Control System Objects with Multiple Streams of Information

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***Abstract* – The article deals with the problem of controlling the flow of information coming from a group of UAVs by radio channel. The stream is a sequence of binary information packages. The inevitable data losses are compensated by repetition of lost packages. Modern methods control of data flow assumes using a mechanism ARQ based on the method sliding window. In this paper the comparative analyses of the known methods are given. The property matching the volume of information, which is transmitted from UAVs with the size M of the sliding window, is set. In base of theoretical calculations is used the concept of bandwidth. Computing bandwidth radio channel with the ARQ technology allows are confirming the main result investigation.**

Keywords – flow data; probability error; automatic repetition query (ARQ); stop and wait scheme; throughput

I. INTRODUCTION

Today the number of researchers takes attention to the collective management of unmanned machines based on radio remote control. It is the task of executing the works with the risk to human life, the need to perform tasks in a limited time, a long time carry out routine work. Application tasks of collective control include search and monitoring operations, extinguishing fires in large areas of the earth's surface and other [1, 2].

When controlling the actions of the group UAVs need to transfer large amounts of information on the ground control station. Information is transmitted package that simplifies the information processing. The movement of aircraft, equipment malfunctions, there is interference on radio propagation path, some data packets may be lost or, for example, there may be no confirmation of it receipt.

Some authors propose technologies actions planning networks of UAVs, which based on discipline scheduling, i.e. the order of processing of the transmitted packages [3-10]. However, an important task becomes developing algorithms compensate for lost packets. A natural approach to solving this problem is to re-send lost packets to the point of reception and processing of information.

Stop and wait mode for re-packages is estimated as inefficient way to retrieve lost packets. In this case, the channel is long time stopped before receiving the series of packages. More promising is the use of window, which slides over the flow of information. If we repeat the lost information in a fixed window, it is possible to improve radio channel using. In practice the selective rejection mode also gives analogical of using channel [11]. The problem, which is studied in this paper, is to compare these technologies in terms of preference and obtaining estimates of the size for sliding window.

In this paper discusses the problem of estimating the load of the transmission channel in the presence of loss of data on the basis of these methods.

II. PROBLEM STATEMENT

Let have a group from n UAVs, which gives information to operator's remote control by radio link. Operator determined for UAVs path, active zone, control and correction routes. Operator and UAV exchange this information as usually by packages. The package is a certain amount of binary information, organized in a certain way that named protocol.

All UAVs transmits information to the ground control station in an asynchronous mode, then processing system for input stream has the form

$$I = I_{UAV_1} + I_{UAV_2} + ... + I_{UAV_n}, \qquad (1)$$

where I_{UAV_i} – the data flow from i of source and $i = \overline{1, n}$. Here the problems of auto identification, authentication don't solving. The packages from all UAVs are considered as whole one stream.

The main problem in this transferring data is motion UAVs, mismatch processing speeds in reception and transmission points, buffer overload is due to data retrieval on a low speed, retransmission data to another address, and errors during transmission data. Consequently, it becomes necessary to control the flow of data.

There are some methods to control the flow of data. Among them stop and wait, return to the M steps, selective rejection. The last two approaches are known as a mechanism automatic repetition query (ARQ) [11]. The first scheme works as follows: if the sender sent the package, the receiver sends the confirmation it ready to get the next package. In this case we have two errors. One error can turn out because of transmission package and another - in time receiving confirmation. In accordance to the second scheme is entering "sliding window" for transmission *M* packages. Error in package leads to the need to repeat it and the subsequent packets transmitted in this window. In the case selective rejection are repeated only the packages that have been damaged and the packages which have the waiting time are expired.

Assume that the system consists of a source, which transmits packages of fixed length T_{pac}, and the receiver, which confirm its decision sent to the request. Time data transmission in one direction is T_{dir}. Considered that the time duration of packages processing and transmission confirmation is very small, so they can be neglected, and then the time required transferring one packet

$$T = T_{pac} + 2T_{dir} . \quad (2)$$

If necessary, *N*-time to repeat transmission one package until successful reception that this time increases to a value

$$T = N(T_{pac} + 2T_{dir}) . \quad (3)$$

Also is given the probability of damage to the package *p*.

