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Design of Sensor Node for Drainage Blockage Monitoring System

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Abstract: Monitoring the drainage systems is essential for maintaining a clean city. The truth is that not all localities have a drainage monitoring crew. As a result, the drainage condition is irregularly monitored. Unreliable monitoring causes drainage to become blocked, which results in overflow and causes flooding. This article discusses the creation of SN's for use in wireless sensor networks to keep an eye on conditions at various drainage system locations. In order to link with one another, some SN's are placed at various predetermined locations. The gathered information will be put into a database that a geographic information system may display (GIS).Water levels in the drainage, water outflow, and the amount of rainfall in the area surrounding the drainage are the monitoring criteria. The drainage conditions should be continuously monitored in real time by this system, and the data should be stored correctly. The data presented by GIS is meant to serve as a guide when creating a drainage master plan for a specific area.

Keywords: *Drainage, Sensor, Monitoring, Nodes, System.*

1. Introduction

The phrase "Internet of Things," which refers to a network of connected gadgets and objects, is one of the most remarkable technological developments of contemporary science. It is also one of the most overused phrases in the English language. The Internet of Things (IoT) is a network that connects disparate physical devices, analyses that data, and then uses that information to carry out predefined tasks [1]. At the moment, applications based on the Internet of Things are widely employed in a variety of domains, including home activities, organizational activities, transportation, health care, agriculture, construction, and so on [2]. The concept of a smart city is introduced in each of these fields. A smart city is described as an urban area's electronic infrastructure mixed with various devices and physical items that are used to gather data in order to use it to handle various city resources effectively and create a strong link between the urban society and metropolitan infrastructure. One of the key elements of a sustainable ecosystem is a functional drainage system. This system eliminates surplus surface water from an area and regulates it either physically or synthetically to stop flooding and to provide a fresh, sanitary atmosphere to enhance quality of life [3]. The requirement for industrial, organizational, and household structure is steadily increasing along with the steady expansion of metropolitan regions. For the foreseeable future, there will likely still be a demand for this. As a direct result of this, the flow of such excessive surface water is also increasing, and in urban areas, the need for effective drainage system management is becoming more and more crucial. In most cases, the groundwater moves via the drainage system and eventually makes its way to a wastewater treatment plant [4] in order to have any contaminants and impurities removed. Sometimes the solid wastes (such as plastic, biodegradable materials, metals, and other such things) that come from the groundwater cause a clog inside the drainage pipeline systems, which then causes the water that comes from the drainage pipes to be contaminated. As a result, it should come as no surprise that the solid wastes carried by groundwater as it moves through the drainage system have the potential to produce a significant barrier to the unfettered flow of water, which would result in significant negative effects on the environment. Therefore, it is of the utmost importance to effectively manage these solid wastes in order to prevent them from impeding the drainage system's normal flow of water.

Taking into account the conditions, it is patently obvious that urban areas would, sooner or later, require a drainage managing system in addition to its waste managing system. This is especially valid for developing countries whose economy is still growing. The manual manipulation of these systems takes up too much time and involves an excessive amount of effort (human work is required to

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collect the garbage that clogs the drainage system). Therefore, the Internet of Things (IoT) paradigm can be utilized to computerize such systems, and then those systems can be regarded as constituent parts of a smart city. As a result, the purpose of this study is to put out an argument for an efficient smart drain management system. The concept of the internet of things has only been used in a limited number of research works concerning drainage management systems. Waste management [5]–[8], underground drainage pipes [9] and manhole monitor system [10], waste water handling or recycle system each have their own unique set of solutions. There are numerous approaches to drainage systems, most of which concentrate on the management of a drainage system [11] in the event that any overflow occurs; nevertheless, most approaches do not address the underlying problem that causes overflow. In addition, there have only been a few works that have dealt with intelligent waste management, which can only control waste on the ground surface. Other works concentrated solely on developing monitoring systems for subterranean drainage systems. There has not been any work done that focuses on both the system that manages trash at the ground surface and the mechanism that is responsible for subsurface drainage. This is where the proposed system takes an innovative step forward. We have worked toward resolving the specific issue that led to the overflow, with the goal of effectively managing the underlying cause.

