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Wireless sensor network based monitoring system for precision agriculture in Uzbekistan

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Abstract

The last decades the WSN technology has been adopted by more and more scientific fields for accurate and effective monitoring of climate phenomena like air pollution, destruction phenomena like landslides, etc. It has been widely used in agriculture for field monitoring. WSN is an emerging technology, which through the research in the labs and the real deployments has been proved to be a significant and valuable tool for scientists to explore another world which is behind the various environmental phenomena using tiny sensor nodes In this article, "Expert Advisory System" was developed to improve the productivity of farmers, save their time and improve the efficiency of the crops. The system monitors real-time crop fields using wireless sensor networks and provides the necessary information to farmers via the Internet. The farmer will be required to undertake the necessary remedial action on the basis of the information received. It's also provided that the simulation of WSN in Contiki Simulator tool. Moreover, the queing model for WSN to also considered in this work.

Keywords: *cotton, crop monitoring, expert advisory system, queuing system*

1. Introduction

Rapid development of Internet networks has led to the introduction of the concept of "internet of things". The Internet of thiings is a broad term that describes how to connect various objects of everyday life over the Internet. In the Internet-based principle, each object is connected to one another through a single network, so it can transmit data in the network without any interrelationship. IoT is recognized as a system based on data analysis in everyday life. IoT based on wireless sensor networks that are integrated with integrated systems for each object's interaction. Sensor networks connect people and devices over a highly distributed network. The main purpose of the sensor network is to connect devices to the global network. In the sensor network, each object is assigned a unique identifier, so each object can connect to the Internet. In the network of sensors, each object can perform three functional functions: notification, provision and interaction. Notification-is the ability of objects to be informed and aware of other objects by their data. Submitting is to present an object information to other objects. Interaction is the ability to communicate with each other.

Researchers in [1] present an implementation of a multi-hop wireless sensor network deployed in a bayberry greenhouse that collects temperature, humidity and light intensity measurements at a central gateway node which, in turn, transmits to a remote server via General PacketRadio Service (GPRS) [2]. Alarm service and micro-environment status information to the user is provided through integration with Google Maps [3]. The system is implemented on TelosB mote hardware [4], designed with the goal of energy efficiency keeping in mind the requirements of research and experimentation, developed at University of California at Berkeley. In order to achieve energy effciency, a simple duty-cycle based MAC protocol (similar to SMAC) is used, where the nodes switch off their transceivers and back on again periodically. However, the sleep-active duty cycles of the nodes may drift due to the randomness inherent in the crystal oscillators of the nodes' clocks (owing to various factors such as temperature,humidity, and manufacturing artifacts). To correct the clock drifts, FTSP (Flooding Time Synchronization Protocol) [5] is used to synchronize the active and sleep cycles of the entire network. In [6], authors present results from a similar deployment in an eggplant field and implementation of a redetection system. The authors stress on the importance of

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energy efficiency and recovery in the event of node power failures. In [7], authors deploy a wireless sensor network to monitor the micro-climate of a green house. The stored data is analyzed using linear regression and DIF analysis [8] to manage the conditions in the greenhouse to be close to the optimal for plant growth.

Today, the IoT has enormous opportunities, including smart home monitoring, food delivery management, agricultural management, and more. This is done by using RFID (radio frequency identification), wireless sensor network (WSN) or other means. Agriculture plays an important role in Uzbekistan economy. A significant proportion of gross domestic product accounts for the agricultural sector [9]. Most of the population of Uzbekistan lives in rural areas, which is the main source of income for the population. Farmers in our country are mainly dependent on traditional methods and techniques. Nevertheless, some agricultural enterprises are making significant progress on the basis of advanced technologies and equipment. Uzbekistan faces considerable losses due to some of the following factors in the agricultural sector:

– use of poor quality seeds;
– environmental pollution;
– insects and various diseases;
– irrationality of the irrigation system;
– not to process timely land;
– misuse of fertilizers;
– lack of machinery and equipment.

