Considerations on the Deployment of Heterogeneous IoT Devices For Smart Water Networks

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Abstract — Water distribution systems are seeing the increased deployment of new technologies that use Internet of Things (IoT) to gather, analyse and extract useful information from data; further enabling Smart Water Networks (SWNs). IoT type technologies have a huge potential to enable more efficient water resources management. Heterogeneous IoT sensors/devices/technologies from different vendors are starting to be employed in SWNs. The deployment of IoT sensors is a critical issue that significantly affects a wireless sensors network’s real-time monitoring performance. The aim of the deployment of IoT sensors (i.e. nodes) for wireless networks is to find the most efficient number, type and locations of sensors that enable satisfying a SWN’s hydraulic and water quality requirements (among the others) while considering issues such as energy consumption of the nodes and coverage of the target monitoring area, to mention just a few. This paper provides an overview of the SWN architecture and its components and scrutinises emerging sensor and communication technologies for developing SWNs focussing on the first two layers of the SWN architecture (i.e. sensing and control, and collection and communication layers of the SWN architecture). Additionally, it presents a selective review of recent literature on issues related to the intelligent deployment of sensors in wireless sensors networks and on sensors deployment for water quality and leak detection/localisation applications in SWNs. The main aim of the literature review carried out and presented here has been to highlight the main challenges of developing IoT-enabled SWNs, so that interesting future research directions for achieving a context-aware IoT framework for SWNs can be identified.

Keywords—Smart Water Networks, IoT sensors deployment

I. INTRODUCTION

Human society has traditionally benefitted from the availability of large amounts of natural resources. Nowadays, however, numerous natural resources are depleted. Freshwater is the most essential need for each form of life on earth. Because of pollution and other human activities, however, only a limited amount of freshwater resources is available. Therefore, it is vital to manage water use in an effective and efficient manner and avoid wastage. Information and Communication Technology (ICT) can play a fundamental role in this regard by providing tools such as Smart Water Management (SWM) solutions. SWM encompass all aspects of the water cycle; from sourcing to treatment, to transfer, to delivery, to consumption and to recovery. SWM can be defined as a group of new technology solutions which support more efficient water management [1]. These solutions utilise state-of-the-art software and hardware to give water utilities enhanced levels of system visibility and automatic control, operational efficiency and customer services. In this context, the application of SWM solutions to urban water systems makes it possible to introduce the concept of Smart Water Networks - SWNs. A SWN is a group of data-driven “components” that help to operate the data-less physical layer of reservoirs, valves, pumps and pipes, among the others. SWN solutions enhance the longevity, efficiency, and reliability of the water network’s physical layer. They also hold the promise to enable water utilities to adopt a more preventative and proactive approach to network operation and management. The recent rise of easy-to-use and low-cost sensing devices and Internet of Things (IoT) technologies means that SWNs may benefit from massive increases in the density of sensor deployments. Recent advances in data analytics then play a key role in enabling efficient SWNs operations – e.g. [2].

This paper aims to provide a brief overview of the SWN architecture and its components and to scrutinise emerging sensor and communication technologies for developing SWNs focussing on the first two layers of the SWN architecture (i.e. sensing and control, and collection and communication). It also aims at providing a selective (i.e. only a few exemplary papers) review of recent literature on issues related to the intelligent deployment of sensors in wireless sensors networks and on sensors deployment for water quality and leak detection/localisation in SWNs as well as at highlighting the challenges of using IoT in SWNs, so that interesting future research directions for achieving a context-aware IoT framework for SWNs can be identified.

The remainder of this paper is organised as follows: Section II provides an overview of the elements that make up a SWN and of emerging sensor and communication technologies for developing SWNs. Specifically, examples of sensing devices used in SWNs, considerations for sensors deployments and power management and different IoT communication technologies and protocols are discussed in that section. Section III presents the selective review of the relevant recent literature. Section IV summarises the challenges of developing IoT-enabled SWNs and highlights interesting future research directions for achieving a context-aware IoT framework for SWNs. Finally, Section V briefly presents the conclusions and directions for future work.

