UDC 004.042

I. Akhaladze, O. Lisovychenko

SOLUTION OF THE COMMUNICATION PROBLEM IN THE CONDITIONS OF LOSS OF COMMUNICATION WITH AZURE IOT HUB

Abstract. An architectural approach and software methods for ensuring a stable communication channel between swarm members in the absence of communication with the control hub are considered and proposed. The proposed architectural approach and software methods make it possible to provide multi-channel communication between drones in a swarm in the low frequency range. The channel ensures guaranteed delivery of messages, even in case of interference or noise.

Keywords: drones, swarm, Azure IoT Hub, LoRaWAN

Introduction

Modern drone remote control systems use cloud technologies and the TCP stack to exchange data between drones and the operator. Clouds allow operators to receive information about the status of drones, give them commands, and receive video and telemetry data from them.

However, in case of loss of communication with the cloud, the drones lose the ability to receive commands and send data. This can lead to a crash, or a swarm hang, where the swarm has no communication with the Azure IoT Hub and cannot complete the flight task.

The problem of loss of communication between drones and the control module (Azure IoT Hub) as it can lead to emergency situations. One way to solve this problem is to build a data transmission network between drones.

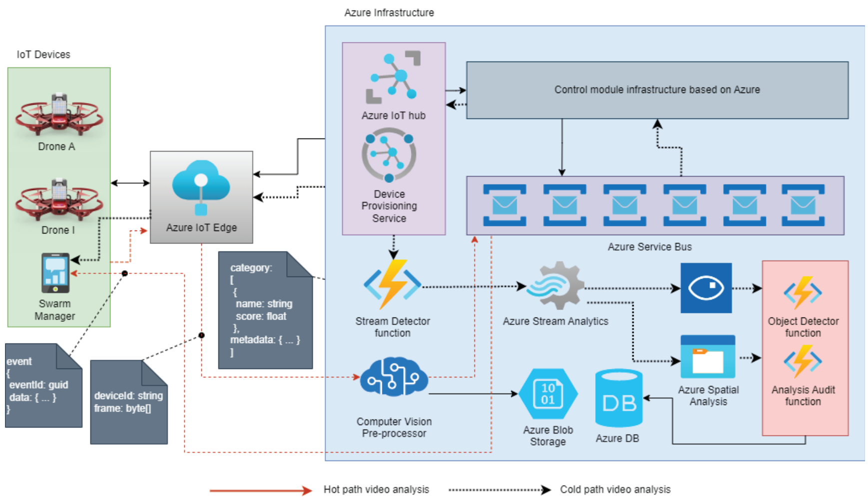

Fig. 1. Block diagram of drone swarm control using Azure IoT Hub

ISSN 1560-8956

In the above diagram, Azure IoT Hub acts as the central control module and handles video streams of each swarm member and telemetry. Analyzing the incoming video stream and telemetry data, the hub determines the behavior of the swarm by sending commands to each participant. In the case of loss of the communication channel with the hub, the swarm goes into an uncontrolled state of waiting (hanging), which poses a threat of losing swarm members.

