

# THE MODEL OF DATA DELIVERY FROM THE WIRELESS BODY AREA NETWORK TO THE CLOUD SERVER WITH THE USE OF UNMANNED AERIAL VEHICLES

Ruslan Kirichek

Department of Telecommunication Networks and Data Transmission  
State University of Telecommunication,  
193232, St.Petersburg, Russia  
E-mail: kirichek@sut.ru

## KEYWORDS

Model, WBAN, UAV, Data, Sensor Node, Channel.

## ABSTRACT

Currently, the wireless body area network for monitoring the human body and preventing the critical situations of life are widely spread. Data from the sensors are collected in the memory of the microcomputer, and should be delivered in a cloud service for the further analysis. The classical methods for delivery via wireless interfaces require large power consumption (Wifi, LTE, 3G technology), whereas the protocols with low power consumption suggest the presence of additional gateway with the Internet, which is not always possible to implement. The paper proposes an original approach of using UAVs to deliver data from the wireless body area network to a remote cloud server. The proposed model takes into account the bandwidth, the ability of generating traffic parameters, the number of sensor nodes and the characteristics of the UAV.

## INTRODUCTION

The Flying Ubiquitous Sensor Network (FUSN) is a new application of the Internet of Things (Koucheryavy et al. 2015; Kirichek and Koucheryavy 2016). The term is rather new, but it has managed to win the attention of the scientific community. The main objective of the FUSN is a collection of data from the remote sensor nodes by using public unmanned aerial vehicles (UAV-P). This effect has become possible and necessary due to the emergence of a large number of objects, equipped with sensors (temperature sensors, humidity, light, etc.) and radiomodules based on protocols: ZigBee, 6LoWPAN, BLE, RPL, AODV and so on (Koucheryavy et al. 2014; Vasiliev et al. 2014; Rosario et al. 2014), as well as a reduction of the cost and promotion the UAV-P that can perform the autonomous flights on a given route (Phuong et al. 2014; Kirichek et al. 2015).

There are two segments of the flying ubiquitous sensor networks: terrestrial and flying. The terrestrial segment is represented as a classical ubiquitous sensor network (Abakumov and Koucheryavy 2014; Vybornova and Koucheryavy 2014; Futahi et al. 2015), and the flying segment as one or several of UAV-P (Sahingoz 2014; De Freitas et al. 2010; Orfanus et al. 2014). Actively

developing medical wireless body area networks (WBAN) are (Kirichek et al. 2016):

- Wearable smart fitness electronics, which acts as a mentor in the observance of a healthy way of life (sleep, physical activity, etc.). The data is collected from all kinds of bracelets, smart watches, pedometers, neurointerface and then is delivered to the cloud service through the Internet, while the smartphone is used as a gateway. As a rule, these products do not require strict medical certification.

- Specialized clothing and high-precision sensors for collecting the data on the state of human health data according to the key performance indicators (heart rate, blood sugar, blood pressure and others.). Sensors are installed in the suits of sportsmen and people of extreme professions. These products are subject to mandatory medical certification.

- Medical nanonetworks are implanted directly into the body of the human and communicate through a dedicated gateway. This area is at the stage of research, but the results are predicting the widespread of this type of network.

In turn, the collected data should be delivered to a single point for storage and subsequent processing. For these purposes, it is advisable to use UAV-P that can quickly fly around the area of people dislocation and transmit data to the cloud server, using the telemetry channel.

An example of such an interaction can be a group of climbers who came under an avalanche of snow. UAV-P is capable of arriving at the accident site in a few minutes, flying around the area, fixing the place where there are people and transmitting the data from the WBAN about their health in the cloud server.

## OVERVIEW OF THE UAV CHANNELS OF INTERACTION WITH THE PUBLIC COMMUNICATIONS NETWORK

One or more UAV can be used for the tasks of data collection and transmission (figure 1). Autonomous UAV flight is performed on the basis of the flight task, which is pre-loaded into the controller (Kirichek et al. 2015).

