

Proposing a conceptualized framework for managing smart water management system in smart cities in India

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Abstract

The Internet, widely seen as the most significant innovation of the 21st century, has profoundly revolutionized worldwide interconnectedness, facilitating unprecedented proximity among individuals. The advancements in computing and communication technology have facilitated the emergence of the Internet of Things (IoT), which represents the next generation of the Internet. Due to the swift growth in population and urbanization, cities need to transform into Smart Cities, a process that can be aided by the Internet of Things (IoT). Efficient management of water is essential for human survival, making smart water management systems a vital component of Smart Cities. This article examines a range of technologies and platforms that are necessary for establishing a smart environment. The text presents an architectural blueprint for intelligent water management and explores the specifics of implementing a smart water monitoring system.

Introduction

Metropolises across the globe function as hubs of ingenuity and originality. Cities serve as catalysts for global economic expansion, facilitating international trade, financial transactions, communication, and transportation networks, while also providing residence to a significant portion of the world's population. Urban areas generally exhibit income levels that are approximately 21% greater than the national average, resulting in the concentration of national wealth. Cities serve as influential centres of culture, facilitating significant changes and improvements in different areas. Urban populations are experiencing significant growth worldwide, and it is estimated that by 2030, cities will accommodate more than 60% of the global population [1]. Presently, over 50% of the world's population lives in metropolitan regions, which exhibit significant variations in terms of their size, population density, cultural influences, governance, socio-economic circumstances and historical background. Certain cities are relatively new, whilst others have been in existence for thousands of years. They vary in inherent characteristics, such as climate, topography, and resource availability, as well as socio-economic factors including industrial development, urban growth, and technological proficiency. Moreover, cities are continuously undergoing changes, adjusting to new circumstances and developing their unique attributes [2]. Due to the wide range of variations,

it is difficult to establish a precise definition for a city. Nevertheless, academic literature categorizes a city into three fundamental components: inhabitants, endeavors, and territory/facilities. The combination of these factors establishes a city as a location where individuals reside, participate in economic endeavors, and establish and sustain social and cultural principles [3]. Hence, the aim of urban planning should be to facilitate individuals in pursuing their individual and communal life aspirations in a salubrious and unrestricted setting. The Internet, considered the most important invention of the 21st century, has transformed the world and increased global connectivity. Mobile gadgets and the Internet have changed business and our lifestyles. The Internet of Things (IoT) follows the Internet. The Internet of Things has emerged due to rapid advances in computers, mobile, wireless, and ubiquitous computing. The Internet of Things connects sensors, cell phones, actuators, RFID systems, and other devices that can send and receive data. These devices, regardless of whether they are fixed or portable, are distinguished by their addresses and are capable of communication using either wired or wireless methods. The interconnectivity and universal accessibility of these objects, together with the additional services they offer, hold the potential to improve the world for mankind. The proliferation of IoT has resulted in a scenario where the quantity of interconnected devices surpasses the worldwide population [4]. As these myriad gadgets establish connections and exchange information, they produce immense quantities of data. The significance of analytics is highlighted by the fact that this data only becomes valuable when we are able to derive practical insights from it. The integration of IoT and predictive analytics plays a crucial role in actualizing the notion of Smart Cities.

Smart city management

The 2011 Census found that urban areas create 63% of India's GDP despite only 31% of the population living there. It is anticipated that by the year 2030, forty percent of India's population would be residing in urban areas, which will account for seventy-five percent of the country's gross domestic product. This is a result of the growing tendency of rural people shifting to urban regions in quest of better living conditions. To accommodate urbanization, physical, economic, and social infrastructure must be established and improved. Both the government and businesses have invested in these areas [5]. The 2014-15 Indian Budget allocated 70.6 billion INR for smart city projects. Smart city solutions can be classified according to service categories, with particular emphasis on water and energy management. Within the framework of India, there are several demanding yet crucial solutions that need to be implemented:

- Implementing smart meters to monitor and manage water usage and distribution, as well as monitoring water quality and discovering leaks, is a key aspect of smart water management.
- Smart Energy Management involves the development of intelligent power distribution networks, the effective management of sustainable energy sources, and the promotion of environmentally-friendly structures.
- Smart Transportation: Introducing advanced parking systems, sophisticated traffic management, and integrated multi-modal transport solutions.
- The Smart Environment project aims to improve the efficiency of waste management, monitor air quality, and track noise levels with advanced technology.

These programmes strive to establish an urban environment that is more effective, environmentally friendly, and pleasant to live in. Their goal is to enable Indian cities to become more intelligent

and adaptable in response to the fast-paced growth of metropolitan areas.

Smart Water Management:

Water is an essential resource for human survival. The combination of drastic climate fluctuations and the growing population has resulted in a shortage of water, posing a substantial challenge for both governmental bodies and water corporations. This challenge involves the provision of high-quality water with minimal expenses and energy consumption. Efficient water management has a significant influence on various facets of human existence, such as water usage, farming, food manufacturing, and the environment. Moreover, water is required to produce energy, and conversely, energy is necessary for the provision of water. Modern platforms frequently allocate an excessive amount of effort to collect data, while dedicating an insufficient amount of time to extracting valuable insights from it [5]. Water levels in tanks are commonly obtained through manual collection, whereas flow meter and pressure meter readings in delivery systems are frequently recorded manually. Water quality is assessed through the collection of samples, which are subsequently analysed in laboratories. This procedure can need several days to produce conclusive findings.

Smart water analytics have the potential to completely transform this process by offering up-to-the-minute data, enabling analysts to concentrate on analysis and acting promptly and efficiently. Smart water management systems encompass the utilisation of real-time monitoring to track water levels, detect leaks in distribution systems, and oversee the maintenance of water quality. This technical innovation has the potential to tackle the urgent problems of water scarcity and inefficiency, thereby guaranteeing a more sustainable and dependable water supply [6].

Literature Survey

Key challenges in world cities today

Although cities differ in their specific qualities, they are currently encountering shared difficulties worldwide. Competition is increasing on the availability of essential resources including land, water, and energy as urbanization grows more concentrated. The swift growth of metropolitan areas has exerted significant strain on land resources, impeding the capacity to offer sufficient housing, food, and transportation. Hence, the rapid increase in the number of slums has emerged as a significant concern, mostly due to the large-scale movement of people from rural to urban regions [6]. Unemployment, social isolation, poverty, and inequality are just few of the complicated socioeconomic concerns that are affecting a great number of cities around the world. The intricate nature and growth of urban areas have posed a significant societal issue for modern nations in terms of governing and managing them effectively [7]. To tackle these challenges, it is necessary to employ inventive and all-encompassing approaches that guarantee enduring urban growth and enhance the well-being of city dwellers.

Climate change is having a growing influence on urban life. In the last five decades, climate-related hazards and disasters have caused the deaths of millions of people. Weather, climate, and water hazards make up half of all disasters, account for 45% of fatalities, and contribute to 74% of global economic losses. These risks largely impact urban areas. Urban concerns are complex. Rapid population expansion will generate issues, say international experts. More than 3 billion people—nearly 40% of the global population—will need housing by 2030 [8]. FAO predicts increased food and non-food agricultural output to satisfy rising demand [9]. Urbanization complicates water resource management and sanitation. Urbanization, climate change, and urbanization have altered the water cycle, creating floods and tropical storms. Disasters threaten thousands of lives and the

environment. Globally, rising urbanization makes it difficult to provide clean drinking water and sanitation. It also hinders water infrastructure management and upgrading in emerging cities. The following discussion will examine five significant water challenges and their effects.

Urban areas make a substantial contribution to climate change, pollution, and the deterioration of the environment. The process of urban expansion results in the degradation of air and water quality, difficulties in managing waste, and the destruction of natural habitats. Moreover, metropolitan regions have a significant role in energy use, representing approximately 75% of the global energy consumption. In order to tackle these difficulties, it is crucial for the future advancement of cities to adopt urban design methods that integrate green spaces, minimize energy consumption, and prioritise circular economy initiatives [10]. Implementing these measures can effectively reduce the negative impacts of urbanization and climate change, while also fostering the development of sustainable and resilient urban settings.