One of the most important crops in Uzbekistan's agriculture is cotton. It is called "white gold". During the cultivation of cotton, it is harmed every year due to the effects of various pest attacks and diseases. According to statistical data, 25% of the cotton harvest was killed by insects in 2017. According to scientific research, 15 percent of cotton harvest will die annually as a result of an attack. Crops are affected by some bacterial and fungal diseases, as well as pests and insects. The demand for air and soil moisture for cotton crops varies with other crops. Demand and duration of insecticides, pesticides and fertilizers impact on the growth of crops. Consequently, regular monitoring is needed to grow healthy fruits.

Farmers are usually consulted by agricultural specialists and other experienced farmers. However, experts are not always available anywhere. Therefore, it would be expedient to create a programmatic system for farmers, who can provide expert advice when needed. We have referred to this as an "expert advice system". fiIt is a tool that solves the problem by using its database. It is a system that aims to repeat human behavior. EAS can identify problems and find solutions. The development of EAS optimal solutions is based primarily on the data from the built-in sensors. The information is accessible through the Internet through the EAS system. EASs process this data and send results or solutions to the farmer's mobile phone. This method of timely preventive maintenance of cotton crops is carried out as a result of effective management of cotton crops, water control, ecological warning, reduction of damage caused by diseases and pests.

2. WSN Model as a Queuing System

Any queuing system consists in fulfilling the flow of demands or requests arriving at it. Service requests are received one after another at random time. Servicing for incoming requests continues for some time, after which the channel is released and it is again ready to receive the next request. Each queuing system depending on the number of channels and their performance has some kind of bandwidth, which allows it to more or less successfully cope with the flow of requests. In practice, usually the moments of recieving of requests are random. In this regard, the process of the system is irregular: in the flow of requests local thickenings and dilutions will be formed. Thickening can lead to either denial of service or the formation of queues. Dilution can lead to inefficient downtime of individual channels or the system as a whole. These problems, associated with the heterogeneity of the flow of requests, are also superimposed by accidents associated with delays in servicing individual requests. Thus, the process of functioning of a queuing system is a random process [10, 11]. In general, a route can be represented as a multiphase queuing system. In addition, each of the maintenance phases is a section of the route. Thus, the number of phases of the queuing system is equal to the number of jumps in the route. In general case, each phase is a queuing system G/G/1/k of queuing system as shown in Figure 1.

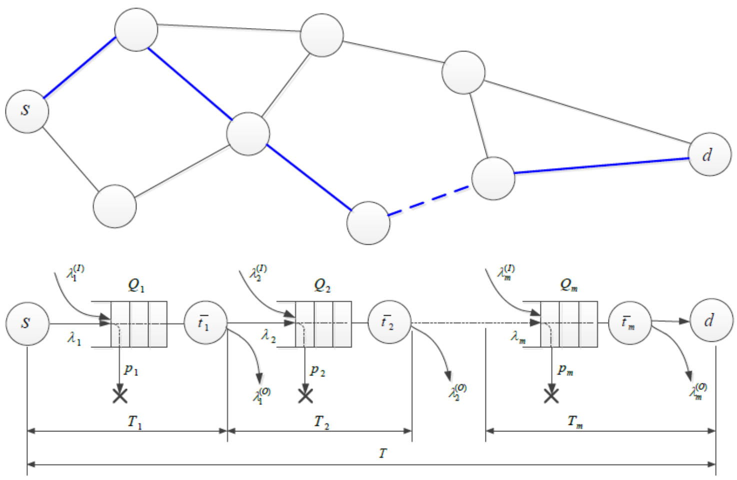


Figure 1. Routing model as a multi-phase queuing system

The delivery time of the message between the source and the receiver depends on the parameters of the servicing phases and their quantity. The number of service phases is determined by the number of transits in a route [12, 13]. To study the probabilistic temporal characteristics a simulation model of a network with a normal distribution of nodes formed by 100 nodes located on a flat surface in an area limited by a square 200×200 m. The communication radius of the node is R=50 m as shown in Figure 2.

