No	Yes
Distribution and scalability	Possible	Possible	Possible
Instantaneous response	Possible	Possible	Possible

http://www.complexevents.com/2006/06/30/the-eight-rules-of-real-time-stream-processing/

COMPLEX EVENT PROCESSING

Microsoft *StreamInsight* Architecture



http://msdn.microsoft.com/en-us/sqlserver/ee476990

Steps in processing events

Data filtering

- Low level filtering
- Semantic filtering

Data transformation and aggregation

- Database updates
- Creating relationships among objects

Complex event definition

- Event constructors specifying the constituent events (non-temporal and temporal)

Processing of non-spontaneous events

- Pseudo-events as objects containing temporal constraints

Wang, F., S. Liu, and P. Liu, Complex RFID event processing. The VLDB Journal, 2009.

Good practices in distributed CEP

Data centric storage – data mapped to different locations

- Data lookup – multi-level hashing
- Data robustness – replication

Data caching – multiple copies of the most requested data

- Consistency – response time trade-off

Group management - cooperation among group of nodes

- Provide higher reliability
- Anomaly detection

Publish/subscribe for event subscription

- Loose coupling

Li, S., et al., Event Detection Services Using Data Service Middleware in Distributed Sensor Networks. Telecommunication Systems, 2004.

Complex Event Processing Application Development

1. **Defining event sources and event targets (sinks)**
2. **Creating an input adapter to read the events from the source into the CEP server**
3. **Creating an output adapter to consume the processed events for submission to the event targets**
4. **Creating the query logic required to meet your business objectives**
    1. **binding the query to the adapters** at runtime, and
    2. to **instantiate the query** in the CEP server

http://msdn.microsoft.com/en-us/sqlserver/ee476990

Examples of Queries in Microsoft StreamInsight (1/2)

Filtering of events

- from e in inputStream where e.value < 10 select e;

Calculations to introduce additional event properties

- from e in InputStream select new MeterWattage {wattage=(double)e.Consumption / 10};

Grouping events

- from v in inputStream group v by v.i % 4 into eachGroup from window in eachGroup.Snapshot() select new { avgNumber = window.Avg(e => e.number) };

Aggregation

- from w in inputStream.Snapshot() select new { sum = w.Sum(e => e.i), avg = w.Avg(e => e.f), count = w.Count() };

http://msdn.microsoft.com/en-us/sqlserver/ee476990

Examples of Queries in Microsoft StreamInsight (2/2)

Identifying top *N* candidates

- (from window in inputStream.Snapshot() from e in window orderby e.f ascending, e.i descending select e).Take(5);

Matching events from different streams

- from e1 in stream1 join e2 in stream2 on e1.i equals e2.i select new { e1.i, e1.j, e2.j };

Combining events from different streams in one

- stream1.Union(stream2);

User defined functions

- from e in stream where e.value < MyFunctions.valThreshold(e.Id) select e;

http://msdn.microsoft.com/en-us/sqlserver/ee476990

Event Models in Microsoft StreamInsight

Interval model

- Event has predefined duration

Event Kind	Start Time	End Time	Payload (Power Consumption)
INSERT	2009-07-15 09:13:33.317	2009-07-15 09:14:09.270	100
INSERT	2009-07-15 09:14:09.270	2009-07-15 09:14:22.253	200
INSERT	2009-07-15 09:14:22.255	2009-07-15 09:15:04.987	100

Point model

- Event is occurrence in a point in time

Event Kind	Start Time	End Time	Payload (Consumption)
INSERT	2009-07-15 09:13:33.317	2009-07-15 09:13:33.317	100
INSERT	2009-07-15 09:14:09.270	2009-07-15 09:14:09.270	200
INSERT	2009-07-15 09:14:22.255	2009-07-15 09:14:22.255	100

Edge model

- Only start time known upon arrival to server; end-time is updated later

Event Kind	Edge Type	Start Time	End Time	Payload
INSERT	Start	t0	∞	a
INSERT	End	t0	t1	a
INSERT	Start	t1	∞	b
INSERT	End	t1	t3	b
INSERT	Start	t3	∞	c

http://msdn.microsoft.com/en-us/sqlserver/ee476990

CEP and Sensor Networks

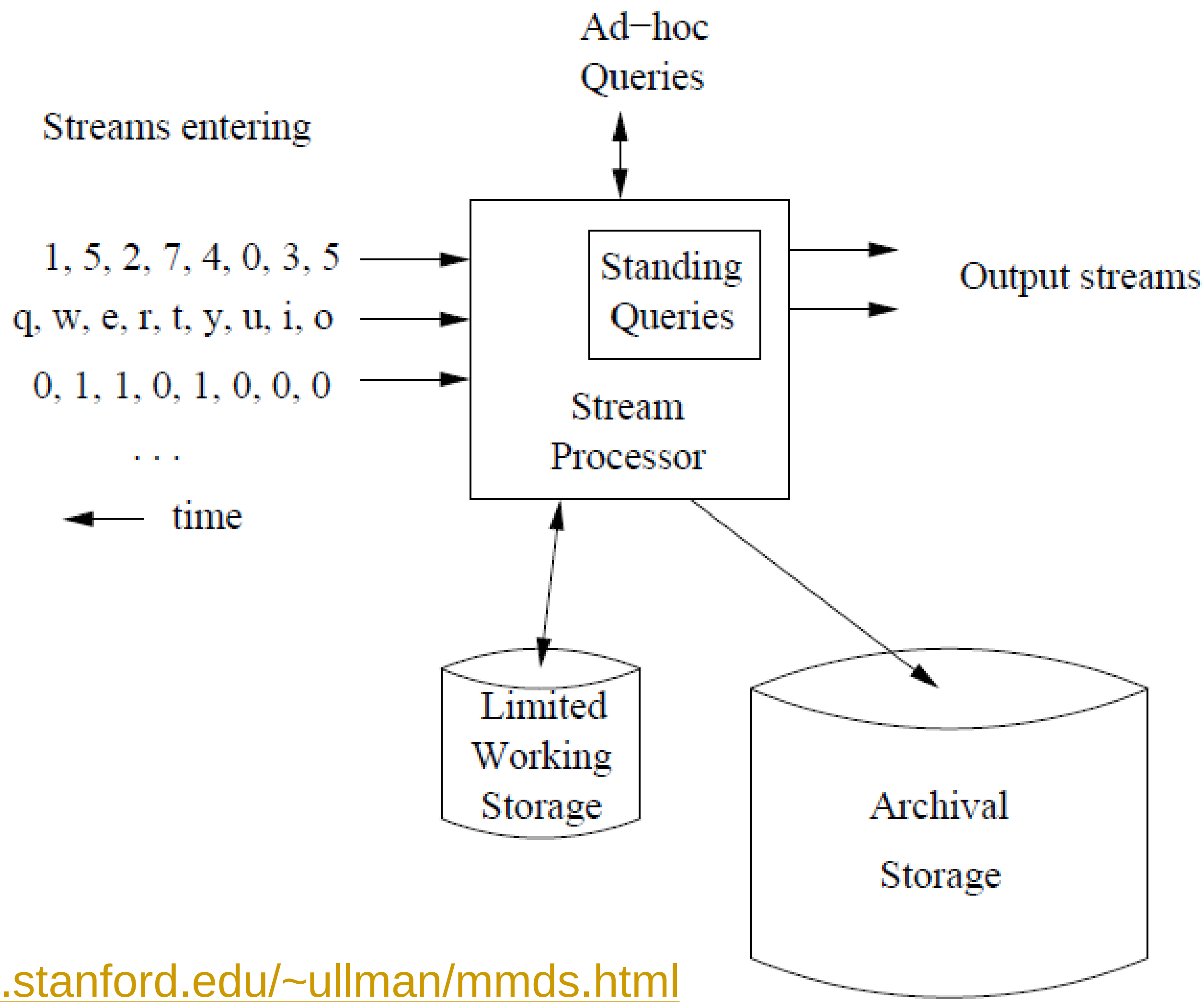
CEP role is to discovering meaningful information from sensor data

- observations – raw outputs of sensors
- event – detected and of interest for the application
- centralized vs. distributed processing

STREAM MINING

Typical stream mining architecture

- Streams can include different types of data
- We can prepare system ahead of time for "Standing Queries"
- We can prepare only for certain class of "Ad-hoc Queries"

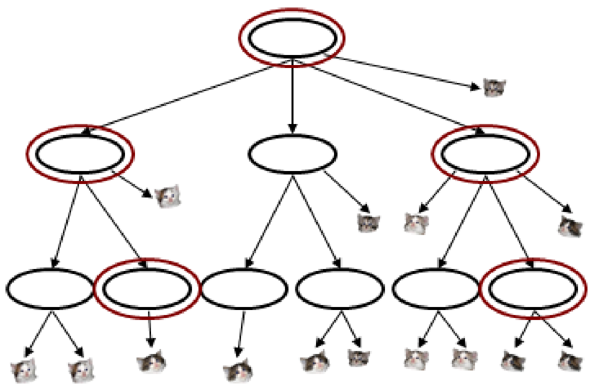


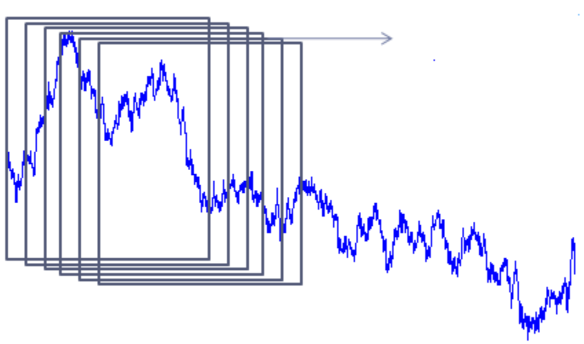
http://infolab.stanford.edu/~ullman/mmds.html

SensorLab

How we mine streams?

- Maintain **summaries of the streams**, sufficient to answer the expected queries about the data
  - …summaries can be in various forms: clusters (flat or hierarchic, statistical aggregates, …)
- Maintain a **sliding window** of the most recently arrived data
  - …operations on a sliding window mimic more traditional database/mining operations

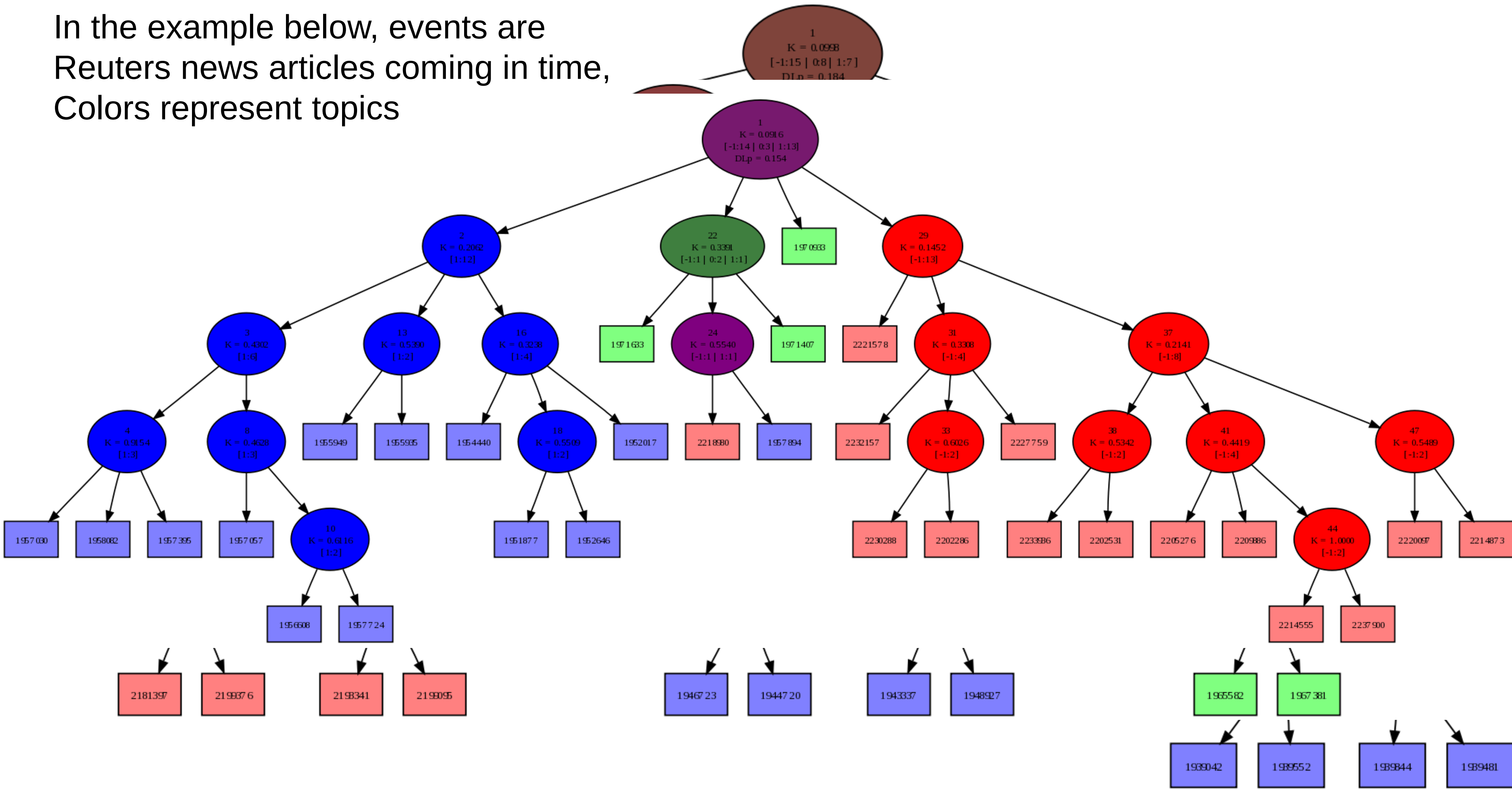




Example: Stream summarization by incremental hierarchical clustering

The goal is to maintain summary of data from stream in a form of a taxonomy of prototype clusters – each new events updates the taxonomy

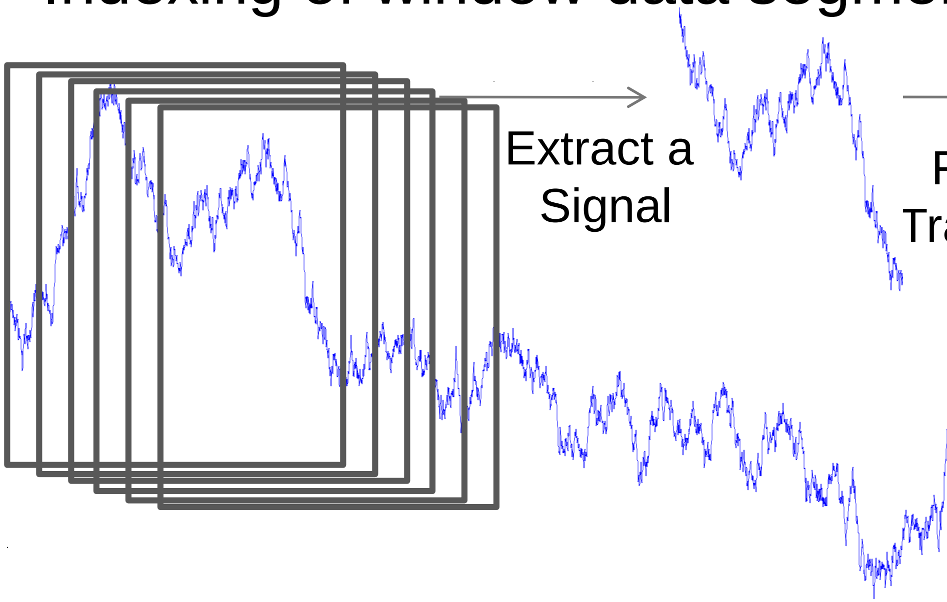
In the example below, events are Reuters news articles coming in time, Colors represent topics



[Blaz Novak, 2008]

Example: Stream processing on sliding window

- Indexing of window data segments



Extract a Signal

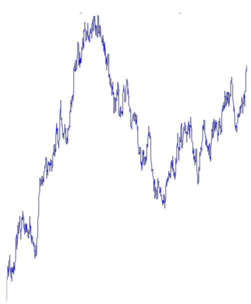
Fourier Transform

Database

11.3	9.0	6.0
12.3	10.0	11.0
2.3	1.0	9.0

Matching with one of distance metrics – if data and query are similar trigger an alert

- Query/Template Pattern Preprocessing



Fourier Transform

10.0	9.5	60

[Faloutsos, 1994]

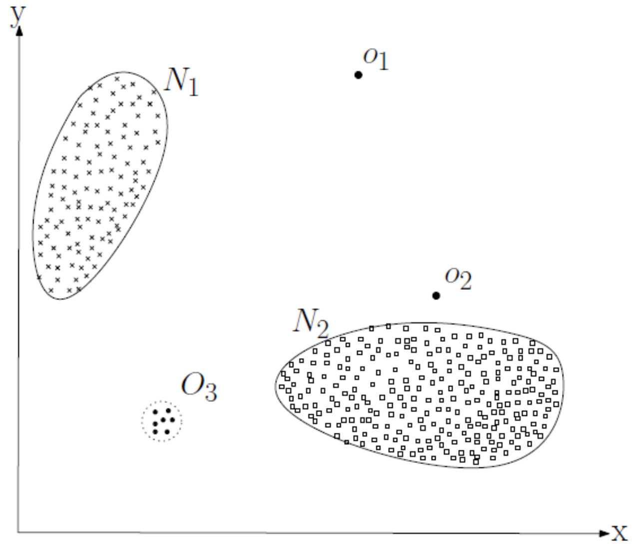
Slide taken from [Pramod Vemulapalli: Pattern Matching with Acceleration Data]

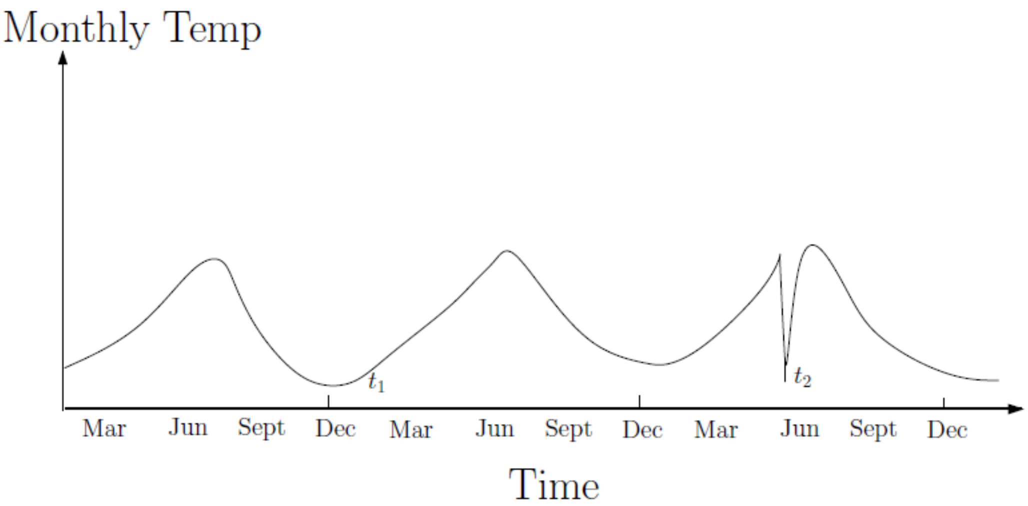
Data reduction stream mining tasks

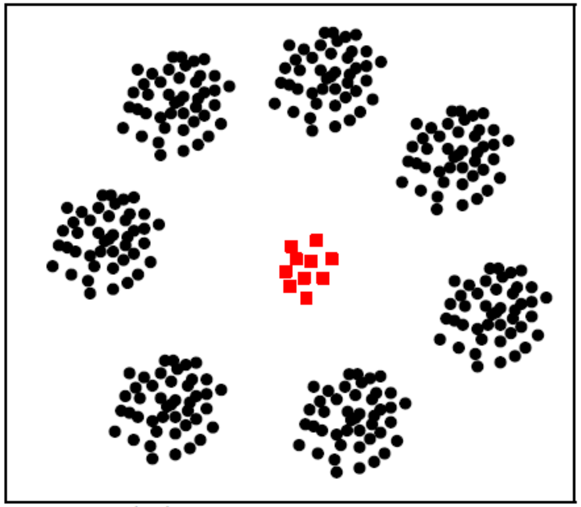
- **Sampling**
  - …challenge is to obtain representative data sample (i.e., enabling to perform correctly required operations on data)
- **Filtering**
  - …simple filters are easy to implement (e.g. simple conditions like “x<10”)
  - …filtering by a membership of a set which doesn’t fit in the main memory requires more sophisticated algorithms (e.g. Bloom filtering)
    - (example of set membership: list of spam URLs)

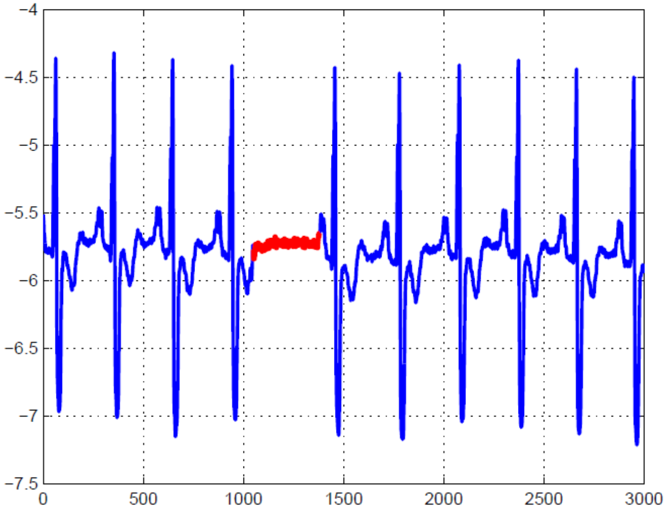
ANOMALY DETECTION

What are anomalies?





