BEYOND THE SMART METERS

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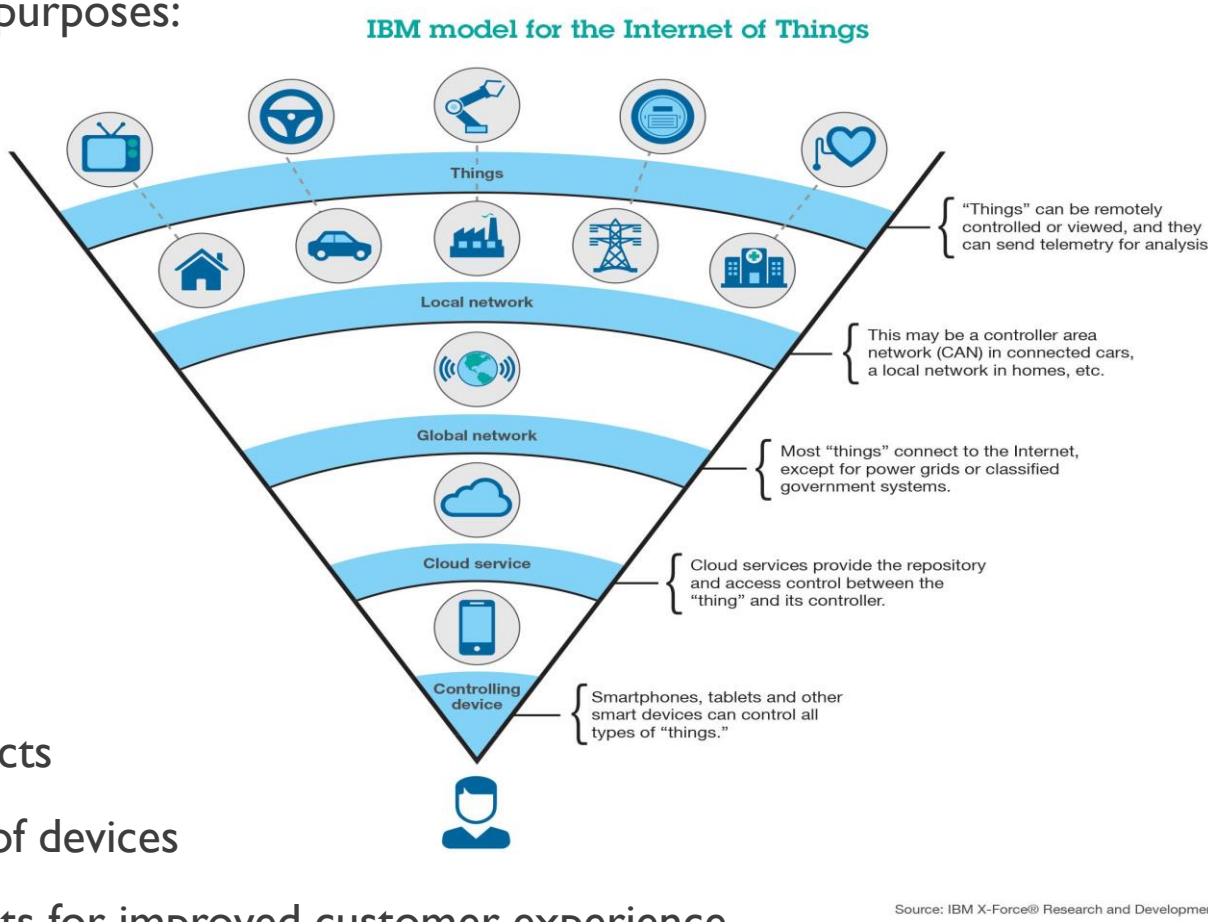
How use IoT

People in general for different purposes:

- Industry
- Production
- Body
- Home
- Environment
- City



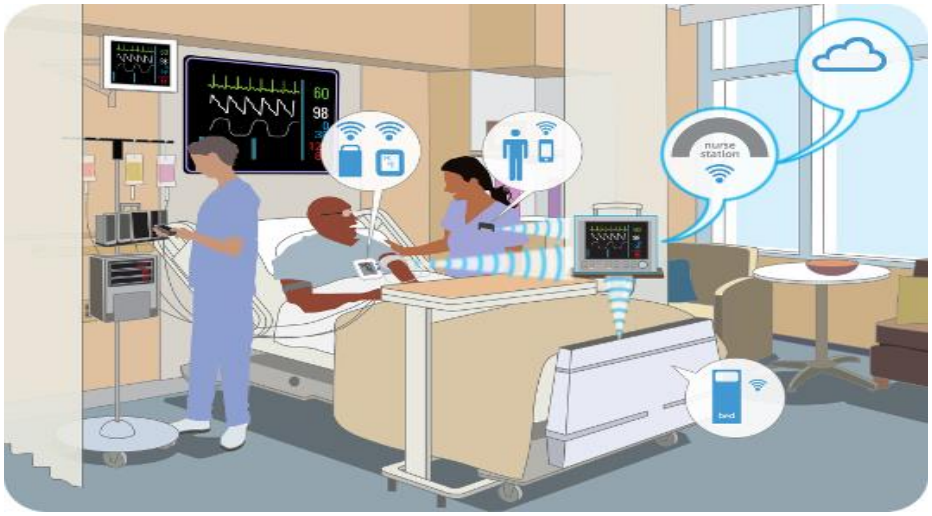
Why

- Extends lifecycle for products
- Improve energy efficiency of devices
- Multiple connected products for improved customer experience
- Ability to remotely monitor and control devices

How IoT looks like?

