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USING INTERNET OF THINGS IN MONITORING AND MANAGEMENT OF DAMS IN SERBIA

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Abstract. *This paper discusses harnessing Internet of Things in monitoring and managing dams in Republic of Serbia. Large dams are of major importance, primarily because of their use for electricity, but risks which are associated with it should be greatly taken into account. There is a need to consolidate information related to dam facilities in order to use them for dam management in the Republic of Serbia. An information system has been developed based on the existing systems, allowing utilization of intelligent network sensors. The aim of the paper is to describe possibilities of the Internet of Things application within a specific system for dam safety management. In order to facilitate the inclusion of a large number of intelligent sensors, a new data acquisition module for communication with sensors in the monitoring network is defined. The system should provide on time alerting in case security parameters deviate from the expected values.*

Key words: *Internet of Things, cloud, dams, dam safety management, monitoring, Serbia*

1. INTRODUCTION

Most of the dams in Serbia were built in the sixties and seventies of 20th century. The risk for security increases with the age of the building, which is why management and security of the facility has to be improved in order to timely consider possible negative situations [1].

It should be noted that these facilities are of vital importance for society, because they are used to produce electricity and water supply. Dams also provide water supply to cities, flood control, and can assist river navigation. Many dams are multipurpose, providing more than one of the above benefits. Their damage or possible demolition can cause serious consequences to the environment.

In order to provide support for the management of complex systems of hydro power plants, it is necessary to establish communication between metering systems and computer models. The complexity of the management of water resources is due to the conflicting demands of different users (hydropower, agriculture, etc.) for limited resources, and this

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complexity increases in extreme weather conditions, such as droughts and floods, which are reflected in populated areas.

Dam safety management is a long-term and continuous process that has to be improved permanently [2] [3] [4]. In this respect, procedures and processes of dam safety management must continually be improved in all aspects, both in terms of measuring equipment, as well as in the management and use of data in the procedures for determining safety facilities. A modern system for dam safety management should be established, so that it primarily provides operational status of monitoring dam safety in real time and to enable operational conclusion on the status of the dam safety practically on a daily basis. The whole concept of technical monitoring, with a posteriori reasoning after a few months, or even more than a year, loses much of its meaning and importance (the past practice was based on the preparation of periodic reports on the behavior of the dam).

The modern concept of dam safety management should be based on the physically based and software-supported technical system [5] [6]. The physical foundation of this concept relates to the provision of data of importance to the safety of the dam and the accurate measurement of relevant physical quantities, which are to be tracked on the dam with installed equipment for technical monitoring. Today's level of information and telecommunication infrastructure enables implementation of the advanced systems for measuring, acquisition and archiving data. These systems should be able to automatically collect monitoring data, to perform data validation and to securely archive them as to provide users with data in unified and efficient manner.

With long-term monitoring of the instruments operation, database obtained by reliable instruments could be formed. Implementation and use of IoT on dams enables creation of databases of reliable instruments which can give more precise evaluation of the dam safety.

Internet of Things (IoT) is a network of physical objects in which electronics are incorporated, as well as software and sensors that allow users to obtain timely and accurate data through services for data exchange between manufacturers, users or other connected devices [7]. Reliable data could enable users to react in the right way at the right time, in case of critical situations or natural disasters and in some cases to predict events.

The aim of paper is to describe possibilities of the Internet of Things application within a specific system for dam safety management. The idea is to improve the system of data collection with the implementation of cloud and WSN. All data processing would be moved to cloud to free up computer resources. WSN would provide more reliable data.

2. Literature Review

2.1. Dam safety management

Observing the safety of dams is one of important measures to ensure the safety of the dam [8]. This is an important and indispensable activity in the work and management of the dam. Computer software plays a vital role in monitoring the safety of dams. Many dam owners have developed information systems for the dam safety management supervision to facilitate management and analysis of data. Fujian Electric Power Company in east China has 27 different types of dam: concrete, earth, arch and embankment dams. All these dams are deployed in remote rural areas, making it difficult to manage security information for all dams. It is therefore important to develop an information system for remote control of the monitoring system, to collect and to transfer dam safety monitoring data so that all this information can be processed, analyzed and evaluated to effectively adopt the decision on the status of the dam safety. Fortunately, such a remote information system was successfully developed jointly by all the participants in the business. It was applied to a group of dams of Fujian Electric Power Company, where the staff can use the system for analysis and evaluation of data observations.

Lately, it is possible to see an increase in damages and failures on the dams due to aging, earthquakes and unusual changes in climate [9]. For these reasons, the safety of the dams is gaining in importance every day in terms of disaster management at the national level. In the world there are numerous organizations that are responsible for the dam safety, and some of them are: The International Commission on Large Dams (ICOLD), Committee on Dam Safety and Dam Security (CODSS), Association of State Dam Safety Officials (ASDSO), the Interagency Committee on Dam Safety (ICODS), The National Dam Safety Review Board (NDSRB) and Dam Safety Interest Group (DSIG). Kwater (Korea Water Resource Corporation) which currently runs and manages 30 large dams developed a system for dam safety (KDSMS). This system is used in a consistent and efficient management of dam safety. KDSMS consists of data for a dam and reservoir, hydrological information system, management system for the area of control and data, system of instruments and observations including the monitoring of earthquakes, a system for improving research and security and information system of corporation.