2. Literature Review

Shathya Duobiene (2022) [12]- Everyday objects from the real world are being transformed into intelligent objects thanks to the Internet of Things (IoT) expertise and its application, which also integrates everything under a single infrastructure to control performance with software and provide timely updates with integrated web servers. Comprehensive environmental monitoring systems that are user-friendly and low-maintenance are required for society's progress in the areas of quality of life, sustainable economic development, and pollution control. It is suggested to construct a wireless sensor network with embedded sensor node(SN) made by the laser-induced selective surface activation approach on the basis of this study Such technology enables the integration of electrical circuits into free-form plastic sensor housing. In the course of this research, an inexpensive asynchronous web server was constructed with the purpose of monitoring temperature and humidity sensors that were attached to an ESP32 Wi-Fi module. On a web server, charts depicting data in real time are created using the data gathered from SN’s spread out around the facility. Access to the sensor data can be granted to several web clients that are part of the same network. Energy could be harvested from the many sources of electromagnetic radiation that are located around the SN’s in order to provide power for them. This automated and self-powered technology aids in quick action while monitoring environmental and climatic conditions by permitting antenna and RF circuit assembly on various plastics, including the device's body. Other benefits include: monitoring environmental and climatic factors; helping with timely action; and benefiting sensor design. In addition to this, it enables greater elasticity in the hardware adjustment process and quick deployment on a broad scale.

Pavithra M (2022) [13], A sign of a healthy city is one that has effective drainage management. Manholes are the primary source of concern in urban areas in today's society. It does not appear like any of the manhole covers have been properly installed. The majority of the drainage system is in a degraded state. As a result of the damaged drainage, there is a possibility that accidents will take place on the road. These manholes are in such poor condition that they pose a risk to people's safety. Our project work include coming up with an efficient method to minimize open drainage in big cities as a means of mitigating the risk of accidents. The sensors, such as tilt sensors and weight sensors, will be used to detect the crack and the damage in the drainage cover, and then the information will be provided to the authority of the corporation department as well as the councilor of the area in which the drainage is located. The Internet of Things is used to perform both the control and the maintenance duties. The successful completion of this project will be of tremendous benefit to the community.

Tushar Pathak (2021) [14] - India is making steady strides toward greater levels of automation and has the ambitious goal of transforming every city into a "smart city." In order to create a smart city, we will need to take into consideration a large number of parameters, such as intelligent water management, intelligent power management, intelligent transportation, and so on. Intelligent subsurface infrastructure will be required, which may include underground water pipes, communication cables, gas pipelines, electric flow, and so on. Since underground drainage systems have been installed in the majority of Indian cities, it is essential that they function properly in order to maintain the city's cleanliness, safety, and inhabitants' health. If they do not do routine maintenance on the drainage system, the clean water may get tainted with drainage water, which may then cause the spread of infectious diseases. As a result, many duties related to these subsurface systems have been completed, including detection, maintenance, and management. Another inescapable aspect of managing water distribution networks is dealing with leaks and bursts. If leaks and bursts are allowed to go unreported for a long time, they can cause a large amount of water loss inside a distribution network. This project entails the implementation and design functions necessary to monitor and manage an underground or road-side drainage system using a variety of methods. It also provides information regarding the safety concerns, such as the presence of gases that are hazardous to the workers, the temperature details, and whether or not they are appropriate for the workers, as well as whether or not there are obstructing parts present.

Rohit Shende (2020) [15] -: Drainage has become one of the most significant challenges facing major cities in modern times. Monitoring of systems plays a very significant part in ensuring that the city is kept clean. The sporadic monitoring ultimately results in the obstruction of the manhole, which leads to the salutation and thus causes flooding. It is necessary to hire a professional worker, but they will only check extremely finite details and will maintain a low level of accuracy. Additionally, when there is a lack of data, it is possible that a worker may be involved in an accident. This is because the person will be unaware of the conditions that will be present in the manhole. The application and design functions of a drainage monitoring system are represented here in this study. A module including Arduino as a microcontroller will be interfaced with a gas sensor, a flow sensor, and NRF, and it will be affixed to the manholes that are already existent in the drainage system. This device will sense hazardous gases that are dangerous to humans, check for blockages between two manholes, monitor water levels, and detect dangerous gases. Once it has gathered all of this information, it will send it to the appropriate authority, who will then take the appropriate action. This entire process will be able to be monitored in real time by the system.