II. SMART WATER NETWORK ARCHITECTURE

A SWN can be divided into several layers as shown in Fig. 1. These layers are: sensing and control, collection and communication, data management and display and data fusion and analysis. Data needs to be collected from different sources. Data sources can be physical sources (like a sensor) or virtual sources (like software). The sensing and control layer comprises the sensing and control devices. The collection and communication layer is responsible for transmitting data from the field to a central point for processing (which could be in the local gateway, remotely in the water utility or in the cloud, among others). The data management and display layer is responsible, inter alia, for managing the data (e.g. storing) and for presenting data to the end users in different ways. Finally, the data fusion and analysis layer is responsible for tasks such as data processing
Collection and Communication Layer

Communication IoT protocols:

1) 1-10 Kilometres
   Power Transmission: Low
   Data Rate: 9.6 Kilobit
   Range: N/A

2) 20 - 250 Kilometres
   Power Transmission: Low
   Data Rate: 40-100 Kilobit
   Range: N/A

3) 0.3-50 Kilometres
   Power Transmission: Low
   Data Rate: 3-80 Kilometres
   Range: 10-100 Metres

4) 30-50 Kilometres
   Power Transmission: High
   Data Rate: 2-600 Megabit
   Range: 10-15 Metres

5) 4.8-100 Kilobit
   Power Transmission: Low
   Data Rate: 2 Megabit
   Range: 100 Metres

6) 1 Kilometres
   Power Transmission: Low
   Data Rate: 7.2 Megabit
   Range: 5-7 Kilometres

7) 5-7 Kilometres
   Power Transmission: Low
   Data Rate: 0.3-50 Kilobit
   Range: N/A

8) 10-50 Kilometres
   Power Transmission: High
   Data Rate: 384 Kilobit–7.2 Megabit
   Range: 3G

9) 10-50 Kilometres
   Power Transmission: High
   Data Rate: 75 Megabit
   Range: WiMax

10) Several Kilometres
    Power Transmission: High
    Data Rate: Up to 100 Megabit
    Range: Broadband PLC

Figure 1. Smart Water Network Architecture

### A. Sensing and Control Layer

This layer comprises the sensing and control devices. Sensors measure some water parameters such as pressure and flow from a District Metered Area (DMA) and water level in tanks. Actuators enable to automatically control elements such as pumps and valves. These devices typically have limited resources in terms of processing power and power supply. Therefore, an interesting research objective is to find ways to cope with such limitations.

1) Sensing Devices in Smart Water Networks Examples:

   Smart meters represent a well-known example of smart sensors currently widely used in SWNs. Based on the way that data is collected from these devices, a distinction between Automated Meter Reading (AMR) and Advanced Metering Infrastructure (AMI) can be made. AMR refers to any framework that permits computerised gathering of meter data (for the most part by radio transmission and walk-by / drive-by data collection), without the requirement for physical inspection of the meters. The AMI framework on the other hand, involves a fixed communications network and enables two-way communications with a water meter. That is to say, water consumption data is transmitted to utilities, while utilities can issue commands to the water meters to perform specific actions. In the last decade, most water utilities around the globe have started to make use of AMR frameworks. However, because of the extra perceived benefits, the industry is beginning to move towards AMI frameworks [3]. Regardless of the framework used, smart meters offer many potential advantages over traditional, “dumb” meters. To mention just a few, advantages include: i) Reduced meter reading costs; ii) Early visibility of customer leak losses; and iii) Reduction in security and safety issues by removing the need for onsite meter reads at dangerous or inaccessible locations.

2) Considerations for Sensors Deployments and Power Management:

   The deployment of sensors is a critical phase that significantly affects the performance of a sensors network [4]. A few factors that need to be taken into account while deploying sensors are: i) Cost of deployment; ii) Coverage maximization; iii) Fault tolerance and load balancing; and iv) Optimization of power consumption.

With specific regard to the optimization of power consumption, it is important to stress that some smart water sensors need to be battery powered (e.g. sensors used in remote areas). When power becomes a challenge self-powered smart sensors become an appealing opportunity. This said, managing power is a broad topic that spans software and hardware. In detail, the following factors are critical for successful smart sensors deployments:

a) Active sensor power;

b) Frequency of data collection;

c) Wireless (radio) communication strength and power;

d) Frequency of communication;

e) Microprocessor or microcontroller power as a function of core frequency;

f) Passive component power;

g) Energy loss from leakage or power supply inefficiency; and

h) Power reserve for actuators and motors.