For effective control of dam life cycle, it is very important to implement the diagnosis in real time and a reasonable estimate of dam safety based on the prototype observation [10]. The development of IEWSDS (Intelligent early-warning systems of dam safety) is an important approach for the realization of this goal. Huai-Zhi Su et al. observed the dam as a vital and intelligent system and constructed a bionic model of safe dams, which consists of a system of observations (nerve), central processing units (big brain), and tools for decision-making (the body). With the above-described model and system engineering, the authors have designed IEWSDS. Intelligent machine that performs reasoning is the central processing unit of the system IEWSDS, it performs data analysis, and applies the algorithm of diagnosis and assessment of the safety of dams. Because of the persistent non-linear and dynamic characteristics, the system has adopted a combined model based on a wavy network to exert approximation and prediction of behavior of the dam. The security status of the dam is changing dynamically, requiring qualitative and quantitative change in behavior. Huai-Zhi Su et al. in the paper propose an expanded method of assessment [10]. The application shows that the bionic model is possible and suggests key technology operation. Systems can provide technical support to improve dam safety management, prolonging the life of dams and avoiding accidents.

Disposal of tailings is of great importance for mining, because the processing of ores produces a large amount of tailings [11]. In the past few years there have been a catastrophic accident at the tailings dam and tailings mines, which have caused enormous damage and great human losses. To improve security of tailings dams, the control and pre-alarm system TDMPAS (The Tailings Dam Monitoring and Pre-Alarm System) is introduced for monitoring tailings dams, which are based on the use of IoT and the cloud with the ability to monitor line saturation, the water level and the deformation of the dam in real time. TDMPAS helped engineers in the mines to monitor the dam 24/7 and automatically receive pre-alarm information from remote locations in any weather conditions. TDMPAS was applied at several mines and showed that the application in the monitoring of the physical condition of the tailings dam was justified.

2.2. The application of IoT

Numerous works related to IoT application in system for observing have been published. For instance in the [12] authors deal with the localization system, based on ZigBee technology in real-time in order to provide prompt support for safe management of the dam construction sites. The system is based on the tracking technology using wireless sensors and a set of servers that run software for processing the collected data, visually monitoring the condition of the site in real-time and remote communication with other systems such as ERP, CRM. A low-power tracking technology is network hardware based on ZigBee technology, which uses the technology of fingerprinting software. The proposed system for observing in real time for employees was successfully implemented in the Xiluodu arch dam construction site.

Implementation and development of the Internet of Things (IoT) is closely connected with the construction of smart grids [13]. Generally, using the technology of wireless communications and observations all electrical devices can be connected in IoT, in order to make the smart grid become interactive electricity network in real time. Qiaoming Zou et al. summarize the current state in that area, analyze the current structure and characteristics, as well as key technologies that enable the implementation of the IoT. Authors brought up some concrete analysis and discussion on the implementation of IoT in asset management and in the automatic reading meter system of smart grid and gave conclusions about the perspective of the application of IoT in smart grids.

Operating state tailings ponds, which are an important production area in the mine, directly affect the safety of people and property, as well as production at the mine [14]. To build a system for the security surveillance of tailings ponds, using GIS technology we cannot only manage the data and information of tailings scientifically and effectively, but also give full play to the advantage of computer's storage of massive data. The interactive operation of GIS spatial query and analysis facilitates accurate and convenient search management, alteration and statistics of data. With the observation of the height of the seepage line of dam body, the water level in the tank, the index of dry coast, deformation and deviation of the dam body, we can promptly obtain information such as the fluctuation of the water level, which is important for timely forecasting stability of the dam body, thus achieving safe management of tailings ponds, as well as early warning of danger.

Lately, much attention has been paid to climate changes, control and management of the environment, so IIS (Integrated Information System) is gaining on importance. The paper described in [15] presents a new IIS that combines IoT, Cloud Computing, Geo-informatics (remote sensing - RS, geographic information system - GIS, Global Positioning System - GPS) and e-Science for monitoring and management of living environment, with a case study of regional climate change and environmental impact. In order to collect data and other information to a perception layer, multiple sensors and Web services have been utilized. Both networks, private and public, were used to access and transport mass data and other information in the network layer. The result of this case study shows that there is a visible trend of the increase in air temperature in Xinjiang in the past 55 years and an apparently growing trend in rainfall since the early 1980s [15]. Besides the correlation between environmental indicators and meteorological elements, the availability of water resources is a decisive factor in the terrestrial ecosystem in the area. The study shows that the IIS greatly contributed to the study, not only in terms of data collection using IoT, but also in the use of web services and applications that are based on the cloud (Cloud) platform and e-science, and that effective evaluation and monitoring can still be improved.