Although the full autonomy of the flight, the telemetry channel is typically used for monitoring parameters of UAV and for supplying the emergency landing command. Given the fact that the maintenance traffic is

transmitted in the channel – the channel utilization is about 60%, the channel resource remains small for efficient data transmission collected from WBAN.

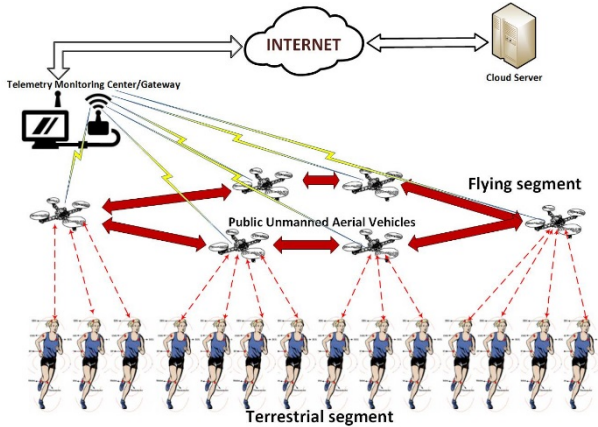


Figure 1: Data Collection from WBAN Using One or Multiple UAVs

Thus, it is necessary to solve the problem of guaranteed data delivery from the sensor nodes (a man with WBAN) on the cloud server via the Internet.

The following parameters can be varied:

- The number of people;
- The number of UAVs;
- The radius of radio coverage of the UAV;
- The size of the territory with people;
- Frequency (various channels of interaction).

### THE MODEL OF DATA DELIVERY FROM THE WBAN TO THE PUBLIC COMMUNICATION NETWORK WITH THE USE OF UAV

The purpose of the UAV network simulation is to choose its parameters to provide the desired quality of service traffic (Kirichek et al. 2015). The quality of service traffic in the context of this task is determined by the delivery of the data from the sensor network (WBAN) in the cloud server. The network parameters are the bandwidth data transmission channel and the number of UAVs required for the task.

In order to build a model, we will make the following assumptions. Let us assume that it is required to transfer the data from a group of  $n$  sensor nodes. The sensor nodes are arranged randomly and form a Poisson field (Ventcel' 1959). Each of the sensor nodes produces a fixed amount of data  $v$  (bytes), which is a set of values obtained from the various sensors. The data from each of the nodes should be delivered to the collection cloud server at a time not exceeding  $T_0$ . The network structure includes a segment of the sensor nodes, the access network segment, implemented with the help of UAVs, gateway and data network segment between the gateway and the cloud services server. We assume that the bottleneck in this structure is a segment of the access network. Further we will consider only the settings for the access network segment, believing that the network settings of other elements have a substantial margin of bandwidth.

The access network is constructed on the basis of the communication nodes located on UAVs. In general,  $k$  UAVs can be located in a service area, where the sensor nodes coverage areas may overlap, as shown in figure 2, 3.

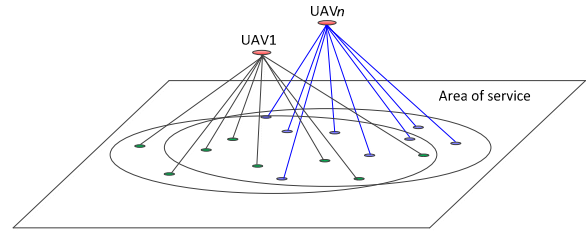


Figure 2: The Sensor Network Areas Model Served by UAVs

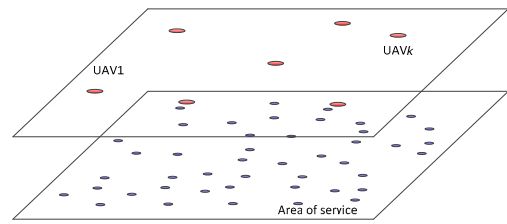


Figure 3: Overlap Sensor Network Areas and UAVs Areas

Area can be served by multiple UAVs. UAVs have a random location at some time, and can also be viewed as a Poisson field.