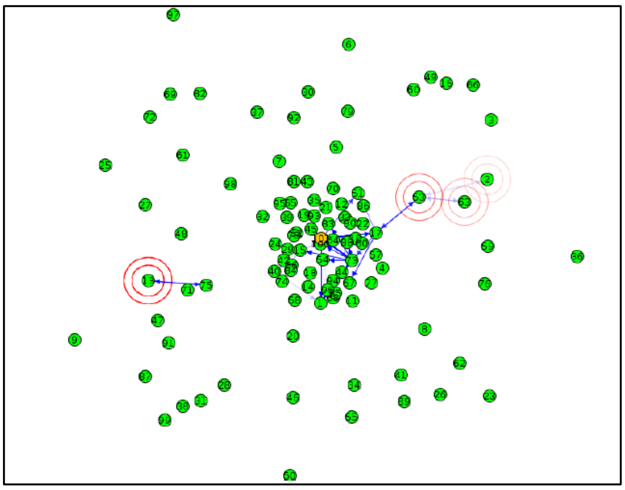


Figure 2. Immitation model of the network with normal distributed nodes and gateways

The network service area is 200×200 m. The network consists of two types of nodes: sensor nodes and a gateway. The network solves the data collection functions, which consist in delivering packets from the sensor nodes to the data collection node (gateway). Sensor nodes act as traffic sources, as well as transit nodes, and can be part of data delivery routes. The gateway is located in the geometric center of the service area and is the only node that receives data from the sensor nodes [14]. An illustration of the model is shown in Figure 3. The model of the radio channel of the node is described by the radius of communication R, which in this case is chosen equal to R=50 m.

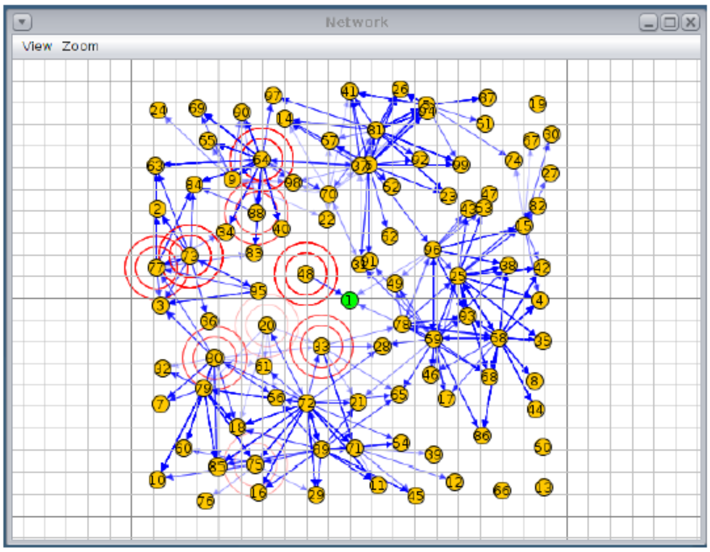
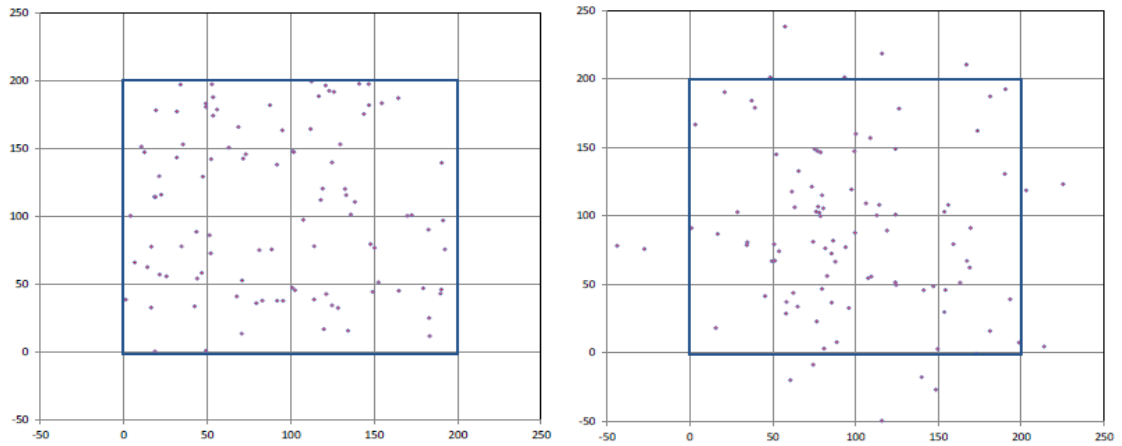