Gaurang Sonawane (2018) [16] - The monitoring of the city's drainage system is an important part of keeping the city clean. In point of fact, not all regions have a team to monitor drainage systems. This results in the monitoring of the drainage situation being inconsistent. The lack of frequent monitoring results in the clogging of the drainage system, which in turn leads to the elevation of the water table, which in turn causes flooding. Monitoring by hand is another inefficient method. It takes the assistance of professionals, but even then, they can only monitor relatively few details and keep the accuracy low. A worker's lack of information can also put them at risk of being involved in an accident. They have no way of knowing what the working conditions will be like in the manholes they are inspecting. This study shows the application and design function of an intelligent and real-time drainage and manhole monitoring system that makes use of the internet of things (IoT). A module equipped with a microcontroller that is interfaced with a gas sensor, level indicator, and NRF will be installed in any manholes that are present in the drainage system. Another inescapable aspect of managing water distribution networks is dealing with leaks and bursts. If leaks and bursts are allowed to go unreported for a long time, they can cause a large amount of water loss inside a distribution network. If it detects any of these things, it will sound an alarm, and it will also provide the relevant information to the relevant health departments so that they can take the appropriate action. Because the system will be able to monitor all of these factors in a real-time setting, it will make it possible for us to take the appropriate steps to address the specific issue with the drainage system.

XieJiaxing (2018) [17] - In order to address the issue of wireless communication barriers and increase the effectiveness of managing micro-irrigation, wireless sensor network (WSN) bidirectional nodes, such as the sensing node and the solenoid valve control node, were developed for information gathering and micro-irrigation monitoring system in a litchi orchard. These nodes included the sensing node and the solenoid valve control node. The sensing node was composed of three parts: an MCU8051, a CC2530 RF chip for communication, and an RFX2401 for amplification. This node is designed to collect data from three different sensors: a DHT22 sensor for measuring the temperature and humidity of the air, a GY-30 sensor for measuring the intensity of the light, and a TDR-3 sensor for measuring the moisture content of the soil. A MCU8051, a CC2530 RF chip for communication, and peripheral drive circuits are included in the control node. These components are used to adjust the bi-stable pulse solenoid valve. In accordance with the Z Stack agreement, the application software as well as the backstage administration software were penned with these two nodes serving as the hardware platform. In areas that were not inhabited, the planned nodes were able to achieve a maximum effective communication distance of 1,205 metres, but in litchi orchards, this distance was reduced to 122 metres. It is possible to make an educated guess that two 3.7 V batteries with a rated capacity of 3000 mA•h can provide power to the sensor node for a period of up to 500 days if the working cycle lasts for 30 minutes. The results of tests carried out in litchi orchards indicate that the average rate of packet loss is 0.75%. For the purpose of information collecting and the regulation of micro-irrigation in litchi orchards, the system was operating without a hitch with the nodes described above.

3. Methodology

Various SN’s that have been deployed in various locations can communicate with one another through a wireless sensor network. A sensor unit, a communication unit, and a power unit are included in the construction of each individual sensor node. In the design of wireless sensor networks, determining how these individual units should be combined is an essential step. The design of a drainage monitoring system is comprised of a few steps, which are as follows:

3.1Design of SN’s

Some of the primary parts present on SN’s include the sensors unit, the processor, the RTC (Real time Clock), the SD cards, the wireless communication unit, and the supply units. A sensor's job is to detect the presence of physical quantities that may then be measured. RTC manage the data transfer time. Data temporarily stored on an SD card for coordinating SN’s, a wireless communication unit. The supply units are responsible for providing electricity to the SN’s [18].

