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Preface

The **International Conference on Water Energy Food and Sustainability – ICoWEFS 2021**, taking place in Leiria/Portugal (May 10–12), Portugal, aims to be a major forum to foster innovation and exchange knowledge in the water-energy-food nexus, embracing the sustainable development goals (SDGs) of the United Nations, bringing together leading academics, researchers and industrial experts.

A climate-neutral continent by 2050 will drive technological, economic and societal transformations towards circular economies using more green and clean technologies and the decarbonisation of energy-intensive industries.

Innovation regarding water, energy, agri-food, bioeconomy, natural resources and the environment will speed up the transition towards sustainability, promoting water and food security in the world.

The forest and wood pine tree from the Leiria region welcomed us, and this material was the basis in the manufacture of the ships used in the Portuguese Navigations in the fifteenth and sixteenth centuries. Now in the twenty-first century, this region has several wind and biogas power plants supported by a solid industrial cluster.

The conference will be a networking and collaboration among participants to advance the knowledge and identify major trends in the fields mentioned above, even in an online format according to the health rules.

We are grateful to the authors from 33 countries with their contribution of 98 papers accepted to be presented at ICoWEFS 2021 and published by Springer Nature, to the directors and staff of the School of Technology and Management of the Leiria and Portalegre Polytechnics for their support, to the research centres and sponsoring companies, to the members of the scientific committee and external reviewers, keynote speakers, and, finally, to the members of the organisation, who with redoubled efforts during a pandemic time managed to carry out this conference.

We hope that we can meet again at the next ICoWEFS.

João Galvão
Paulo Brito
Conference Chairs

Sandra de Jesus Martins Mourato

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Water

eSmartWatering - A More Sustainable Solution for Irrigation

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Abstract. The management of natural resources, through the conscious control and use of energy sources, is essential and necessary, so implementing mechanisms that enable better management is today an increasingly frequent effort. Due to its unsustainable consumption, water use has long one become of the main problems of modern times. Much of the current efforts use the concept of the Internet of Things (IoT), present in vast modern sectors, transforming high water consumption into a greener and more sustainable consumption. In areas often affected by severe droughts, the management of this consumption is critical, because water it's an important resource for humanity, since it affects countless sectors that depend on it, such as the development of various agricultural crops. The use of manual processes to irrigate these crops remains frequent, leading to much higher water consumption than necessary for optimal crop growth. Focused mainly on reducing water consumption, and ensuring minimum conditions for crop growth, the solution presented in this article, through technologies such as NB-IoT, a small set of sensors and based on the analysis of the humidity variation of the soil throughout the day, time and possibility of precipitation, allows to set efficient and sustainable rule times. Additionally, given the characteristics of the NB-IoT network, the solution allows not only remote consultation of the humidity levels of the soil, as the scheduling of manual watering cycles.

Keywords: Water · Irrigation · Sustainable · Agriculture

1 Introduction

Water management, as a natural resource, must be in a clear balance between its availability and demand, avoiding conflicts that may result from its use. The existence of water is what distinguishes our planet from all the others we know. Although the available global freshwater supply is more than adequate to meet current demand, it's spatial and temporal distributions aren't [1]. It's estimated that about 1.8 billion people in seventeen countries [2] may be approaching a severe water shortage crisis in the coming years. With this negative trend, it's predictable that water resources will not have a very encouraging future. Although no one can accurately predict the future of water, based on current data [3, 4], the world population will face several wars related to its consumption. It will certainly be one of the main challenges of this century, to reverse this negative

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trend, leading to the idea of a new planning for the management of water consumption, transforming the current one into something more sustainable. A more sustainable consumption will certainly go through several transformations in the management of water consumption in the different areas of activity. The urban, industrial, agricultural and energy sectors are where the use of water is considered more unsustainable. Of the total water consumption in Europe [5], it's estimated that around 44% is used in the agricultural sector for activities such as irrigation, 40% is consumed in industry and energy production and 15% is used in the public water supply. Analyzing the previous numbers, it's possible to understand the importance of water in agricultural activities. Of the total value of cultivated land [6], around 20% are associated with irrigated agriculture, contributing 40% of the total food produced worldwide. On average and per unit of land, irrigation agriculture is at least twice as productive as non-irrigated agriculture, thus allowing greater intensification of production and diversification of crops. With the current population growth, it's estimated that agricultural production will need to expand by approximately 70% by 2050 [6], which will necessarily increase water consumption. The water level of the soil and the atmospheric humidity have a profound influence on the development of the plants [7]. Given the influence of water consumption on plant growth and given the forecast of expansion of the agricultural sector, it's important to find mechanisms that allow the correct growth of production, but, in parallel, enable the sector to have a sustainable consumption of water. The eSmartWatering solution, illustrated in this paper, will certainly help to achieve a more sustainable balance in the management of agricultural water resources. Using a set of sensors and chips and a mobile application, the solution presented allows the automatic and optimized management of soil moisture, based on meteorological factors (humidity of the atmosphere, temperature, probability of rain timetable, type of crop and daily history of soil moisture variation throughout the day. The remainder of the paper is organized in the following sections: Sect. 2 illustrates a brief analysis between the described solution and similar solutions; Sect. 3 describes the architecture designed for the problem presented; Sect. 4 illustrates the conclusions of the article and the objectives for the future work.