Wearable Tech

Smart Appliances



Healthcare

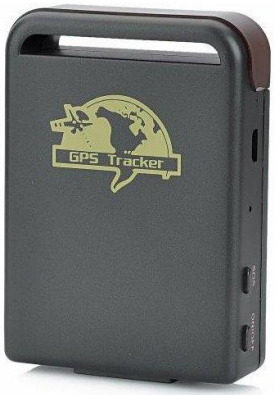
IoT Device

Amazon dash

Google NEST

Philips HUE

fitbit

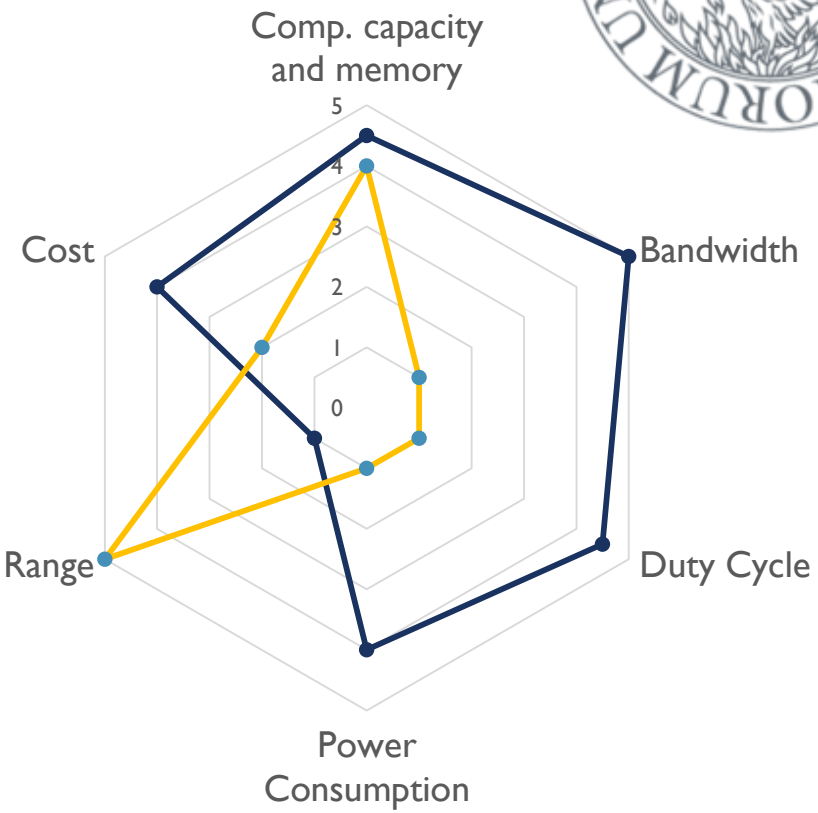


GPS gsm tracker

NETGEAR Arlo

IoT Device

- Computational capacity and memory
- Bandwidth (bit-rate)
- Communication duty cycle
- Communication range
- Power consumption
- Cost



Motion tracking

- Accelerometer 3-axis 100Hz
- STM32F405 - Cortex M4
- WiFi (MQTT) - 50mt
- Power supply

Smart agriculture / smart city

- Large set of sensors
- STM32L4 Low-power
- LoRa - 5/10Km
- Battery - Harvesting

Data

- Different from traditional computing
- Small in size
- Frequent in transmission
- Huge number of connected devices

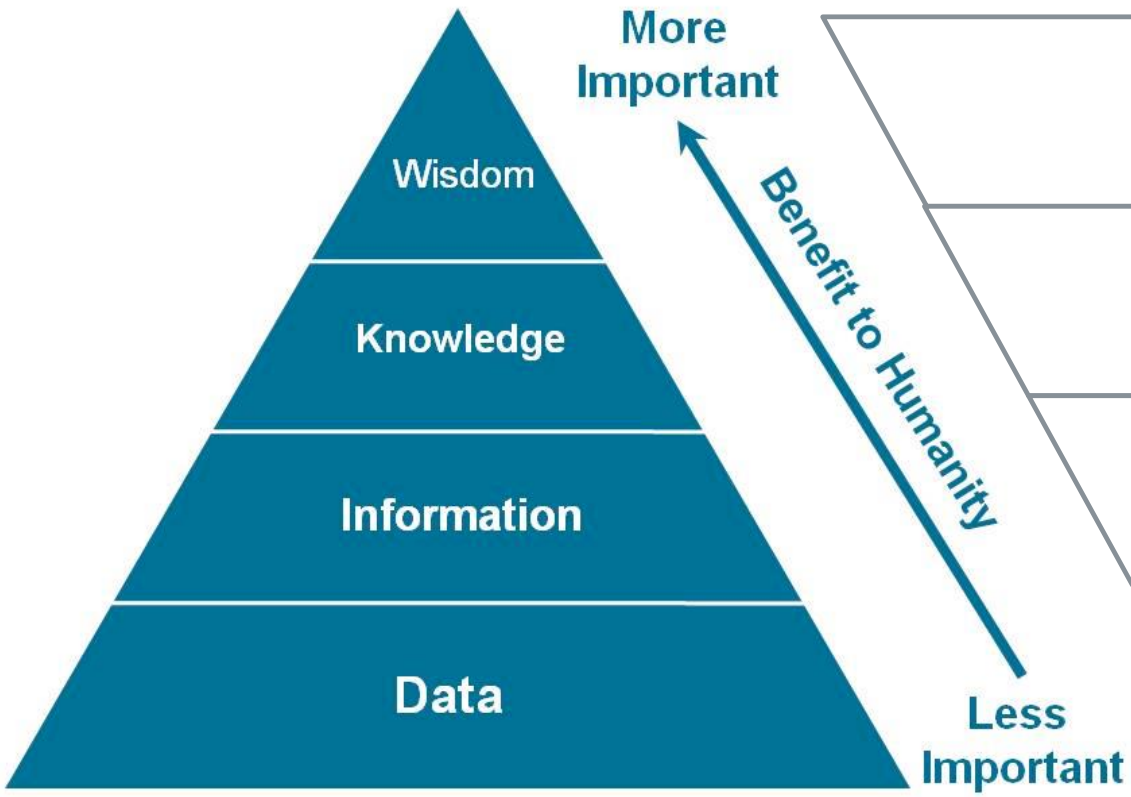
Communication

- Share info to people and system
- New different type of data
- Collected frequently
- Visibility into a device's condition

Cost saving

- Performance data
- Equipment health
- Minimizing equipment failure
- Perform planning maintenance

