DOI: 10.13009/EUCASS2017-316

Routes Generation in On-board Space Data Systems with SpaceWire Networks

Nadezhda Matveeva, Elena Suvorova, Yuriy Sheynin, Sergey Pakharev
Saint-Petersburg State University of Aerospace Instrumentation (SUAI)
190000, Saint-Petersburg, Russian Federation

Abstract

In article we shall consider problems of different traffics transmission in space data systems. We shall present an approach, which can be used to generate routes for different traffics with user requirements in an on-board SpaceWire network. In order to generate effective data transmission routes in the network we use information about receivers and transmitters which communicate with each other in system, size of packets, packet sending frequency and packets' priority system designer defines also requirements and constraints for each traffic. The main issue of the presented approach is to search such routes for each traffic that will correspond system designer requirements.

1. Introduction

Prospective space data systems include dozens of units for data acquisition, processing, transmission. On-board interconnections to connect them are built as scalable network infrastructure. SpaceWire, [1, 2], is a communications network was designed specifically for connecting together instruments, mass memory, processors, downlink telemetry, and other subsystems on-board spacecraft. SpaceWire is simple to implement and has specific features to support real time data-handling applications in space. High-speed, low-power, relatively low implementation cost and a flexible architectural makes it adaptable to many space missions. Supported by ESA, Roscosmos, NASA and JAXA, [3], it have been used in many scientific and Earth observation spacecrafts. SpaceWire network is based on a set of terminal nodes and a set of routers. SpaceWire networks are not limited by network size or topology. It provides wide opportunities to design scalable on-board space networks. Small SpaceWire networks are easy to build and to configure. However, building SpaceWire network and development of its logical structure become tough problems as the network size scales.

There are different traffics in modern space data systems. Data streams between network nodes are dramatically increasing. In spacecraft on-board data networks great attention is paid to algorithms and methods, which ensure data transmission characteristics, increase performance and guarantee quality of service (QoS), [4]. Crucial QoS characteristics for on-board networks that should be guaranteed may be data unit delivery latency, jitter, throughput, etc.

2. SpaceWire

2.1 Features of the standard

SpaceWire is a perspective technology for high-speed communication and integration of high speed systems in aerospace systems. SpaceWire technology meets the needs of on-board tasks of gathering, processing information and control on spacecraft board.

SpaceWire also supports the integration and testing of complex on-board systems by connecting ground equipment directly to the data processing and control system. Monitoring and testing can be carried out without the need to create a separate physical interface with on-board spacecraft equipment.

The SpaceWire standard is developed in accordance with the requirements of future space applications: high data transmission rates, small delays for message delivery, resistance to failures, low power consumption, electromagnetic compatibility, compact implementation in VLSI, support for real-time systems and system functions.

2.2 Types of transmitted data

In accordance with the specification of the SpaceWire standard it provides packet data transmission. The package format is very simple. The package consists of three parts. A packet shall comprise a destination address, a cargo and an end_of_packet (EOP or EEP) marker.

destination address	cargo	end_of_packet (EOP or EEP)

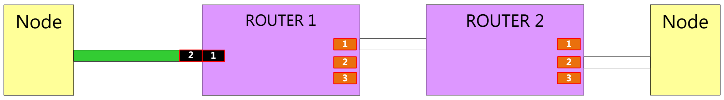
Figure 1: Format of SpaceWire packet

Moreover SpaceWire provides the transmission of control characters and codes. Time-code used to distribute system time over a SpaceWire network.

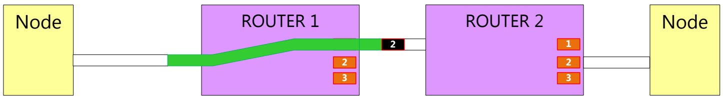
2.3 Addressing

The SpaceWire standard supports several types of addressing. These include path, logical, regional-logical and marking intervals.