2 Related Work

There are some solutions with similar functionalities as presented in this paper. This section analyses the most relevant aspects, including a comparison with the features presented by eSmartWatering. The irrigation automation system of Hortau [8] allows producers to have more control in the irrigation process. One of the features offered by the system is to allow producers to start watering cycles using their mobile phone or PC. This cycle start can be done manually or automatically, depending on the soil water readings or temperature. Compared to what is presented in eSmartWatering, the activation of the system offered by Hortau is not influenced by climatic factors, that is, this system does not consider the probability of precipitation at the time of activation of a watering cycle. In addition, the history of variation of the water level in the land is also not included, contrary to what happens in eSmartWatering. Arable Mark [9] offers a complete irrigation management tool. Synthesizes climate, plant and soil data to produce useful information for plant growth. To achieve the capture of various climatic parameters, the offered solution incorporates many sensors for reading the values. Although both solutions can do treatment of climate parameters, eSmartWatering does not need so many sensors, since by using NB-IoT it can read various climate parameters of the terrain where it's configured. Finally, the solution presented by Arable Mark does not analyze the historic of the variation in the percentage of water in the land. The approach used by Tule [10] for better water management is somewhat different from the approach used in eSmartWatering. The solution presented by the company Tule is able to quantify the actual evapotranspiration - the process of evaporating the surfaces of the plants and the soil and from within the tissues of the plants, which is done by putting hardware over each plant. This approach is close to the analysis of the historic of variation of the percentage of water in the soil performed by eSmartWatering, but it achieves more accurate values that can allow a more precise performance at the moment of activating the watering cycle. However, eSmartWatering only needs a sensor to measure water in the soil, while the solution presented by Tule requires specific hardware. Through many sensors for measuring different parameters, the company Cropx [11] can offer a solution that makes it possible to collect and send data to the cloud for later consultation. However, contrary to eSmartWatering, this solution requires multiple sensors to collect the various weather data, while in the solution presented in this paper, integration with the OpenWeather API is sufficient to access the climate data of the terrain region where eSmartWatering is configured.

3 Proposed Architecture

The presence of the IoT concept in the various sectors of activity of today's society is increasingly frequent and the agricultural sector is no exception. Building mechanisms for the management of irrigation cycles in agriculture is no easy task, since numerous factors can influence the activation/deactivation of these cycles. When it comes to automatic irrigation management, it is important to understand what factors can lead to the need to activate a normal watering cycle. Based on the solutions presented in Sect. 2, it was understood to consider the following factors: precipitation probability, time of day (time) and daily historic of percentage of water present in the soil for the land in question. One of the key points of the solution presented is the analysis of the probability of precipitation. The presence of excess of water [12] in the soil negatively affects a large number of plants and causes other environmental problems (e.g., land displacement, etc.). At the time when it is verified whether a cycle should be activated or not it is important to understand what the probability of rain in the following hours. Being high, the watering cycle should not start. This small analysis makes it possible, not only to reduce water consumption, but also to mitigate other environmental problems that arise as a result of excess of water in the soil. Another important point of this solution is the analysis of the historic of the percentage of water in the soil at the time when the watering cycle should be started. Performing the analysis of the water variation in the soil along a time window, allows to understand the absorption/evaporation rate of the water. It's expected that there will be a variation in the presence of water in the soil, which can be higher or lower depending on the climatic conditions and the time at which the measurement is carried out. Understanding the absorption/evaporation rate allows adjusting the percentage of water that is introduced into the soil at each watering cycle. The eSmartWatering settings define the percentage value of water that must be kept in the soil and its safety margin. Knowing the absorption/evaporation rate and the percentage value of water that should be kept in the soil, it is possible to manage the amount of water used in each irrigation cycle. For example, the evaporation rate of water tends to be lower as the atmospheric temperature varies [13]. Thus, by keeping the percentage of water in the soil between the defined percentage value and its withdrawal interval, based on the evaporation/absorption rate calculated at the beginning of each cycle, a reduction in water consumption between the different watering cycles is possible. The eSmartWatering architecture, represented in Fig. 1, consists in the following components: a mobile application; an Arduino MKR 1500 [14]; a small set of Restfull services with the OpenWeather API integration [15]; multiple pairs composed of a chip ESP32 [16] with several Soil Moisture Sensors [17] and a Solenoid Valve [18]. It's based on the area of the terrain where the eSmartWatering will be configured that it is calculated the number of chips ESP32 and Soil Moisture Sensors required. Each ESP32 chip will be responsible for reading the values of the sensors it controls. Using BLE 5, which supports communication up to 200 m distance [19], all ESP32 chips, which function as Slaves in this solution, receive a provident parameter of the Arduino MKR 1500 that have the role of master. The received value corresponds to the query frequency of the value of the various Soil Moisture sensor associated with each chip. This value is transmitted to the Arduino board via the mobile application shown in Fig. 1. In addition to this functionality, it is through the mobile application that the identifiers of all ESP32 chips will be transmitted to Arduino. Finally, this application allows a manual watering cycle to be started at any time throughout the land where the solution is configured or only in a section of it. When the area exceeds the possible distance limit for communication with the BLE resource, a mesh network [20] was conceived for data transmission. With this solution, it is possible to cover large areas using a single master device. For each read cycle, all ESP32 chips send the read values of the sensors they control to the master. Using the NB-IoT [21] network, the master sends to the cloud all the received data adding the identifier of the respective ESP32 chip that performed the reading. When data is received in the cloud, it is initially recorded in the database. After recording the data, they are analyzed to verify if there is any section of land that requires the activation of a watering cycle. This verification shall be carried out based on the reference value and its defined safety margin for the land concerned, the precipitation probability read from the OpenWeather API integration and the evaporation/absorption velocity value that was calculated based on the historic of readings already performed for that instant. After the completion of this check is sent as a response to the connection established by the Arduino the sections of the terrain that need the activation of the watering cycle.