We Evolve Because We Communicate



4. Business

3. NILM

2. How to communicate

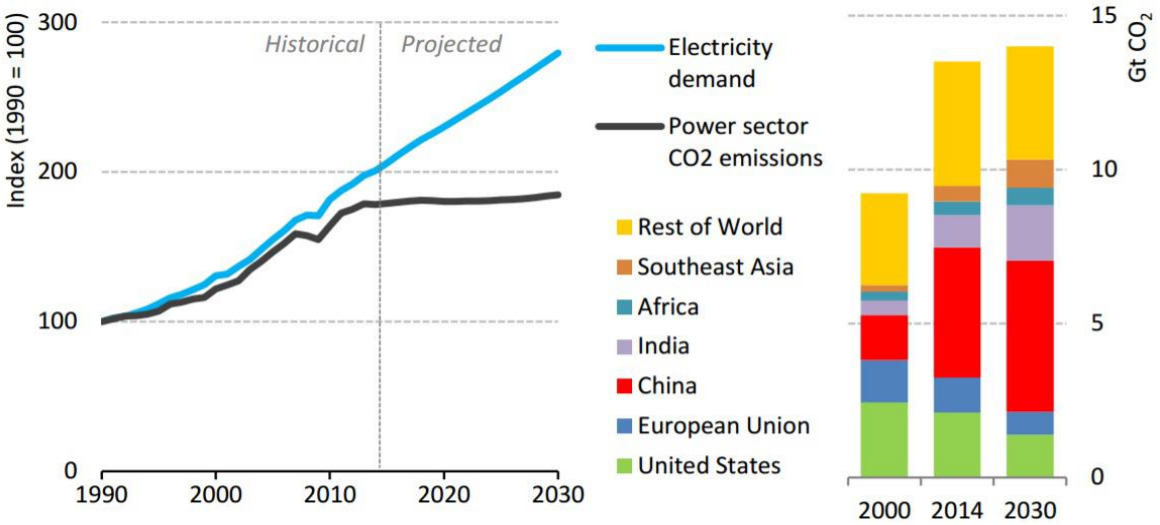
1. Sensing and Smart meters

Case Study

IoT as enabling technology for Electrical Energy efficiency in Buildings

Energy efficiency

- One of the main challenge of Smart Cities, is the **reduction of energy consumption.**
- In Italy, domestic energy usage accounted for approximately **20% of overall energy consumption in 2016.**
- **Efficiency of energy usage is essential.**



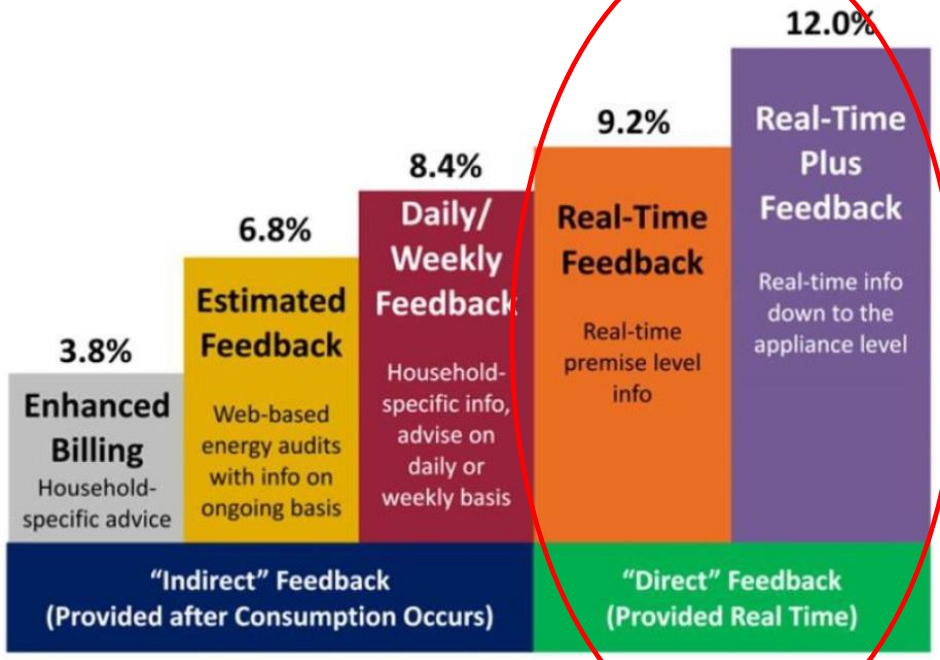
- In households is achieved by **eliminating wasted energy or getting people to match their usage with the availability of renewable energy.**

Energy efficiency

Monitoring
- Intrusive
- Non-Intrusive

Feedback
- Has a great influence on the amount of saved electricity.

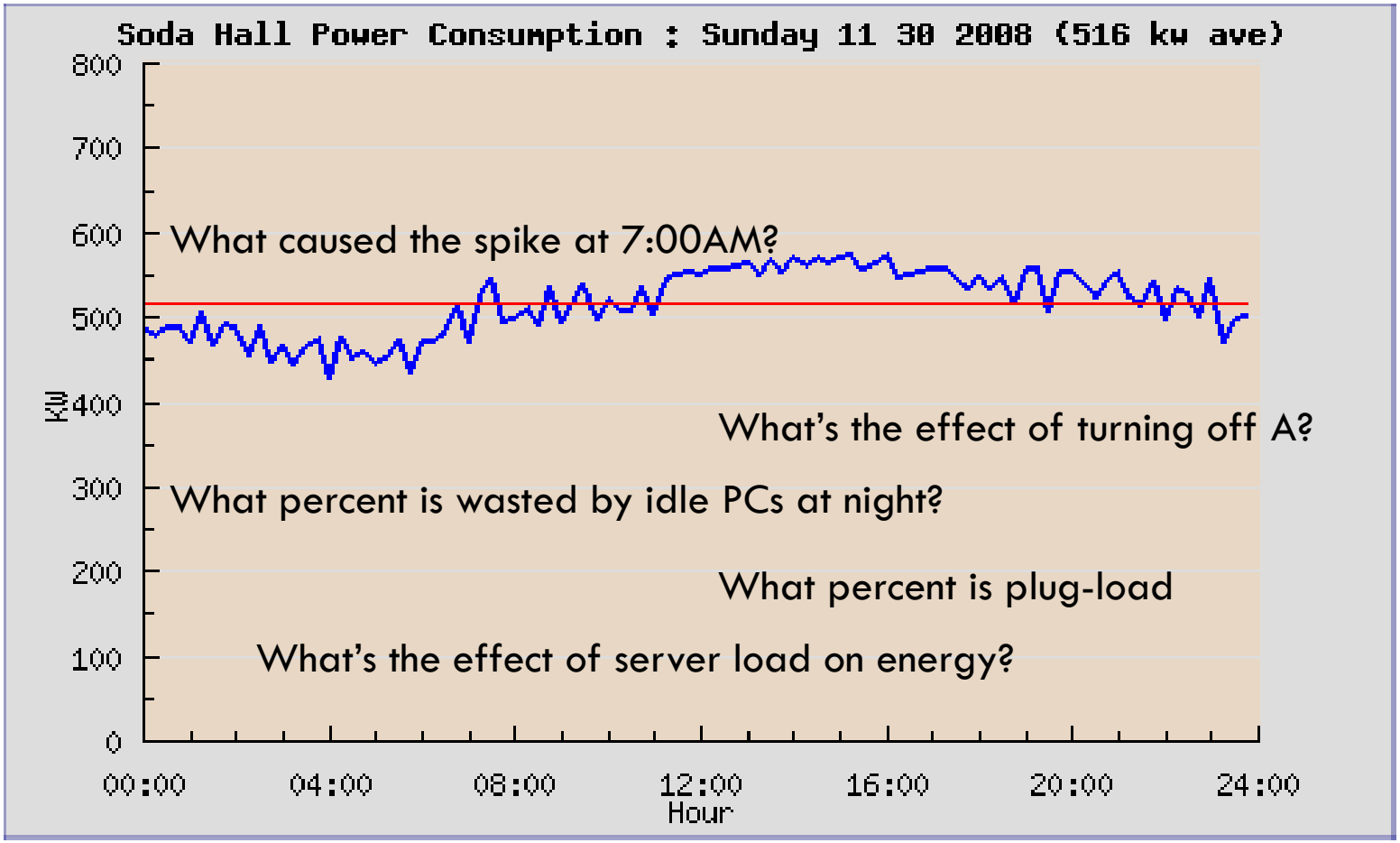
Result
- Appliance-specific feedback empowers inhabitants to take steps towards reducing their energy consumption.



