An IoT-Based Mechanism for Monitoring Dam Structures

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Abstract: Large dams are crucial, especially given how they generate power, but their hazards must also be carefully considered. To utilize them for dam supervisory purposes, compiling facts regarding dam infrastructure is necessary. On the basis of current technologies, a computerized system has been designed that enables the use of IoT for the safety monitoring of dams and mega hydropower projects. The purpose of the study is also to discuss potential IoT applications within a particular dam's security surveillance tools. A novel data collection module for communication with sensors in the monitoring network is designed to make it easier to integrate many intelligent sensors. So that when security parameters depart beyond anticipated levels, the technology should promptly warn the relevant authority to take necessary actions. The danger of a significant breakdown of the dam is decreased by the deployment of infrastructure for controlling and tracking dam security as well as new technologies.

Key words: IoT, Dams Monitoring, Safety Monitoring, Thermal Analysis, Internet of Things

1. Introduction

The outdated state of the structure dam increases the risk associated with safety; thus, supervision and ability of the safety must be strengthened to take potential bad scenarios into account quickly[1]. The Dams are utilized to generate energy and provide water, these infrastructures are extremely crucial to civilization. Dams may help with river transportation as well as controlling floods and the water supply for towns[2]; numerous dams serve several purposes and offer several of the aforementioned advantages. Their destruction or potential impairment could have detrimental effects on their surroundings[3]. Connectivity must be established between monitoring systems and computer simulations in order to enable the administration of the hydroelectric plants' intricate systems. As a result of competing demands from many researchers (hydropower, agriculture, etc.) for extremely limited resources, managing water resources is complicated. Dam security operations are a lengthy, ongoing process that has to be continually improved. In this regard, techniques and procedures for managing dam protection must always be upgraded in complete extents, including measurement decision-making regarding tools as well as the administration and application of data in safety facility selection measures[4]. In order to enable functional findings on the condition of the dam's safety nearly every day, a contemporary system for managing dam safety ought to be built. This system shouldn't basically give operational information regarding comprehensive dam protection in real time[5]. Following just a couple of months or even over a year of continuous operation, the entire idea of technological monitoring which was previously based on the production of regular reports on the dam's operation loses a considerable amount of its value. The physical infrastructure and software-supported technical system should serve as the foundation for the contemporary idea of dam safety management. The physical basis for this idea is the supply of critical information critical to the dam's safety and the precise dimension of pertinent corporeal parameters that remain in the direction of are monitored on the dam using connected devices intended for technological surveillance. Modern information and communication network infrastructure makes it possible to use cutting-edge technology for data measurement, collection, and archiving. In order to make available handlers through information in a coherent and effective method, these types of systems require being equipped to autonomously collect surveillance data, undertake verification of the information, and permanently preserve the information[6]. A database that was created using trustworthy instruments might be produced with long-term instrument operation monitoring. Implementing and utilizing IoT (Internet of Things) on dams allows the development of records of trustworthy devices that can provide an additional accurate assessment of the protection of the dam[7].

One of the crucial steps in ensuring a dam's safety is to monitor its real-time monitoring; this is a crucial and essential task for maintaining and operating the dam[4]. The safety of dams is closely monitored by computer software. To make data administration and analysis easier, Data maintenance surveillance methods for dam security surveillance have been developed by numerous dam administrators. It is challenging to handle security information for dams since they are all situated in isolated rural locations; so every last bit of the data can be properly ingested, investigated, and evaluated before making choices regarding the overall security state of the dam[8]. It is essential to develop a computerized system for controlling from afar the surveillance system and collecting and sending dam security surveillance statistics. Due to aging, earthquakes, and unusual climate changes, it's possible to see an increase in damages and dam failures recently[9]. The security of the structures such as dams has grown more and more important for nationwide disaster mitigation as a result of such causes. In this regard, different organizations are working for protecting dams are the International Commission on Large Dams, Committee on Dam Safety and Dam Security, Association of State Dam Safety Officials, Interagency Committee on Dam Safety, National Dam Safety Review Board, and the Dam Safety Interest Group[10]. Implementing real-time assessment and a conservative assessment of dam safety based on pattern monitoring are crucial for the successful control of the dam life cycle. The creation of Intelligent Early Warning Systems of Dam Safety (IEWSDS) is a crucial strategy for achieving this objective[11]. In order to create a bionic model of safe dams, Huai-Zhi Su et al. viewed the dam as a living, thinking system; the nerve (observations), the brain (central processing units), and the body (tools for making decisions)[12]. To increase the protection of residue dams, the supervision and pre-alarm mechanism; The Tailings Dam Monitoring and Pre-Alarm System (TDMPAS) has been carried out[13]. It depends on the utilization of IoT as well as cloud computing and has the capacity to observe line saturation is reached, the state of the water, and the deterioration of the reservoir in instantaneously.