We believe that the communication nodes which are located on UAVs, have a choice of free frequency channel to communicate with the sensor nodes. Frequency Division Multiplexing makes it possible to serve the nodes of sensor network with multiple UAVs crossing their service areas. We assume that the sensor node periodically performs the data sending operation. If at the time of this operation there is a free channel resource, the data is transmitted at a rate determined by the free channel bandwidth. If there is no available resource, the data waits to be sent. Time data delivery through the access network will be determined by the transmission rate in the channel and the standby transmission start time

$$\bar{T} = \bar{W} + \bar{t} \quad (1)$$

where  $\bar{W}$  - waiting time of the beginning of transfer;  $\bar{t}$  - transfer time through a channel.

Considering this system as a queuing system, it is possible to estimate the delay associated with waiting for the start of service.

The flow of requests for the system input is determined by the activity and the number of the sensor nodes. We proceed from the fact that the traffic characteristics, which are produced by various different nodes, differ (different frequency of sending data and different amount of data). Then the resulting flow of quite a large number of nodes can be described by a simple flow model, the intensity of which is equal to

$$\lambda = \sum_{i=1}^n \lambda_i \quad (\text{requests/sec}) \quad (2)$$

where  $\lambda_i$  – the flow rate produced by the  $i$ -th node. The average volume of transmitted data is:

$$\bar{v} = \frac{1}{n} \sum_{i=1}^n v_i \quad (\text{bit}) \quad (3)$$

where  $v_i$  is the volume of data transmitted by the  $i$ -th node.

At a constant speed of data transmission in the channel  $b$  (bit/s) the average service time of requests is equal to

$$\bar{t} = t_c + \frac{\bar{v}}{b} \quad (\text{s}) \quad (4)$$

where  $t_c$  - the time required for channel selection and communication (sec).

$v$  - the amount of sensor data (bit);

$b$  - the data transmission rate in the channel (bits/sec).

If  $t_c$  is significantly less time required for transmission, it can be neglected.

If at the moment of awakening the node selects a free, at the moment, frequency channel, i.e. channel which is not currently transmitted to a traffic, then the model can be described with a queuing system form M/G/k in service procedure with expectation. Assuming that the communication channels with the UAV  $1 \dots k$ , are identical, it is possible to present that their total capacity is equal to

$$\mu_k = \frac{k}{\bar{t}} \quad (\text{requests/sec}) \quad (5)$$

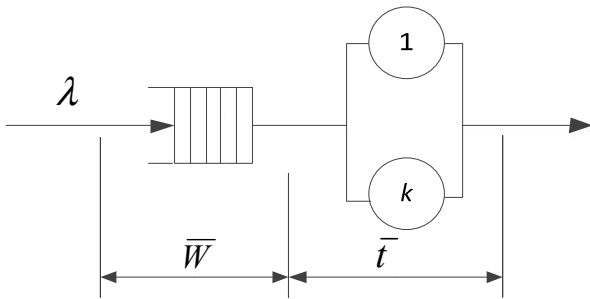


Figure 4: Model of Service Sensor Network Nodes

If we make the assumption that the time of service requests (the time of its transmission over the channel)  $\bar{t}$  is accidental and has an exponential distribution, for the system M/M/k we can estimate the waiting time at queue as the

$$\bar{W} = \frac{E_C(k, \lambda, \mu)}{k\mu - \lambda} \quad (6)$$

$$\text{where } E_C(k, \lambda, \mu) = \frac{\frac{a^k}{k!} \cdot \frac{k}{k-a}}{\sum_{i=0}^{k-1} \frac{a^i}{i!} + \frac{a^k}{k!} \cdot \frac{k}{k-a}} \quad \text{is the}$$

second formula Erlang (Erlang C-formula) (Iversen 2001);

$a = \lambda \cdot \bar{t}$  - the intensity of the load (Earl);

$k$  - the number of available channels (UAV);

$\mu = \frac{1}{\bar{t}}$  - the average number of requests served (sent) by one channel per unit of time.