Ehrhardt-Martinez et al. Advanced Metering Initiatives and Residential Feedback Programs : A Meta-Review for Household Electricity-Saving Opportunities.

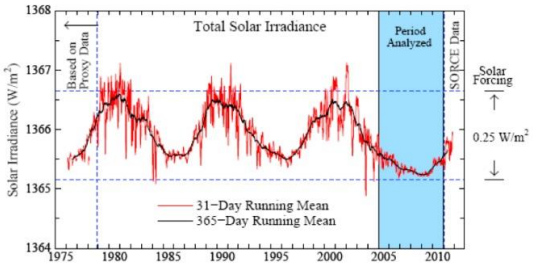
"The current energy systems are like a store without prices on individual items, which presents only one total bill at the cash register."

Aggregate is Not Enough

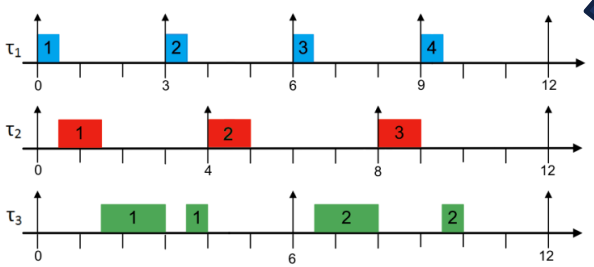


An information-centric energy infrastructure: The Berkeley view
Randy H. Katz et al.

Non-Intrusive Load Monitoring - NILM
The Big Picture



Aggregated Load monitoring



Identification of the appliances
Signal Disaggregation

Market Objectives

- Meter manufacturers are currently going on the **market** with a differentiated offer:

  - **low-cost** meters solutions for large scale distributed monitoring;

  - **High-end** instruments for accurate and scientific measurements to assess the quality of the energy provided.

- Smart Meters will be used in residential and commercial buildings for:

  - Peak **Load Management** for utility companies

  - Non-intrusive single-Appliance **Load Monitoring.**

  - **Non-intrusive Load Monitoring** from the household's total electricity consumption.

Availability on Market

Commercial ICs with accurate analog front-end (AFE)

- **Microchip MCP3905** supports real power measurement using two ADC channels optimized to perform both current and voltage measurement.
- **Analog Devices ADE7953** measures voltage and current, and calculates active, reactive, and apparent power, as well as instantaneous RMS values.
- **NXP EM773 energy metering** IC is a 32-bit microcontroller (an ARM Cortex-M0 core) solution designed specifically for electricity metering applications.
- **MCP3903 AFE** provides six synchronously ADCs for the three-phase energy measurement.