When the Arduino board receives the response with a request to activate the watering cycle of certain areas of the land, it sends requests to the ESP32 chips that control the targeted areas, to start the watering cycle, opening the associated solenoid valves.

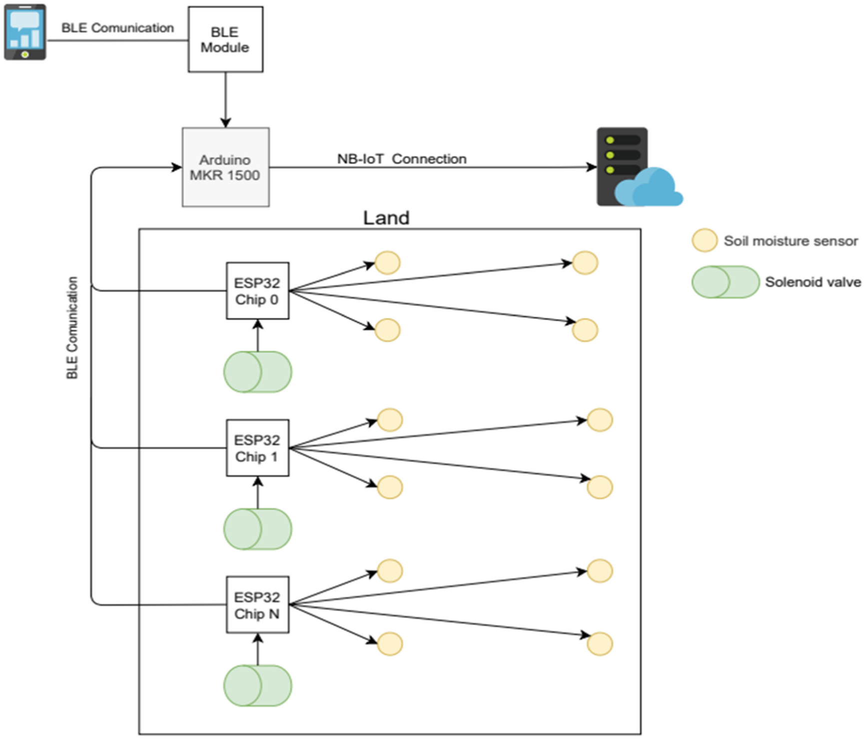

Fig. 1. eSmartWatering architecture.

4 Conclusion

This paper introduces a new tool that can contribute to improve water management in current agricultural activities. Through highly optimized watering cycles, this tool makes it possible to use only the volume of water strictly necessary for each cycle. Although data capture already started and solenoid valves actuation is also possible, Winter does not promote the climate conditions to assess the solution.

One of the many applications of this project is to understand the impact of water levels variation on the soil in the evolution of crop growth. Carrying out this analysis not only allows a more sustainable management of water, but also promotes new opportunities at the level of the business model of the agricultural sector. The availability of freshwater [22, 23] limits the growth of plants on the earth's surface. For terrestrial plants, freshwater is a basic requirement for life, where its soil absorption facilitates inorganic mineral nutrition. In addition, water retention drives the expansion of plant cells contributing to their shape and size. Controlling this dependency between water level of the soil and growth of the crops allows, even if, indirectly, controlling the demand for certain productions enabling new business models in the agricultural sector.

4.1 Future Work

Despite the great potential presented, this solution still has a long way to go. Thus, the following points were left for future work:

- Understand the exact percentage of water saved by the presented solution.
- Optimize analysis processes to the maximum extent to reduce water consumption as much as possible.
- To carry out a comparative study between the solution presented in this paper and the solutions presented in Sect. 2 in order to understand which one allows a further decrease in water consumption.
- To idealize an alternative solution for regions where communication using NB-IoT is not supported.

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