Water -M Project

D1.3 IT State of the Art
v2.2

History

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Contents

Abstract

This document analyses the state of the art in the areas underlying the Water-M innovation with a view to forming one filter of the requirements engineering methodology. The technology areas addressed by this document include communication technologies for water providers and consumers, water sensing devices, water measurement use cases, related services as well as visualization of water consumption performance. In particular, this document evaluates existing technology for Water Management Platforms (services, multi-agent platforms, existing water instrumentation standards, real time databases, communication systems and protocols etc.). This state of the art will be based not only on a bottom-up analysis in studying existing and new technologies and standards, proposed at a low level (Hardware, OS, ...), for servers and external devices (water sensors, concentrators, routers, storage bays, IO switch, ...), but also on the outputs of other tasks within this work package. It will be the first step to specify models and services that will be used at different management levels (Hardware, System and Enterprise) and for filling in all the user's requirements and expectations.

1 Introduction

The rise of the global population and the limited availability of fresh water are key issues of public concern over water availability, water quality, failing water infrastructures, and overall water management complexity. As a result, the market for safe, available water and for the infrastructure and technologies that treat and transport water is expected to grow rapidly as stakeholders look for new solutions and approaches to integrated water resource management. The adoption and integration of ICT to the water sector is one viable solution for a better decision support and improved productivity.

Smart water networks apply ICT to deliver solutions to numerous water-related issues which are currently handled inadequately by inefficient and often manual processes. For example, these systems can remotely and continuously monitor (hydraulic and water quality), report water consumption, and diagnose problems (leakage and burst detections); pre-emptively prioritize and manage maintenance issues, and remotely control and optimize all aspects of the water distribution network using data-driven insights. They can also be used to provide water customers with the information and tools they need to make informed choices about their behaviors and water usage patterns, and to comply transparently and confidently with regulatory and policy requirements on water quality and conservation [1].

1.1 Business Drivers

The need for advanced water managements is driven by the advancement in ICT and the following issues.

- Aging infrastructure: water providers need to upgrade old water infrastructures.
- Water scarcity: on top of the challenges that existing water sources are experiencing, water demand is on the rise globally.
- Leakage and other water loss: huge amount of water is lost from the water system because of leakage, theft, and faulty/old meters. Water usage efficiency and thereby the revenue should increase.
- Utility operation savings: utilities are looking for advanced water management systems to reduce operation costs by replacing traditional meter reading methods and water loss reporting and control mechanisms with advanced ones.
- The water-energy issue: the water business consumes a lot of energy. Therefore, water utilities want to reduce energy costs.
- Impact of urbanization: the number of city dwellers and hence the need for clean drinking water is expected to increase globally.

1.2 Required Technologies

In order to achieve a comprehensive smart water network solution, water systems require measurement and sensing devices (smart meters, sensors, and actuators), real-time communications channels, basic data management software, real-time data analysis and modeling software, and automation and control tools to conduct network management tasks remotely and automatically.

1.3 Challenges

The key challenges to implementing smart water systems are lack of the following issues [1], [2]: a strong business case (customer propositions/pricing/availability), cooperation between water utilities and/or between other utilities, policy and regulation (privacy/security/encryption), standards and reference architectures (technology and protocols, both national and international), technology architecture (systems integration/ communications/ event handling), and readily available power source.

1.4 Opportunities

Despite many research and development projects carried out in the field of smart water infrastructures and applications [3], [4], the extensive deployment of smart water systems is still immature. Leveraging the sector across different services and stakeholders including utilities and municipalities, policy regulators, investors, industry and utility associations, technology providers and academia may revolutionize the field. On top of that, existing and emerging opportunities which have a big role in facilitating the development of smart water systems are listed below.

- Energy smart grids - many of the solutions developed in the Energy Smart Grids could be implemented in water smart grids with minor modifications [5], [6].
- Advances in battery and power storage technologies, and power harvesting mechanisms.
- Constant miniaturization of electrical devices and advances in low power electronics.
- Advances of wireless sensor networks (WSNs) [7], communication and sensing technologies, internet, and emergence of new wireless communication technologies (e.g. machine-to-machine (M2M) communications and internet-of-things (IoT)).

2 ICT technologies for Water management

2.1 Water measurement use cases

2.1.1 Water quality monitoring

Clean drinking water is a critical resource, important for the well-being of all humans. Due to the limited water resources, growing population, ageing infrastructures, increasingly stringent regulations and increased attention towards safeguarding water supplies from contamination, water utilities are looking for real-time water quality monitoring systems. Water quality monitoring is key to measuring and understanding the chemical and biological quality of water and for taking a reactive remedial action. Traditional water quality control mechanisms are inefficient because of the following drawbacks.

- Lack of real-time water quality information to enable critical decisions for public health protection (long time gaps between sampling and detection of contamination).
- Poor spatiotemporal coverage (small number of locations are sampled).
- It is labor intensive and has relatively high costs (labor, operation and equipment).

Therefore, there is a clear need for continuous real-time water quality monitoring with efficient spatio-temporal resolutions.

Drinking water quality standards are determined according to World Health Organization (WHO) [8], EU [9], and US Environmental Agency (USEPA) [10] guidelines for drinking-water quality. These organizations set the standards for drinking water quality parameters and indicate which microbiological, chemical and indicator parameters must be monitored and tested regularly in order to protect the health of the consumers and to make sure the water is wholesome and clean. Most water quality monitoring systems are required to be low cost, reliable, continuous, and based on

WSNs. Sensor nodes measure predefined qualitative water parameters (temperature, turbidity, conductivity, oxidation-reduction potential, pressure, pH level, chlorine, or dissolved oxygen) and the WSN sends the parameters' measurements through the available communication network to Remote Control Centers for recording and analysis.

Research related to water quality monitoring applications has increased recently. Continuous monitoring is critical to detect microbiological and chemical contamination events. The state of the art in using sensor networks for water quality monitoring is reviewed below.

A number of multi-parametric sensor arrays have been proposed and developed based on various sensor technologies. A prototype monitoring system to monitor hydraulic and water quality parameters, and water levels using WSN was developed in [11]. This research work provides operational challenges of using WSN as well as hardware and software limitation to manage a large scale water supply system. The system has neither power access nor an energy harvesting mechanism, and thus, the sensors depend on battery operation. Batteries have to be replaced every 60 days. Besides, it lacks water quality anomalies and contamination detection algorithms. In [12], a low-cost WSN that can be used at consumers' sites to continuously monitor qualitative water parameters and contamination detection is developed. The paper emphasizes on low-cost, light-weighted implementation, and reliable system operation. The proposed system has contamination detection algorithm and provides spatiotemporally rich data. The limitation of this work is it does not have power saving nor power harvesting mechanisms. Besides, the system is prone to false alarm in the network. A recent review on multi-parametric solid-state sensors for water quality is presented [13]. A chemical water quality monitoring WSN is presented in [14]. The authors designed and developed a reusable, self-configurable, and energy efficient system for real-time monitoring. The system implements an energy efficient routing protocol and a sleeping scheduling mechanism to prolong the network lifetime, and provides a web-based information portal for customers and administrators.

