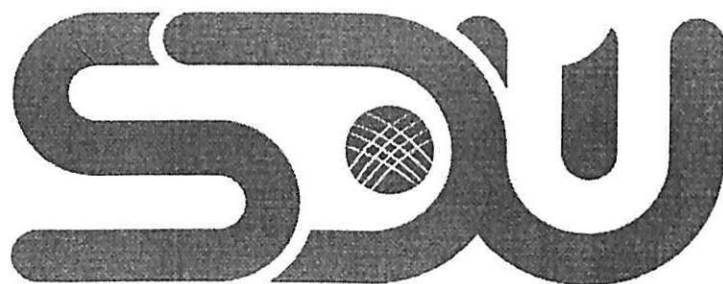


Ministry of Education and Science of the Republic of Kazakhstan
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Development of Animal Tracking System for Long Range using IoT Technologies

THESIS

Presented in Partial Fulfillment for the
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Abstract

The population of our planet is growing at a rapid pace, with an annual growth of 1.1 percent. The population is expected to continue to grow and reach 8.4 billion by 2030. Although this is a fairly positive fact, this phenomenon carries with it enough negative aspects. And one of which is the lack of food, which requires the rapid development of agriculture. Agriculture will have to increase its production massively by 70 percent. The solution to this problem is the technology of the Internet of things. With the help of technology we can avoid morbidity in livestock, excess in power consumption and generally make life easier for the farmers. In this work, a strong focus will be placed on tracking the location of animals, which will be quite cheap and of high quality. This research aims to find the most optimal technologies to track animals on long ranges, while being low-priced and effective enough.

Аңдатпа

Біздің планетамыздың халқы жыл сайын 1,1 пайыздық өсіммен жылдам қарқынмен өсуде. 2030 жылға қарай халық санының өсуі жалғасып, 8,4 миллиардқа жетеді деп күтілуде. Бұл айтарлықтай оң факт болғанымен, бұл құбылыстың жағымсыз жақтары да жеткілікті. Ал соның бірі – ауыл шаруашылығын қарқынды дамытуды қажет ететін азық-түліктің жоқтығы. Ауыл шаруашылығы өнімін жаппай 70 пайызға арттыруға тиіс. Бұл мәселенің шешімі – заттар интернетінің технологиясы. Технологияның көмегімен біз мал ауруынан, электр қуатын шамадан тыс тұтынудан аулақ бола аламыз және жалпы шаруалардың өмірін жеңілдетеміз. Бұл жұмыста жануарлардың орналасқан жерін қадағалауға қатты назар аударылады, бұл айтарлықтай арзан және сапалы болады. Бұл зерттеу бағасы төмен және жеткілікті тиімді бола отырып, жануарларды ұзақ қашықтықта бақылаудың ең оңтайлы технологияларын табуға бағытталған.

Аннотация

Население нашей планеты растет быстрыми темпами, ежегодный прирост составляет 1,1 процента. Ожидается, что население продолжит расти и к 2030 году достигнет 8,4 миллиарда человек. Хотя это достаточно положительный факт, это явление несет в себе достаточно негативных сторон. И одним из которых является нехватка продовольствия, что требует быстрого развития сельского хозяйства. Сельскому хозяйству придется резко увеличить производство на 70 процентов. Решением этой проблемы является технология Интернета вещей. С помощью технологий мы можем избежать заболеваемости скота, превышения энергопотребления и в целом облегчить жизнь фермерам. В этой работе большое внимание будет уделено отслеживанию местонахождения животных, что будет достаточно дешево и качественно. Это исследование направлено на поиск наиболее оптимальных технологий для отслеживания животных на дальних дистанциях, при этом недорогих и достаточно эффективных.

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To my family

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1. Introduction

1.1 Main information

In past decades, modern farming technology solutions have just become broadly utilised industrialized nations, leading to substantial increases in overall employment, lower manufacturing and inventory costs, and an enhancement of the quality of considering factors of agricultural inputs.

Technologically advanced smart devices, computer controlled planning and monitoring infrastructure for industrial applications, global positioning system (gps, mechanical devices, and other digital devices are used in different innovations and guidelines such as "Precision Farming," "Smart Farming," "Smart Agriculture," digitalization, and the Internet of Things.

The supervision and enhancement of the task areas process of manufacture in intensive agriculture through into the progression including the use of "intelligent" device types that transfer and procedure alerts from each thing and its eco system (sensor systems analyzing the specifications of soil, greenhouses, temperate climate, wildlife attributes, equipment condition, and so on) made it possible to transform agriculture from a traditional technology-based industry to a high-tech industry. [1]

The information obtained in one central core from numerous gadgets, on the farm, on industrial equipment, from weather stations, drones, satellites, and external entities all across the production life cycle provides immediate details of a new high quality, recognize patterns, and increase its value including all respondents, using current techniques of big data processing, on the basic principle from which disputes are resolved that minimize risks, strengthen the manufacturing environment, and make things better for all participants.

Digital ("smart") agriculture can predict yield and income, as well as choose

the best fertilizer and harvest time. It can also measure the time of stacking and shipment of passes to the buyer, maintain the temperature with in transport and storage area to reduce losses, and obtain recommendations for enhancing cultivation and livestock farming techniques.

The variety of devices and equipment used to generate digital agriculture is being enhanced and increased in order to acquire information on field fertility and crop state, which is required for generating optimal decisions when arranging modern production. Electronic gadgets utilized in precision agricultural systems are being developed further, as is the technological usage of the Internet.

The most widespread use of precision agricultural technology has been in the realm of employing satellite navigation systems. Several applications and software platforms are available for documenting manufacturing processes and tracking product movement and quality. High-performance communications and digital technologies manage and make data available in a number of formats. Information that has been digitized may be accessed at any time and in practically any volume, independent of location. This has a significant impact on the way agricultural processes are organized.

Due to a significant increase in productivity and a decrease in non-productive costs, the digitalization of the industry, relying on something like a vast range of applications and mechanisms compatible with information systems and related software, will make it possible to transform the industry into a high-tech sector of the economy, as defined by German experts as Agriculture 4.0.

This strategy combines automation and digitization of production with the Internet of Things (where machines and equipment communicate with one another without human involvement), a significant volume of data, and electronics that pervade all aspects of agricultural production.

According to UN estimates, food production would need to expand by 70 percent by 2050 owing to global population growth. This entails increased and consistent demand for agricultural goods, as well as the creation of new standards for agricultural labor productivity. As a result, the domestic agriculture sector has an urgent problem of enhancing labor productivity and agricultural product competitiveness through the use of cutting-edge scientific findings and the development of innovative production technologies.

As per PricewaterhouseCoopers Consulting (PwC) research, there has not

been an innovative leap in productivity due to automation as of 2000, spite of the rapid opening of technological advancements in the field of communications technology, data transmission, and the development of the Internet, so how should a specified sufficient number of technological advances introduced into the production field be accumulated for this? [5]

The automatization of the economy, which includes different parts of automation dominated by technology such as the IoT, machine learning, robots, digital platforms, and other sectors, is held in high regard in all industrialized nations.

According to experts' predictions, by 2020, 25 percent of the global economy will have adopted digitalization technologies that enable the state, business, and society to function properly.

According to estimates, a farmer must make more than 40 decisions during the season, including what beans to cultivar and when, how and when to treat, how to cure a damaged facility, and others in short periods of time. Several of these solutions have been transformed into digital artifacts.

The current state of digitalization in domestic agriculture is cause for concern: a lack of academic and engineering knowledge about advanced agricultural production technologies and methodologies, a sudden loss of a worldwide forecast for agricultural prices, and a lack of development in the logistics, storage, and delivery systems all contribute to high production costs.

Only a tiny percentage of agricultural farmers have the financial means to invest in new equipment and platforms. According to Rosstat, the cost of ICT (information and communication technologies) in the area "Agriculture, hunting, and forestry" was 4 billion rubles in 2015, or 0.34 percent of total ICT investments in all sectors of the economy, and 0.85 billion rubles in 2017, or 0.2 percent. This is the smallest industrial indicator, indicating that domestic agriculture has a low degree of digitization, but it also suggests that the sector has the most opportunity for engagement in ICT technology.

In agriculture, digitalization allows for the creation of workflow automation production and logistics chains that include chain stores, wholesalers, logistics, agricultural farmers, and their suppliers all in one process with adaptive management. The digitization of primary commodities flows and production allows for the systematic collection of trade parties for agricultural product export. [3]

The goal of information technology (IT) is to automate as much of the man-

ufacturing process as possible in order to decrease waste, increase business efficiency, and achieve maximum management. Further automation is a greater degree of intelligent automation that entails the most hierarchical organisational change in the industry, but its adoption can have a significant impact on product profit and competitiveness. By combining the generated data with a range of clever IT systems that evaluate it in real time, numerous factor analysis and the justification for action are transforming farmer decision making.

Simultaneously, the more transmitters and field controllers that are interconnected channel and transfer data, the more "smart" the information system acquires and the more meaningful data it can deliver to the user.

The Internet of Things (IoT) is one of the most effective tools for achieving a new level of digitalization, and its widespread adoption in world practice has been made possible by the following technological trends: decreasing the expense of computing power (processors, memory, and storage systems) and transmitting data; the construction of "cloud" technologies and "big data," which have made flexible systems for collecting and analysing data available; and the development of "big data" technologies, which have made flexible systems for storing and analyzing data

1.2 Agriculture in Kazakhstan

Agriculture plays one of the key roles in the economy of Kazakhstan. The technical support of the village is a determining factor in the development of agriculture. To reduce the operating costs of machinery and improve production efficiency in general, it is necessary to monitor and optimize the operation of agricultural machinery. This becomes especially relevant during the period of sowing and harvesting, when agricultural machinery is used to the maximum and the risks of misuse of equipment and unjustified excessive consumption of fuel increase sharply.

Such problems can be solved by installing GPS monitoring systems, which minimizes the influence of the human factor and solves the problem of the remoteness of the controlling dispatcher from the equipment during the work performed.

The satellite monitoring system is built on the basis of modern GPS and GSM technologies, and, in general, consists of three components: space, control and

user. At the same time, GPS / GLONASS satellites controlled from the ground center broadcast radio signals from space, which are used by ground receivers (controllers, trackers, "beacons") to calculate their coordinates in real time. Further, via an Internet connection and a GPRS module, the received coordinates are transmitted by the tracker to a pre-programmed IP address. The user gets secure access to data and sees on the screen the location, movement, direction and speed of their objects in real time (Figure 1.1).

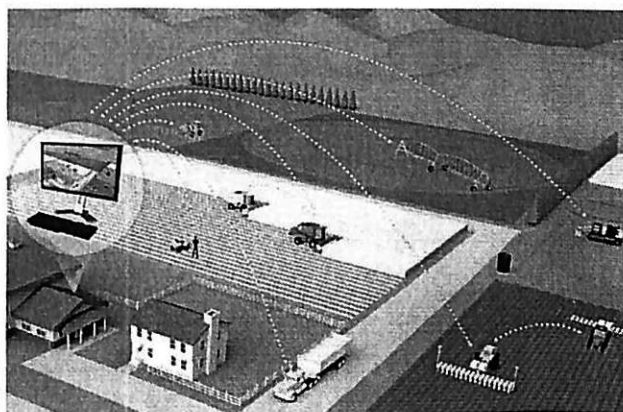


Figure 1.1: Example of a 'smart' farm.

GSM coverage conditions on fields remote from the infrastructure are not stable. But trackers are able to remember information and transmit it later, when GSM coverage appears. If the GSM coverage is not stable ("torn"), then when the GSM base is first detected, all information is transmitted to the server. Usually the tracker's memory is enough for a day of equipment operation.

In addition to GPS trackers, other sensors can be installed on agricultural machinery, allowing you to control many other parameters. Fuel consumption sensors are especially relevant for the agricultural sector. When such sensors are connected to agricultural machinery in parallel with the GPS monitoring system, the process of monitoring fuel consumption is automated.

To date, there are many domestic and foreign companies on the market offering their services for the installation and technical support of GPS monitoring tools. For example, individually configured access control systems of the Kazakh company TerraPoint provide not only a comprehensive solution to the problems associated with the operation of agricultural machines, and even include driver identification using fingerprints and RFID cards, as well as unloading grain from a combine only into a registered vehicle. However, the cost of a GPS monitoring kit for one piece of equipment with installation is at least 200 dollars, which is

quite expensive.

We set the goal of making the kit as cheap as possible. To do this, we used the Arduino microcontroller and bench tests of individual modules and sensors were carried out on its platform. Arduino microcontrollers are relatively cheap compared to other platforms. The most inexpensive version of the Arduino module can be built by hand, and some pre-built modules cost less than 50 dollars.

The Arduino Uno board is the most popular and most affordable Arduino device. It is based on the ATmega 328 chip. Arduino Uno has a convenient size and the ability to connect external devices, it is available, a large number of free lessons and sketches have been written for it.