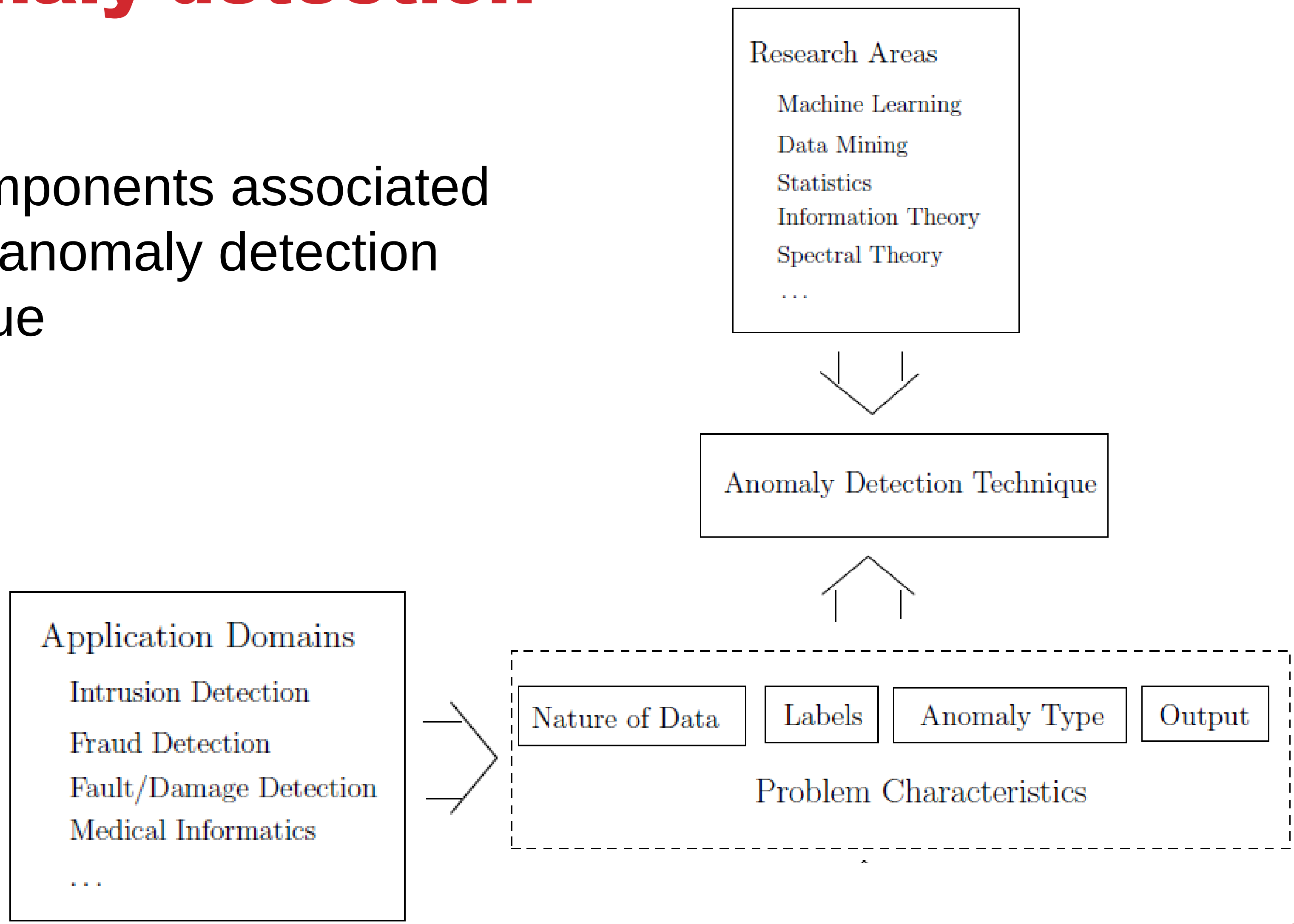




http://www.dtc.umn.edu/publications/reports/2008_16.pdf

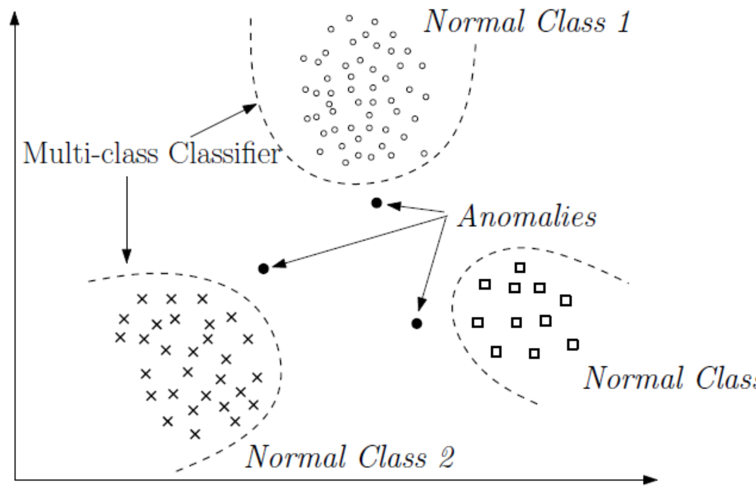
Anomaly detection

Key components associated with an anomaly detection technique



http://www.dtc.umn.edu/publications/reports/2008_16.pdf

Techniques to detect anomalies



Classification based

- A pre-trained classifier can distinguish between normal and anomalous classes

Clustering based

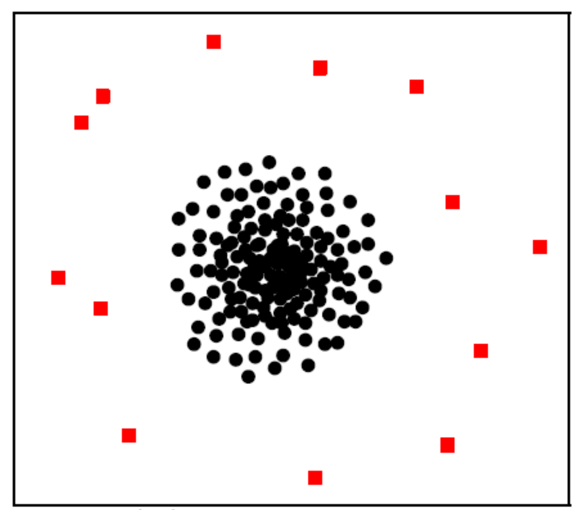
- Normal data instances belong to large and dense clusters, while anomalies either belong to small or sparse clusters

Nearest neighbor approaches

- *Normal data instances occur in dense neighborhoods, while anomalies occur far from their closest neighbors*

Statistical approaches

- *Normal data instances occur in high probability regions of a stochastic model, while anomalies occur in the low probability regions*



Information theoretic approaches

- *Anomalies in data induce irregularities in the information content of the data set*

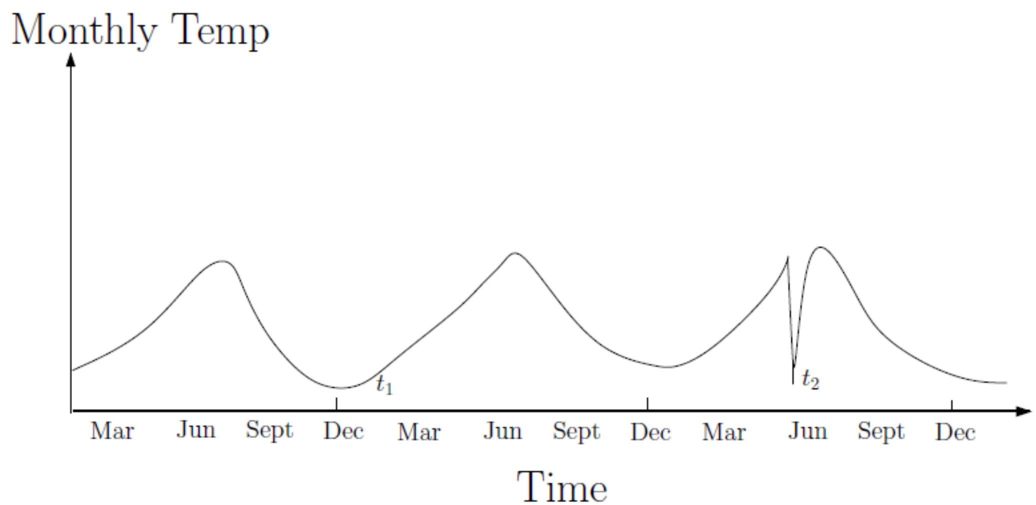
Spectral methods

- *Normal instances appear in a lower dimensional subspace, anomalies in the rest (noise)*

http://www.dtc.umn.edu/publications/reports/2008_16.pdf

The key to a successful anomaly detection is proper feature engineering!

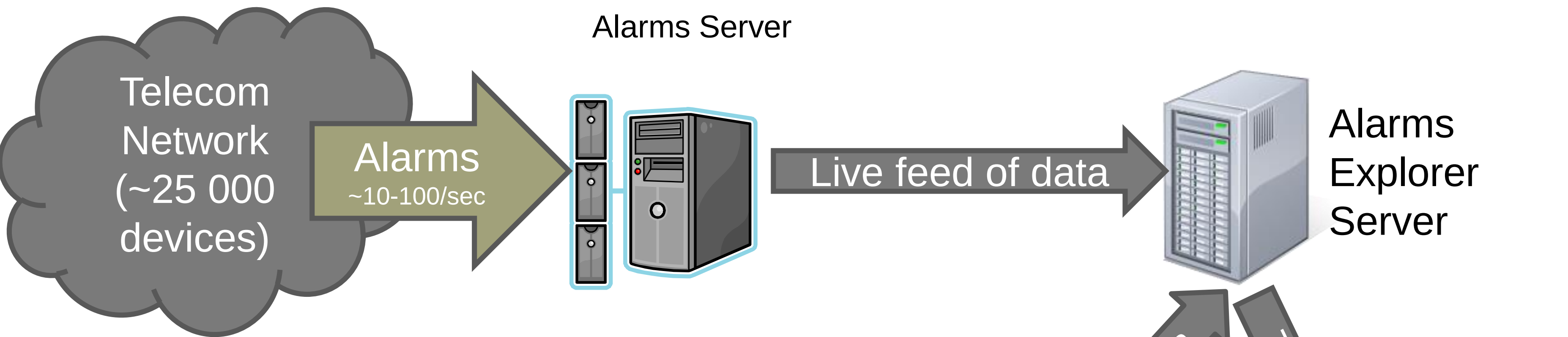
Anomalies are detectable if data instances are represented in an informative feature space



Contextual anomaly *t*2 in a temperature time series. Note that the temperature at time *t*1 is same as that at time *t*2 but occurs in a different context and hence is not considered as an anomaly.

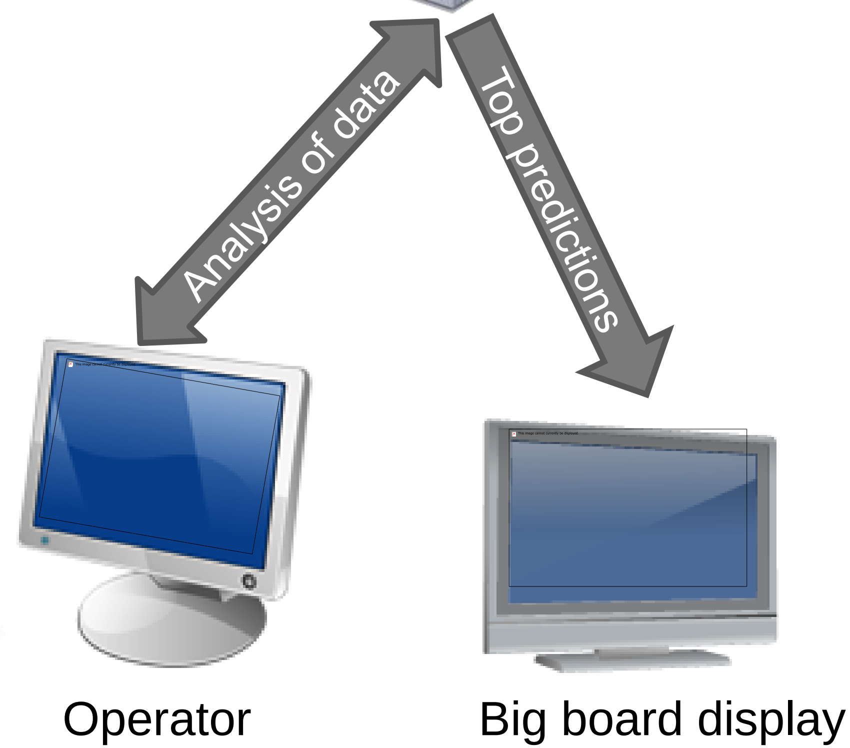
http://www.dtc.umn.edu/publications/reports/2008_16.pdf

Application: Telecommunication Network Monitoring



Alarms Explorer Server implements three real-time scenarios on the alarms stream:

1. **Root-Cause-Analysis** – finding which device is responsible for occasional “flood” of alarms
2. **Short-Term Fault Prediction** – predict which device will fail in next 15mins
3. **Long-Term Anomaly Detection** – detect unusual trends in the network



Outline

Part I. Motivation & background

Part II. Technology and tools for exploiting the WoT

Part III. Demos, Tools & Research directions

Outline

Part III. Demos, Tools & Research directions

Use cases

- What systems and prototypes exist?

Open problems

- Are there unsolved problems?

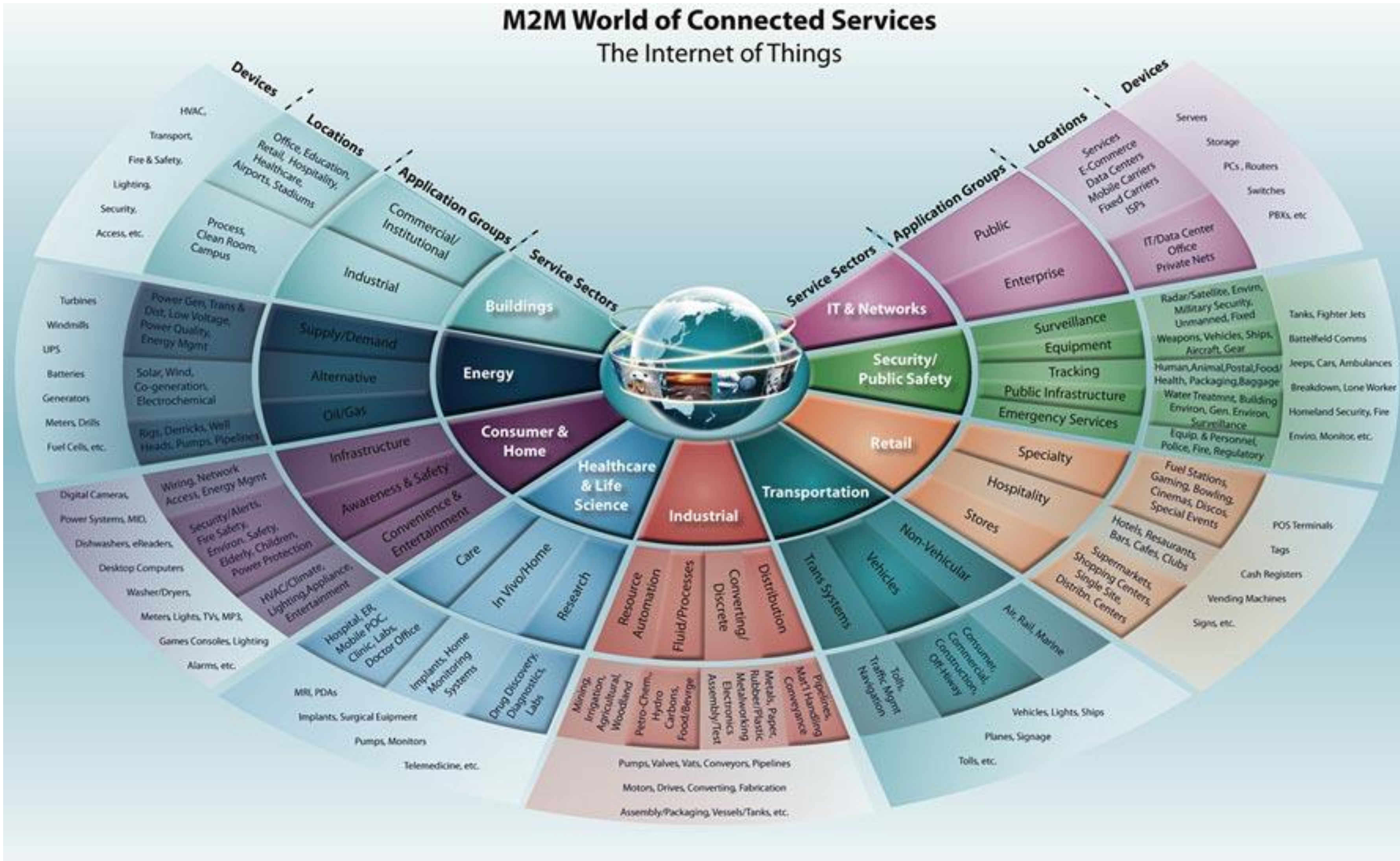
Summary

- What was this tutorial about?