3. Management and Monitoring of Large Dam Safety

In [16] and [17], authors describe the current state of dams in the Republic of Serbia. Over time, the sensors cease to operate or provide inaccurate values, so it is necessary to replace or implement new modern sensors.

Although the system of maintenance of dams in Serbia is not up-to-date and fully equipped on all dams, dams have not had a harder disasters or major problems which is primarily, due to the good design and high quality of the works during their construction.

However, despite the fact that so far there has not been any greater damage on the individual objects, which could have jeopardized their security and stability, or reduced their functionality, we must keep in mind that especially with aging dams, we can expect emergence of various problems which have already been testified by some peculiar features, which will be described later.

Most dams have technical monitoring systems that are essential from the point of monitoring and control the state of the facilities. These systems generally date from the time of building the facilities, and in the meantime have not been significantly renewed nor have they been further developed. Often, those systems are technologically outdated, so failure of old instruments and missing of the data needed for monitoring dam safety is not uncommon. The system monitoring of the dam becomes incomplete as per the type and frequency of monitoring. In the last few years, the reconstruction process of system for monitoring (Djerdap 1 [16], Gruza [17]) has started. In the forthcoming period it is obvious that significant activities will happen with regard to these issues. It is necessary to establish a modern, functional and optimized system for technical monitoring of most of the remaining dams, in the form of automatic telemetry system for acquisition, which should allow continuous automatic measurement and recording of measurement data in a given time interval.

In the future, increasing the fund of collected data will create conditions for a more detailed analysis of the condition and behavior of the facilities during operation, which is an integral part of the concept of dam safety management and would enable a precise definition of the trend behavior of the dam and should provide an opportunity for early detection of possible anomalies in the condition of the dam. This could be an example of a dam on which there have been good initial assumptions for the development and application of modern control system of dam safety.

On many dams in Serbia, the state of monitoring system can be assessed as partially satisfactory. This means that based on all available results of observations it is possible to make assessment of the condition of the facilities, but it is necessary to take steps to improve the situation of monitoring. The implementation of a new, up-to-date system of monitoring can provide more accurate assessment of the state of the system.

In recent years, steps have been taken to improve the system of technical surveillance by implementing advanced information technologies and a software system for managing the security of the dam. Because the first system is a prerequisite for the latter, phase development in the area of dam safety in Serbia should be expected. This complete system is applied on the rock fill dam Prvonek, near Vranje, while the realization of systems for high gravity concrete dam "Djerdap 1" and "Djerdap 2" is in progress.

Advanced system for technical measurement usually consists of following mechanisms: automatic acquisition, validation, archiving and access to all relevant data obtained in the system of technical surveillance. The core of this system is an information system for technical measurement, whose purpose is to be technical support in the collection, management and processing of measurement data. The aim is to allow merging diverse data in one place from the entire system of technical monitoring, having a score of reliability, as well as access to all data to be simple, interactive and fast.

Establishing a system for dam safety management implies the existence of an advanced system of technical monitoring, and thus the information system of technical surveillance. Relying on advanced system of technical surveillance as a source of reliable data, it is possible to develop a set of statistical and mathematical models based on physics, as well as following mathematical apparatus for monitoring the state and analysis of dam safety.

This established system of dam safety management is used for:

- tracking and monitoring the behavior, which consists of continuous monitoring, measurement and determination of compliance measured values and their expected values,
- checking of the dam safety, which may be initial, periodic and extraordinary, and refers to determining the condition of the facilities and determining the degree of the facilities safety.

The activity of monitoring and tracking behavior relies on established statistical models based on measured inputs that can provide the expected value of a variable. If the measured value deviate within permissible limits which are expected, it can be concluded that the system has no major changes. In the modern automated system, this process is daily and has an alarming role in the case that on the basis of measurements concluded that the facility does not behave as expected. This alarm is a signal that a special security check should be performed.

Checking the safety of dams is carried out to determine the condition of the facility and degree of the safety, by checking the facility behavior in a series of scenarios, respectively situations that are valid from the standpoint of dam safety. This check is done periodically after the expiry of a defined period or extraordinary, because the system of technical surveillance and the use of statistical models have shown that facility is behaving differently than it is expected.

Given that in the analysis of state of complex real objects, it is not possible to a priori completely define in homogeneity and the actual characteristics of the material, and on the other side having a large number of measuring different indicators of the state of the facility, for determining the current state of all parameters, it is necessary to establish assimilation mechanisms of real measurements. Practically, based on the measurements of relevant physical quantities, calibration of physical parameters of the system is performed (such as: e.g. elastic modules, filtration coefficient, etc.), so the calculated quantities can be more appropriate to the measured ones. In this way, identification can be performed in the zone where changes have occurred.

Only over the updated model is it possible to carry out safety analysis and based on the analyses it can be decided which measures must be undertaken to improve the safety of the dam. Dam safety management is reflected in the use of systems to support dam safety management, and it continues through the entire life cycle of the dam.

