



Collecting and analysis of data from autonomous sensors with applications to smart buildings

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MOTIVATION AND OBJECTIVES

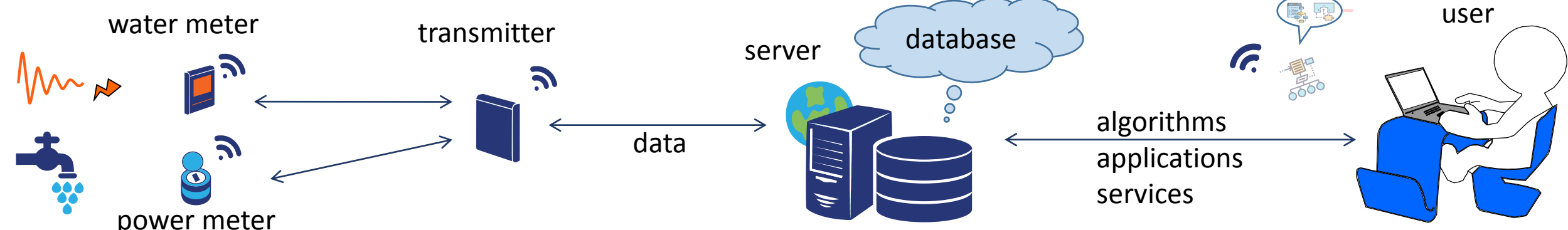
New environmental challenges arise in the context of energy and water resources management. They impose innovative developments, especially in the day-to-day use of these resources, which exist only in limited quantities. The Internet of Things (IoT) shall be a major contribution to what is called smart buildings and smart cities by being able on one side to integrate a large number of differences and heterogeneous end-systems and to another side to provide new digital services.

Our main objectives consists in:

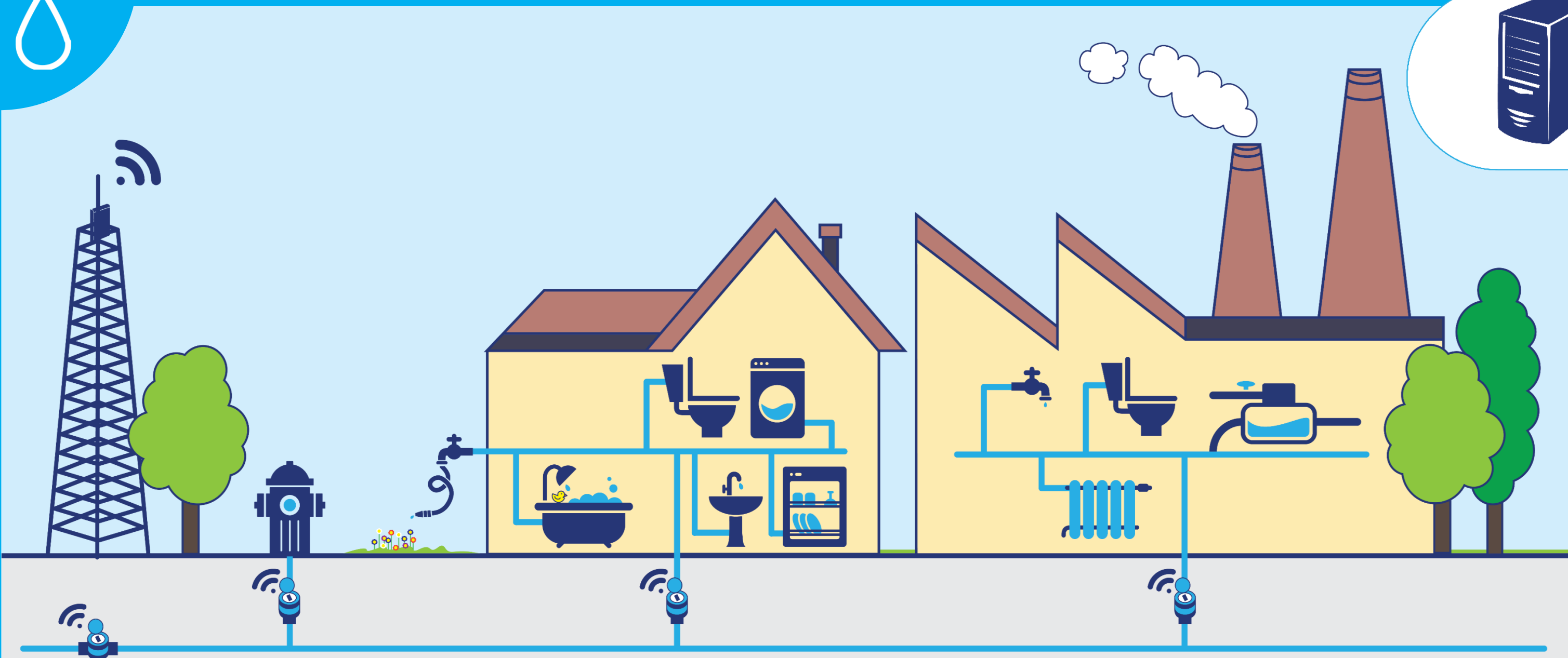
- Collecting Data from several sensors (power meters, water meters, etc.) according to different protocols (standard or proprietary),
- Processing and analyzing data with statistical and/or machine learning approaches in order to detect anomalies and to improve the energy efficiency of buildings,
- Combining heterogeneous data collected from different sensors with modular approach.