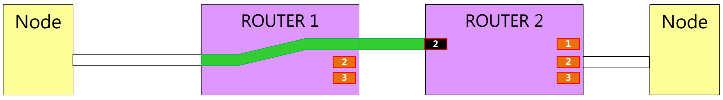
With the path addressing, the destination address is the sequence of the output port numbers which are used to send the packet over the network. At each stage of the packet passing through the network, it is perceived as a packet having the destination address (first byte), the data field and the end-of-packet marker. The first byte of the packet header is used to determine the output port of the router. Having received the first byte, the router determines the output port, removes this byte and sends the packet further, without it. The next byte of the header (now the first one) is used by the next router to determine its output port. The packet arrives at the destination node with an empty header (Figure 2).



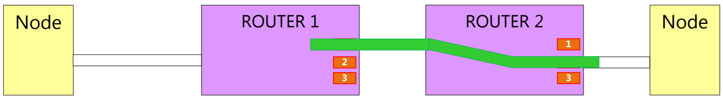
ROUTER 1 received the packet header and checks the required 1st output port



ROUTER 1 has removed the first byte and transmits the packet through the 1st output port



ROUTER 2 received the packet header and checked the required 2nd output port



ROUTER 2 has removed the first byte and transmits the packet through the 2nd output port

Figure 2: Transmission of the packet over the network with the path addressing

The disadvantage of the path addressing is the rather large size of the destination address in case the packet must pass through several routers. Also, the size of the destination address may vary depending on the location of the receiver in the network relative to the source. The complexity of packet addressing lies at the source, the routers are relatively simple.

With logical addressing, each receiver in the network has a unique number (logical address) associated with it. These numbers can be assigned arbitrarily, provided that the network does not have two nodes that have the same logical addresses. When the source sends the packet to the receiver, it simply indicates the receiver's logical address. To maintain logical addressing, each router must have a routing table. For each valid logical address, the routing table determines the number of the output port through which the packet should be sent to reach the node with this logical address. Next figures show an example of a routing table and an example of a network with logical addressing.

Routing table	
logical address	output port
0...31	path addressing
32	8
33	1
34	3
35	1
…	…

Figure 3: Example of Routing table

In this example, the received packet with logical address 32 should be sent to the output port with the number 8. Packages with logical addresses 33 and 35 should be sent to the output port with number 1. The packet with logical address 34 should be sent to the output port with the number 3 .

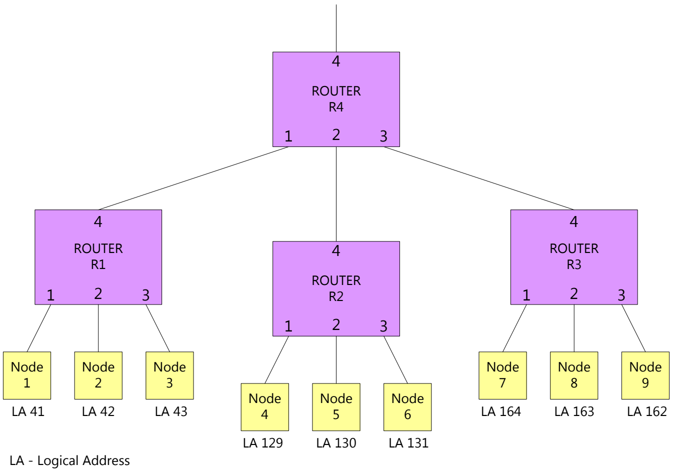


Figure 4: Example of SpaceWire network with logical addressing

The number of nodes in the network with logical addressing is limited by the size of the address (1 byte), which allows you to address up to 224 nodes in the network. When using logical addressing, the main complexity of implementation lies with routing switches. Logical addressing is advantageous in relatively small networks with a small number of fast intelligent routers.

Regional-logical addressing assumes the use of logical addressing in which the header can be deleted. In this case when the routing table stores information about deleting or not deleting the header for each logical address. This leads to the appearance of multilevel schemes of logical addressing. A single logical address is used to send the packet to the local receiver, whereas two or more logical addresses (depending on the network) are used to send the packet to the more remote receivers. In the latter case, the first logical address indicates the destination region, and the second logical address is the logical address of the receiver within the region. When the packet is delivered to the receiver's region, the routing switch transmitting the packet deletes the first logical address, after which the logical address of the local recipient becomes visible for subsequent local routing. The follows figure shows an example of a network with regional logical addressing.