In addition to the research works on WSN for water quality monitoring, there has been efforts to develop software and algorithms for the detection of water quality anomalies and contamination events. The detection of anomalous water quality events has become an increased priority for drinking water systems, both for quality of service and security reasons. Because of the high cost associated with false detections, both missed events and false alarms, algorithms developed for this purpose must be evaluated to understand their capabilities and limitations. In [15], water quality change detection algorithms were developed and their performance studied for different water quality anomalies. Moreover, the authors detailed the steps necessary for evaluating detection tools. A general water contamination event detection method that can be implemented in any water distribution system is given in [16]. The methodology can provide both visual and statistical indications of contamination events. Finally, CANARY software [17] was developed to provide a platform within which different event detection algorithms can be developed and tested. These algorithms process the water quality data at each time step to identify periods of anomalous water quality. It indicates possible contamination events by using a range of mathematical and statistical techniques to identify the cause of anomalous water quality incidents from online raw sensor data, while at the same time, limiting the number of false alarms that occur.

In recent times, the research work in water quality monitoring has been advancing. However, a number of limitations are observed in many of the research works, and among them are:

- High installation and operation costs.

- Lack of hardware (e.g. power management circuits) and software platforms for real-time monitoring.
- Lack of water quality anomalies and contamination event detection softwares and algorithms.
- Lack of energy harvesting techniques (short network lifetime).

2.1.2 Smart water meter reading

Smart water systems use the AMR (Automatic Meter Reading) technology to automatically collect meter measurements and transferring to the central database for billing, troubleshooting, and analyzing. A key element in an AMR system is communications between meters and the utility servers. Several communication technologies have been proposed in the literature for this purpose [18], [19]: RS-232 interface, Infrared, short range radio frequency, internet, and cellular etc. Whichever technology is used, the AMR should be capable of providing, but not limited to, reliability, scalability, real-time communication, and security. The next key element of the AMR system is energy efficiency, as the meters are mostly battery powered. Desirably, the lifetime of the batteries should be as along as the maintenance or calibration cycle of the meter, which typically is 8-12 years.

The design of a smart water meter makes a tradeoff between data transmission rate and power efficiency, as continuous transmission is an aggressive power consumer. In general, the meter applies three data transmission modes to send the measurement data: event driven - e.g. for leak detection, water misuse or fraud, demand driven – by polling from data collection center, and scheduled - for regular reporting and considers bandwidth, power and other resources in the design.

AMR gives multiple benefits to customers and utilities [20]: real-time pricing, remote modification of meter functionality, easier to identify customer and utility loses, increased revenue from previously unaccounted water, and demand management by providing real-time information about water usage. However, to provide these benefits, it requires designing a low-cost and autonomous meter but supports high-rate metering, low operation cost, long battery lifetime, and developing appropriate communication standards. Battery lifetime depends on the transmission duration, transmission power, metering rate, and environmental conditions like variations in temperature.

In recent times, several research works on smart water meter reading have been proposed in the literature. It is observed that the AMR system is heavily dependent on WSNs such as ZigBee for short-range communications between the meters and the gateways, and on various technologies (such as 2G, 3G, 4G, WiMAX, satellite) for a backhaul communication between the gateways and data centers. The key issues in choosing an optimal communications technology for an AMR system include cost of deployment, security, regulatory compliance, range, and power consumption [21].

The authors in [22] present an energy autarkic, RF-based water meter with energy aware routing. They claim that the developed meter is cost efficient; integrates an energy harvesting and storing mechanisms and an energy aware routing protocol, which is developed based on the Q mode of wireless M-Bus (WM-Bus) protocol. The meters use WM-Bus protocol to communicate with the gateway, and Ethernet is used for the communication between the gateway and the central unit. They also try to show that energy harvesting systems are capable of being applied in real industrial applications. In [23], a design schema of a wireless smart meter reading system is given. In this work, the authors propose a smart water meter which uses ZigBee to communicate with the gateway, and GPRS for the long-range communication. However, they did not provide any experimental or simulation works in the paper. N.S. Islam et al. [24] discuss an SMS based integrated prepaid water metering system. In the system, water is supplied only when the meter is recharged with some balance. When the credit expires water supply is halted. The server also halts water supply whenever there is a security breach. The meters are fitted with GSM modems and thus send remaining credit, water used, and security breach information by SMS to the server. The authors argue that data collection can be done at any time: hourly, daily or monthly. However, they do not discuss the source of power.

A. Zabasta et al. [25] present a battery-powered AMR system which uses WM-Bus protocol for communication between the sensors and data concentrators, and GSM between the data concentrators and the central server. The developed metering system tries to utilize existing mobile operator networks to expand the water services without major investment. Furthermore, it provides a web-based information portal for customers and administrators. Others like in [26], [27], [28] discuss ZigBee based smart water meter reading systems.

2.2 Networking technologies and protocols

Over the years, several WSN-based communication technologies have been proposed and developed for various applications. Most of these technologies operate in the unlicensed ISM frequency band (Industrial, Scientific and Medical), which is internationally reserved for the use of industrial, scientific, and medical purposes other than communications. IEEE 802.15 [29] is a typical group of standards developed for WSN applications, out of which Bluetooth Low Energy (BLE) [30] offers higher data rates, but short ranges, and IEEE 802.15.4 [31] is optimized to provide low power consumption, low data rate, low-cost, and short range wireless sensor communication. WSN applications choose communication protocols based on their requirements; some need a very low latency, others need a highly secure connection, a long battery life, or a combination of them.