There have been several published papers on IoT applications in observation systems. The researchers discuss a real-time localization arrangement to facilitate safe control over dam building locations[14]. The creation of intelligent power systems is intimately related to the establishment and growth of IoT. IIS (Integrated Information System) is becoming more significant as a result of the recent focus on climate change, environmental management, and control[15]. The study demonstrates how the IIS significantly aided the study's data collection efforts using IoT, as well as the usage of network facilities and suggestions grounded on the cloud (Cloud) platform and e-science. It also demonstrates how the IIS considerably aided the study's data collection efforts using IoT[16].

The IoT is an interconnected system of corporeal things with embedded software, electronic components, and devices that enables operators to access real-time and precise information over facilities used for sharing statistics among producers, customers, or else more devices that are connected[17]. Users may be able to react appropriately and on cue in the event of emergencies or natural catastrophes and, in certain circumstances, foresee outcomes with the use of accurate information. The main aim of this study is to deliberate potential IoT applications inside a particular dam safety management system. With the use of the cloud and WSNs (Wireless sensor networks), the data collection system is intended to be improved. The Internet's cloud service would be used for all data processing in order to free up the capabilities of computers. WSNs are capable to make available more trustworthy information.

2. IoT based Safety Monitoring of Dams

The majority of dams feature technological surveillance equipment, which is crucial for controlling and tracking the condition of the infrastructure[18]. Most of these systems were installed while the structures were being built. The system to monitor dams using IoT has begun to be rebuilt in recent years. There will undoubtedly be important developments in relation to these topics in the near future. This system ought to permit continuous automatic measurement and record-keeping of information from measurements over a specified period of time. The prospects for a further comprehensive examination of the state and behaviour of the services throughout procedure, which is a crucial component of an understanding of dam security management, will be made possible by an increase in the amount of data that has been collected[19]. This analysis will allow for a detailed description of the inclination in the conduct of the dam and ought to present a chance for initial acquaintance of any potential irregularities in the condition of the dam. The condition of the surveillance system may be rated as somewhat adequate for the numerous dams. This indicates that while it is feasible to assess the facilities' status based on all available observational data, action must be taken to strengthen the surveillance circumstances. A more precise diagnosis of the system's condition may result from the adoption of a new, modern surveillance system. The creation of a dam safety administration system necessitates the establishment of a sophisticated technological monitoring system and, consequently, an engineering surveillance data management system[20]. It is feasible to create a collection of numerical and computational representations grounded on the field of quantum mechanics, as well as the subsequent measured tools for security control the condition and investigation of dam protection, by depending on modern electronic surveillance systems as an alternative source of reliable information. Monitoring and tracking behaviour is a process that is dependent on statistical models that have been developed and are grounded on measurable participations that can offer the predicted quantity of a variable[21]. If the restrained quantity differs between the permitted and anticipated ranges, it may be concluded that there have been no significant adjustments to the system. This procedure is automated in today's systems and has a concerning function in the situation that measures-based conclusions were made about the building not acting as one would anticipate. This warning indicates a unique security measure is in place and should be checked. By observing how the capability behaves in a variety of circumstances, or situations that are relevant from the perspective of dam security, it is possible to assess the state of the facility and the degree of safety[22]. This inspection is carried out routinely following the end of a predetermined time or in exceptional circumstances because the technological monitoring system and the use of numerical representations have revealed that the capability is acting another way than it should. Considering that it is impossible to a preceding fully describe uniformity and the true features of the material when analysing the state of complicated real-world items and that there are many different determining measures of the state of the capability, it is essential to establish the process of assimilating the processes of real examinations in order to determine the current state of all parameters. In practice, adjustments of the system's material properties (such as elastic modules, filtration coefficient, etc.) are carried out by taking assessments of pertinent tangible quantities so that the calculated numbers may be more accurately compared to the observed ones. Recognition of the area where modifications have taken place is possible in this way. Only with the most current version is it able to do safety evaluations, and depending on the assessments, it is possible to choose which actions should be performed to increase the dam's reliability. Throughout the entire life cycle of the dam, dam safety administration is ongoing and apparent in the use of organisations that facilitate it[23].

