PROTOTYPE OF AUTONOMOUS WATER MANAGEMENT SYSTEM IN MOUNTAINOUS HOMESTEAD

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Abstract:

Among the basic requirements for a rural household to be suitable for sustainable living is to provide a sufficient amount of water. If the grid is not available, the required quantities of water can be obtained locally on the property. Besides, mountain households often must cope with a water source located below the objects, by pumping the collected water into the reservoir located on the high spot of the system. Traditional manually controlled systems often are not feasible due to required personal engagement, especially if the homestead is not inhabited fulltime, or the water source is not permanent. As currently available water must be preserved for later use, computerized nodes based on the Arduino microcontroller can be of great benefit due to the ability to detect water levels in the reservoirs, communicate and exchange information wirelessly, and autonomously control the water pump without the need for human intervention.

Keywords:

Homestead water system, Homestead automation, Internet of things, Arduino, Automatic watering system.

INTRODUCTION

Until recently, the notion of rural life was closely associated with intensive labour, primitive machines, and poverty [1,2]. However, with the outbreak of the COVID-19 pandemic and the transition of a significant part of the population to working online, an increasing number of middle and upper class people from urban areas are acquiring rural properties for partial or full-time living, the so called trend of exurbanization [3,4]. In most cases, these people are not interested in commercial agriculture, for which they do not have the necessary equipment, know-how, nor can they afford the time for such activities besides their regular jobs. However, they can be interested in limited agricultural production for personal needs, and automation of the activities related to the maintenance of the property, if possible.

Among the basic requirements for a household to be suitable for sustainable living is to provide a sufficient amount of drinking water, as well as technical water that could be used for personal hygiene and watering of animals and plants. If the water supply network is not available, the

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required quantities of water can be provided from natural water springs, watercourses or wells on the property, by collecting rainwater or by fog harvesting. Collected water can be stored in a purpose-built pond or in tanks, from where it gets distributed to the targeted points on the property [5].

2. CONCEPT OF WATER MANAGEMENT IN THE HOMESTEAD

A rural household requires a stable supply of water and electricity, which can be most easily solved by connecting the property to the existing water supply, sewerage and electricity network. However, this is often not an option for various reasons, such as the remote location of the property.

The most energy efficient solution for water distribution is gravity drop, in case of suitable terrain configuration. Otherwise, the use of electric pumps is required, including optional solar panels and batteries for electric power production and storage. Level and quality of water in the reservoirs must be controlled on regular basis, e.g. in case of the algae appearance [6], especially if the water is being stored in IBC totes due to possibility of sunlight leakage. The water system can be divided into smaller, independent subsystems, depending on the layout of the water collection points and reservoirs. Gray water can be filtered and reused for irrigation and in flush toilets, while black water must be stored properly to prevent contamination. The size of reservoirs must be calculated based on the estimated needs of the homestead for daily and seasonal consumption and the regime of seasonal water availability.

Designing a reliable water distribution system for a given terrain configuration and within the required technical parameters requires consideration of various technical solutions. The main components of the water distribution system are one or more pumps, piping and fittings, including valves, reducers and ventilation openings [7]. If the well is equipped with a pump that exceeds its capacity, it can lead to a drop in the capacity of the well [8]. In terms of maintaining of water pressure in the system, the most common solutions are gravity feed or hydrophore.

Mountain households can be observed as a special case scenario where the water spring or well are located below the house and other objects on the property. In this case, the collected water must be pumped into the water reservoir first, located on the high spot of the system, and then distributed by gravity feed to the facilities. The traditional setup usually implies the water pump connected to the power grid and controlled by the manual switch placed in the house, Figure 1. However, manual control of the electric pump, as the simplest solution, often is not feasible due to required personal engagement regardless to the method of implementation, either by the simple mechanical switch, or by remotely controlled electronic switch.