2. Literature review

[lazer2014parable] In paper 1, An LP-WAN-based point architecture is proposed to extract data from ships and show it through some method of data presentation platform or control system. The Radio Access Network (RAN), the platform as a service, and the user domain are the three regions. The use of an LP-WAN system, which permits interaction amongst sailboats and land-based base stations/gateways, facilitates RAN. This is the most complex component of the design due to the difficulties that dispersion and scenario circumstances may present. The router provides a point of engagement for receiving and transmitting data to the cloud. In this intermediary phase of the design, data is delivered to a centralized server in charge of aggregation through a transmission networks, such as the Internet. At this stage, a variety of services might be provided, varying from with a parameter display system to more demanding systems related to data analytics or alert systems. This portion of the architecture houses the system intelligence. Finally, the digested data is delivered to consumers as pertinent data, providing for viewing and even interactivity, depending on the system in question. This architecture's end-users will be able to accurately monitor maritime activities, such as ship locations and other observed data.

The system was created to monitor and review the progress of small and light boat races. They employed our LoRa-enabled tracking devices to track a portion of the Optimist Class boats' practice sessions in the harbor of Vigo in this scenario (Spain). They watched a sequence of one-hour practice sessions within the port with maximum transmission lengths of one kilometer. The boats were outfitted with detectors and a LoRa transceiver in order to communicate their location and other data to a base station located on the top of a tall building in the port. There are considerable energy and payload limits on these boats due to their nature and inherent limitations, therefore both the components and

the sent data have been tailored to fit these demands. Because of the growing interest in these occurred events in history years, an online monitoring tool has been developed. As an outcome, the central server uploads the data it receives to a web service that shows race stats to users through a web-based dashboard. Notice how the dashboard immediately updates the geolocation and other information for each boat, letting the race to be streamed live with a tiny lag relative to the LoRa link. As aforementioned, LP-WAN solutions deliver low data rates, which increases data transmission latency; nonetheless, this propagation delay is also to be anticipated for the operation in issue.

The cutting-edge modulation schemes that are appearing under the IoT paradigm might be valuable for marine communications. As a result, the use of LP-WAN technologies to provide ships with land connectivity has been studied in this study. The present condition of existing technologies, as well as the benefits given by all these unique transmission methods, have been investigated. It has been observed that they are suitable for use in boats with large payloads and energy limits, such as tiny sailboats, or low-cost maritime hardware, such as radio-control boats.

As a consequence, an LP-WAN-based architecture was proposed, and a field experiment was conducted to validate it. A sample effort was launched to examine the effectiveness of LoRa, amongst the most attractive LP-WAN technologies, with the purpose of monitoring the behaviors of Optimist Class sailboats. A genuine LoRa-based connection has been established in the harbor of Vigo (Spain). The results showed that utilizing LoRa to detect ship maneuvers and monitor a variety of parameters at the port is feasible. Various LoRa configurations have been tested and discussed, with the result that in order to decrease transmission time-on-air, high data rates should be used in favorable transmission conditions. Furthermore, large amounts of broadcast dependency (beyond 100 percent PDR) were reached utilizing the most robust LoRa configuration.

There was also a transmission range investigation, which found a greater range of 4 km under test-bench circumstances. They reasoned that this distance would be adequate for tracking lightweight and small boats, therefore they constructed a number of structures for simulating an Optimist Class race. Finally, end-device power consumption was evaluated, resulting to the result that reduced batteries can enable one-day autonomy. They decided to expand this study in the future to evaluate the system's efficacy in a completely different situation, including bigger

ships and, as a direct consequence, a specific variation of transmission equipment.

In paper 2, they suggested developing an Internet of Things-based public gps tracker that would use LoRa (Long Range) and ITS technologies to improve public transit in intermediate cities. In this work, they developed the developed methodology as a working prototype. They created and carried out experiments to fine-tune the parameters of the LoRa technology and evaluated its functionality. This page details the methodology they used to build the solid evidence concept, but also a synopsis of the tests and their results. Once important technological restrictions, items similar to Line of Sight (LoS), are properly considered, the findings lead one to think that LoRa technology and an IoT-based architecture are sufficient for deploying a mobility service.

Their approach is founded on an ITS framework as well as IoT and LoRaWAN solutions (Long Range). Furthermore, their plan lays out software architecture, including how to create a solid evidence model and test it. The four phases of our study are the conception of the proposed application, the development of the concrete evidence model, the execution of trials, and the analysis of results.

The platform's development is largely concentrated on the elements that are regarded critical, such as vehicle-to-management-center communication and information display to system users. To communicate between cars and the management center, information must be delivered through gateways. These gateways capture vehicle data and send it over the Internet to a control centre using LoRa technology. Because the best circumstances for deploying LoRa equipment for the principles that enable service were not immediately apparent, it was necessary to conduct tests where during system's development and then confirm its performance. When creating the platform, which was done using minimal equipment and free software tools, budget restrictions were taken into mind. Thanks to the trials, we were able to determine operational aspects including the distance of LoRa communication, the percentages of incoming signals, as well as the number of data packets per minute. The number of packets was determined by the message size as well as the largest number of automobiles in which each gateway can handle. Lastly, the results analysis highlights major limits that must be taken into account during system construction, notably in terms of LoRa functionality.

They developed the software that enables the microcomputer card (the vehicle's primary OBE component) to communicate with the gateway through LoRa.

For this scenario, the GPS device gave information such as vehicle position (longitude and latitude), speed, and altitude. They also developed the application that receives LoRa communications from OBEs and sends the data into the cloud host through the Internet. Both modules were made with the Arduino Software (Integrated Development Environment). The source code for the modules may be found on the internet.

They investigated the potential of creating a LoRaWAN or just transmitting LoRa messages to transport data from either the OBE gadgets to the gateway (via testing). The gateways use standard IP connections to interact with the webserver and act as a translucent bridge, converting RF transmissions to Ethernet frames and vice versa. They have used TTN platform to conduct LoRaWAN tests (The Things Network). Low-power devices may join to an accessible, distributed system via lengthy bridges and exchange the data with apps using the Things Network (TTN). OTAA (over-the-air activation) or ABP (activation by personalization) options can be used to connect devices to TTN. At last, they were capable of connecting to the LoRaWAN in a respectable length of time; nevertheless, LoRa message communication proved to be quicker. We decided that transmitting LoRa messages, rather than establishing a LoRaWAN, was the best option because cars link to many gateways during their path.

Some precise criteria must be established in order to send and receive LoRa messages, like the frequencies, the Spread Factor (SF), and the bandwidth (BW). We operated in the 902–928 MHz frequency range, which is prevalent in the United States (US), using 915 MHz serving as that of the data-sending/receiving channel. The ideal SF (which can be set between 1 and 12) and BW (which may be 125 KHz, 250 KHz, or 500 KHz) value was calculated to just be 7 for the SF (which can be set from 1 and 12) and 125 KHz for the BW (which could be 125 KHz, 250 KHz, or 500 KHz) (which can be 125 KHz, 250 KHz, or 500 KHz)

On contrast to the application for the OBE and the gateway, they wrote a program throughout the cloud server to accept texts from the gateway and put those inside the Event Processing database. The XAMPP package, which comprises an Apache web server, PHP computer language, MariaDB sql server engines, and a database administrator, was utilized (phpMyAdmin). We utilized RESTful operations to link the LoRa gateway to the Transit Management Center in the cloud. These activities employ the POST HTTP method of the LoRa bridge

software to convey information about all cars, and the GET HTTP method of the internet server program to accept the data and put it in the database.

The recommended tracking system for public transportation vehicles employing an IoT-based system, LoRa technology, and ITS services is appropriate for deployment in an intermediate city if numerous major technical elements of LoRa operation are reviewed. During the experiments for this investigation, several technical qualities were identified.

The following article proposes and implements a LoRaWAN protocol-based communication architecture for a the outside geolocation solution. The suggested system uses a Microchip bridge receiving station, model DV164140-2, to receive coordinates from a U-blox company's NEO6 product line GPS device and broadcast information via an ST-Microelectronics P-NUCLEO-LRWAN1 model kit. A communication source node to a destination on Semtech's SX1257 type transceivers chip-sets makes up the Microchip DV164140-2 gateway.

To make sending Gps location to the gateway easier, the P-NUCLEO-LRWAN1 package from STMicroelectronics was used. A wireless system (RF) extension board using the Technique is the process SX1272 reduced power transceiver is included in this kit. The SCX1272 transceiver is responsible for Modulation scheme, including on Modulation scheme (OOK) and Frequency-Shift Keying (FSK) modulations used in the LoRa transmission system.

For precise position measurement, a GPS from the company U-Blox, model NEO-6, was used to obtain geographical coordinates utilizing satellite signals. This GPS has also been configured to deliver just the messages that are of relevance at a reduced level, which for this instance is a regular text as from National Marine Electronics Association (NMEA) and a form of Global Positioning System Fix Data (GGA Type).

The antenna used is an Amphenol Antel MPA-806N type, which has good operating and mechanical properties. This radio has a sampling rate of 806 to 960 MHz and gives 3 dBi gain for both straight vertical and cross-polarization modes on positional and omni-directional irradiation. The attenuation generated by the 3 feet of RG213 wire linking it to the gateway is 0.7db, according to the supplier data sheet. The antenna was installed on the top of the Instituto Nacional de Telecomunicações (INATEL) building 6 in Santa Rita do Sapuca, Minas Gerais, Brazil, at a height of 885 meters, to give the optimum coverage area based on

local terrain relief.

To connect the terminal to the network, the solution was constructed in Activation By Personalization (ABP) mode, and it was intended to operate as a class A terminal. In order to obtain a good evaluation with other standards in the same context, a 12-byte payload was constructed to enable the exchange of position, greenwich meridian, and height information, read and delivered that use the GPS module UBlox, reported previously. Various Wireless transmission channelization settings of the terminal have to be altered to meet the features and constraints of the catalyst radio module used, including restricting the broadcasting of the first 8 stations of the LoRa 915 MHz channel allocation spectrum. It's worth mentioning that the LoRa baseline transmission mechanism only used the top eight channels for random channel selection. At the gateway receiver, a 125 kHz frequency and a spreading factor of 12 were used to obtain a Signal to Noise Ratio (SNR) of around -20 dBm and a sensitivity of -137 dBm.

When data is received by the gateway, it is demodulated, decimated, and verified, and the correct attributes of latitude, longitude, and altitude are evaluated and recorded. A packet containing all of this data is addressed, wrapped, and provided inside of an IP networking interface linked to the Internet for usage by a visible user application interface. In order to monitor command line range of motion on the very same hardware platform as the gateway database and application server, an Application Programming Interface (API) was established to obtain the repository and correlate the location information obtained with an interface plug-in of a topographic map management platform. This system displays the observed terminal displacement in real time on a customer graphical map interface.

Once the LoRa system is tested by the idiosyncrasies of moving items, it works remarkably well, according to the analysis. Since there was signal coverage or clear LOS, the system's performance revealed a low lost message index, allowing for effective tracking of the intended item in both the town, at which average angular velocity is moderate, and on the highways, where the average speed of travel is greater. Furthermore, both the gathering of geographic location and the transmission of this data to the management system are fully independent of the mobile telecommunications communication network and systems. The energy consumption of the GPS module isn't really an issue because satellites can gather

positions at a low interest rate, as well as the energy consumption of sending data across cellular networks is far greater than the combined energy consumption of the GPS module and LoRa transmission.

3. Architecture of the System

3.1 Internet of Things

The "Internet of Things" refers to the network of physical objects ("things") which are connected to the Internet and interact with the outside environment or with others. The term "Internet of Things" is taken from the English term "Internet of Things," which would be shortened as "IoT." An automated soft drink vending machine upgraded by American students in 1982 was one of the earliest IoT devices. This was possible to check its filling as well as the temperature of liquids from a distance.

The theoretical foundation of IoT was laid a little later, in the nineties, based on the use of artificial intelligence, mobility, and wireless data transmission. The rapid advance of technology in the 2000s led to the implementation of IoT projects, large-scale plans, and ideas of smart cities, and the enhancement and automating of normal production processes.

Kevin Ashton, the founder of the Auto-ID research group at the Massachusetts Institute of Technology, coined the term and concept of wireless data transmission for the first time in 1999. The essence of the concept was presented to Procter Gamble officials in a presentation. It was proposed suggested RFID tags have been used to modify the supply chain management system in order to improve the corporation's efficiency.

In a 2004 Scientific American article, a visual demonstration of the concept's potential for home use was shown. This post shows how infrared, wireless, power, and low-voltage networks could be used to communicate household appliances (air conditioners, alarm clocks, computers), household systems (fire protection system, lighting system, garden watering system), temperature sensors, motion sensors, and "things" with identifying marks. All this allows you to store energy

and manage the use of it. The devices will remind you to take your medicine on time, provide timely watering, and adjust the brightness, among many other items.

Even though the idea of home automation wasn't really new, the merging of devices and "things" into a common network reachable through Internet protocols swiftly gained any traction.

According to Cisco Corporation's research, the period 2008-2009 marked "the actual birth of the Internet of Things," because as number of devices connected to the global network exceeded the world's population. The People's Technology has transformed into the Internet of Things.

The Internet of Things was included in Gartner's standard measure of new technologies from 2011, at the stage of "technology trigger" with a development timeline of more than 10 years, and a special maturity cycle for Internet of Things technologies was released in 2012.