### B. Collection and Communication Layer

This layer is responsible for connecting the various smart sensors/actuators to a gateway (sink node). The gateway is the core of the communication infrastructure as it provides data exchange between the smart sensors/actuators and the utility. The gateway can make use of different communication technologies. For example, ZigBee can be used for local communications between the smart sensors and between the smart sensors and the local gateway; Wi-Fi can be used for the long-range communications between the gateway and the utility. Communication technologies for collecting and transporting data can be wired, wireless mobile, wireless fixed network, or a combination of them. The choice of technology depends on multiple factors such as deployment configuration, importance of the data, working processes inside a utility and the costs [5-6]. Table 1 details the main characteristics of communication technologies that can be used [7].

| Technology   | Transmission Range | Data Rate (per seconds) | Power |
|--------------|--------------------|-------------------------|-------|
| Wi-Fi        | 50 Metres          | 2-600 Megabit           | High  |
| Wavneis      | 1 Kilometres       | 4.8–100 Kilobit         | Low   |
| ISTEON       | 50 Metres          | 28.4 Kilobit            | Low   |
| ZigBee       | 10-100 Metres      | 20–250 Kilobit          | Low   |
| Z-Wave       | 100 Metres         | 40-100 Kilobit          | Low   |
| 6lowPAN      | N/A                | N/A                     | Low   |
| LoRaWAN      | 5-7 Kilometres     | 0.3-50 Kilobit          | Low   |
| NB-IoT       | 10-15 Metres       | 2 Megabit               | Low   |
| SigFox       | 10-50              | 0.3 Kilobit             | Low   |
| Bluetooth    | 1-100 Meter        | 25 Megabit              | Low   |
| GPRS         | 1-10 Kilometres    | 8 Kilobit               | High  |
| GSM          | 3-80 Kilometres    | 9.6 Kilobit             | High  |
| 3G           | 10-50 Kilometres   | 384 Kilobit–7.2 Megabit | High  |
| WiMax        | 10-50 Kilometres   | 75 Megabit              | High  |
| Broadband PLC| Several Kilometres | Up to 100 Megabit       | High  |

1) Communication IoT protocols: One of the main challenges in the collection and communication layer is to establish communication between the participating parties. The protocols that can be implemented can be divided into three categories, namely: data-oriented, message-oriented and resource-oriented [8]. Further details about each of these...
categories are provided in the following three sub-sections (i.e. a, b and c) while Table 2 and sub-section d provide a comparison of the most common IoT protocols in these categories.

a) Data Oriented Communication Protocol
The most common data-oriented communication protocol is the Data Distribution Service (DDS). DDS has been characterised by the Object Management Group (OMG) to give a standard data-centric publish-subscribe programming model and specifications for the implementation of appropriate frameworks. DDS has been applied for the development of high-performance applications in the automotive and finance domain to mention just a few. Key features of the DDS are:
- Discovery of all communication parts at run-time;
- Support multiple Quality of Service (QoS) configurations;
- Support peer-to-peer communication between two parties with no broker;
- Support retransmission of missed data for subscribers.

b) Message-Oriented Communication Protocol
The main concern of message-oriented protocols is to deliver messages from producers to consumer. The most common message-oriented communication protocol is the Message Queueing Telemetry Transport (MQTT). The communication of this protocol is established at Machine to Machine (M2M) level [9]. It is a publish/subscribe-form of light-weight protocol streaming over TCP/IP with reliable bi-directional message conveyance. A publisher sends the message on the topic and a subscriber consumes a message on their registered topic of interest. MQTT broker matches publications to subscriptions. If one or more matches are found, the message is sent to the corresponding subscriber and if no matches are found the message is discarded. The MQTT is intended for constrained systems [10-11].

c) Resource-Oriented Communication Protocol
Since sensors are resource constrained (i.e. nodes with limited processing and power), they are often connected to a computer node that is used to process the data [12]. In some cases, the computer node is represented as a server that exposes data from sensors and processes using Representational State Transfer (REST) full web service. RESTful web services allow the requesting systems to access and manipulate textual representations of web resources by using a uniform and predefined set of stateless (i.e. communications protocol in which no information is retained by either sender or receiver) operations. In a RESTful web service, requests made to a resource's Uniform Resource Identifier (URI) will elicit a response with a payload formatted in some format such as Hypertext Markup Language (HTML) or other. The response can confirm that some alteration has been made to the stored resource, and the response can provide hypertext links to other related resources or collections of resources. When Hypertext Transfer Protocol (HTTP) is used, as is most common, the operations available are GET, POST, PUT, DELETE, and other predefined CRUD (Create Read Update Delete) HTTP methods. As a result, a resource-oriented approach seems the most appropriate for connecting mobile devices cloud to sensors cloud.