List of sources for further studies

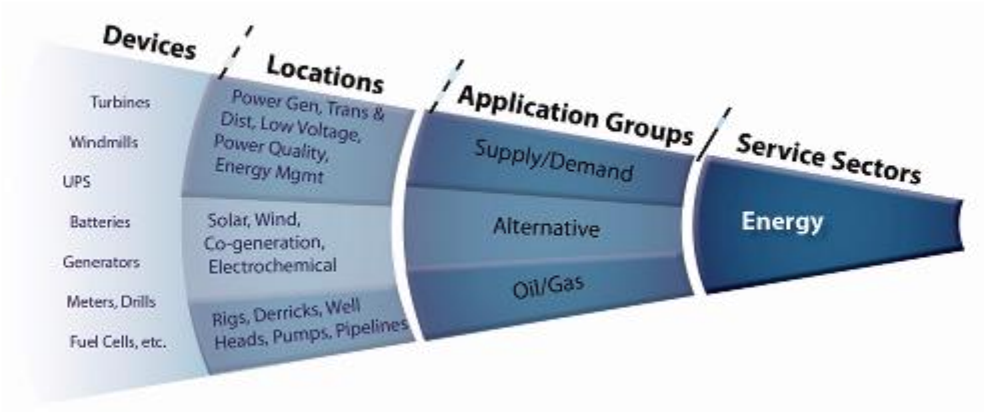
- Where to start digging?

Web of things use cases according to Beecham Research



Web of things use cases mapped to the Beecham Research classification

A case for Energy: dynamic power pricing using smart grid technology



Commercial use case: Power grids[1]

“If the power grid in America alone were just 5% more efficient, it would save greenhouse emissions equivalent to 53m cars (IBM).“

Solutions:

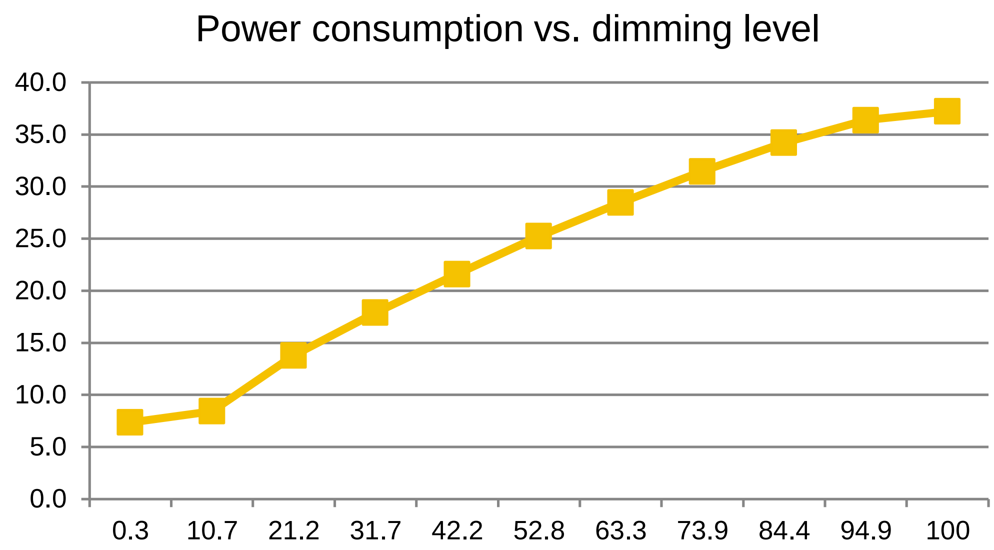
- demand pricing – 10-15% peak hour demand cut
    - Energy consumption monitoring with smart meters encourage shifting consumption to off-peak hours through personalized price plans
- demand response – extra 10-15% cut
    - Save energy by sensing and actuation: smart meters + actuators turn off air-conditioning systems when demand for electricity is high

[1] Ludwig Siegele, A special report on smart systems, The Economist, Nov. 4 2010.

SensorLab

Public lighting control: greener lights + control

Dimming level [%]	Power consumption [W]
0,3	7,4
10,7	8,4
21,2	13,8
31,7	17,9
42,2	21,6
52,8	25,2
63,3	28,5
73,9	31,5
84,4	34,2
94,9	36,4
100	37,2



SGA LSL 30 main characteristics

- the number of LED: 30*1w
- consumption: 35W (at full power)
- colour of the light: 4200K
- light current: 2700lm
- life-expactancy: min. 60.000h
- IP66
- NET mass: 4,8k

Public lighting control: lights dimming

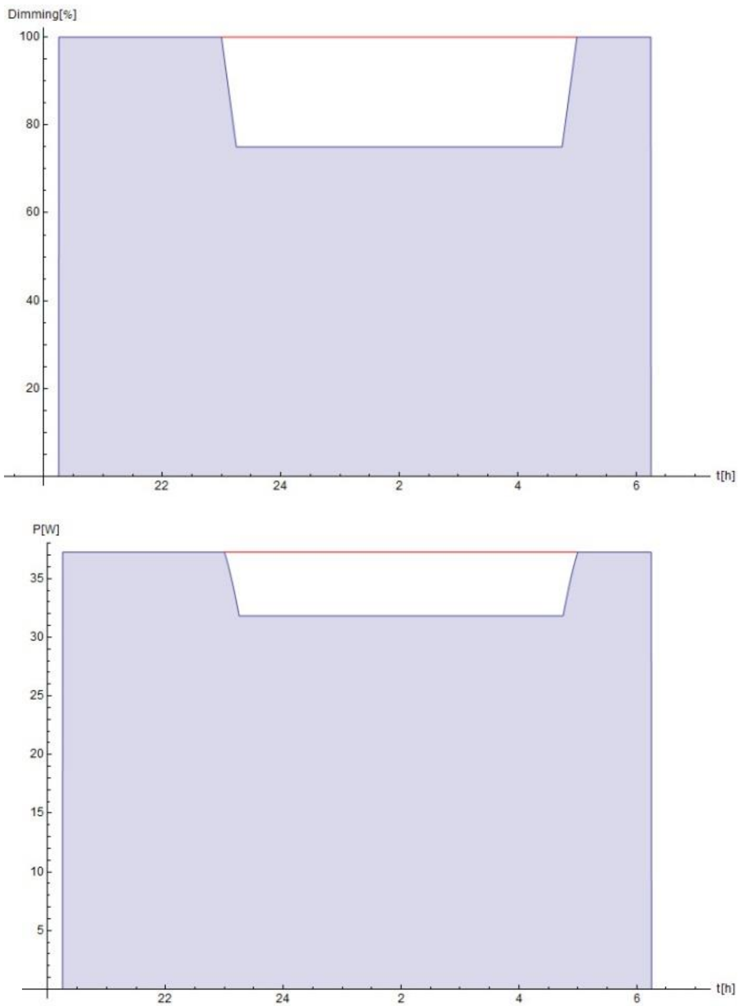
Lights dimmed to 75% luminosity between 23:00 and 5:00 with smooth 15-minute linear transitions.

$$P(not\ dimmed) = 37.2W$$
$$P(dimmed) = 31.8W$$

Electricity consumption per night:

$$A_e(no\ dimming) = 0.372kWh$$
$$A_e(dimming) = 0.341kWh$$

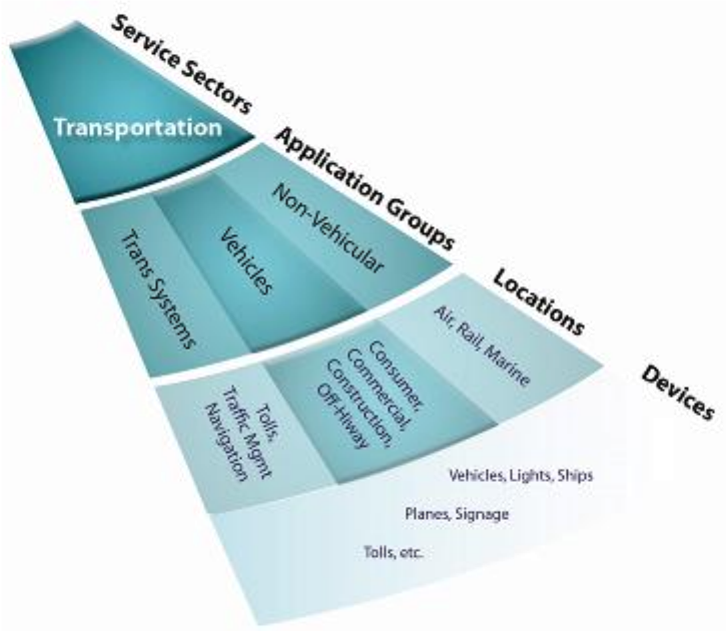
Reduced by ~ 8,3%.



Dimming and power in time. Red line represents light poles with no dimming.

Web of things use cases mapped to the Beecham Research classification

A case for transportation systems: dynamic pricing for congestion, automatic parking finding assistats



Commercial use case: Transport systems[1]

"In 2007 its congested roads cost the country 4.2 billion working hours and 10.6 billion litres of wasted petrol (Texas Transportation Institute)" [1]

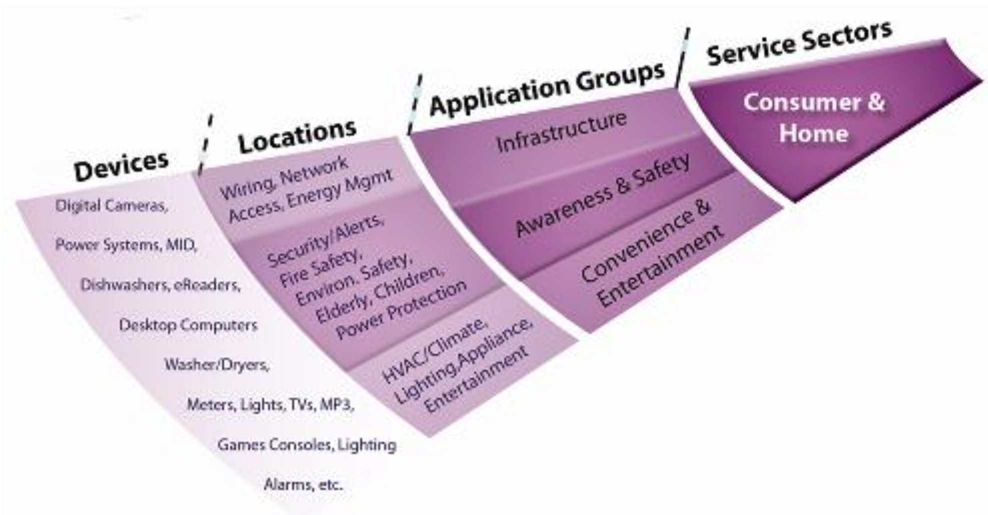
Solutions:

- Charging for city centers and busy roads
  - London, Stockholm, Singapore, etc.
- Green wave
  - Adjustment of traffic lights to suit the flow of vehicles
- Automatic parking guidance
  - Singapore is developing a parking-guidance system (cars looking for somewhere to park are now a big cause of congestion).
- Real-time dynamic pricing
  - Singapore

[1] Ludwig Siegele, A special report on smart systems, The Economist, Nov. 4 2010.

Web of things use cases mapped to the Beecham Research classification

A case for infrastructures: automated fixture findings and intervention management



Commercial use case: Water distribution[1]

Utilities around the world lose between 25% and 50% of treated water to leaks (Lux Research).

Solutions:

- Renew infrastructure
  - London, UK, Thames Water was losing daily nearly 900m litres of treated water and had to fix 240 leaks due to aging infrastructure[1].
- Install sensors for monitoring the pipe system
  - Automatically detect leaks fast (instead of customers calling and reporting leaks). London, Singapore, etc.
- Automate the management and maintenance process
  - Automatic scheduling of work crews and automatic alerts (i.e. text messages to affected customers)

[1]Ludwig Siegele, A special report on smart systems, The Economist, Nov. 4 2010.

SensorLab

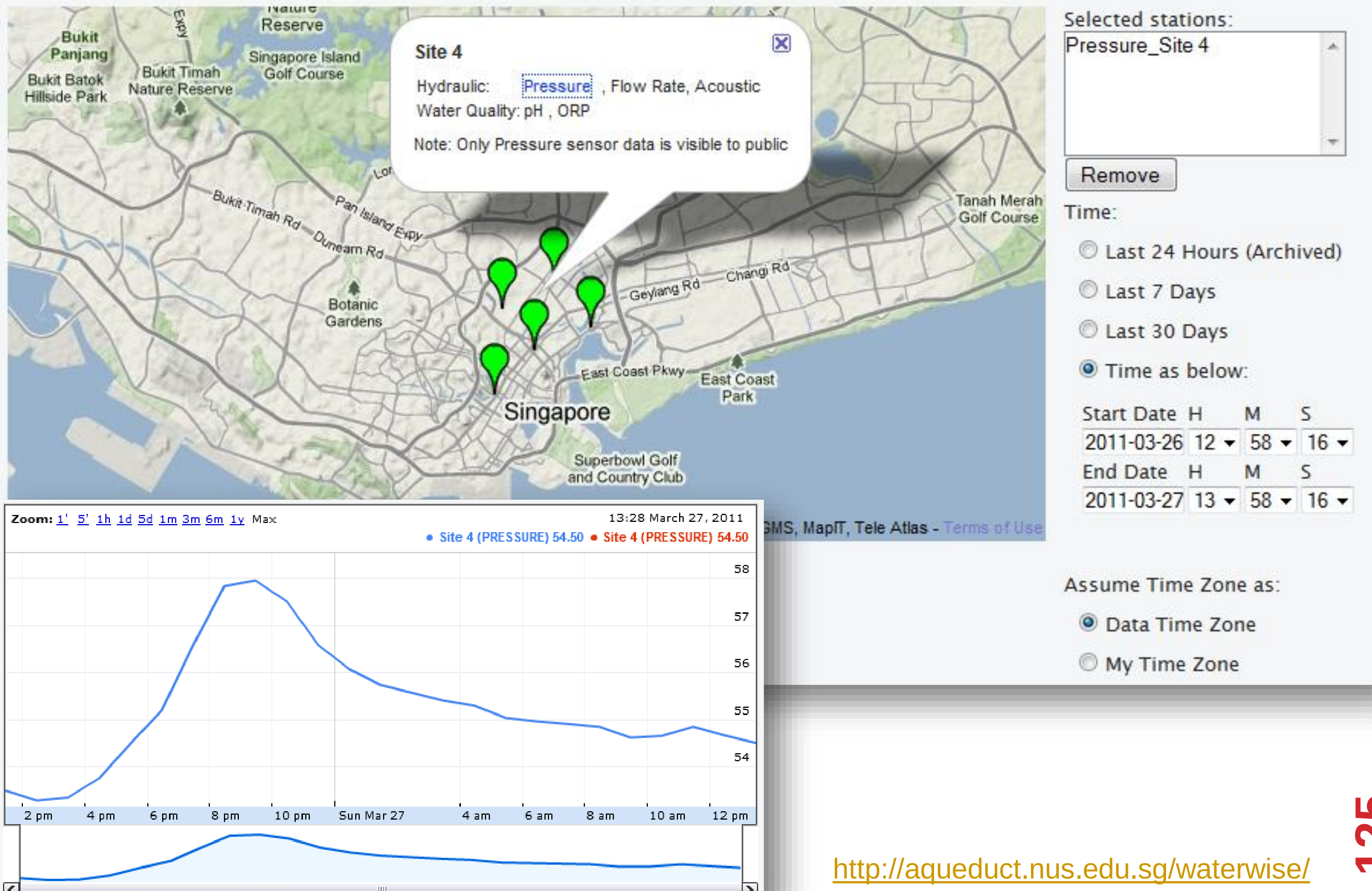
Water distribution

WaterWiSe in Singapore

- develop generic wireless sensor network capabilities to enable real time monitoring of a water distribution network.
- three main applications:
  - On-line monitoring of hydraulic parameters within a large urban water distribution system.
  - Integrated monitoring of hydraulic and water quality parameters.
  - Remote detection of leaks and prediction of pipe burst events.

http://aqueduct.nus.edu.sg/waterwise/

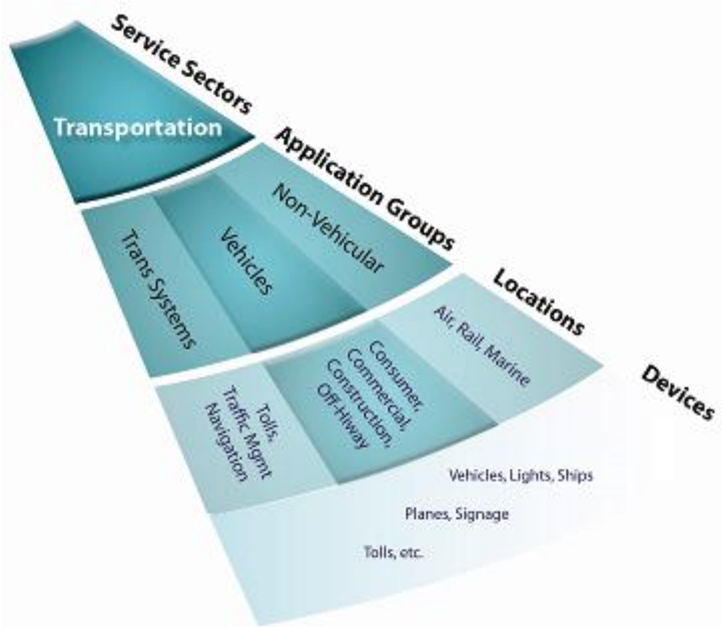
You are free to play with a limited data sets from a few deployment sites you see on the interactive map. We are streaming a lot more data for many more hydraulic, water quality and derived parameters from many other locations that are not available through this public portal.



http://aqueduct.nus.edu.sg/waterwise/

Web of things use cases mapped to the Beecham Research classification

A case for logistic systems: automated asset tracking and supply chain management



SensorLab

Commercial use case: Logistics

Cargo loss due to theft or damage is significant, estimates that the global financial impact of cargo loss exceeds $50 billion annually (The National Cargo Security Council)1. The cost is eventually passed to the customers.

Solutions:

- Automatic track and trace
  - Tag and trace their wares all along the supply chain (RFIDs and sensors) - and consumers to check where they come from (i.e. FoodLogiQ, SenseAware)[2]
- Event detection and mitigation
  - Detect events that affect the cargo (i.e. delay, inappropriate transport conditions) and minimize damage (i.e. re-route)

[1] Tom Hayes, The Full Cost of Cargo Losses

[2] Ludwig Siegele, A special report on smart systems, The Economist, Nov. 4 2010.