The number of devices which use Internet of Things software and link to the worldwide network is rapidly increasing. As per the Statista research center, the number of connected devices and sensors based on Internet of Things technology in the worldwide is currently above 26 billion, and by 2025, it is anticipated to surpass 75 billion. (Figure ??).

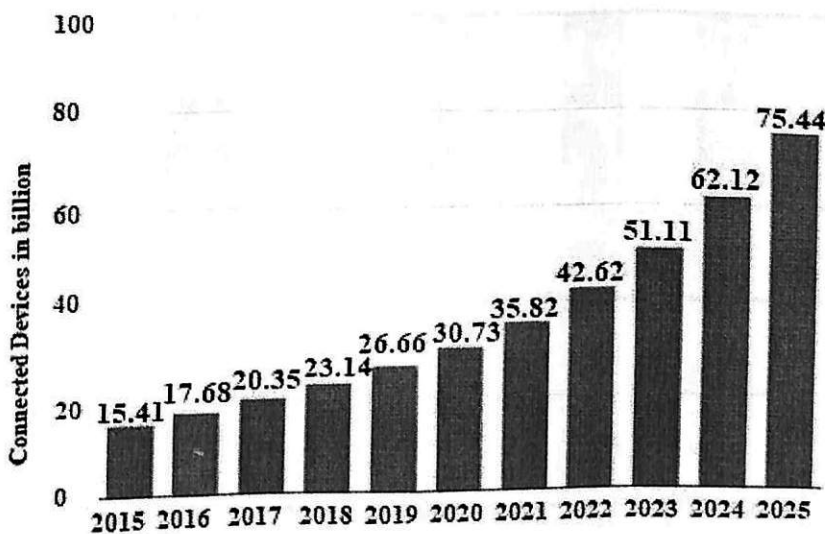


Figure 3.1: Triple G

The tasks addressed by Internet of Things technology require the deployment of powerful computer resources, which are divided into two levels: (1) a remote set of computing powers (for example, distributed data processing centers) and

(2) a native set of computing powers.

- Cloud Computing (Cloud Computing).
- Fog Computing'' (Fog Computing).

Cloud computing makes it easy to access shared system resources which would include servers, applications, and services on demand. Fog computing, but at the other side, is a type of cloud service that's also implemented by local sensor networks and is spread all through the cloud. The Internet of Things networks are arranged in the this way since some of the data processing load is moved from the cloud to the desktop computers. (Figure 3.2)

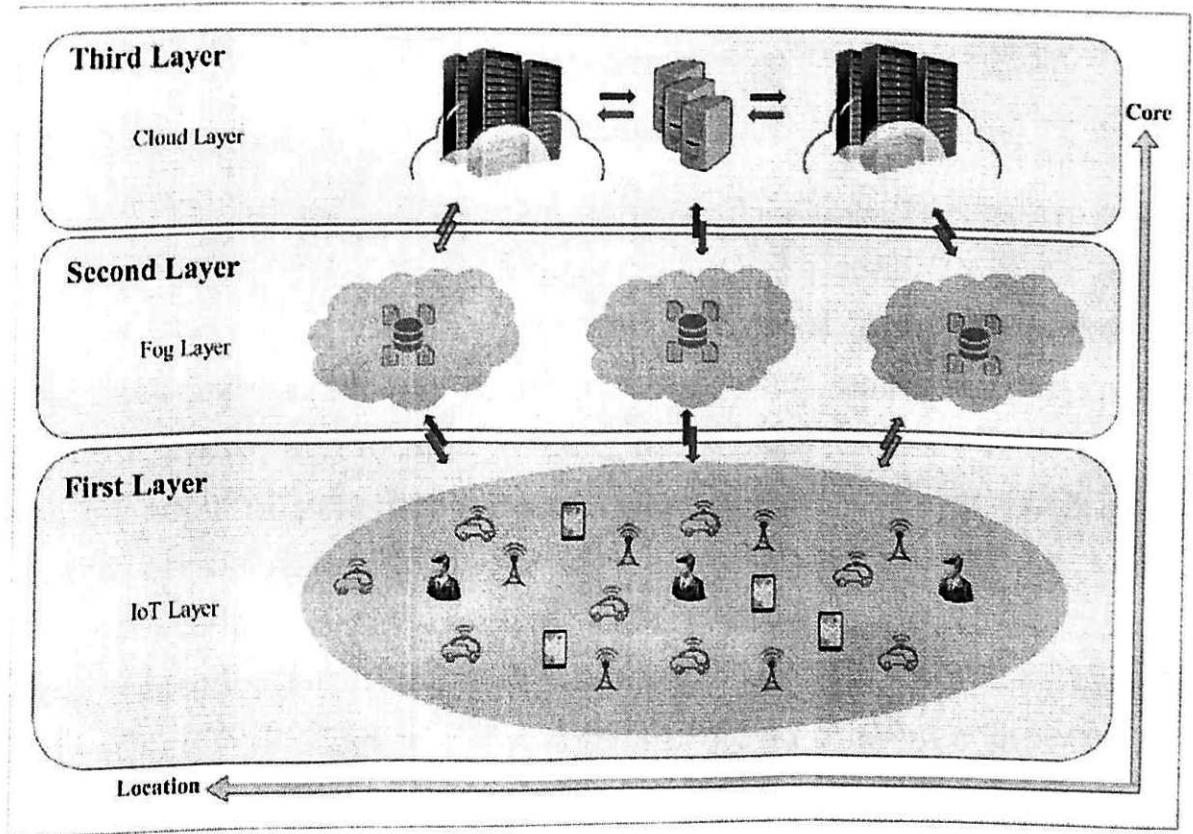


Figure 3.2: IoT layers

While evaluating the network parameters of IoT technology, one could detect a common feature: heterogeneity. Several security infrastructure standards have been proposed to enable IoT networks develop further. Consider the six-level architecture as the most honest depiction of the functional levels' relationship. (Figure 3.3).

Level of encoding: Each object is assigned its own identification number (ID), making it easy to distinguish between all. Perceptual Layer: In IoT devices, this

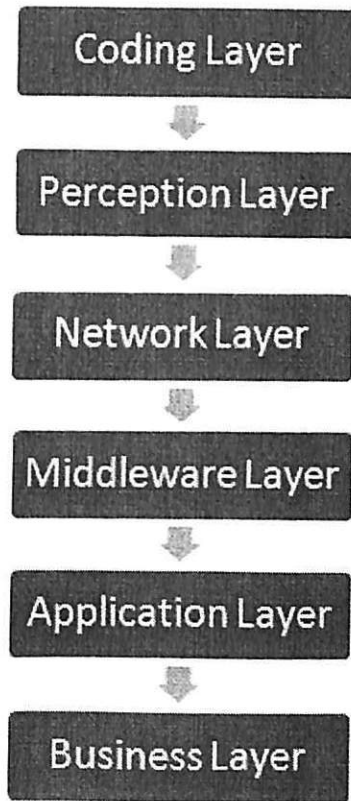


Figure 3.3: IoT six-level architecture

is the layer where each object is provided a physical meaning. It consists of a range of data sensors, such as RFID tags and other sensor networks, that read temperature, speed, and location, among many other factors. This layer gathers information about objects from various sensors to them and converts it into digital signals that are being sent to the network layer for processing.

The network layer receives payload data (digital signals) from the perception layer and transmits it to the middleware layer's systems via a data transmission channel such as WiFi, Zigbee, GSM, Bluetooth, and others for processing. IPv4, IPv6, MQTT, and other protocols are being used.

The processing layer of a middleware layer utilizes cloud and global computing technologies to interpret the data received from the sensors. The intermediate aspects that contribute direct access to the database in order to activate the necessary data into it. After the data is processed, a programmed activity is carried immediately (Intelligent Processing Equipment technology).

Application layer: Based on the collected and processed data, IoT applications for various industries are implemented. This training is necessary for large-scale industrial Internet of Things network development. Smart cities, smart roads, and smart homes can be connected to the Internet of Things at the application

level.

Business Layer: Manages IoT services and applications, and also Internet of things research. He offers a broad range of commercial proposals along with effective business solutions.

The examination of the Internet of Things technology's considered architecture prompted researchers to discover the peculiarities of physical object interaction in IoT networks and conclude that regular computer network models cannot be applied to IoT networks. objects.

In this context, we may deduce that the Internet of Things technology is currently a mixture of multiple computer networks, with its own objective. These networks are using a variety of information transfer protocols and were not well linked. In this view, we can expect that IoT technology will differ accordingly in the direction of consolidating existing networks into a single network and establishing a shared protocol for their correspondence.

Internet of Things (IoT) technologies are increasingly being integrated in very many elements of society today. We make our world simple and easy by actively utilizing various electronics. Device pattern formation them to hear, see, think, and, in some occasions, act.

3.2 Arduino

Arduino is a combination of hardware and software for easy electronics development. The hardware part includes a large number of types of Arduino boards with built-in programmable microcontrollers, as well as additional modules. The software part consists of a development environment (programs for writing sketches and flashing Arduino microcontrollers), a simplified programming language, a huge variety of ready-made functions and libraries.

Arduino was created by teachers to involve students more in electrical engineering. The idea was a huge success and Arduino went much further. Thanks to the open architecture, anyone can produce these microcontrollers, supplement the model range, and write programs. All schemes and source code of programs are in the public domain. [6]

After the Arduino became more widespread, many electronics manufacturers began to produce their own boards based on Arduino microcontrollers. When

Chinese manufacturers joined the production, Arduino became much more accessible and received an even larger audience. Arduino microcontroller boards in Chinese online stores cost from 1.09 dollars.

Arduino was created to teach students and schoolchildren electrical engineering, programming, radio electronics, and automation systems. With the help of microcontrollers, you can make not only educational projects, but also really useful devices. Arduino is used to create automation projects, smart home devices, portable weather stations, robotic arms and many other useful devices.

The original purpose of the Arduino is to learn. Children are much more interested in learning if they can immediately apply new knowledge in practice, and even see and touch the fruits of their labors. It is much more interesting to learn by experimenting, rather than listening to dry theory. From a technical point of view, Arduino is able to receive and send signals in accordance with the instructions in the firmware. It sounds very modest, but in practice this allows you to receive and process information from sensors and transmit commands to actuators or other devices. For example: a microcontroller can receive data from temperature, pressure, humidity sensors and display summary information on the display.

These capabilities are enough to implement complex devices, such as unmanned aerial vehicles, 3D printers, robotic arms, radio-controlled cars, boats, all-terrain vehicles, etc. The possibilities of Arduino are limited only by the imagination. If you miss the capabilities of Arduino, then there are more powerful microcontrollers such as Arduino Mega, NodeMCU, STM32, Wemos, Raspberry Pi, Orange Pi.

The appearance of the first microcontrollers marked the beginning of a new era in the development of microprocessor technology. The presence in one case of most system devices made the microcontroller similar to a conventional computer. In domestic literature, they were even called single-chip microcomputers. Accordingly, the desire to use microcontrollers as ordinary computers appeared almost with their appearance. But this desire was restrained by many factors. For example, to assemble a device on a microcontroller, you need to know the basics of circuitry, the design and operation of a particular processor, be able to program in assembler and manufacture electronic equipment. You will also need programmers, debuggers and other auxiliary devices. As a result, one cannot do

without a huge amount of knowledge and expensive equipment.

This situation for a long time did not allow many amateurs to use microcontrollers in their projects. Now, with the advent of devices that make it possible to work with microcontrollers without a serious material base and knowledge of many subjects, everything has changed. An example of such a device is the Arduino project of Italian developers.

Arduino and its clones are kits consisting of a ready-made electronic block and software. The electronic unit here is a printed circuit board with an installed microcontroller and a minimum of elements necessary for its operation. In fact, the Arduino electronic unit is an analogue of the motherboard of a modern computer. It has connectors for connecting external devices, as well as a connector for communication with a computer, through which the microcontroller is programmed. Features of the used Atmel microcontrollers ATmega allow programming without the use of special programmers. All you need to create a new electronic device is an Arduino board, a communication cable and a computer. The second part of the Arduino project is software for creating control programs. It combines the simplest development environment and a programming language, which is a variant of the C / C ++ language for microcontrollers. It added elements that allow you to create programs without learning the hardware. So, to work with Arduino, it is practically enough to know only the basics of programming in C / C ++. Created for Arduino and many libraries containing code that works with various devices.

The user of a modern computer does not think about the functioning of individual parts of the PC. It simply launches the necessary programs and works with them. In the same way, Arduino allows the user to focus on developing projects, and not on studying the device and the principles of operation of individual elements. There is no need to create complete boards and modules. The developer can use ready-made expansion boards or simply directly connect the necessary elements to the Arduino. All other efforts will be directed to the development and debugging of the control program in a high-level language. As a result, access to the development of microprocessor devices was received not only by professionals, but also simply by amateurs to do something with their own hands. The presence of ready-made modules and software libraries allows non-professionals in electronics to create ready-made working devices to solve their problems. And the options

for using Arduino are limited only by the capabilities of the microcontroller and the available board option, and, of course, the developer's imagination.