The performance as well as the amount of energy used will be impacted, making the processor an essential component. Microcontrollers, field-programmable gate arrays (FPGAs), and integrated circuits (ICs) designed for a particular application are some examples of the kinds of processors that can be utilized. The reliability of SN’s is also impacted by the type of sensor that is used. Due to the fact that the sensor will be positioned outside, it is necessary for the sensors to be resistant to both noise and the elements. GSM and radio frequency (RF) communication are the two types of wireless communication units that can be utilized (GSM).

3.2Design of Communication units

Figure 1 illustrates the different types of network topologies that can be utilized in wireless sensor networks. These topologies include the mesh, tree, ring, bus, star and completely connected topologies. The bus topology is the one that was used for the network in this architecture.

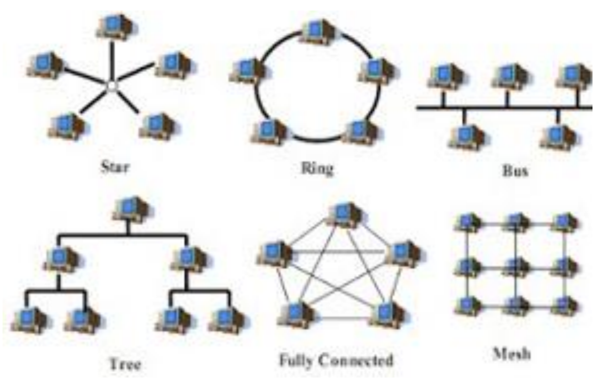

Fig 1. Network Topology Types

The SN’s will be linked to one another by wireless communication made possible by radio frequency modules. The gateway served as the last point of communication between the SN’s. The data are sent to the server over a GSM connection (which stands for "Global System for Mobile Communication") after being processed at the gateway. Figure 2 presents a block schematic of the communication that takes place between the several SN’s.

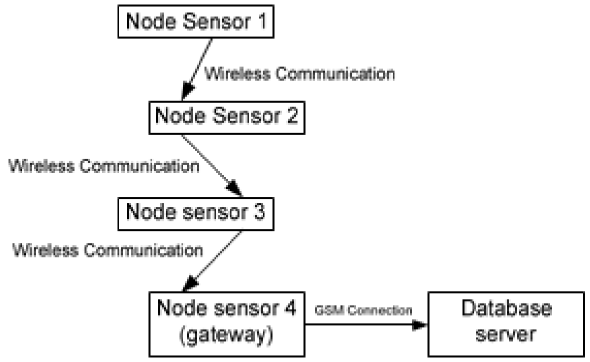

Fig 2. A Wireless Sensor Network Block Diagram

3.3 Layout design for SN’s

The following are some crucial considerations that must be made when laying out the SN’s: The location of the sensor node must accurately depict drainage situation. The distance among any two SN’s must fall within the radio frequency module's transmission range. The connections between any two SN’s must be made close to other SN’s to reduce delay and noise. The gateway's location needs to have adequate GSM signal availability. In the centre of the sensor network, the gateway ought to be situated. [19].

3.4 Design of data base system

The purpose of the design of a data base is to make the management of data (the editing of data) easier, to simplify the process of searching for data, to provide data in real time, to be user friendly, and to assist in the process of decision making.

4. Results and Discussion

It has been discussed that the components of a WSN include a supply unit, communication units, and sensor units. The gathering of data by the sensors, which is then processed and sent on to the gateway by the processor, can be thought of as the fundamental operating concept of wireless sensor networks. The data will be processed at the gateway before being sent to the server. The server will notify the controller to enhance or decrease the performance of electrical equipment when the sensor device report parameter exceeds the predetermined limit. In this segment, we will talk about the several types of sensors that can be used for the drainage monitoring system, as well as the processor, the connection module, the layout for the SN’s, and the overall design for the data base [20].