DOI: 10.13009/EUCASS2017-316

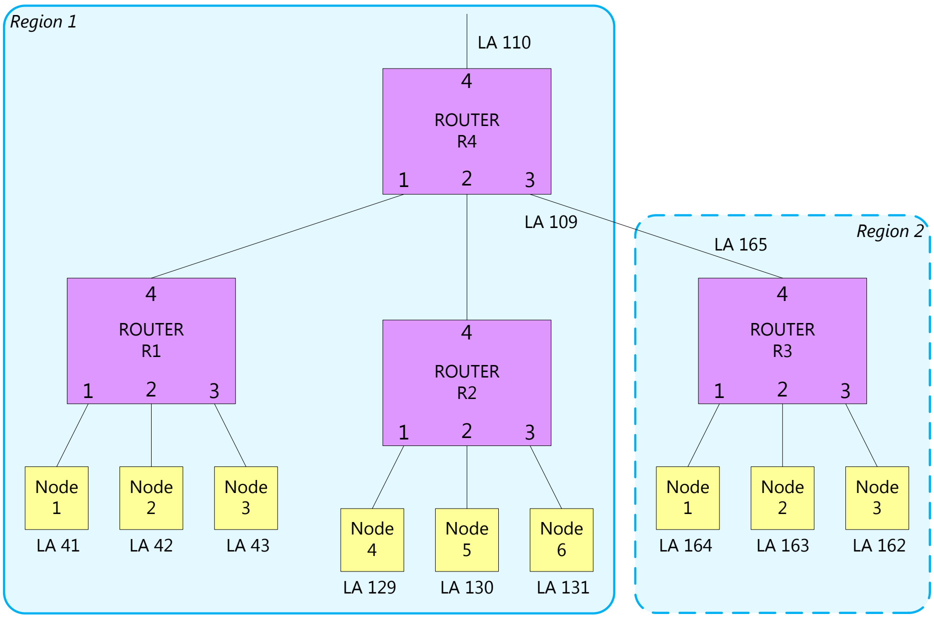


Figure 5: Example of SpaceWire network with regional-logical addressing

In this example, LA <109> corresponds to the transmission from Region 1 to Region 2. In the routing table in Router 4, the logical address LA <109> matches output port 3; there it will be marked that port 3 is a transition to another addressing region. Passing the packet with LA <109> in the first byte of the header will be a kind of combination of the packet passing procedure for path and logical addressing. By LA <109>, the output port 3 will be defined for further packet transmission; It will be clarified that this is a transmission to another region of addressing. The router 4 discards the first byte of the header of any packet sent to the output port 3.

Such addressing methods are good in cluster structures. The number of nodes in the network with regional-logical addressing is not limited [5].

The interval labelling is based on logical addressing. The addresses of the receivers are grouped into adjacent intervals, for example, 1-3, 4-9, 10-32. Each interval corresponds to the output port so that in the example above, packets with logical addresses 1, 2, and 3 will be routed through one output port. The interval marking reduces the size of the routing tables and increases the decoding speed of the logical address in the router. The implementation of interval marking is more complex than logical addressing, but allows the use of smaller routing tables.

2.4 Group adaptive routing

Group adaptive routing allows to send packets over the network to the desired destination node in various ways. An example of group adaptive routing is shown in the next figure.