3.3 Arduino Uno

Arduino Uno is a board based on the ATmega328P microcontroller with a frequency of 16 MHz. The board has everything you need for convenient and fast work with the controller. I will tell you more about the microcontroller, the board and working with it later in this article.

The Arduino Uno is the most basic and most popular version of the microcontroller board. It is very convenient to work with it due to the fact that the pins are wired with single-row female connectors. Usually this board is used for prototyping projects, and the finished device is assembled based on smaller arduino boards, such as the Arduino Nano. This is easy to do since the firmwares is compatible and in most cases the pin numbers are the same. There are many expansion boards (shields) for Arduino Uno, such as Ethernet shield, motor shield, servo shield and others.

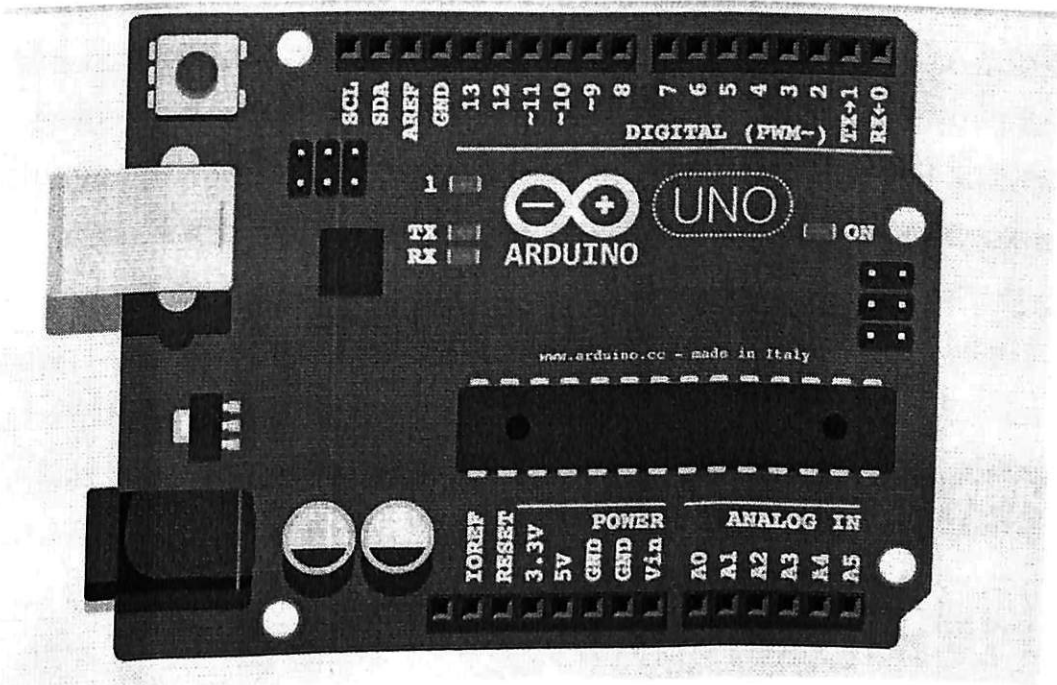


Figure 3.4: Arduino example

This arduino comes in two different versions: DIP and SMD. They differ in that the microcontroller itself can be DIP version (rectangular and legs) and inserted into the block, or simply soldered on the board if it is the SMD version

(square). There are no differences in performance, pin assignment or their number in these versions.

6 analog input pins inputs, 14 general-purpose digital outputs (which may be simultaneously inputs and outputs), a 16 MHz power amplifier, two power and USB connectors, an ISCP socket for an in programming, and a device hot reset button are included on the board. The chip must be powered either by the built-in USB port or by attaching the power cable to a source of 7 to 12V for reliable operation. The board may also be supplied by a Krona battery through the power adaptor.

The key distinction between the Arduino Uno and earlier boards is that the Arduino Uno communicates through USB using a separate ATmega8U2 microprocessor. For this, previous Arduino versions needed an FTDI programming chip. Because the Arduino Uno computer chip is Open-Hardware, all of its specs are publicly available. The panel is 69mm x 53mm in length and breadth. The power and USB connections protrude 2 mm beyond the printed circuit board's edges. The connector spacing is conventional 2.54 mm, although there is a 4 mm gap between pins 7 and 8.

The Microcomputer includes three ways to attach power: USB, external power, and the Vin connection, which is connected to the one of the slots on the side. The system has a designed stabilizer that allows the controller to not only automatically choose the source of power, as well as to balance the current to the requisite 5 volts. External power can be directly available from the computer's Usb or via the power connection or USB from every AC/DC power supply.

The board contains many outputs that may be used to power sensors, sensors, and actuators that are linked to it. These discoveries are all labeled: Vin - voltage input, which is used to receive voltage from an external entity. Only power is given to the board via the data output; it is unable to receive power for external devices from there. To minimize heat build - up and ignition of the built-in stabilizer, it is advised that voltage be applied to the Vin input in the interval of 7V to 20V.

- 5V - a voltage source of five volts for charging external devices You can always have a consistent voltage of 5 volts upon the pin whenever the motherboard expectations have been met at all from any source (USB, power connection, or Vin). It can be supplied straight to the relevant device or output to a breadboard.

UNO PINOUT

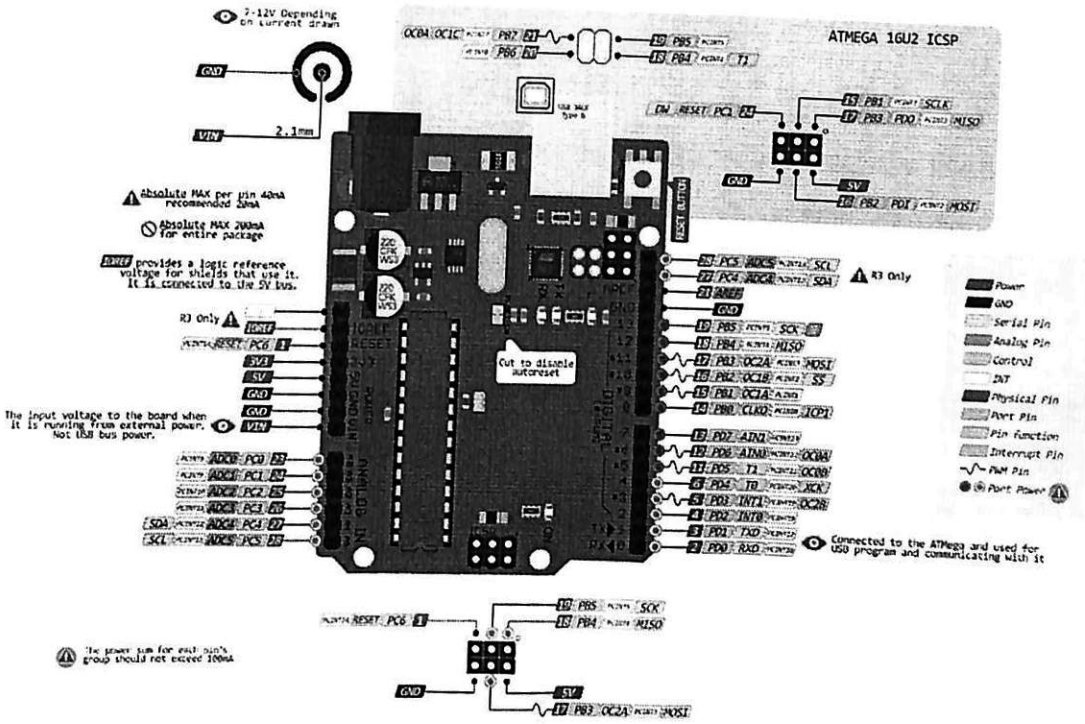


Figure 3.5: Arduino Uno pinout

- 3V3 - a 3.3-volt supply for charging external devices. It operates in the same way as a 5V contact. You may also send voltages to the breadboard or directly to the necessary sensor / sensor from this leg.
- GND - The ground is connected by a contact. Whenever attached to the Vin, 5V, or 3V3 pins, a closed circuit is required. The GND leg have to be output as a negative in all circumstances; otherwise, the loop will not be closed, and no energy (both internally and externally) will be delivered.

As already mentioned above, the board has 14 digital pins. They are labeled on the board with a leading "D" (digital). They can be both input and output. The operating voltage of these pins is 5 V. Each of them has a pull-up resistor and a voltage lower than 5 volts applied to one of these pins will still be considered as 5 volts (logical one).

The analog pins on the board are marked with a leading "A". These pins are inputs and do not have pull-up resistors. They measure the voltage applied to them and return a value between 0 and 1024 when using the analogRead() function. These pins measure voltage with an accuracy of 0.005 V.

3.4 Arduino Nano 33 IoT

The Nano 33 IoT module has a Cortex M0+ SAMD21 CPU, a WiFi+BT unit founded on ESP32, a cryptographic processor which can safely store licenses and pre-shared keys, and a 6-axis IMU. When employing pin headers, the module may be standard form to the crenelated pads as a DIP component or as an SMT element (when using pin headers).

The Nano 33 IoT, like all Nano product line boards, does not come with a battery charger, but it may be driven through USB or headers. Please keep in mind that now the Arduino Nano 33 IoT solely offers 3.3V I/Os and is not 5V resistant, therefore do not connect 5V signals to this board directly or it will be harmed. Furthermore, unlike Arduino Nano boards that support 5V functionality, the 5V pin doesn't really supply voltage but is instead linked via a jumper to the USB power input.

A Cortex M0+ CPU with a peak clock frequency of 48MHz serves as the primary processor. The bulk of its pins are attached to outside headers, while some are used to connect to the WLAN component and on-board I2C accessories internally (IMU and Crypto).

Pins A4 and A5 on the Arduino Nano have an inner pull up and are configured to be used as an I2C Bus by configuration, hence they should never be used as analog inputs. Through this serial interface and an SPI bus, the below pins are utilized to interact with the NINA W102.

Nina W102 is an ESP32-based chip with an Arduino software layer pre-installed. The microcontroller source code is available. Switching the wireless component's programming with a custom one would invalidate compliance with Arduino-approved radio standards; hence, this is not recommended unless the application is used in a secluded environment away from other digital equipment and people. Any modified firmware put on radio modules is strictly the responsibility of the user.

The encryption microchip in Arduino IoT panels sets them apart from weaker secure boards by providing a secure means for storing keys (including certificates) and for speeding up data encryption whilst not exposing secrets in plain text. The Arduino Nano 33 IoT has a built-in 6 axis IMU that may be used to measure board orientation (by verifying the gravity acceleration vector orientation),

shocks, vibrations, acceleration, and rotation speed.

The U-blox NINA-W102 module with an integrated ESP32 chip is responsible for wireless communication for data exchange over the air in the 2.4 GHz band via Wi-Fi and Bluetooth. Output power control provides an optimal balance between communication range, data transfer rate and power consumption. The IMU-sensor for 6 degrees of freedom includes an accelerometer and a compass. The assembly is made on the LSM6DS3 chip according to the technology (eng. System-in-Package - a system in a package), where the accelerometer and gyroscope are sandwiched in a plastic case.

Microchip's ATECC608A Cryptographic Co-Processor combines the ECDH (Elliptic Curve Diffie Hellman) security protocol with ECDSA (Elliptic Curve Digital Signature Algorithm) for Internet of Things (IoT) approved authentication, such as home automation, industrial networks, medical services, and authentication of accessories and consumables, to create an ultra-secure method for key negotiation for encryption/decryption.

The micro-USB connector is designed to flash the Arduino Nano Every platform using a computer. The MPM3610 switching buck regulator provides power to the ATSAMD21G18 microcontroller and other platform logic when the platform is connected via the Vin pin. Input voltage ranges from 5 to 18 volts. 3.3V output voltage with 1.2A maximum output current.

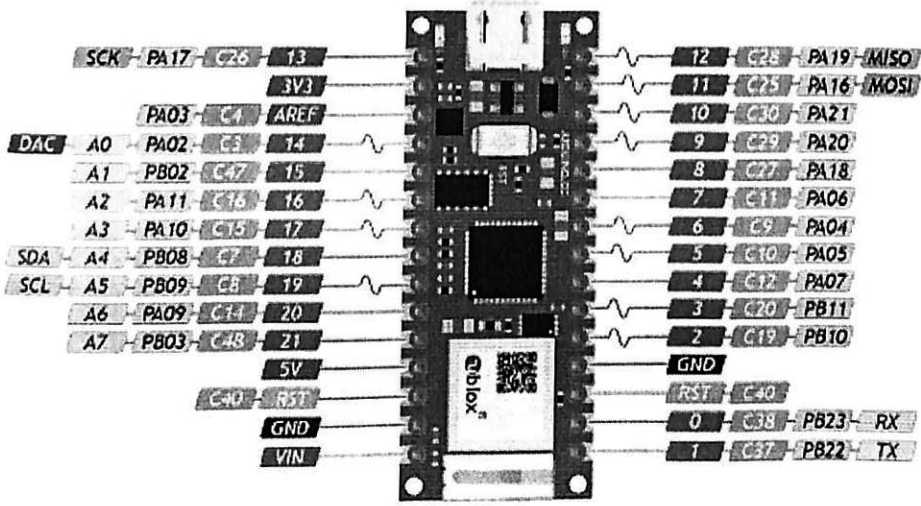
A custom button with two useful features: 1) Single click (Single Click): serves to reset the microcontroller. 2) Double Click: Puts the microcontroller in BOOT mode, which is useful when the board freezes or other crashes in the program.