4.1 Sensor Unit

According to the requirements for drainage monitoring, the monitoring variables employed include rain, water stage, and water release. Therefore, the sensors that we require are those that measure rainfall, the level of water, and the speed of the water flow. In addition to graduated cylinders, weighing gauges, tipping bucket gauges, and straightforward buried pit collectors, there are many other types of rainfall sensors. When it comes to collecting data on rain, each variety has a set of benefits and drawbacks unique to itself. The tipping bucket gauges type is the one that will be utilized in this design. The components of this sensor are a container, a seesaw, and a funnel. The water is first collected using a funnel, and then it is transferred to the container using a seesaw. In the event that the seesaw topples, the gathered water will be emptied, and the signal will be sent. This signal is going to be counted in order to determine the amount of rainfall. The tipping bucket sensor is a great option for the drainage monitoring system even if it isn't quite as accurate as a typical rain gauge. The tipping bucket sensor's ability to make obtaining information on the rain easy is one of its advantages.

A water level sensor helps in the computation of water discharge and is used to find out the water level. If the rainfall and water discharge remain the same, but the water level continues to rise, this indicates that siltation is taking place in the channel. GTL500TM piezo-resistive sensors are the kind of level sensors that were used in this particular application. This sensor stands out thanks to its unique construction and application [21]. It has a great degree of precision. It finds widespread application in projects including the monitoring of coastlines, the treatment of sewage, the irrigation of water-saving crops, and other similar endeavors.

The quantity of water discharge can be calculated by multiply the velocity of the water flow, or V, by the area of the wet cross section (A). A current meter is used to measure the speed at which the water is flowing. When calculating the wet cross section area, the hydraulic formula is used. There are three distinct shapes that can be used for the cross section of a drainage channel: trapezoidal, rectangular, and circle. Because it has the figure of a normal channel, the trapezoid shape is frequently used for irrigation or drainage channels. This is possible because the incline of the edge can be utilized to change the angle of the normal slope of the land that is used for the channel. The narrow land was bisected by a drainage channel that was in the shape of a rectangle. At intersections, you'll frequently see people using circles (Chairil 2013). Figure 3 demonstrates the calculation that must be used to determine the wet cross sectional area. The high variable that was received from the water level sensor result (represented by the letter 'y' in rectangular and trapezoid types and the letter 'd' in circle types).

Qd =Vf x Aw---------- (1)

Qd = water discharge (m3 /s)

Vf = flow of water (m/s)

Aw =area of wet cross section (m2)

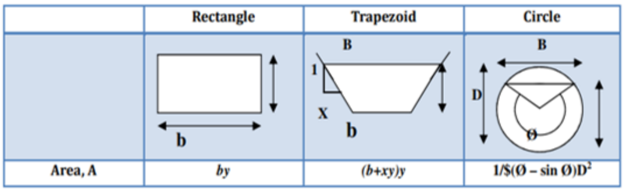

Fig 3. Wet cross sectional area calculation formula

4.2 Node sensor and gateway hardware

A sensor unit, signal conditioning, processor, Real Time Clock (RTC), SD cards, Radio Frequency (RF) modules, and supply units are among the hardware elements of the node sensor. Figure 4 presents a block diagram of the SN's for your viewing pleasure. The microcontroller ATMega 128 was chosen to serve as the processor. The ease of usage, reduced power or energy consumption, and cost effectiveness of using an ATMega 128 are all factors to consider. X-BeeTM was the brand of RF modulator that was utilized. This module has a low power need and ensures that data may be delivered between faraway devices in a reliable manner. The modules function inside the 2.4GHz frequency spectrum that is designated for ISM (Industrial, Scientific, and Medical).

According to Figure 4, the output of the rainfall sensor, the water discharge sensor, and the water level sensor were conditioned to serve as a standard input signal for the microcontroller. The microcontroller's built-in analog-to-digital converter (ADC) will receive the output of the signal conditioning process as an input. The RTC determines the time at which data is collected, the SD card is used to temporarily store the data, and the RF Module (X-BeeTM) is responsible for transmitting the data to the other SN's. The sensor node can receive its power from the supply unit in the form of either a battery or a solar cell [22].