A typical communication architecture for Advanced Metering Infrastructures (AMIs) or AMR in water systems is based on a hierarchical topology: sensors/meters are connected to access points, or gateways, which in turn collect data and send it to a central unit, where data is stored and processed. The gateways send measurement data to the central unit using different wireless technologies. To this aim, gateways are usually powered by the grid, or from solar cells, due to their long-range transmission requirements. On the contrary, the sensors usually located at public, domestic, or industrial sites are usually battery-powered and are capable of performing short or medium range communication at a low power consumption. Therefore, the main requirement of the communication protocol used between the sensors and the nearby gateway is power consumption minimization while ensuring the required QoS and coverage area. Other protocol selection or design criteria for water management application like AMI/AMR include:

1. In AMI/AMR, packets carry unique information identifying a specific meter and the exact time of the measurement. Thus, the data from individual devices must reach the gateways while preserving its information; no data aggregation is required.
2. Devices locations are fixed. As such, a protocol that considers the device location is preferred.
3. If a device ceases to operate or malfunctions, immediate investigation and maintenance must take place. In other words, a fault detection protocol that considers the periodic data reporting and static topology characteristics is essential.
4. The protocol should support bidirectional communication to allow for device set-up and reconfiguration at any time.

5. AMI/AMR is delay tolerable for some predefined time window, determined by the metering schedule.
6. In some cases, the network size is so big. So, a protocol which is scalable, tolerant to interference, and incurring low delay is preferred.
7. Stringent security (to avoid unauthorized access, tampering with data, and denial of service) and high network reliability are very crucial.

An extensive survey of AMI/AMR technologies is given in [18]. The authors in [32] present an overview of current and emerging technologies for supporting wide-area M2M communications and their challenges. In general, low-power WSN technologies can be divided into two groups: Low power Wireless personal area networks (LoWPAN) having a range of some meters and Low power Wide area networks (LPWAN) having a range of several kilometers which may serve as a backbone network to many LoWPAN networks. In this section, among the several communication standards developed for WSN applications, the ones which are suitable for water management are discussed in each group.

2.2.1 Low Power Wireless Personal Area Network (LoWPAN) technologies

ZigBee [33] is a communication standard developed for WSN while adopting the IEEE 802.15.4 standard [31] for its reliable communications. IEEE 802.15.4 and ZigBee are two tightly connected standards, which aim for short range (about 100 m), low complexity, low cost, low power consumption, low data rate, short delay, and bidirectional wireless networks for residential and building automation, and energy monitoring. A ZigBee network has self-organizing and self-healing capabilities, and supports complex network topology and a variety of strong routing protocols. The network not only has good scalability, but also makes reliable data communication between sensors. Its other features include low duty-cycle to enhance long battery life, low data rate (20 kbps at 868 MHz and 250 kbps at 2.4 GHz), low latency which is suitable for real-time observation, collision avoidance mechanisms and retransmissions, and multiple channels (16 channels in the 2.4 GHz ISM band, 10 channels in the 915 MHz band, and 1 channel in the 868 MHz band). ZigBee/IEEE 802.15.4 supports two types of network topologies: star and peer-to-peer topology for communication between network devices. In the star topology, all the end-devices communicate with a central controller while the peer-to-peer topology allows more complex network formations to be implemented, such as mesh networking topology. A peer-to-peer network can be ad-hoc, self-organizing, and self-healing. Star topology is preferred when coverage area is small and low latency is required by the WSN application, whereas peer-to-peer topology is suitable for a large coverage area where latency is not a critical issue.

ZigBee has been implemented in a wide range of WSN applications in the literature [34], [35], [36], [37]. Because of its good features, it has received big attention as a solution in smart water applications recently. A water quality monitoring system using ZigBee based WNS is presented in [38]. In [39], a web based water quality monitoring WSN that relies on ZigBee and WiMAX technologies is proposed. Other research works in this area are also given in [12], [14], [40]. Even though ZigBee is a viable protocol for smart water grids, it is worth noting a number of limitations. Its short transmission range has an impact on the application area. To cover a large area, large numbers of concentrators are required, or multiple-hop way of communication must be implemented in each network. But this method is not energy efficient. With the increase of the number of sensors, interference increases dramatically. In such scenarios, its connections and routing paths become unstable and incur high delay. Therefore, ZigBee/IEEE 802.15.4 is suitable for small capacity WSN applications.

The 6LoWPAN standard (RFC 4944) [41] has been defined by IETF to adapt IPv6 communication on top of IEEE 802.15.4 networks. 6LoWPAN refers to IPv6 over Low power Wireless Personal Area Networks. It enables IPv6 packets communication over low power and low rate IEEE 802.15.4 links and assures interoperability with other IP devices. 6LowPAN devices can communicate directly with other IP-enabled devices. IP for Smart Objects (IPSO) Alliance [42] is promoting the use of 6LowPAN and embedded IP solutions in smart objects. 6LoWPAN provides an adaptation layer, new packet format, and address management to enable such devices to have all the benefits of IP communication and management. Since IPv6 packet sizes are much larger than the frame size of IEEE 802.15.4, the adaptation layer is introduced between MAC layer and the network layer to optimize IPv6 over IEEE 802.15.4. The adaptation layer provides mechanisms for IPv6 packet header compression, fragmentation and reassembly allowing IPv6 packets transmission over IEEE 802.15.4 links.

ISA100.11a standard [43] is developed by the ISA100 standards committee which is a part of the International Society of Automation (ISA) organization. Its main application is in industrial automation and to meet the needs of industrial applications, it supports various network topologies, such as star and mesh networking. ISA100.11a WSN consists of field devices, gateways, and hand-held devices. Field devices are responsible for gathering sensor data and some of them can also provide routing functionalities. The gateways ensure connection between the WSN and the user application and also support interoperability with existing standards, such as WirelessHART [44] by translating and tunneling information between the networks. Handheld devices support device installation, configuration and maintenance. One of the key features of ISA100.11a is the low latency or fast response time of 100 ms. ISA100.11a uses only the 2.4 GHz ISM band with frequency hopping to increase reliability and prevent interference from other wireless networks. IEEE 802.15.4a-Ultra Wideband (UWB) is a Radio Frequency (RF) communication technology in which the information is transmitted through a series of very short impulses emitted in periodic sequences [45]. A UWB signal can be defined as a signal with instantaneous spectral occupancy in excess of 500 MHz or a fractional bandwidth of more than 20.

Bluetooth is a wireless technology for short-range and cheap devices intended to replace the cables in WPANs. It operates in the 2.45 GHz ISM band and uses frequency hopping to combat interference and fading. Bluetooth can cover a communication range of 10-100 m and allows data rate up to 3 Mbps. It was standardized as IEEE 802.15.1, but the standard is no longer maintained. Currently, Bluetooth is managed by the Bluetooth Special Interest Group, which adopted Bluetooth Core Specification Version 4.0 in 2010.

