NOVATEUR PUBLICATIONS
INTERNATIONAL JOURNAL OF INNOVATIONS IN ENGINEERING RESEARCH AND TECHNOLOGY
[IJIERT] ISSN: 2394-3696 Website: ijiert.org
VOLUME 9, ISSUE 12, Dec. -2022

APPLICATION OF MASS SERVICE THEORY FOR ANALYSIS OF DIAGNOSTIC PROCESSES OF DATA TRANSMISSION NETWORKS

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The article deals with the application of the queuing theory apparatus for analyzing the diagnostic processes of data transmission networks (DTN). It is shown that with an increase in the complexity of DTN and existing tools and algorithms for their diagnostics, it seems expedient to create automated diagnostics systems that take into account the disadvantages and advantages of existing network diagnostics methods. The existing analytical methods (in the capacity of which probabilistic methods of the queuing theory are used) and statistical (methods of simulation modeling) are presented. In terms of the queuing system (QS), the analysis of the closed (QS), open (QS) is carried out and their characteristics are determined. The analysis of the statistical method for modeling the diagnostic system in the GPSS World environment is carried out. Models of the DTN diagnostics system are considered from the point of view of closed and open queuing systems. For analytical models of DTN diagnostic systems, the possibility of using the QS is considered, as a result of which the general structure of the main elements and procedures for the functioning of the diagnostic system are determined. The analysis of the possibilities of using the queuing theory made it possible to determine the analytical regularities for the model of diagnostic systems. The creation of automated diagnostic systems based on a queuing system provides a deep and accurate analysis of the characteristics of diagnostics and, therefore, is a promising direction in the development of systems for the technical operation and maintenance of DTN.

Keywords: data transmission systems, testability, probability, closed QS and open QS.

When constructing modern DTNs, an urgent task is to study methods to improve the quality of their functioning. The difficulty in solving this problem lies in the fact that the continuous increase in the complexity of modern DTNs causes significant difficulties in the reliable assessment of their technical condition under operating conditions [1-6].

The main criterion for DTN reliability is the availability factor, which is the mean time between failures, which characterizes the system's reliability and the mean recovery time, which characterizes the maintainability. Under DTN operating conditions, the most important of the two components is the recovery time, which is determined by the time of detection (control) and the time of search (diagnostics) of a malfunction. As international practice shows, one of the main areas of work is associated with improving the technical and operational characteristics of the DTN and its technical means by improving the maintainability indicators [7-10]. In turn, DTN maintainability is largely determined by testability, which must be ensured at an early stage of systems design. The use of most of the existing control methods leads to a large space-time gap between the occurrence and detection of faults.

Currently, there is no single concept of ensuring traceability and, accordingly, there is no universal method for determining the effectiveness of increasing the level of traceability, taking into account all stages of the DTN life cycle [11].

Testability is understood as a property of a system that determines its adaptability to monitoring its technical condition during operation. The DTN design stage is the stage at which the testability requirements are formed and the testability indicators are assessed.

When creating a DTN diagnostic system, the diagnostic process includes such stages as collecting initial information, identifying a malfunction and localizing a malfunction. At the same time, the initial information includes information about defects received from users, information about non-standard situations during maintenance and other data collected by service personnel.

There are analytical methods (in the capacity of which probabilistic methods of queuing theory are used) and statistical (methods of simulation) [10].

In the general case, a simplified algorithm for the functioning of the diagnostic system will correspond to the following.

Let us imagine a diagnostic system (DS) as a queuing system and a data transmission network with its network elements as sources of requests. Consider possible mathematical models in terms of QS, closed QS and open QS [1].

Consider a closed DM model as a system of a single-line model with several sources of requests with a queue [11].

The model belongs to a closed form with final sources of claims. In such a model, each source generates claims, but cannot generate a subsequent claim until the previous one is served or leaves the service system. When considering the model, we will accept the condition that incoming claims are always service generators and that they always occupy a place of unit length in the queue. By loading the DS model, we agree to understand its analogue from the queuing theory, i.e. the ratio of the number of requests served during the same interval.

In a closed QS, the source of claims is located inside the system, i.e. interaction of the DM with a network element that periodically requires maintenance. The intensity of service requests depends on how many technical devices are currently operating. Service request receipt from one item. We will consider the flow of requests for servicing to be a Poisson flow with parameter λ. The flow of claims from j devices is Poisson with intensity jλ. The failed device can be serviced by one of the service channels. Let μ be the service rate in a separate channel.

The characteristics of a closed QS include.

