Fog computing in new approach for monitoring of hazardous phenomena

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Abstract. This paper presents an investigation on applying fog computing to develop a new system of forecasting and monitoring of hazardous phenomena and ensuring the population safety. So, there have been various negative natural phenomena and processes that affect the coastal areas and coastal infrastructure in Ponto-Caspian region recently. Currently, data of hydrological, meteorological and biological monitoring systems are splitted. At present one of the promising trends of developing new methods and algorithms for the forecasting and monitoring systems of natural hazardous phenomena is processing of large volumes of unstructured data coming from various sources, detectors and so on. The authors of the paper estimate the developing of the methods and algorithms of forecasting and monitoring of hazardous phenomena and ensuring the population safety that could be realized in the base of fog computing.

1. Introduction
There have been various negative natural phenomena and processes that affect the coastal areas and coastal infrastructure in Ponto-Caspian region recent years. Natural hazards cause to adverse effects on population health and safely and coastal infrastructure in many cases. So, climate changing leads to a pollution of fresh water. There are new problems concerning clean water supply in regions which have been safe and comfortable before the climate has started to change. For instance, there are new ecological problems in the lower reaches of the river Don. It is significant to salinize water (up to the maximum allowable concentrations), there is significant shallowing and etc. [1].

Hydrological, meteorological and biological monitoring is carried out to prevent the development or reduce the negative effects of natural phenomena in our country. However, most of the monitoring systems are local systems. It leads to hydrological monitoring data that do not correlate with biological monitoring data and so on. So, data of hydrological, meteorological and biological monitoring systems are splitted. It is necessary to combine any data from different sources of the local monitoring systems to create a new combined system which is based on modern technologies of data collecting and unstructured data processing. The new system may include many different types of data sources, such as monitoring of social networks for user messages about natural hazardous phenomena, for instance, the messages about unusual water properties, dangerous odors or precipitations, unusual weather, death
of fish, or spoiled food.

At present one of the promising trends of developing of new methods and algorithms for the forecasting and monitoring systems of natural hazardous phenomena is processing of large volumes of unstructured data coming from various sources, detectors and so on. The application of modern technologies such as fog computing to the monitoring of natural hazardous phenomena is relevant. This paper presents a new method of the selection of source data and the application of fog computing for designing of the new system of monitoring and forecasting hazardous phenomena of Ponto-Caspian region.

2. Analysis of existing monitoring and forecasting methods of hazardous phenomena and processes

Currently, there are a lot of hazardous phenomena monitoring systems which have no data computing. It is possible to make these systems cheaper and more effective, if we apply modern information technologies using the existing infrastructure of sensors at the same time.

Thus, the authors of [2] provide data of geological, geomorphological and geophysical monitoring of the coastal zone of the eastern part of the Gulf of Finland with the support of the Committee of Nature Management, Environmental Protection and Environmental Safety of St. Petersburg and the Federal subsoil use Agency. These works of monitoring include observing of coastal routes, reference profiles after strong storms, analysis of the beach sediments and the underwater coastal slope. Laser scanning, archival cartographic material and high-resolution aerial photography provide an opportunity to estimate coastal reflection speed using retrospective analysis of remote sensing materials. But there is no information about online monitoring systems.

The authors [3] consider the main natural, man-made and biological-social hazards phenomena of the beginning of the XXI century. The phenomena are associated with emergency situations and their monitoring and forecasting. The paper [3] presents the analysis of existing systems for monitoring and forecasting of natural hazards phenomena. The state of critical and potentially dangerous objects and possible threats has been observed. We described monitoring and forecasting risks in the Arctic region. The methods of predicting natural and man-made hazardous phenomena are described. The structure of this system could be taken as a prototype of a developed system for monitoring and forecasting of hazardous processes. But the structure of the new system and methods for data computing could be improved.

The authors [4] investigate the actual nutrition of the population, the quality and safety of food products. There is a trend to improve nutrition, the presence of a low proportion of non-compliance of food products with hygienic requirements for sanitary and chemical indicators, a low risk of nutritional intake of contaminants in the body of the population of the Penza region. Such methods can be used to monitor the health status of population of the coastal zone of Ponto-Caspian region.

