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Internet of Things (IoT) Security Alarms on ESP32-CAM

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Abstract. The article presents the basic requirements for systems operating on the technology of the industrial / industrial "Internet of Things" (Industrial Internet of Things, IIoT). presents the main technologies with which it is recommended to develop IIoT devices. These are low-level programming of microcontrollers using the STM32 example, working with real-time systems (using Mbed OS as an example), using low-power wireless technologies, such as LoRa, 6LoWPAN, NB-IoT, ZigBee, Bluetooth Low Energy (BLE). It is also necessary to use special protocols, for example, the MQTT application layer protocol, the use of special cloud services, for example, Artik Cloud, IBM Cloud, Intel Cloud. The article also provides the main features of the choice of hardware - a development board for a microcontroller, wireless communication modules, as well as features of choosing software to accelerate the stage of initial debugging and development of a device prototype. It also provides a brief overview of existing security alarm solutions based on the Internet of Things (IoT) and Smart Home technologies. The idea of creating a budget solution based on Arduino and ESP32-CAM is presented. A prototype was assembled, the device was tested in operation.

1. Introduction

Nowadays, you will not surprise anyone with household appliances with the prefix "smart" or "smart home". These are all IoT products for the consumer market. And yet the industrial / industrial "Internet of Things" (IIoT) is much more relevant, which can significantly increase labor productivity. And this puts forward requirements on a completely different level both to the technologies and to the hardware used. For example, no one will use hobby electronics to produce livestock products or street lighting. Therefore, according to the Samsung IoT Academy [1-5], it is necessary to master the following technologies: low-level programming of microcontrollers (for example, STM32, OS RIOT), high-level programming (Samsung Artik, OS Tizen), wireless communication technologies (LoRa, 6LoWPAN), application-level protocol MQTT (Mosquitto server) [6], cloud services (Artik Cloud). To reduce the entry threshold, it is proposed to study STM32 in conjunction with the Mbed real-time operating system [7]. The high level of abstraction, Arduino-like syntax and a lively community with many ready-made libraries and examples make it easy to learn, even for people who have never worked with hardware in their life. It is proposed to use a training microcontroller board based on STM32 Nucleo (Fig.1.) [8] and peripheral devices: sensors, executive devices and communication modules [9].

The choice of STM32 Nucleo is due, firstly, to the fact that earlier boards, for example STM32Discovery do not support Mbed, it is also important that Nucleo boards are compatible with Arduino sockets [10].



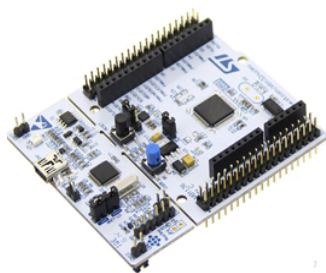


Figure 1. STM32 Nucleo.



Figure 2. RAK811 LoRa transceiver.

Wireless solutions most suitable for IoT are low-power networks such as LoRaWAN (Fig. 2) [11] which are most suitable for automation in agriculture and in areas with poor cellular coverage. Since this network is not widespread in Russia, a base station will be required for its deployment [12]). Another common in Russia non-cellular global LPWAN "Strizh" uses the closed protocol Marcato 2.0. LoRaWAN is characterized by a low degree of propriety. LoRa chips are patented by Semtech. However, the owner of the patents is not opposed to the fact that the equipment was produced by several companies. In addition, the end devices are produced by several dozen third-party manufacturers. As a result, the user has access to many budget-friendly and effective options for building IoT solutions based on LoRa.

Low-power NB-IoT networks from mobile cellular operators are also developing, for example, the Development Kit (DevKit) from MTS [13] (Fig. 4). In 2009, Bluetooth 4.0 was announced, including Bluetooth Low Energy [14].



Figure 3. Vega BS-1.2 base station.



Figure 4. Development Kit (DevKit) NB-IoT from MTS.

An important advantage of this technology should be noted - open access to the official specification: most other protocols require you to be a member of an official consortium. The Bluetooth specification is completely open and available for download from the official site. Also an important factor is the affordable price of modules (in comparison, for example, with ZigBee): chips with Bluetooth support are produced by many large companies such as Cambridge Silicon Radio, Dialog Semiconductor, Nordic Semiconductor, STMicroelectronics, Cypress Semiconductor, Silicon Labs and Texas Instruments, etc., in addition to this, you can find Chinese counterparts at an even more affordable price. We also note that today Bluetooth is supported by every smartphone and laptop, which gives the technology an advantage over other common protocols, such as ZigBee, where a special hub is required. The technology also supports a feature that reduces the traceability of a BLE device over a period of time. This is achieved by frequently changing the address of the Bluetooth device. A changing address is called a public address, and related devices can translate a private (unchangeable) address from a public address.