1. Average number of technical devices in the queue for service

$$\bar{r} = \sum_{r=1}^{m-n} rP_{n+r} \tag{1}$$

2. Average number of serviced technical devices:

$$\bar{\kappa} = \sum_{k=0}^{n} kP_k + n\sum_{n=1}^{m-n} P_{n+r} \tag{2}$$

3. Average number of non-working technical devices:

$$\bar{l} = \bar{r} + \bar{k} \qquad (3)$$

4. The likelihood that the technical device will be idle:

$$\beta = \frac{\bar{l}}{m} \qquad (4)$$

5. The likelihood that the technical device will work:

$$\gamma = 1 - \beta = 1 - \frac{\bar{l}}{m} \qquad (5)$$

6. Average number of channels occupied by service:

$$\bar{z} = 0P_0 + 1P_1 + ... + n(P_n + P_{n+1} + ... + P_m) \qquad (6)$$

7. The average number of technical devices serviced per unit of time (the performance of the queuing system, or the absolute throughput of the QS):

$$\lambda_0 = \bar{z}\mu \qquad (7)$$

Let us consider an open (open) QS (OQS) as a system that contains one or more external independent sources of applications, i.e. whether the element works as a whole or there is a malfunction in the block of the element that generates claims to the network, regardless of the number of claims in the network. Any number of applications can be simultaneously in the OQS, their number is not limited. An external environment is associated with the OQS, from which requests come to the network and to which they return after being serviced in the network.

The network characteristics of OQS include:

- the average number of claims waiting for service in the network and the average number of claims in the network;
- average waiting time and average time of requests staying in the network;

$$L = \sum_{j=1}^{n} lj \qquad M = \sum_{j=1}^{n} mj \qquad (8)$$

where l_j – average queue length and m_j – average number of requests in a node j;

$$W = \sum_{j=1}^{n} \alpha_j w_j \ ; \qquad U = \sum_{j=1}^{n} \alpha_j u_j \qquad (9)$$

where w_j u_j – respectively, the average waiting time and the average residence time of claims in the node j; a_j – transmission coefficient for node j, which shows the average number of hits of a claim to node j during its time in the network.

The composition of the parameters of the open and closed QS differs in only one parameter, namely, for the CQS, in contrast to the OQS instead of the intensity λ_0 the arrival of applications in the network, it is necessary to set the number of applications constantly circulating in the network M.

Based on the above, an analytical model of the interaction of data transmission equipment with a diagnostic center can be presented.

In this case, the main component of the flow of applications, of course, are messages related to the detection of various kinds of failures, failures and malfunctions in the operation of the DTN. It can be assumed that the main factors affecting the characteristics of the flow of information messages are the intensity of the flow of registered faults, which depends on the functioning of the diagnostic control system. Hence, a closed QS system can be considered as a model of interaction without an adapter, and an open QS with an adapter.

Models of interaction between the diagnostic center and the diagnosed DTN Fig. 1, closed QS and Fig. 2, open QS.