3.1. Software system to support the dam safety management

Software system to support the dam safety management, shown in [18], was realized on the principles of service-oriented architecture (SOA), which enables not only the use of data in real-time, but also the expandability and interconnection with other information systems. To create this system, commercially available technologies such as SQL Server databases, .NET Framework, ADO.NET to connect to databases and Web services were used. The system architecture is shown in the following figure.

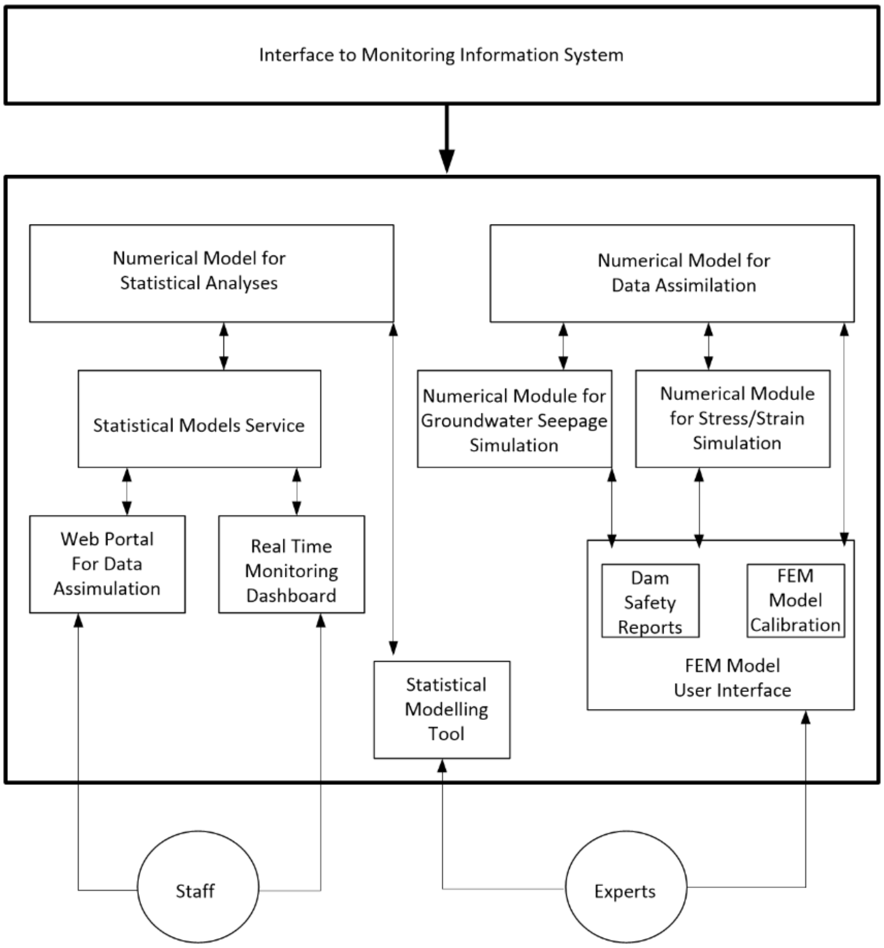

Fig. 1 The structure of the software system for managing dam safety (adopted from [19])

Software system consists of the following components:

- Interface with the system to technical monitoring
- Number of modules for statistical analysis
- Numeric module for the simulation of surface leakage
- Numeric module for stress-strain analysis
- Numeric module for data assimilation

Applications that are an integral part of the solution allow users to see current measurements (measurements in real time) as well as the estimation of the state of the dam at the time. For details see [19].

4. The Acquisition Module for Communication with Sensors in the Monitoring Network

Dams have a lot of different instruments, such as rain gauges, water level gauges, flow meter, precipitation meter, etc. In order to improve the observation of dams it is necessary to bring these instruments into a single network and allow them to communicate with each other. Due to the large number of different instruments, it is essential to enable communication between devices. This can be achieved with the help of SensorML and Wireless Sensor Networks (WSNs).

4.1. Sensor model language

The goal is to make all types of devices discoverable and accessible using standard Web services and schemas [20]. Standard XML encoding scheme can be used for metadata describing sensors, sensor platforms, sensor tasking interfaces, and sensor-derived data, if connections can be layered with Web and Internet protocols. Sensor can enable direct communications by publishing XML descriptions of its control interface, so it is possible to receive real-time or stored monitoring data, determine the sensor's location, identify the characteristics of its monitoring capabilities, and even request specific monitoring tasks.

Sensor Web Enablement (SWE) standards are open standards based on open and universally accepted standards for the Internet and Web, and for spatial location and they are foundational standards for communicating with sensors, actuators and processors whose location matters [21]. They are a key enabler for the Internet of Things.

The Sensor Model Language (SensorML) 2.0 provides a standard encoding and supports the Internet of Things (IoT) and Web of Things (WoT) by providing the ability to describe a sensor (or other online processing component) and to provide a link to the real-time values coming from this component [20]. The SensorML is a head component that provides sensor information necessary for discovery, processing, and geo-registration of sensor monitoring.