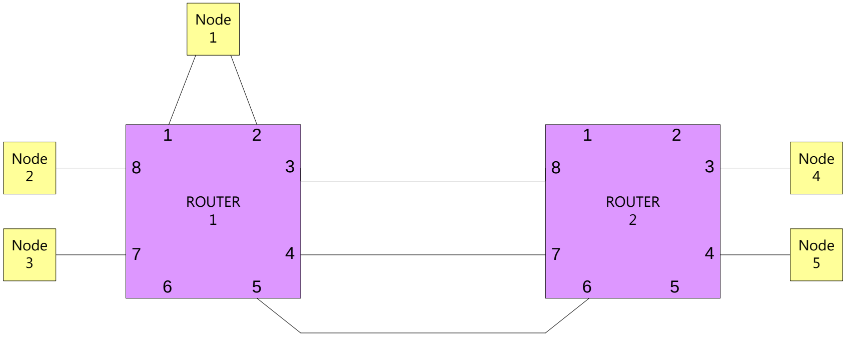


Figure 6: Example of SpaceWire network with group adaptive routing

We suppose that node 2 sends a packet to node 4 when using logical addressing. The packet is sent by the node 2 and received by the router1. The routing table of the router 1 indicates that the output port with the number 3 should be used to transmit this packet. The output port 3 is currently busy due to transmitting the other packet. Thus, the packet should be delayed until port 3 will be free. Routers 1 and 2 are connected by three channels. Any free channel can be used to transmit the packet. Redirecting a packet to one of the allowable equivalent channels is called group adaptive routing. Channels connected to one receiver (node or router) are called a group. Any channel in the group can be

DOI: 10.13009/EUCASS2017-316

used to send the packet to the receiver. Moreover data transmission routes with using group adaptive routing can be different. It means that one data transmission route can consists of one list of routers of network. In the same time another data transmission route can consists of other routers of network.

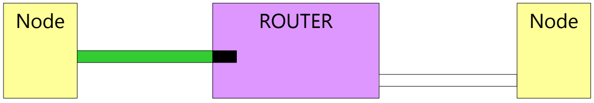
Group adaptive routing means of regulating the bandwidth of channels, which ensures efficient use of available network resources. SpaceWire allows to connect neighboring network elements (nodes and routers) with an unlimited number of channels, build redundant communication systems, to increase the fault tolerance of computer networks in general.

The independence of the protocol stack from the composition, size and topology of the links between the nodes of the network provides a wide range of scalability of the SpaceWire network. While logical addressing uses the byte format of logical addresses, regional-logical addressing allows to cluster the logical address space, building networks with any necessary number of nodes and subscribers. Practical limits to the scaling of the SpaceWire network will be determined by the requirements for the technical parameters of information delivery, specified in the course of its system design, primarily by indicators of packet delivery delays and control codes.

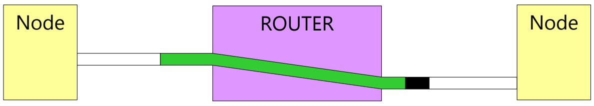
2.5 Routing

"Wormhole routing" [1,2,3] is a special method of routing packets belonging to the category of methods of switching "on the fly". Each packet contains a header with the destination address of the packet, represented either as the identifier of the receiver, or as a path across the network. Once the packet header is received, the router at the destination address determines the output port. If the desired output port is available, the packet is immediately sent to this port. The used output port is marked as busy and is considered as busy until the last symbol of the packet-the symbol of the end of the packet passes through the router. Wormhole routing reduces the required size of the buffers used in each router, compared to the store-and-forward method, in which the entire packet is first stored in the router buffer and then forwarded. Store-and-forward method is difficult to implement in SpaceWire networks due to unlimited maximum size of data packet.

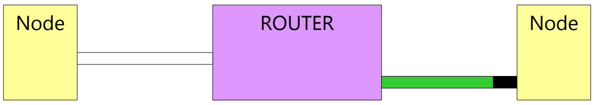
Wormhole routing is shown in the next figure, which shows the transmission of a packet from one node to another via a router. The header of the package is indicated in black, the rest in green. Once the router receives the header, it immediately checks the required output port. If the desired output port is free, the router establishes a connection between the input and output ports. Then the packet is transmitted through the router. Once the routing switch receives the end-of-packet character (EOP or EEP), it breaks the connection and releases the output port for the next packet, which can come from any input port.