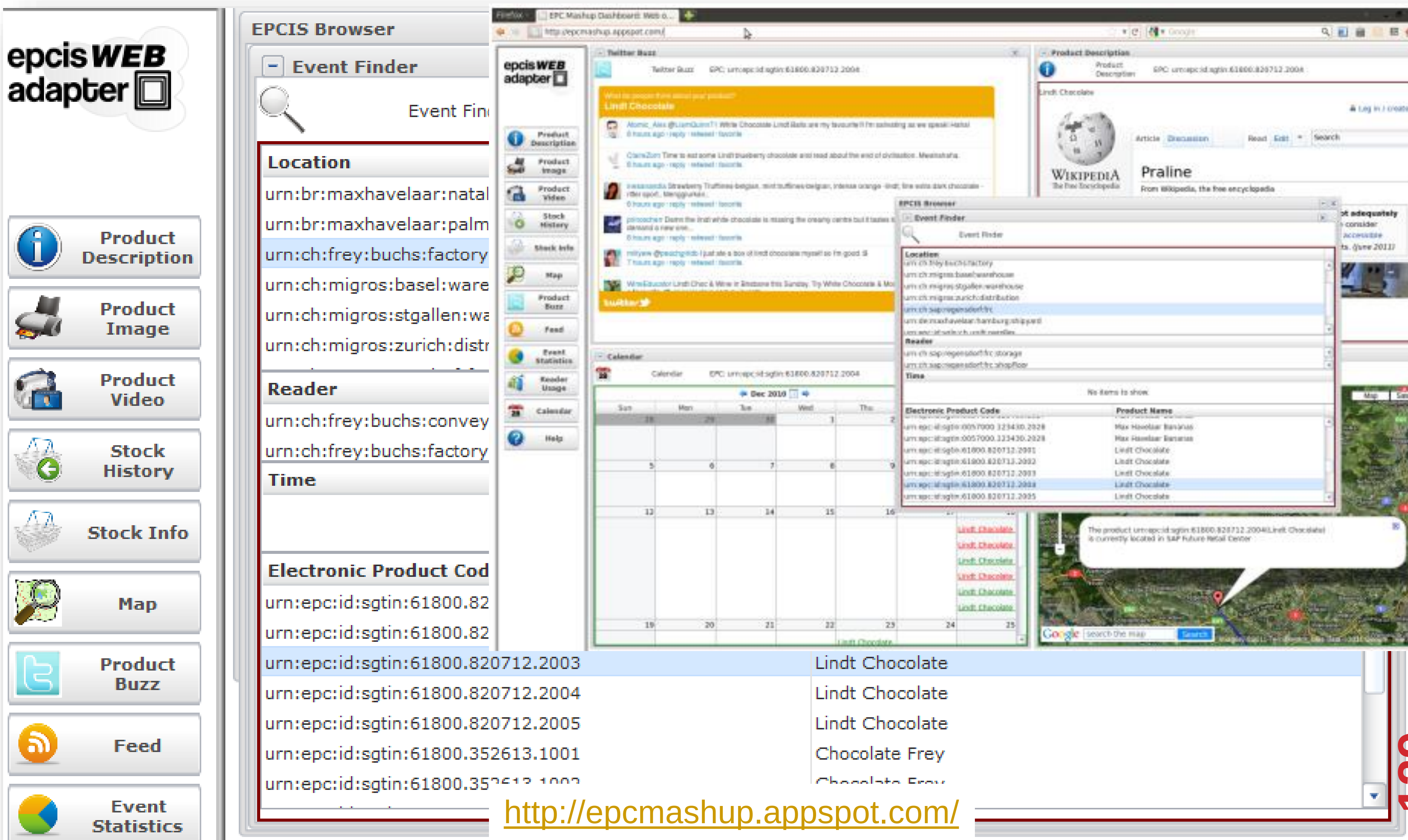
SensorLab

Logistics

- SenseAware
  - temperature readings
  - shipment's exact location
  - shipment is opened or if the contents have been exposed to light
  - real-time alerts and analytics between trusted parties regarding the above vital signs of a shipment

http://www.senseaware.com/

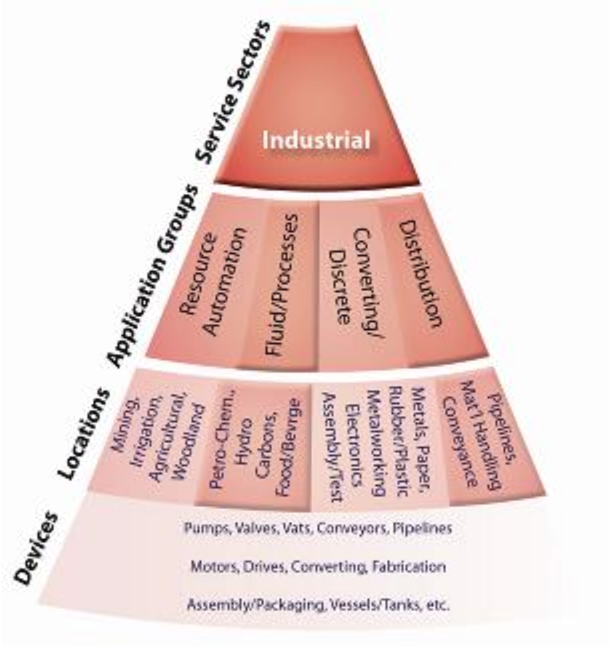
Supply chain mash-up



http://epcmashup.appspot.com/

Web of things use cases mapped to the Beecham Research classification

A case for industrial automation: automatic event detection and reporting



Commercial use case: Industrial automation

The integration gap between the production and business processes comes at a high cost, especially in multi-site enterprises.

Solutions:

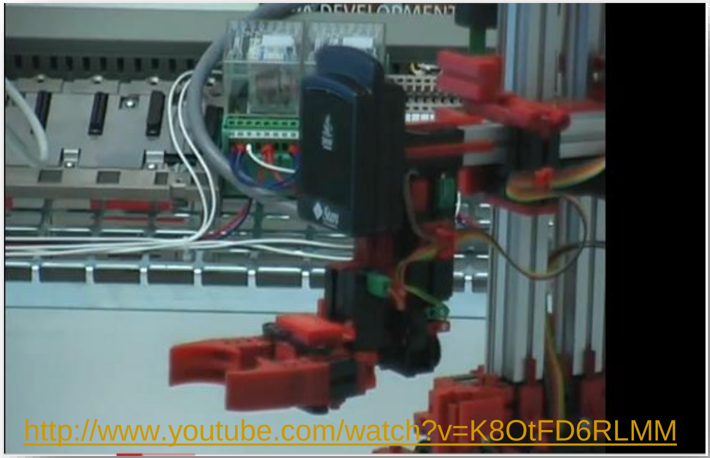
- Automatic monitoring of the production process
  - Monitor the devices on the production floor (i.e. robotic arm overheating)[1]
- Automatic event detection and notification
  - Process the measurements, detect anomalies and notify the business process (i.e. production at site interrupted, relocate)
- Productivity comparison
  - Machines equipped with sensors allow productivity comparison based on sensed data (i.e. Heidelberger Druckmaschinen)[2]
- Dynamic production optimization
  - 5% increase in paper production by automatically adjusting the shape and intensity of the flames that heat the kilns for the lime used to coat paper[2]

[1]SOCRADES project, http://www.socrades.eu/

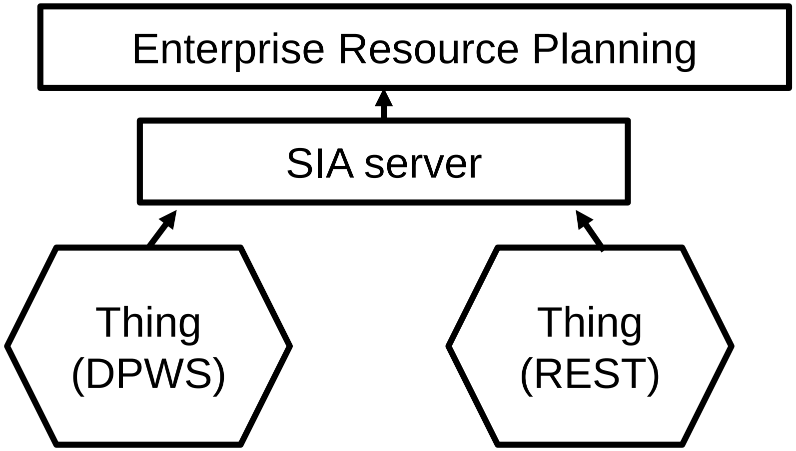
[2]Ludwig Siegele, A special report on smart systems, The Economist, Nov. 4 2010.

Process integration

- SunSpot on Robotic ARM, exposing measurements as Web service
- SunSpot GW connected to Windows machine, then to the Enterprise Network or Internet
- Failure, production interruption alarm – moving to alternative production site



http://www.youtube.com/watch?v=K8OtFD6RLMM



[1]SOCRADES project, http://www.socrades.eu

[2]D. Guinard, V. Trifa, S. Karnouskos, P. Spiess, D. Savio, Interacting with the SOA-based Internet of Things: Discovery, Query, Selection and On-Demand Provisioning of Web Services, IEEE Transactions on Services Computing, Vol. 3, July-Sept 2010.

Discover things

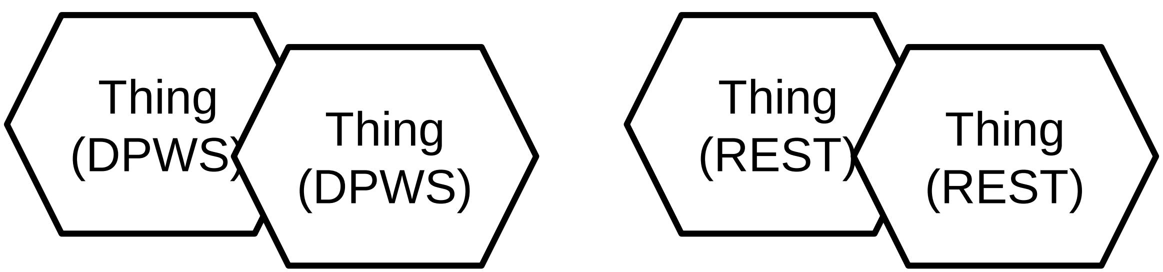
Automatic context data collection

Device Profile for Web Services (DPWS)

- Subset of Web Service standards (WSDL and SOAP)
- Successor of Universal Plug and Play (UPnP)

Representational State Transfer (REST)

- Lightweight, suitable for less complex services

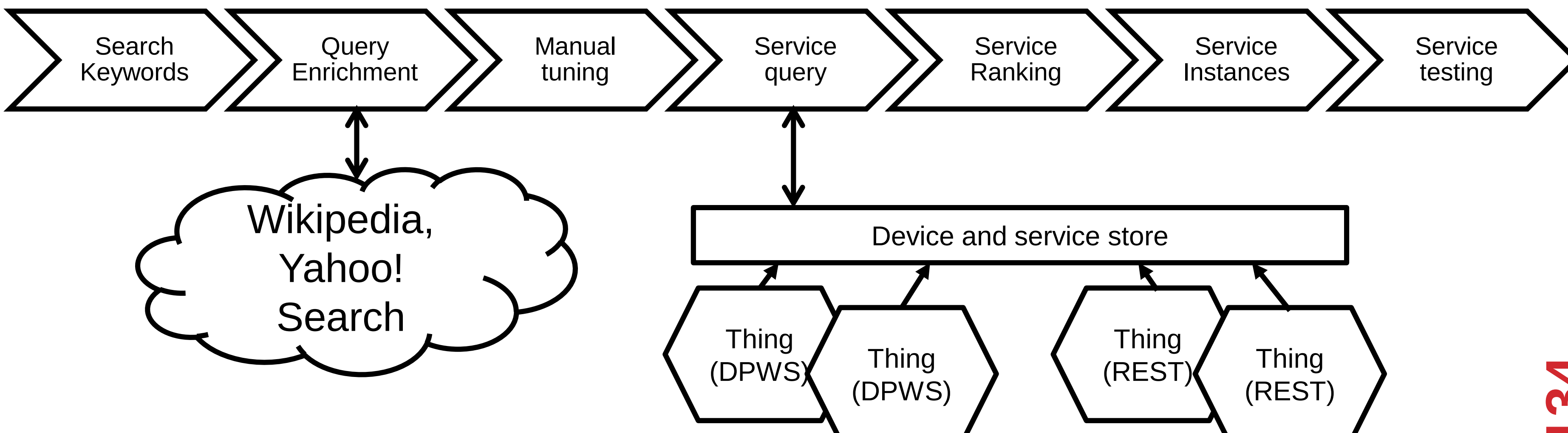


[1]SOCRADES project, http://www.socrades.eu

[2]D. Guinard, V. Trifa, S. Karnouskos, P. Spiess, D. Savio, Interacting with the SOA-based Internet of Things: Discovery, Query, Selection and On-Demand Provisioning of Web Services, IEEE Transactions on Services Computing, Vol. 3, July-Sept 2010.

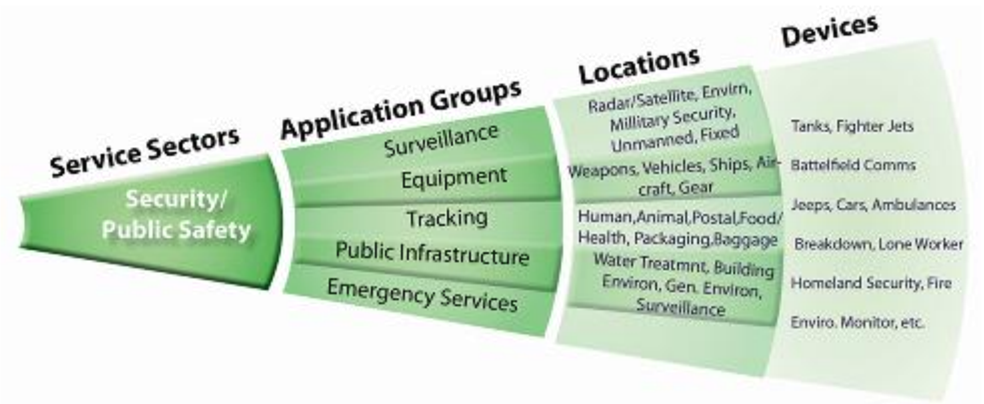
Query embedded services

- Insert search keywords, perform query enrichment (augmentation)
  - Tested 2 strategies: Wikipedia and Yahoo! Search
- Manually tune the augmented query by adding/deleting keywords
- Search services in the store and rank them according to some criteria (i.e. QoS)



Web of things use cases mapped to the Beecham Research classification

A case for security and public safety: environmental monitoring



Commercial use case: Environmental intelligence

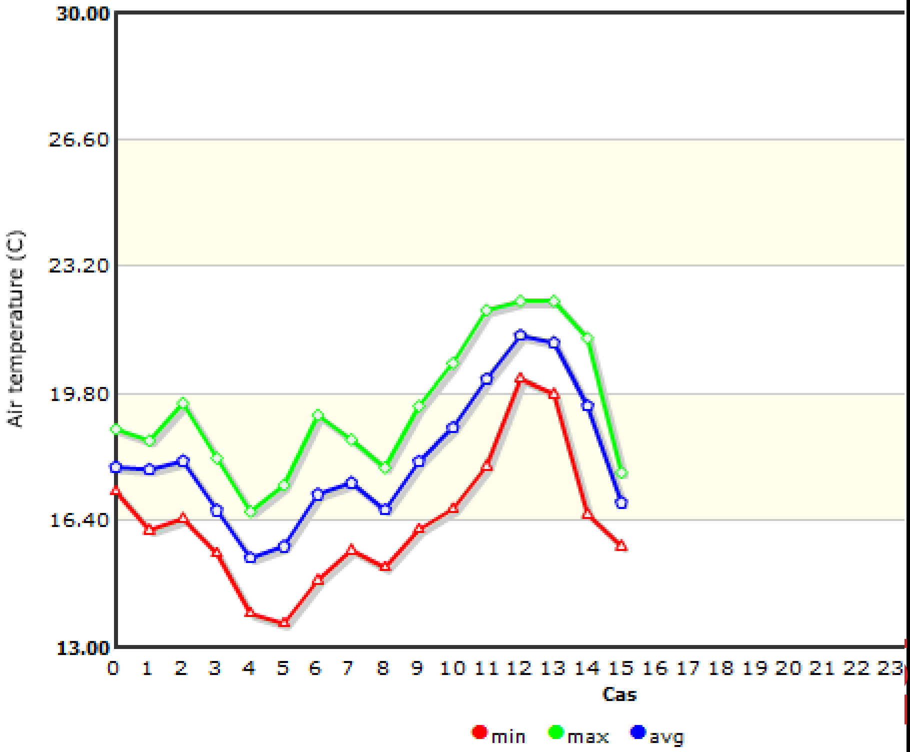
Data from large number of sensors deployed in infrastructure (such as roads) or over other area of interest (such as agriculture fields) can give decision makers a real-time awareness on the observed phenomena and events.

Solutions:

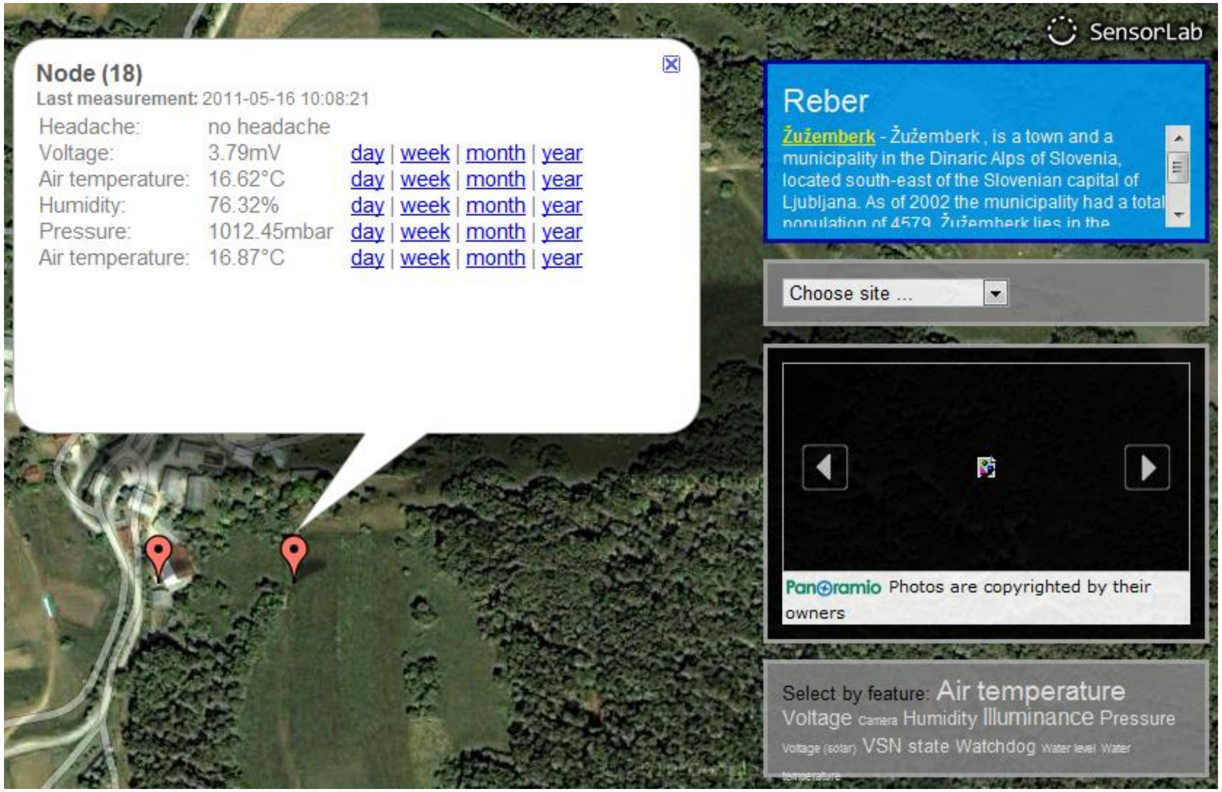
- Remote monitoring of cultures, soil moisture, insect infestations or disease infections
- Irrigation and pesticide spraying in precision agriculture
- Livestock monitoring for maximizing production (meat, milk, eggs) and achieve higher reproduction rates

Hyperthermia detection in stables

- The goal is to measure temperature and humidity inside and outside stables in order to detect the danger of hyperthermia at cows and issue an early warning.