The technologies of convergent distributed data processing are considered in studies [5–8]. The technologies are based on the convergence of GRID, cloud computing [9–11] and fog computing [12–15]. It is proposed to process big sensor data [16; 17] in SCADA systems for the organization dispatching control for spatially distributed objects of engineering energy networks and energy distribution and consumption processes. In this concept the model «fog computing» can be implemented for processing, normalizing and aggregating sensory data at the sensor network level for nodes and industrial controllers. These items can be used for systems of forecasting and monitoring of hazardous phenomena systems. For instance, to develop a new sensor network of meteorological sensors and GRID or cloud computing models for data analyze aggregates in the central computing cluster of the SCADA dispatching system. The authors propose to use the ZigBee wireless sensor network [18] and cellular communication network segments to realize «fog computing» to support collection processes and sensory data processing. Data aggregates and integral indicators are transferred, then these indicators accumulate in a special database for subsequent extraction and intellectual analysis in a computing cluster of the GRID system.

All the technologies and methods discussed in articles [5–8] above can be applied to create a new
system of forecasting and monitoring of hazardous phenomena and ensuring the population safety of the coastal infrastructure for various classes.

Paper [19] proposes principles and a scheme for combining wireless sensors for managing water supply to water resources with QoS system in the Kingdom of Saudi Arabia. It was predicted about 4 million people would face a serious shortage of drinking water according to a study conducted by the Water Bank on Water Management. Lack of pure water is one of the main problems in the Kingdom of Saudi Arabia. The goal of the authors' study was to build a structure for current research related to addressing the issue of drinking water shortages. The efficient and reliable architecture was developed for water management using wireless sensor networks that supported «quality service» (QoS) in KSA. The proposed structure uses touch-sensitive n-hop clusters which are based on an idle time of a transport port is served by each cluster.

The article [20] presents the structure of the environmental monitoring system for digital economy technologies [21–25], fog computing and Internet of Things [26–30] that can be applied to build the structure of the system of monitoring and forecasting hazardous phenomena and ensuring public safety related to the shortage of drinking water in the event of natural and human-made emergencies. The system structure is presented in figure 1.

3. Proposed method of monitoring and forecasting of hazardous phenomena based on fog computing

The concept of fog computing is a further development of the concept of cloud technologies [31]. The concept of fog computing is based on the approach using the computing resources of those devices that are located topologically between users and remote servers. Fog computing technology reduces computational load of server, communication load of information channels and processing time.

Fog computing provides implementation and storage of network and computing services and convenient platform for Internet of Things.

However, there is a threat of confidentiality and ensuring data security and availability of the computing services. Existing security methods are developed for cloud computing, so the methods cannot be used for fog computing. The reason is other mechanisms of ensuring the confidentiality of data. Fog computing is characterized by large territorial spread between computing devices in the network. The computing devices are mobility and heterogeneity of their location. So, the new safety methods of data storage should be developed and new methods to implement the data privacy should...
be developed for the new system of forecasting and monitoring of hazardous phenomena. The authors of the current paper propose the new «combined method» which are based on selecting initial heterogeneous data for the system of monitoring and forecasting hazardous phenomena. The method involves existing information infrastructures which are the current local systems for analyzing hazardous phenomena, mobile infrastructures and so on.

The new system of monitoring and forecasting of hazardous phenomena should ensure the subsystems of safety of coastal infrastructure and population safety and safety of various classes including benthic communities of coastal zones of Ponto-Caspian region. This system should be based on digital economy technologies. The system should contain different types of sensors and intermediate devices which performing preliminary processing including computing and analysis (smartphones, tablet and portable computers, laptops, smart watches, activity tracking devices, etc.), data centers and storage monitoring data servers and so on. The system should give recommendations on stabilizing these facilities or possible activities to ensure the people safety or safety of coastal infrastructure. The system structure is shown in figure 2.

**Figure 2.** The structure of the system of monitoring and forecasting of hazardous phenomena.

Ending devices of the system are represented by heterogeneous sensors which can be located in the coastal zone, shallow water zone, on the equipment, clothing of windsurfers, kayakers, yachtsmen, buoys, marine protection boats, etc. These sensors collect data on the surrounding (air, water, near-bottom) environment. All sensors are equipped wireless module. The ending devices can be as drones with separate sensors or analyzers on board, photo and video capabilities. The data can be sent to intermediate computing devices. Moreover, the data about state of the environment can be obtained by analyzing open data from social networks (photo, video, messages), meteorological data at reference points of observation, analysis of images from LANDSAT satellites, Google Earth, shoal maps and coastal abrasion and so on.

Some sensors can be equipped with gyroscopes, compasses, clocks or other time control devices, GPS and GPS altimeters, and transmit latitude and longitude coordinates, time data.

Data about weather (temperature, atmospheric pressure, direction and speed of the wind, cloudiness, precipitation) can be collected by various types of air sensors.

Various types of sensor for the aqua environment can collect data about depth, water temperature, salinity, pH, pressure, dissolved oxygen, the composition of the water layer under study, wave data (wave height, direction, speed and kinetic energy of the wave and etc.).