The router has received the packet header and checks the required output port



The router has established a connection between the input and output ports and transmits the packet



After receiving the EOP symbol, the router completes the connection and releases the output port

Figure 7: Wormhole routing

Thus, the routing of the incoming packet is performed at the network node, and the packet immediately are forwarded after processing the packet header, the packet byte stream is switched and is sent directly from the input port to the output packet.

The routing of a packet in a network node is based on one of the four destination addressing methods proposed by the SpaceWire standard: Path addressing, Logical addressing, Interval Labelling and Regional logical addressing.

The wormhole routing of packets in network nodes used in SpaceWire allows to minimize delays at each step of the packet passing through the network node-the router. It seems that this will correspond to the needs of prospective on-board systems.

DOI: 10.13009/EUCASS2017-316

3. Types of traffic in on-board space data systems

In modern spacecrafts, various types of traffic are transmitted. These include control signals, control commands, streaming traffic. Data transmission routes are intersected in routing switches. Traffic of several types can be transmitted through one data link between routing switches. The achievable characteristics will largely depend on the network settings, the routes of their transmission.

Traffic of control signals is the most critical. It must be transmitted between the source and the receiver with minimum delays. As a rule, these signals have the highest priority level.

The SpaceWire standard provides the ability to send time markers, wedging it into the main data traffic. This means that the time markers are embedded in the stream of transmitted symbols. They have the highest priority in transmission. The format of these codes is shown in next figure.

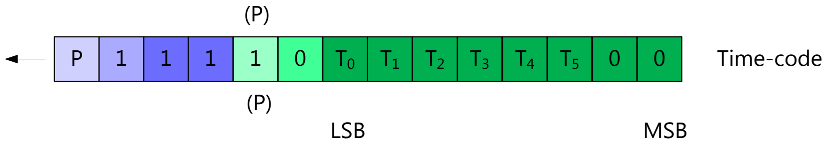


Figure 8: Format of Time-code

Priorities of symbols and control codes for transmission to a channel are distributed as follows:

1. Time-code, highest priority.
2. FCT symbol.
3. Information symbol.
4. NULL character, lowest priority.

The time code is used to propagate the system time over the SpaceWire network. It consists of an ESC character followed by one data symbol consisting of six bits containing the value of the system time and two reserved bits. A distinctive feature of Time-codes is that they are broadcast over the network.

Control commands are used to control various blocks of the spacecraft. As a rule, the size of control commands is calculated by several dozen bytes, they are transmitted quite rarely, delivery time is a critical parameter.

Therefore, it is advisable for the control teams to assign the highest priority level for transmission over the network. But in this situation it is important to understand that when transmitting data in accordance with the SpaceWire standard, there is no suspension of transmission of the packet in the output port.

This can lead to the fact that if the output port is busy due to it is transmitting one packet, then if necessary to transfer a critical control command through this port, the control command will be transmitted only when transmission of the previous packet is completed. Thus, in the worst case, the transmission of the command will be delayed for the time of transmission of the maximum size packet that can be transmitted through this port. Therefore, it is necessary to take this feature into account and form data transmission routes with these features in mind.

To solve a large number of problems existing in aerospace vehicles, it is required to transmit large volumes of streaming traffic through the on-board network in compliance with the required time delays and minimum overhead costs. Different tasks can use different types of traffic and different network structures. In many tasks, there is a need to transfer a video. This type of data is represented by traffic of the highest intensity.

Modern and prospective data processing networks in spacecraft consist of a large number of systems and sensors that produce streaming traffic. In particular, video cameras generate streaming traffic. Transmission of the video imposes restrictions on the delay in data transmission and speed.

The following main features of streaming traffic can be distinguished:

- packages of the same size;
- packets follow the same time intervals;
- packages are structurally homogeneous;
- packets are delivered sequentially and continuously;
- insensitivity to single losses and distortions;
- predictability of the buffer size, which simplifies the reception / transmission equipment [6].

The next table shows the parameters of the transmitted video for the industry standard CCSDS 766.1-B-1 Digital Motion Imagery. This standard describes recommendations for the use of television and industry standards for the transfer of video on board a spacecraft, between spacecraft, spacecraft and Earth. The CCSDS specification describes the transfer of video in real time and video broadcast. Data can be transmitted in compressed, uncompressed form and encrypted form (Secure JPEG2000) [7].