An example on the web page http://www.sensorml.com/sensorML-2.0/examples/iot Simple.html describes a sensor with a simple data stream consisting of temperature. It is combination of simple sensor and IoT. The data themselves can be accessed through the URL [22]. Accessing this URL would return either the latest value(s) or open up an html stream of real-time values.

The proposal of authors of this paper is to use a Web service that will access to sensor's data via the above mentioned URL. In addition for obtaining real data, the role of the Web service is also transmission and storage of real data in the central database. The end user calls the web service via the software that is described in the previous chapter. The Web service can be used for all types of sensors.

4.2. Wireless sensor network

The constant evolution of technologies, low cost technologies with embedded wireless transmitter, low-power and powerful chipset led to the massive use and development of wireless sensors networks (WSNs). WSN can scale from tens to hundreds of nodes and seamlessly integrate with existing wired measurement and control systems [15].

The network cluster architecture, which takes advantage of multi-hop and clustering, is adopted to lower the energy consumption. A wireless sensor network consists of a number of smart nodes, gateways or sink nodes and a computer management center [23].

Sensor's data are shared among smart nodes and sent to distributed or centralized system for analytics, which can be on cloud or in local [24].

WDSN (WSN applied on dams) is a self-organized wireless network with dynamic topology structures, which consists of sensor nodes and gateway nodes. The sensor nodes collect the dam data about water level, shift, stress and leakage, temperature, rainfall, seepage and displacement in the dam sections which is transferred to the database server through the gateway nodes.

The sensor used in WDSN is different from the common one. It is an intelligent one which can not only perceive the variation of tested physical value and output the corresponding change information, but also communicate with others. The intelligent sensor has several parts, such as sensitive components, embedded processors, storages and power supplies.

These smart sensors in WDSN network are very important for measuring the reliability of the dam because at any moment it is possible to get information about the functionality of the device.

WDSN structure is shown in **Fig. 2**.

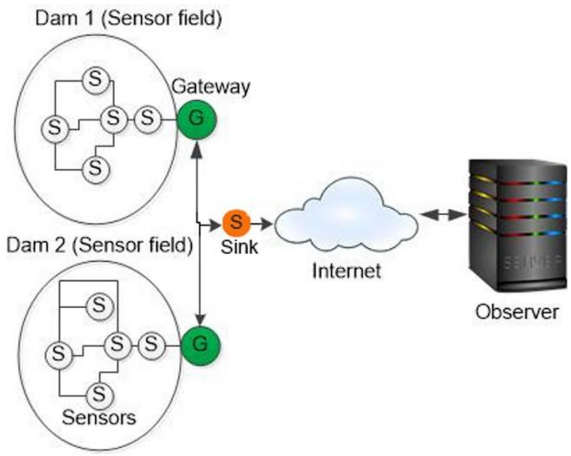

Fig. 2 Wireless Sensor Network (WSN)

The whole network is divided into several clusters, each of which is a monitoring area. The wireless sensor nodes in each cluster can communicate with each other and transmit the data to the gateway through multi-hops. The gateways can also communicate with each other and transmit the data to the sink.

4.3. Communication services

For automated measurements which are not included in the information system which could provide data to user outside of the system, it is necessary to set up special services for communication with measuring systems. Due to the specific requirements for the reliability of the measurement system it is not recommended to directly access data. These services carry out local data collecting and sending on the processing and validation.

In the structure of the service communication, module for data collection is directly connected to measuring systems and has a central role [25]. Module collects data from various sources, translates them into a standard format and passes them to a service for processing and validation of data. With this module, depending on the number and types of measuring systems which need to communicate, participants in the services are software components for the acquisition, which are divided into: Components for communication with passive sensors, Components for communication with active sensors, Components for communication with passive data logger, The components for communicating with an active data logger and Components for the information contained in the files.

Each of these components must implement the appropriate interface module for data collection. The number of components of one type is only limited with computing resources, while the number of these types of components is specified with configuration of measuring systems. The latter means that the concrete implementation of these services on an object does not have to contain all the components, but it is possible to add the components in the case of the extension configuration.