This paper presents analytical framework to evaluate loading channel "UAV-point control" for determined flow control methods. The framework included calculations per-flow throughput for system with fixed delay and time-independent wireless channel.

III. Stop and wait scheme

As known, throughput is a metric characteristic that showing the relation limiting the number of passing units (information items, the volume) per unit time through a channel. In our case throughput is value *C*, which calculated such as

$$C = \frac{T_{pac}}{T} = \frac{T_{pac}}{T_{pac} + 2T_{dir}} . \quad (4)$$

If we set $\bar{t} = T_{dir} / T_{pac}$ that (4) can write in form

$$C = \frac{1}{1+2\bar{t}} . \quad (5)$$

The throughput *C* in (5) is normalized and takes values in interval [0; 1]. If $\bar{t} < 1$ then $C \to 1$, that corresponds to high productivity channel, and if $\bar{t} > 1$ then $C \to 0$, that corresponds to low productivity channel.

If a transmission error occurs and the information is necessary repetition of data being sent, the throughput channel deteriorates in *N*-time

$$C = \frac{1}{N(1+2\bar{t})} . \quad (6)$$

In the general case *N* in (6) is a the random value, which for a long transmission interval determined by the probability

$$N = \sum_{k=1}^{\infty} k p^{k-1}(1-p) , \quad (7)$$

where *k* – the number of repetitions transmission and $p<1$. In accordance to [12, formula (21.2-39)] record (6) transformed to

$$N = \frac{1}{1-p} , \quad (8)$$

then (6) write in form

$$C = \frac{1-p}{1+2\bar{t}} . \quad (9)$$

Formula (9) is setting loading ability radio channel in scheme with stop and wait.

IV. ARQ scheme

Analysis of ARQ algorithms isn't different from that considered in the section III. Let's begin to consider its effect when errors transmission is absent. For the M-packages defining the size of the sliding window, there are two variants for transferring information.

Case 1. The size sliding window *M* more than exceeding the time allowed for transmission of information, i. e. $M \geq 1 + 2\bar{t}$. In this case the channel is not overloaded and has the best performance. This statement allows to set the numerator (5) limit the transmission time value, then the throughput is equal to $C = 1$.

Case 2. The transmission time of the channel is limited to the size of the window, i. e. $M < 1 + 2\bar{t}$. Here the numerator equals *M* and (5) can be written as

$$C = \begin{cases} 1, \ if \ M \geq 1+2\bar{t}, \\ M/(1+2\bar{t}), \ if \ M < 1+2\bar{t}. \end{cases} \quad (10)$$

Transmission errors are deteriorates throughput that in case with selective rejection, when returning on *N* steps for single package occurs in virtue of (8), (9), takes the form

$$C = \begin{cases} 1-p, \ if \ M \geq 1+2\bar{t}, \\ M(1-p)/(1+2\bar{t}), \ if \ M < 1+2\bar{t}. \end{cases} \quad (11)$$

In the scheme of return on *N* steps retransmits *L* packages. Here, the number of return *N* steps is a function of the number of transmitted packages

$$N = \sum_{k=1}^{\infty} f(k) p^{k-1}(1-p) . \quad (12)$$

In (12) *f* (*k*) – the total number of retransmitted packages and a lost packet transmitted *k* times. *f* (*k*) can be represented as [11]

$$f(k) = 1 + (k-1)L. \quad (13)$$

After the substitution of (13) to (7) is obtained by the number of the repeated packages

$$N = \frac{1-p+Lp}{1-p}. \quad (14)$$

For derivation of (14) essentially used the results of (21.2-38) and (21.2-39) in [12].