Table 2. COMPARISON OF MQTT, DDS AND RESTFUL COMMUNICATION PROTOCOLS

| Protocol | Method      | Transport | QoS       | Security                  |
|----------|-------------|-----------|-----------|---------------------------|
| DDS      | Publish-Subscribe | TCP/IP    | Extensive | TLS/DTLS                  |
| MQTT     | Publish-Subscribe | TCP/IP    | 3 levels  | TLS                       |
| RESTful  | Request-Response | TCP/IP    | N/A       | TLS/SSL                   |

d) DDS, MQTT and RESTful Comparison
As mentioned in the previous three sub-sections, the most promising communication protocols are DDS, MQTT and RESTful. The main features of these communication protocols are compared in Table 2.
With regard to the QoS, MQTT and DDS provide different QoS while the RESTful does not provide any QoS. MQTT provides only three QoS for message deliveries, which are as follows:
- At most once: the message is delivered at most once, or it is not delivered at all. Its delivery across the network is not acknowledged;
- At least once: the messages are assured to arrive, but duplicates can occur;
- Exactly once: messages are assured to arrive exactly once. This level could be used, for example, with billing systems where duplicate or lost message could lead to incorrect charges applied.

DDS provides a rich set of QoS providing control on the following aspects:
- Data availability: reliability and availability of published data;
- Resource usage: memory and bandwidth utilisation;
- Timeliness: data prioritization and end-to-end traffic differentiation.

Based on the QoS only, DDS is the best protocol because it provides many QoS. While the RESTful is the worst because it does not provide any QoS.
With regard to security, the DDS protocol supports Transport Layer Security (TLS) and Datagram Transport Layer Security (DTLS) - in which TLS uses reliable connection (TCP) and DTLS use connectionless (UDP). DTLS provides more functions to solve the problems of packet lost and reordering. On the other hand, the MQTT and RESTful protocols support the same security protocols, which are TLS and Secure Socket Layers (SSL). SSL is a security protocol for establishing encrypted connection between the two parties, and it ensures that all data are encrypted during transmission. Therefore, MQTT and RESTful outperform the DDS in term of security because they provide both reliable and encrypted protocols.

III. SELECTIVE LITERATURE REVIEW
Sensor deployment is one of the most critical issues in wireless sensors network design because it has a significant impact on its efficiency and performance. The choice of deployment model depends on the type of sensors, the number of sensors that can be deployed, the particular application under scrutiny and the environment in which the sensors will operate, among other things. Generally speaking,
deployment strategies/techniques for wireless sensors networks have to consider three important issues: (i) coverage maximization, (ii) network connectivity and routing protocols and (iii) power management. A brief review of selected research works that looked into these issues has been carried out in this study and presented in the following three sub-sections. The relevant works examined there encompass techniques and strategies for sensor deployment in various fields. However, in sub-section D, a number of research works that focus on sensors placement in SWNs and real-time monitoring for water quality and leak/burst detection/localisation applications in SWNs are also reviewed to highlight the need for additionally considering issues associated with wireless sensors networks deployments.

A. Coverage maximization

Coverage maximization of an area of interest is an optimization problem. Simply put, in the coverage maximisation problem each point in the area of interest should be in the sensing range of the deployed sensors. Lin et al. [13] proposed a Coverage Aware Sensor Automation (CASA) protocol that includes two centralised algorithms: Enhanced Virtual Forces Algorithm with Boundary Forces (EVFA-B) and Sensor Self-Organizing Algorithm (SSOA) to provide and maintain maximum sensing coverage. SSOA is activated when the energy of the sensor is consumed or an unexpected failure happens. It performs local repair by relocating the sensors to the “uncovered” area. The performance of the proposed methods were evaluated in terms of maximising the coverage, moving energy consumption and monitoring density. Yoon and Kim [14] proposed a genetic algorithm framework, Maximum Coverage Sensors Deployment Problem (MCSDP) to maximise the coverage and reducing the number of deployed sensors using a novel normalization method. The results showed that the performance of the genetic algorithms were improved using the proposed normalization method. The sensor deployment was evaluated using Monte Carlo methods. Liao et al. [15] proposed a sensor deployment method to maximise coverage based on Glowworm Swarm Optimization (GSO). GSO starts with an initial deployment of sensors and then each sensor is treated as a separate glowworm emitting a luminous substance, called luciferin. The intensity of luciferin depends on the distance between the sensor node and the adjacent sensors. The sensor node is attracted to its neighbours with less luciferin intensity and can decide to move to one of them. The results showed that the proposed algorithm provides high coverage with static sensor nodes. Senel et al. [16] proposed an efficient deployment scheme for Under Water Acoustic Sensor Network (UWASN) which guarantees sensors connectivity while maximising the coverage. The proposed scheme’s performance was validated using simulation and the results showed that connectivity is granted regardless of the sensing and transmission range. Frattolillo [17] proposed a deterministic algorithm to enhance coverage that allows to control the degree of redundancy that can be achieved by covering the area of interest and ensure the deployment of a network characterised by the minimum number of wireless sensor nodes.