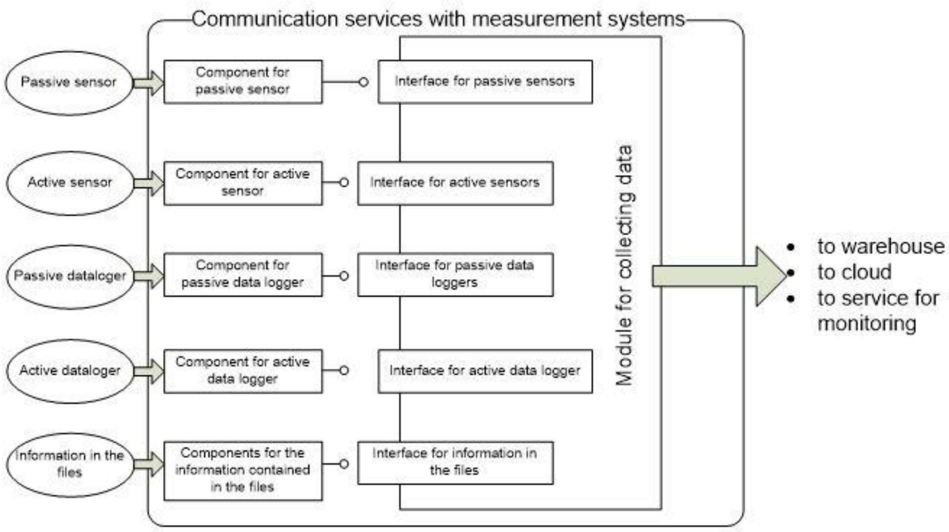

Fig. 3 Communication services with measurement systems (adopted from [25])

5. DETECTING SENSOR FAILURE AND CONTINUING FURTHER WORK

During the life cycle of the dam instruments the risk of cancellation of individual sensors is, of course, increasing, so the safety assessment of the dam should be brought without taking into account the measurements from these sensors. Consequently, in order to implement the IoT in monitoring and dam safety management, it is necessary to implement the adaptive algorithm for detecting sensor failure. Algorithm should signal on time which measurements are missing, i.e. without which sensor the decision on safety of the facility has been made.

The algorithm for failure detection of sensors, suitable for use in IoT, represents the connection between the adaptive system for modeling the behavior of the dam and the acquisitions module for communication with sensors in the monitoring network.

There are several different approaches to modeling the behavior of the dam. The earliest models were based on the application of statistical [26] and numerical [27] methods. The development of artificial intelligence has enabled the application of new techniques such as artificial neural networks [28], genetic algorithms [29] and adaptive neuro-fuzzy systems [30]. For application in the Internet of Things are the most suitable adaptive models that provide results in real time. One such has been described in [18]. It is a hybrid system that combines statistical models and genetic algorithms, so it can model the expected behavior of the dam. The basis of this system is the linear regression model, which is sensitive to the change of input parameters set. For this reason, the adaptive part is added to the system, in which, genetic algorithms, represent the basis. In accordance with the theory of genetic algorithms, model of linear regression is seen as the optimization problem, where each regression model represents one entity within the population. Based on the available measurements, the generator of regressor creates a corresponding set of functions that can be applied. This means that there is always an alternative to the main model in case that some information is not available, so that the safety dam monitoring is not compromised.

At the same time, in case of missing data, through the communication module with sensors, it is possible to get information from which sensor in network, the information is received and the system should timely alert about partial malfunction of the sensor. In the case of missing the entire set of data from a sensor (all measurements that the sensor performs), the system announces a complete malfunction of the sensor.

Results of regression models represent the parameters on the basis of which the current state of the dam is estimated and alarming is performed, in case that the parameters deviate from the expected values. With this information, it is also important to give information of the available measurements in the system and the state of the sensors, because as noted earlier, the regression model is formed on available measurements in the system. This could jeopardize the credibility of the results obtained from the regression model in a situation of incomplete measurements. For this reason, the condition of sensors is an important factor in making a correct decision about the real state of the dam.

Further development will be directed to the use of collected data in the advanced numerical models (FEM etc.) and implementation of cloud computing.

5.1. FEM

For the modeling of the stress-deformation and filtration phenomena on the dam finite element method (FEM) is used. FEM can form a physical model of the building with the surrounding rock mass. To make this model fit the real model of a dam, it is necessary to repeat a particular phenomenon at the dam that occurred during operation. Based on the results of technical surveillance calibration of material parameters is carried out and FEM gives information about a realistic model of the dam, which should serve to further monitor the behavior of the object in order to anticipate certain undesirable situations in the further exploitation [31] [32].

An example of an arch dam model is shown in **Fig. 4**.

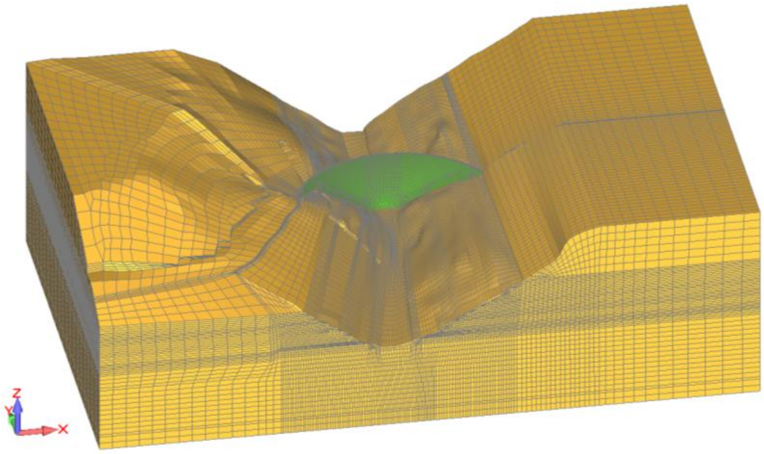

Fig. 4 FEM Arch dam

To carry out safety analysis over the present state model, numerical module for assimilation of measured data should be developed. This module should enable, on the basis of the data obtained from the information system for technical monitoring, assimilation of measurements, i.e. determine updated values of FEM model parameters. The core of the module consists of optimization algorithms required for the assimilation of measurements and automated communication with numerical modules. Up to date parameters of individual material models that form the FEM model describe real state of construction.