Hyperthermia detection in stables



http://sensorlab.ijs.si/sl/demos.html

Remote observation of sport-fishing conditions

By using WSN technology information on water level, picture of a fishing spot and water and outside temperature can be provided

http://sensorlab.ijs.si/sl/demos.html

Remote observation of sport-fishing conditions

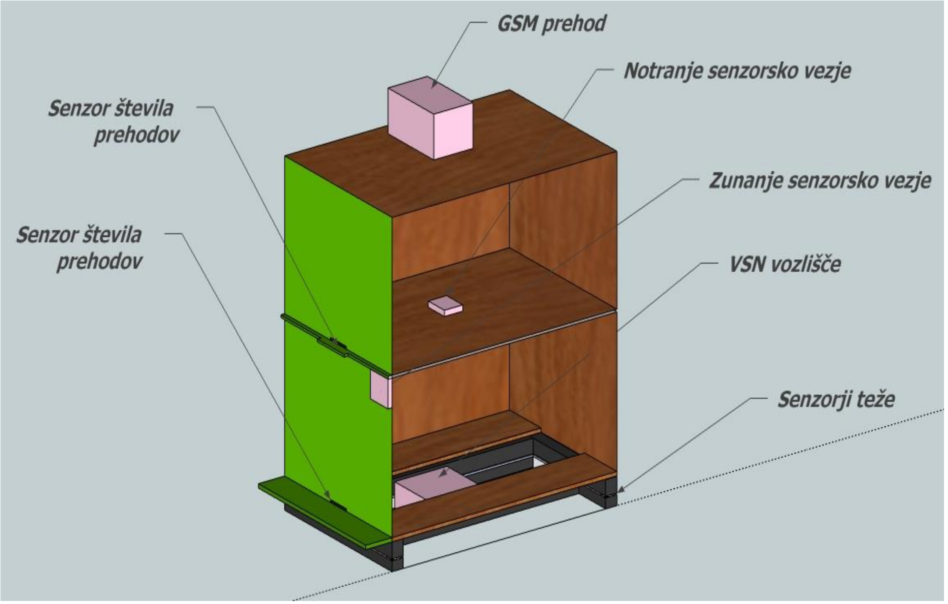
http://sensorlab.ijs.si/sl/demos.html

SensorLab

Beehive local climate conditions

The purpose of this testbed is to monitor climate conditions inside (temperature and humidity) and outside (temperature, humidity, air pressure, wind direction and speed) of the beehives.

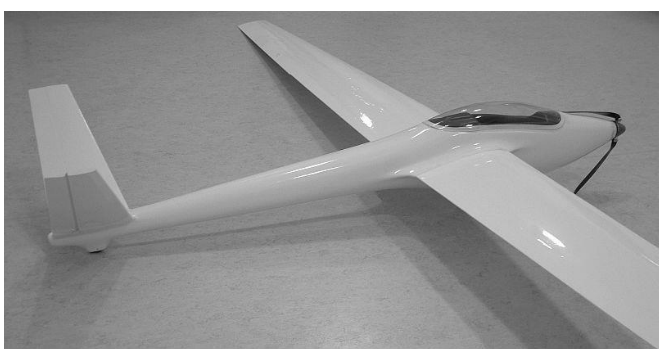
Through bee counting sensor presence of pesticides in the vicinity can be detected. For the test purposes also sound monitoring is possible



Multispectral imaging and data harvesting over Unmanned Aerial Vehicle (UAV)

Data harvesting over large areas where deployed WSNs have no Internet connection can be a very time consuming and expensive task.

Our solution uses Unmanned Aerial Vehicles (UAV) equipped with a gateway sensor node. In addition, UAV is used to collect multispectral images with a Tetracam ADC camera.



Experimental infrastructures for IoT/WoT

All results have to be based on real data collected from real infrastructures (see iDiary, FixtureFinder)

- **experimental infrastructure enabling such research is mandatory**

For experimental research on the sensor network infrastructure and services

- FIRE (EU) and GENI (USA) initiatives (also PPP and Living Labs)
- *experimental sensorial infrastructure*

For experimental research by application domain experts

- smart cities, smart grids
- *sensorial infrastructure for experimental research*

SensorLab

The LOG-a-TEC experimental facility

LOG-a-TEC joint name for several specific testbeds

The main testbed situated in Logatec (SI)

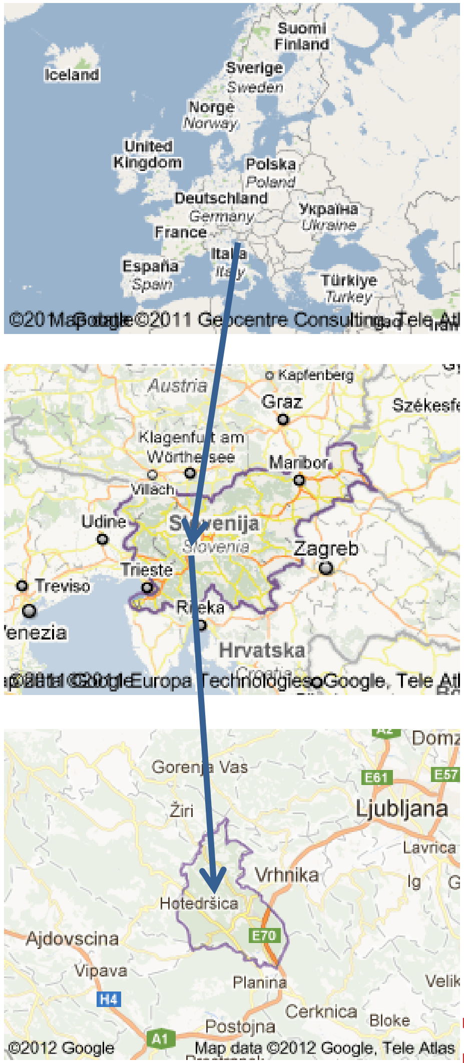
Based on wireless sensor network

Focus on

- low-cost spectrum sensing hardware
- wireless sensor network applications (AQ)

Sensor nodes are (primarily) installed on public light poles

Infrastructure rewiring ensures 24/7 power supply



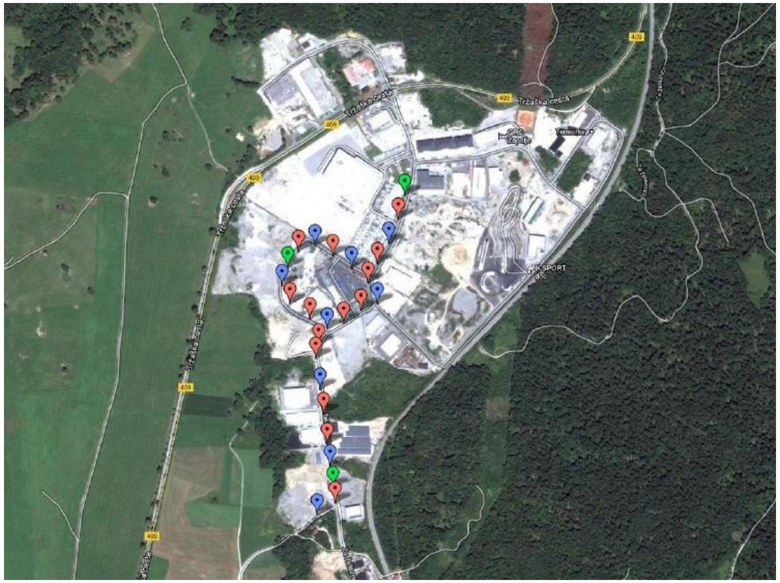
Experimental sensor network LOG-a-TEC

50+ VESNA sensor nodes

City center & industrial zone

ZigBee based management network @ 868 MHz (& OTAP)

Coordinating node provides gateway to the internet

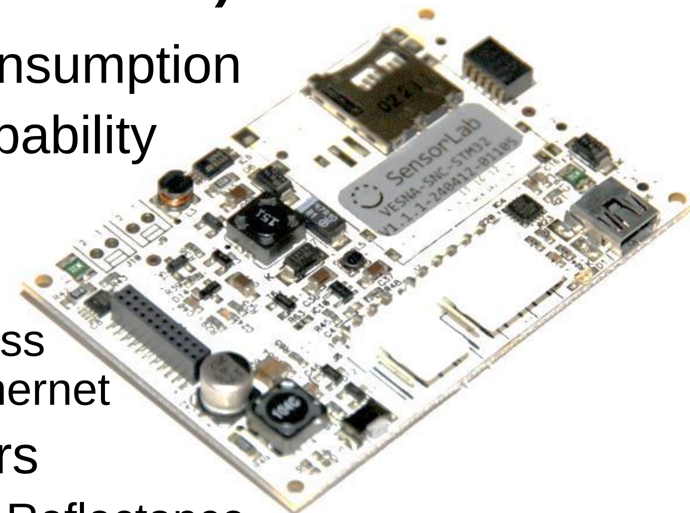


green – UHF, blue - ISM 868 MHz, red - ISM 2400 MHz, yellow - reserve locations

VESNA plaform

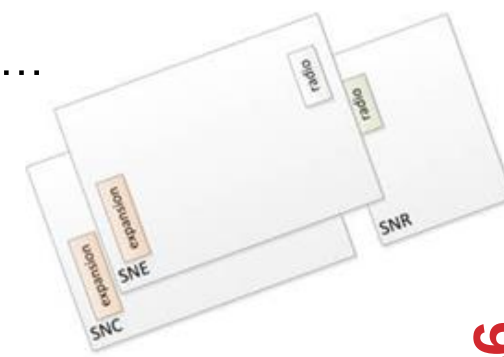
Modular platform for WSN (VESNA=SNC+SNR+SNE)

- High processing power and low energy consumption
- Sensor node & gateway (multi-tier / IP) capability
- Battery, solar or external power supply
- Multiple communication technologies
    - IEEE 802.15.4, ZigBee, 6LoWPAN, Wireless M-BUS, Bluetooth, Wi-Fi, GSM/GPRS, Ethernet
- Extensive portfolio of sensors and actuators
    - Temperature, Humidity, Luminance, Color, Reflectance, Pressure/Force, Camera, GPS, Microphone, Accelerometer, Gas (O2, CO2, CO), Hall effect, Motion/presence/range (IR, ultrasonic, Doppler), Capacitive/inductive touch, Gyroscope, Compass, …
    - Analog, Digital, PWM, LED, LCD, Relay, Motor, …

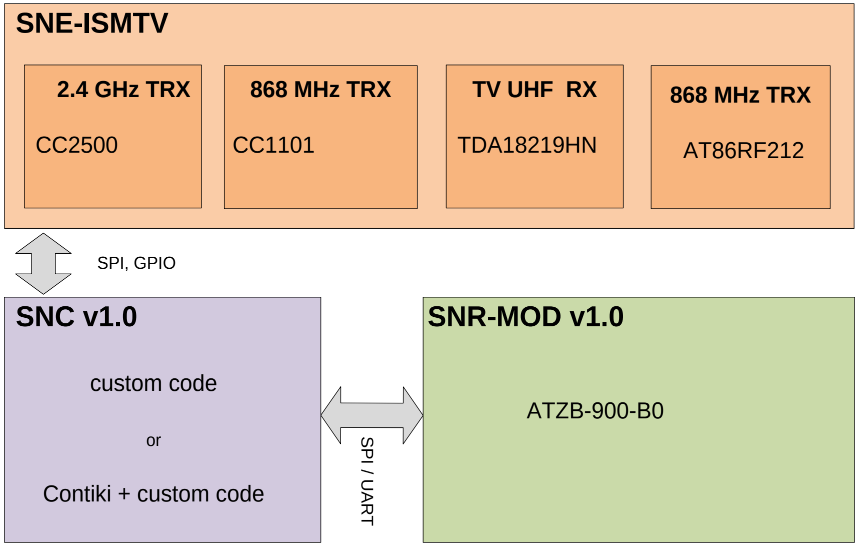


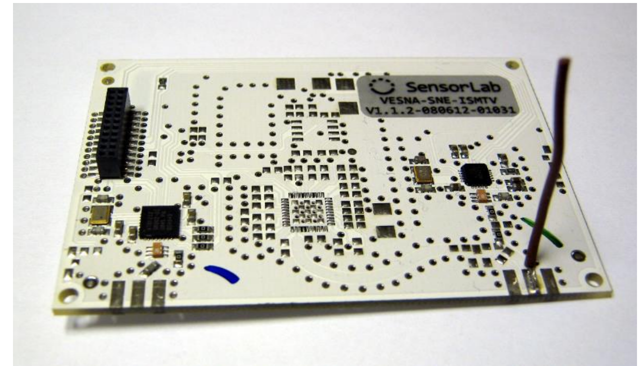
Open HW / SW / dev. tools

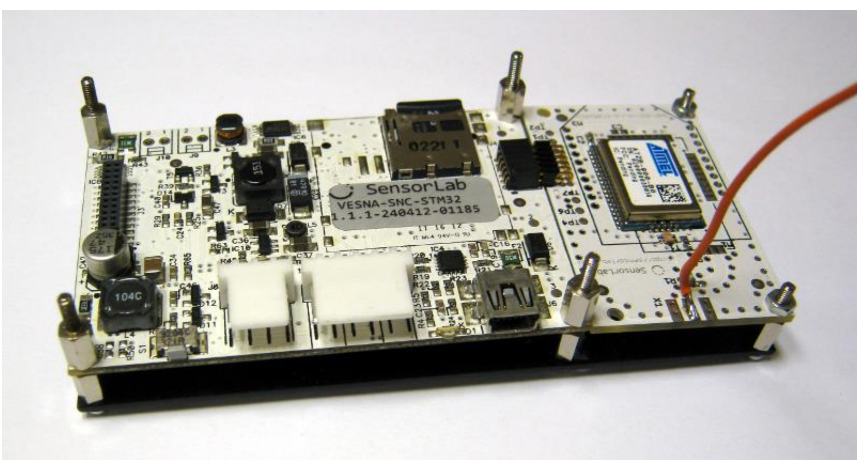
Contiki OS port (6LoWPAN)



VESNA assembling







SensorLab

LOG-a-TEC deployment

Spectrum sensing and cognitive radio

SensorLab

3 clusters

ZigBee mesh

Ethernet

VESNA

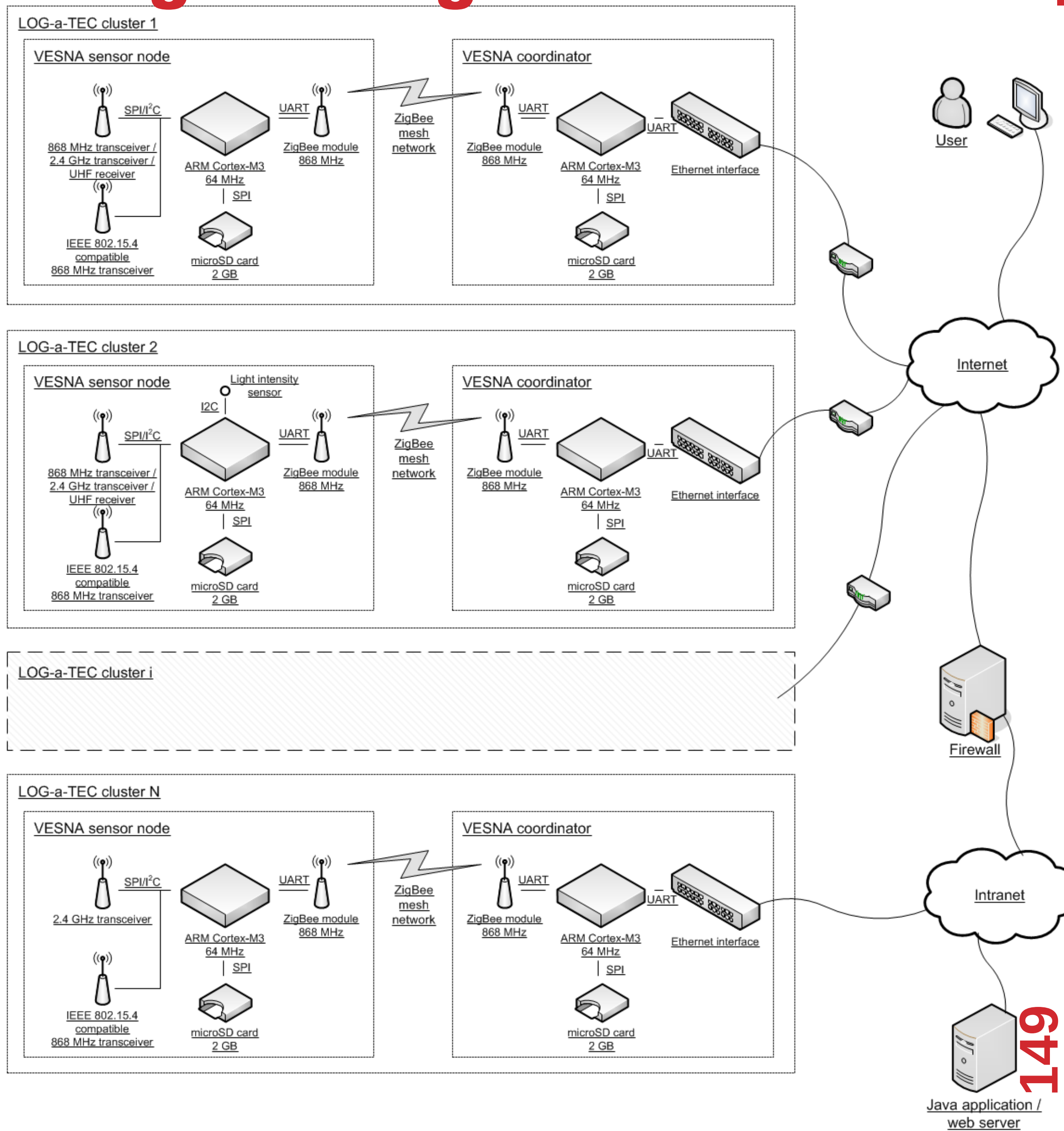
- ISMTV
- IEEE 802.15.4
- SD card

other devices

- USRP, SA, ...