B. Network Connectivity and Routing Protocols

Network connectivity is another important point for wireless sensors networks. In a connected network, each pair of nodes can communicate directly or indirectly with other nodes. The connected network aims to find the minimum subset of active nodes to send the measured data to the gateway. Ranga et al. [18] proposed a strategy to restore lost network connectivity based on spiral format of Fermat points. This strategy groups each three segments of lost networks as a triangle and computes the centroid of the triangle that acts as the Fermat point. The Fermat point is a point in the triangle in which the sum of the distances between the point and the three vertices of the triangle are minimised. The simulation results seemed to prove the efficiency of the proposed scheme. Hashim et al. [19] proposed an enhanced algorithms for sensor deployment based on Artificial Bee Colony (ABC). ABC works based on two phases relay node deployment in the 3-D space. In the first phase, the core (backbone) network is connected using the smallest number of relay nodes. In the second phase, a new approach is introduced using the heuristic method to search for global optima. The network connectivity is maintained and guaranteed by optimizing the network parameters. The results showed that the proposed algorithm enhances the lifetime of the network and validate the effectiveness of the proposed scheme. Lee et al. [20] proposed the Connectivity Restoration with Assured Fault Tolerance (CRAFT) algorithm. CRAFT tends to form the largest inner cycle or Backbone Polygon (BP) around the centre of the damaged area, where there are no partitions inside. The Relay Nodes (RNs) are then deployed to connect each external partition to the BP via two non-overlap paths. The results showed that the proposed algorithm is highly connected with short inter-partition routes while utilizing RS better than competing schemes.

On the other hand, sensor nodes communicate with each other using different wireless strategies, which are controlled by routing protocols. Thus, the performance of sensor networks depends to a large extent on routing protocols. Al-Roubaiey et al. [21] proposed an energy-aware middleware for wireless sensors networks based on the DDS standard. Using DDS for wireless sensors networks greatly eases the development and integration of wireless sensor networks applications into IoT. Ahmed et al. [22] studied the use of MQTT protocol to collect data remotely from the network to applications into IoT. Pradhan and Panda [24] attempted to enhance the wireless sensors network’s life-time and connectivity using a Multi-Objective Particle Swarm Optimization (MOPSO) algorithm. They proposed the use of energy efficient sensors based on a multipurpose particle swarm optimization algorithm, which is compared with a non-dominated genetic sorting algorithm. During the optimization process, sensor
nodes are moved to a fully connected network. The results showed that the proposed algorithm outperforms other multi-objective algorithms for sensor deployment. Restuccia and Das [25] proposed a novel algorithm named Swarm-Intelligence-based Sensor Selection Algorithm (SISSA) to optimise the network life-time and satisfy pre-determined QoS constraints. They analysed and derived the mathematical model of power consumption, coverage time, and the number of messages transmitted. The efficiency of the proposed algorithm was evaluated with a testbed using 40 sensors and the results showed that SISSA is efficient and scalable.

D. Sensor Placement in Water Distribution Systems for contamination detection and leak/burst detection and localisation

Sensor placement techniques have been applied in Water Distribution Systems (WDSs) for various purposes. With regard to contamination detection in WDSs, contamination can occur in any node of the system and spread along the edges to the entire system. Water quality sensors could be installed on all nodes to effectively detect contamination. However, because of the high cost of water quality monitoring sensors and the large-scale of WDSs, optimal sensor placement techniques are required. To mention just a few relevant examples, Berry et al. [26] used a mixed-integer programming formulation for optimizing the location of sensors in water distribution systems that includes information on the temporal characteristics of pollution events derived from standard network simulation models. Water quality simulation calculates the time series of contaminant concentrations for each compound in the system. These time series data are then used to evaluate the impact of a pollution event, including the effects of detection at various network nodes. Rathi and Gupta [27] proposed a method that uses a Genetic Algorithm (GA). The results showed that the proposed work provides optimal solution for sensors placement compared to other tested techniques.