Figure 3. Wireless sensor network model in Contiki simulator
(100 nodes, in 200x200 service area)

3. WSN Model for Point-to-Point Topology and Route Length Investigation

The point-to-point topology is characterized by a direct connection between two nodes. There is no need to organize such a topology for addressing devices [15-16]. When examining the length of a random route for the point-point was considered a random distribution of nodes in the territory when equipartition and normal laws of distribution of independent coordinates x and y as shown in Figure 4.



(a) (b)

Figure 4. Equipartition (a) and normal (b) laws of distribution of independent coordinates x and y

For the normal distribution law value of dispersion equal to equipartition distribution law:

$$D_U(x) = D_U(y) = \frac{(b-a)^2}{12}, m^2 \quad (1)$$

where, b and a are the border of a random variables (in our example, a=0, b=200 m). To find the shortest route between all pairs of nodes Floyd algorithm has been used, which allows finding the shortest paths between all pairs of vertices of the graph. The key idea of the algorithm is the partitioning of the shortest path search process into phases [17]. Figure 5 shows the empirical histograms of the shortest lengths routes (including transits) and their approximation by probability density Weibull distributions:

$$f(x,\alpha,\beta) = \frac{\alpha}{\beta^{\alpha}} x^{a-1} e^{-\left(\frac{x}{\beta}\right)^{\alpha}} \quad (2)$$

where, α and β are distribution parameters.

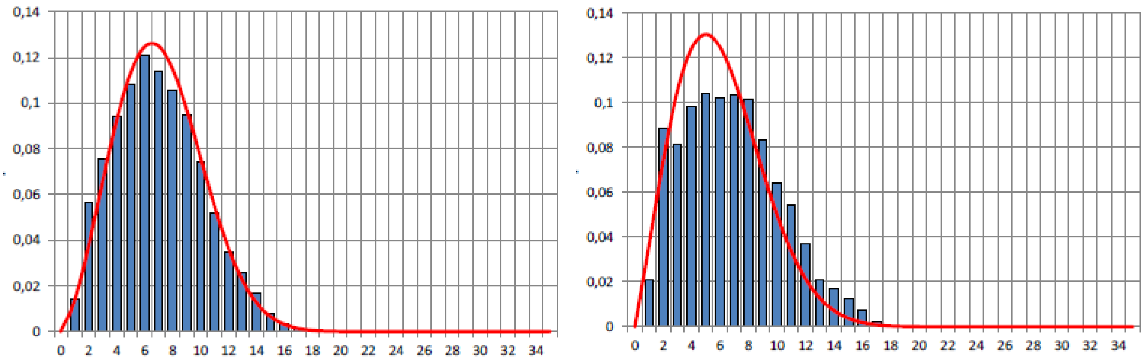


Figure 5. The number of transits in the route for equipartition and normal distribution laws (with equal dispersion)

As can be seen in Figure 5, the obtained forms of the distribution of the number of transits and their mean values are statistically equal for equipartition and normal distribution of coordinates of nodes. According to the experiment results, an empirical dependence was obtained the average number of transits from dispersion:

$$\overline{m} \approx \begin{cases} k_p \frac{\sigma}{R}, & \frac{\sigma}{R} < 1{,}5 \\ 0, & otherwise \end{cases} \quad (3)$$

where, k_p=4,48 from the modeling results. The simulation results showed that the average number of transits increases until the phase of the network transition to a disconnected state

4. Research Method

Quality of information of cottons, depends on the topology of sensory networks, i.e. the location of the sensors in the crop area. According to IEEE 802.15.4, the topology of sensor networks can be star, tree and mesh [10]. In general, the location of the sensors on the crop field can be considered casually. Taking into account the location of the cotton field, we place the sensors in the area of the crop using the "tree" topology. One of the main parameters of the network is timely delivery of information on cotton crop to the EAS.