Bluetooth v4.0 [46] is the most recent version. It introduced Bluetooth Low Energy (BLE) technology [30] that enables new low-cost Bluetooth Smart devices to operate for months or years on tiny, coin-cell batteries. Potential markets for BLE-based devices include healthcare, sports and fitness, security, and home entertainment. BLE operates in the same 2.45 GHz ISM band as classic Bluetooth, but uses a different set of channels. Instead of Bluetooth's 1-MHz wide 79 channels, BLE has 2-MHz wide 40 channels. As compared to classic Bluetooth, BLE is intended to provide considerably reduced power consumption and lower cost, with enhanced communication range. BLE allows 1 Mbps data rates with 200 m range and has two implementation alternatives; single-mode and dual-mode. Single-mode BLE devices support only new BLE connections, whereas dual-mode devices support both classic Bluetooth as well as new BLE connections and have backward-compatibility.

The Z-Wave is a low powered RF-based wireless communications technology designed specifically for remote control applications in residential and light commercial environments. It was developed by Zensys [47] and is currently supported by Z-Wave Alliance [48]. Z-Wave's main advantage with respect to IEEE 802.15.4-based technologies is that it operates in sub-1GHz band (around 900 MHz); unaffected to interference from Wi-Fi and other wireless technologies (Bluetooth, ZigBee, etc.) in the crowded 2.4-GHz range. The 868 MHz band used by Z-Wave in Europe is limited by European regulations to operate at or under 1GHz.

EnOcean is an emerging WSN technology that is promoted by EnOcean Alliance. The EnOcean wireless standard [49] is optimized for solutions with ultra-low power consumption and energy harvesting. The battery free EnOcean technology brings together wireless sensing and energy harvesting to enable energy harvester-powered WSNs. The goal of EnOcean's energy harvesting wireless sensor technology is to draw energy from the surroundings, for example, from motion, pressure, light or differences in temperature and convert that into energy that can be used electrically. Thus, combining miniaturized energy harvesters and highly efficient wireless technology enable designing WSN that is supplied via energy harvesting. EnOcean provides wireless sensor solutions for buildings and industrial automation. It uses 868 MHz and 315 MHz and supports transmission range of up to 30 m indoor and 300 m outdoor. EnOcean products available in the market include battery-less self-powered wireless sensors and switches. Battery-less EnOcean modules with energy harvesting are available which reduce the life cycle cost as they are maintenance free.

2.2.2 Low Power Wide Area Network (LPWAN) technologies

IEEE 802.15.4k is adopted IEEE 802.15.4k [50] as a communication protocol for low energy critical infrastructure monitoring (LECIM) applications. It is an amendment of IEEE 802.15.4 with the aim of providing physical layer (DSSS and FSK) and MAC layer specifications which meet the LECIM requirements [50]. It has the following main features: supports professionally installed, thousands of end-nodes, coverage area of up to 10 km, capability to operate in areas with propagation pathloss of up to 120 dB, maximum data rate is about 40 kbps, ultra-low power consumption, low installation cost, supports star topology with an asymmetric communication link between the end-nodes and the coordinator, and supports priority access (which is useful to transmit urgent messages with high priority). Looking at most of the features, IEEE 802.15.4k can be a viable communication protocol for water management networks.

WI-SUN [51] is developed based on the IEEE802.15.4g-2012 standard [52] defined to be a communications protocol for Smart Utility and related networks. The Wi-SUN Alliance has released specifications to promote an open and interoperable protocol for Smart Utility Networks. The protocol is optimized to support mesh-enabled field area networks for large-scale outdoor communications. Mesh-enabled field area networks provide resilient, bidirectional, secure, and cost effective connectivity in a range of topographical environments, from dense urban neighborhoods to rural areas, with minimal additional infrastructure. The Sub-1GHz bands provide links which are ideal for transmitting and receiving small amount of data to and from up to 1000 remotely connected devices at data rates ranging from 40 kbps - 1000 kbps, depending on the application. A Wi-SUN based device operates in the Sub-1GHz and the 2.4 GHz ISM bands. Examples are 863 MHz in Europe, 915 MHz in the United States, and 920 MHz in Japan. The major application of WI-SUN includes home energy management systems, AMI, demand/response, distribution automation, low power meter reading e.g. gas metering, and in smart cities - e.g. street lighting. However, water management networks have energy limitations and mesh topology is an aggressive power consumer. Therefore, it is not a suitable communication protocol for such networks.

Wireless M-Bus [53] is a new European standard proposed by the Open Metering System group [54] for remote reading scenarios and recommended for use in smart metering as well as for various sensors and actuators. Wireless meter reading requires communication for small amounts of data with little protocol overhead. WM-Bus transceivers provide low energy operation as the standard supports low overhead protocol, Transmission-only modes, and long sub-GHz transmission bands. The first version of the standard (EN 13757- 4:2005) is designed to operate at 868 MHz ISM band, whereas the second version (EN 13757- 4:2013) added the 169 MHz band for new Transmission modes. As there are different requirements for different applications, WM-Bus has different communication modes and corresponding data rates in both frequency bands [53]. Depending upon the application, one of a number of communication modes can be selected. The 169 MHz band enables longer transmission range than the 868 MHz one due to the reduced pathloss experienced by the propagating radio signal. Moreover, the lower data rates in the 169 MHz band enable higher sensitivity for the receiver, allowing a reduction of the transmission power at the transmitter, or a longer range at the same transmission power. Compared to ZigBee/IEEE 802.15.4, WM-Bus can achieve longer transmission ranges. This is because WM-Bus uses lower frequency bands than ZigBee, and thus, the lower frequencies enable the RF waves to travel longer distances for a given output power and receiver sensitivity.

WM-Bus has good features for SWM networks: 100 kbps data rate, 20-30 km (rural) and 1 km (urban) transmission ranges, supports mesh and star topologies, battery life up to 20 years, and good security. Accordingly, it has been implemented in many applications in the literature. The authors in [55], [56], [57] made extensive research to confirm its suitability for smart water grids. Other research works on WM-Bus for similar applications are given in [22], [25], [58], [59]. WiMBex technology [60] is an AMR system developed for water utilities using WM-Bus protocol.