Another type of application in SWNs is burst/leak detection and localisation. To mention just a few relevant examples, Rosich et al. [28] proposed an iterative methodology concerned with the identification of the main sensors, which ultimately leads to an improvement in the optimal efficiency of detecting and isolating the leaks in a DMA. The algorithm presented was successfully applied to a real DMA in the Barcelona network. Cugueró Escofet et al. [29] proposed a general method for placing sensors that geographically clusters alike leak behaviours. The proposed method gave promising results. Gamboa-Medina and Reis [30] proposed a sampling design technique based on four criteria: the maximization of the overall leakage sensitivity and the coherence of the sensitivity, as well as the minimization of the redundancy of information and the number of sensors. The optimization procedure uses a GA approach to search for a complete set of nodes for sensor deployment. The proposed method can be applied to sampling design for any water distribution network, requiring as input a complete hydraulic model.

IV. FUTURE DIRECTIONS FOR DEVELOPING IOT-ENABLED SWNS

Based on the literature review of sensor placement methods in both wireless sensors networks for general applications and for SWN applications carried out in the previous section, it is possible to state that different criteria have been used for the development of such methods. In general applications the main criteria focused on coverage maximisation, network connectivity/fault tolerance and the use of different routing protocols, and power management. On the other hand, the sensor placement for SWN applications mainly focused on maximising the performance of the different algorithms proposed to solve a particular problem while minimising the costs of deploying the required instrumentation. For example, in water quality applications the focus has been on minimising the detection time and maximise detection likelihood to mitigate the impact of (un)intentional pollution events while minimising the number of water quality sensors that have to be used.

Bearing in mind the above, it is clear that sensor placement methods for SWN applications would benefit from additionally taking into consideration the issues that have been considered in wireless sensors networks for general applications. This is because with the rise of emerging low-cost sensing devices and IoT technologies, the recent advances in data analytics and the resulting envisaged massive increase in the density of heterogeneous sensors deployed in SWNs, additional challenges will have to be faced by the water industry. In this context, it is envisaged that, in addition to maximising the performance of the different algorithms and minimise cost, the optimal deployment of heterogeneous devices in SWNs will have to aim at developing solutions that reduce computation and communication overhead, provide a high degree of coverage with reliable network connectivity and are resilient to node failures, among other things. To mention just a few examples, the following topics are envisaged to be of particular interest for further research in sensors deployments in SWNs:

- Power Optimization: power consumption in wireless sensors networks is one of the biggest problems because sensors are commonly battery powered and batteries may be difficult to replace or recharge. Novel routing protocols can play a key role in this space. Recent techniques for reducing energy consumption include special routing methods for wireless sensors networks, such as data aggregation and in-network processing and clustering. An advanced sensor deployment method can effectively reduce the power consumption of wireless sensors networks and extend the corresponding network life-time.
- Maximising Coverage and Connectivity using Mobile Sensor Networks (MSNs): mobile sensors may become available for SWN applications. For example, mobile acoustic loggers that are inserted into a pipe and then move along the water network to detect the noise of a leak. Another example could be to have sensors deployed at specific positions, while the relay or collector nodes are allowed to move. Finally, combinations of static and mobile sensors could also help with coverage and connectivity issues.
- Linear Wireless Sensor Networks (LWSNs): LWSNs are defined as new category of wireless sensors networks where the sensors are deployed in a strictly linear or semi-linear form. This LWSN architecture has been exploited in applications such as, monitoring of roads, long oil/gas pipelines, river environment and international borders for illegal crossing. Node deployment, lifetime optimization and routing are important research problems in the LWSN network. LWSN solutions proposed for the aforementioned applications could be exploited for SWN applications as well.
V. CONCLUSION

In this paper, an overview of the SWN architecture and its components and of emerging sensor and communication technologies for developing SWNs with specific focus on the sensing and control and collection and communication layers has been provided. The main aim for this has been to look into (i) examples of sensing devices used in SWNs, (ii) considerations for sensors deployments and power management, and (iii) the advantages and disadvantages of different IoT communication technologies and protocols. A selective review of recent literature on issues related to the intelligent deployment of sensors in wireless sensor networks and on sensors deployment for water quality and leak detection/localisation in SWNs has also been carried out and reported in this paper. The main aim of this selective literature review has been to highlight the challenges of using IoT in SWNs and identify potential future research directions for achieving a context-aware IoT framework for SWNs. Dynamic deployment of sensors deployments and energy aware communications emerge as key issues. Future work should therefore address these important challenges.

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