NXP EM77

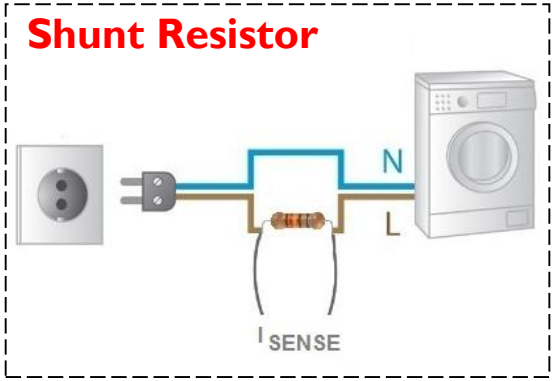
MCP3905

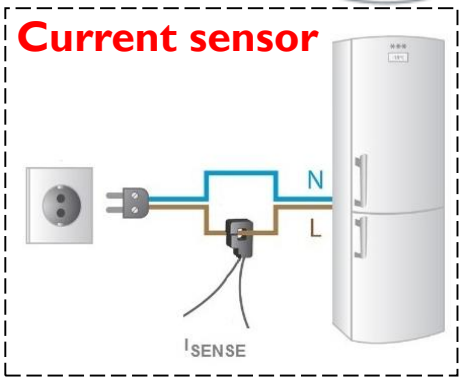
MCP3903 AFE

Devices designed for measuring
and not open to the IoT opportunities

Smart Meter general description

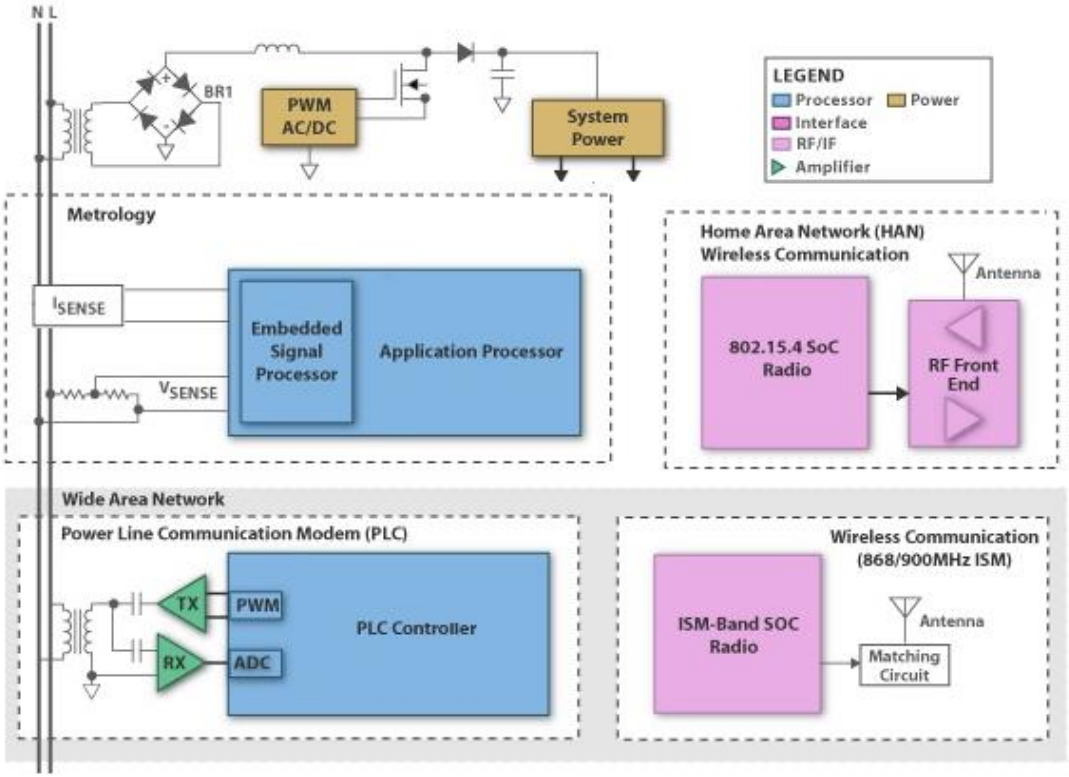
- **Metrology**
  - Precision resistor is typically used in series with the AC load
  - Current sensor





- **Network Connection**
  - **Wireless Solution**
    - Sub-GHz LoRaWAN
    - 2.4GHz
  - **Power line solution**
  - M2M 3G connection

- **Power Supply**
  - Rectifying an AC signal

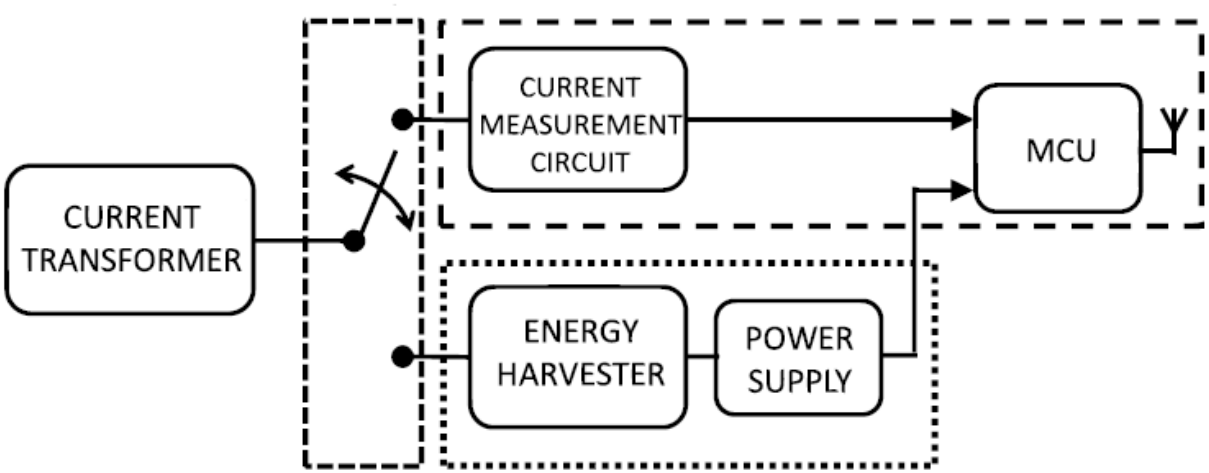


Contactless Self-Powered Meter Designed for IoT

- The Energy Meter exploits a **clamp-on current transformers** for
  - non-intrusive current measurement;
  - **Energy Harvesting**;
- **Contact-less voltage** measurement;
- Power consumption and enviromental measurament;
- **RMS, FIR** and **DFT** analysis;
- Low-power, 32-bit microcontroller and LORAWAN wireless standard;
- A primary batteries for start-up and backup operation;

Energy Harvesting Section

- The energy harvesting circuit uses the same current transformer for the current measurement as power transducer.
- Moreover, it is able to guarantee the start-up reliably without using any external energy source (e.g. batteries).