Despite the convenience and ease of learning, Mbed is good to use only to speed up the initial debugging and prototyping stages. For the final serial device, it is desirable to use proprietary software STM: STM32Cube [15], and for example, the compiler also from STM - Atollic True Studio [16].

The Internet of Things (IoT) and Smart Home technologies have been rapidly developing lately [17-21], and one of the interesting solutions based on these technologies is presented here. A security alarm is a set of electronic elements that allows you to monitor a protected object from a distance during non-working hours, to detect intrusion, and immediately transmit a notification of danger.

The problem of obtaining data on the state of the object is relevant at the present time, as there is an increasing demand for the protection of residential, warehouse, office premises from unwanted intruders into the protected area. Ready-made device solutions have not only a high cost of the product itself, but also their maintenance.

The automatic alarm system of the facility is part of the smart home system. Such a system is implemented using a wide range of automation tools. One of the available tools is an Arduino microcontroller with the connection of all sorts of elements that are compatible with the board.

2. Review of existing solutions

The modern security alarm system Ajax already has cloud and P2P technologies. Alarms are controlled remotely, and notifications about anything suspicious are sent to the smartphone.

The delivery set of the device from the Ajax company includes: an intelligent control panel (head unit) - Hub Plus (Fig.5.) , DoorProtect MotionProtect opening and motion sensors, SpaceControl panel; one smartphone is enough to control and configure the entire system. And also separately from this set of equipment you can buy the necessary devices that are produced by this company [22].



Figure 5. Security Alarm Ajax StarterKit.



Figure 6. Security Alarm Xiaomi Smart Home Suite.

Another interesting solution is the Xiaomi Smart Home Suite [23]. Xiaomi began its development with smartphones firmware in 2010. The main advantage of a small company at that time was the high quality of the product for not much money. This decision of the young company brought them to a high level of popularity and sales. Xiaomi became so visible that it could compete with global manufacturers. For 11 years on the market, the company has survived more than a dozen manufacturers. To this day, Xiaomi continues to evolve and stay in the leading positions.

The work of the security alarm Xiaomi Smart Home Suit is performed only through the proprietary Smart Home application. Those. access via a browser and programs on a PC is not possible. For the device to work, a personal Xiaomi account is required to connect the device, with the help of this, the electronics can update the software. A very convenient feature is that the alarm can work remotely without setting up a router and network equipment due to branded cloud services from Xiaomi.

The package includes: Xiaomi Smart Home controller (Fig. 6.) which has support for ZigBee and Wi-Fi protocols for data transfer. 2 wireless sensors (motion; opening doors or windows, which work on the principle of a reed switch and a magnet), a smart socket and a Mijia Wireless Switch button.

Based on the review of existing solutions, we consider it relevant and propose to develop a budget security alarm system operating on Smart Home technology.

3. Development prototypes devices

The main element of the device is the ESP32-CAM [24], which interacts with the motion sensor, the ov2640 camera and the android Telegram application (Fig.7.) . ESP32-CAM communicates with the messenger through Telegram, a bot that works autonomously.

The Telegram application allows you to receive and process messages, as well as send commands to check the protected premises, such as:

- 1) / start: send a welcome message with valid commands to control the alarm;
- 2) / flash: enable ESP32-CAM LED flash;
- 3) / photo: takes a new photo and sends it to your Telegram account;

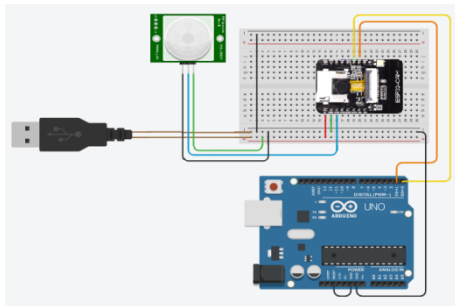


Figure 7. Device prototype scheme.

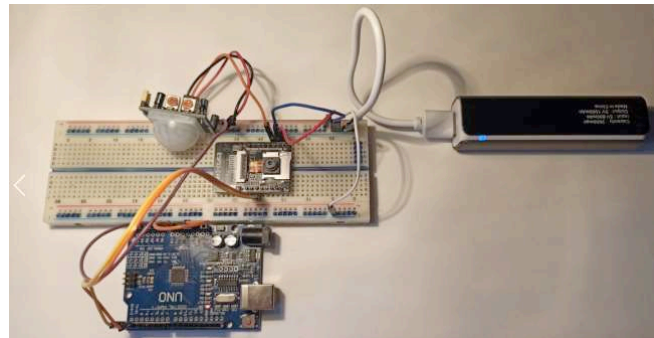


Figure 8. Assembled prototype.