The EAS program is located on the server and infromation is forwarded to the server via the gateway. When messages are transmitted to the gateway from each sensor, they may also be transmitted over other sensors [18]. This causes some information remains in the network. Additionally, information may also be lost on the network. It depends on to the number of transit routes and their length. These characteristics are randomly identified by the probability distribution law. The transmission of messages from the sensors to the gateway is carried out in accordance with the principle of multicast. Located in the gutter area of the gate will be located in the geometric center of the service area. Transmission of data from the sensors to the gateway is centered from the service area. In this case, the transmit position of the sensors on the route traffic can be consistent with the normal distribution law [19]. Access to the gateway and the server at the time of the transmitted data from the sensors causes the EAS to analyze the data and deliver the required information to the farmers at the time [20].

4.1. Expert Advisory System

The Expert Advisory System (EAS) is a application that analyzes the problems which occurs in the cotton fields and develops their solutions and transfers them to a farmer’s server. The EAS for cotton crops firstly identifies the symptoms of the disease. The description of the disorders like a text or images.

Many farmers in rural areas do not have enough knowledge about the diseases that occur in the cotton fields. Some crops in agriculture are difficult to distinguish, since two or more diseases have the same homogeneity. Therefore, this creates a problem to farmers. This problem can be solved by using the EAS to integrate the knowledge of various experts into one application. As a result, the farmer will receive timely advice and increase the productivity of cotton crops.

4.2. Expert Advisory System based on the Internet

Our main task is to improve the web-based so application to tackle the problems facing the cotton fields. The proposed solution to solve the problem consists of three stages: first localization the sensors required for the cotton field; In the second stage, sensors transmit data on soil, moisture, temperature, and insects through the gateway to the server; In the third stage, the server will redirect the information through the EAS to the farmer's mobile phone through the Internet.

5. Results and Analysis

5.1. Localization of Sensors in the Cotton Field

Sensors on the cotton fields are placed to collect information about the environment humidity, soil moisture, leaf moisture and pest insects. The sensor card consists of an AT Mega 1284 processor and a micro SD card with a resolution of 2 Gigabytes. Each sensor panel consists of four sensors, a soil humidity and temperature sensor as well as air temperature humidity sensor.

We can simultaneously learn about the ambient temperature, the moisture content of the environment and the moisture content of the leaf and the soil content. Zigbee-802.15.4 communication module has been used for cotton crops data transfer. It can communicate with microcontroller at 38400 bps. Data transmission distance is approximately 500 meters. Gateway-serves as a bridge between sensor nodes and server. We can connect wirelessly with the sensor and a computer through a USB port. We have experimented with this experience in Chust district of Namangan region.

5.2. Algorithm of EAS Processing for Cotton Crops

The sensor-based EAS system differs from traditional systems. It uses data collection using real-time sensors data. Sensor nodes send data to the gateway for a given period of time. The server receives data from the gateway via a USB port. The EAS system processes the data processing on the server and sends the information-based recommendations to the farmer's mobile phone through the Internet. The proposed EAS system consists of the following main components: a database; fast working memory; data processing chain; user interface. The EAS performance algorithm is shown in Figure 6.

The proposed EAS system needs information on pests, insects, diseases, weeds and the conditions necessary for the cultivation of cotton.We met with experts and learned about the types of disease in the cotton fields, the causes of the disease, the signs of the disease, the insects that attack the cotton harvest, the weeds that kill the cotton harvest and the insects that spread the disease from one plant to another.

Sensors placed on cotton fields collect data from different sources. In particular, earth sensors collect data about soil condition, soil moisture content, and soil composition [21]. Air detectors detect air humidity and temperature and transmit data to the gateway. The gateways send data to the server, and the server decides on the EAS system based on the list of data used in the operation. All the arguments are simple, but based on a particular logic.