Flooding

In the previous 50 years, floods have devastated people and businesses. Cities near rivers or coastal areas and with certain geological or topographical features might flood. Urban flooding frequently arises in areas with insufficient or nonexistent drainage systems. Floods have substantial and wide-ranging effects, causing severe social, economic, and environmental implications for individuals and communities. The consequences of these effects go beyond the initial harm, as they disrupt supply chains and transportation networks, ultimately impacting the future development of a city. At present, floods directly impact around 20% of the world's population. Flood damage to urban property costs over USD 120 billion annually, with half in North America (Sadoff et al., 2015) [11].

Many cities worldwide have experienced flooding and are vigilant for future floods. Gujarat, Tamil Nadu, Kerala in India, Miami and New Orleans in the USA, Shenzhen in China, Paris in France, and Manila in the Philippines etc., have all experienced substantial flooding. Urban areas need effective flood control and mitigation to reduce losses and support sustainable growth. Mumbai, the economic hub of India, is particularly susceptible to flooding as a result of its geographical positioning, high population density, and infrastructural constraints. The city is situated on the western coast of India, with a substantial section of its land either at or below sea level. Mumbai is especially susceptible to intense rainfall and storm surges. Mumbai had a catastrophic flood on July 26, 2005, as it encountered one of the most intense rainfall episodes in its history. The city was inundated, with numerous parts seeing water depths of up to 3 meters. The floods caused widespread destruction to infrastructure, residences, and commercial establishments, leading to more than 500 fatalities and substantial financial setbacks. In August 2017, Mumbai had intense monsoon rains which resulted in significant flooding [12]. This flooding had a detrimental impact on transportation, leading to the displacement of thousands of people and causing disruptions to daily activities.

Houston, Texas, is susceptible to frequent flooding mostly because of its geographical and meteorological characteristics. The urban area has encountered a multitude of flood occurrences, primarily as a result of hurricanes and tropical storms. Hurricane Harvey caused one of the most devastating flood catastrophes in the history of Houston in August 2017. The storm precipitated more than 1,500 mm of rainfall in the area, resulting in disastrous floods. A significant portion of Houston experienced severe flooding, with water levels reaching several feet, resulting in the displacement of several individuals and causing considerable destruction

to homes, businesses, and infrastructure. The flood resulted in a significant number of deaths and was one of the most expensive natural calamities in the history of the United States. In April 2016, Houston had substantial flooding as a consequence of intense precipitation, leading to enlarged bayous and extensive destruction of properties. This incident resulted in numerous deaths and underscored the city's susceptibility to extreme weather phenomena. In recent decades, both cities have experienced an increase in sewer overflows and floods as a result of heavy rainfall [13]. The expectation is that this pattern will persist, creating difficulties not only in providing water services to people but also in adding to the deterioration of the city's coastal water bodies. The case studies of Mumbai and Houston highlight the immediate necessity for strong flood management techniques to reduce future hazards and guarantee the durability of urban assets. Both Mumbai and Houston exemplify the urgent requirement for increased flood management measures, improved infrastructure, and comprehensive planning to alleviate the consequences of floods and safeguard communities.

Water Scarcity

Water scarcity refers to a state where there is an inadequate amount of water available to meet the demands of both humans and the environment (UNICEF, 2021) [14]. This problem might occur due to natural phenomena, human actions, or a combination of the two. Water scarcity can be caused by natural factors such as physical scarcity of water and drought. In addition, economic water shortage arises from insufficient infrastructure that restricts access to accessible water resources. Water scarcity imposes substantial limitations and occasionally results in the cessation of water deliveries. Industrial users and energy producers are adversely affected by this, as they have higher operations and maintenance expenses. Additionally, the agricultural sector suffers from reduced income and competitive disadvantages. Furthermore, businesses that rely on public water supplies, such as those in the tourism sector, also suffer financial losses (Spinoni et al., 2016) [15]. Droughts have the ability to limit a city's economic growth by as much as 12% (Zaveri et al., 2021) [16].

Water shortages plague urbanites. The WHO and UNICEF (2019) report that 143 million of the 4 billion people living in cities lack clean drinking water and 605 million lack basic sanitation. Water availability in over 570 cities is expected to drop by 10% by 2050, affecting 685 million people [17]. Global migration rises 10% due to water constraint. This scenario emphasizes the need for sustainable water management and infrastructure to serve growing urban populations with water. Cities such as Delhi, Mumbai, Mexico, Cape Town, Bangalore, Cairo, London, Venice and São Paulo face water scarcity. Freshwater availability is anticipated to drop 30% to 49% in Amman, Cape Town, and Melbourne. Santiago, the capital city of Chile, is projected to experience a fall of more than 50% according to a report by UNESCO and UN-Water in 2020 [18].

The Algarroba reservoir in Spain demonstrates a substantial decrease in water capacity during a span of ten years, dropping from 102 hectometers cubed (hm^3) in 2011 to 50 hm^3 in 2021. The decrease in economic activity has put the local economy at risk, as it heavily depends on agriculture and tourism. Nakuru, a rapidly expanding urban center in Kenya, Africa and the fourth most rapidly expanding city worldwide, is confronted with a significant shortage of water. The city presently has a daily water demand of 70,000 m^3 , whereas the current water supply is insufficient at 45,000 m^3 . By 2050, the anticipated increase in population will result in a water demand of 191,000 m^3 per day. These instances illustrate the difficulties presented by water scarcity and underscore the necessity for strong solutions to tackle this problem. It is imperative to implement

sustainable water management methods, improve infrastructure, and embrace innovative technologies [19]. The following are examples of possible strategies: enhancing water efficiency: enforcing sophisticated irrigation methods, water reclamation, and optimizing domestic water consumption.

- Infrastructure Development: Constructing and enhancing infrastructure to guarantee a dependable water supply and minimize losses.
- Governance and Policy: Enacting regulations and policies that encourage the sustainable utilisation and administration of water resources.
- Public Awareness: Disseminating knowledge to communities regarding water conservation methods.

For the purpose of minimizing the effects of water scarcity and guaranteeing a sustainable and secure water future for urban populations, these actions are absolutely necessary.

Deficient Water Quality

Water scarcity is a state marked by the inadequate supply of water for both human and environmental needs. This scarcity might arise from natural phenomena, human interventions, or a blend of both. Examples of natural causes of water scarcity include physical phenomena like droughts. Conversely, human causes frequently stem from insufficient infrastructure that hinders access to available water supplies, which is referred to as economic water scarcity. The paucity of water imposes substantial limitations and temporary interruptions in the provision of water. As a result, industrial users and energy producers have to deal with increased costs for operating and maintaining their facilities, while the agricultural sector faces lower revenue and disadvantages in competition. Furthermore, economic losses are incurred by activities that depend on public water, such as tourism. Droughts can limit a city's economic growth by as much as 12% [16].

Metropolitan residents face a water deficit. About 3.58% of the world's 4 billion urban residents lack access to drinking water, and 15.13% of urban people lack basic sanitation (WHO & UNICEF, 2019) [17]. More than 570 urban areas would lose at least 10% of their freshwater by 2050, affecting 685 million people. Furthermore, there is a direct correlation between water scarcity and a 10% rise in worldwide migration. The severity of water scarcity highlights the urgent requirement to implement sustainable water management methods and establish strong infrastructure to guarantee an adequate water supply for growing urban populations.

Many cities, including Cape Town, London, Venice, São Paulo, Bangalore, and Cairo, face water scarcity. Amman, Cape Town, and Melbourne may lose 30–49% of their freshwater. Santiago, Chile's capital, may fall by over 50% [8]. This study shows two water scarcity cases. The Algarrobo reservoir in Spain dropped from 102 hectometres cubed (hm³) in 2011 to 50 hm³ in 2021. Agriculture and tourism drive the local economy, but this change threatens it. Moreover, Nakuru, situated in Kenya, is not only the most rapidly expanding city in Africa but also the fourth swiftest-growing metropolitan worldwide. Currently, the city is facing a daily water demand of 70,000 m³, whereas the current water supply is only 45,000 m³. By 2050, the expected population expansion is estimated to lead to a significant rise in water demand, reaching 191,000 cubic metres per day [18]. These stories exemplify the difficulties caused by water scarcity and the measures that have been proposed and implemented to tackle this problem.