There are special equipment for biomonitoring data as qualitative and quantitative determination of zoo and phytoplankton, bacteria, fungi, etc.

The sensors collect initial data. The initial data are transmitted to servers and data centers. The initial data are passing partial processing on various mobile devices (smartphones, tablet and laptop computers, laptops, smart watches, activity tracking devices, etc.) which contain mobile applications for receiving initial or partially processed data. The mobile applications provide quality assessment of the initial data, determining the reliability of the received data and elimination of data errors and analysis of incoming data.

The «complex» analysis of various sources data (data from the drones, satellite video and
photography, weather stations, social networks) allow to improve accuracy of determination of biological monitoring of hazardous natural phenomena. So, it is possible to determine in advance place and time of sampling of benthos. It will reduce the costs of SSC RAS expeditions, as it will reduce the costs of bottom samples and improving the quality and significance of the biological samples for research.

Recently, information and control systems and decision support systems have been based on network technologies for organizing information exchange (Ethernet, CAN, ZigBee, WiFi), touchscreen manufacturing techniques, processing big data technologies (cloud and fog computing, service-oriented architecture, real-time processing technologies). Such system hierarchy contains the level of sensors for collecting information, the level of controllers for preprocessing, the level of application servers, the level of workstations. The processing of the system is centrally as a rule. On the one hand it is easier to organize the such system. On the other hand, there is big response time to events as latency in data transmission. There is less reliability of the system or we need to reserve the central elements of the system. This is because the failure of central elements of the system leads to the whole system failure. There are some problems with the centralized system scaling as limited bandwidth, which explained by processing data are transmitted through limited number of devices.

Decentralized computer systems have no lacks which have been listed above. Also, fog computing can be used to transferring the computational load to the edge of the system to reduce the network load and to reduce the response time of the decentralized system.

Data centers contain server applications with software modules for receiving initial data. The software apply an algorithm for assessing the quality and reliability of the received initial data and eliminating data errors. Also software realize an algorithm for analyzing the initial data to fix the state of coastal and water regions and to provide recommendations for stabilizing the state of these objects and organizing actions to ensure people and coastal infrastructure safety.

The effectiveness of fogging calculations can be carried out in terms of reducing the load on communication channels. Sensors can be used that transmit the following types of information: video signal, acoustic signal, digital readings.

Video signals give the most burden on telecommunication networks. So, video sensors generate about 1139 MB/s with Full HD resolution and RGB24 color depth. But modern video cameras have coding devices. Such devices allow you to compress data up to 7-8 Mb/s. Thus, in cloud processing, it is necessary to ensure a stable communication channel with a bandwidth of at least 8 Mb / s from each video sensor to the cloud server. Within the framework of the proposed “combine approach” we proposed to carry out a preliminary analysis of video images at a foggy level, as shown in figure 3.

![Diagram of sensors, fog, and cloud communication channels](figure3.png)

**Figure 3.** Evaluation of reducing the load on communication channels when using the new «combined method».

The fog-level device receives compressed video data and performs pattern recognition using the algorithms developed by the authors [32, 33]. The fog-level device makes a decision about the presence or absence of critical situations in the frame. If the fog-level device does not detect a critical situation in a frame, it buffers the last minute of the video stream and sends a message to the cloud server indicating that there is no critical situation of 64 bytes every second. This requires approximately 500 MB of RAM.
In the case of preliminary detection of a critical situation, the foggy device sends a preliminary detection message (64 bytes) and a fragment of a video stream of 2 minutes to the cloud server. A fragment of the video stream will contain one minute before detection and one minute after detection of a critical situation in the frame. This allows for more detailed analysis using the computing tools of the cloud server or even with the involvement of experts. At the same time sending a two-minute fragment is in real-time and 2-5 times slower. The data transfer rate is 2-4 Mb/s in this case. Thus, the average load on the communication channels between the foggy device and the cloud server is 64 bytes/s, the maximum load is 2-4 MB/s.

The situation is similar to the pre-processing of acoustic and other digital sensors.

4. Conclusion
There are some questions in designing of new methods of monitoring and forecasting of hazardous phenomena, as the most current methods and systems of monitoring and forecasting of hazardous processes are locally fragmented. It is necessary to develop new common monitoring systems that would allow to get various data from various sources. Such distributed systems should have high scalability and resistance to non-deterministic changes in the structure of the system. The authors presented applying fog computing to develop the new system of forecasting and monitoring of hazardous phenomena and ensuring the population safety of the coastal infrastructure of Ponto-Caspian region for various classes.

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