The computerized arrangement used to assist the dam in managing its security, was created using the concepts of SOA (Service Oriented Architecture), that allows for the expansion of the structure and connectivity with additional databases in addition to real-time data utilization[24]. Commercially accessible technologies were utilized to build this system, including Web services, SQL, .NET Framework, and ADO.NET to link the records. The subsequent graphic depicts the system's configuration. The following are the components of a software system: System interface for technical monitoring; the number of numerical investigation modules; Numeric component for outward outflow modelling; Numerical modules for data assimilation and stress-strain analysis.

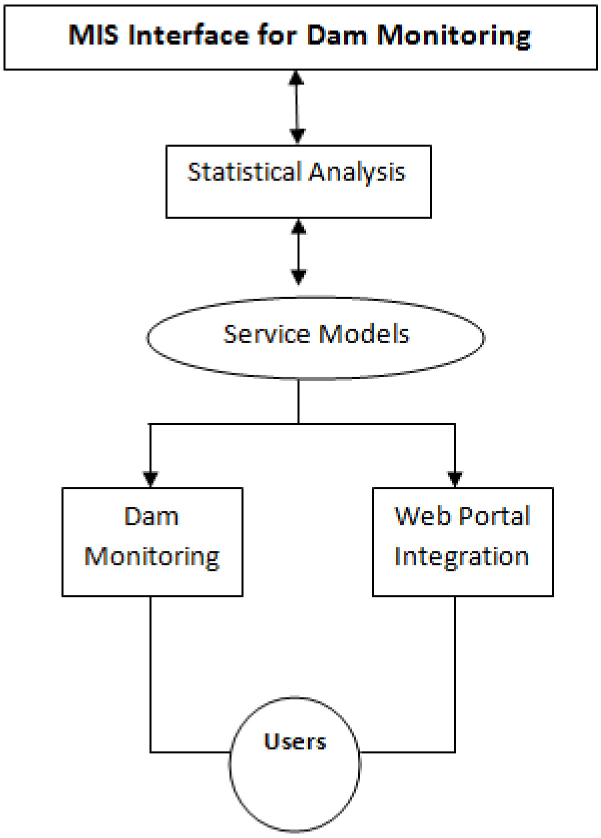

Fig.1.MIS Interface for Dam Monitoring

From figure number 1, users may view existing quantities (capacities in real time) as well as an estimate of the dam's present status using applications that are an essential component of the solution.

3. IoT Based Information Transmission Method

The many sensors used in dams include precipitation measures, water level measures, flow meters, rainfall meters, etc. This equipment must be connected to a single network and allowed to interact with one another in order to enhance dam surveillance. Interaction among sensors is crucial since there are so many distinct types of equipment. Wireless sensor networks (WSNs) and SensorML can be used to do this[25].

Sensor model language: Utilizing common internet services and conceptual frameworks, the objective is to make every kind of equipment identifiable and readily available. If interconnections can be overlaid with Web and Internet protocols, a standard XML serialization approach may be utilized for metadata defining sensors, sensor platforms, and interfaces for instrument entrusting along with information obtained from sensors[26]. A sensor's manufacturer can provide immediate proximity by releasing XML description of its administration interface, allowing it feasible to identify the sensor, obtain real-time or recorded tracking information, find out more concerning the device's surveillance competence, as well as request particular surveillance operations. The Sensor Web Enablement (SWE) standards serve as the basis for communication with sensors, actuators, and processors whose position matters[27]. They are open specifications built around accessible, especially widely recognized protocols for connectivity to the Web and for geographical positioning; they are a crucial IoT facilitator. The Wireless SensorML encourages the worldwide IoT and WoT (Web of Things) through providing the capacity to articulate the properties of a device's sensor (or other internet-based analysing component) and by offering the amount of link to immediate data that is generated by this portion of the system[27]. The sensor data needed for detector tracking, processing, and finding is provided by the SensorML, a head element. On the website http://www.sensorml.com/sensorML-2.0/examples/iotSimple.html, an illustration of a sensor providing a straightforward data stream is provided. It combines a straightforward sensor with the IoT. The researchers of this research suggest using a Web service to obtain sensor information. Web customer support's responsibilities include sending and storing real data in the centralized database in addition to acquiring it. The software that was covered in the preceding section is used by the end user to access the internet-based service. All types of sensors can be used with the Web service.