SSL server

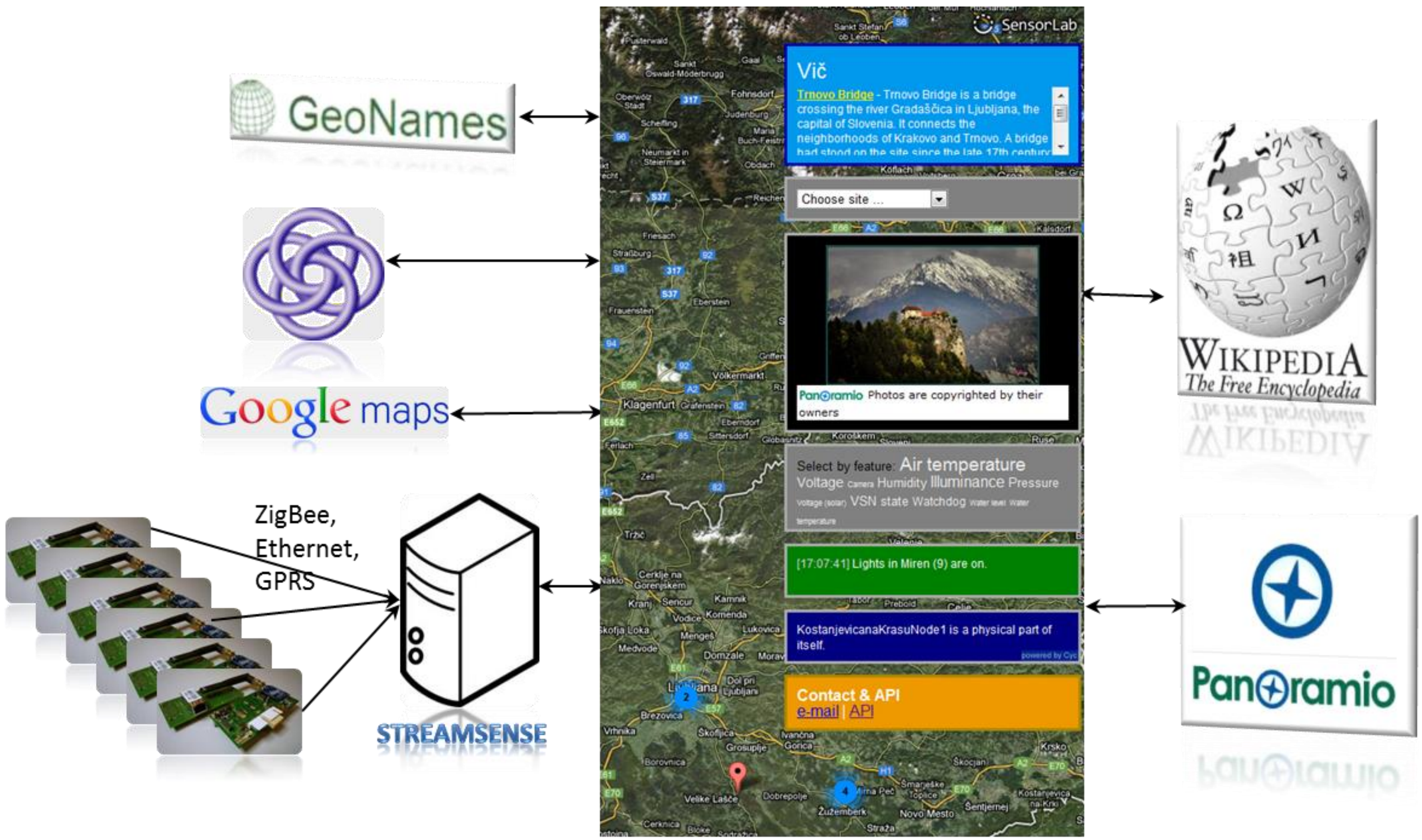
HTTPlike custom protocol



Environmental monitoring and lights control testbed

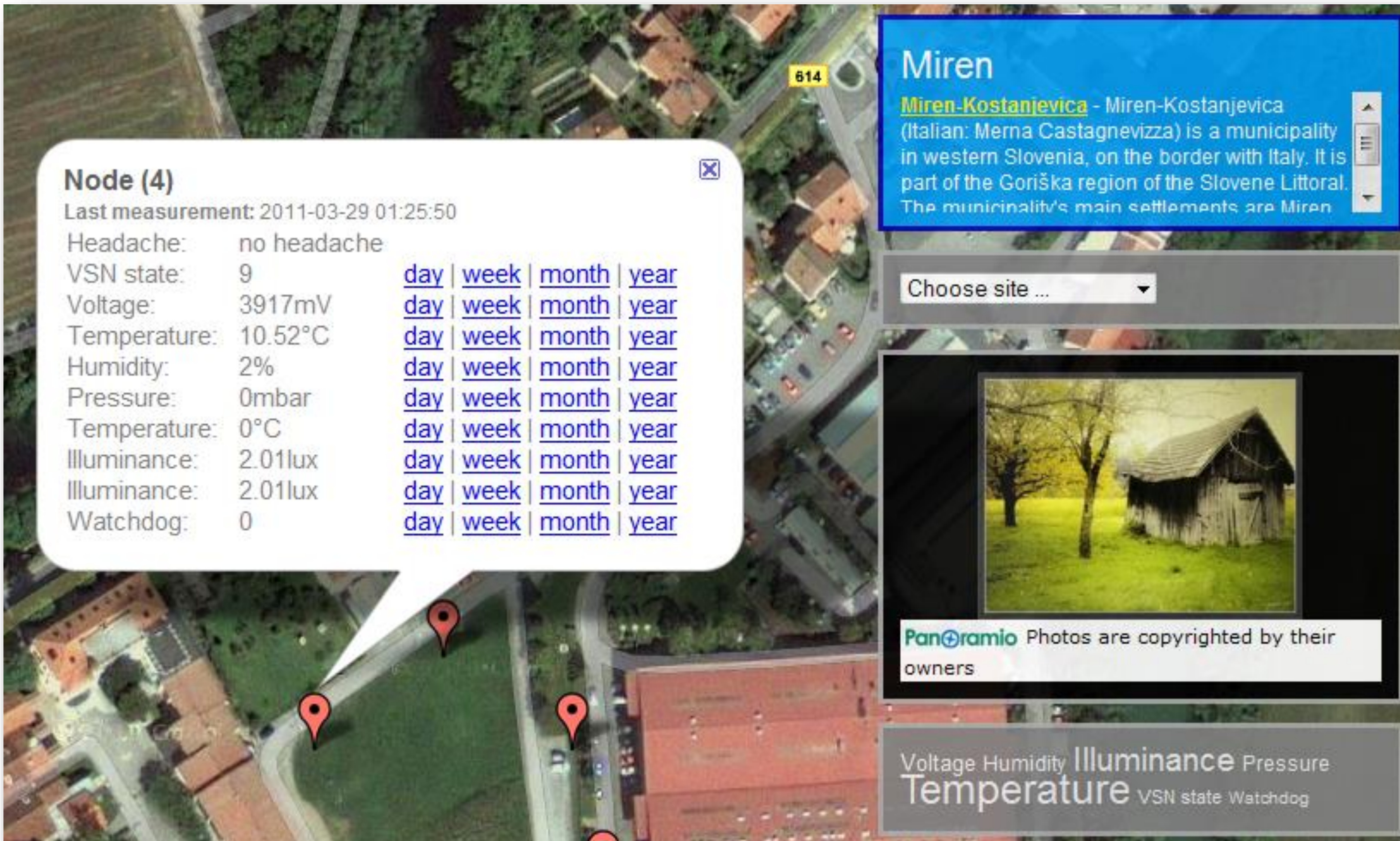
- Location: Slovenia, Europe (August 2010 – Sept 2012)
- The “things”: public light poles + VESNA sensor nodes
- Sensors: temperature, humidity, pressure, illuminance, etc.
- Actuator: dim the intensity of the light (pulse width modulation)

Videk: mashed sources of data



http://sensors.ijs.si/

Videk – UI



http://sensors.ijs.si/

Sensors, knowledge modeling and transliteration

SensorLab

Individual : VicNode1 CURE

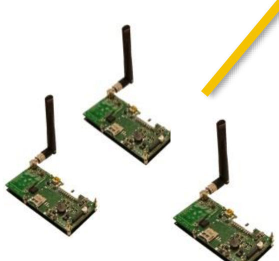
on the term

isa : ElectronicDevice
isa : Computer
connectedTo : virtualsensor3VicNode1 TSL2561VicNode1 sht11VicNode1
(connectedTo scp1000VicNode1 VicNode1)
(connectedTo virtualsensor2VicNode1 VicNode1)
(connectedTo virtualsensor1VicNode1 VicNode1)
(deviceUsed Testing VicNode1)
hasDevices : virtualsensor3VicNode1 TSL2561VicNode1 scp1000VicNode1 sht11VicNode1 virtualsensor2VicNode1 virtualsensor1VicNode1
latitude : (Degree-UnitOfAngularMeasure 46.042873)
longitude : (Degree-UnitOfAngularMeasure 14.487469)
nameString : "VicNode1"
objectFoundInLocation : IndoorMounting Vic
physicalParts : virtualsensor3VicNode1 TSL2561VicNode1 scp1000VicNode1 sht11VicNode1 virtualsensor2VicNode1 virtualsensor1VicNode1
(queryHasVeryHighPertinenceForThing GetLinkToMap VicNode1)
supportedBy : VicBuilding1

Knowledge base

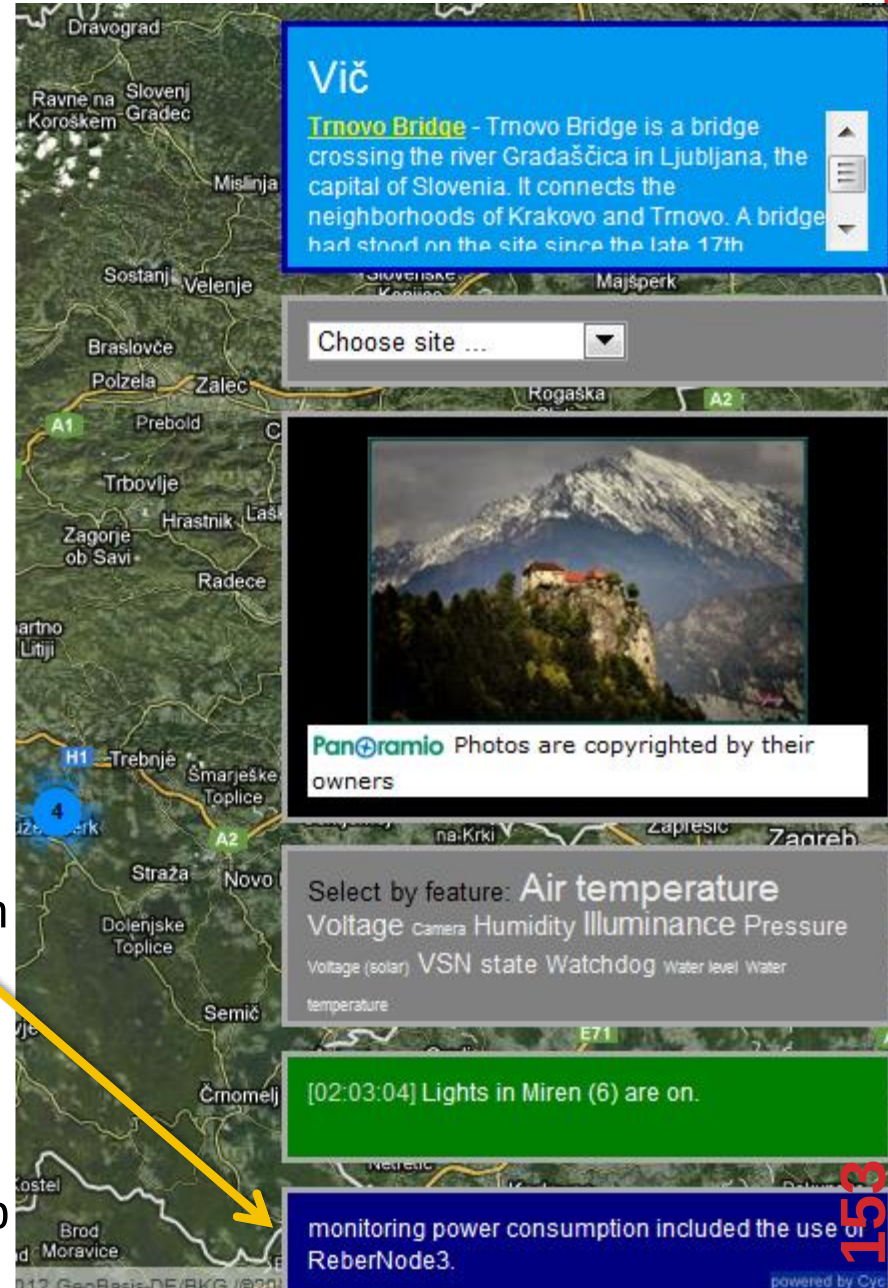
Transliteration

Device Identification Protocol



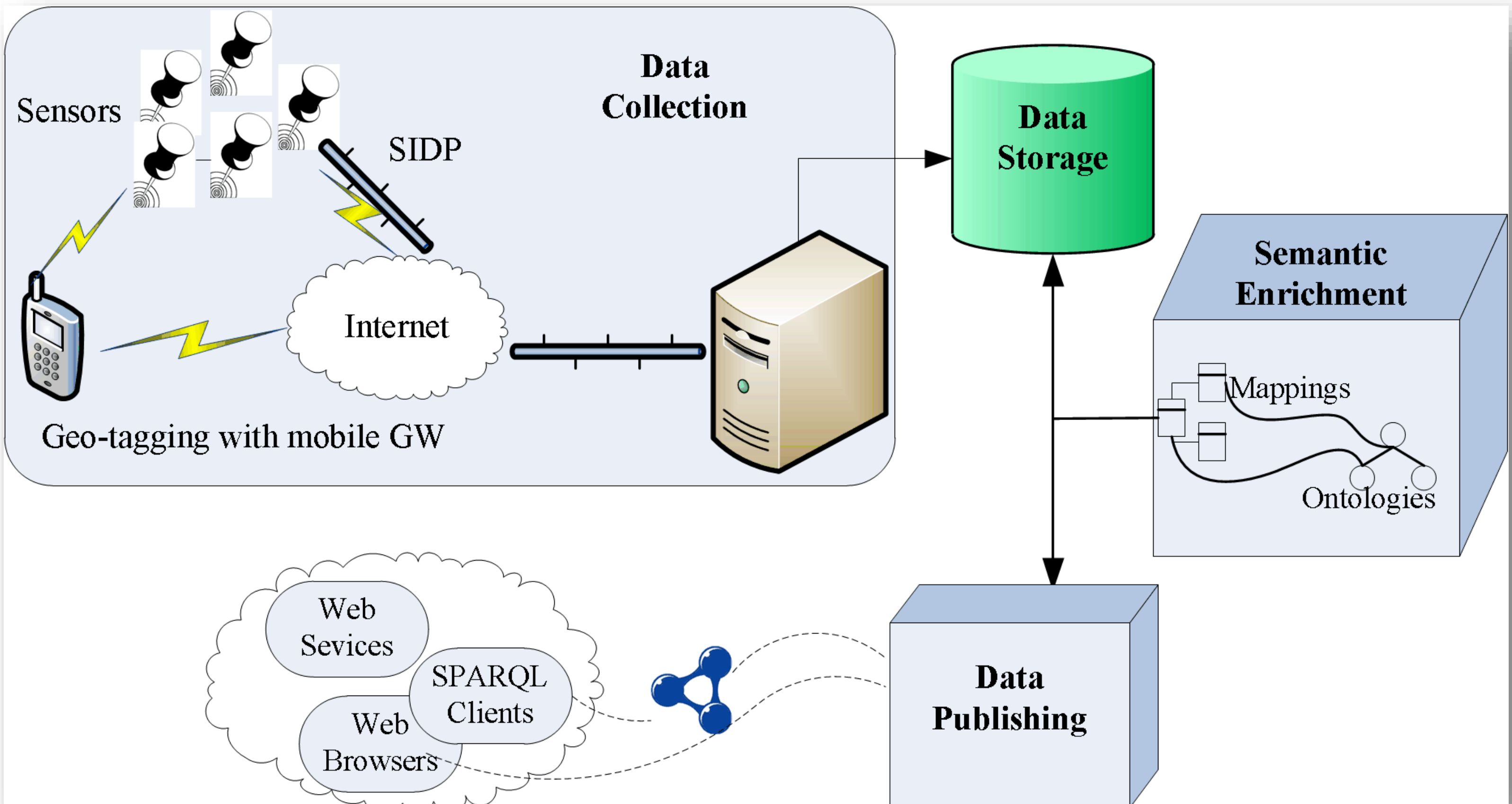
Sensors

Mash-up



Fortuna et al., Web of Things, 2012.

Environmental intelligence: SemSense system architecture



Moraru et al, Exposing Real World Information for the Web of Things, IIWeb (WWW2011), Hyderabad, India.

Environmental intelligence: SemSense implementation details

Scenario

- architecture for collecting real world data from a physical system of sensors and publishing it on the Web

Implementation:

- VESNA Sensor Nodes platform are the “things”
- Self-Identification Protocol
  - Custom protocol for collecting meta-data and data
- MySQL database for storage of data and meta-data
- Meta-data semantic enrichment component
  - RDF representation
  - Semantic Sensor Network (SSN) ontology, Basic GeoWGS84 Vocabulary, GeoNames and FOAF as vocabulary
  - Linking to Linked Opened Data Cloud
  - D2R for mapping the database schema

A. Moraru, M. Vucnik, M. Porcius, C. Fortuna, M. Mohorcic, D. Mladenic, Exposing Real World Information for the Web of Things, IIWeb (WWW2011), Hyderabad, India.

SensorLab

Environmental intelligence: browse the semantic representation

JSI SensorLab

Running at http://sensorlab.ijs.si:2020/

Home | Archive-1Day-Sampling DeviceType Observation ObservationValue Platform Property SensingDevice SensorOutput System

This is a database published with D2R Server. It can be accessed using

1. your plain old web browser
2. Semantic Web browsers
3. SPARQL clients.

1. HTML View

You can use the navigation links at the top of this page to explore the database.