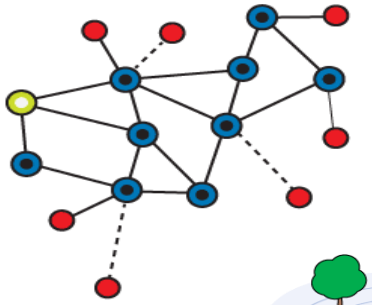


IoT communication

Three main approaches

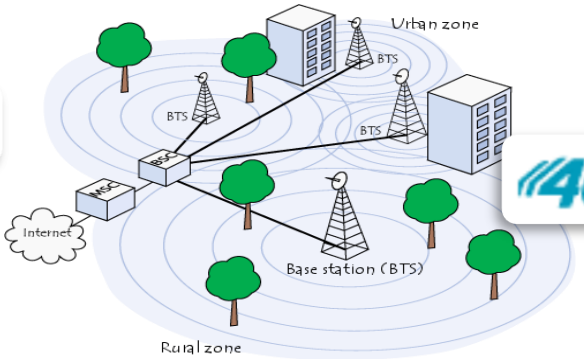
Short-range multihop

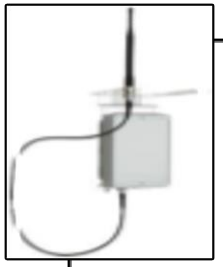
- ZigBee
- WiFi low energy
- RFID



Mobile phone operators

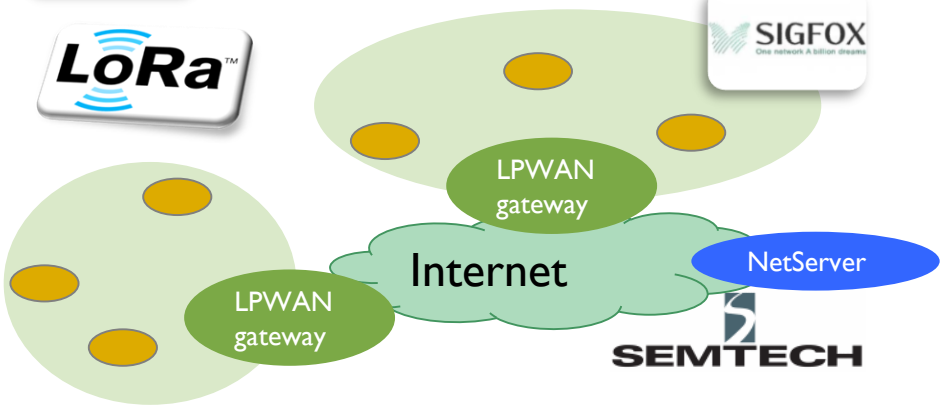
- GSM
- LTE-A
- 5G





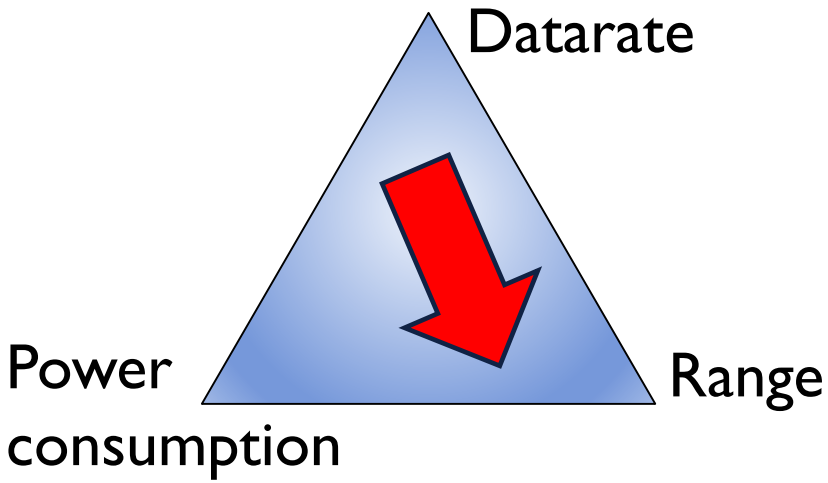
Low Power Wide Area Networks (LPWAN)

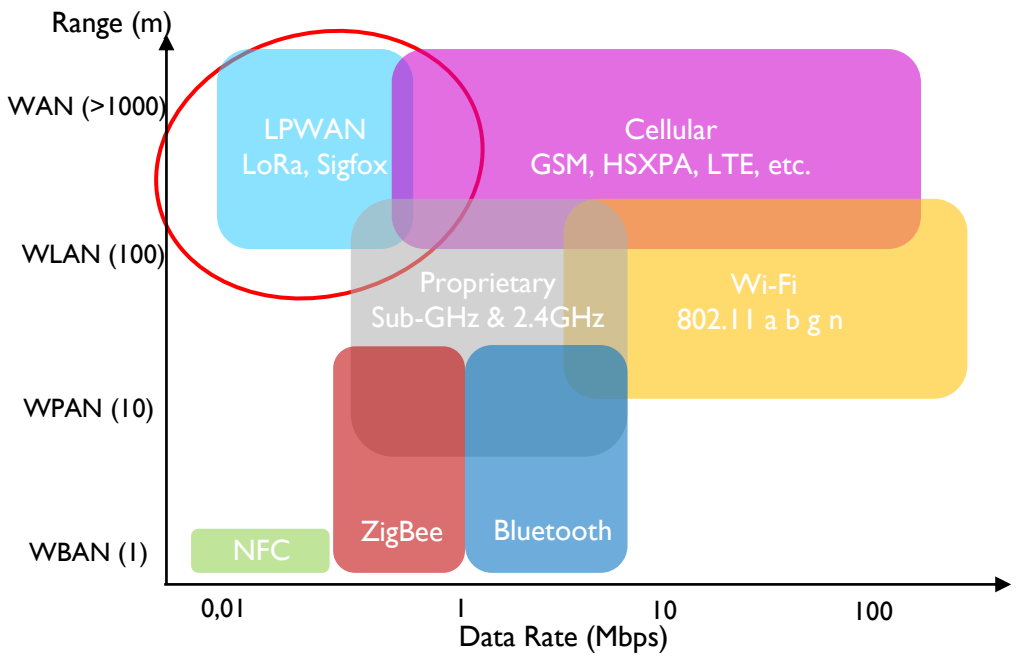
- SIGFOX
- Neul
- LoRa



LoRa *Long Range transmission*

- LPWAN Low Power Wide Area Network
- Low cost: end-node and infrastructure
- ISM Sub-GHz 868MHz
- Hight range: 5/10Km
- Flexible bitrate: 1bs to 37.5Kbs





Trento Valley

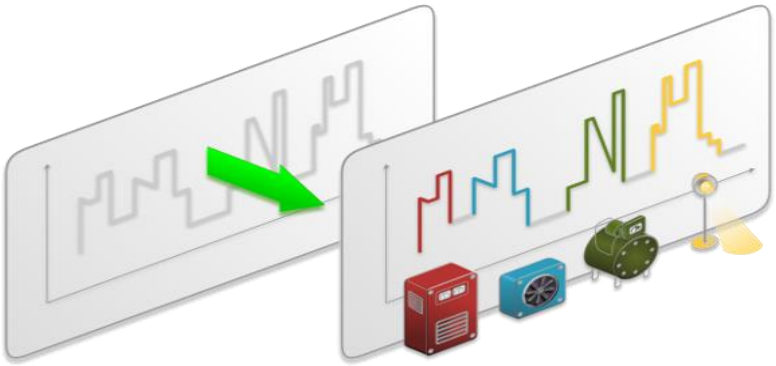
Free and Open Communication HUB for citizens IoT applications