Wireless Sensor Network: Sensor networks that are wireless (WSNs) have become widely used and developed as a result of the continuous advancement of innovations, low cost technologies with implanted wireless transmitters, and low-power and efficient processors. WSN can easily interface with current wired monitoring and control systems. To reduce the use of electricity, the system's ensemble design, which benefits from multi-hop and clustering, is used. A computer control centre, as well as a number of smart nodes, passageways, or drop nodes, makes up wireless network of sensors. Intelligent networks collaborate on sharing sensor data, which is then delivered to a decentralized or centralized system for statistics that might be local or on the cloud. CWSM (Complex Wireless Sensors Model)[4] and WDSN (WSN used on dams)[28], are made up of sensor nodes and gateway nodes. The sensor nodes gather information on the dam's sections' water levels, shifts, stresses, and leaks, as well as their temperatures, rainfall, seepage, and displacement. This information is then transmitted to the server for the database via the access point nodes.

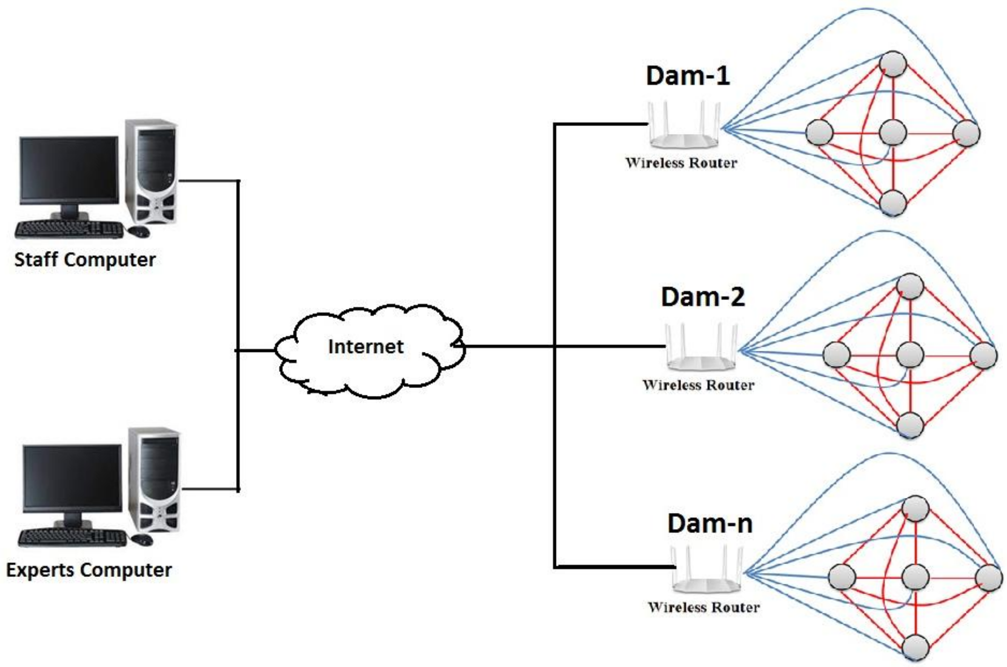

Fig.2. Internal and External Networking of Connected Dams

From figure number 2, every single one of the groupings, which make up the entirety of the system, serves as a surveillance region. Each cluster's nodes of wireless sensors can connect with one another and provide data to the gateway over multiple hops. Additionally, each of the gateways has the ability to speak with one another and send information to the fall away.