Solution

We propose to study the complete implementation of a solution for collecting and exploiting power and water consumptions using autonomous and connected meters (IoT) [1]. The solution we propose is based on real time acquisition and transmission of consumption data to a cloud. The communication is based on an IoT architecture.

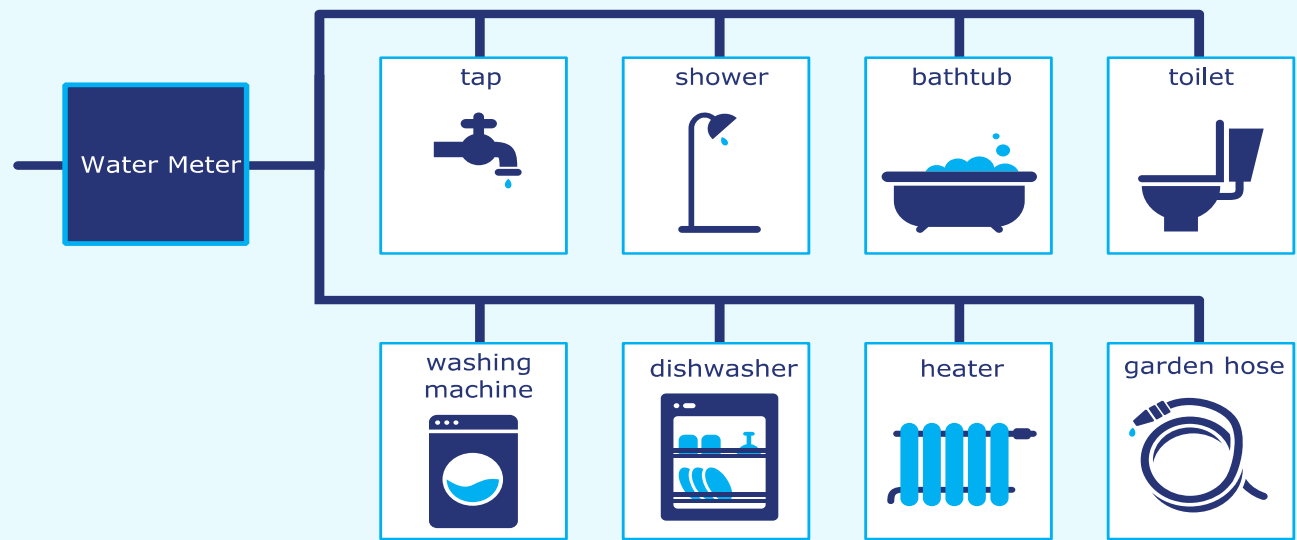


WATER



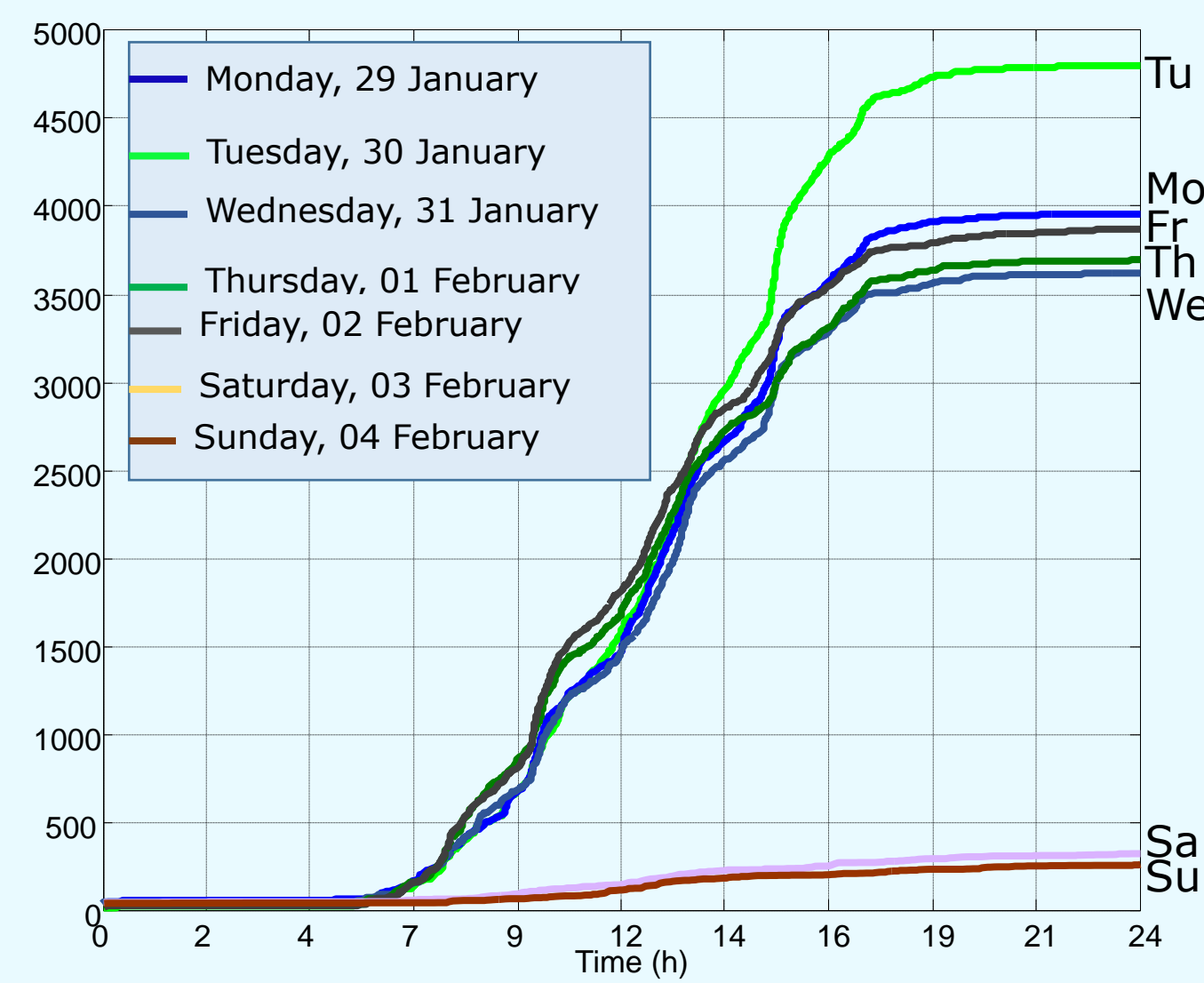
The global load curve is obtained from a single water meter that records the general water consumption.