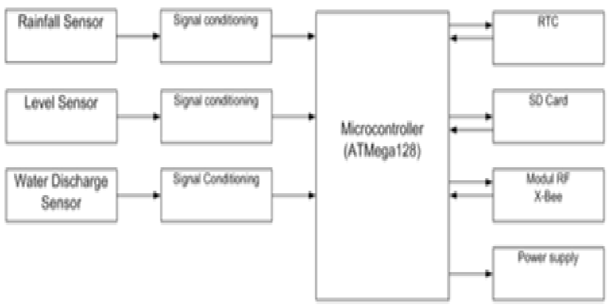

Fig 4. Sensor Node block diagram

The gateway is a special kind of sensor node that has additional capabilities, including the ability to relay data to a server. GSM, which stands for "Global System for Mobile Communication," is the connection mode that was employed for this design's communications. GSM modem is the component that we employed in our system. Figure 5 presents a block diagram of gateways for your perusal.

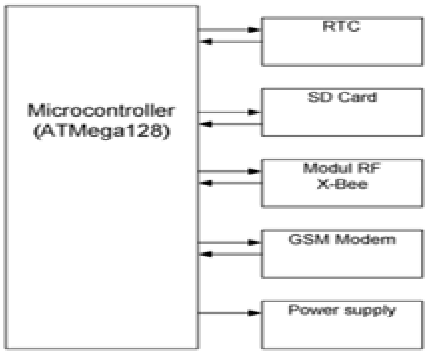

Fig 5. Gateway Block Diagram

4.3 SN's' Layout

It has been clarified that the location SN's are required to accurately portray the drainage conditions. Figure 6 provides an illustration of one possible configuration for the placement of the SN's. Catchment area needs to be established based on the geography of the area (zone rainwater). There are three catchment areas displayed here. In addition, the direction of the drainage is established as demonstrated in the picture. There are three channels in the drainage system. These are the tertiary channel, the less important channel, and the major channel. The tertiary channel and secondary channel both receive the rainwater from the catchment area's drainage system. Rainwater travels through the less important channel, the primary channel, and finally the tertiary channel. Rainwater enters the sewer after flowing from the secondary channel into the primary channel. [23].

Fig 6. Condition of Drainage Channels and Topography

At particular points in each of the different types of channels, the installation of sensors to measure water output and water level will take place. In the meantime, rainfall sensors are going to be installed all around the tertiary channels in order to figure out how much rain water falls in that area. Figure 7 provides a visual representation of the node sensor arrangement.

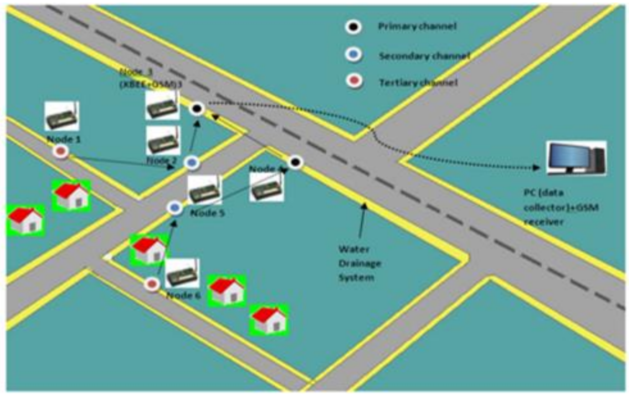

Fig 7. Node sensor layout

There are a total of six node sensors seen in Figure 7; those that are near to one another will communicate with one another. Where as the sensor node number 3 also serves as the gateway. The data collected by SN's will be sent to the sensor node that is geographically nearest to them in order to be relayed to other SN's that double as gateways. In addition to this, the data will be transmitted to the server by the gateway. The server will receive information regarding the water level, the water output, and the rainfall for each region [24]. The data that was recorded will be saved into a database, and the Geographical Information System will be used to show the data (GIS).

4.4 General Design of Data base System

The database that is being developed for this research will be utilized to handle data for drainage monitoring. This drainage data management system's primary objective is to determine the specific drainage issues that exist in each region. Therefore, the method makes it easier for the monitoring crew to make observations and keep records regarding the drainage conditions in each region. The management of these data will involve a number of activities, which will be broken down into many stages based on the activity of developing software (SDLC - Software Development Life Cycle). The following are the stages:

4.4.1 Planning / Requirements

At this point in the process, the activity consists of obtaining the information and data that is required to determine the specification business rule and the business process. During this phase of the project, data will be collected using several methods, including interviews and observations of system users.