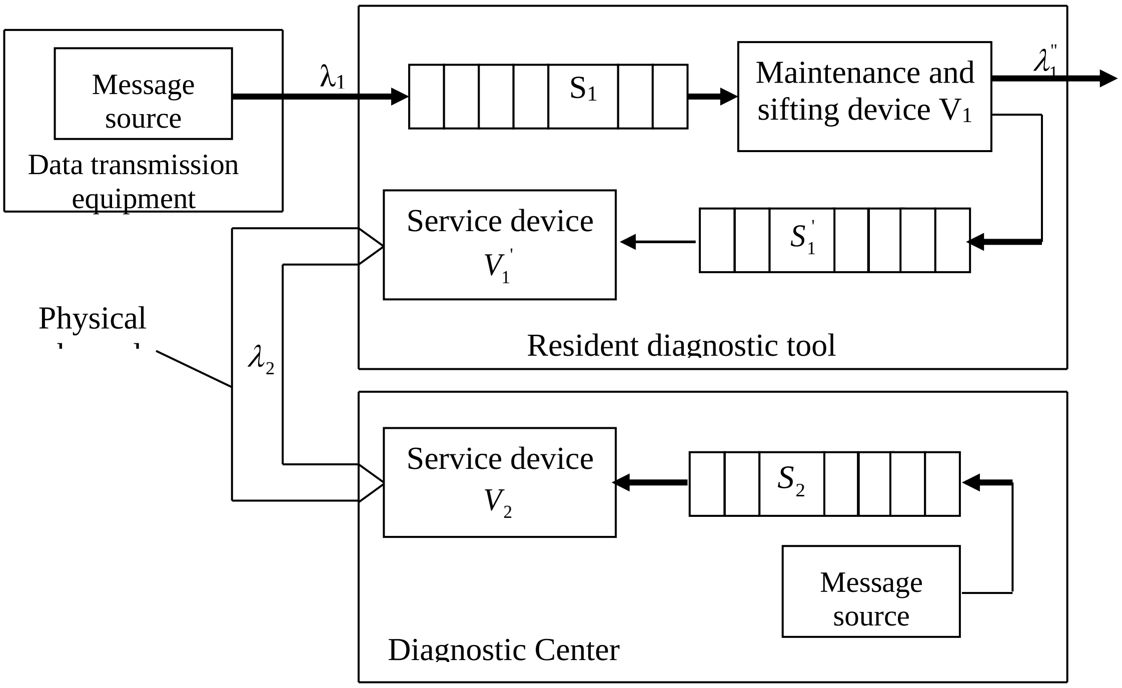


Fig. 1. Model of the diagnostic system from the point of view of a closed QS

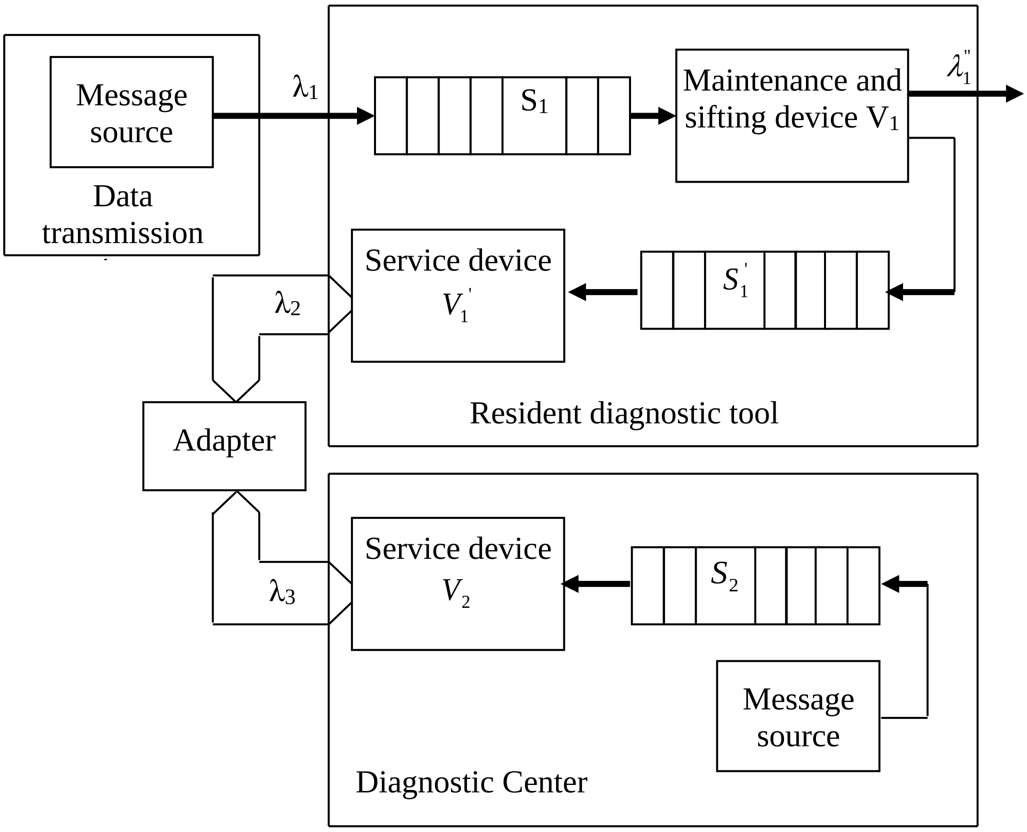


Fig. 2. Model of the diagnostic system with the inclusion of the adapter from the point of view of an open QS

- Let's describe the following blocks and the principle of operation:
- λ_1 – the intensity of the message flow from the diagnostic object (data transmissionequipment) to the resident diagnostic tool (in-system messages);
- λ_1' – the rate of message flow from the resident diagnostic tool to the diagnostic center;
- λ_1'' – the flow of messages served automatically in the resident diagnostic tool;
- λ_2 - message flow from the diagnostic center;
- S_1 – queue that accumulates messages from a stream λ_1;
- V_1 – service and sieve flow device λ_1;
- S_1' – queue that accumulates messages from a stream λ_1';
- V_1' - device serving and sieving flow λ_1';
- S_2 – queue that accumulates messages from a stream λ_2;
- V_2 - device serving and sieving flow λ_3.

In this model, after issuing a diagnostic task to the device V_1 diagnostic information (the result of the diagnostic control) is received from the data transmission equipment. The V_1 device in the resident diagnostic tool performs the basic functions of the diagnostic control, as well as processes and sifts the stream of service messages. Some of the messages coming from the side of the diagnosed data transmission equipment are processed directly in V_1, and the sifted stream is transmitted to the V_1 'device, which transmits it via a physical channel to the diagnostic center. The V_2 device is implemented in the diagnostic center, which is responsible for processing incoming messages from V_1' and translating messages generated in the diagnostic center.