Aging or Insufficient Infrastructure

Worldwide, infrastructure deterioration, defective pumps and motors, and water leakage are common issues. Inadequate infrastructure wastes 21% of water before distribution. This scenario decreases access to clean water and sanitation and water disaster protection. Water infrastructure, including decades-old systems, is expensive to renovate. In 2016, the OECD polled 48 cities from OECD and non-OECD nations and found that 92% of them had trouble modernizing and repairing their water infrastructure. In addition to decaying infrastructure, cities also confront issues related to inadequate water supply and sanitary facilities, which are unable to satisfy the needs of expanding populations and urbanization. The estimated global investment required for water supply and sanitation by the year 2050 is almost \$6.7 trillion. According to the OECD (2020b), the projected cost of water-related infrastructure is expected to triple by 2030 due to the requirement for a wider range of infrastructure [19].

Mumbai, India, a densely populated city with a population of 8.5 million, has a meagre 300,000 water metres. The scarcity of metres poses considerable difficulties in accurately assessing the water requirements of the population and efficiently managing the already burdened local water resources. Authorities in Mexico concluded that water leakage constituted 47% of the overall water distribution. The significant rate of leakage emphasises the considerable difficulties caused by deteriorating and insufficient infrastructure in accurately assessing and fulfilling the actual water needs of the people. These examples illustrate the challenges presented by the process of getting older and the insufficiency of the existing infrastructure. Tackling these difficulties necessitates substantial financial resources [18]. The estimated worldwide investment required for water supply and sanitation infrastructure highlights the pressing necessity for immediate action. In the absence of significant investment, urban areas will face difficulties in ensuring the provision of safe potable water and sufficient sanitation services, hence worsening the hazards linked to water scarcity and infrastructure breakdown. In order to protect and supervise local water resources, cities must give priority to the upgrading and enlargement of water infrastructure. It is essential to invest in the enhancement of water distribution systems, the improvement of monitoring capacities, and the implementation of efficient water management methods. The Annex offers a comprehensive examination of the particular measures undertaken by different cities to address these difficulties.

Inadequate Urban Water Planning

In addition to the provision of services for sanitation and drinking water, cities are confronted with substantial issues as a result of deficient planning practices and decaying infrastructure. Efficient urban water management goes beyond just providing safe water services. It includes the protection of the environment, maintaining public health, promoting social cohesion, enhancing emotional well-being, and improving overall quality of life. Effective water infrastructure planning encompasses not only the guarantee of a consistent provision of clean water, but also the encouragement of the responsible utilisation of water resources and the preservation of urban ecosystems [21].

The availability of well managed, ecologically sound water features in urban settings, such as coastal or waterfront districts, fountains, parks, and green spaces, significantly improves the overall welfare of citizens and promotes inclusiveness. These areas serve multiple purposes, including fostering beneficial social connections, promoting healthy activities, and helping to reduce the negative effects of floods and increasing sea levels. By strategically incorporating these components into urban planning, cities can enhance their ability to withstand and recover

from challenges, promote environmental responsibility, and enhance the overall well-being of their residents [6, 22].

Busan, the second most densely populated city in South Korea, is adopting a progressive strategy for urban planning by improving accessibility to water-based leisure and recreational areas. The Busan Eco Delta City (BEDC) is a prominent urban development initiative scheduled to commence construction to the west of Busan by 2028. It aims to effectively incorporate green and blue areas, including parks, riversides, and wetlands, into the city's infrastructure. The objective of this programme is to guarantee that inhabitants have abundant access to these natural resources, which will be integrated into different sectors of the city, such as commercial, residential, and cultural regions [23].

By contrast, Hong Kong, a city with scarce natural water resources, has effectively met its water demands by implementing an inter-basin transfer system that redirects water from other regions. Notwithstanding this resolution, the city encounters difficulties associated with excessive allotment of water. In order to address this problem, Hong Kong has initiated a smart metering pilot project aimed at mitigating excessive water usage and fostering conservation endeavours. These examples demonstrate how both developing and well-established cities may utilise intelligent water technologies and strategic urban design to improve their urban landscapes and tackle water management difficulties [24].

Table 1. Analysis of selected cities with respect to water management and its challenges

Region	Type of City			City/ Country	Type of Challenge Addressed
	Population	New or Existing Urban Development	Economic Development		
North America	Large City	Existing	High-Income Economy	New York City, USA	Flood Risks
Asia & The Pacific		Existing	High-Income Economy	Hong Kong, China	Inadequate Urban Water Planning
Asia & The Pacific		Existing	Upper Middle Income	Ningbo, China	Flood Risks
Africa	Small City	Existing	Lower Middle Income	Nakuru, Kenya	Water Scarcity
Latin America & The Caribbean	Urban Settlement	Existing	Upper Middle Income	Heredia, Costa Rica	Deficient Water Quality

Europe		Existing	High-Income Economy	Algarroba, Spain	Water Scarcity
North America	Medium Size	Existing	Upper Middle Income	Ciudad Juarez, Mexico	Aging or Insufficient Infrastructure
Asia & The Pacific	Megacity	Existing	Lower Middle Income	Mumbai, India	Aging or Insufficient Infrastructure
Asia & The Pacific	Medium Size	New	High-Income Economy	Busan Eco Delta City, Republic of Korea	Inadequate Urban Water Planning

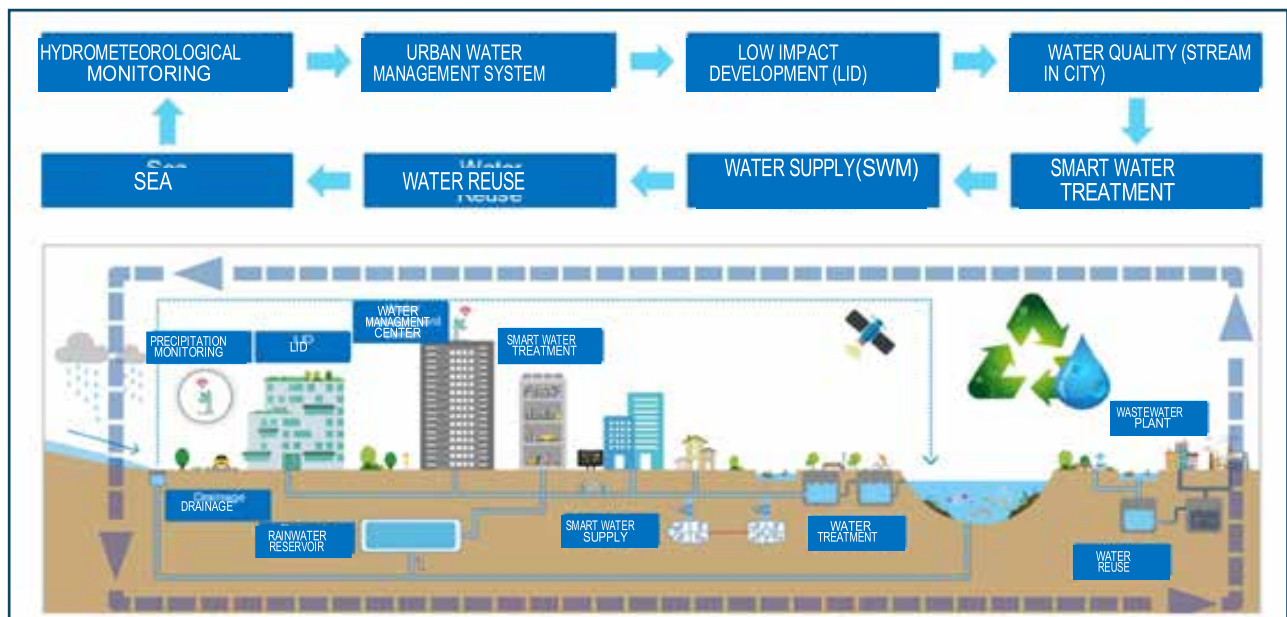
Table 1 provides a thorough comparison of the urban situations addressed in the Annex of this study. It is crucial to acknowledge that numerous metropolitan environments have multiple water-related difficulties concurrently. Water scarcity, insufficient infrastructure, and substandard water quality frequently overlap. Table 1 showcases the main water difficulty that each city has specifically tackled, however any intervention aimed at addressing one challenge can have an impact on the total water condition of the city. Human actions, including as irrigation, water extraction, reservoir construction, deforestation, and desalination, have greatly modified the natural water cycle. These alterations have impacted the flow of water through its many phases. Urban areas have significantly altered the water cycle, prompting scientists to propose the idea of a "urban water cycle" that is separate from the natural water cycle.