4.4.2 Analysis and Design

This stage's activity consists of analyzing all of the information, data, and big business procedures that were the output of the stage preceding it. Determine the items or entity, attributes, and relations that must be handled in the drainage system in order to complete the analysis. Then, to explore the viability of putting the system into operation, we conducted data modeling using entity relationship diagram design (ERD). The ease of accessing and saving data in the database can be affected positively by having a good ERD.

4.4.3 Implementation

A particular DBMS, such as SQL Server or Oracle Database, will be used to implement the data that was generated in a previous stage of the modeling process after it has been turned into the form of a table. This stage of the modeling process is known as the implementation stage. Figure 8 provides a visual representation of the current stage reached in the process of developing the drainage database system.

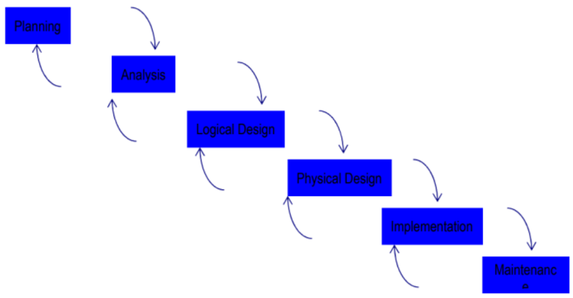

Fig 8. Development of a database

This information about drainage systems will be presented in a graphical information system format (GIS). In particular, the GIS software is composed of three primary stages, which are referred to as the input, the process, and the analysis [25]. One of the GIS's sources of information will be the data that is maintained by the database drainage. Figure 9 provides a visual representation of the phase in the GIS development activities.

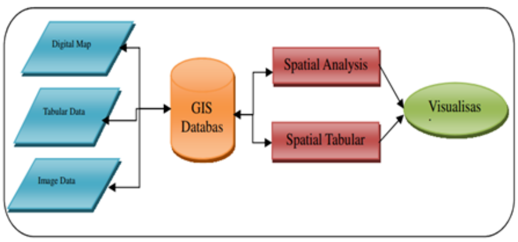

Fig 9. Development GIS Activity

Input into the development process of a GIS that takes the form of tabular data includes information regarding drainage systems that will be controlled by a database management system (DBMS). Therefore, in general, the following is a explanation of each of these data:

1. Digital Map: Information for GIS maps, including a road network map, an administrative region map, and a drainage system map.

2. Tabular Data: Tabular data examples include information on the volume and density of population, administrative boundaries, geology and topography of the region, rain, water height, and water loss. Tabular data also includes information about water level and water release.

3. Data Image is used to complement the data by providing additional information, such as photographs of the location of the building, photo-gates, and other important objects.

5. Conclusion

A WSN is a system that communicates among numerous SN's that have been placed in different places. Each individual sensor node is built using a sensor unit, a communication unit, and a power unit. The process of designing a wireless sensor network-based drainage monitoring system involves numerous steps. Among these steps are the creation of a sensor node, a communication device, a layout for the SNs, and a database system.

The main parts of SN are are the sensors unit, the processor, the RTC (Real time Clock), the SD cards, the wireless communication unit, and the supply units. Rainfall sensors, water level sensors, and water discharge sensors are the types of sensors that are utilized in drainage monitoring systems. Through the use of the Radio Frequency module, node sensors can communicate with one another (XBeeTM). GSM module is used for communication between the gateway and the server. The data that was recorded will be saved into a database, and the Geographical Information System will be used to show the data (GIS).

When planning the layout of the SN's, there are several factors to take into account. The location of the SNs must accurately reflect drainage conditions. The distance between any two SNs must be within the communication range of the radio frequency module being used. The connections between any two SNs must be made as close to the SNs as is practical in order to minimize delay and noise.

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