VIN Pin for connecting an external voltage source in the range from 5 to 18 volts.

- 5V: For backwards compatibility with Arduino Nano projects, the 5V pin was left in place, but there is no 5V voltage regulator on the board and the pin is hanging in the air. To get an active 5 volt supply line, you will need to solder a jumper for the VUSB pads and connect external 5 volt power through the USB port.
- 3V3 Pin from a voltage regulator with a 3.3V output and a maximum current of 1.2A. The regulator provides power to the ATSAMD21G18 microcontroller, the NINA W-102 wireless module, and other auxiliary logic on the board.

ARDUINO NANO 33 IoT PINOUT

	Power
	GND
	Arduino pin name
	Port name
	Physical Chip pin name
	Analog input
	SPI
	UART
	I ² C
	Special Pins
	DAC
	PWM



Pin 5V not enabled by default.
More details for wiki.amperka.ru

Figure 3.6: Arduino Nano 33 IoT pinout

- AREF: Pin for connecting the external reference voltage of the ADC against which analog measurements are made when using the `analogReference()` function with the "EXTERNAL" parameter.
- GND: Ground pins.

3.5 LPWAN and LoRaWAN

Recently, wireless technologies are characterized by the search for solutions to reduce power consumption and increase the transmission range. As a result of such searches, LPWAN technology was created. So what is LPWAN? LPWAN is a wireless technology designed for distributed telemetry networks, machine-to-machine communication, and the Internet of things. The LPWAN technology is based on the property of radio systems - energy increase. By reducing the bit rate, it is possible to put more energy into each bit, which will make it easier to distinguish it from the noise in the receiving part of the system. Thus, by reducing the transmission rate, the receiving range increases.

It should be noted that LPWAN is one of the wireless technologies that pro-

vides an environment for collecting data from various equipment: sensors, meters and sensors.

Communication structure of LPWAN technology: data is transmitted from a modem or from a device via a radio channel to a base station. After the station receives a signal from all devices located within the range, it digitizes and transmits to a remote server. The server uses the received data for display, analysis, reporting and decision making. For transmission, they usually use an unlicensed frequency spectrum that is allowed for free use in the region where the network is built: 2.4 GHz, 868/915 MHz, 433 MHz, 169 MHz.

The advancement of wireless technology has paved the way for the Internet of Things revolution (IoT). IoT technology has paved the way for a slew of interconnected smart devices and applications that make monitoring and running from any location a breeze. It is recognized as one of the methods for facilitating navigation between locations.

In order to deliver information to the cloud or a recipient's mobile phone, IoT-based apps that monitor and track devices, human or animal behaviors have preferred to use narrow communication protocols like Bluetooth and Wi-Fi. However, due to their limited reach and high energy consumption, these communication methods are unsuitable for certain IoT systems, such as livestock or tree monitoring in large farms. As a result, Long Range Wide Area Network (LoRaWAN) software is seen as a viable communication mechanism in a smart monitoring system.

For a range of monitoring and tracking purposes, many communication mechanisms have lately been deployed in IoT deployments. These technologies include RFID, ZigBee, WSN, like as IEEE 802.15.4-based designs, cellular technologies, including GSM (Global System for Mobile), 3G, and 4G, and VHF/UHF-based solutions. However, there are a number of drawbacks to using these technologies in monitoring applications, including reduced energy efficiency, greater costs, conference proceedings, and frequent wireless link termination. The comparison of many communication methods in terms of energy usage and communication range is shown in Figure 3.7. As a result, this article will demonstrate a test bench using LoRa technology in order to present a preliminary experimental perspective.

LoRaWan is a wireless communication, which is a set of gateways connecting end devices and through a network server, an application server. This technology

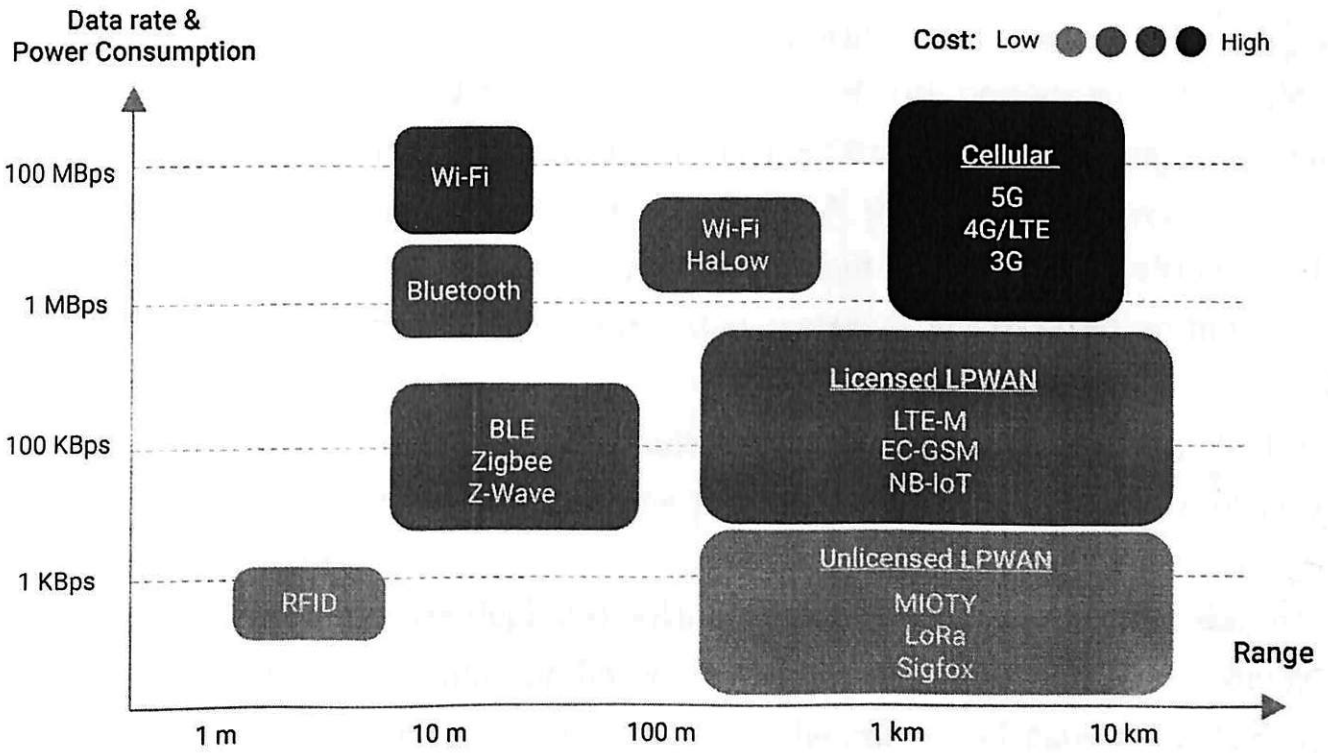


Figure 3.7: Comparison of different IoT deployments

is characterized by a star topology.

The LoRaWan network appeared relatively recently, or rather, it was patented in 2008 by Cycleo (France) and has been constantly developing since then. At the moment, the network is owned by Semtech (USA), and this is a fairly common brand in the wireless technology market. Let's take a closer look at the standard.

In LoRaWan, data is encoded by wideband chirp - pulses with a frequency that increases or decreases over a certain time interval. And this has its advantages, for example, such as increasing the sensitivity of the receiver. The main advantage of frequency modulation is high noise immunity. It can be achieved due to the fact that the noise in the radio path mainly affects the amplitude of the signal, and not its frequency. However, frequency modulation has a significant drawback in the form of a large bandwidth of the spectrum, which significantly reduces the throughput of the communication channel.

LoRaWAN networks operate in a frequency range that does not require licensing. They have high noise immunity. The battery life is about 10 years. One base station serves tens of thousands of devices. The network has many advantages. Battery life. Data exchange occurs asynchronously and only when there is a need. In conventional networks, devices "wake up", synchronize with the network, and check messages. The whole process consumes electricity and wears out

the battery. Battery life is 3-5 times longer than other technologies.

Network capacity. In order to provide optimal network performance, the gateway must have a very high bandwidth or receive information from a huge number of end devices. The large capacity of the LoRaWAN network is achieved through the use of a self-tuning data rate, as well as through the use of a multi-channel transmitter in the gateway. This ensures that messages are received on multiple channels at the same time.

Gateways make it possible to simultaneously receive information from devices with different data transfer rates on one channel. The adaptive data rate also improves battery life.

LoRaWAN networks are deployed with a minimum amount of infrastructure. With an increase in the number of devices in the network, it is possible to change the data transfer rate, as well as an increase in the number of gateways.

Immunity to radio interference. The network has a high penetrating power of the radio signal. It will provide a stable connection where other technologies cannot cope. LoRa modems can suppress interference up to 19.5 dB (Gaussian filtering). This interference suppression capability will allow the system to be used in a modern big city.

The term "network topology" itself refers to the way devices are connected to a network. In another way, it is also called the structure or configuration of the network. It determines the placement of devices, the method of laying cables, and equipment. At the present stage, several topologies are used. Most often "bus", "ring", "star". The architecture of LoRaWAN networks uses a star topology. This is a topology for a local area network in which each device is connected to a central device. When building LoRaWAN networks, this topology has become the main one. This happened because this topology has many advantages: if one workstation fails, it will not affect the network, excellent scalability, and new equipment is easily integrated. [8]

In a LoRaWAN network, gateways transmit data received from end devices to a central server (network server). All data is encrypted. End devices contain a set of sensors. Further, the data goes to the application server, and from there to the end user. Terminal devices perform the functions of measurement, control and monitoring.

The introduction of this technology will not require large investments, alloca-

tion and redistribution of additional frequencies, and restructuring of the mobile communication network. All leading manufacturers support this trend, so there is no shortage of hardware or software. For our country, the main problem is the weak digitalization of the municipal economy. Although more attention has been paid to this problem recently. To solve this problem, a cloud video surveillance project has been launched. The project provides for the deployment of a network with the connection of 19,000 cameras. This will enable individuals to access certain cameras through a mobile app, as well as law enforcement to keep cities safe. Further implementation of video analytics is planned. This software platform will automatically recognize faces. Such a solution can be used in education, medicine and other areas. [10]

3.6 Lora devices in Kazakhstan

Currently, the LoRaWAN network is rapidly developing in the Republic of Kazakhstan and the CIS countries, which is one of the areas of LPWAN technology used in various fields of activity to transfer small data over long distances. This technology is one of the promising wireless technologies in the modern Internet of Things (IoT) market.

There are a number of companies in Kazakhstan wishing to deploy IoT networks based on LoRa technology. The specificity of LoRaWAN technology involves the use of a channel width of 125 kHz in the frequency band 864-869 MHz. [7]

However, in Kazakhstan, the frequency band 863-868 MHz is used by non-specialized SRD devices operating with a maximum occupied bandwidth of 100 kHz and equivalent isotropically radiated power (EIRP) up to 25 mW. SRDs are transceiver systems or devices that provide one-way or two-way communication over short distances (up to several hundred meters). LoRaWAN equipment transmits data over long distances. Thus, LoRaWAN equipment does not apply to SRD devices.

In this regard, at the last meeting of the working group on radio frequency spectrum management under the Commission for the Regulation of the Use of the Radio Frequency Spectrum and Satellite Orbits of the Regional Commonwealth in the Field of Communications, it was decided to approve the development of

a document containing information and reference materials, technical parameters and frequency bands for the deployment of LoRaWAN networks in the RCC member countries.

The procedure for obtaining permits in the field of communications in the Republic of Kazakhstan is governed by the Order of the Acting Minister for Investments and Development of the Republic of Kazakhstan dated January 21, 2015 No. 34 "On authorization of the Rules for the assignment of frequency bands, radio frequencies (radio frequency channels), operation of radio electronic technology and high-freq devices, as well as carrying out the electromagnetism calculation" (hereinafter referred to as the Rules).

In accordance with paragraph 21 of Appendix 1 of the Rules, non-specialized SRD devices operating in the frequency ranges of 863-868 MHz with a channel width of 100 kHz (EIRP up to 25 mW) can be used on the territory of the Republic of Kazakhstan without obtaining permits.

According to the technical documentation, the LoRaWAN base station operates in the 864-869 MHz band with a transmitter power of 25 mW. The base station is equipped with an external antenna with a gain of 10 dBi. Therefore, the plant's EIRP is 250 mW.

According to Appendix 4 of Decision No. 5/8-11 of the working group on radio frequency spectrum management of the Regional Commonwealth in the Field of Communications (hereinafter - RCC) "Information and reference materials on the use of short-range devices in the countries of RCC participants", SRD (short range devices) - these are transceiver systems or devices that provide one-way or two-way communication over short distances (up to several hundred meters), and whose ability to interfere with other radio equipment is very small.