Our challenge is to disaggregate water consumptions, identify specific uses of water (shower, toilet...), detect the presence and absence of users and abnormalities such as leaks, etc.



The water load curve [2] is a representation of a cumulated water flow rate over a period of time (one day for example).

Each device using water has its own signature which is present in the load curve. This signature specifies one device over the others. Any changes in the water load curve represents a switching on or off of a device.

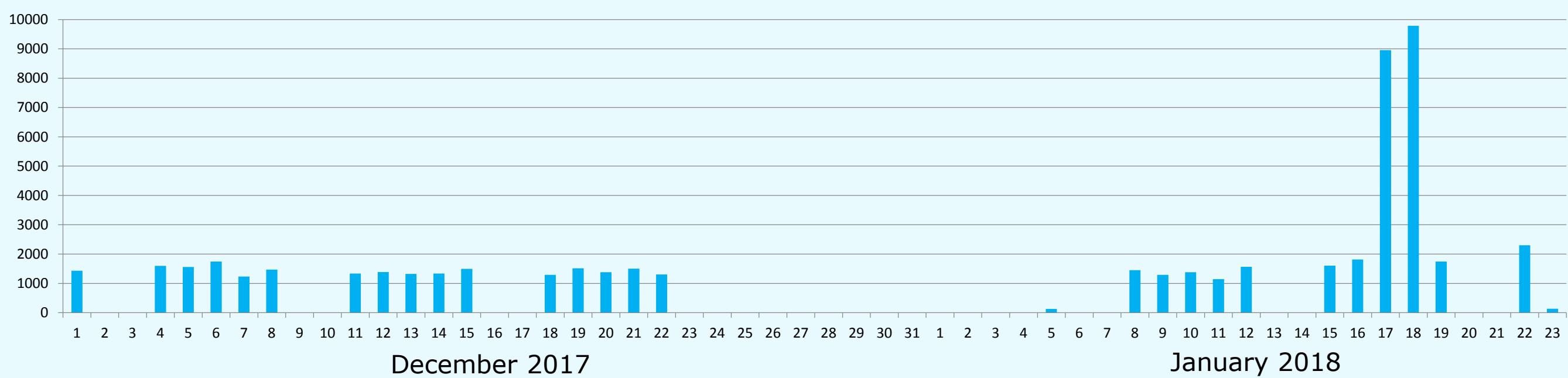


Cumulated water consumptions over 24h (liter)

We analyze of the water load curves in order to detect anomalies and the presence of users. In our case, anomalies are water leaks.