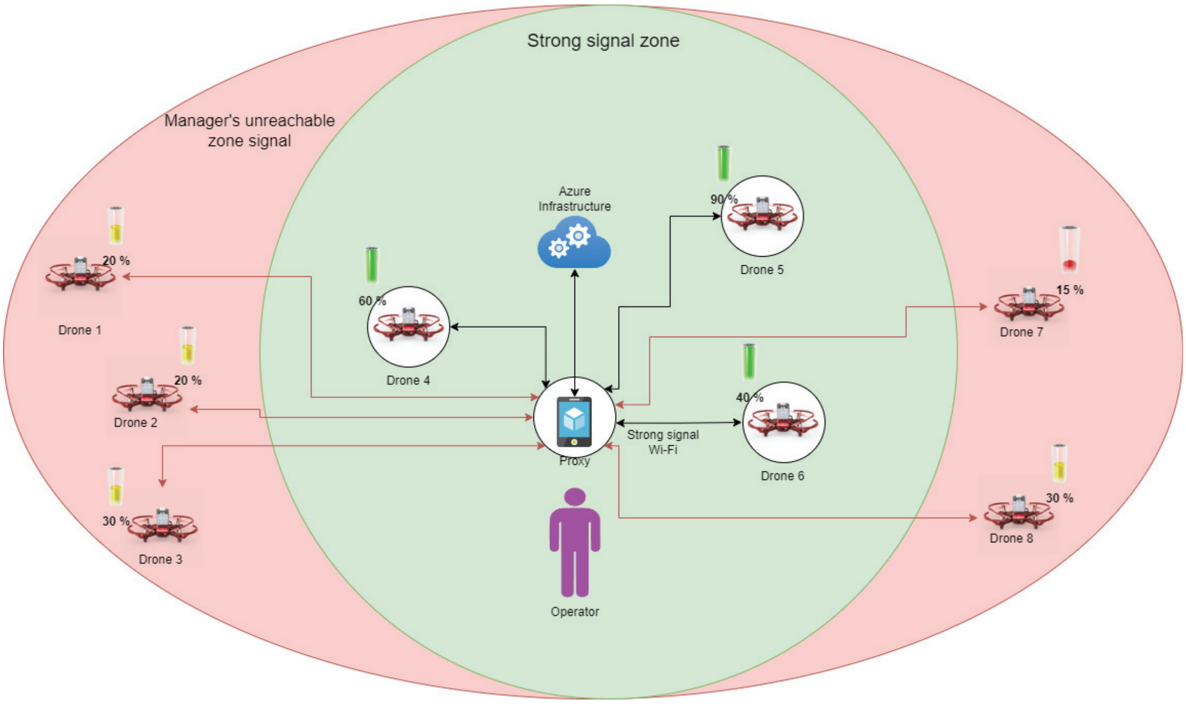

Fig. 2. Structural diagram of communication zones between swarm participants

Problem statement

Solve the communication problem in the drone control system in languages of loss of communication with the control hub to maintain control of the swarm. The proposed approach must meet the following requirements:

1. Ensuring guaranteed transmission of information at a distance of 5 to 10 km. depending on technical capabilities.

2. Defining the logic of assigning the role of communicator between the control hub and swarm members.

Solving the tasks

In order to solve the problem of ensuring the guaranteed transmission of information between swarm members in the swarm management system, we will analyze the existing transmission protocols.

Figure 3 shows a comparative scheme of gradation from 0 to 6, where the further from the center of the value, the better the rating of the characteristic. For example, the LoRa protocol is close to Sigfox in terms of energy consumption and protocol efficiency, but LoRa allows the transmission of packets of different sizes with less delay.

Table 1. **Comparison of data transmission protocols in drone control systems**

	LoRaWAN	**NB-IoT**	**Sigfox**
Range	Long (up to 15 km rural, 2-5 km urban)	Reliable in urban conditions	Very long (up to 50 km in rural areas)
Energy consumption	Low	Low	Very Low
Data transfer speed	Low (up to 50 kbps)	Low (up to 250 Kbit/s)	Very low (up to 100 bps)
Scalability	High	High	Average
Open standard	Yes	No	Yes

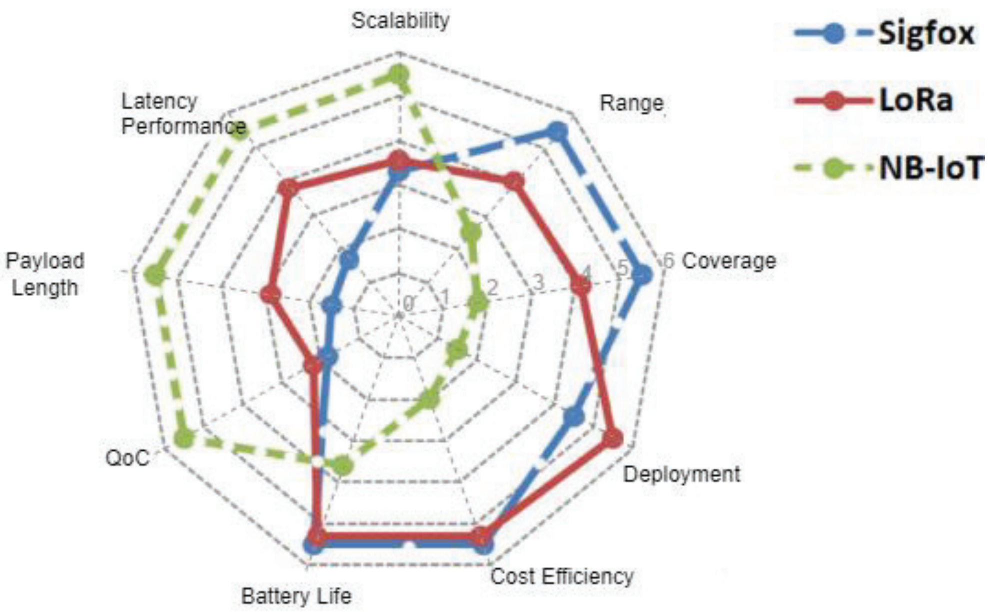

Fig. 3. Comparative diagram of data transfer protocols between swarm participants

After analyzing open communication protocols in IoT architectures, we can choose LoRaWAN, since scaling to transmission speed plays an important role in drone control systems. Also, LoRaWAN has a described standard that allows it to be integrated into the system.