From the description of the model of this system, it can be seen that it is a two-phase queuing system (closed): the first phase is performed by the device V_1, and the second – V_3. In this case, the processes of servicing threads λ_1 and λ_1' are described by the distribution function between messages (claims) of the flow λ_1 and the distribution function of the service time of the stream λ_1' respectively, S_1 and S_1' – the number of messages (requests) in the queues.

Consider a statistical modeling method based on the GPSS program.

GPSS (General Purpose Simulation System) is a general purpose simulation system designed to develop models of complex systems with discrete and continuous functioning and conduct experiments in order to study the properties and patterns of processes occurring in them, as well as select the best design solution among several possible options ... Among the many implementations of GPSS, one of the most available and popular is GPSS World, in which the following models were simulated, which are designed to work on personal computers running the Windows operating system. GPSS World has a convenient multi-window user interface, built-in visualization and interactive control of the modeling process, an extensive library of built-in procedures, including random variable generators for more than two dozen probability distributions. All this makes the modeling process efficient and intuitive.

Model 1: closed QS with a homogeneous flow of applications

We assume that the above linear open QS with a homogeneous flow of requests and two nodes is transformed into a closed one. QS (Fig. 3), in which a constant number of applications circulates: M = 5.

As in the previous model, after service at node 1 customers with probability p_{12}=0,8 go to service at node 2 and with probability p_{10}=0, 2 return to node 1, and $p_{10}+p_{12}=1$. Let the zero point be chosen on the arc outgoing from node 1 and entering again into node 1 as shown in Fig. 3.

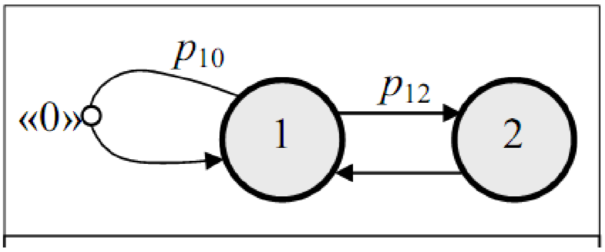


Fig. 3.Closed QS

- With respect to this point, such network characteristics will be measured as the performance of the CQS and the time spent by applications in the network. The duration of servicing requests in two-channel node 1 is distributed according to a uniform law in the interval from 10 to 20 seconds, and the duration of servicing requests in a single-channel node 2 is distributed exponentially with an average value of 20 s.
- Thus, a brief description of the considered closed QS is as follows:
- \- the number of streams (classes) of applications: H = 1;
- \- number of nodes in the network: n = 2;
- \- the number of applications circulating in the closed network: M = 5;
- \- the number of service devices in node 1: K_1=2 ;
- \- the duration of servicing requests in node 1 is distributed evenly in the interval from 10 to 20 s (15 ± 5 s);
- \- the number of service devices in node 2: K_2 =1;

\- the duration of servicing requests at node 2 is distributed exponentially with an average value of 20 s.

\- the capacity of the storage units in the network nodes is sufficient to ensure that there is no loss of claims in the network, which determines the linearity of the network; in our case, we can assume that the capacity of each storage device coincides with the number of applications circulating in the network.

The main difference between a closed QS and an open one is the absence of an external source of claims (element blocks), while in the GPSS-model of a closed QS, it is necessary to implement circulation in the network of a constant number of claims (in our model, five claims).

4. Closed CQS

A fragment of the report is presented, from which all the main characteristics of the closed QS functioning (the most interesting and important simulation results are highlighted in a frame). This shows that the GENERATE statement generated only 5 transactions during the simulation, which were constantly circulating in the model. At the same time, transactions passed through the first node (ENTER block) N_1 = 61934 times, through the second (SEIZE block) - N_2 = 49658 times, and through the zero point (TABULATE block) - N_0 = 12272 times. The last value allows you to calculate one of the main network characteristics of a closed QS - network performance, as the ratio of the number of requests (transactions) that have passed through the zero point of the QS during the simulation T = 1,000,000, by this time [3]:

$$\lambda_0 = \frac{N_0}{T} = \frac{12272}{1000000} = 0{,}012272 \ \text{c}^{-1} \approx 44{,}18 \ \text{ч}^{-1},$$

about 44 applications per hour.