Accordingly, LoRaWAN equipment does not belong to the SRD devices specified in paragraph 21 of Appendix 1 of the Rules due to the discrepancy between the requested channel width, and also does not fit the definition of the SRD device described in the document "Information and reference materials on the use of short-range devices in the countries of RCC participants ". Thus, there is no regulatory framework in the country to regulate the use of devices operating on the LoRaWAN protocol. However, a number of domestic companies offer "smart" solutions based on LoRa technology.

The LoRaWAN gateway or base station receives data from end devices over

the air. Several of these base stations will provide a large coverage area, as well as data transmission between the server and end nodes. Today, the formation of the Internet of things market is actively underway in Kazakhstan. All over the world, this market will be a large source of income in the budget of countries. Experts predict that by 2025 in Kazakhstan the number of devices connected to the Internet of Things will reach 100 million.

Taking into account all the main global trends, in our country the most active participant in the formation of the Internet of Things market is Kazakhtelecom JSC. The company is implementing an ambitious project to build an energy-efficient LoRa network. For Kazakhstan, this is the optimal technology for creating Smart Cities.

Why did you choose this particular technology? LoRa is an accessible, open technology. There are a lot of economical, advanced offers on the market of network equipment manufacturers. More than 80 telecom operators gave her their preference.

Market	Potential
18 million people population	
5.2 million households	75 million sensors
4 million cars	4 million eCall terminals
80 thousand buses	200 thousand cameras and 200 thousand POS terminals
100 kms of roads	100 thousand cameras, detectors, sensors
26 thousand manufacturing enterprises	> 400 enterprise detectors, sensors
220 million hectares of agricultural land	> 1 million soil sensors
7.5 thousand schools	1.5 million students with the tracking devices
900 medical institutions	10 million wearables
87 towns	> 1 million parking detectors, GPS-trackers, cameras, bike sensor

Figure 3.8: Kazakhstan IoT statistics

As part of the first stage, the construction of the largest energy-efficient LP-WAN network in the CIS based on LORA technology was completed in the cities of Nur-Sultan, Almaty and Shymkent.

The progress of the project is quite successful. At the end of 2018, more than 400 LORA base stations were installed in 19 cities of the country. The operation of the stations covered about 7 thousand square kilometers of the city territory, which is 1.5 million apartments. The new network is laid as the basis for the implementation of Smart City solutions. At this stage, automatic readings are provided for resource metering devices and smart lighting.

The second stage of the project will be aimed at the development of the Smart Connectivity platform with the functionality of SIM-management, connection-management, device-management and others. M2M services based on GSM/LTE networks from Kazakhtelecom and its Tele2/Altel mobile assets are already available on the market.

It is possible to connect different devices to this platform. The most rapid implementation of smart solutions in the field of transport. An example of this is the city of Almaty. In 2018, in Slovenia, in the city of Ljubljana, the European Forum of Smart Cities Smart city-2018 was held. Almaty received the highest award for the implementation of transport reform. Now in the public transport of the city, 97 percent of all transactions are made non-cash. This will bring the turnover of companies out of the shadows and make income transparent.

The city has an extensive photo and video recording system. All violators of traffic rules are under the control of the police. The system controls 709 traffic lanes, and there are plans to double the number. Forming approaches to the transport reform, the city authorities relied on the best world experience and attracted the world's leading experts. Among them are experts from Gehl architects for the modernization of public spaces and pedestrian streets, UNDP for the Sustainable Transport project, A + S Transproject and Systra for the development of an integrated traffic scheme, as well as the Canadian-American company Hatch for the development of the concept master plan of Almaty.

In Kazakhstan, since 2017, the LPWAN energy-efficient network system based on LoRa technologies has been actively implemented, covering all private and multi-apartment buildings, buildings and urban areas in the cities of Astana, Almaty and Shymkent. Kazakhtelecom JSC has already completed the first stage

of the project. "LoRa" will allow you to manage utilities, collect remote data from various types of sensors: cold water, hot water, heating, gas, electricity. It will provide an opportunity to increase the transparency of energy consumption and the efficiency of energy use. In addition, "LoRa" will reduce the operating costs for the collection and processing of energy metering data.

This M2M network will serve as the foundation for utilizing smart city solutions, including digitalizing the catalogue of observations from asset advanced metering infrastructure (Smart Metering - Smart meters are a type of meter that determines consumption indicators in systematic sampling) and lighting control (Smart Lightning). High scalability owing to a huge coverage radius (up to 25 km), extended battery capacity of end devices (up to 10 years), and accessibility of its interface for a wide range of devices are all advantages of the LoRa network.

The Vice Minister of Information and Communications of the Republic of Kazakhstan, Tuyakov D.Sh., has received several inquiries from enterprises requesting to adopt this technology in Kazakhstan. It was decided to accept the "Plan for the Implementation of the 5G Pilot Project and the Application of LoRaWAN Technology."

LoRaWAN technology, which carries data across great distances, is one of the most anticipated wireless networks in the current Internet of Things industry. This technology can establish machine-to-machine (M2M) connections at distances of up to 20 km at speeds of up to 50 Kbps, yet it consumes very little power, lasting several years on a single AA battery. This technology has a wide range of applications, ranging from home technology and the Internet of Things to industrial and smart cities.

The importance of LPWAN networks will expand fast, given the rising requirement for connection for the Internet of Things, including the creation of a component base for affordable and small devices. However, the implementation of the LoRa network is unfeasible owing to a lack of a legislative structure, necessitating more study to make relevant revisions to the regulatory various legislation in the areas of telecommunication.

3.7 GY-NEO-6M

The development of radio assistance and landing associated gene to be a difficult and complex operation. Because for an outcome, the satellite radio navigation system (SRNS) was a much more reasonable navigation system, as it effectively solves various navigation challenges. Issues clearly related to the requirements of further modernization of the GPS SRNS, as well as the development and installation of more significant additions, as well as the application of new high-tech solutions, are of particular importance.

Differential GPS modes offered by systems such like LAAS, WAAS, MSAS, GAGAN, and others are known to somehow be deployed to strengthen satellite navigation accuracy. In comparison, differential mode calls for the development of further local, regional, or widespread ground or air systems. Accuracy may still be maintained besides using differential mode via using integrated and unified satellite receivers, as well as signal processing and measurement approaches.

Long-term satellite navigation has now become achievable since to the development and implementation of coordinated aircraft navigation solutions. GARMIN International is just a well producer of built-in satellite receivers.

The Garmin system is widely known, especially in smaller planes including Cessnas. The Garmin G1000 system, which interprets underlying flight information, geology, traffic, weather, and other elements, is featured in the mass of these aircraft.

The comprehensive reversal capability on the G1000 permits you to fastly assess all pivotal flight data and transformation to a secondary foremost flight status screen.

Two identical GIA63 (Garmin Integrated Avionics unit) units with built-in GPS receivers, VHF communications, VHF navigation with ILS, a CPU, and an optional WAAS hardware for the Americas capture the essence of the G1000 system. The G1000 system's most important attributes are outlined below:

- Digital automatic flight control system in three-axis mode;
- The presence of the transponder mode "S";
- International Cartography and Obstacle Database and Warning System (TAWS), etc.

An Enhanced Vision System (EVS) showcasing an infrared vision system has been recently expanded toward the G1000, providing new insights behind the cab in all climate zones. As an optimal compliment to the SVT (Synthetic Vision Technology) G1000, EVS delivers a truly moving view of the world.

KLN-90B receivers are more professional, provides one of most appropriate solution to GPS navigation challenges, and are implemented globally on long-haul airliners. Both IFR and non-precision approach flights can stand to gain from certain receivers.

The KLN-94 is part of a new generation of GPS receivers that incorporate functionalities such a GPS color marker for moving chart instrument flights, database raw data, and the capacity to control to on-board computers for aircraft roll data, everything the of which should be combined further with KAP-140 autopilot.

Various navigation modules, which maintain the specificity of calculated coordinates within 7-15 m, have mostly been widely applied on board smaller aircraft, micro- and nanosatellites in recent years.

The NEO-6M is a stand-alone GPS positioning module with a high-performance u-blox 7 processor which thus provides the best technical and budget performance of these modules. With a range of operating conditions, design, and connection options, these modules are simple to install and influence on various positioning performance. [2]

The GPS modules NEO-6M and NEO-7M feature actually needs aspects: an RF unit and a processing section. An input assist characteristic, a surface acoustic wave filter, a built-in moderate amplifier, and an oscillator have been included into the RF unit. A GPS processor, a real-time clock, and auxiliary functions, including a FLASH memory, are already included in digital block.

A GPS module, power supply, hardware, and software to download module configuration data (Arduino) are trained to determine the location agnostic of time. With the NEO-6M or NEO-7M, you might scrutinize GPS signals. (Fig. 3.9) receiver modules, which have 50 (56) channels and operate at L1 frequency.

The module is based on a 0.1 mm pin pitch u-blox NEO-6M (NEO-6M-0-001) Global positioning system chip. The UART (TTL) is used to communicate to a microcontroller and has a supported baud rate of 4800 to 230400 baud, with 9600 baud being the default. With only 45mA from the source of energy, the equipment can record up to 22 satellites on 50 channels with -161dB sensitivity.

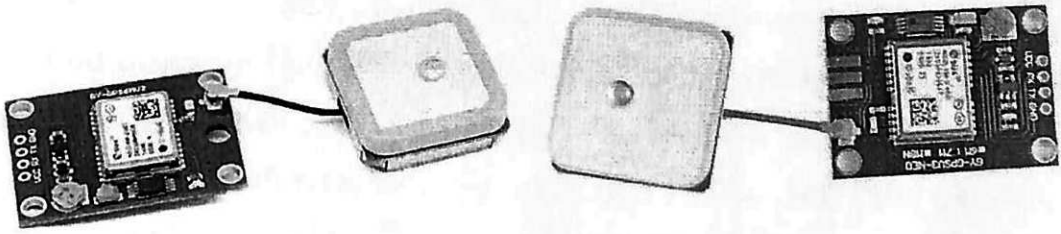


Figure 3.9: GY-NEO-6M and GY-NEO-7M

Since the NEO-6M chip's functioning voltage ranges 2.7 and 3.6 V, the layer includes a voltage regulator MIC5205 with a 3.3 V output voltage.

A rechargeable battery operates as a supercapacitor, and then a HK24C32 (EEPROM) chip with 4K memory is paired to the NEO-6M throughout an I2C interface. These have been used by the NEO-6M module to mitigate positioning time to 1 second. [9]

The component does seem to have a microUSB interface, providing access it to a machine and retrieve information without the need for an Arduino controller.

3.8 ThingSpeak

In amateur location tracking, it is often necessary to collect, store and subsequently view and process a variety of information coming from various sensors. One of the options for solving this problem is to equip each sensor or their group with its own microcontroller with Internet access. These devices must send the collected information to a Web server, where it is entered into a database. The server must have an interface that allows you to view, and possibly process the stored information. [4]

When implementing such a system on its own, the Web server must support PHP and have a database server, which is far from always available on free services. In addition, you need to have certain web programming skills.

The task is greatly simplified if you use the free ThingSpeak service (URL: <https://www.mathworks.com/help/thingspeak/>). It is an Internet of Things (IoT)

platform that allows you to collect and store information in the cloud. It provides an interface that allows you to analyze and visualize information in MATLAB.

The basis of the ThingSpeak platform is the channels into which users send information for storage and visualization. Each channel contains, in addition to the name and description, eight fields for information of any type, three fields for geographical coordinates (latitude, longitude, height), a field for linking to the site where the stored information is used, a link to the YouTube channel.

By registering a channel in ThingSpeak, you can immediately send information there, process it and get access to it. Channels can work with information in JSON, XML, and CSV formats.

It is very easy to register in the service and check its work. To do this, on the service page <https://thingspeak.com/>, click the Get Started For Free on-screen button. To register and create a new channel, it is enough to specify its name and define the fields used. For example, for the device described below, there are two fields for collecting information about humidity and temperature (Fig. 1). The service will assign a unique Channel ID to the channel.

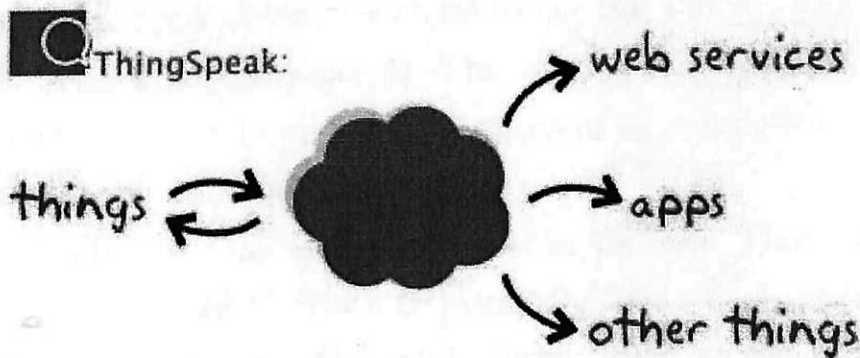


Figure 3.10: ThingSpeak API

Figure 3.11 shows a more detailed view of what happens, particularly on the server side. When a device transmits data via HTTP request (communication), the IoT service (in this case ThingSpeak) processes it and sends it to a virtual server. The application is directly communicated with by both the server and the IoT service. Finally, there are security and data transfer management needs at all levels of communication, from the device to the application. Unfortunately, ThingSpeak does not provide technical documentation on how the various parts of the diagram are handled. If you have enough time and expertise, you should be able to find an answer by reading through the (open source) code base.