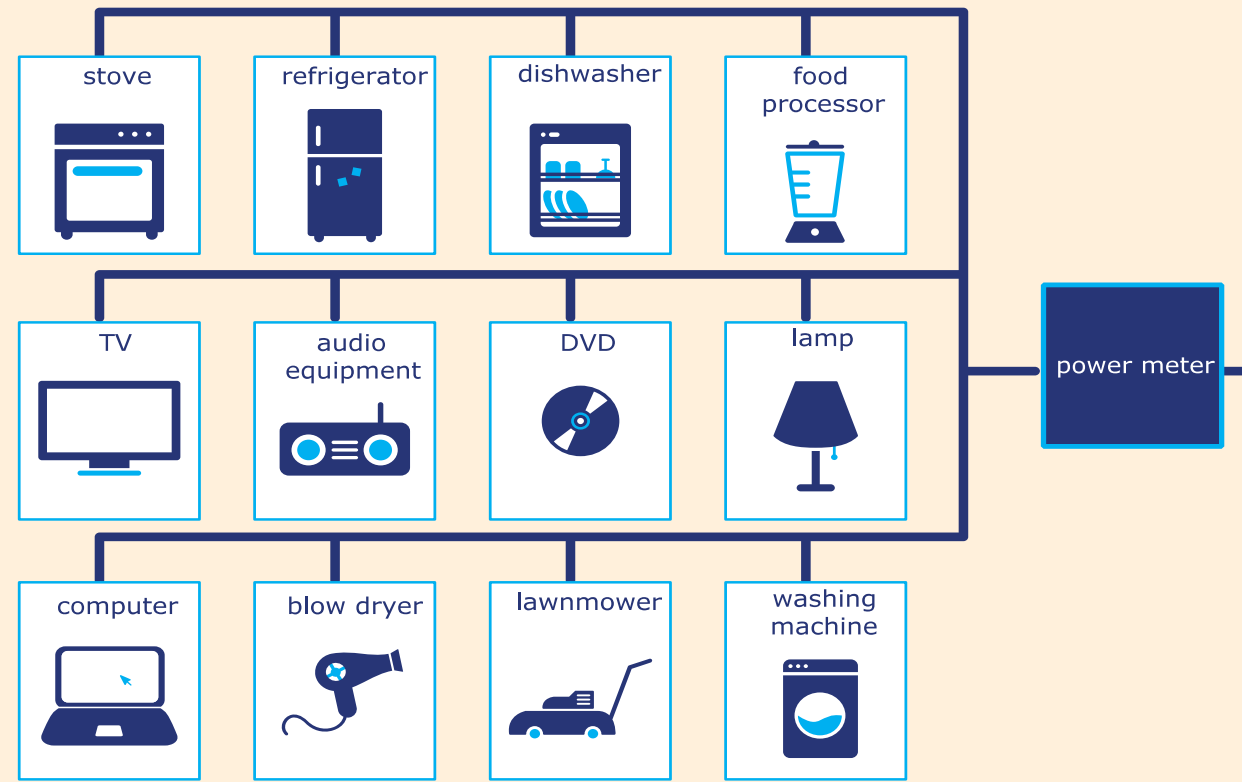
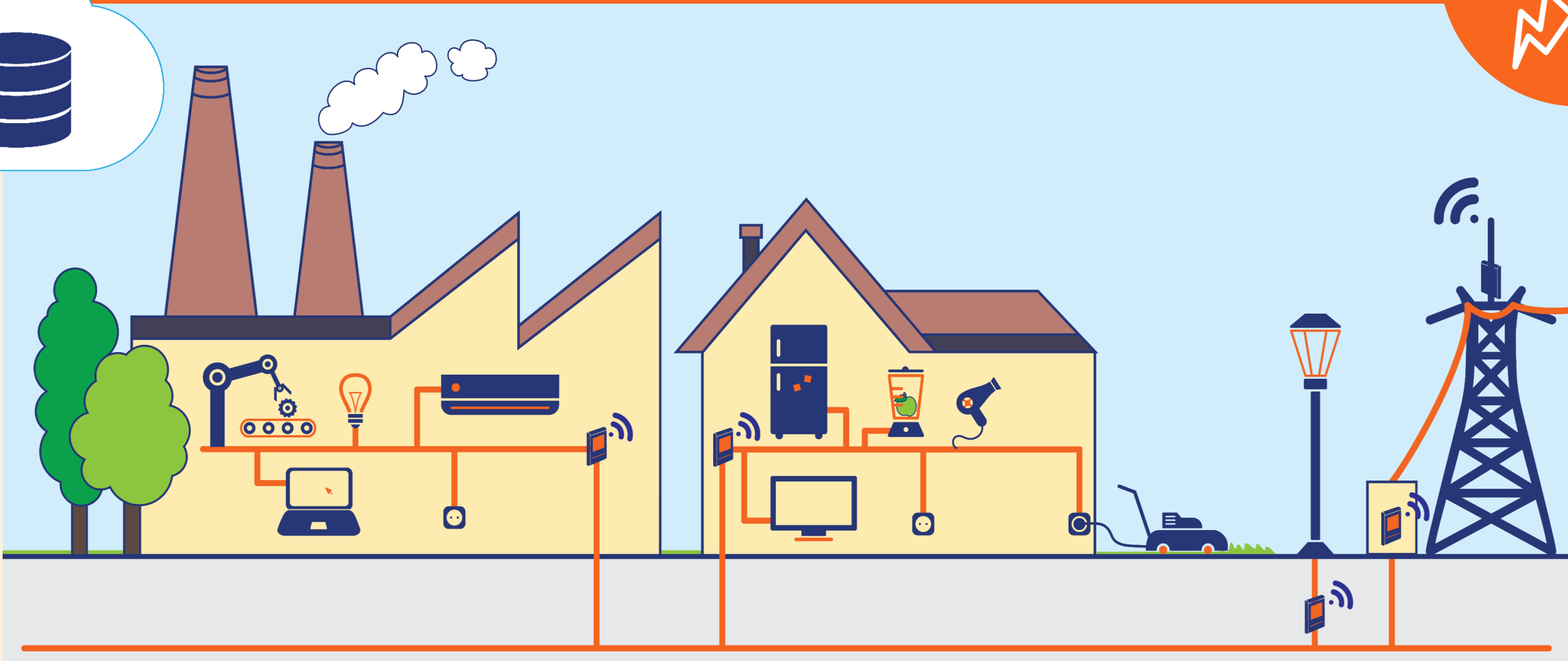
The figure below is a representation of the water consumption per day over a 50 days period. It is clear that the consumption does not exceed 1000 l/day for most days with the exception two successive days for which the consumption exceeds 8000 l/day.