To ensure the guaranteed transmission of information at a distance of up to 10 km, and to create a communication channel between swarm members in the absence of communication with the hub, we will use the Pixhawk flight controller and integrate the data reception transmission module with support for the low-frequency LoRaWAN protocol[13].

 ISSN 1560-8956

Let's develop an algorithm for data transmission between swarm participants with two roles: communicator and executor, where each swarm participant is an executor and at the same time can act as a hub for routing messages in the swarm.

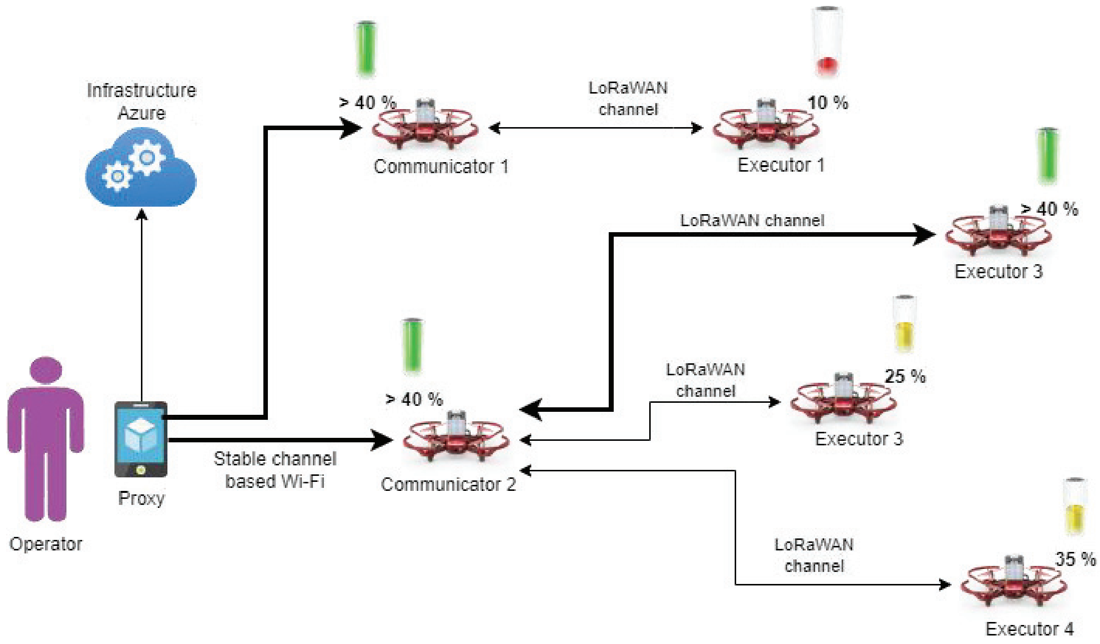

Fig. 3. Structural diagram of data transmission between swarm participants

If a drone loses contact with the Azure IoT Hub due to limited Wi-Fi or cellular range, it can use the LoRaWAN network to transmit data and commands to other drones in the swarm. Since LoRaWAN has a limit on the size of the transmitted packet, video data is recorded on each member of the swarm without transmitting the data over the network.

Data and commands received by other drones via LoRaWAN can be transmitted to the Azure IoT Hub through a drone that has active communication with the hub as shown in Figure 4. In addition, swarm members acting as gateways perform data pre-processing about the battery charge, if it approaches the level of energy required to return the drone (Edge) to the location of the drone-gateway, the performer drone receives a command to move to the point of the drone-gateway position.

The drone gateway performs the role of routing messages from the hub to each member of the swarm and back to the hub. Azure IoT Hub processes this data and commands and provides an appropriate response on each drone.

The possibility of assigning the role of a communicator allows you to expand the coverage area and ensure the necessary condition, namely the provision of guaranteed information transmission at a distance of 5 to 10. Having the ability to transmit information using swarm participants as a communicator and in accordance with the technical characteristics of the network, namely the transmission range from 2 to 5 km in the conditions of the city provides coverage of the corresponding range from 5 to 10 km.