Facilities for transmission: It is important to build up particular services to interact with measuring systems for computerized measures that are not part of the information system and might offer data to users independently of the system[29]. Direct access to information is not advised due to the specific needs for the measuring system's dependability. These services handle the collection of local data and its transmission to be reviewed and authenticated. The data gathering module, which is directly related to measurement devices, is crucial to the structure of service communication. The application gathers knowledge from many different places, formats it according to an accepted, and then sends it to an outside organization for analysis and verification. The software elements for collecting measurements are separated into elements that enable interaction with passive detectors, elements for interactions with influential sensors, elements for interactions with a passively collecting data logger, elements for interaction with an active data logger, and elements for storing the data comprised in the development based on the number and type of measuring systems that must exchange data. For gathering data, each of these elements needs to utilize the proper interaction modules. Even though the quantity of these natures of mechanisms is determined by the conformation for evaluating arrangements, the number of elements of a single kind is only constrained by computing resources. Accordingly, not each aspect needs to be included in the actual setting up of the services in question on an object; instead, it can be accomplished to include more elements when configuring an extension to be used[30].

4. Mechanism for Sensor Errors Identification

Individual sensor cancellation risk naturally increases over the duration of a dam sensor's lifespan, so the safekeeping assessment of the dam ought to not be conducted without taking assessments from these instruments into consideration. As a result, the adaptive method for identifying sensor failure must be used in order to use the IoT for tracking and dam safety supervision[31]. The algorithm should promptly indicate which extents are absent, i.e., despite which device, the organization's safety cannot be determined. The link connecting the adaptive framework for simulating the behaviour of the dam and the gathering component for interacting with instruments in the assessment system is represented by an approach for malfunction identification of sensors that is appropriate for use in IoT. Understanding the actions of the dam may be done in a variety of ways. The first models were constructed using statistical and numerical techniques. The implementation of novel approaches such as artificial neuronic systems[32], heritable procedures[33], and adaptive neuro-fuzzy organisations[34] has been made possible by the advent of intelligent machines. The most acceptable adaptive models for use with the IoT are those that deliver findings instantly; provides a description of one such It is a combination of techniques that integrates statistical models and genetic algorithms in order to simulate the anticipated dam behaviour. The generalized linear regression model, which is responsive to changes in the parameter values, serves as the system's theoretical foundation. Due to this, a system's adaptive component is included, with biological algorithms serving as its foundation. According to the notion of genetic computations, each regression model reflects a single organism throughout the overall population, making the framework of linear regression a question of optimization. In the event that variables differ from the predicted values, alerting is carried out. Regression analysis model results indicate the parameters on the basis of which the dam's current status is evaluated. Given that the regression model is built using the system's available measurements, as was previously mentioned, it is crucial to include information about the measurements that are currently accessible within the framework as well as the condition of the sensors[35]. In the case of insufficient measurements, this may put the validity of the regression model's findings in danger. The use of computing resources in the cloud and the usage of gathered data in sophisticated computational models (such as FEM) will be the focus of future research.

4.1 Finite Element Method (FEM)

The finite element technique (FEM) is utilized to describe the emphasis-deformation and filtration processes on the dam. FEM may use the local rock mass to create a physical model of the structure[36]. It is important to replicate a certain phenomenon that took place at the dam when it was in operation in order for this model to match the genuine model of a dam. FEM gives data on an accurate representation of the dam, resulting in could assist in monitoring the object's functioning to attempt to anticipate expected adverse conditions in future detrimental manners. A test for verification of the material properties is performed using the findings from scientific monitoring[37]. Following figure number 3 is an illustration of FEM;