Figure 1 suggests that within urban settings, the basic framework of the water cycle remains intact, although significant alterations have occurred as a result of urbanization, industrialization, and population expansion. Human endeavors to cleanse water and guarantee its compliance with regulations have modified its trajectory from collection regions, passing via reservoirs and treatment plants, to household use, and ultimately returning to the environment. The abundance of concrete and pavements in metropolitan areas hinders the absorption of water, leading to a rise in runoff that transports pollutants and debris into stormwater systems, while also restricting the replenishment of groundwater. These modifications have influenced both the amount and the

standard of water that is available for use.

Figure 1. The Urban Water Cycle

When it comes to urban design that is both functional and integrated, having a comprehensive understanding of the many functions that water plays is absolutely necessary. Understanding



the many stages of the water cycle and the influence of urban growth on water resources and the environment is essential for creating cities that are more integrated, effective, and environmentally sustainable. Smart water technologies are a major improvement in water resource management, providing instruments that improve the delivery of clean drinking water and sanitation services, as well as supporting urban planning objectives [25]. These technologies enhance the effectiveness and durability of water management, bolster the ability of urban ecosystems to withstand challenges, and promote a harmonious connection between humans and the natural environment. Through the utilisation of intelligent water technology, municipalities may enhance their ability to effectively oversee their water resources, tackle ecological obstacles, and promote the advancement of sustainable urban growth. Comprehensive knowledge of these technologies and their consequences is crucial for the advancement of Smart Water Cities, which strive to incorporate sophisticated water management systems into urban planning to create more resilient and adaptable urban settings [26].

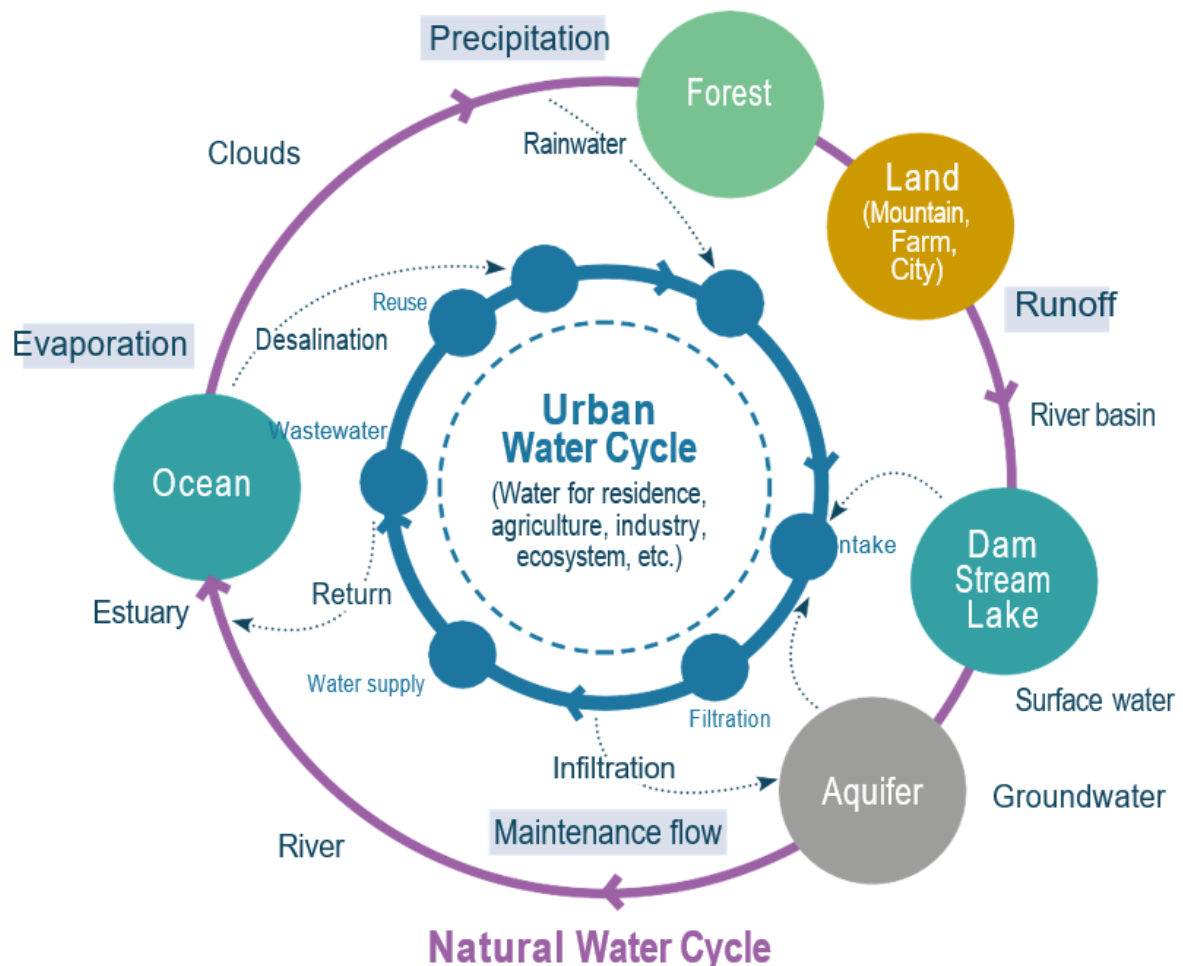


Figure 9. The Natural and Urban Water Cycles

Smart water technologies in world cities today

The swift progress of intelligent technology is generating a diverse range of inventive and integrated solutions to address urban difficulties. This emerging sector is creating a new industry, marked by substantial economic opportunities, and encouraging growth prospects. Adroit Market Research (2022) predicts that the worldwide smart city market would have a valuation of \$651.7 billion by 2028. Although the implementation of Information and Communication technology (ICT) in the water sector has been rather gradual, there is an increasing emphasis on using smart technology for water management and service delivery [27]. Smart pipes and sensor networks are developed to identify and track irregularities in water pressure, temperature, and strain. Smart meters enable accurate measurement of water usage, while membranes and cloud computing are employed to improve information exchange and infrastructure management. In addition, the objective of smart materials development is to enhance water infrastructure and systems (Leflaive et al., 2020) [28]. Advanced technologies are expected to have a significant impact because to the predicted annual growth of global water consumption, estimated to be up to 1% across different sectors (UNESCO & UN-Water, 2020) [8, 29]. These advancements provide instantaneous, automatic information on the quality of water, its utilisation, and the performance of infrastructure. These qualities are essential for dealing with urgent water-related problems that are made worse by climate change and changes in population.

There are a number of critical technologies that are currently being implemented in order to fulfil the requirements of the availability and quality of water resources, the reduction of risks associated with urban water, and the enhancement of water services in urban areas. The instances demonstrate how these technologies may be used to address urban water concerns such as flooding, water scarcity, poor water quality, ageing infrastructure, and inadequate urban planning. Developments in flood monitoring and early warning systems are crucial. These gadgets are designed to monitor water bodies and detect sudden level changes. These technologies inform water authorities, residents, and organizations about potential floods. Ningbo, China, which confronts significant flood risks, uses smart water technology to monitor water levels and create a proactive alert system. Through the use of this preventative technique, local authorities are able to improve their flood planning and lower the likelihood of future harm [30]. Cities are implementing diverse solutions to tackle stormwater management concerns, in addition to flood management. For instance, New York City has enacted a range of measures with the goal of diminishing stormwater runoff into the sewer system. These techniques encompass the implementation of green infrastructure projects, the modification of public and private assets, and the establishment of new pilot drainage systems. These methods aim to optimise stormwater management and restore natural water cycles, thereby mitigating the adverse effects of stormwater on the city's infrastructure and environment [31].

Moreover, the incorporation of Information and Communication Technologies (ICTs) in urban planning is playing a crucial role in the restoration and preservation of the natural water cycle. ICTs are utilised in integrated water management programmes to enable cities to effectively manage large amounts of water during storms and flooding incidents. Cities can strengthen their resilience to extreme weather events and minimize possible harm by efficiently managing water flows. Ultimately, the progress of intelligent water technologies and their implementation in urban settings is essential for tackling the intricate obstacles presented by climate change and urban expansion. By implementing real-time data collecting, enhancing monitoring systems, and employing new infrastructure solutions, cities are more effectively prepared to oversee their water supplies, minimise hazards, and adjust to evolving environmental conditions [32].