Substituting (14) into (6) and considering the cases 1 and 2 relative to the size $M = L$ of the sliding window, we obtained throughput for ARQ-mechanism that based of return on N steps

$$C = \begin{cases} \dfrac{1-p}{1-p+Mp}, & if\ M \geq 1+2\bar{t}, \\ \dfrac{M(1-p)}{(1+2\bar{t})(1-p+Mp)}, & if\ M < 1+2\bar{t}. \end{cases} \quad (15)$$

Expressions (11) and (15) correspond to throughput data flow control mechanism with ARQ. It is noteworthy that for $M = 1$, both expression degenerates to stop and wait scheme (9).

Expression (5), (10), (11), (15) prove the following THEOREM. If the size M of the window satisfies condition $M \geq 1+2\bar{t}$, then the channel is effectively used and $C(\bar{t}) = C_{\max}$.

Corollary. The number of bits l of the sliding window is determined by expression

$$l \geq 1 + \log_2 T_{pac} + \log_2 T_{dir}. \quad (16)$$

Formula (16) follows from the theorem and the value $\bar{t} = T_{dir} / T_{pac}$ and

$$M = 2^l - 1. \quad (17)$$

V. SIMULATION RESULT

We validate the analytical results obtained and analyze them. In all study estimates throughput, we assume that the probability of errors in the transmission of the data packages is $p = 10^{-3}$.

The value M is selected from the condition (17), where l - the number of bits of the transmitted package. Selected the numbers of 1, 7, 127, wherein the number M1 = 1 corresponds to a stop and wait scheme, M2 = 7 applies to packets of small size (3 bits) and M3 = 127 (7 bits) is typically used in high-speed wide-area networks.

The value the number $\bar{t}$ is determined by time of the transmission and time spread packages to the point of control. Considering different data rates and different transfer size package the value $\bar{t}$ are in interval 0 to 1000.

In Fig. 1-5 shows the results of numerical modeling throughput for these initial data. Thus, in Fig. 1, 2 is shown throughput selective rejection scheme and based on return on window sizes M1, M2, M3. Fig. 3 and 4 are graphs of the bandwidth for different schemes of the window size M2 in comparison with the scheme stop and wait. So, Fig. 3 correspondence for window size M2, and Fig. 4 windows for size M3. Summarizes the results is shown in Fig. 5 that allows us to understand the correspondence between the various schemes of flow control schemes that are considered.

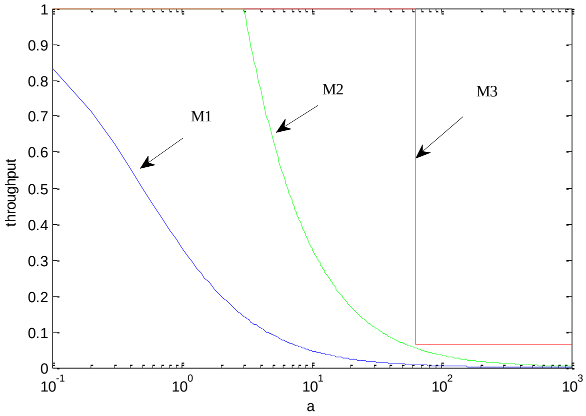

Fig. 1. Function C (*a*) for stop and wait and selective rejection with sizes M1, M2, M3 sliding window.

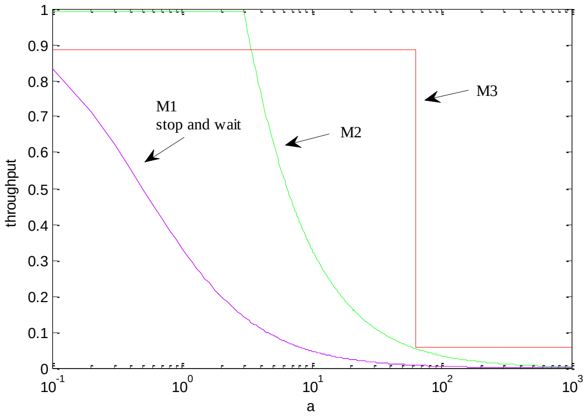

Fig. 2. Function C (*a*) for stop and wait and scheme ARQ based on return on M1, M2, M3 steps.