The gear ratios for each of the nodes can be calculated as follows:

$$\alpha_1 = \frac{N_1}{N_0} = \frac{61934}{12272} \cong 5 \quad и \quad \alpha_2 = \frac{N_2}{N_0} = \frac{49658}{12272} \cong 4$$

Node loads (UTIL) are respectively equal: p_1=0,464 and p_2=0,993.
Average queue lengths (AVE.CONT.) In the QS nodes is: l_1=0,143 and l_2=2,936.
The distribution of the waiting times of claims at the QS nodes and the time spent by claims in the network, in addition to the average values of time characteristics, allows us to obtain their standard deviations [3]:

$$w_1 = 2{,}305\ с; \qquad \sigma_{w_1} = 4{,}777\ с;$$

$$w_2 = 59{,}113\ с; \qquad \sigma_{w_2} = 39{,}951\ с;$$

$$U = 407{,}368\ с; \qquad \sigma_U = 442{,}685\ с.$$

For the purpose of a detailed analysis of the properties of the system under study, it is possible to obtain the result in the form of histograms of the density distribution of the waiting time of claims in the node.
The simulation program is presented in the appendix. The histograms show the performance of the network: at node 1, there is a gradual decrease in claims, while at the node there is a gradual accumulation of claims, and then a decrease, which is characteristic of a closed QS.
We assume that an inhomogeneous flow of requests of two classes arrives at a linear open QS with two nodes. Applications of class 1 (solid line, element blocks) and class 2 (dashed line, elements) arrive at node 1 and form the simplest flows with average intervals of 100 and 50 seconds, respectively. After service at node 1, claims of class 1 with probability P_{12} = 0.8 go to service at node 2 and leave the QS with probability P_{10} = 0.2. Class 2 orders are served only in node 1, after which they leave the QS.
The duration of servicing claims of class 1 and 2 in a two-channel node 1 are uniformly distributed random variables in the intervals (15 ± 5) and (10 ± 5) seconds, respectively.
The duration of servicing class 2 claims in a single-channel node 2 is a random variable distributed exponentially with an average value of 20 seconds.

- Brief description of the considered QS:
- - the number of streams (classes) of applications: H = 2;
- - number of nodes in the network: n = 2;
- - the number of service devices in node 1: K_1 = 2;
- - the number of service devices in node 2: K_2 = 1;
- - the storage capacity in the network nodes is not limited, that is, there can be no loss of claims in network 2, which determines the linearity of the network;
- - the flows of applications of class 1 and class 2 are the simplest;
- - the average interval between incoming applications of class 1:$a_0(1)$=100c;
- - the average interval between incoming class applications 2: $a_0(2)$=50c;
- - the duration of service of claims of class 1 at node 1 is distributed evenly in the interval from 10 to 20c: $b_1(1)$=15±5c;
- - the duration of service of claims of class 2 at node 1 is distributed evenly in the interval from 5 to 15 s: $b_1(2)$=10±5c;
- длительность обслуживания заявок класса 1 в узле 2 распределена по экспоненциальному закону со средним значением 20с: $b_2(1)$=20с.

A report is presented with the results of simulation of an open-loop QS with two classes of applications for a value of 100000. And in the START command, specified at the start of the simulation process. Analysis of the presented report allows us to obtain the main characteristics of the functioning of an open-loop QS with a non-uniform flow of applications.

Model 2: open-loop QS with a non-uniform flow of applications.

We assume that an inhomogeneous flow of requests of two classes arrives at a linear open QS with two nodes (Fig. 5). Applications of class 1 (solid line, element blocks) and class 2 (dashed line, elements) arrive at node 1 and form the simplest flows with average intervals of 100 and 50 seconds, respectively. After service at node 1, claims of class 1 with probability $P_{12} = 0.8$ go to service at node 2 and leave the QS with probability $P_{10} = 0.2$. Class 2 orders are served only in node 1, after which they leave the QS.