SigFox [61] is a technology, similar to cellular systems, which enables remote devices to connect using ultra narrow band (UNB) technology, mainly developed for low throughput M2M/IoT applications. It provides low power, low data rate, and low cost communications where wide area coverage is required and which until recently was served using the ill-suited cellular connections. SigFox is a wireless connectivity optimized for low-bandwidth applications. The use of UNB is key to providing a scalable, high-capacity network, with very low energy consumption (very low transmitter power levels), while still being able to maintain a robust data connection. SigFox operates in the ISM bands (868 MHz in Europe and 902 MHz in the USA) and co-exists in these frequencies with other radio technologies, but without any risk of collisions or capacity problems. SigFox uses a very simple and easy to rollout star-based cell infrastructure to provide a highly secured unidirectional and/or bi-directional communications. The density of the cells is based on an average range of about 30-50 km in rural areas and 3-10 km in urban areas. The range can even extend up to 1000 km for LOS outdoor devices. The network can support up to a million devices and it is easily scalable to handle more devices by augmenting the density of base stations. A SigFox device can send up to 140 messages per day (payload size for each message is 12 bytes) at a data-rate of 100 bps. Besides, each device is fitted with a certified SigFox compatible modem for communications with SigFox base stations. To minimize energy consumption, the network is used only when the device needs to transmit a payload. The exact power consumption over time obviously depends on how many messages are sent and how often. To illustrate this, a smart energy meter that transmits three messages a day using a 2.5 Ah battery can last up to 20 years, which is a few months if the traditional cellular network is used. SigFox's main application areas includes smart metering, healthcare, automotive management, remote monitoring and control, retail including point of sale, shelf updating, etc., and security. Therefore, looking at its features, SigFox is a good wireless connectivity for water measurement applications. Its main downside is that it is proprietary and must be leased to use it.

LoRa [62] is another cellular style wireless system developed to enable low data rate, ultra-low power and long-range communications for M2M and IoT applications. It is similar to SigFox in many ways except that LoRa is optimized for wideband CDMA implementation [63]. While using the ISM bands (868 MHz for Europe, 915 MHz for North America, and 433 MHz for Asia), the technology applies new specifications to support long-range, optimal battery life, and minimal infrastructure requirement, which results in improved mobility, security, bi-directionality, and lower costs. LoRa uses a star-of-stars topology in which gateways are transparent bridge relaying messages between end-devices and a central network server in the backend. Gateways are connected to the network server via wired or wireless connections while end-devices use single-hop wireless communication to one or many gateways. The communication between different end-devices and gateways utilizes several different data rates. To maximize both battery life of the end-devices and overall network capacity, the network server manages the data rate and the RF output for each end-device by means of an adaptive data rate scheme.

LoRa technology has the following salient characteristics.

- Long range: 15 - 20 km, in favorable environments, and more than 2 km in dense urban environments.
- Data rates range from 0.3 kbps to 50 kbps.
- Supports millions of devices.
- Long battery life: in excess of 10 years.
- Provides secured and reliable data communications.

LoRa networks can be applied in smart metering, inventory tracking, vending machines, automotive industry, utility applications, in fact anywhere where data measurement and control may be needed. And compared to SigFox, LoRa standard supports higher data rates and deploys more base stations.

Weightless [64] is another cellular-styled LPWAN connectivity open standard that provides the ability for data transmission between a base station and thousands of machines in IoT/M2M networks. It uses a very simple and easy to rollout star-based network infrastructure. To meet the IoT/M2M requirements, it focuses on free, plentiful, and globally harmonized low frequency spectrum. Accordingly, it is designed to operate in the Sub-1GHz transmission bands and co-exists in these frequencies with other technologies, but without any risk of interferences or capacity problems. By using a UNB technology, it offers excellent coverage (up to 5 km in urban areas), long battery life (up to 10 years), low data rates, ultra-low device cost (about $2), very low signal interferences, and large network capacity (a single cell can serve between 100 000 and 1 million devices). The standard uses spreading techniques to achieve long range and very low-power consumptions, and some whitening methods to achieve very low signal interference in the very stringent industrial IoT/M2M sector.

Weightless technology has three standards: Weightless-W is developed for use in the White space; Weightless-N is developed for use in the ISM frequency bands – for example, 868MHz in Europe and 915MHz in the US; and Weightless-P which is designed to operate on all unlicensed SRD/ISM bands including 169, 433, 470 - 510, 780, 868, 915 and 923MHz, ensuring worldwide availability. Weightless-P provides fully acknowledged two-way communication offering data rates ranging from 200bps to 100kbps. It enables higher capacity than existing LPWAN and cellular technologies for uplink-dominated traffic with short-to-medium payload sizes. Weightless standards can be applied in smart metering, retails including point of sale, shelf updating, asset tracking, healthcare and many more.

Wavenis is an ultra-low-power and long-range wireless technology developed by Coronis [65] for M2M and WSN applications in which communication ability and device autonomy present conflicting requirements. It was originally developed as a proprietary technology, and is now promoted by the Wavenis Open Standard Alliance. Wavenis-based devices are used in telemetry, industrial automation, remote utility meter monitoring, home healthcare, access control and cold-chain monitoring. Its key features include reliability, power savings, network coexistence, robustness against interferers, and automated 2-way communications. Wavenis operates worldwide in the 868, 915, and 433 MHz ISM bands. Its data rates vary from 4.8 kbps to 100 kbps and they are ideal for low traffic, 2-way data and M2M applications. Most Wavenis applications communicate at 19.2 kbps, and typical LOS communications ranges up to 1 km (25mW, +15dBm), and up to 4 km (500mW, +27dBm).

Dash7 [66] is an open source, ultra-low-power, and long-range wireless sensor networking technology based on the ISO 18000-7 open standard. It operates in the sub-1GHz ISM frequency bands, usually between 315 MHz and 915 MHz, with 433 MHz being a typical one. It is promoted by the Dash7 Alliance [67] that focuses on the interoperability among Dash7 devices. The Dash7 network uses a new concept called BLAST (Bursty, Light, Asynchronous, and Transitive) technology that makes it best suited to the uses that have bursty, asynchronous communication between devices. Dash7 system devices are portable and upload-centric, so there is no need to manage devices by fixed infrastructure (i.e., base stations). The main characteristics of Dash7 include a multi-year battery life (5-7 years), even supports energy-harvesting mechanisms, communication range of up to 10 km, low latency for connecting with moving objects, security support, interoperable, inexpensive, data rate of up to 200 kbps, and real-time location precision within 4 m. The major applications of Dash7 include supply chain management, inventory management, mobile payments, manufacturing and warehouse optimization, hazardous material monitoring, advanced location based services, smart meter, and building automation.