2. RDF View

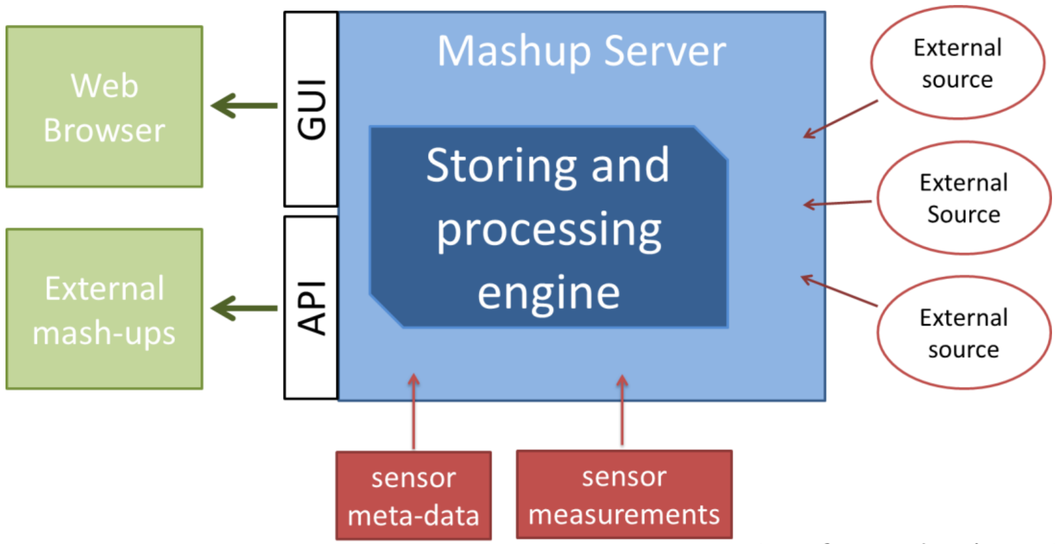
You can also explore this database with **Semantic Web browsers** like Tabulator or Disco. To start browsing, open this entry point URL in your Semantic Web browser:

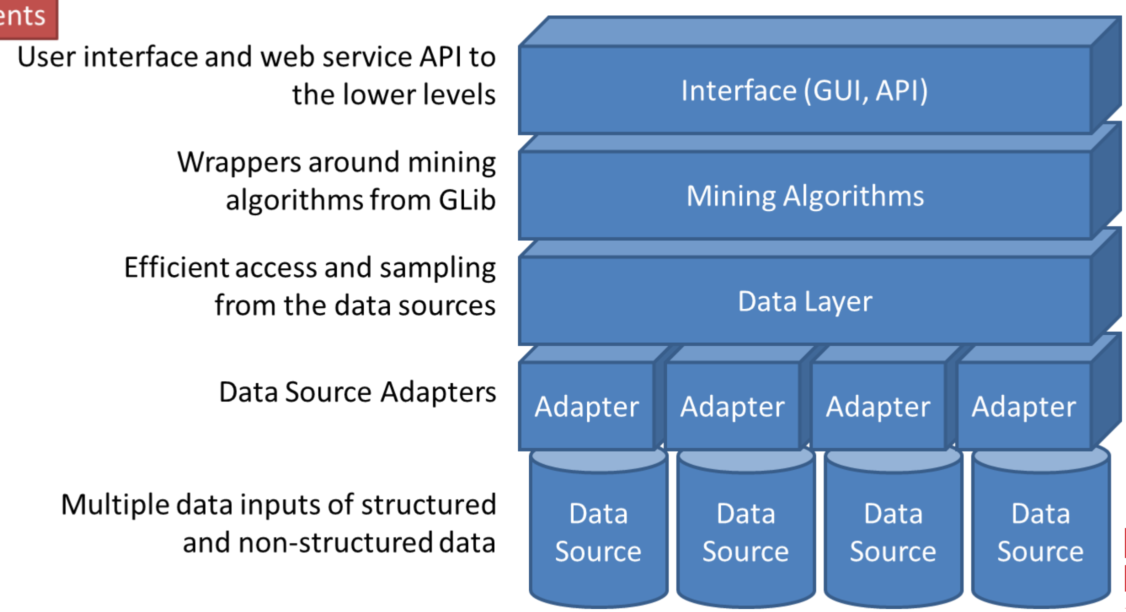
http://sensorlab.ijs.si:2020/all

3. SPARQL Endpoint

Browse at: http://sensors.ijs.si:2020/

Technology behind Videk





Photovoltaics system monitoring

Motivation

- Systematically investigate the pros and cons of different PV technologies, effect of panels deployment (orientation) and impact environment (weather) conditions

Sensorics

- Light intensity in different spectrum (UV/VIS/IR)
- Solar panel U/I characteristic
- Performance of inverter MPP tracker
- Temperature of a PN junction
- Environment conditions (context)

Measurements stored and post processed in the web platform

Photovoltaics system monitoring

5 sets of PV panels

- S, E, W orientation
- Amorphous & crystalline silicon

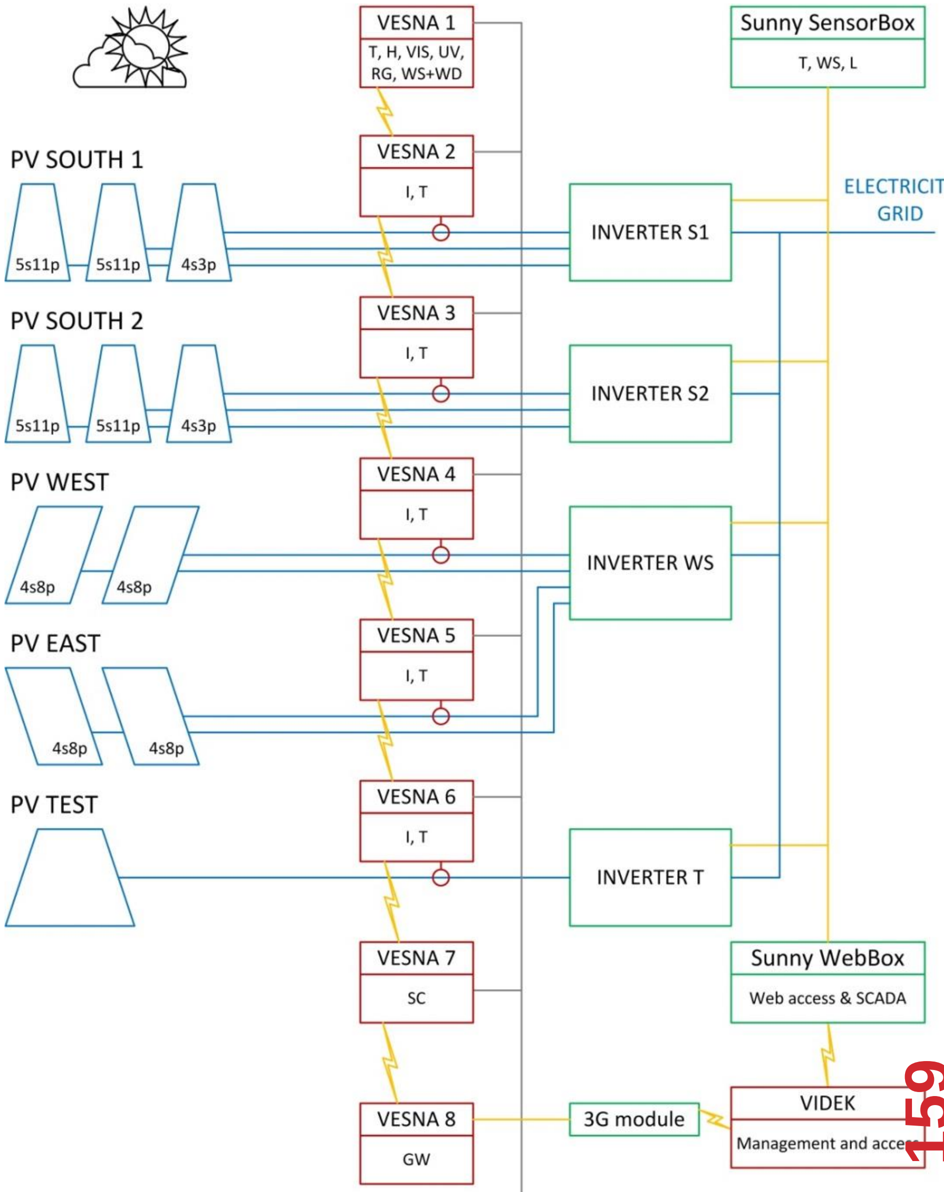
7 VESNA sensor nodes

- Weather
- Temp. + current
- Reference solar cell

1 VESNA GW

- 3G radio module

ZigBee sensor network @ 868 MHz



SensorLab

Air quality monitoring

CITI-SENSE

FP7 CITI-SENSE- Development of sensor-based Citizens' Observatory Community for improving quality of life in cities

- Urban quality
- Public spaces
- Schools indor

Indoor/outdoor air quality, weather, radiation, noise level …

VESNA

- Gas sensors - CO_2, CO, Nox, VOC
- Environmental sensors – air pressure, temperature, humidity, luminence, weather
- Noise sensor

LOG-a-TEC testbed

- Trial and validation of VESNA based prototype system
- Final pilot system deployed in Ljubljana (+ 8 EU cities)

Smart Mobile Home

Global environment

Local environment

Micro environment

Sensing:
- Gas
- Electricity
- Petrol
- Fridge
- …

Sensing:
- Car to Car
- Road conditions
- Twitter on Events
- Weather
- Geography
- Tourism
- Parking

Communication:
- Social network among camper drivers
- Car service & advice

The goal is to help a driver to manage complexity of all the data sources
…typical age of a driver is over 60 years not being to skilled in driving a camper

EnStreaM

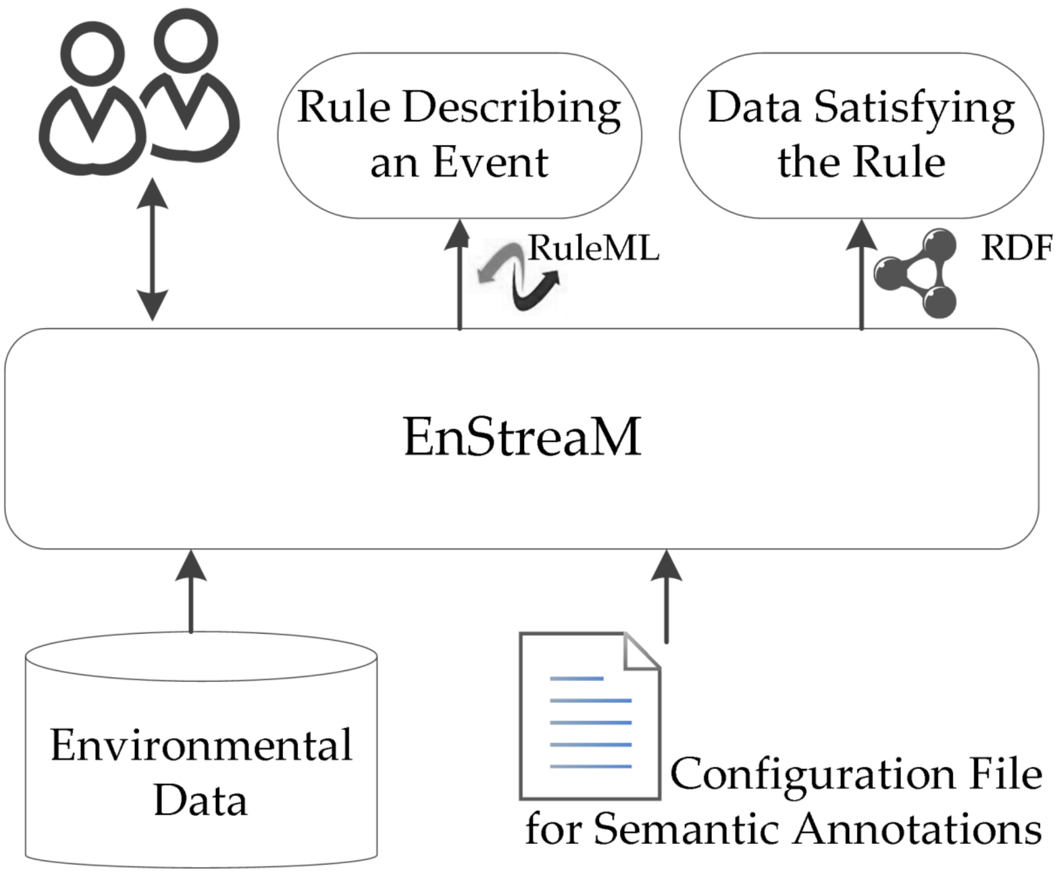
SensorLab

Rule generation and validation on environmental data

- The supporting architecture is capable of handling large amounts of data
- The system is meant for domain experts to generate and validate rules that describe specific events
- Applied in environmental scenarios: landslides, oil spills and river floods, where main source of data comes from sensors

Also a ESWC 2012 demo: Supporting Rule Generation and Validation on Environmental Data in EnStreaM

System Overview



- Input: **sensor data** and **event data**
  - e.g.: volume of rainfall for a given geographical location and landslides that occurred
- Output: **rules** and the related **dataset**, semantically annotated

SensorLab

Data Layer Schema

Node

- Name, URN
- GPS Latitude, Longitude, Altitude, Sattelite No., Speed
- Description, Geolocation (string), Owner

Sensor

- SensorNodeId
- SensorTypeId
- CurrentState fields (current aggregates)
- LastMeasurementId

Type

- Name, Measured Phenomena, URN
- Sampling information, Reporting interval, feature of interest, unit of measurement

Measurement

- SensorId
- Value
- Timestamp

Aggregate

- SensorId
- Value
- Aggregate type
- Timespan
- Timestamp

Events

- Name, URN
- Timestamp
- GPS latitude, longitude

Aggregates

Saves aggregates after transition into a new time window: Count, Average, Sum, Min, Max, Standard deviation

Primary aggregates

Calculated from raw measurements, fine grained.

Secondary aggregates

Calculated from other aggregates (only possible to use with on-line type).

```xml
<?xml version="1.0" encoding="utf-8"?>
<configuration>
  <timespans>
    <timespan id="1" timewindow="3600" />
    <timespan id="2" pid="1" timewindow="24" interval="1"/>
    <timespan id="3" pid="2" timewindow="7" interval="1"/>
    <timespan id="3" pid="2" timewindow="30" interval="1"/>
    <timespan id="4" pid="2" timewindow="365" interval="1"/>
  </timespans>
  <aggregates>
    <aggregate type="MAX"/>
    <aggregate type="MIN">
      <timespan id="1" timewindow="3600">
      <timespan id="2" pid="1" timewindow="48" interval="24"/>
    </aggregate>
    <aggregate type="AVG"/>
    <aggregate type="SUM"/>
    <aggregate type="STD"/>
    <aggregate type="MED"/>
    <aggregate type="1QU"/>
    <aggregate type="3QU"/>
    <aggregate type="CNT"/>
  </aggregates>
  <sensortypes>
    <sensortype id="1">
      <aggregate type="MAX"/>
      <aggregate type="SUM"/>
    </sensortype>
  </sensortypes>
  <sensors>
    <sensor id="1">
      <aggregate type="MAX"/>
      <aggregate type="SUM"/>
    </sensor>
  </sensors>
</configuration>
```

Time windows & intervals

- Time windows of aggregates can overlap
- Overlapping interval is set in configuration file (interval)
- For example:
  - Weekly aggregates can be calculated from Monday to Monday, from Tuesday to Tuesday, etc.

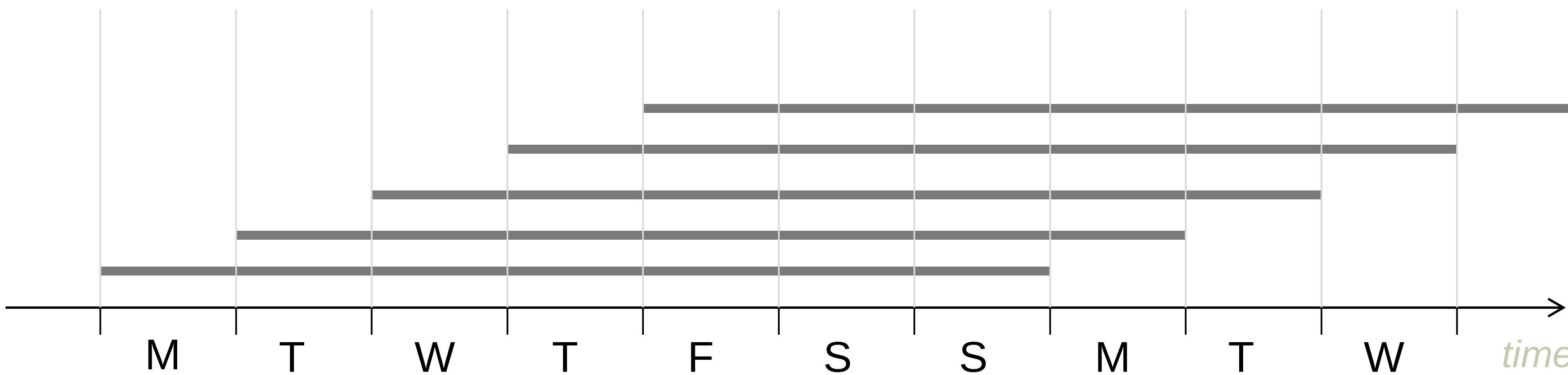
```
<timespan id="1" timewindow="3600" />

<timespan id="2" pid="1"
 timewindow="24" interval="1"/>

<timespan id="3" pid="2"
 timewindow="7" interval="1"/>
```

7-day time window

Overlap/update interval is 1 day



Example queries

Easy and fast detection of events on current state data (very simple rules)

Fog forming example

```
If

    (humidity[AVG,1h] < 90%) &
    (humidity[AVG,10m] > 95%)

Then

    trigger fog forming risk event.
```

Simple validation of more complex event queries (using current state and previous aggregates)

Road Icing example

```
If

    (precipitation[SUM,12h,6h ago] > X) &
    (temparature[MAX,12h,6h ago] > 0) &
    (temperature[MIN, 6h]) < 0)

Then

    trigger road icing risk event.
```

Can handle time queries

Time example

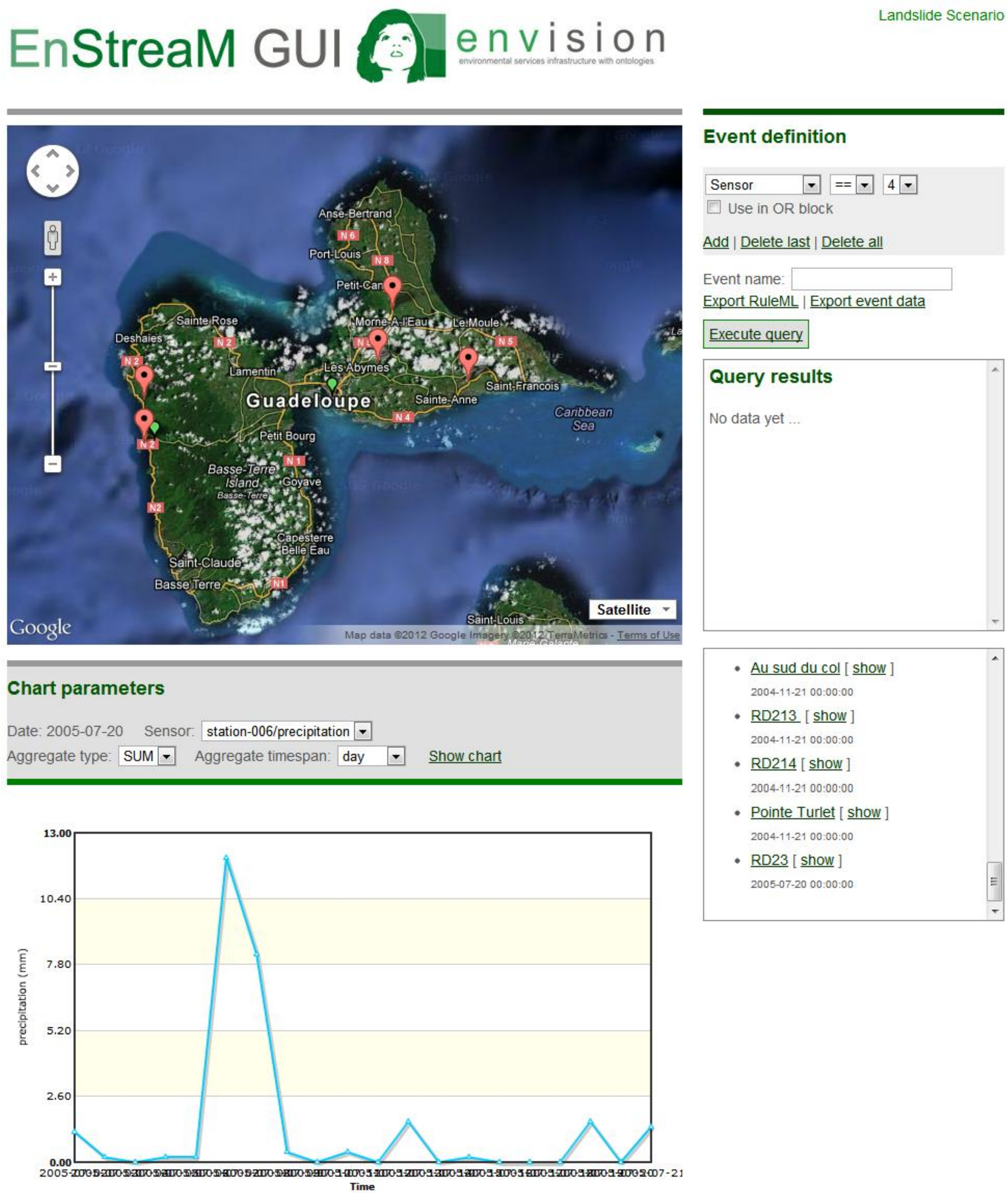
```
If

    (temperature[AVG,1w,3d ago] <-5) &
    (temperature[AVG,24h,2d ago] < 5) &
    (temperature[AVG,24h,1d ago] < 5) &

Then

    trigger lake still frozen event.
```