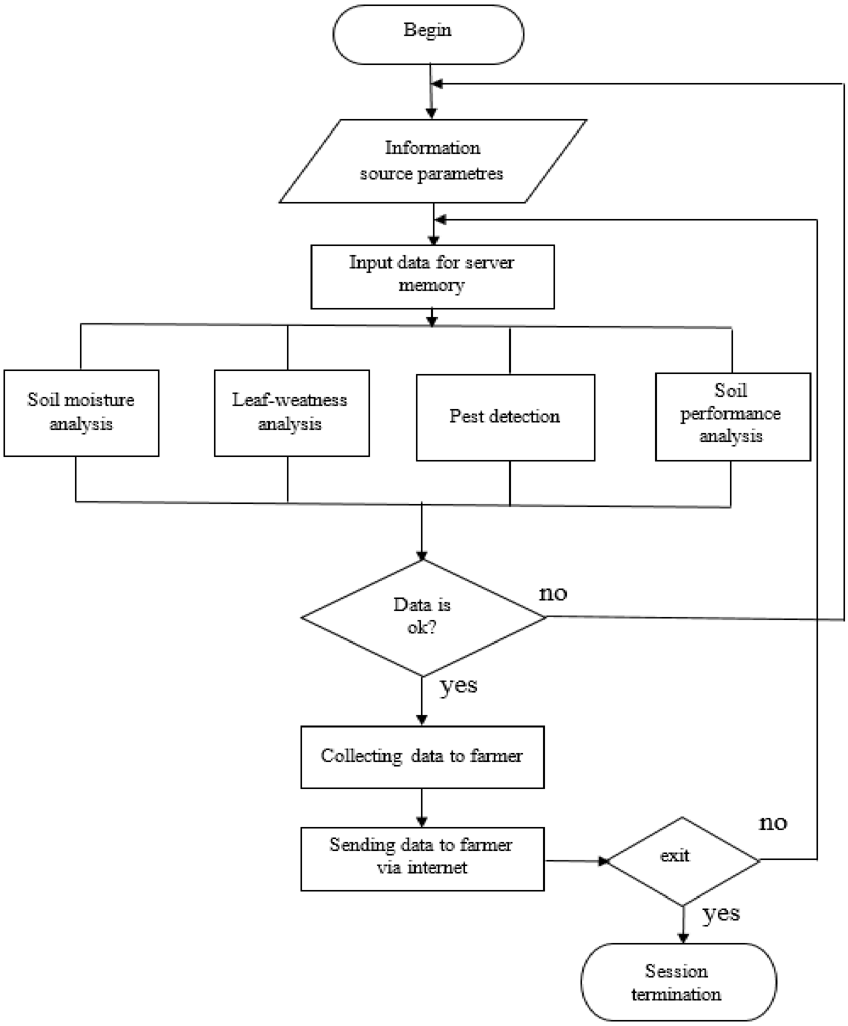


Figure 6. EAS algorithm flowchart

5.3. Server Sends Recommendations to Farmer

The data sent from the server sensors is processed. The developed recommendations of the EAS will be sent to the mobile phone of the farmer. We conducted this experiment from May 2018 to August 2018 in Chust district cotton fields. Figure 7 shows experiment location using Google Earth Pro 7.3.2 version.

Figure 7. Experiment location

Irrigation of cotton crops depends on several factors, such as soil moisture, soil type, root zone and environment [22]. Each cotton field needs different water requirements, so the amount of irrigation varies depending on the soil composition. Environmental change is also an important factor for planning irrigation [23]. Cotton yields a certain limit of irrigation, and if the cotton harvest reaches the limit of water reductions it is necessary to apply irrigation. Given its low energy consumption, wide availability, and ease of use for farmers, smartphone-based BT has been employed in different agricultural applications [24-26], such as controlling irrigation systems, monitoring soil and weather conditions, and controlling the use of fertilizers and pesticides.

5.3.1. Expected Result from Research

As a result, the proposed EAS helped identify diagnostics of diseases occurring on cotton fields, detection of weed attacks and pest management. Based on the EAS sensor data, recommended the planning of irrigation, depending on the temperature and soil composition, as well as the dose of irrigation of cotton crops. Farmers can use the EAS system at any time. For this, access to the EAS site through the Internet will be possible with the login and password of its own field as shown in Figure 8. In Figure 9, online monitoring data, saved reports are shown. According to the displayed data from online monitoring farmers can monitor daily the cotton field. EAS can use online archived data through the system control panel.