LTE-M: LTE-M represents LTE for M2M communications. Currently, M2M/IoT applications are supported using cellular networks such as GSM, CDMA1x, and UMTS. With the widespread introduction of LTE, many M2M/IoT applications are migrating to LTE for greater security, longevity, ease of deployment, efficiency, speed, and reliability. However, most M2M applications do not need the higher bandwidth of 4G/LTE as data rates of a few hundred kbps could meet their needs. LTE is a complex system capable of carrying high data rates. To successfully support massive M2M deployment, the key requirements for LTE are: wide service spectrum, support of large network capacity, low cost devices, long battery life, large coverage, easy deployment, interoperability, and support for last-gasp scenario. Besides, since a number of M2M networks like LoRa and SigFox are being deployed, LTE needs its own M2M capability to ensure that it is able to compete with these growing standards. Otherwise LTE may not be suitable for carrying this form of low data rates from M2M devices. LTE-M is the cellular operators' answer to this, an optimized LTE for M2M/IoT communications [68].

The evolution of LTE to LTE-M began in 3GPP Rel-12, where low cost M2M devices (Cat-0) were specified. In Rel-12, low cost M2M devices with reduced capability were introduced. The cost of the modem for this device is approximately 40-50% of regular LTE devices. These low cost devices are restricted for M2M services, and have reduced capabilities such as one receive antenna and slower speed Max. 1 Mbps UL/DL data channel. In addition, coverage enhancement techniques, which would be required to support M2M in LTE, will be standardized in Rel-13. Some of the proposed features in Rel-13 are reduced bandwidth to 1.4 MHz for uplink and downlink, reduced transmit power to 20 dBm, and reduced support for downlink transmission modes. With the completion of LTE-M in 2017, the standard will offer long battery life (up to 5 years for AA batteries), low cost devices, enhanced coverage by 20 dB etc.

LTE-M is likely to evolve beyond Rel-13 (bandwidth will be reduced to 200 KHz) to enhance local mesh networking, very low cost devices ($5), very long battery life (up to 10 years), and low data rates with two-way (including duplex) communication. For M2M communication, a narrowband system has certain advantages as presented in [69]: low cost device, coverage improvement, and efficient use of spectrum as a smaller bandwidth is needed. Typical LTE-M applications include utility metering, vending machines, automotive applications, medical metering and alerting, and security alerting and reporting.

ETSI LTN [70] or simply LTN is a standard optimized for low throughput M2M/IoT networks where data volume is limited and low latency is not a strong requirement. It operates in the sub-1GHz ISM frequency bands, usually at 433, 868, or 915 MHz. LTN is a standalone network that provides open interfaces for an ecosystem of end-points, access points, networks and service providers. LTN defines specifications to achieve ultra-low power on end-points (up to 20 years battery life), low data rate (10-100bps), high budget link for enhanced coverage (urban, underground, fixed objects), and low cost of operations. Typical transmission ranges are 10-12 km in cities and 40-60 km in open areas. For certain applications, LTN supports underground communications with buried end-devices. The technology implements advanced signal processing to mitigate signal interferences. The major application areas for LTN include utility metering, infrastructure monitoring, environment monitoring, automotive, healthcare etc.

2.2.3 Routing and Transport layer protocols

This section describes some routing and transport layer protocols which have been standardized by IETF for WSNs.

RPL: The IPv6 Routing Protocol for Low Power and Lossy Networks (RPL) designed by the IETF workgroup ROLL [71] enables implementing an IPv6 routing protocol optimized to work on LLNs, such as IEEE 802.15.4 with 6LoWPAN. RPL supports many-to-one traffic, where nodes periodically send information to one or more data sinks (border routers) to connect to the outside networks. RPL is a distance-vector based routing protocol. It organizes a topology as a Directed Acyclic Graph (DAG) that is partitioned into one or more Destination-Oriented DAGs (DODAGs). RPL routes are optimized for traffic to or from one or more roots or LBRs (LoWPAN Border Routers) that act as sinks for the topology, which means there is one DODAG per sink. RPL builds a DODAG (graph) at the border router (root) using a set of metrics and constraints with an objective function to build the "best" path, such as latency or power consumption optimization routes. A node in the network can participate and join one or more graphs (referred as RPL instances) and mark the traffic according to the graph characteristic to support QoS aware and constraint based routing.

Constrained Application Protocol (CoAP) is a protocol intended for objects to communicate interactively over the Internet. It is particularly targeted for small low power sensors, switches, valves and similar components that need to be controlled or supervised remotely, through standard Internet networks. CoAP is an application layer protocol that is intended for use in resource-constrained internet devices, such as WSN nodes. CoAP is designed to easily translate to HTTP for simplified integration with the web, while also meeting specialized requirements such as multicast support, very low overhead, and simplicity. Multicast, low overhead, and simplicity are extremely important for IoT and M2M devices, which tend to be deeply embedded and have much less memory and power supply than traditional internet devices have. Therefore, efficiency is very important. CoAP can run on most devices that support UDP or a UDP analogue.

2.3 Energy harvesting mechanisms

Unlike in smart grids, the sensors or devices in water grid applications enable measurements in harsh or isolated environments, such as under extreme heat, cold, humidity, or corrosive conditions, and cannot be easily wired to the power grid. So, a big issue remains somehow troublesome in these applications, i.e. how to ensure power supply for operating the sensors and sensor networks for sensing, processing, and communication. The power supply and power management strategy affects the number or position of sensors, the maintenance costs, the transmission technology and range, the type of application (low power requirements limit the transmission rate, information acquisition rate and data throughput), and possibly their interoperability.

Current WSNs rely on batteries to supply the required energy for their operation. However, batteries have their own drawbacks: they have short lifetime, contain hazardous chemicals, and need replacement regularly which is uneconomical and unmanageable in hard access environments. Besides, their limited power capacity does not support continuous water measurements as it is an aggressive power consumer. Implementing energy efficient algorithms, energy efficient routing protocols, MAC schemes, and special operating systems are some of the solutions proposed to extend battery lifetime. But still these solutions do not support autonomous WSN for water measurements as battery replacement is not avoided, which causes a lot of errors and data missing.

A simple but effective way to power sensors in the water grid is by means of energy harvesting. The harvested energy enhances autonomous and continuous monitoring applications using sensor networks. Powering sensor networks in water grids encompasses energy harvesting from the surrounding environment, energy management and storage, and implementation of energy saving communication mechanisms. These energy saving methods include long sleep times, applying energy efficient MAC schemes and routing protocols, and harvested-energy-amount based mode of data transmission (smart usage of the stored energy to optimize the execution of certain tasks) [72].

Several energy-harvesting techniques have been proposed in the literature: solar [3], mechanical [73], thermal [74] and radio waves [75].