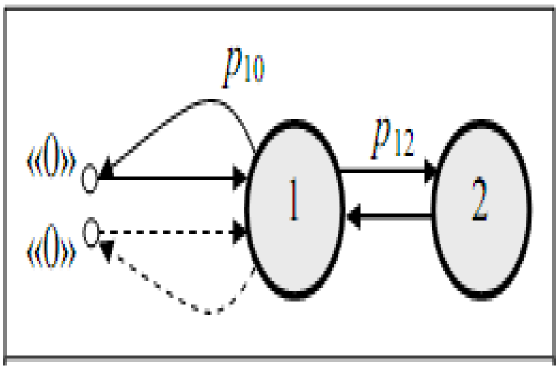
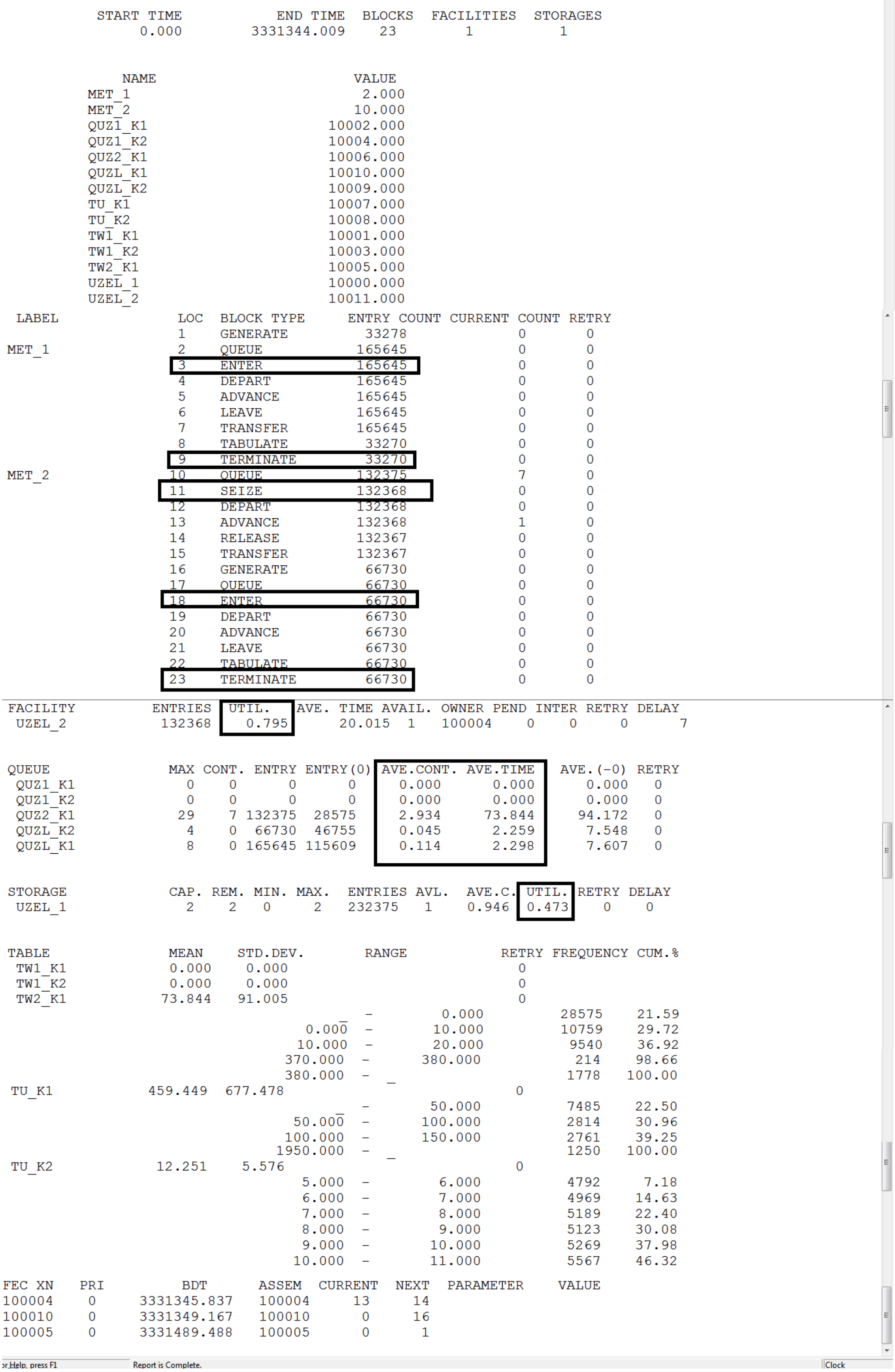


Fig. 5. Open-loop QS with an inhomogeneous flow of applications

The duration of servicing claims of class 1 and 2 in a two-channel node 1 are uniformly distributed random variables in the intervals (15 ± 5) and (10 ± 5) seconds, respectively.

The duration of servicing class 2 claims in a single-channel node 2 is a random variable distributed exponentially with an average value of 20 seconds.