ICTs are being used more and more to address water scarcity problems in cities throughout the world. An exemplary information and communication technology (ICT) strategy is smart metering, which has proven to be crucial in mitigating water wastage. This system enables accurate monitoring of water usage, providing timely and dependable digital notifications to both water service companies and consumers. Smart metres are expected to lead to a decrease of approximately 15% in water usage in cities with higher levels of affluence. When it comes to growing metropolitan areas, although the initial amount of water used by residents may be smaller, there is still a considerable opportunity for savings. However, these savings may not be as great as in more developed areas (Woerzel et al., 2018) [33].

The main objective of deploying smart meters is to efficiently monitor water consumption and enable the detection of water leaks. Smart metering improves users' knowledge of water usage and promotes the adoption of water-saving initiatives by delivering real-time consumption statistics. Urban centers including Ciudad Juarez, Mumbai, and Hong Kong have implemented smart metering systems as a solution to combat water constraint. While the specific methods employed may differ, the primary goals remain constant: to reduce water consumption and save

resources. Smart metering has been found to be particularly useful in identifying problems in ageing infrastructure, like as leakages and low or uneven pump pressure, in these cities. This capability has enhanced the efficiency of maintenance and replacement endeavors for obsolete infrastructure, enabling prompt interventions and improved water resource management [34]. Furthermore, numerous cities have implemented tactics to improve their water storage, retention, and recharge capacity, with the implementation of smart metering. These measures are essential for guaranteeing a dependable water supply during periods of increased demand. The story of Nakuru, Kenya, exemplifies a successful remedy for water constraint. In this context, Information and Communication Technologies (ICTs) have been employed to gather excess water and enable its retention during periods of drought. Nakuru's strategy prioritises citizen participation in decision-making processes, enabling citizens to highlight concerns, participate to mapping endeavours, and suggest remedies. This participatory approach highlights the capacity of ICTs to not only tackle technical difficulties but also involve people in the administration and preservation of water resources [35].

The use of smart technology is growing in order to reduce the need for more fresh water resources by repurposing reclaimed water, such as wastewater and grey water, to meet the water needs of local areas. The increasing acknowledgement of the worth of reclaimed water is broadening its utilisation in diverse sectors, such as urban and peri-urban agriculture, golf course irrigation, park and residential property care, highway median upkeep, toilet flushing, and car washing. An exemplary instance of this approach can be observed in the municipality of Algarrobo, Spain. In this context, cutting-edge technology have been utilised to convert urban wastewater into a valuable resource for irrigating and fertilizing agricultural land. This strategy has resulted in substantial ecological advantages by reducing the burden on already stressed local water resources. In addition, it has stimulated the economies of many regions and generated employment possibilities, showcasing the diverse benefits of reclaiming and reusing water [36].

Water technology have played a crucial role in enhancing substandard water quality. Automated sensors have been installed in multiple nations to observe and gather data on the quality of water in both freshwater and drinking water sources. These devices are strategically positioned at pollution monitoring stations and are crucial for delivering up-to-the-minute data on water conditions [37]. The incorporation of modern information and communication technologies (ICTs) has effectively facilitated public health and environmental preservation by permitting timely reactions to instances of pollution. This proactive strategy aids in mitigating harm to aquatic systems and the interconnected ecosystems reliant upon them. An exemplification of this technique in operation can be witnessed in Heredia, Costa Rica. Advanced technology is used to treat surface water that is otherwise turbid and unfit for consumption. This technology enables the surveillance of water quality, the retrieval of water sediments, and the evaluation of substandard drinking water, guaranteeing that the water complies with safety regulations and is fit for consumption [38].

In addition to that, the solutions that are made available by technologies even go farther. An environmental development centre called the Busan Environmental Development Centre (BEDC) is now being established in Busan, Republic of Korea, with the purpose of evaluating a variety of technologies that are intended to address water challenges at various stages of the urban water cycle. When it comes to urban water planning, this innovative method addresses

water challenges across the urban water cycle, thereby increasing the resilience of ecosystems and encouraging harmony between humans and the environment. ICTs and water management are given high priority in the urban development strategy of the city in order to facilitate future expansion [39]. The plan accomplishes the two-fold objectives of advancing public health and protecting the environment. Anticipated advancements in technology will allow for accurate monitoring, purification, distribution, utilisation, and recycling of water in urban areas. These advancements are expected to have several benefits, including environmental protection, improved water quality, effective management of flood hazards, mitigation of urban heat islands, and efficient treatment of wastewater. These many examples demonstrate how smart policies and technologies have solved urban water problems in many contexts. They have shown advances in urban water services and highlighted new technical and policy developments [40]. Knowledge of intelligent approaches is crucial, but our understanding of how ICTs affect the urban water system is inconsistent. Although case studies provide examples, they do not explain the essentials of transferring solutions between sites. In addition, they cannot define particular sites that need improvement, which hinders urban water performance criteria. When confronted with different local circumstances and constraints, replicating and adjusting the scale of a project becomes a difficult undertaking. Therefore, there remain a number of vital questions that have yet to be answered:

When it comes to solving the wide variety of water issues that are currently and will be in the future in metropolitan areas, one of the most important topics of investigation is the efficiency of water technologies. Smart water technologies, which utilise Information and Communication Technologies (ICTs), are crucial in the development of "Smart Water Cities" as they provide novel methods for effectively managing urban water supplies. These technologies enhance the resilience, efficiency, and sustainability of urban water systems by improving water quality, minimizing waste, and optimizing infrastructure management [41]. Smart water solutions efficiently tackle current water issues, including water scarcity, insufficient infrastructure, and subpar water quality. Technologies such as smart metering, automated sensors, and improved treatment procedures aid in the monitoring of water usage, detection of leaks, and maintenance of drinking water safety. These technologies facilitate the capture and analysis of data in real-time, enabling timely actions and better-informed decision-making. Implementing this proactive strategy enables cities to optimize their water resources and mitigate the consequences of water-related problems.

In order to tackle the rising issues posed by climate change, population increase, and urban expansion, it is imperative to prioritise the implementation of intelligent water technology. These technologies can bolster cities' capacity to adjust to fluctuating circumstances by enhancing water storage, recycling, and conservation endeavors. For instance, the use of recycled water for different purposes and the adoption of sophisticated water purification techniques helps alleviate water scarcity and guarantee a dependable provision of pure water. The process of creating "Smart Water Cities" entails the incorporation of Information and Communication Technologies (ICTs) into the water industry in order to improve water management methods. A city is considered a "Smart Water City" when it adopts and efficiently employs these technologies to optimise water services and infrastructure [42]. Nevertheless, the degree of intellect and progress in water management may range among various sectors within a metropolis. Certain regions may lead in the adoption of intelligent technologies, while others may fall behind due to issues such as budgetary limitations, inadequate infrastructure, or poor technical proficiency.

In order to measure and compare the efficiency of intelligent water systems, it is crucial to establish a thorough evaluation process. This technique should thoroughly examine the extent to which smart water technologies effectively address the several functions of water in urban environments, such as its provision, quality, and preservation. Additionally, it should evaluate the efficacy of these technologies in converting cities into "Smart Water Cities." This evaluation procedure can facilitate the identification of elements that contribute to the effective implementation and underscore the barriers encountered by policymakers and water professionals [43]. A methodology for assessment that is both efficient and effective will provide useful insights into the development of smart water technologies and the impact that these technologies have on the management of urban water. Additionally, it will provide guidance to cities in the development of smarter and eco-friendly water solutions, ultimately assisting in the establishment of urban settings that are more sustainable and resilient.

Smart Water Management (SWM) aims to tackle and alleviate problems in the water industry by incorporating sophisticated Information and Communication Technologies (ICTs). SWM aims to greatly improve both social and economic well-being by utilising these technologies. The primary function of SWM entails the ongoing surveillance of water systems, identification of irregularities, and enhancement of the distribution network through the use of real-time data. The process commences by gathering data through diverse technologies, such as sensor networks and smart metres. These gadgets offer comprehensive analysis of the condition and efficiency of water systems [44]. The gathered data is subsequently distributed via communication channels such as Wi-Fi or the internet, guaranteeing its prompt delivery to pertinent parties. After the data is gathered and sent, it undergoes processing and storage through cloud technology. This allows for the implementation of storage solutions that can handle massive amounts of data and provides the ability to do complex computations on that data. Subsequent to that, sophisticated modelling and analytics techniques are utilised to analyse the data, discern patterns, and forecast future trends. This study is crucial for making well-informed decisions on water management.