5.2. Big data and cloud in remote sensing

Internet of Things (IoT) is a concept that includes all the objects around us as part of the Internet. Coverage IoT is very large and includes a variety of smart devices such as smart phones, digital cameras, smart rain gauge, an outside temperature sensor and a variety of other types of sensors. When all these devices are interconnected, they provide much more intelligent processes and services that can be used in various areas. Such large number of devices and sensors on dams connected to the Internet provides a multitude of services and produces a large amount of data (big data). Cloud computing is a model for on-demand-access to repository of configurable resources (budget, networks, servers, storage, applications, services, software, etc.), which can easily provide such infrastructure, applications and software. Platforms based on a cloud help us to connect to the things that surround us, so it is possible to access them from anywhere at any time. Cloud acts as a front-end to access the IoT. Applications which interact with devices, such as sensors, have special requirements for massive storage to record big data, a huge power computation that would provide data processing in real-time and high speed Internet to allow high speed data throughput [33].

6. Proof of Concept

The main goal of practical work is the dam safety. Computers with limited resources need to be less burdened, i.e. the execution of operations should be relocated to the server. Furthermore, it is necessary to increase the level of reliability of the dam safety system. This new innovative system would be implemented on dam Prvonek, which is one of the last built dams in Serbia and has modern sensors.

Fig. 5 describes implemented system on Dam Prvonek. The figure shows the data flow from the measuring instrument to the end-user. The measured data are temporarily stored in data logger. Every data logger has own software for downloading data, which is installed on acquisition server. Downloaded data format is csv (Comma Separated Values). The acquisition server sends data to the central server. End-users use specific software for data analyses. The installed software on the computer of end-user uses resources of the computer and not server. If operations are complex, it is possible that operations will need a lot of computer resources.

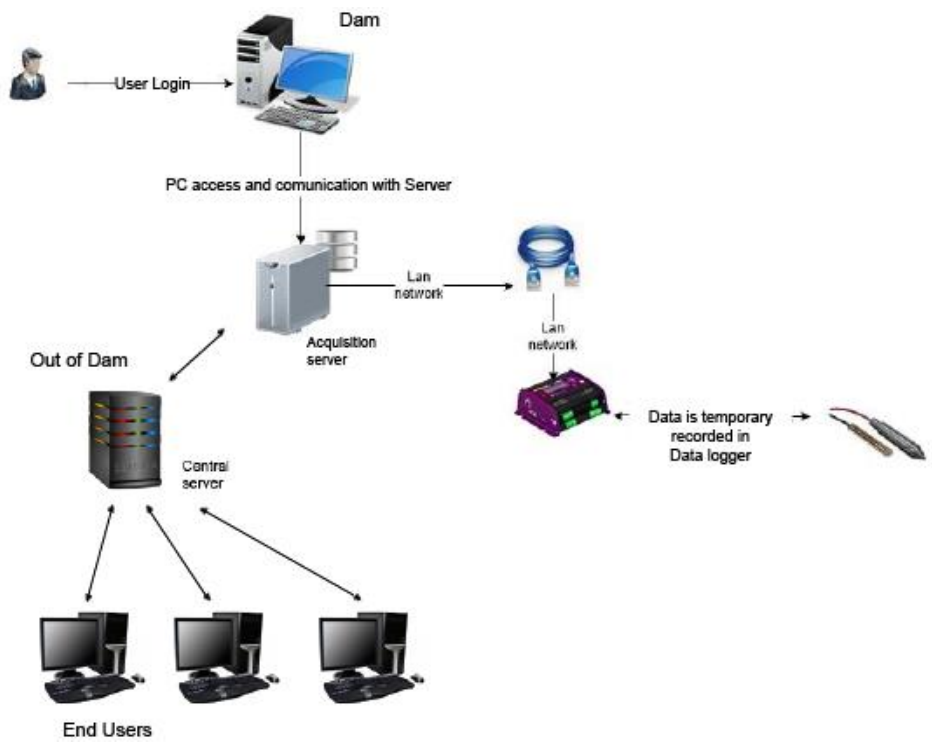

Fig. 5 Current data flow on dam Prvonek

The next figure (**Fig. 6**) shows further project improvement. All data from acquisition servers are sent to the central server on the cloud. All data transformation and processes are performed in the cloud. The above mentioned represents an ETL process (Extract, Transfer and Load). All operations use server's resources. End-user computer works only with prepared data for reports and has much more free resources for other operations.