- Brief description of the considered QS:
- - the number of streams (classes) of applications: $H = 2$;
- - number of nodes in the network: $n = 2$;
- - the number of service devices in node 1: $K_1 = 2$;
- - the number of service devices in node 2: $K_2 = 1$;
- - the storage capacity in the network nodes is not limited, that is, there can be no loss of claims in network 2, which determines the linearity of the network;
- - the flows of applications of class 1 and class 2 are the simplest;
- - the average interval between incoming applications of class 1:$a_0(1)=100c$;
- - the average interval between incoming class applications 2: $a_0(2)=50c$;
- - the duration of servicing claims of class 1 at node 1 is distributed evenly in the interval from 10 to 20 s:$b_1(1)=15\pm5c$;
- - the duration of servicing claims of class 2 at node 1 is distributed evenly in the interval from 5 to 15 s:$b_1(2)=10\pm5c$;
- - the duration of servicing claims of class 1 at node 2 is distributed exponentially with an average value of 20s: $b_2(1)=20c$.



```
              START TIME           END TIME  BLOCKS  FACILITIES  STORAGES
                   0.000        3331344.009    23        1          1


                 NAME                          VALUE
             MET_1                              2.000
             MET_2                             10.000
             QUZ1_K1                        10002.000
             QUZ1_K2                        10004.000
             QUZ2_K1                        10006.000
             QUZL_K1                        10010.000
             QUZL_K2                        10009.000
             TU_K1                          10007.000
             TU_K2                          10008.000
             TW1_K1                         10001.000
             TW1_K2                         10003.000
             TW2_K1                         10005.000
             UZEL_1                         10000.000
             UZEL_2                         10011.000
 LABEL                LOC  BLOCK TYPE     ENTRY COUNT CURRENT COUNT RETRY
                       1   GENERATE         33278             0       0
MET_1                  2   QUEUE           165645             0       0
                       3   ENTER           165645             0       0
                       4   DEPART          165645             0       0
                       5   ADVANCE         165645             0       0
                       6   LEAVE           165645             0       0
                       7   TRANSFER        165645             0       0
                       8   TABULATE         33270             0       0
                       9   TERMINATE        33270             0       0
MET_2                 10   QUEUE           132375             7       0
                      11   SEIZE           132368             0       0
                      12   DEPART          132368             0       0
                      13   ADVANCE         132368             1       0
                      14   RELEASE         132367             0       0
                      15   TRANSFER        132367             0       0
                      16   GENERATE         66730             0       0
                      17   QUEUE            66730             0       0
                      18   ENTER            66730             0       0
                      19   DEPART           66730             0       0
                      20   ADVANCE          66730             0       0
                      21   LEAVE            66730             0       0
                      22   TABULATE         66730             0       0
                      23   TERMINATE        66730             0       0

FACILITY         ENTRIES  UTIL.   AVE. TIME AVAIL. OWNER PEND INTER RETRY DELAY
 UZEL_2          132368    0.795     20.015  1    100004    0    0     0      7


QUEUE              MAX CONT. ENTRY ENTRY(0) AVE.CONT. AVE.TIME   AVE.(-0) RETRY
 QUZ1_K1             0    0      0      0     0.000      0.000      0.000   0
 QUZ1_K2             0    0      0      0     0.000      0.000      0.000   0
 QUZ2_K1            29    7 132375  28575     2.934     73.844     94.172   0
 QUZL_K2             4    0  66730  46755     0.045      2.259      7.548   0
 QUZL_K1             8    0 165645 115609     0.114      2.298      7.607   0


STORAGE            CAP. REM. MIN. MAX.  ENTRIES AVL.  AVE.C. UTIL. RETRY DELAY
 UZEL_1              2    2    0    2   232375   1    0.946  0.473    0     0


TABLE              MEAN    STD.DEV.       RANGE           RETRY FREQUENCY CUM.%
 TW1_K1            0.000    0.000                            0
 TW1_K2            0.000    0.000                            0
 TW2_K1           73.844   91.005                            0
                                      -       0.000                28575    21.59
                                0.000 -      10.000                10759    29.72
                               10.000 -      20.000                 9540    36.92
                              370.000 -     380.000                  214    98.66
                              380.000 -                             1778   100.00
 TU_K1           459.449  677.478                            0
                                      -      50.000                 7485    22.50
                               50.000 -     100.000                 2814    30.96
                              100.000 -     150.000                 2761    39.25
                             1950.000 -                             1250   100.00
 TU_K2            12.251    5.576                            0
                                5.000 -       6.000                 4792     7.18
                                6.000 -       7.000                 4969    14.63
                                7.000 -       8.000                 5189    22.40
                                8.000 -       9.000                 5123    30.08
                                9.000 -      10.000                 5269    37.98
                               10.000 -      11.000                 5567    46.32

FEC XN   PRI          BDT      ASSEM  CURRENT  NEXT  PARAMETER    VALUE
100004    0     3331345.837   100004    13      14
100010    0     3331349.167   100010     0      16
100005    0     3331489.488   100005     0       1
```

Fig. 6. Opened QS

Figure 6 shows a report with the results of simulation of an open QS with two classes of orders for the value of 100000 of operand A in the START command, specified at the start of the simulation process. Analysis of the presented report allows one to obtain the main characteristics of the functioning of an open-loop QS with a non-uniform flow of applications (the most interesting and important results of modeling are highlighted in a box).