By comparing the average consumption to adaptive thresholds over a previous similar period it is possible to detect water leaks and the absence of people. Here, a 2-days leak has been quickly identified (January 17-18) and days with a very low consumption correspond to either weekends or holidays with is no users in the building that has been monitored.



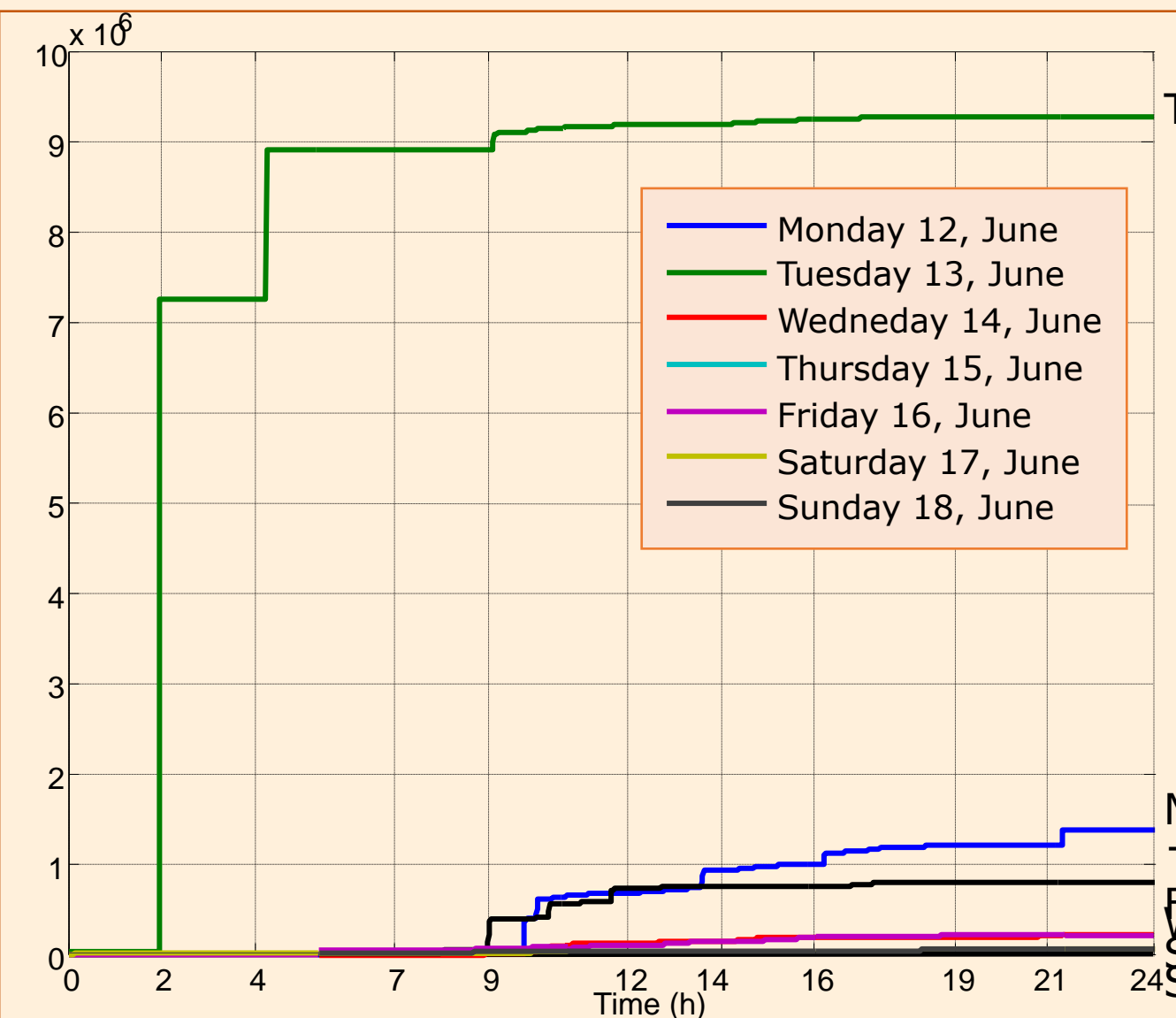
The gap in daily water consumption

POWER



The global load curve is obtained from a general power meter that records the electric power consumption of several loads.

Our challenge is to detect anomalies, predict consumption needs, identify specific devices, provide information to adjust the power production... for a better grid integration.



Cumulated power consumptions over 24h (Watt)

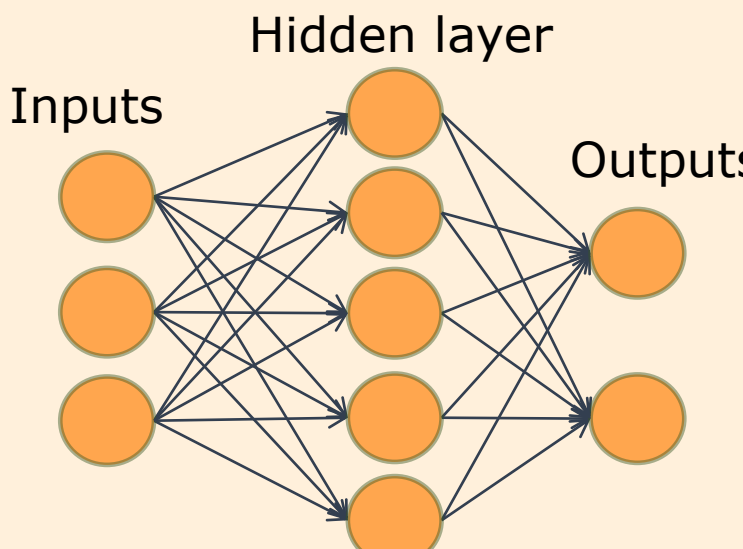
The electric power load curve [3] is an additive linear combination of cumulated electric device consumptions during a given period (over one day for example).

Each device using electric power has a signature which is present in the load curve. This signature can distinguish one device from the others. A variation in the curve means a connection or disconnection of a device or a modification of a device's power consumption.