Table 1: Video parameters, given in the CCSDS 766.1-B-1 standard

Assign of traffic	**Resolution**	*** Frame size, Kb**	*** String size, Kb**	**Playback frequency, Hz**
Personal video conference	320x240..1280x720	150..1800	0,625..2,5	10 – 60
Conference call of medical purpose	320x240..1280x720 typical 640x480	150..1800 600	0,625..2,5 1,25	10 – 60
Notification of the situation	640x480..1280x720	600..1800	1,25..2,5	25 – 60
External communication				24, 25, 60
HD video	1920x1080..4096x2160	4050..17280	3,75..8	24 – 120

* - The calculations are performed at a color depth of 16 bits.

Typically, video frames are large, they can potentially be transmitted over the network by one or more network layer packets, the data stream can be of high intensity, the delivery time is a critical parameter, but less critical than for command traffic, and jitter in the delivery time.

Transmission of video frames has a periodic nature. If uncompressed video is used, then all frames are the same size. The size of one frame of uncompressed video can be 1-2 MB or more. If compressed video is transmitted, then the frame size may differ significantly depending on their type. In addition, it should be noted that streaming sources with different packet lengths may exist on the same system.

4. Routing of traffic in space on-board networks

For small networks developers are usually able to find data transmission routes inside of onboard network and configure them manually. But nowadays onboard networks become larger and larger. Number of different data flows is also increasing. At the same time requirements to QoS are also becoming stricter. That is why it is so important to develop methods and algorithms of data transmission routes generation. Using them it would be possible to implement automatic or semiautomatic tools for data transmission routes generation in onboard networks. These methods and algorithms should take into account the specifics of data flows in onboard networks and requirements to QoS. Spacewire standard does not mention the support of virtual channels. This fact should be taken care of when building routes as well.

Due to the fact, that the majority of existing spacecrafts is built based on "bus" technology, there is very little information about data transmission routes generation in spacecraft onboard networks, which would be built using data communication devices. Nowadays there are methods, which solve the problem in the area of computational networks which are used in different areas. When designing computational networks depending on specifics of transmitted traffic different companies take into account different combinations of data transmission restrictions. For example, for network technology MPLS TE [8] they use the method which accounts for throughput. This method assumes definition of a coeffecient of maximal possible throughput usage. This coefficient should be obviously less than 1; it allows to account for all network overheads appearing due to specifics of routing switches implementation.

This approach assumes two possible methods of routes selection:

1. To simplify optimization problem selection of routers for these tunnels usually happens in order. Search of TE-routes in order reduces quality of the decision.
2. Simultaneous analysis of all flows allows to use resouces more rationally, but has higher computational complexity.

When using the first method pairs of nodes receiver-transmitter between which it is necessary to built a route, generally are picked randomply. Every next route is generated so channels utilization coefficient is as close as possible to the current minumim value. At the same time data routes restrictions are used. For example, only shortest routes can be analyzed or only the routes with length not more than some preset value. If there is no restriction on data path length then the shortest route is built provided that above conditions are met. This method is reasonable to use in the cases when new pair of receiver-transmitter can be added during system operation and it is necessary to quickly organize new logical configurations of the network.

This method is also useful in designing big networks when computational complexity of the second method turns out to be unacceptable.In the second method for each receiver-transmitter pair the set of potentially acceptable routes is determined (routes length of which meets user requirements on data transmission time).

DOI: 10.13009/EUCASS2017-316

Then from each set only one route should be selected so the set of these routes meets bandwidth requirements.

In some cases, a choice can also be made for the uniformity of loading channels. This requirement is due to the implementation features of typical SpaceWire routers, the absence in them of explicit support for services providing guaranteed throughput. Since the SpaceWire standard does not explicitly define support for guaranteed bandwidth, this requirement is relevant for SpaceWire networks.