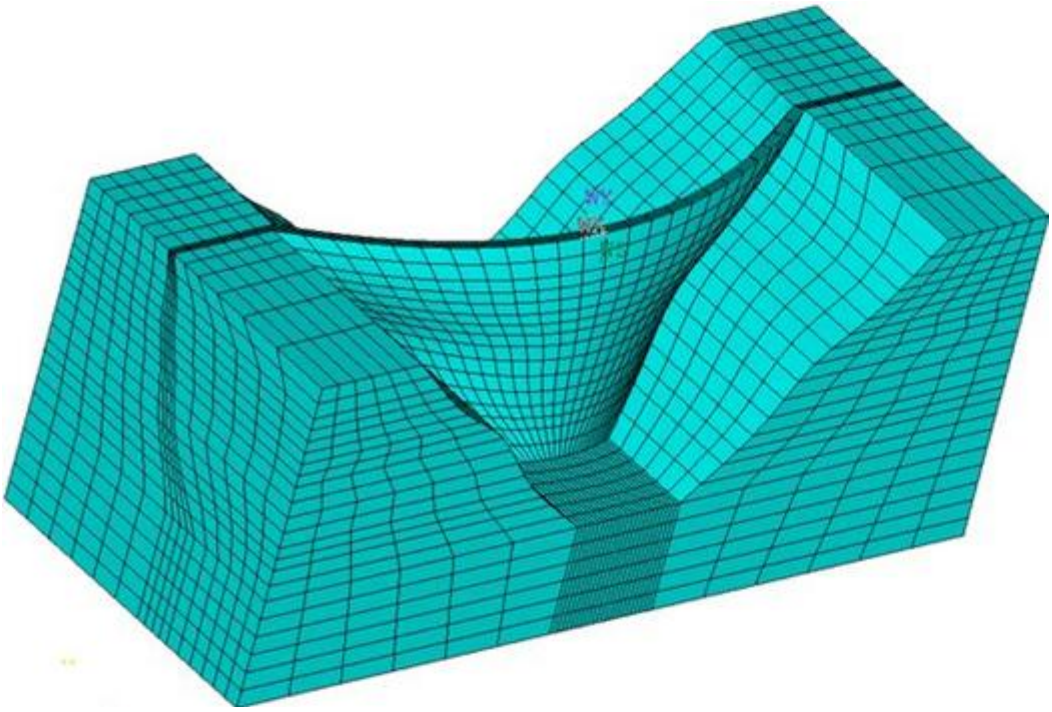

Fig.3. Illustration of FEM analysis of Dam Body

It is necessary to construct a computerized module for the integration of measured data in order to perform safety analysis over the current circumstances practice. The aforementioned module should make it possible to assimilate measurements or compute the most recent values for the variables of the FEM model using the data that has been collected from the technical surveillance information system. The mathematical optimization techniques needed for the integration of observations and automatic interaction with the mathematical modules make up the module's core[38]. The actual state of structure is described by the settings of the individual substance algorithms that make up the FEM model.

4.2 Use of Cloud Computing and Mining Big Data

Every single one of the things in our immediate environment is considered to be a part of the IoT[39]. IoT has very broad range of smart devices that it covers, including phones with GPS, digital cameras, smart rain gauges, outdoor sensors for temperature, and many other kinds of sensors[40]. These gadgets offer considerably more sophisticated procedures and services that can be applied in many different sectors when they are all connected. A huge number of sensors and equipment installed on dams that are linked to the Internet offer a wide range of amenities and generate a lot of data, know as big data. A concept for streaming services Utilization of a pool of reconfigurable resources (such as funds, networks, servers, storage, applications, services, and software) known as cloud computing may quickly offer the necessary infrastructure, software, and apps[41]. Technologies built on the cloud enable us to make connections to the objects around us so that we may access them whenever and from anywhere because the cloud serves as an obverse conclusion to the IoT. The dam's protection is the primary objective of the actual construction. Less work ought to be placed on workstations with limited capabilities; therefore, activities ought to be transferred to the web-server. Additionally, the dam safety technique's reliability and dependability need to be raised. The information stream on or after the tool being used to the end consumer is depicted in the image. The data logger momentarily stores the measured data. Each data logger has its own software that is placed on the acquisition server for downloading data. Comma Separated Values (CSV) is the format used for the obtained data[42]. Data is sent from the procurement attendant to the fundamental server. Software-specific tools are used by end users to examine data. The installed program on the end user's computer utilizes PC resources rather than server resources. Processes may need a significant amount of computational power if they are sophisticated.

Data from the acquisition servers is delivered in its entirety to the main cloud server. The cloud is used for every data translation and processing operation as shown in figure number 4. The procedure described above is known as ETL (Extract, Load and Transfer). The server's capabilities are used by every function. Only the end-user computer functions with ready-made report information and lot freer assets for additional activities.