Ultimately, the outcomes are visually represented and showcased via web-based apps. These platforms facilitate decision-making by providing intuitive interfaces and interactive tools that assist stakeholders in comprehending and taking action based on the data. Through the integration of these components, Smart Water Management converts unprocessed data into practical insights, resulting in improved water management techniques that are both more efficient and effective. The architecture of the Internet of Things (IoT) is composed of three levels, each with a vital function in ensuring the smooth integration and operation of IoT systems [45]. The lowest tier consists of a wide range of elements, such as sensors, mobile phones, and actuators. These devices have the task of collecting data from the physical environment or executing certain actions based on input. The network tier, sometimes referred to as the middle tier, plays a crucial role in conveying the data gathered by these entities. It guarantees the dependable transmission of data, utilizing either wireless or wired connections. The existence of this tier is crucial for ensuring a seamless transmission of data between the IoT devices and the application layer. The application layer is responsible for processing and analysing the data at the highest level. The primary function of this layer is to transform unprocessed data into valuable insights and knowledge that can be utilised by end users [46]. It communicates this information via user interfaces, allowing for informed decisions to be made based on the analysed data.

Multiple technologies enable the application of IoT, such as RFID, wireless sensors, and diverse

addressing methods. An examination of wireless technologies, such as Bluetooth, Wi-Fi, and XBee, demonstrates notable disparities in performance parameters. XBee has superior range, reduced battery usage, and quicker wake-up times in comparison to Bluetooth, which requires 3-4 seconds to exit sleep mode. XBee utilises sophisticated security methods, as ACL or AES, to guarantee strong data protection. The text also addresses the difficulties encountered in transmitting data and distributing electricity. Various wireless communication systems, such as device-to-device communication (PAN), KAN, WLAN, Wi-Fi, mobile broadband, RFID, and satellite communications, possess distinct benefits and constraints. If it is possible to maintain a consistent distance between sensing devices, it is advisable to use a mesh network design. This design enables each device to function as a communication hub for others, thereby improving network resilience and coverage. Furthermore, the need for the IPv6 addressing method is emphasised as a result of the growing number of internet-connected devices. IPv6 has a significantly bigger capacity for addresses, allowing for 2^{128} devices, whereas IPv4 can only accommodate 2^{32} addresses. This expansion is essential for the ongoing development and ability to be scaled up of IoT systems. These observations regarding the structure and technologies of the Internet of Things emphasise the intricacies and factors to be taken into account while creating IoT solutions that are both efficient and capable of growth.

The proposed Internet of Things (IoT) system utilises Raspberry Pi and Arduino for data collecting, with each device offering unique benefits that are well-suited for certain areas of the project. Raspberry Pi and Arduino have distinct functions due to their respective designs and capabilities. The Raspberry Pi is an affordable and fully capable computer that performs very well in jobs that demand superior processing power and advanced computing capabilities. Its powerful operating system and computational resources make it well-suited for software applications and sophisticated processing activities. Arduino, in contrast, is a microcontroller rather than a complete computer. This characteristic makes it particularly suitable for hardware projects that require real-time and analogue data collecting. The key advantage of Arduino is its capacity to directly connect with a wide range of sensors and components, which makes it highly suitable for long-term, uninterrupted execution of individual tasks. Arduino surpasses Raspberry Pi in applications that demand real-time reactions and analogue input.

Moreover, the ESP8266 WiFi Chip plays a crucial role in this system. This module is self-contained and may enhance the Wi-Fi capabilities of any microcontroller, such as Arduino. This chip establishes connection with microcontrollers via UART (Universal Asynchronous Receiver/Transmitter) and enables wireless data transmission by connecting to sensors or application-specific devices using GPIO (General-Purpose Input/Output) pins. Within the realm of cloud computing, the application platform is commonly delivered as a service, referred to as Platform as a Service (PaaS). Platform as a Service (PaaS) provides developers with a development environment that enables them to create and deploy apps with minimal effort in managing infrastructure. Notable Platform-as-a-Service (PaaS) solutions for Internet of Things (IoT) encompass IBM Bluemix, Ubidots, Carriots, Nimbits, and Thingspeak. These platforms enable the incorporation and control of IoT devices and data, providing a range of tools and services to assist in the creation and implementation of IoT applications. Table 1 presents a concise summary of the comparison of various platforms, offering a comprehensive picture of their characteristics and functionalities. This comparison emphasises the advantages and capabilities of each platform, assisting in the choice of the most appropriate one for specific IoT requirements.

Xively

Xively is compatible with a wide range of hardware devices, such as sensors, gateways, and embedded systems, manufactured by many manufacturers. Commonly employed hardware includes Raspberry Pi, Arduino, and various other microcontrollers. Xively is compatible with multiple operating systems, including Linux (such as Raspbian for Raspberry Pi), Windows, and macOS. Xively provides software development kits (SDKs) and application programming interfaces (APIs) that are compatible with multiple programming languages like Python, JavaScript, C, and C++. Xively is designed to efficiently handle a large number of devices and vast amounts of data. The system provides extensive Application Programming Interfaces (APIs) and Software Development Kits (SDKs) to ensure smooth integration with various devices and applications. Additionally, it offers strong security protocols such as data encryption and secure authentication. The price structure may be complex and potentially more costly than other platforms, posing a difficulty for smaller projects or organisations. Some users may consider the available personalisation options to be restrictive when compared to other platforms.

Thingsquare

Thingsquare is able to communicate with several low-power, wireless Internet of Things (IoT) devices, including those that employ technologies such as Bluetooth Low Energy (BLE) and Thread. Examples of devices that are enabled with Bluetooth Low Energy (BLE) include Nordic Semiconductor's nRF52 series and other comparable products. Thingsquare is frequently used with embedded systems that run on lightweight operating systems or real-time operating systems (RTOS). Contiki OS and FreeRTOS are commonly used operating systems. Thingsquare primarily supports the utilisation of C and C++ programming languages for application development on its platform. Moreover, it provides libraries that streamline the incorporation of other programming languages through its application programming interfaces (APIs). This technology is specifically designed to operate efficiently with low-power devices, making it very suitable for Internet of Things (IoT) applications that depend on battery power. Additionally, it facilitates the utilisation of mesh networks that may easily expand in scale as the quantity of devices rises. Interoperability is the ability of a system or device to function smoothly with various communication standards and protocols. It may provide less support for advanced application development compared to other platforms. Individuals who are not familiar with embedded systems and mesh networking may find the setup and configuration to be challenging.

ThingWorx

ThingWorx is capable of working with a wide range of hardware, including industrial sensors, equipment, and devices from many suppliers. It effortlessly communicates with industrial machinery and commonly used IoT hardware platforms. ThingWorx is capable of functioning with multiple operating systems, including Linux and Windows Server. It is typically utilised in server setups or virtual machines. ThingWorx is capable of working with a wide range of programming languages and development environments. The platform provides software development kits (SDKs) for JavaScript, Java, and .NET programming languages. Advanced Analytics offers powerful analytics and machine learning capabilities for obtaining deep insights from Internet of Things (IoT) data. It provides extensive integration possibilities with existing enterprise systems and data sources. The system has an intuitive interface specifically created for building and managing IoT applications, including dashboards and visualisations. The cost can be rather significant, particularly for smaller businesses or initiatives with limited financial means. The

platform's numerous capabilities may complicate implementation and oversight, requiring a more demanding learning process.

Xively exhibits remarkable scalability and effortless integration capabilities, yet it may feature complex pricing structures and limited customization choices. Thingsquare is particularly suitable for low-power devices that function within a mesh network. While it exhibits strong scalability, this system may have limited support for high-level applications and can be intricate to configure. ThingWorx provides advanced data analysis and extensive integration capabilities, yet it can be costly and demanding to manage.