System GUI


EnStreaM GUI
envision
environmental services infrastructure with ontologies
Landslide Scenario
Anse-Bertrand
Port-Louis
Petit-Canal
Sainte-Rose
Deshaies
Morne-A-l'Eau
Le Moule
Lamentin
Les Abymes
Guadeloupe
Saint-François
Sainte-Anne
Caribbean Sea
Petit Bourg
Basse-Terre Island
Goyave
Capesterre Belle Eau
Saint-Claude
Basse Terre
Saint-Louis
Satellite
Google
Map data ©2012 Google Imagery ©2012 TerraMetrics - Terms of Use
Event definition
Sensor
==
4
Use in OR block
Add | Delete last | Delete all
Event name:
Export RuleML | Export event data
Execute query
Query results
No data yet ...
Au sud du col [show]
2004-11-21 00:00:00
RD213 [show]
2004-11-21 00:00:00
RD214 [show]
2004-11-21 00:00:00
Pointe Turlet [show]
2004-11-21 00:00:00
RD23 [show]
2005-07-20 00:00:00
Chart parameters
Date: 2005-07-20
Sensor: station-006/precipitation
Aggregate type: SUM
Aggregate timespan: day
Show chart
13.00
10.40
7.80
5.20
2.60
0.00
precipitation (mm)
Time

Use cases

Environmental intelligence

Others

- Intelligent buildings
- Smart cities
- Smart infrastructures
- …

Intelligent building

Berkley: Motescope*

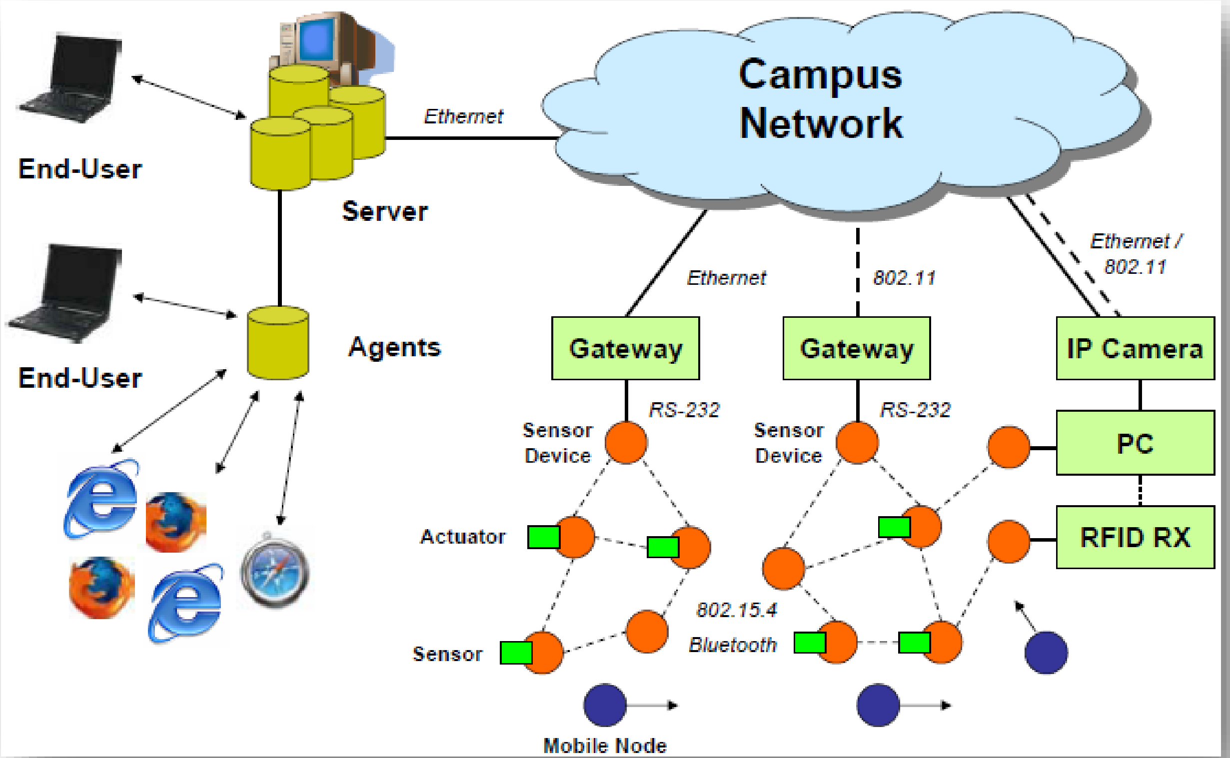
- Soda Hall, the Computer Science building
- Permanent testbeds for research, development and testing
- 78 Mica2DOT nodes

*According to web site visited on Oct 2010.

University campus

CMU: SensorAndrew*

- campus-wide testbed
- Firefly nodes
- Unknown scale



* According to web site on Oct 2010 and tech report from 2008.

Smart city

MIT: Senseable City Lab*

- Sensor nodes built into the wheels of bikes
- Unknown number

*Neil Savage, Cycling through Data, Communications of the ACM, Sept 2010.

Smart infrastructure

Harward, BBN: CitySense*

- 100 wireless sensors deployed across a city
- Sensor nodes are embedded PC, 802.11a/b/g interface, and various sensors for monitoring weather conditions and air pollutants
- open testbed

* According to web site visited on Oct 2010, last modified in 2008.

SensorLab

Outline

Part III. Demos, Tools & Research directions

✓ **Use cases**

- What systems and prototypes exist?

Open problems

- Are there unsolved problems?

Summary

- What was this tutorial about?

List of sources for further studies

- Where to start digging?

Current state and open problems with respect to Sensor Nodes

WSN is

- Well developed field with many degrees of freedom
- Complex, large-scale, resource constrained systems
- Focus is on intra network communications

Efficient management and maintenance of the “things”

- Remote reconfiguration of parameters
- Remote software updates
- Real implementations solving real problems, particularly large scale (see next slide)

Myths & lessons regarding Sensor Networks

Myth #1: Nodes are deployed randomly.

Myth #2: Sensor nodes are cheap and tiny.

Myth #3: The network is dense.

Lesson #1: It’s all about the data.

Lesson #2: Computer scientists and domain scientists need common ground.

Lesson #3: Don’t forget about the base station!

M. Welsh, **Sensor Networks for the Sciences**, Communications of the ACM, Nov. 2010.

Challenges with respect to conceptualization

WoT covers a long pipeline of technologies from sensors to high level services

- ...current ontologies are covering just parts of the space and are yet to be interlinked
- ...ideally, sensor network domain should be linked to general common-sense ontologies and further to domain specific service ontologies

Challenges with respect to analytics & CEP

- Traditional mining and analytic techniques are not ready for the scale and complexity coming from large sensor setups
- ...in particular:
  - connection to background knowledge (ontologies) for enrichment of sensor data for expressive feature representations needed for analytic techniques
  - "complex events" are in the context of WoT much more complex compared to traditional "complex events" research
  - real-time response on complex events appearing in WoT setups

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Summary

The tutorial had 3 parts:

1. Motivation & background
   - Problems that the Web of Things can solve
   - Components and complexity of the system, from “Things” to Apps and Services
   - Quick start
2. Technology and tools for exploiting the WoT
   - Semantic aspects
   - Analytic aspects
   - Services
3. Demos, Tools & Research directions
   - Overview of existing setups and tools used for their implementation
   - Research directions

Outline

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Relevant Conferences

- **WWW** - International World Wide Web Conferences
- **ICML** – International Conference of Machine Learning
- **NIPS** – Neural Information Processing Systems
- **KDD** – ACM Knowledge Discovery in Databases
- **ICWS** - IEEE International Conference on Web Services
- **ISWC** – International Semantic Web Conference

- **IPSN** – Information Processing in Sensor Networks
- **Percom** - IEEE Pervasive Computing and Communication
- **SenSys** - ACM Conference on Embedded Networked Sensor Systems
- **MobiSys** - International Conference on Mobile Systems, Applications, and Services
- **INSS** – International Conference on Networked Sensing Systems
- **DCOSS** - International Conference on Distributed Computing in Sensor Systems

- **iThings** - IEEE International Conference on Internet of Things

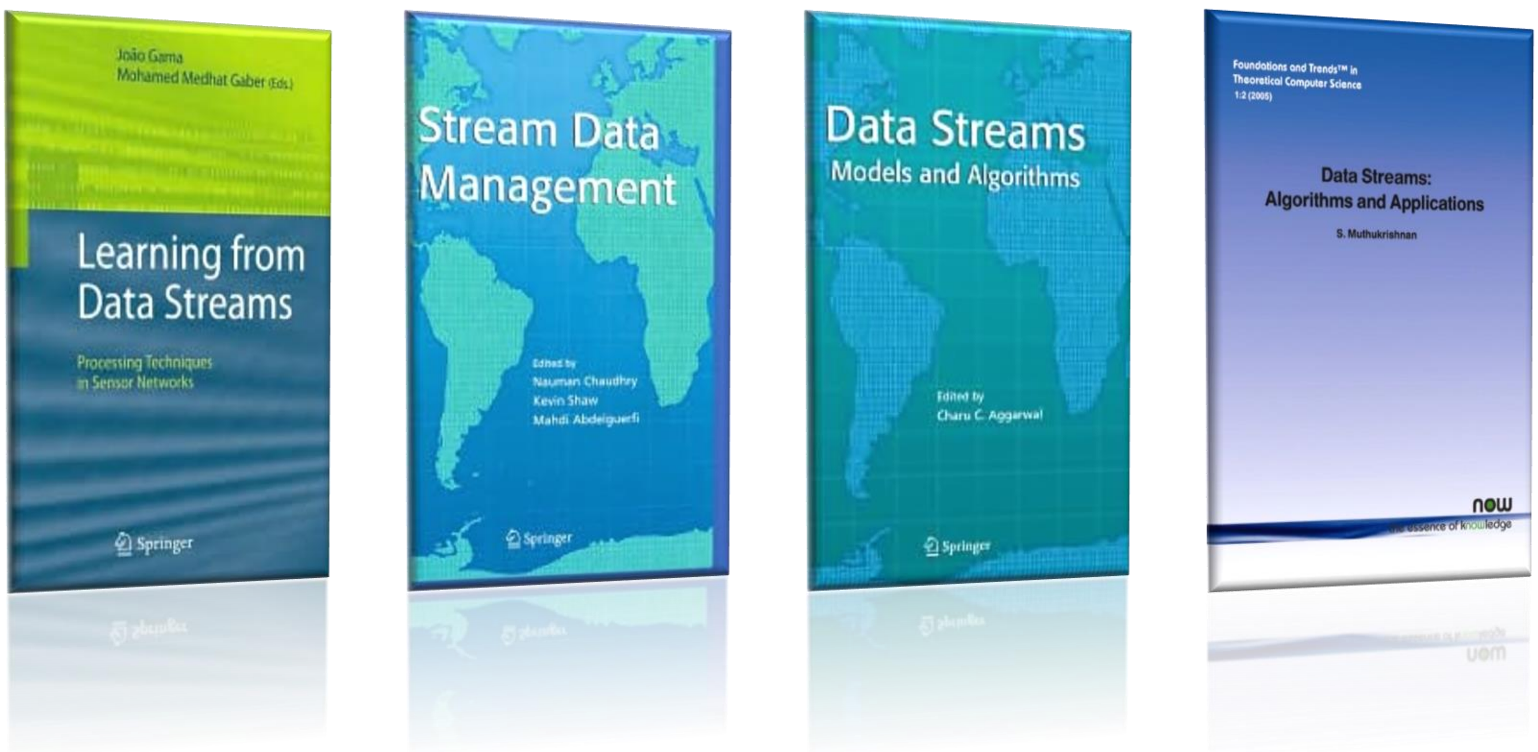
Apps and Services

“Glue”

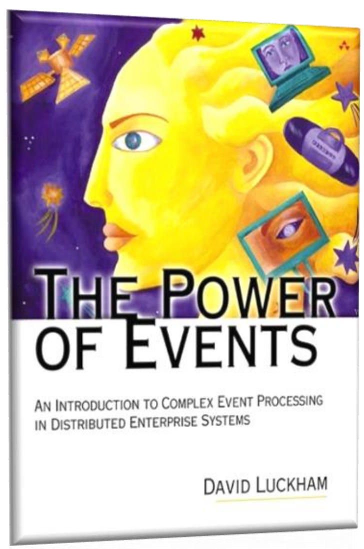
Relevant Workshops

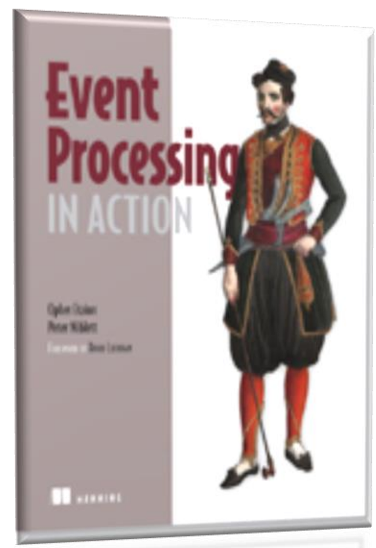
- **WebOfThings** - International Workshop on the Web of Things
- **SensorKDD** - International Workshop on Knowledge Discovery from Sensor Data
- **PURBA** - Workshop on Pervasive Urban Applications
- **Urban-IOT** – the Urban Internet of Things Workshop
- **Web Enabled Objects** - International Workshop on Web-Enabled Objects
- ….

Books on data streams

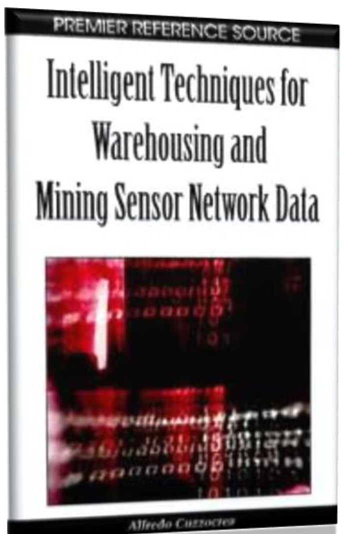


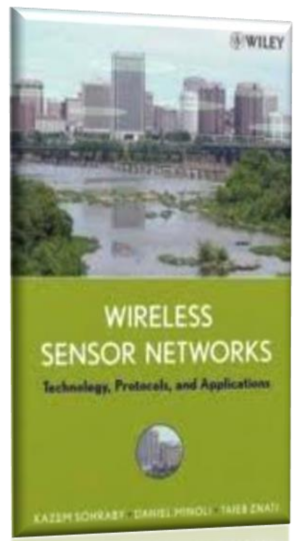
Books on event processing

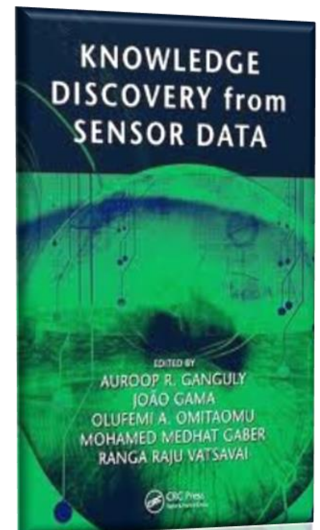




Books on sensor networks







Relevant blogs

- Web of Things Blog
- Wireless Sensor Network Blog
- The Internet of Things
- Dust Networks – In the News
- ReadWriteWeb

Related Wikipedia Links

Data Stream Mining: http://en.wikipedia.org/wiki/Data_stream_mining

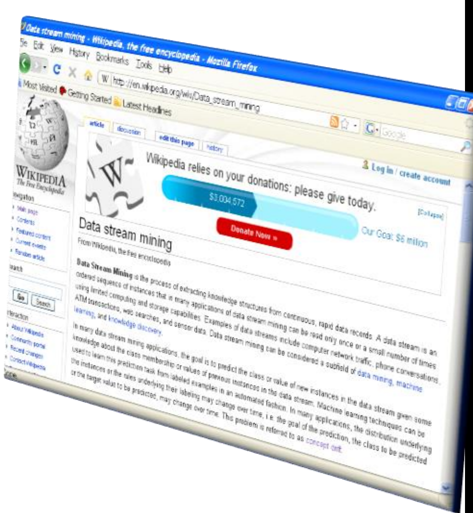
Complex Event Processing: http://en.wikipedia.org/wiki/Complex_Event_Processing

Real Time Computing: http://en.wikipedia.org/wiki/Real-time_computing

Online Algorithms: http://en.wikipedia.org/wiki/Online_algorithms

Worst Case Analysis:

http://en.wikipedia.org/wiki/Worst-case_execution_time



Related Wikipedia Links

Web of Things:

http://en.wikipedia.org/wiki/Web_of_Things

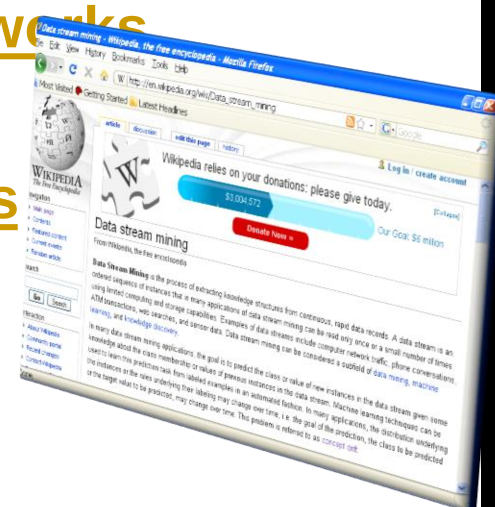
Internet of Things:
http://en.wikipedia.org/wiki/Internet_of_Things

Wireless Sensor Networks:
http://en.wikipedia.org/wiki/Wireless_Sensor_Networks

Major Appliance:
http://en.wikipedia.org/wiki/Household_appliances

RFID – Radio Frequency Identification:

http://en.wikipedia.org/wiki/RFID



Video Tutorials

State of the Art in Data Stream Mining: Joao Gama, University of Porto

- http://videolectures.net/ecml07_gama_sad/

Data stream management and mining: Georges Hebrail, Ecole Normale Superieure

- http://videolectures.net/mmdss07_heb

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Thank you!

[CAROLINA.FORTUNA@IJS.SI](mailto:carolina.fortuna@ijs.si)

[MARKO.GROBELNIK@IJS.SI](mailto:marko.grobelnik@ijs.si)

[HTTP://SENSORLAB.IJS.SI](http://sensorlab.ijs.si)

SensorLab

Help us improve the tutorial!

Send comments and relevant info to carolina.fortuna@ijs.si

(…and irrelevant to marko.grobelnik@ijs.si :)

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