- Solar - Solar power is a promising alternative used to power WSN, but this option is not feasible as it is not abundantly available in all water measurement scenarios.
- Mechanical - kinetic energy harvested from vibrations of objects is used to generate electric power using piezoelectric or electromagnetic mechanism. Also, mechanical energy obtained

from turbine wheel rotation in fluids is used to generate electric power. The energy generated from turbine wheel rotation is proportional to the flow of the fluid.
- Thermal - temperature difference applied over two junctions of a conducting material generates electric power through the Seebeck effect. The Peltier Cell is a common material used to convert thermal energy into electrical energy.
- Radio waves - RF energy harvesting is becoming a viable source of energy by converting radio waves into AC power. In this case, energy can be harvested from different wireless energy sources such as from intentional remote power transmitters, or from TV and mobile base stations.

Hoffmann et al [76] developed a low-cost radial-flux energy harvester based on a flow-driven impeller wheel in domestic pipelines. The energy harvester is used to power a smart metering system buried underground. The authors are able to generate an output power of 15 mW at 5 l/min flow rate to 720 mW at 20 l/min flow rate. The limitation of this work is when the flow rate is below 5 l/min, the output power is very low. Besides, power management and storage mechanisms are not discussed.

Mohamed et al [72] discuss the application of WSNs for continuous monitoring of water distribution systems, necessary power harvesting solutions, and energy management algorithms which help to optimize the system performance based on the harvested energy. Moreover, the authors outline the main design challenges of energy harvesting for continuous monitoring using WSNs as follows.

- Potential resources for power harvest - choosing an appropriate one between available resources and techniques according to how much power will be generated, feasibility to integrate in sensor node and deploy within the water pipelines.
- Estimating the generated power from flow-induced vibration is not easy.
- Communication - determining a suitable transmission medium, power budget of transceivers, and the type of communication protocol used.
- Power Storage - choosing an efficient storage to store the power during inactive period. Rechargeable batteries have hazard problems in the pipelines.
- Integration - integrating different parts such as communication, processing, sensing, power harvesting along with power management algorithm is needed to optimize the performance of the sensor node in water distribution networks.

2.4 OneM2M standard

Internet of things (IoT) paradigm in general, which includes water management as well, poses new challenges. One of the major challenges is to address the fragmentation created by multiple proprietary M2M solutions that lack interoperability with other M2M systems or solutions.

OneM2M [77] is a global initiative for interoperability of M2M and IoT devices and applications. It aims at developing specifications for a common M2M Service Layer platform that builds on the existing IoT and Web standards, defining specifications of protocols and service APIs. OneM2M specifications provide a framework to support applications and services such as the smart grid, connected car, home automation, public safety, and health. OneM2M has recently published its Release 1 standards providing specifications to enable optimized M2M interworking and develop a platform for M2M and IoT devices and applications. Work in [78] reviews various working groups of oneM2M and their work in progress towards the standardization of M2M communications.

Recent advances and spread of M2M technologies has led to development of several M2M platforms, for example, the OpenMTC platform [79] is a prototype implementation of an M2M middleware to provide a standard-compliant platform for developing M2M and IoT applications.

OneM2M defines a specification for interoperability of IoT platforms at the service layer. Nevertheless, though the details of functionality, protocols, and APIs of platform services are provided, many implementation details are left open. For example, it lacks the scalability, availability, and deployment aspects of the IoT platforms implementing these services [80].

2.5 Data management and analytics

Data analytics is one of the important tasks of water management system. Raw data coming from sensors, installed in the water distribution network, gets continuously streamed, which in turn needs to be processed to obtain useful information and actionable knowledge. Data analytics can provide information, for example, on the health of the distribution network by correlating different sensor values. It can also detect some anomalies such as water leaks in the distribution system or water quality degradation.

This section thus introduces the important concepts related to data analytics and covers the state of the art of these approaches.

2.5.1 Ontologies and semantic modeling

The use of semantic data modeling and ontologies is essential to facilitate the structuring and semantic integration between different data and different processing platforms. An ontology, in ICT, is a description of the knowledge of a field of interest, whose core consists of machine-processable specifications [81]. Gruber [82] defines ontology as “an explicit and formal specification of a conceptualization of a domain of interest”.

Today, we need an ontology adapted to the field of water management which takes into account different sub-areas of water distribution, smart meters, sensors, actuators, and generating alarms and events also new data sources such as social networking (to get feedback from the users). In the project Water-M, a water domain ontology will be created for the description of data in the field of water.

The aim of such a data model is to propose a link between, on one hand, high level data description that can be easily understood by users and, on the other hand, a heterogeneous and highly evolving data system. In essence, they can be adapted to any kind of data and thus, to water relative data. For example, Ahmedi et al. [83] propose to integrate ontologies in a sensor network to monitor water sources pollution.

For Water-M project, the initial task is to define a domain ontology. As a first step, the interest focuses on the water distribution network. At this step, the peculiarities of water are not really taken into account. Thus, the semantic sensor network ontology [84] proposed by the W3C could be enriched to take into account the specificities of water distribution. In the second step, in order to focus on water quality, this ontology should be completed with water description.

An ontology is an abstract description of a domain. This description is the result of a collaborative process. Thus, even if it is possible to make it evolve, it is a landmark for its users. As a consequence, it can be understood as an interface between the users and the data sources. Each data source is linked to the ontology and the users address the data through the ontology. Since the data access is not direct, several data sources and several kind of data sources can be linked. In the case of data source removal or replacement, user interactions are not modified.

As a standalone artefact, an ontology is an efficient reasoning tool based on first order logic. In addition, if linked to a (set of) data source(s) it become a data management tool with its semantic query language.

2.5.2 Data analytics tools and languages: RDF, RDF(S), OWL, SPARQL

RDF (Resource Description Framework) is a formal model for data annotation based on URI (Uniform Resource Identifier) proposed by the W3C [85]. It aims at making data exchange easier over the difference between the schemas used to access to the data through a formal common vocabulary. Published in 2004, it is, by now, considered as a standard in the semantic web domain.

Data annotated with RDF vocabulary can then be organized as a conceptual graph through RDF(S) [86] or OWL statements. A statement is a subject-predicate-object triple where subject and object are RDF annotated data and predicate is a relation. The set of possible relations is defined by the RDF(S) or the OWL language.

Both RDF(S) and OWL schemas can be queried using SPARQL [87] to get the data like any DBMS (Database Management System). Close to SQL, SPARQL takes advantage of the conceptual graph description to produce, in addition to the statement provided by relational algebra, statements provided by first order logic reasoning.

2.5.3 Stream data processing

Stream processing [88] is about handling continuous information as it flows to the engine of a stream processing system. In this paradigm, the user inserts a persisting query in the form of rule in the main memory that will be performed by the engine to retrieve incrementally significant information from the stream. This process is the reverse of traditional database system management system DBMS, where data is persisted and the users define queries to poll information one at a time. Some of the existing stream processing system [C-SPARQL, Streaming SPARQL, TrOWL, CQELS] extend their engine to operate with semantically annotated input data, and enrich SPARQL language to define continues queries over semantic streams.