Proposed Smart Water Management System

Water is a limited resource that requires careful monitoring and management to ensure its efficient provision and distribution. In light of this essential requirement, our project is dedicated to the creation of a Smart Water Management System that utilises sensor technology and sophisticated analytics within the context of the Internet of Things (IoT). The goal is to shift from manual data collection and processing techniques to an automated, Internet of Things (IoT) driven solution, with the aim of enhancing the efficiency and precision of water management on our campus [47]. At now, the collection and analysis of water data is done by hand, which poses difficulties such as possible inaccuracies and inefficiencies. In order to address these constraints, we are in the process of designing a system that utilizes sensors to consistently check the water levels in tanks. The sensors will deliver instantaneous data on water levels, guaranteeing our ability to immediately and precisely monitor any fluctuations. The data gathered by these sensors will be transferred to a centralized server using Arduino and Raspberry Pi technology. These devices are selected based on their dependability and capacity to connect with sensors and efficiently manage data transmission [48].

After the data is transmitted, it will be presented via a web interface, facilitating convenient and instant access to the information. This web interface will streamline real-time monitoring and enable stakeholders to access the up-to-date condition of water levels at any given moment. In addition, the data will be saved in the cloud via the Ubidots cloud platform. Cloud storage provides the benefit of flexible and protected data administration, enabling the handling of substantial amounts of data and guaranteeing its accessibility for future analysis and decision-making [49]. For the purpose of enhancing the functionality of the Smart Water Management System, we are implementing an alert system that is intended to rapidly notify users of any significant changes or anomalies in water levels [49]. The alert system will transmit notifications through SMS and email, guaranteeing that pertinent staff members promptly obtain updates regarding matters necessitating immediate care. The system intends to enhance water monitoring operations, enhance data accuracy, and provide early alerts by using this modern technology [49]. Ultimately, this will provide more efficient and sustainable water management practices on our campus.

The system architecture has multiple essential components to accomplish its aims. An essential component is the Point of Use (PoU), which designates the precise sites where water level sensors are placed. The PoUs are classified into two categories: Sumps and Overhead Tanks (OHT). At each Point of Use (PoU), there will be four sensors placed at pre-determined intervals of 20%, 40%, 60%, and 80%. Every sensor is specifically engineered to produce a TRUE output when it detects water at its designated level, and a FALSE output when it does not detect water. This configuration enables accurate monitoring of water levels at different phases [50].

Each Point of Use (PoU) utilizes an Arduino board that is equipped with Bluetooth Low Energy

(BLE) capabilities to manage data collecting. The primary function of this board is to collect data from the sensors and process it in preparation for transmission. Nevertheless, the connectivity range of Points of Use (PoUs) can differ, and certain PoUs may be situated beyond the Wi-Fi coverage zone. In order to resolve this problem, we have incorporated an Echo Module. This module utilises an additional Arduino board equipped with BLE capabilities to function as a relay or intermediary between PoUs and the Wi-Fi network. The quantity of Echo Modules needed is contingent upon the proximity of the Points of Use (PoUs) to the nearest Wi-Fi service zone. The receiving end is equipped with a Push Module, comprising an Arduino board that possesses both Bluetooth and Wi-Fi functionalities. The board establishes a connection with the Echo Modules using Bluetooth Low Energy (BLE) and sends the gathered data to a local server using Wi-Fi. The Push Module guarantees the efficient transmission and storage of data from all Points of Use (PoUs) on the server for subsequent analysis and visualization [51]. The integration of these components in the Smart Water Management System enables the system to provide real-time monitoring and efficient management of water resources, thus promoting more sustainable water practices on campus.

The Raspberry Pi will function as the primary hub for data processing and integration in the Smart Water Management System. This affordable, fully functional PC with Wi-Fi capabilities is ideal for overseeing and enhancing water monitoring operations. The setup and configuration of the Raspberry Pi entail certain essential activities to guarantee efficient functioning and communication inside the system. Initially, the Raspberry Pi will be tasked with retrieving data from the local server. This entails obtaining and collecting the water level data that has been gathered from the different Points of Use (PoUs) through the Echo and Push Modules. After collecting the data, the Raspberry Pi will commence processing methods to analyse and interpret the information. In order to enhance efficient data management and visualization, the Raspberry Pi will populate pertinent tables with the gathered data. This stage is essential for producing precise and informative visual depictions of water levels, trends, and patterns of usage [52]. The Raspberry Pi can facilitate comprehensive research and reporting by arranging the data into organised tables. In addition, the Raspberry Pi will manage the transmission of data to the cloud storage platform. This interface facilitates remote access and enables the long-term storage of data, so facilitating additional analysis and ensuring the integrity of the data. Cloud storage enables seamless data sharing and accessibility across various platforms and devices. A crucial aspect of the Raspberry Pi configuration is the capability to activate email and SMS notifications. Once the water level drops below a specified threshold, the system will instantly initiate messages to inform users. This function guarantees that pertinent personnel are notified of any crucial matters necessitating prompt action. Ultimately, the Raspberry Pi will be set up to regularly dispatch emails with numerous reports. The generation of these reports can be customized to occur either daily, monthly, or yearly, based on the specific requirements and preferences of the users [53]. The Raspberry Pi will enhance water management practices by automating the process of generating and distributing reports, hence improving efficiency and responsiveness in continuous monitoring and management operations [54].

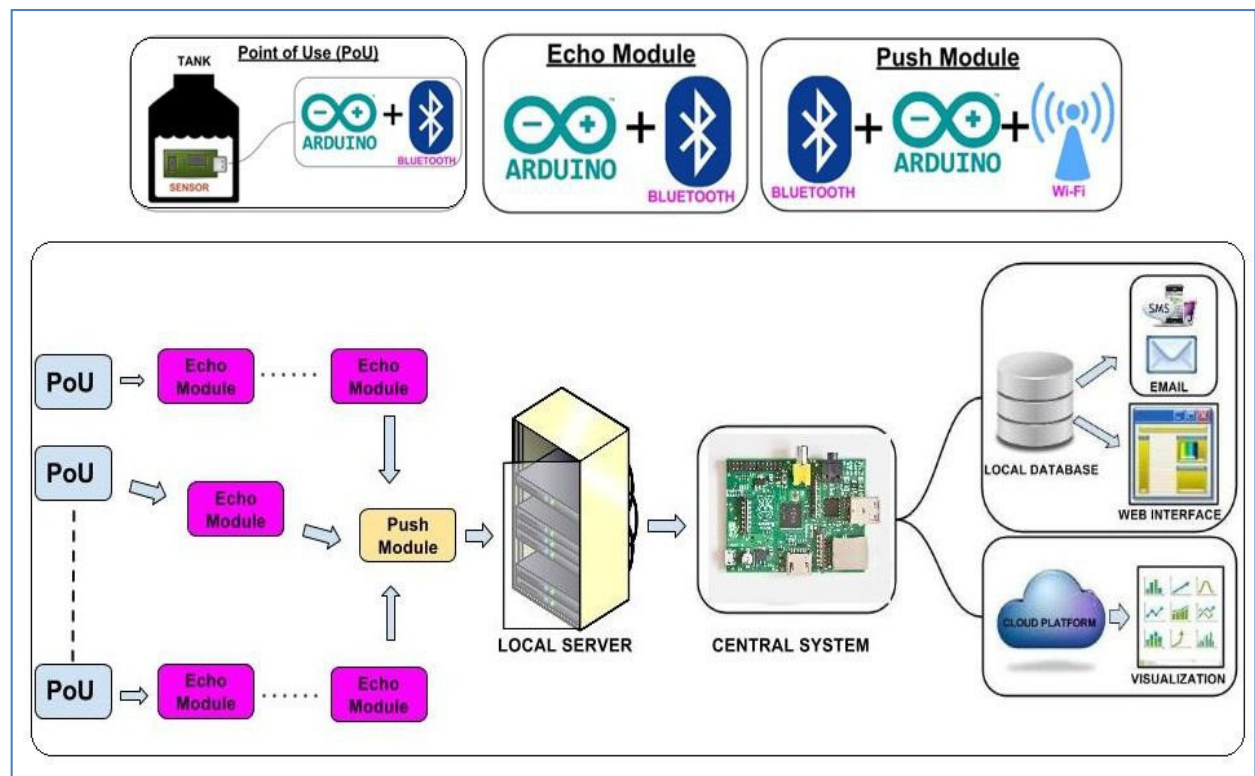


Fig.2 Proposed architecture diagram for a SMW system

Implementation and Results

The deployment of the Smart Water Management system is divided into two separate but interrelated stages, both of which are essential for ensuring efficient water monitoring and management. The initial phase involves the extraction and manipulation of data from the Points of Use (PoUs). This entails gathering data from the several sensors positioned at the Points of Use (PoUs), which oversee water levels at particular thresholds. Subsequently, the acquired data is analysed and transmitted to a centralized database. This stage involves the meticulous collection, storage, and organisation of all pertinent information obtained from the Points of Use (PoUs) for future utilisation. In the second stage, the stored data is retrieved from the database and made available for visualization, alert systems, and other operational uses [55]. At this level, the Raspberry Pi functions as the central system, responsible for performing essential activities such as data processing, integration, and communication. The Raspberry Pi is equipped with the Debian operating system, which offers a robust and efficient foundation for controlling a variety of system functions. In addition, the Raspberry Pi has been configured with the LAMP (Linux, Apache, MySQL, PHP) server environment to act as a platform for hosting websites and administering the MySQL database.