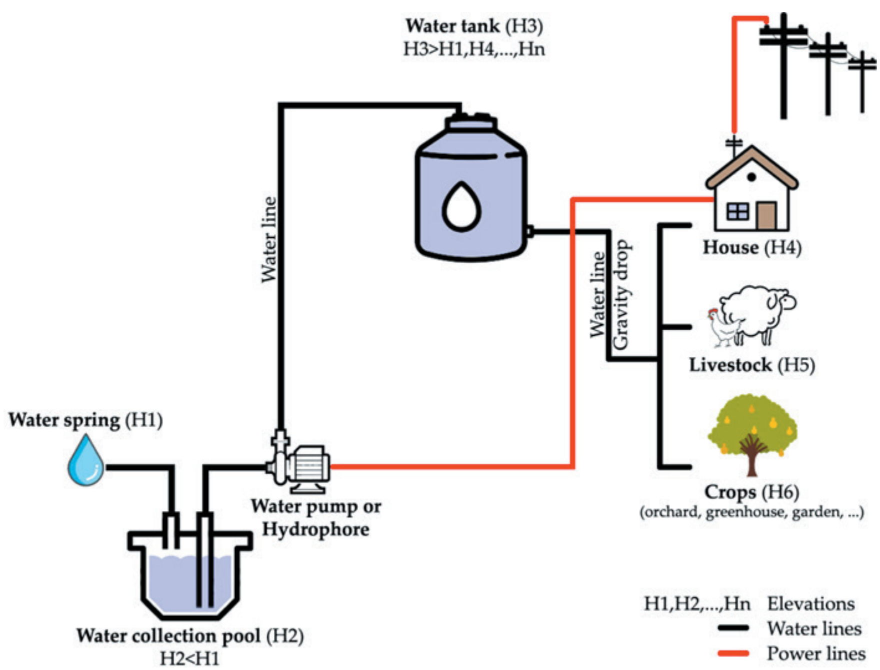

Figure 1 – Manual water management system

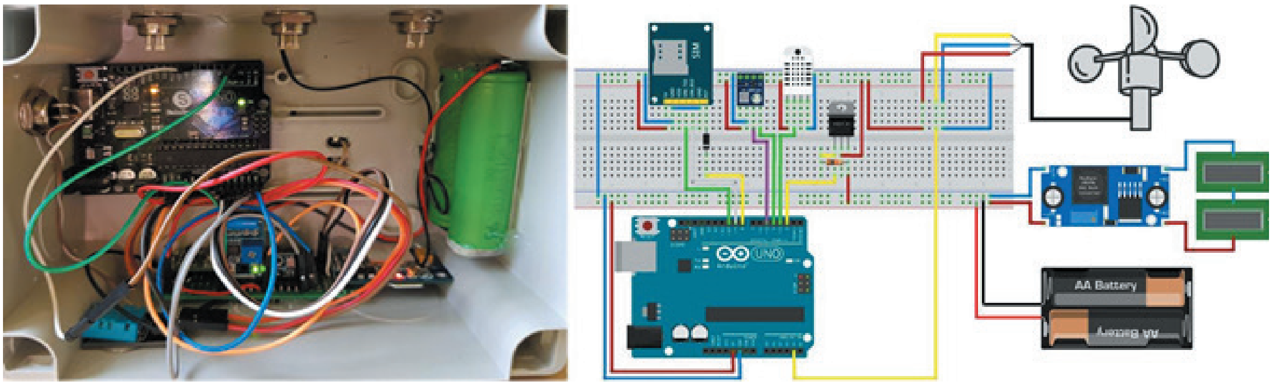

Figure 2 – Arduino AMS, electronic components (left) [9] and breadbord scheme (right) [5]

If the water source on the property is not permanent, or if the available amount of water varies, e.g. in accordance with the season, atmospheric temperature and the amount of local precipitation in the previous period, the currently available water needs to be preserved for later use, which represents a specific problem on properties that are not permanently inhabited.

Providing enough water to the plants requires time and personal commitment. The most popular irrigation systems used to reduce required work hours are the drip system and sprinklers.

The water flow is controlled by manually operated valves, or by a microcontroller via electric valves at preprogrammed time intervals. If the irrigation regime is not in accordance with the current weather conditions, it can lead to insufficient or excessive watering of plants. To prevent this, automated meteorological stations (AMS) based on the Internet of Things (IoT), Figure 2 [9], can be used to monitor current meteorological parameters on the property, and detect potentially extremes that may pose a risk to plants and animals, e.g. highs and lows in temperature, hailstorms, floods. etc.

In general, water distribution can be controlled by a computer, microcontroller, mechanical or digital timer, thus minimizing the man hours required for monitoring and management. The watering process can be carried out in accordance with the weather conditions, soil moisture and current needs of plants. The type and configuration of the system depends upon terrain configuration, soil properties, quantity and quality of the available water, types of plants to be irrigated and the microclimate [10].