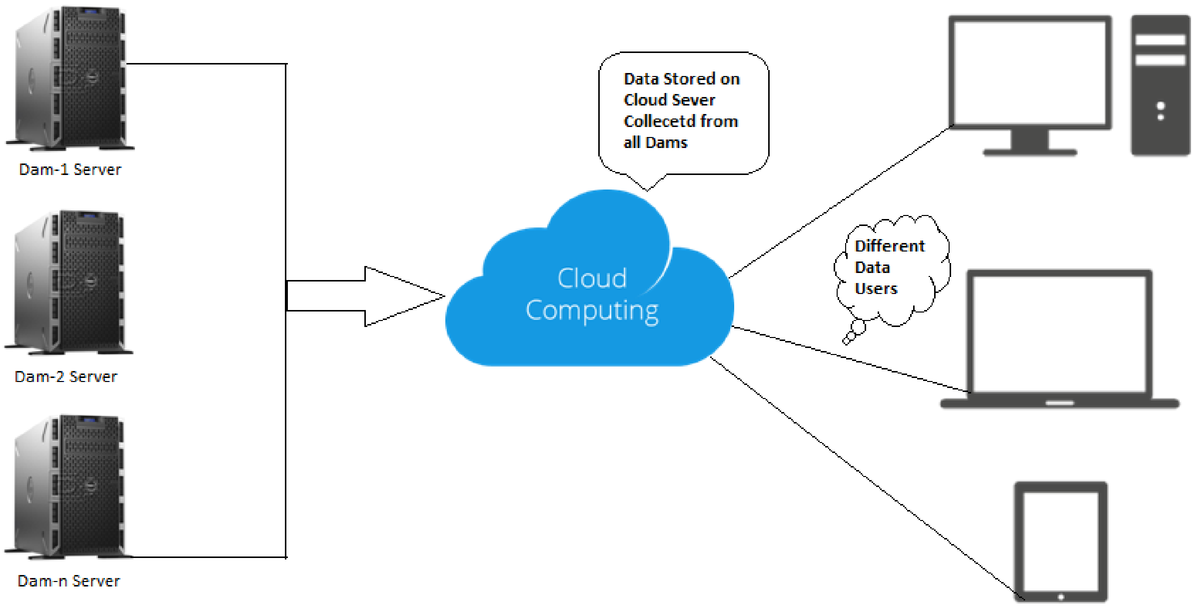

Fig.4. IoT based Cloud Computing and Big Data Model for Dams Monitoring

All devices, including rain devices, water level devices, flow meters, rainfall meters, etc, can be used with a new system. All types of dams can benefit from this new system. On a server located in the cloud, an SQL database is used to store all received data. The new approach gives the relational database more trustworthy data, allowing for improved analyses and reporting.

5. Conclusion

The investigators of the present research provide an illustration of how modern techniques like the Internet of Things, SensorML, and wireless networked sensors may be used in conjunction with dam security administration computer software. The fusion of these advances in technology and algorithms enhances the efficiency of dams. Collectively, sensors that are available, a computer system, and technology for networks are developing since there is an increasing need for means of integrating IT infrastructure with the outside world. Integration is providing novel approaches for plant safety, manufacturing regulations, weather prediction, and geotechnical engineering surveys, flood surveillance, risk assessment, threat tracking, ecological surveillance, protection, logistics administration, and numerous additional uses by fusing multiple technologies in this productive, competitive marketplace. By linking devices to the Internet, a form of technology known as the "Internet of Things" enables them to develop intelligence. This makes it possible for sensors to talk to each other. The use of IoT in contemporary companies greatly enhances organizational efficiency. The use of IoT on dams would enable additional effective recording of malfunctioning devices, thereby lowering the likelihood of harm. It is feasible to create a database of instrument reliability that directly demonstrates the dependability of dams using the information gathered about failed sensors. Cloud technology, which is gaining traction as part of the Internet of Things, may make it possible to store massive amounts of data online. End users possibly will get the information from any location at any time with cloud computing. Since all data processing would take place in the cloud, the system for collecting data would operate much more quickly and consistently. Utilizing cutting-edge technologies like big data, cloud computing, and IoT will enhance dams' functionality and dramatically decrease the likelihood of disaster. The danger of a significant breakdown of the dam is decreased by the deployment of an infrastructure for controlling and tracking dam security as well as new technologies.

Competing Interests: The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Ethical Issues: There are no ethical issues. All data in this paper is publicly available.

Author Contribution Statement: Z.Y and J.A conceived idea and designed the research; Analyzed interpreted the data and wrote the paper

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