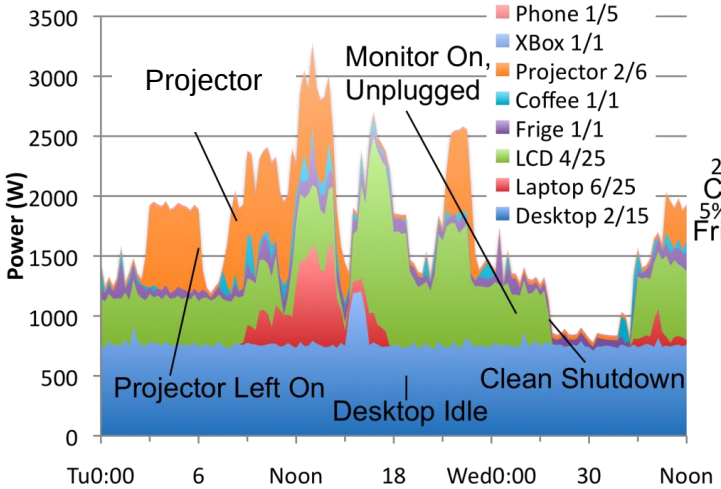
http://front.dii.unitn.it/

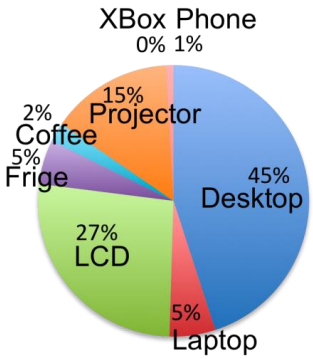
http://www.thingsforest.com/

Non Intrusive Load Monitoring (NILM)

- **Non-Intrusive Load Monitoring (NILM)** is a method to perform detailed energy sensing and provide information on the consumption of energy spent with a single sensing point.
- Aggregated load data is used to extract and identify the loads of the individual devices. This is referred to as "disaggregation".
- Appliance identification is highly dependent on load signatures, which are further characterized by the appliance category.







NILM: techniques

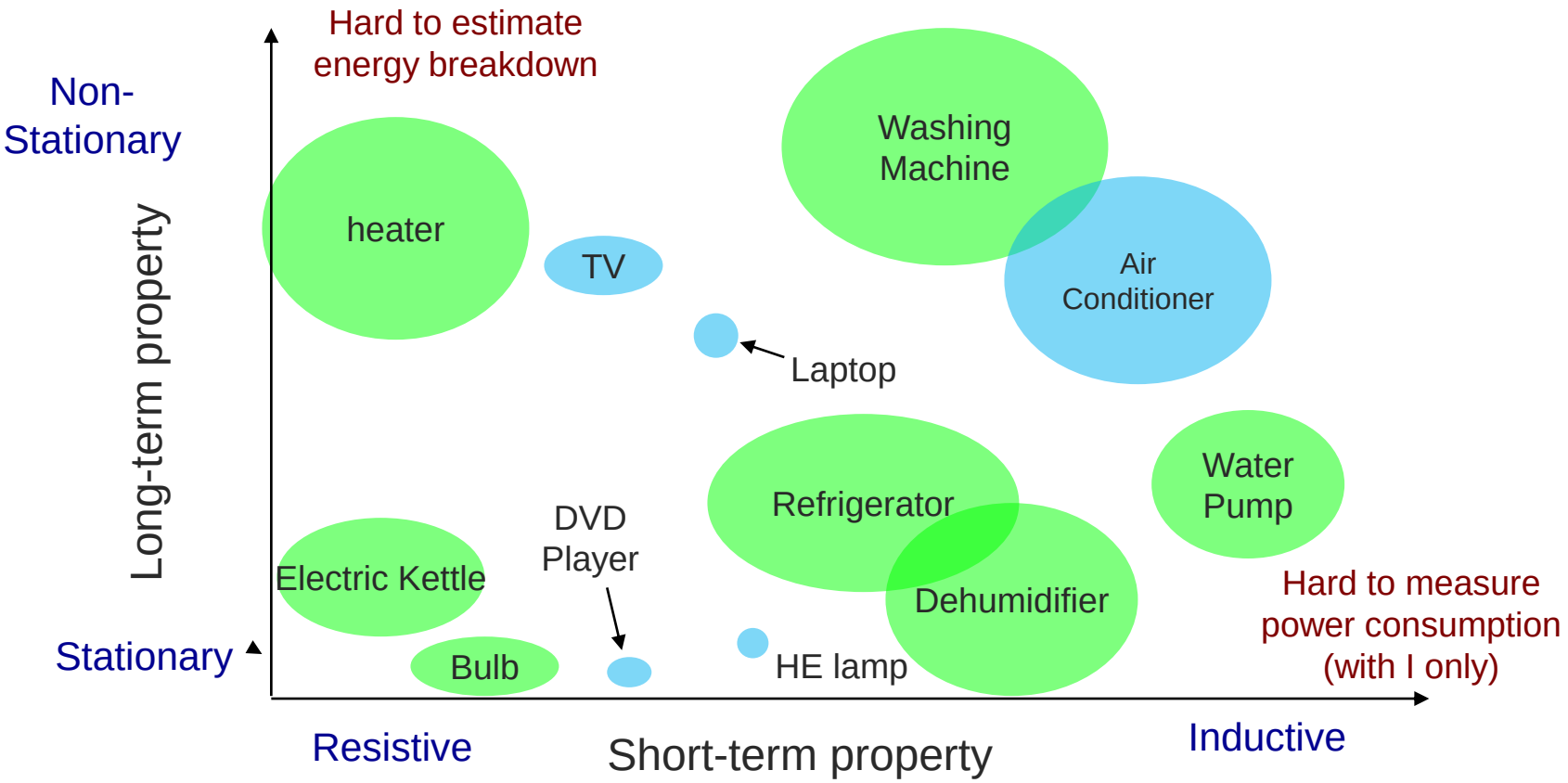
Consumer appliances can be categorized based on their operational states as follows:

- **On/Off**: devices that are either turned on or off and draw constant power while they are on (e.g., table lamp, electric kettles, water pumps).
- **Finite State Machine (FSM)**: devices which have a load, where the variance can be described by a finite set of states (e.g., washing machine, tumble dryer, heat pump, refrigerator).
- **Continuously Varying**: devices with a continuous, variable power draw (e.g., PCs, TV, dimmer lights, power tools).
- **Permanent consumer devices**: devices with a constant power draw, that are on for 24 hours a day, 7 days a week (e.g., smoke alarm, telephone sets, cable TV receivers).