Automation of irrigation systems can be classified as follows:

- Irrigation systems that use the basic principles of physics, i.e. gravity drop for water distribution.
- Irrigation systems controlled by electronic timers, which in turn control the water control valves.
- Irrigation systems controlled by computer, the most expensive group, but almost complete automation provides savings in increased yield, number of harvests and reduced need of man power.

3. PROTOTYPE

In case when the water source (water spring, or water well) with elevation H1 on Figure 3 [5], is located below the house (elev. H4) and other facilities (elev. H5-Hn), captated water must be pumped to the tank placed on the highest point of the system (H3=Hmax), and then distributed by the gravity drop. The suggested system prototype has two wireless Arduino automated nodes, Figure 3, capable of mutual communication according to algorithm displayed on Figure 4:

- Node #1, located on the water collection pool, monitors the water inflow from the water spring in liters per second [l/s] and the current water level in the water collection pool.
- Node #2, located in the main water reservoir, monitors the current water level and the water consumption in [l/s], and controls the master valve.

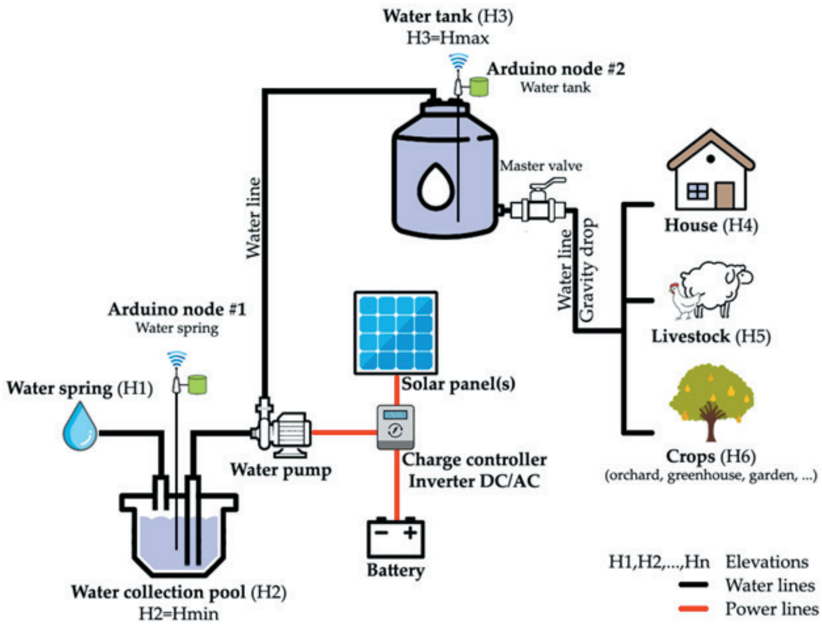

Figure 3 – Autonomous water management system

Both nodes mutually communicate via wireless network in order to pump water to the upper tank, provided that there is water at all, and that the upper tank is not full in order to prevent unnecessary cycles and provide dry run protection on the pump. The goal is to keep the main water reservoir as full as possible, with pump working in optimized cycles in order to reduce the power consumption. Described system working in autonomous mode is especially suitable for periodically inhabited homesteads with water spring that occasionally dries out, because of its capability to store currently available water for future use, without human intervention.

Aggregated data may be logged locally on the nodes, on the microSD card. More efficient approach would be to relay and log data on the local web server, or upload to the cloud for real-time monitoring and analysis.

Data provided by the AMS can be used to control the master water valve by the Arduino Node #2, in order to provide appropriate watering of plants on the property. For precision agriculture, the system can be expanded with additional slave nodes, positioned in various sections of the homestead in order to provide data on soil moisture, soil pH values etc. The same nodes in turn can control various devices based on received instructions,