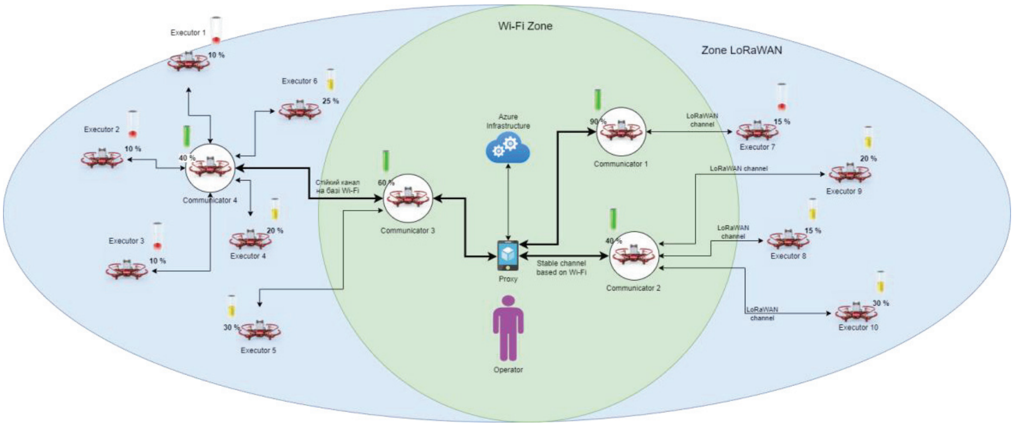

Fig. 4. Block diagram of drone swarm control using
Azure IoT Hub and network communication between drones

Figure 4 shows the structural diagram of swarm management, with a clear demarcation of the coverage area for swarm participants in the Wi-Fi zone, and an extended coverage area with a developed algorithm for assigning the role of a communicator to a swarm participant.

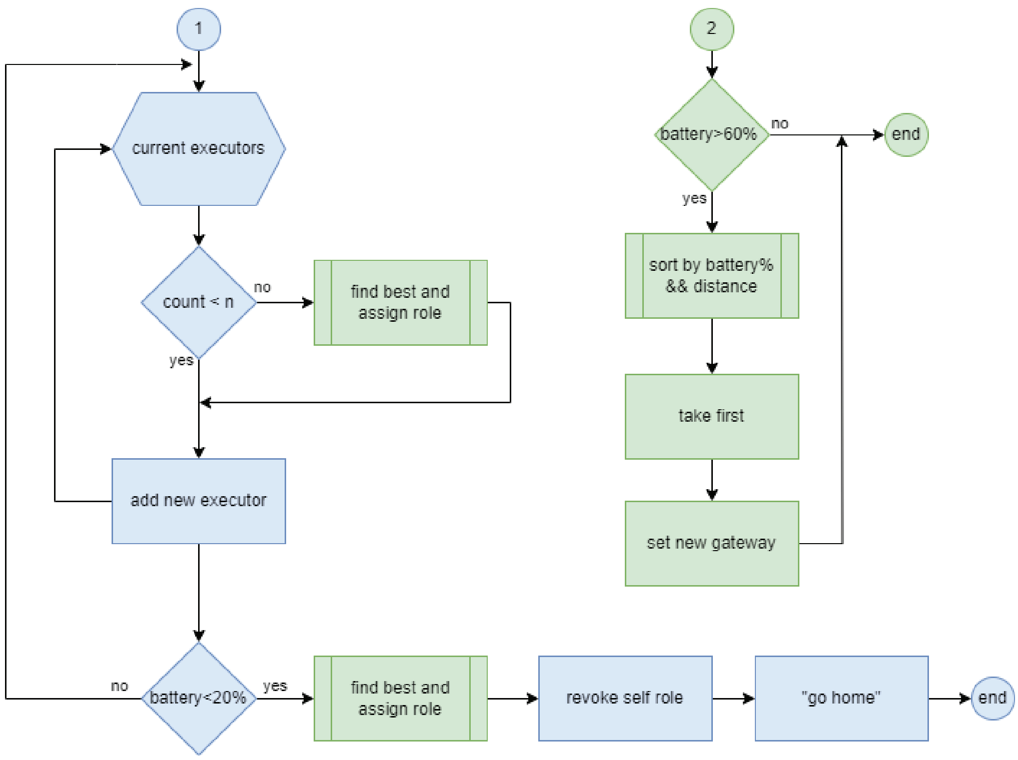

Fig. 5. Logical scheme for assigning the role of communicator to a swarm participant

ISSN 1560-8956

Figure 5 shows the logical scheme for assigning the role of a communicator. Each member of the swarm can perform the role of communicator under the following conditions: the drone has a charge level of more than 40%, and has a connection with the control hub or a drone that performs the role of communicator. The number of drones that can be connected to the communicator is also taken into account. There are restrictions on the number of drones connected to the communicator no more than n (in the research, this indicator is equal to 5), if the number of drones is 5, then an attempt to connect 6 (n+1) starts the subroutine for finding the best candidate for the role of the communicator. One of the 6 drones with the highest charge level and the one closest in distance is considered the best. The communicator sends the communicator assignment command to the best candidate.