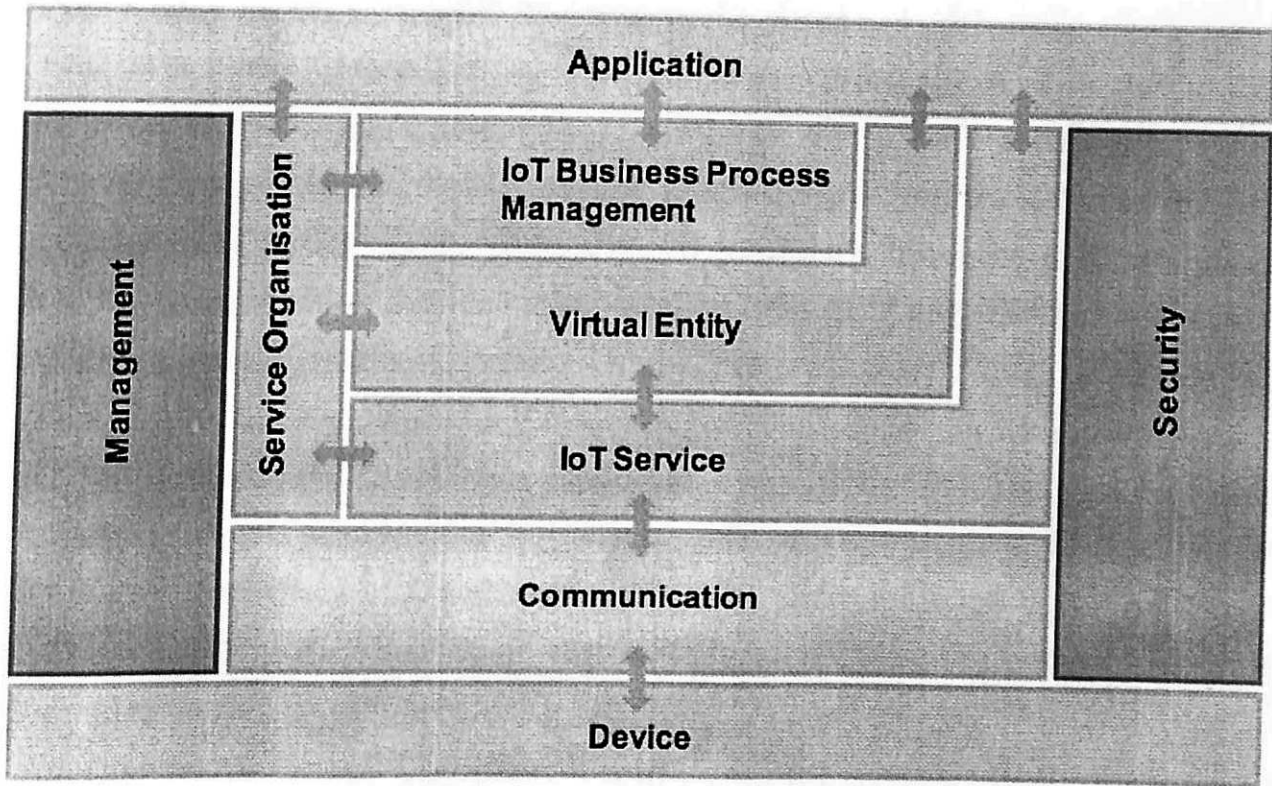


Figure 3.11: ThingSpeak layers

There are several reasons why we chose to use the ThingSpeak API over other platforms that provide similar services. This section compares the various advantages and disadvantages of ThingSpeak to those of its competitors, such as Smart Objects, Sensorthings, and Carriots.

One of the main reasons why we chose to use the ThingSpeak API over other platforms is because Carriots is primarily focused on providing business and industry-focused services. Other platforms, such as Sensorthings, Skynet, and SmartObject, are open-source and can be updated and customized according to our needs.

Despite being similar in terms of functionality, the various open-source APIs have their own advantages and disadvantages. For instance, the Skynet API has been used with various boards such as the Arduino, which has resulted in a large number of programs that can be used with this platform. On the other hand, the SmartObject API is not as user-friendly, and it requires a lot of programming experience to get started.

As a result, it is not suggested for novices or those who only want to try things out on a very basic level. Finally, the SensorThings API appears to follow the same ideas as ThingSpeak, such as transferring data via HTTP requests. However,

the API's data model is divided into two parts: sensing and tasking.

And as a result, depending on whether you're using the API to just gather sensor data or to communicate with an actuator, you'll have a different profile. This is very beneficial for troubleshooting problems or if you want to use the API for both sensing and tasking. Similarly, all platforms have the ability to work with nearly any open or bespoke hardware, as long as it has Internet access and can communicate with the aforementioned APIs.

ThingSpeak distinguishes itself from the competitors by allowing users to construct public channels, fostering a feeling of community. It's the first and only open data platform designed exclusively for IoT on the cloud. Additionally, the API makes spline plots a straightforward way to view collected data. As a consequence, compared to other open source APIs, it is more aesthetically pleasing and simpler to review gathered data.

Another bonus is that ThingSpeak uses Phusion Passenger Enterprise, a web and application server. As a result, Ruby, Python, and Node.js programming languages are supported by the API. Because these languages are well-known for their power and popularity, additional support and features are welcomed. Although the other open source APIs may work with a variety of languages, adding additional capabilities for the most popular ones is always a benefit. It's also unclear if the other APIs' servers are using Phusion Passenger.

ThingSpeak, SmartObject, and SensorThings are open source APIs that, like Carriots, may be used with any hardware device, including Arduino, Raspberry Pi, and any home-made microcontroller. ThingSpeak's source code includes functions for processing HTTP requests, storing (alphanumeric and numeric) data, processing numeric data, position tracking, and status updates. Additionally, anybody may construct the platform, thus if a desired feature isn't present, it can be coded. As a result, the ideal solution for any "do-it-yourself" (DIY) project would be open-source APIs that allow communication with any microcontroller.

An open source API also has the benefit of being able to be utilized locally or on a server. As a result, the user has a lot of control and freedom over their projects. The fact that data channels are hosted for free gives ThingSpeak an advantage over the competition. As previously noted, these channels might be private or public. This not only makes it easy for someone who does not operate or administer a server, but it also makes using HTTP POST and GET for data for

newcomers to web technology quite straightforward. Finally, because users can view and enjoy the work of others, public channels may be a source of inspiration.

Overall, the ideal API for connecting an object to the Internet of Things is decided by the individual's (or organization's) unique needs. Each has a different set of talents depending on the scenario. ThingSpeak stands out as one of the easiest APIs to learn and use, with the possibility to establish a channel for data uploading on a community server. It also contains Ruby, Node.js, and Python extensions.

There are a few components of the ThingSpeak API that can be classed as defects after weighing all of the benefits. When uploading data to the API, for example, the number of updates per channel is limited to fifteen seconds. We believe the upload restriction was imposed because of the potential for excess bandwidth consumption, which would result in increased expenses for ThingSpeak as a non-profit organization. Moving the whole API to a new web server provider will eliminate this issue.

Although this is not a disadvantage in compared to the competitor APIs stated above, it would be useful to have a variety of charts available for graphing data, such as pie charts, bar charts, and histograms. Exporting the data to other programs that may produce more intricate and colorful charts to present data, on the other hand, is quite simple.

For newbies, using the ThingSpeak API, like many open source projects, may be tricky. To put it another way, although being significantly easier to use than some of its competitors, ThingSpeak isn't exactly a "turnkey" API. As a result, using ThingSpeak requires some coding knowledge. To assist with integration, Carriots and other commercial APIs give code snippets. They are able to give more support since they are compensated. In the same way, the ThingSpeak community is only somewhat active (about 3 days between forum entries). As a result, if one need technical support from others in the community, having to wait a long time for a response might be annoying.

Finally, the question of privacy must be addressed. By default, channels are set to private, and to access the data, people or machines must have a read or write key. The data becomes accessible to anybody without the requirement for a read key when the channel is changed to public. The website of ThingSpeak makes no mention of where the data is stored or how it is safeguarded. It's also

unknown how long their servers keep data.

Even though the initial goal of the ThingSpeak API was to "give voice" to common objects, it appears that there is a developing trend in what people are creating and sharing through the Internet of Things. Smart metering of power, home automation, and intelligent purchasing for people and private dwellings are all projected to be part of the Internet of Things.

ThingSpeak, is from the other side, is a free and open source application programming interface. As a result, we anticipate a lot more 'home/private' use apps rather than corporate use, as this is often how new, open source technologies are employed first. Home sensors are, without a doubt, the focus of the majority of public channels. Surprisingly, the vast majority of devices were used to track weather parameters including temperature (indoor/outdoor), humidity, light levels, and atmospheric pressure. As a result, the API is utilized for personal measurements by the vast majority of ThingSpeak users. Corporations, on the other hand, were not uncommon users of ThingSpeak, and some of them utilized it to monitor workplace temperature and humidity.

A second common ThingSpeak use is light assessment, although not to determine how bright a space is. Instead, ThingSpeak was used to determine the amount of energy generated by a solar panel [14]. The panel in issue was discovered in a remote part of Germany. In rural areas, roof space is routinely rented for the installation of solar panels that may be paid for by supplying the public energy grid. As a result, many solar panel owners are located distant from their installations, necessitating the ability to remotely monitor power generation. The ability to monitor panels enables owners to determine which ones are in the optimal position and whether or not they are experiencing any technical difficulties.

ThingSpeak has also been used to monitor and manage the temperature of a water bed, which is a type of environmental monitoring. This is exciting since it allows you to record the ideal temperature for going to bed and determine whether the bed is being used by (unwanted) tenants such as dogs. As a result, there are a variety of applications and specifications for sensing changes in one's environment.

Finally, a common usage of ThingSpeak is to monitor a household's energy use. This allows customers to keep track of when their power use peaks so that

they may adjust their behavior to reduce grid load and save money. However, there are certain hazards to making this data public, which will be discussed in the next section.

While there aren't many genuinely unique ThingSpeak apps right now, it'll only be a matter of time until more arise. Allowing ThingSpeak to send data to the Internet of Things brings up some exciting 'out of the box' uses (or repercussions) of having that much device-use data available.

Another example found made use of the 'React' application from the ThingSpeak web service. This program allows the user to submit an HTTP request or send a tweet when a channel meets a defined criteria (giving the impression that the device is 'reacting' autonomously). In this scenario, the channel owner may utilize geographic data to ensure that their house thermostat is turned on at the right time based on their location. This guarantees that their home is at the right temperature when they arrive.

Artist Nathan Brunstein has designed a concept design for a toaster that imprints the day's weather report on your toast, albeit it does not use the ThingSpeak API directly. As a result, future toast eaters might not have to go any further than their breakfast for weather information. Unfortunately, this is only a concept that has yet to be realized. It does, however, show how the Internet of Things might be put to new uses.

4. System Implementation

4.1 Animal attached device

LoRa 433MHz modules, as mentioned previously, work with other connected devices via a serial communication port using the TX and RX pins for this. In this regard, connecting them to Arduino boards will not cause any problems.

The communication range in our project can be up to 3 kilometers and will depend on the antennas used, environmental conditions and the level of electromagnetic interference at the place of deployment of the system.

These modules have 4 possible modes of operation. We will use the simplest mode in our project - Normal Mode. In this mode, contacts M0 and M1 of the module must be shorted to ground (GND). Other possible operating modes for LoRa modules are Power Saving, Sleep, and Wake-up Mode.

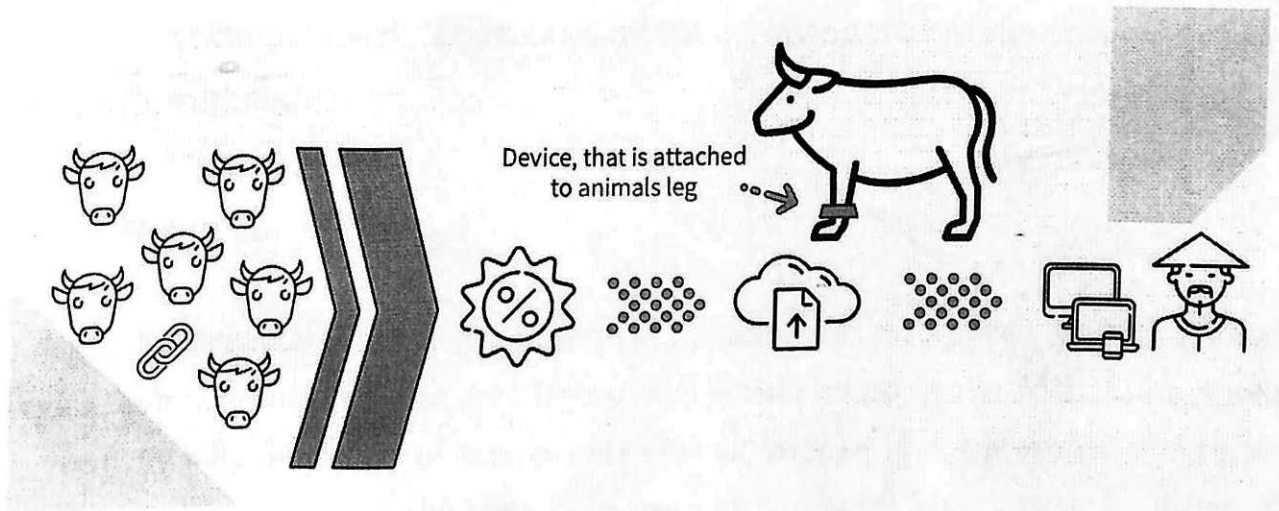


Figure 4.1: Visual idea of the tracking system

The pin assignment (pinout) of the Lora E32 module is shown in the following figure 4.2.