All data are available to end-users 24/7. End-user can access data any place any time.

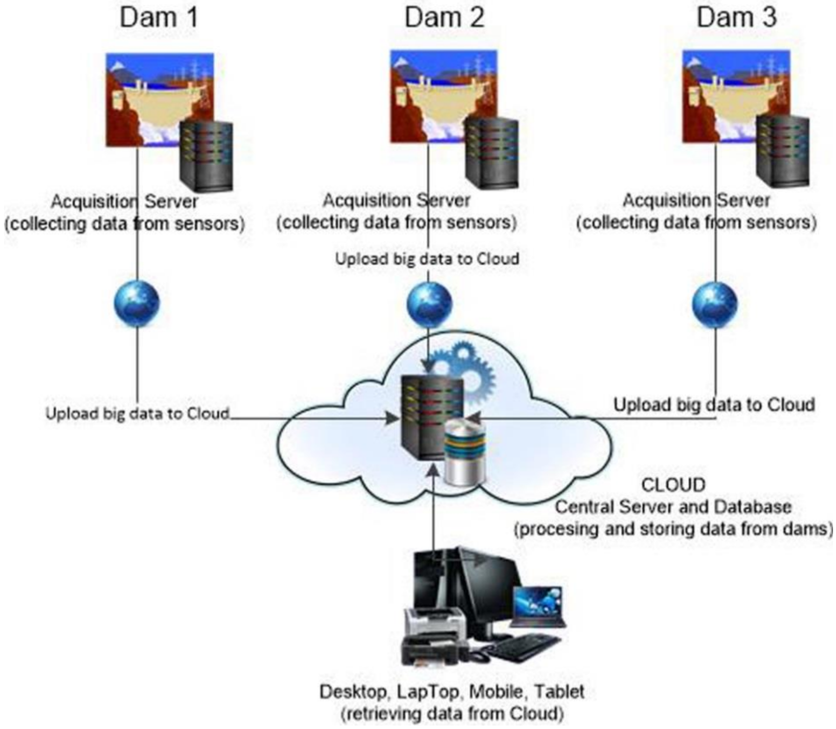

Fig. 6 Model for Cloud and big data

It is possible to apply a new system on all instruments: rain gauges, water level gauges, flow meters, precipitation meters, etc. This new system is useful for all types of dams.

Implementing WSN architecture from Fig. 2 will make a system of sensors more reliable and data more accurate. The nodes within WSN network communicate between themselves and send data about the malfunctioning sensor in real time through gateway to sin node, which further sends data onto the cloud server. The software for mathematical calculations generates statistical curve of dam stability using the received data. This statistical curve has to be in specific value limits. The curve could be generated based on data from different instruments. Most frequently used instruments are piezometer, coordinometer, clinometer and thermometer. Piezometer measures level of ground and underground flows. Coordinometer measures dam movements. Clinometer measures the angle of movement, while thermometer measures temperature. If there is a malfunctioning of instrument, a new formula, which excludes given instrument, is automatically generated by specific algorithms and provides approximately the same curve as if all instruments were in perfect working order. End user launches software for generating curve.

All received data are stored in database on cloud server. The new system provides database with more reliable data which enables better analyzes and reporting.

7. CONCLUSION

In this paper authors give an example for possible application of latest technologies such as Internet of Things, SensorML and Wireless Sensors Networks with software for dam safety management. Combination of these technologies and software improves functionality of dams.

Sensor technology, computer technology and network technology are advancing together while the demand grows for ways to connect information systems with the real world. Linking diverse technologies in this fertile market environment, integrators are offering new solutions for plant security, industrial controls, meteorology, geophysical survey, flood monitoring, risk assessment, tracking, environmental monitoring, defense, logistics and many other applications [34].

Internet of Things, as a technology that is in trend, allows sensors to become intelligent by connecting them to the Internet. This allows sensors to communicate with each other. Application of IoT in modern business significantly improves operations of companies. Application of IoT on dams would provide more efficient recording of failed sensors, which would significantly reduce the probability of damage occurring. With the collected data about failed sensors, it is possible to make database of reliability instruments, which directly shows the reliability of dams. Combination of WSN, big data, cloud computing with IoT would greatly improve the operation of the dams. All technologies produce a lot of data, which requires massive data storage. Cloud, as a form of technology, that gains momentum as IoT, could allow storage of large amounts of data on the Web. With cloud computing end users could access the data anytime and anywhere. All data processing would be done on a cloud, which would considerably make the functioning of the system for data collection faster and more reliable. Using the last forms of technology such as big data, cloud computing and IoT will improve the operation of dams in Serbia and significantly minimize the chances for failure to happen.

Serbia has good quality dams, so it is only needed to start implementing new technologies so that we could possibly prevent potential failure from happening.

The implementation of the system for managing and monitoring dam safety and the implementation of new technology reduces the risk of a major failure of the dam.

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