During the simulation, through the open QS passed N_0=100000 applications of both classes. All serviced orders got into two TERMINATE blocks and were removed from the model. By the number of transactions of each class that have passed through the corresponding blocks ENTER, SEIZE and TERMINATE, you can calculate the transmission ratios for class orders 1($\alpha_1(1)$, $\alpha_2(1)$) and 2 ($\alpha_1(2)$, $\alpha_2(2)$) at nodes 1 and 2 of an open QS, respectively [3]:

$$\alpha_1(1)=\frac{165645}{33270}\cong 5 \quad \text{и} \quad \alpha_2(1)=\frac{132368}{66730}\cong 2,$$

$$\alpha_1(2)=\frac{66730}{66730}=1 \quad \text{и} \quad \alpha_2(2)=0.$$

The loads of the QS nodes (UTIL.) Are equal:p_1=0,473 and p_2=0,795. Average number of orders (AVE.CONT.) In nodes 1 and 2 QS: $l_1(1)$=0,114 and $l_2(1)$=2,934. Average number of applications of class 2 in the queue of node 1 of the QS: $l_1(2)$=0,045. Note that at node 2 only the first class customers form a queue. The total length of the queue of claims at node 1 is equal to $l_1=l_1(1)+l_1(2)$=0,159. The total number of applications pending in the QS

: $L=l_1+l_2$=3,05.

Average waiting times (AVE.TIME) of class 1 claims at nodes 1 and 2 of the QS, respectively, are: $w_1(1)$=2,25c and $w_2(1)$=73,8c... Average waiting time of class 2 claims at a node 1 QS: $w_1(2)$=2,3c.

For the purpose of a detailed analysis of the properties of the system under study, the result can be obtained in the form of histograms of the densities of the distributions of waiting times and sojourn of requests in the QS of class 1 and class 2. The simulation program is presented in the appendix.

A large number of repetitions of requests is set so that the load of the system is visible, to find vulnerabilities in the system, at what stage is the accumulation of requests, and what kind of requests. As the claims of the 1st class arrive, a certain accumulation of claims of the 2nd class occurs, but gradually, upon the end of the arrival of the 1st class claims, the system stabilizes.

Conclusion

The increasing requirements for the reliability of DTN necessitate the introduction of advanced methods in diagnostics, therefore, it seems expedient to create diagnostic systems that will take into account the disadvantages of traditional diagnostic methods. To create analytical models of DTN diagnostics systems, the possibility of using the apparatus of the queuing theory was considered, as a result of which the general structure and main elements and procedures of the diagnostics system functioning were determined. The analysis of the possibilities of using the queuing theory made it possible to determine the analytical regularities for the model of diagnostic systems. The creation of automated diagnostic systems based on a queuing system provides a deep and accurate analysis of the characteristics of diagnostics and, therefore, is a promising direction in the development of systems for the technical operation and maintenance of DTN.

Literature

1 Бестугин А.Р., Богданова А.Ф., Стогов Г.В. Мониторинг и диагностика телекоммуникационных сетей - СПб: Политехника, 2003. 174 с.: Ил.Иванова А.Б. Контроль качества в телекоммуникациях и связи -Москва 2001г.

2 Гаранин М.В., Журавлев В.И., Кунегин С.В.. Системы и сети передачи информации. - М.: Радио и связь, 2001.

3 Арипов М.Н., Присяжнюк С.П., Шарифов Р.А. Контроль и управление в сетях передачи данных с коммутацией пакетов. Ташкент.: Fan, 1988. - 160р

4 Арипов М.Н. Джураев Р.Х., Джаббаров С.Ю. Техническая диагностика цифровых систем. Учебное пособие Ташкент 2006 с.82.

5 Abramovici M, Breuer M.A, Friedman A.D. Digital Systems Testing and Testable Design. IEEE Press, Piscataway, New Jersey, 1994.

6 Moslem Amiri, Vaclav Prenosil. Digital Systems Testing. Verilog HDL for Design. a Embedded Systems Laboratory. Faculty of Informatics, Masaryk University. Brno, Czech Republic. 2014.

7 N. K. Jha and S. Gupta. Testing of Digital Systems. Cambridge University Press 2003.

8 Давыдов П.С. Техническая диагностика радиоэлектронных устройств и систем. -М .: Радио и связь, 1988. - 256 с..

9 Khakhanov V.I. Technical diagnostics of digital microprocessor devices. Textbook. K.: IZMN, 1995. - 252p.

10 Djurayev, R. K., Jabborov, S. Y., Omonov, I. I., & Rajabov, J. R. (2022). Research on the Model of Malfunction and Diagnostics of Digital Devices of Data Transmission Equipment. *International Journal of Innovative Analyses and Emerging Technology*, *2*(3), 31-35.

11 Djurayev R. K., Jabborov S. Y., Omonov I. I. Interconnection of Performance Indicators and Reliability of Data Transmission Systems //2021 International Conference on Information Science and Communications Technologies (ICISCT). – IEEE, 2021. – С. 1-7.