If the distribution of the service time is different from the exponential, it is possible to resort to an approximate evaluation of its upper limit, for example (Kleinrock 1975).

Assuming an exponential distribution service time, the necessary number of available channels (UAV) can be estimated as the solution of the inequality  $\bar{T} \leq T_0$  that can be obtained by minimizing the expression

$$k = \arg \min_k \left| \frac{E_C(k, \lambda, \mu)}{k\mu - \lambda} + \bar{t} - T_0 \right| \quad (7)$$

The conditions of the model  $k$  - should be viewed as the average number of UAVs, which are simultaneously in communication area where the density can be obtained, i.e. the average number of UAV unit area service area

$$\rho_{UAV} = \frac{k}{\pi R^2} \quad (8)$$

where  $R$  – the radius of the node connection.

Thus, using the expressions (7) and (8) based on the intensity of traffic data which is produced by the sensor nodes, and their amount of traffic intensity, the amount of transmitted data and the radius of connection, one can estimate the required number (density) of the UAV which is necessary for data delivery over the time, which does not exceed a predetermined value.

## CONCLUSION

The paper suggests the new ways of using UAVs to deliver the real-time data on a remote cloud server. The proposed model will enable to calculate the number of UAVs required for the collection and delivery of data, taking into account the intensity and volume of traffic to the network underwear, the number of units and the radius of their connection.

These results will be used to conduct a series of experiments on the flying ubiquitous sensor network.

## ACKNOWLEDGMENT

The reported study was supported by RFBR, research project No.15 07-09431a “Development of the principles of construction and methods of self-organization for Flying Ubiquitous Sensor Networks”.