Optimizing the coverage of communicators and the reception of construction of optimal topologies will be studied in the next work.

Conclusions

Modern drone remote control systems use cloud technologies and the TCP stack to exchange data between drones and the operator. Clouds allow operators to receive information about the status of drones, give them commands, and receive video and telemetry data from them. However, in case of loss of communication with the cloud, the drones lose the ability to receive commands and send data. This can lead to a crash, or a swarm hang, where the swarm has no communication with the Azure IoT Hub and cannot complete the flight task.

A communication channel was built in the swarm of drones with guaranteed delivery of messages, which makes it possible to maintain control over the swarm of drones even when communication with the control hub is lost. The developed algorithm for assigning the role of a communicator between the control hub and swarm members allows to preserve the functionality of the swarm of drones. Also, it should be noted that additionally. the advantage is that the area covered by the control signal for the swarm of drones has increased.

Research results make it possible to maintain control over drones even when communication with the control hub is lost. The developed logic for assigning the role of a communicator allows you to maintain control over all participants of a swarm of drones outside of WiFi coverage.

REFERENCES

1. Akhaladze I.E. Increasing the efficiency of streaming video processing using serverless technologies // Adaptive automatic control systems. 2021. No. 39. C.32-40 https://doi.org/10.20535/1560-8956.39.2021.247393

2. Akhaladze I.E. The use of serverless functions in the algorithm for calculating the target point of the trajectory under dynamic load. 2022. № 40. C.34-38 https://doi.org/10.20535/1560-8956.40.2022.261531

3. Akhaladze A.E. Using IoT to synchronize flight trajectories of drones // Adaptive automatic control systems. 2021. No. 39. C.20-26 https://doi.org/10.20535/1560-8956.39.2021.247381

4. Akhaladze A.E. Synchronization of flight trajectories based on the "Internet of Things" architecture when implementing swarm control Adaptive automatic control systems. 2022. No. 40. C. https://doi.org/10.20535/1560-8956.40.2022.261536

5. K. He, X. Zhang, S. Ren, and J. Sun, “Deep residual learning for image recognition,” in Proceedings of the IEEE conference on computer vision and pattern recognition, 2016.

6. Y. LeCun, Y. Bengio, and G. Hinton, “Deep learning,” Nature, vol. 521, no. 7553, pp. 436–444, 2015.

7. J. Schmidhuber, “Deep learning in neural networks: An overview,” Neural Networks, vol. 61, pp. 85-117, 2015.

8. S. Levine, C. Finn, T. Darrell, and P. Abbeel, “End-to-end training of deep visuomotor policies,” Journal of Machine Learning Research, vol. 17, no. 39, pp. 1-40, 2016.

9. D. Silver, A. Huang, C. J. Maddison, A. Guez, L. Sifre, G. van den Driessche, J. Schrittwieser, I. Antonoglou, V. Panneershelvam, M. Lanctot, S. Dieleman, D. Grewe, J. Nham, N. Kalchbrenner, I. Sutskever, T. Lillicrap, M. Leach, K. Kavukcuoglu, T. Graepel, and D. Hassabis, “Mastering the game of go with deep neural networks and tree search,” Nature, vol. 529, no. 7587, pp. 484-489, 2016.

10. S. Guadarrama, N. Silberman, J. Susskind, and R. Farrell, “Pixhawk: A system for autonomous flight using onboard computer vision,” in Proceedings of the IEEE International Conference on Robotics and Automation, 2015.

11. C. H. Lampert, H. Nickisch, and S. Harmeling, “Learning to detect unseen object classes by between-class attribute transfer,” in Proceedings of the IEEE conference on computer vision and pattern recognition, 2009.

12. Krizhevsky, I. Sutskever, and G. E. Hinton, “Imagenet classification with deep convolutional neural networks,” in Advances in Neural Information Processing Systems, 2012.

13. A comparative study of LPWAN technologies for large-scale IoT deployment. https://www.researchgate.net/publication/322018958_A_comparative_study_of_LPWAN_technologies_for_large-scale_IoT_deployment. Date of application: July 20, 2023

 ISSN 1560-8956