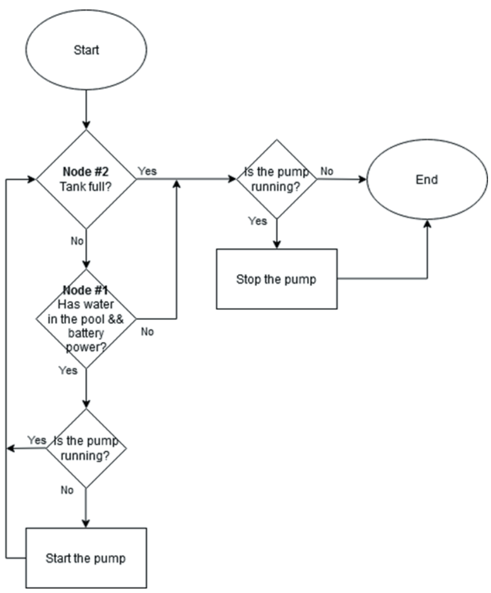

Figure 4 – Simplified communication algorithm between wireless nodes

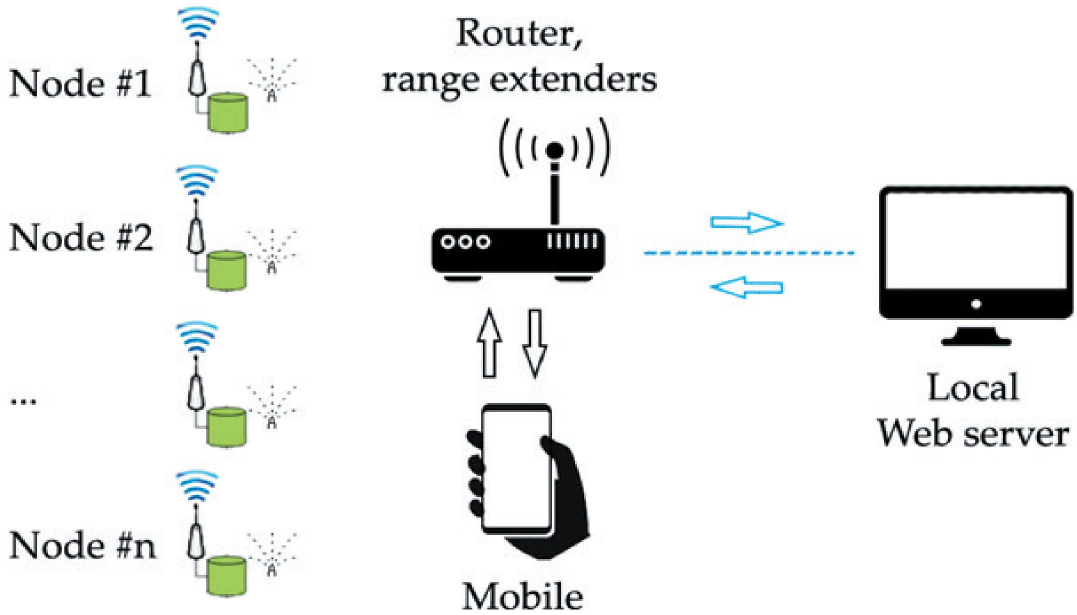

Figure 5 – Simplified communication algorithm between wireless nodes

e.g. secondary water valves. In such scenario, the data would be relayed to the local server, Figure 5, for initial filtration and optional processing by algorithms based on machine learning and artificial intelligence, and then the instructions would be sent back to selected nodes to provoke concrete actions, e.g. activate sprinklers.

4. CONCLUSION

With the outbreak of the COVID-19 pandemic and the shift of a the population to working online, a significant number of people returned to rural properties for at least occasional life in a more peaceful environment. Since they keep their city jobs, usually they are not interested in agriculture besides limited production for their own needs, and thus the need to automate household chores as much as possible in order to have free time for other activities.

One of the most important elements for the functioning of any household is the water supply. As rural households can be located far from the water grid, it is necessary to provide their own water source. In mountainous areas, the water source often may be located under the house and other facilities. This problem can be solved with a reservoir placed at the high spot of the household, from where the water gets distributed to the facilities. Also, due to climate change, it is increasingly common for water sources to dry up at certain intervals, and if the property is inhibited only occasionally, opportunity to provide water reserves for the dry season may be missed.

In such situations, the application of Information Technologies can be useful, which can lead to a better understanding of the current situation in the household, and more efficient decision-making. The described system of application of computerized nodes for monitoring the process of collecting and storing water in the household is self-sufficient and can operate off-grid. Nodes can mutually communicate via a wireless network and exchange information obtained through appropriate sensors, which allows more efficient system operation and reduced power consumption. The described system is especially suitable for households used for part-time living, because of its capability to function autonomously as a whole, or as part of a larger system, without the need for human intervention.

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