2.5.4 Complex event processing (CEP)

CEP is like stream processing systems, but it focuses on detecting complex patterns in the stream of Data. CEP engine implements a processing tool for high-level events that may result from low level factors or low level raw events. The analysis and identification of causality relation between complex events and low-level events from multiple streams of real-time data, allows to take effective action and to take immediate action in response to specific scenarios, such as the appearance a problem in the water distribution chain or leak detection and fraud, etc.

Some CEP approaches [89] are based on relational models without integrating semantic models or ontological knowledge. Because of these limitations processing dynamic data having variable and heterogeneous semantics from multiple sources, is still an open question. It has been shown that the exploitation of knowledge in ontological form, and the events of relations with other non-event concepts can improve the quality of complex event processing [90]. Thus, one important point to consider is a CEP engine extension by integrating the ontological knowledge to build a "Semantic Complex Event Processing (CEP)" engine.

There are a few contributions that currently support RDF triples as input. One of them, EP-SPARQL [91] uses the black box approach supported by a logic engine (ETALIS). The EP-SPARQL language allows to define hybrid queries to handle background and RDF streaming data. Background data is specified as RDFS ontology and used to enhance the description of the detected events by describing its context. The EP-SPARQL's black box translates the defined queries to Prolog rules, which enable timely, event-driven, and incremental detection of complex events in a single thread of execution. In this context, parallel and distributed processing is still an open issue for CEP to improve the throughput of such a system.

Another important extension of the existing CEP state of the art solutions concerns the analysis of temporal-geospatial data and the prediction of events. The events of the water distribution chain have Geospatial meaning. The location of the events and a modeling infrastructure can be used to detect and generate complex geo-localized events considering the spatial relationships between events and infrastructure. In addition, considering temporal dimension in the data and event prediction will help in proactive decision making [92], [93]. Existing CEP solutions have no ability to predict events. Therefore, they cannot be used for proactive decision making. The forecasts are useful to anticipate problems, provide water demands, etc. Water-M project is considering an extension of CEP solutions including the prediction of events. This will anticipate problems and take proactive decisions to resolve or prevent them.

2.5.5 Reasoners:

Recently, research is being done on injecting meaning and semantics in the data, which in turn helps machine to understand the data and process it more efficiently. The job of the reasoners [94] is to input data from multiple sources and then infer implicit information from the data, to detect incompatibilities, or obtain new information. As compared to simple stream processing, reasoning is more complex and demands more computational resources. Thus, reasoners use different architectures based on clusters, GPU processing power utilization, etc. Recently, incremental reasoning has evolved as a new paradigm. It processes the data as it arrives without re-processing the previous data.

2.6 IoT data platforms

In IoT, for smart monitoring and actuation, the data must be stored and used intelligently. This requires developing artificial intelligence algorithms (centralized or distributed), fusion algorithms to analyse the gathered data. In addition, state of the art machine learning methods, genetic algorithms, neural networks, and other artificial intelligence techniques are required for effective automated decision making. In general, such novel intelligent systems with characteristics such as interoperability, integration and adaptive communications are apt for emerging IoT applications. Further, a centralized infrastructure to support storage and analysis is significant for IoT. A recent work [95] provides an overview of algorithms and techniques used in the data mining domain and how to apply them to data analytics tasks in the IoT. Another recent work [96] reviews data mining algorithms for the IoT and discusses challenges and open research issues for applying these algorithms to IoT to extract hidden information from data.

One of the platforms considered for Water-M project is called **SOFIA (Smart Objects For Intelligent Applications)** [97]. It is an IoT platform which was developed by ARTEMIS project. It provides a middleware which in turn helps in connecting different devices, systems and applications. SOFIA offers a semantic interoperability platform, which connects different IoT objects and applications allowing the creation of composed services. It has been used in many projects related to smart buildings, energy management, etc. SOFIA continues to be developed and the latest platform is called SOFIA2. SOFIA2 apart from the features supported by SOFIA, has security features, big data functionalities and cloud approach. SOFIA2 comes under 2 licenses: free version which excludes some functionalities like complex event processing and enterprise version which includes all the functionalities.

Currently, many Cloud based storage solutions are gaining popularity and Cloud based analysis and visualization platforms are expected to be used in IoT [98]. Since many IoT nodes are limited in their processing power, battery life and communication speed, cloud computing offers a real option to satisfy the computing needs that arise from processing and analyzing the data gathered by sensors. Cloud computing [99], [100] is a new emerging paradigm for the Internet based software systems. The cloud provides scalable processing power and several kinds of connectable services. Combining the concept of wireless sensing with cloud computing makes WSNs attractive for long term observations, analysis, and use in different kinds of environments. For example, WSNs with cloud computing can be used to monitor civil infrastructure or public health, by building a new computing, communication, and management system architecture for sensing, processing, and storing physical data [101]. The Shelburne Vineyard project [102] uses synergy between WSN and cloud computing to monitor its vines. A wireless environmental sensing system has been deployed to monitor key conditions during the growing season of grapes. A distributed network of low-power wireless nodes and a new cloud-based data service called SensorCloud are used to remotely monitor temperatures in real-time to ensure crop health. The SensorCloud platform is used to access unlimited continuous environmental data, to analyze trends and to create alerts, which notify key personnel when environmental thresholds are exceeded. The scalable network monitors all the plant varieties of the vineyard and supports cost-effective condition based cultivation and harvesting.

2.7 Projects

The Non-intrusive Autonomous Water Monitoring System (NAWMS) [103] is a novel easy-to-install and self-calibrating water monitoring system developed for homes using distributed WSNs. It uses wireless vibration sensors attached to the water pipes to provide real-time water usage information at different locations of the water pipe system, thus enabling to improve the efficiency of homes. The water utility companies only provide total water usage in a house, which makes it difficult to determine the individual sources that contribute to the total consumption. The NAWMS system localizes the wastage in water usage and alerts residents about more efficient usage. Thus, using NAWMS, the water usage in each pipe of the plumbing system of the house can be monitored at a low cost.

3 Conclusion

This report presented the state of the art on communication technologies as well as data analyses techniques that can be used in Water-M project. The long range as well as short range low power communications technology was covered. Table 1. provides a comparison of different technologies. In the data analyses part, different concepts such as ontologies and data modeling as well as techniques such as Complex Event Processing were discussed.

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