The ESP32-CAM module is an affordable and powerful platform (Fig. 9), which you may need to develop smart projects on Arduino, the module supports data transfer via WiFi and Bluetooth. The ESP32-CAM microcontroller, unlike its predecessor ESP8266, has more interfaces. ESP32 was released by Espressif Systems in 2016. A powerful and inexpensive microcontroller released on a chip, which was built on the basis of TSMC 40nm technology. ESP32 is equipped with a dual-core 32-bit processor, clocked at 80, 160 or 240 MHz. The microcontroller has a special cable for connecting the OV2640 camera, a slot for a microSD memory card and the ESP32-S chip itself. Images can be stored on SD card in JPEG format. In order to connect the module to a computer, you need an adapter from UART to USB. The OV2640 camera provides the ability to obtain and analyze the image of objects that are present in the room, due to a microcontroller that works with low-level protocols. Because of this, the module has become popular in addition to the ESP8266 or ESP32-CAM. The module consists of a cable for connection and directly the camera sensor OV2640, which has a wide-angle lens with a viewing angle of 160 °, which allows obtaining images with a resolution of up to 1600x1200 with a maximum refresh rate of 15 FPS. The OV2640 camera (Fig. 10) provides the ability to receive and analyze the image of objects that are present in the room, due to a microcontroller that works with low-level protocols. Because of this, the module has become popular in addition to the ESP8266 or ESP32-CAM. The module consists of a cable for connecting and directly to the camera sensor OV2640, which has a wide-angle lens with a viewing angle of 160 °, which allows obtaining images with a resolution of up to 1600x1200 with a maximum refresh rate of 15 FPS.

Because of this, the module has become popular in addition to the ESP8266 or ESP32-CAM. HC-SR501 is a motion sensor (Fig. 7), developed on the pyroelectric effect [25]. The prototype of the device is assembled and tested in operation. A video demonstrating his work is posted on the network (Fig.8) [26].



Figure 9. ESP32-CAM module.



Figure 10. Ov2640 camera.

4. Creating a bot in telegram

In order to create a bot, you need to go to Google Play or the App Store, and install Telegram. Having opened the application, you need to find “botfather” in the search engine and click on it. After that, a window will open in which you will be asked to click on the start button “/ start” (Fig. 8). Enter “/ newbot” in order to give the bot name and username.

In order for ESP32 to be able to interact with Telegram, a message must be received with the bot address “t.me/Signalka1_bot” and the bot token, which is needed to access the corresponding section of the page.

To make sure that messages are coming from our Telegram account, you need to get your Telegram user ID. When a bot receives a message in the Telegram app, ESP32 can check if the sender's ID matches the user's ID and process the message or ignore it. To do this, you need to find “IDBot” in the Telegram search engine and click on it. Communication begins with the “/ start” command, then we enter “/ getid”. Then comes a message with a user ID.

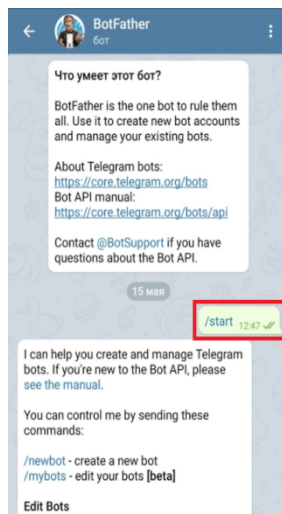


Figure 11. Start communicating with the bot.

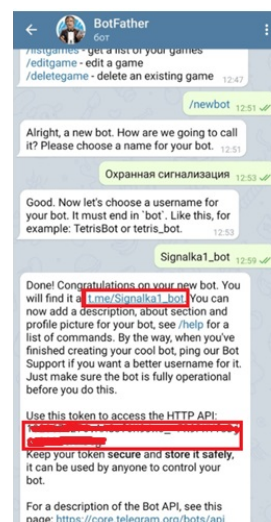


Figure 12. Message with the bot's address and key.

5. Conclusions

The article presents the basic requirements for systems operating on the technology of the industrial / industrial "Internet of Things" (Industrial Internet of Things, IIoT). presents the main technologies with which it is recommended to develop IIoT devices. A brief overview of existing security alarm solutions based on Smart Home and Internet of Things (IoT) and other technologies is presented. The idea of creating a budget solution based on Arduino and ESP32-CAM is presented. A prototype was assembled and the device was tested in operation.

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