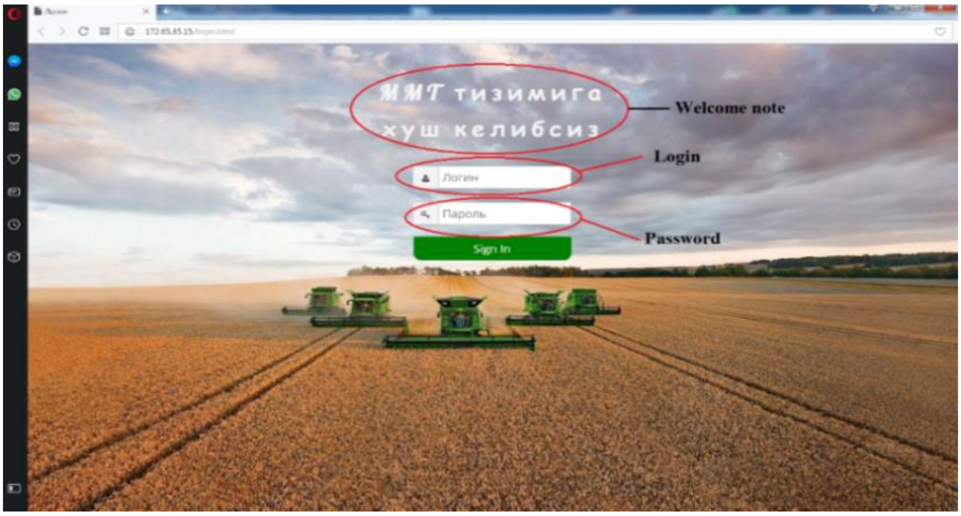


Figure 8. Expert advisory system login

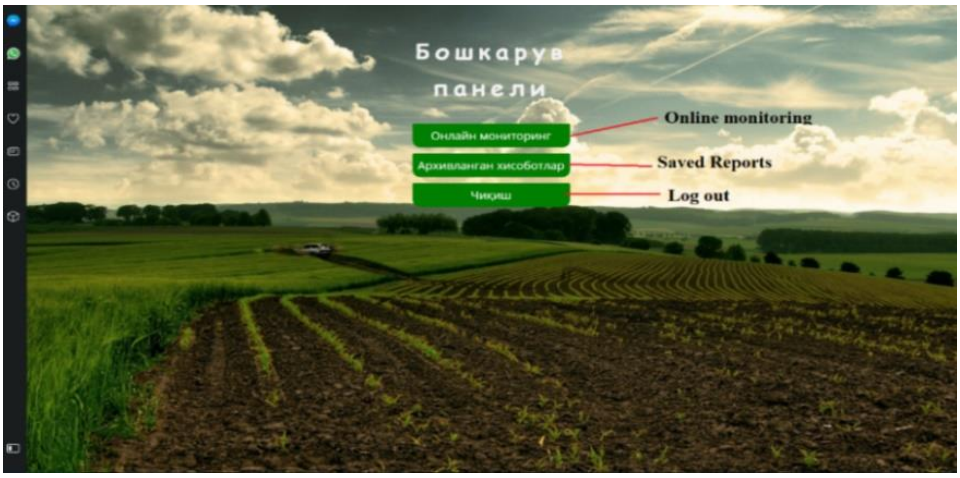


Figure 9. Control panel of EAS system

6. Conclusion

To sum up, EAS monitoring system for crops and wireless sensor network modeling are given in this article. To do this, the sensors were placed in the cotton fields. The information received from them was sent to the gateway using a wireless network and transferred from the gateway to the server. Sensors monitor moisture, leaf moisture, temperature and humidity levels in the environment and send recommendations to farmers on irrigation during cotton harvesting. In this article, we have used EAS to identify various types of weeds, pests and various insects that attack the cotton harvest. These recommendations are sent to the farmer's work station to take the necessary precautions. As a result of the research, it should be noted that as a result of the use of MFIs, the efficiency of the cotton harvest in 2018 has increased by 13% compared to the cotton harvest in 2017.

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