The scheme of the transmitting part of the project is shown in the following

Pin No.	Pin item	Pin direction	Pin application
1	M0	Input (weak pull-up)	Work with M1 & decide the four operating modes. Floating is not allowed, can be ground.
2	M1	Input (weak pull-up)	Work with M0 & decide the four operating modes. Floating is not allowed, can be ground.
3	RXD	Input	TTL UART inputs, connects to external (MCU, PC) TXD output pin. Can be configured as open-drain or pull-up input.
4	TXD	Output	TTL UART outputs, connects to external RXD (MCU, PC) input pin. Can be configured as open-drain or push-pull output
5	AUX	Output	To indicate module's working status & wakes up the external MCU. During the procedure of self-check initialization, the pin outputs low level. Can be configured as open-drain output or push-pull output (floating is allowed).
6	VCC		Power supply 2.3V-5.5V DC
7	GND		Ground

Figure 4.2: Pinout of the Lora E32

figure.

As you can see, it is very simple - you just need to close the necessary contacts to ground, and connect the input and output of the serial port to the corresponding pins of the Arduino board. The scheme of the receiving part of the project is shown in the following figure.

4.2 Server/Cloud

To begin, a microcontroller with an internet connection is required for ThingSpeak to work, even though it is not required in the actual setup of the API. ThingSpeak can connect with any sort of microcontroller as long as it is networked, therefore the type is entirely up to the user. We used an Arduino board with an ethernet shield in our demonstration. The first stages in setting up ThingSpeak are always the same after the microcontroller has been chosen.

You can log in and establish new channels after creating a new user account. When you're logged in, go to Channels > My Channels and then Create New Channel to start a new channel. When reading or uploading data, the channel

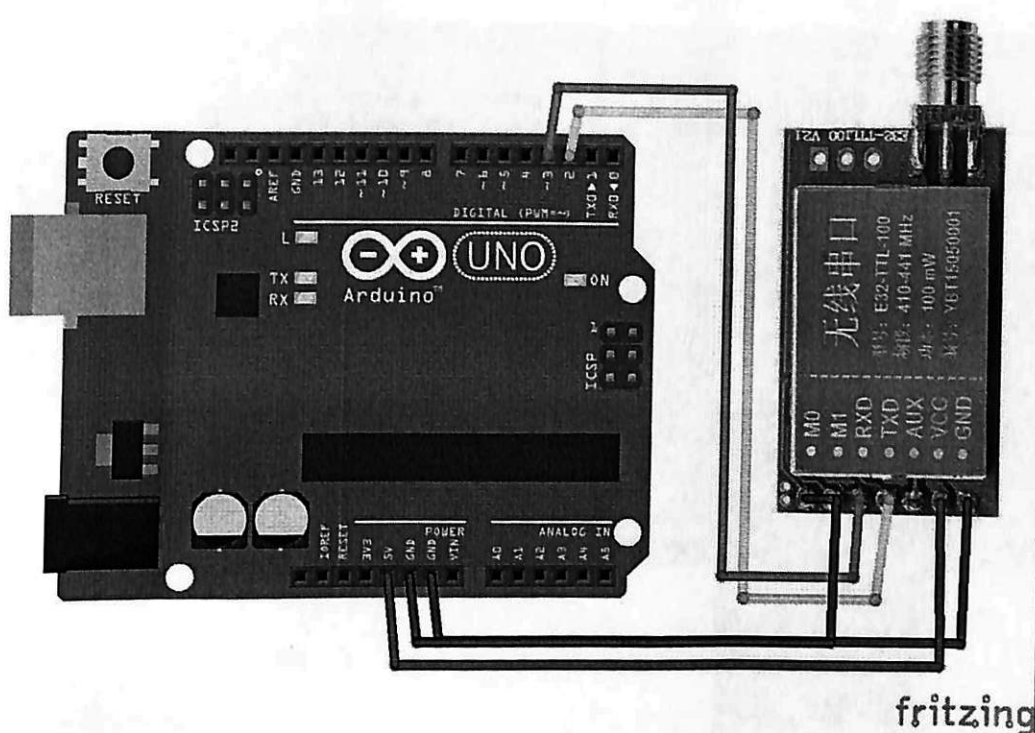


Figure 4.3: Arduino Uno and Lora E32 connection scheme

has a unique identifying key that is used to identify it.

Data (both numeric and alphanumeric formats) can be stored in up to eight fields on each channel, with four additional fields for location details. Each entry is given a unique identification as well as a date and time stamp. Data from a "Comma-Separated Values" (CSV) file, a popular format for storing tabular data, can be loaded.

If you don't have any existing data, you can start adding it to your channel right away. This is accomplished by combining the POST method of HTTP with your unique channel write key. Select the channel in the channels screen and then the API keys tab. With the API, we can already get to the 'Hello world' stage.

This HTTP POST can be used in a variety of applications, including the Arduino IDE. But, because it's evident that writing 'Hello world' to a meaningless, object-free channel isn't enough, we'll continue with how to deliver data to a Twitter channel.

The ThingTweet add-on was one of the first implementations of the ThingSpeak API, allowing us to store each location change by sending device geolocation. We utilized an Arduino with an ethernet shield for this demonstration. The Arduino is always checking for incoming signals, which would occur when the doorbell was pressed. To put it another way, when the location is changed, an

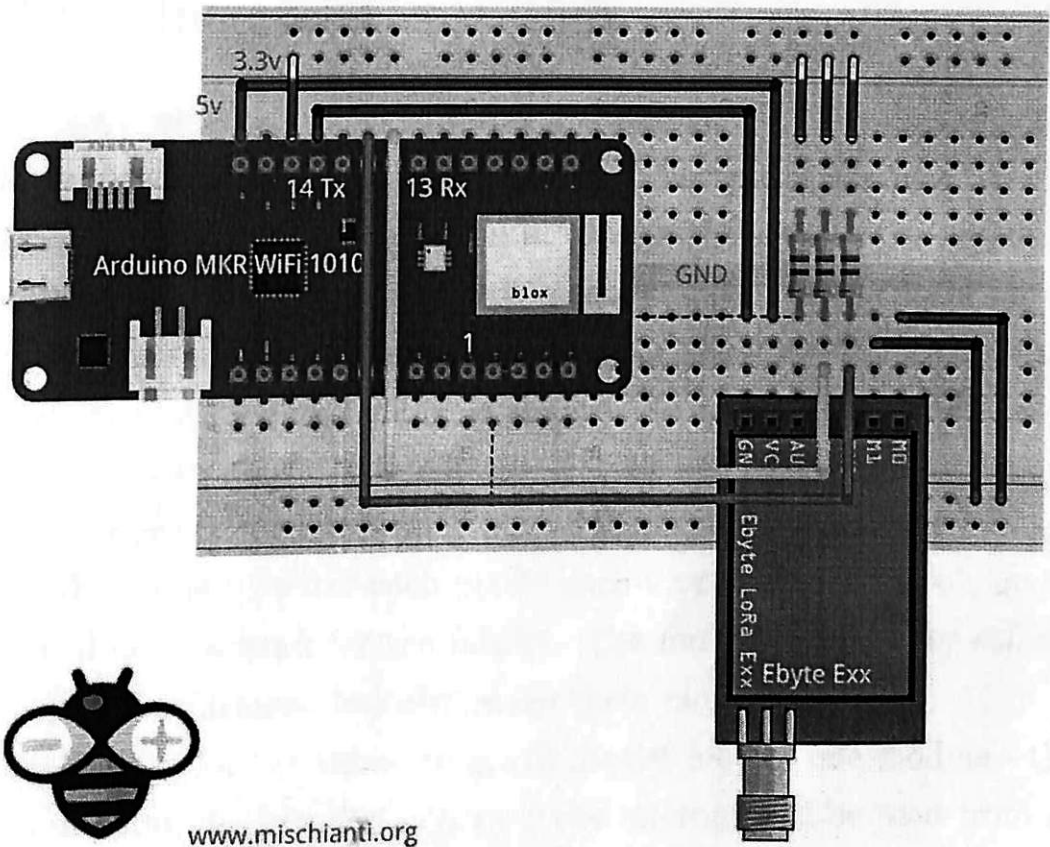


Figure 4.4: Arduino SAMD and Lora E32 connection scheme

update is delivered to ThingSpeak via the API using a simple HTTP post. This server post included a latitude and longitude, as well as the date and time it was sent.

You can retrieve data from ThingSpeak by selecting a time range or an entry ID. The HTTP GET method is the most straightforward method. If the channel isn't public (which it isn't by default), you'll need a read key, which you can get via the channel view tab.

It is also possible to retrieve only the most recent entry by changing the URI below, replacing the information in the brackets with the user's channel id, the field id, and the type of data to be retrieved. For integration into other (third-party) applications, the channel supports GET formats such as JSON, XML, and CSV.

4.3 User interface

A smartphone is an essential attribute of a student's life. The degree of influence of mobile applications is increasing every day. They penetrate into all spheres of life and occupy more and more space in it. One of the areas is the organization of the agricultural process. An example is a self-irrigation application for farmers. Such applications are relevant today, because they allow you to monitor and water plants from one place without going anywhere. No need to go to the site and look for everything to be fine. It is enough just to open the application, and the information necessary for the farmer will be displayed on the screen. No need to remember what time to water each plant: each 2 or 3 hours, doesn't matter, the algorithm will do this work for the farmer. The mobile application will not only make life easier for farmers, but also make them more organized.

Our application for the time-being will consist only of one module - the map. The data sent from devices and sent over the internet will be read from a server and update our UI in our application. The red flag will show on a map where the concrete coordinates of a sender are. The data will be available in a JSON format which will be taken by code written in Swift.

The JSON format has become very popular and is commonly used to transfer data and execute requests in client-server applications. Parsing JSON requires tools to encode/decode this format, and Apple recently updated them. In this article, we will look at methods for parsing JSON using the Decodable protocol, compare the new Codable protocol with its predecessor NSCodering, evaluate the advantages and disadvantages, analyze everything with specific examples, and also consider some of the features encountered in the implementation of protocols.

At WWDC2017, along with the new version of the Swift 4 language, Apple introduced new data encoding / decoding tools that are implemented by the following three protocols:

- Codable
- Encodable
- Decodable

In most cases, these protocols are used to work with JSON, but they are also used to save data to disk, transfer over the network, etc. Encodable is

used to convert Swift data structures into JSON objects, while Decodable helps convert JSON objects into Swift data models. The Codable protocol combines the previous two and is their typealias.

To develop a mobile application, you can use one of two approaches - native and cross-platform. Native development is a classic solution that involves writing an application for each platform separately, using different languages and taking into account the features of each platform. In the case of IOS, these are Swift and Objective-C. The main advantages of this approach are the support of all native technologies and hardware capabilities, the optimization of the application for the IOS platform, and familiar and user-friendly interface elements.

In our app we decode data using Alamofire framework and put our data into the UI views. Alamofire is an HTTP networking library written in Swift. It adds a beautiful interface to Apple's Foundation networking stack, making routine networking chores easier. Chainable request/response methods, JSON and Codable decoding, authentication, and more are among its capabilities.



Figure 4.5: Proposed application screenshot

5. Conclusion

IoT technology provides real-time monitoring of object status when the Internet is unavailable by establishing connections between humans and objects, as well as among objects. The LPWAN technology has been suggested as a way to efficiently support IoT technology, and the LoRaWAN technology of LPWAN was used to construct a bicycle position tracking and management system in this article.

Using low-cost and long-range communication enabled IoT technologies, a device for measuring the current position and welfare level of cattle in remote locations has been built. The results of the tests reveal that the coordinates generated are correct and that data is transferred in real time. Furthermore, the technologies employed do not require any maintenance costs, and the cost of implementation is low. However, because all LoRa modules operate at the same frequency, there may still be some issues with data transfer security. As a result, security risks must be addressed in future development. Furthermore, a significant quantity of the data collected in the storage might be utilized to analyze and build a machine learning model to monitor cattle health and wellness, which will be explored in a future work. Different states and welfare of an animal can be learned based on the results. A user interface application will be built to obtain information about a cattle and to monitor its condition.

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