Data Processing

Our Smart Water Management System utilizes sensors placed at specific Points of Use (PoUs), such as sumps and overhead tanks. Each PoU is equipped with four sensors that are strategically positioned at varying water levels (20%, 40%, 60%, and 80%). These sensors generate an accurate signal indicating the presence of water at their respective levels, and an inaccurate signal otherwise. Each Point of Use (PoU) is equipped with a specific Arduino board that captures and encodes the data into a string format, making it more convenient for further processing. The encoded string adheres to the format `#<tanktype><tankID>_<T/F><T/F><T/F><T/F>#`. For instance, the string

#S105_TTFF# signifies that the data originates from sump 105, where the water level is above 40% but below 60%. To simplify, we estimate that this corresponds to a water capacity of 50%. The encoded data strings from all Points of Use (PoUs) are sent to a centralized server located on campus. This server then initiates the processing to monitor and control the water levels around the campus.

Algorithm for Data Population

1. Master Script: This master script will run the Process_file script after every 5 minutes.
2. Process_file Script:
 - Copy Strings for Processing: This will copy all the strings to the main server file in the form of temporary file for processing.
It then further clears the original server file so that string file for the next batch of incoming data can be prepared.
 - Read and Process Each String: This further read all the strings saved in temporary file in the server to retrieve the data.

For Example, string: #S105_TTFF#

Verify and Divide the String:

Verify that the string format is accurate.

Divide the string into its constituent parts:

Tank Classification: S

Identification of tank: 105

Water level: 2 (inferred from the TTFF component)

Perform operations according to the kind and level of the tank:

If the tank type is O (overtank),
then the upd_consum operation should be executed.

Perform the upd_exus procedure.

Perform the upd_waterlevel function with the parameters type, tank_id, and lvl.

If the tank type is S (sump) and the level is below 2, then the sms_alert function will be executed with the tank_loc and level as parameters.

If the tank type is O (overtank) and the level is below 1, then trigger the sms_alert function with the parameters tank_loc and level.

Procedure for updating consumption (upd_consum)

The Upd_consum process is responsible for modifying the consumption records using the latest water level data.

Verify the presence of a preexisting record:

Validate the presence of a record corresponding to the specified tank ID on the present day.

Update Existing Record: If a record already exists and the prior water level is higher than the current level: Increment the existing quantity by the amount drank in the current interval.

If the prior water level is lower than the current level, increase the refill count by one.

Create a new record: If there is no existing record for the supplied tank ID and date: Insert a new record with the tank ID and date.

Procedure for Updating the Exus System

Usage verification for excessive consumption:

Ascertain whether the disparity between the preceding water level and the present water level is equivalent to or surpasses 2 units.

Determine whether the time interval between the current and previous records surpasses 5 minutes.

Create a new entry:

If both criteria are satisfied, add a new entry to the Excess Use table. The provided data will be utilized for subsequent analysis.

Procedure for updating the water level

Update Water Level: Modify the Water Level table by inserting the current water level, along with the date and time of the recording.

Visualization and Alert System

Visualization: Generate graphical depictions of water levels, consumption, and other pertinent metrics utilizing the gathered data. This could entail the use of web-based dashboards or graphical interfaces to deliver immediate and up-to-date insights.

Notification System:

Develop a notification system that utilizes SMS or email to inform appropriate individuals when specific thresholds or irregularities are identified. This guarantees a prompt reaction to crucial matters, such as insufficient water levels or excessive use.

Fig.3 Screenshot of Web Interface for Smart monitoring system



The Smart Water Management system utilizes a two-fold strategy to visualize and manage water data. This is achieved through a tailor-made webpage and the Ubidots cloud platform. The webpage, constructed with HTML and PHP, functions as the main platform for users to obtain extensive water management data. The application includes multiple tabs, each designed to focus on distinct areas of water monitoring. The Water Level Tab refreshes every 5 minutes, providing essential details such as the capacity, amount, and current water level of any sump or overhead tank. The system incorporates RGB visualizations that offer a lucid visual depiction of water levels, facilitating users in promptly evaluating the condition of their water resources. Furthermore, this tab provides a concise overview of the total capacity, current availability, and necessary volume of water for both sumps and overhead tanks.

The Consumption Information Tab provides comprehensive data on water usage, including the quantity of water drunk and the frequency of refills. Users have the ability to access this data across several time intervals, such as daily, weekly, monthly, or yearly. This enables authorities to observe usage patterns and tackle problems associated with excessive consumption. This tab facilitates the issuance of warnings or notifications to promote the adoption of more efficient water usage. The Excess Usage Tab identifies occurrences of elevated water usage, offering practical

information to properly monitor and decrease water consumption. The Inactive/Out of Order PoUs Tab displays a list of Points of Use (PoUs) that are presently not in operation or experiencing malfunctions, facilitating prompt maintenance and repairs.

The Ubidots Cloud Platform is essential for data visualization and alert management, in addition to the webpage. This platform offers instantaneous monitoring and administration functionalities, including an alert system that dispatches notifications by SMS and email when sensor values surpass certain thresholds. Every user is allocated an API key for accessing these notifications, guaranteeing that pertinent individuals are instantly notified. The Ubidots dashboard utilises unique identifiers to assign to each Point of Use (PoU), enabling exact management of variables and accurate data monitoring. The Raspberry Pi captures data, and a Python script establishes a connection between this device and the Ubidots cloud, enabling efficient transmission and storage of the data.

The Notification System is a crucial element of the Smart Water Management system. Email notifications are generated by extracting excessive water use data from the exus table and using it to create alerts. The Python SMTP module manages the transmission of these emails, while the Thexlswriter programme generates Excel files from the data tables, which are then appended to the emails to provide comprehensive reports. An SMS system is implemented to provide text message notifications to truck drivers when water levels drop below a specific threshold. The Txtweb service utilises 20 APIs to guarantee the delivery of SMS messages to the intended recipients. The incorporation of these visualization and alerting techniques improves the effectiveness of water management on the campus. The system enhances decision-making and operational effectiveness in water management by offering real-time data, insights, and alarms, thereby supporting sustainable and effective practices.

Conclusion and Future Enhancement

The Smart Water Management System incorporates cutting-edge technology such as IoT sensors, cloud platforms, and smart metering to improve urban water management. The system employs Raspberry Pi and Arduino for data acquisition, enabling real-time monitoring, efficient data processing, and extensive visualization via a dedicated webpage and the Ubidots cloud platform. The system includes strong alerting mechanisms for alarms by SMS and email, enabling proactive administration and maintenance. This comprehensive strategy not only enhances the efficiency and quality of water usage but also promotes sustainable methods and proactive administration, with the goal of revolutionizing urban water management into a more intelligent, effective, and adaptable system. A thorough analysis of cutting-edge technologies such as the Internet of Things (IoT) and Predictive Analytics has shown their importance in the context of Smart Cities. This debate examines a range of technologies that can be used in Smart Water Management Systems, including cloud-based Internet of Things (IoT) solutions. An economically efficient plan for a smart water management system has been created, utilising Internet of Things (IoT) technologies. The installation on the Amrita campus has effectively established a system for a restricted number of tanks, with future intentions for further growth. The gathered data provides significant insights for other analytical applications, such as predicting consumption patterns and detecting water leaks, hence improving overall efficiency in water management.

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