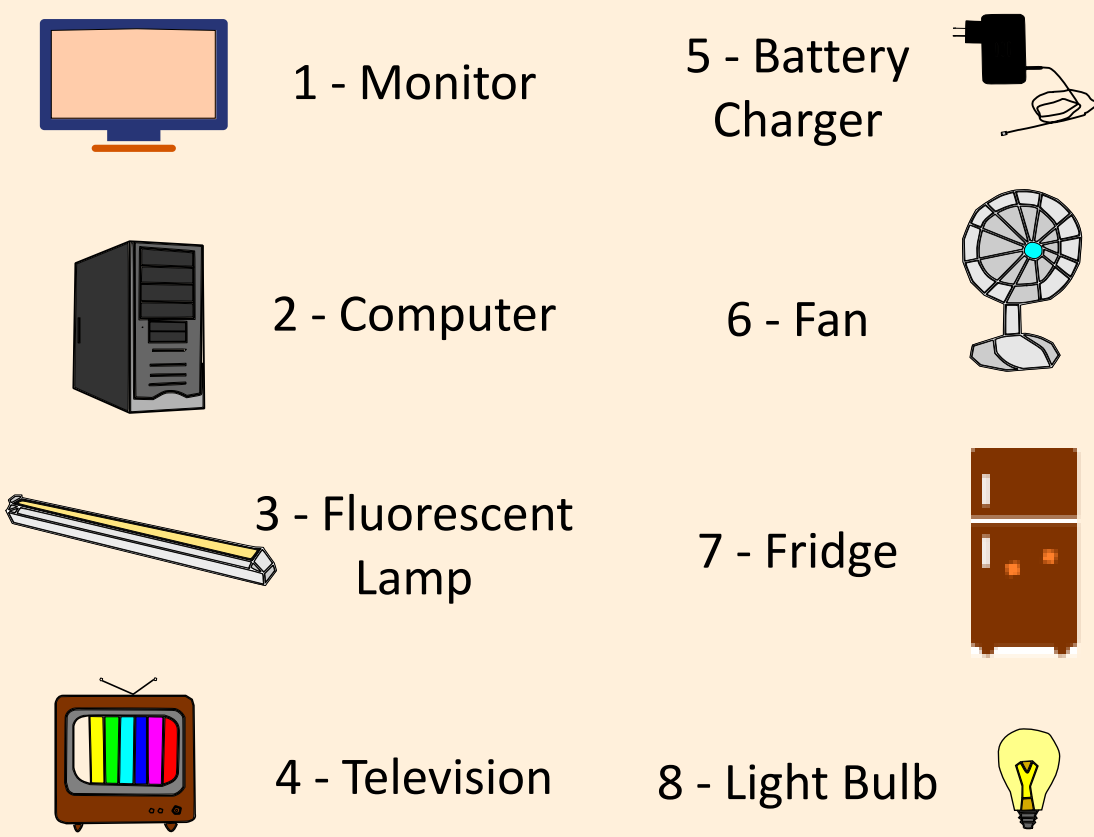
We classify the electrical devices from power load curves and highly-sampled data [4].

Several classification algorithms are used and compared: Decision Trees (DTs), the k-nearest neighbors (kNNs), and artificial neural networks like Multi-Layer Perceptrons (MLPs).

The MLP is the best known learning method. It consists in different steps: To train the network from samples, test and finally classify new samples in predefined classes. Our classes are divided into 8 groups of devices consuming electric power.



Multi-Layer Perceptron (MLP)



Device categories

Algorithm	DT	KNN	MLP
Classification rate (%)	99,8	100	100

Classification performances

Discussions

We proposed a platform that allows to collect, transmit and store large sets of data in order to analyze them. In our case, data represent water consumption, electric power consumption which can be also combined with additional environmental data (temperature, humidity, solar irradiance, etc.) in the context of a smart building. These data can be exported from a cloud to scientific environments for analyzing and classification tasks. From water consumptions, we can detected anomalies like leaks. From the power consumptions, we can classify the devices with automatic learning algorithms.

Our future work consists in deducing the user's behaviors from daily consumption of water and electric power in order to improve their consumption habits. A systematic analysis of leak detection, abnormal consumption and risk behaviors will also be implemented.

References

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[2] B. Ellert, S. Makonin, et F. Popowich, Appliance Water Disaggregation via Non-Intrusive Load Monitoring (NILM), in Smart City 360°, 2016, p. 455-467

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[4] T. M. Nguyen, Contribution to the analysis and understanding of electrical-grid signals with signal processing and machine learning techniques, PhD thesis, Université de Haute Alsace, Mulhouse, 2017