The Diverse Nature of Loads

Resistive vs. Inductive -> Short-term property

Stationary vs. Non-stationary -> Long-term property



NILM techniques

Not only one solution

NILM engines can be categorized by means of			
Type of analysis	**Used features**	**Learning requirements**	**Sampling Frequency**
Event Based	Steady state	**Supervised**	High Frequency
Non-Event based	Transient state	Un-Supervised	**Low Frequency**
	Non traditional		

An algorithm tailored for IoT devices

- The proposed algorithm formalizes a supervised learning event-based disaggregation technique

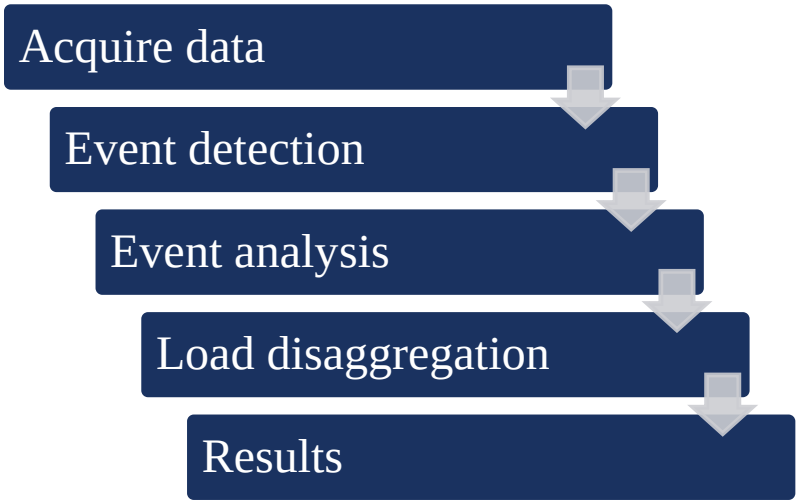
- The goal of the NILM is to perform decomposition of P(t) signal to achieve appliance-level power signals.
  - $P(t)$: *aggregated power consumption*
  - $p_i(t)$: single appliance contribution
  - m: number of appliances within period t
  - t: analysis period
  - $e(t)$: residual error

$$P(t) = p_1(t) + p_{2(t)} + \cdots + p_m(t) + e(t)$$

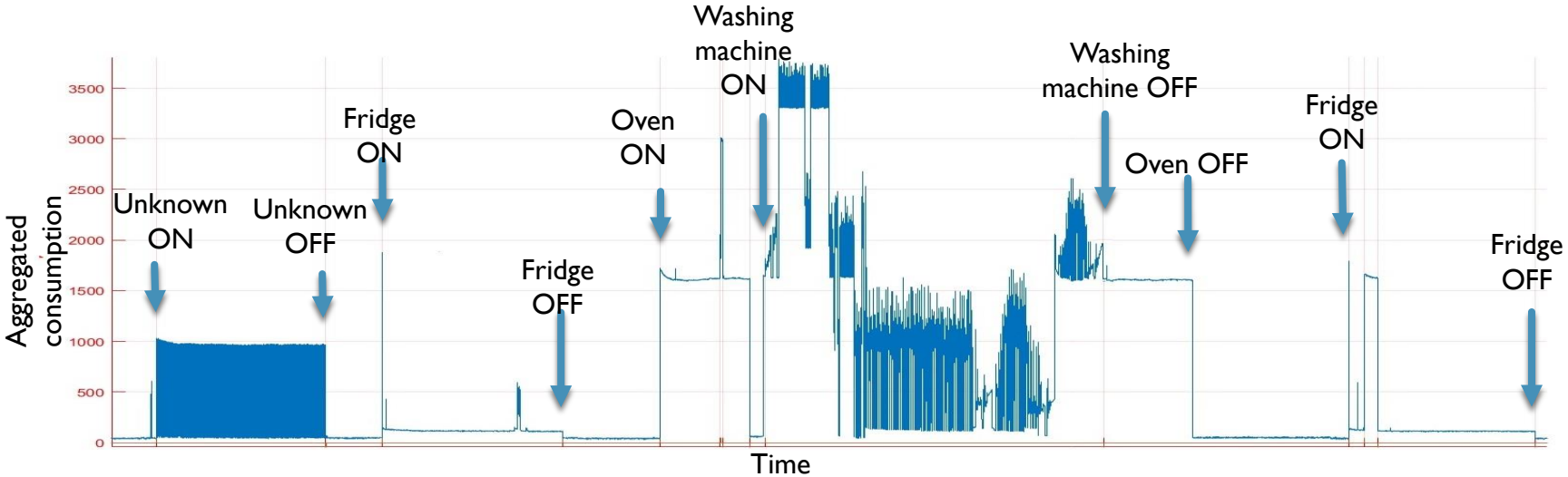
- The disaggregation process is based on pattern recognition techniques. For choosing the appliance associated with the event analyzed, the algorithm adopts a maximal probability approach

- Event detection and analysis tries to identify when a switch ON or a switch OFF occurs
  1. Background Consumption Zone (BCZ) computation
  2. Detecting events outside the BCZ

- Load disaggregation involves periodicity analysis
  - Spectral density estimation
  - Number of event
  - Number of signal edges



Performance



Parameter	Value
Event interval	4 [Sample]
Event threshold	65[W]
Spike rejection threshold	20[W]
Decision interval	1000[Sample]
Appliance state change interval	6 [Sample]

Appliance	House #1	House #2
Oven	96,4%	98,2%
Electric heater	99%	100%
Coffee Machine	89,6%	91,8%
Microwave	94,1%	92,2%
Fridge	94,9%	96,9%
Washing Machine	69,3%	71,1%

Conclusion

- Effective strategies for energy efficiency are easier with IoT
- There is much more information behind IoT data than supposed
- Business is on using such "hidden information "
- IoT devices are not just "wireless sensors"
  but can integrated intensive and non-trivial intelligence locally

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