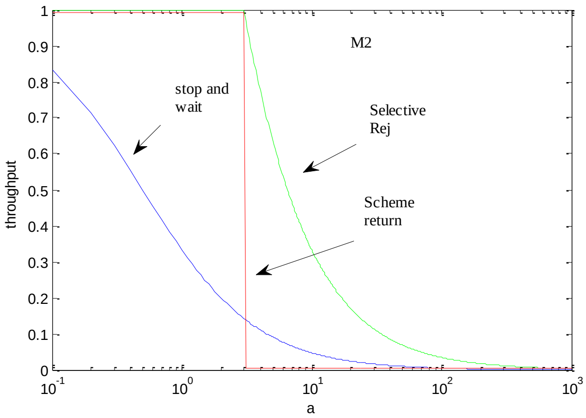

Fig. 3. Function C (*a*) for stop and wait and scheme ARQ based on return on M2 steps.

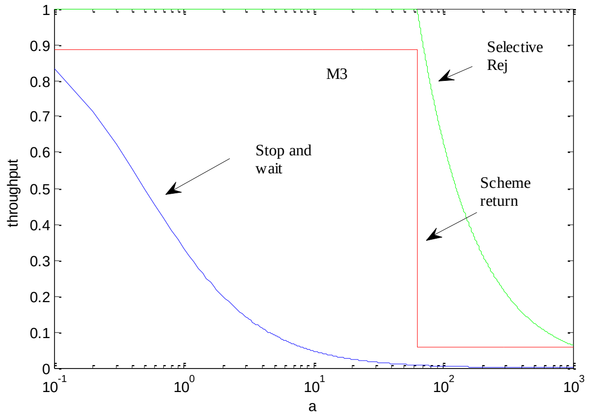

Fig. 4. Function C (*a*) for stop and wait and scheme ARQ based on return on M3 steps.

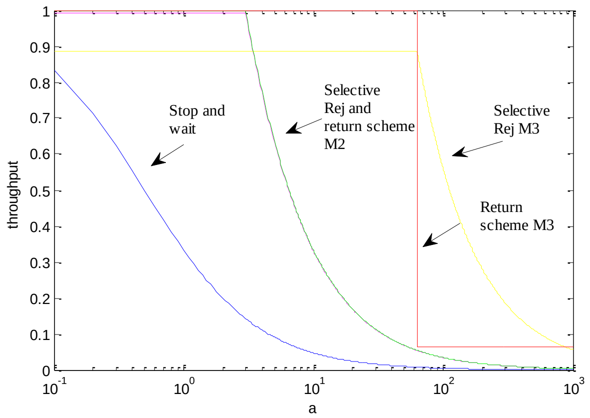

Fig. 5. Function C (*a*) for stop and wait and schemes ARQ based on return and selective rejection on M1, M2, M3 steps.

This figures show that if the effective load channel for stop and wait scheme correspondence level is $a = 1$, then return and selective rejection schemes this is approximately equal to the number of *M*.

This analysis leads to conclusion that the greatest throughput schemes are based on the approach of creating a sliding window. There is a direct relationship between the window size and bandwidth. The larger the window size that the higher the throughput. By comparison two schemes creating "sliding window" the best characteristics has the selective rejection scheme.

VI. Conclusions

Exchange information with the group UAV is done by radio channel "UAV- point control". The movement of UAV and equipment imperfections causes errors reception information. Troubleshooting the received information is achieved by repetition of data packages is called flow control.

In this paper analyzes the known methods of flow control that are focused on re-processing of the lost information. These are methods to stop and wait, to repeat the last *N* packages and selective rejection. The absence of errors in the received information is estimated by ARQ based on sliding window. In investigation the indicator of bandwidth is essentially used.

In research found that the best throughput is a method of selective rejection, in which the window size *M* must match with the channel bandwidth.

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