## REFERENCES

- Abakumov, P.; and A. Koucheryavy. 2014. "The Cluster Head Selection Algorithm in the 3D USN". *Proceedings of the 16th International Conference on Advanced Communication Technology, ICACT 2014* (Phoenix Park, Korea, Feb. 16-19), IEEE, 462-466.
- De Freitas, E. P.; T. Heimfarth; I. F. Netto; C. E. Lino; C. E. Pereira; A. M. Ferreira; F. R. Wagner; and T. Larsson. 2010. "UAV relay network to support WSN connectivity". *Proceedings of the International Congress on Ultra Modern Telecommunications and Control Systems 2010* (Moscow, Russia, October 18-20), IEEE, 309-314.
- Futahi, A.; A. Koucheryavy; A. Paramonov; and A. Prokopiev. 2015. "Ubiquitous Sensor Networks in the Heterogeneous LTE Network". *Proceedings of the 17th International Conference on Advanced Communication Technology, ICACT 2015* (Phoenix Park, Korea, July. 1-3), IEEE, 28-32.
- Iversen, Villy B. 2001. *Handbook "Teletraffic engineering"*. ITU-D Study Group 2, Question 16/2, June 20, 2001
- Kirichek, R.; A. Paramonov; and K. Varelzhyan. 2015. "Optimization of the UAV-P's Motion Trajectory in Public Flying Ubiquitous Sensor Networks (FUSN-P)". *Proceedings of the 15th International Conference, NEW2AN 2015, and 8th Conference, ruSMART 2015* (St.Petersburg, Russia, August 26-28), LNCS 9247, Springer, 352-366.
- Kirichek, R.; A. Paramonov; and A. Koucheryavy. 2015. "Flying Ubiquitous Sensor Networks as a Quening System". *Proceedings of the 17th International Conference on Advanced Communication Technology, ICACT 2015* (Phoenix Park, Korea, July. 1-3), IEEE, 127-132.
- Kirichek, R.; and A. Koucheryavy. 2016. "Internet of Things Laboratory Test Bed". *Proceedings of the Wireless Communications, Networking and Applications 2014, LNEE, Springer, T.348, 485-494.*
- Kirichek, R.; R. Pirmagomedov; R. Glushakov; and A. Koucheryavy. 2016. "Live Substance in Cyberspace - Biodriver System". *Proceedings of the 18th International Conference on Advanced Communication Technology, ICACT 2016* (Phoenix Park, Korea, Jan.31-Feb.3), IEEE, 274-278.
- Kleinrock, L. 1975. "Queueing Systems". John Wiley & Sons.
- Koucheryavy, A.; A. Muthanna; A. Prokopiev; and A. Paramonov. 2014. "Comparison of protocols for Ubiquitous wireless sensor network". *Proceedings of the 6th International Congress on Ultra Modern Telecommunications and Control Systems and Workshops 2014* (St. Petersburg, Russia, October 6-8), IEEE, 434-437.
- Koucheryavy, A.; A. Vladyko; and R. Kirichek. 2015. "State of the Art and Research Challenges for Public Flying Ubiquitous Sensor Networks". *Proceedings of the 15th International Conference, NEW2AN 2015, and 8th Conference, ruSMART 2015* (St.Petersburg, Russia, August 26-28), LNCS 9247, Springer, 299-308.
- Orfanus, D.; F. Eliassen; and E.P. de Freitas. 2014. "Self-Organizing Relay Network Supporting Remotely Deployed Sensor Nodes in Military Operations". *Proceedings of the 6th International Congress on Ultra Modern Telecommunications and Control Systems and Workshops 2014* (St. Petersburg, Russia, October 6-8), IEEE, 326-333.
- Phuong, T. H.; H. Yamamoto; and K. Yamazaki. 2014. "Data Synchronization Method in DTN Sensor Network using Autonomous Air Vehicle". *Proceedings of the 16th International Conference on Advanced Communication Technology, ICACT 2014* (Phoenix Park, Korea, Feb. 16-19), IEEE, 382 - 387.
- Rosario, D.; Z. Zhao; T. Braun; E. Cerqueira; and A. Santos. 2014. "A Comparative Analysis of Beaconless Opportunistic Routing Protocols for Video Dissemination over Flying Ad-hoc Networks". *Proceedings of the 14th International Conference on Internet of Things, Smart Spaces, and Next Generation Networks and Systems, NEW2AN 2014* (St.Petersburg, Russia, August 27-29), LNCS 8638, Springer, 253-265.
- Sahingoz, O. K. 2014. "Networking Model in Flying Ad Hoc Networks (FANETs): Concepts and Challenges". *Journal of Intelligent & Robotics Systems. V.74, issue 1-2, Springer, 513-527.*
- Vasiliev, D. S.; D. S. Meitis; and A. Abilov. 2014. "Simulation-Based Comparison of AODV, OLSR and HWMP Protocols for Flying Ad Hoc Networks". *Proceedings of the 14th International Conference on Internet of Things, Smart Spaces, and Next Generation Networks and Systems, NEW2AN 2014* (St.Petersburg, Russia, August 27-29), LNCS 8638, Springer, 245-252.
- Ventcel', E.S. 1959. "Probability theory". M. "Nauka" (in Russian).
- Vybornova, A.; and A. Koucheryavy. 2014. "Traffic Analysis in Target Tracking Ubiquitous Sensor Networks". *Proceedings of the 14th International Conference on Internet of Things, Smart Spaces, and Next Generation Networks and Systems, NEW2AN 2014* (St.Petersburg, Russia, August 27-29), LNCS 8638, Springer, 389-398.

## AUTHOR BIOGRAPHIE



**RUSLAN KIRICHEK** was born in 1982 in Tartu (Estonia). He graduated Military-Space Academy A.F. Mozhaiskogo and St.Petersburg University of Telecommunication in 2004 and 2007 respectively. R.Kirichek received Ph.D from St.Petersburg University of Telecommunication in 2012. Since 2004 he worked at IT-department of the Air Force as a senior engineer. Since 2008 worked as a senior researcher at the FSUE "Research and Development Center "Atlas". Supervised research testing communication networks in terms of destructive influences. Since 2012 worked as the Head of the Internet of Things Laboratory at St.Petersburg University of Telecommunication. His e-mail address is: kirichek@sut.ru and his Web-page can be found at <http://www.iotlab.ru>