In accordance with this method, in the first stage, all possible path groups can be selected, and in the second stage, a group of routes with the most evenly loaded channels will be selected among them. Another approach is also possible, when in the process of selecting routes, options are immediately excluded from consideration, in which the download of some communication channels exceeded the value specified by the designer as a constraint.

IBM developed methods for generation data routes for Systems Network Architecture (SNA) [9]. SNA exists and now, the protocol stack, which ensures its functioning, constantly undergoes changes in accordance with the new requirements that are formed by the needs of the modern telecommunication technology market. Currently, even developed a technology that allows you to use SNA over IP.

In SNA routes take one of two forms: explicit or virtual, [10]. Explicit routes are physical connections between two nodes of the subzone, expressed as ordered sequences of subzones and connecting transmission groups. Explicit routes are unidirectional, and two such routes are needed to create a duplex channel.

Virtual routes are bidirectional logical connections between two nodes of the subzone. The virtual route passes through both unidirectional explicit routes - direct and reverse, - belonging to the same physical path. Virtual routes do not cross the boundaries of the network. The session connector of the SNA interconnection is used to communicate between the two virtual routes. The virtual route includes transmission priority parameters and step-by-step control of the general flow, when the receiver with sufficient buffer provides the sender with step-by-step windows.

To assess the quality of the service that is required to provide data transmission in this technology, the term of Class of Service (CoS) SNA is used. It defines the transport characteristics of the network. Depending on the requirements of the user, different classes of CoS can be assigned to the SNA network. These classes provide a mechanism for determining all SNA routes and describe acceptable levels of service. CoS also defines a number of characteristics, including response time, security level and availability. CoS can be installed automatically when you log on to the network or manually (by the user) when the session is initialized. Each CoS name is associated with a list of virtual routes that meet the requirements of the desired level of service. Information related to this session is accumulated in the CoS sub-zone and stored in the APPN tables.

When sub-zone routing, the user determines the CoS for the given connection. Each virtual route corresponds to certain services, and the characteristics of CoS are associated with the corresponding explicit routes. The System Services Control Point (SSCP) uses the CoS table to provide the route guidance function with information about the virtual route and the transmission priority. Route management, in turn, selects the virtual route and the transmission priority for the given session. The CoS table entries for sub-zone routing contain the CoS name, the Virtual Route Number (VRN) and the TRansmission Priority (TRPI). The CoS name is a standard name, for example, SEC3, which satisfies the naming conventions. VRN defines a separate route between sub-zones. Up to eight virtual routes can be assigned between two subzonal nodes. Each virtual route can be assigned up to three transmission priorities, and up to 24 virtual routes can be established between the two sub-zones. TRPI determines the priority of the session information flow between logical modules (LU-LU) over an explicit route. Users can assign to each virtual route one of three priority values: 0 (lowest), 1 or 2 (highest) [10].

CoS in APPN is determined explicitly, through the parameters of the CoS table. There are more CoS options in APPN than with sub-zone SNA routing. In particular, CoS in APPN allows you to select a route by bandwidth, by route estimation, security level, propagation delay, and by user-defined characteristics. The class of service is not limited only to communication controllers, as in the sub-zone SNA routing, but extends up to the end nodes (End Nodes-EN). In the CoS APPN topology database, each CoS has a tree structure that tracks all costs and routes. CoS APPN also provides memory management options for such CoS tree structures.

The CoS table entries for APPN routing contain the CoS name, index, APPN transmission priority characteristics (TRPI), and the Weighted Field (WF) of the CoP APPN. The CoS name is a standard name, for example, SEC3, which satisfies the naming conventions. The data in the index field allows saving in the table and extracting the weights of the route components from it. This entry refers to a record in the CoS weights array.

The TRPI APPN determines the priority of the LU-LU session data stream over an explicit route. For each record in the CoS table, only one value of the TRPI field is defined. The APPN TRPI requires that the flow of a particular session with a particular CoS in the given APPN network has the same transmission priority.The characteristics of the node and the transmission group are a list of user-defined characteristics that are acceptable for this CoS. Each row defines a set of characteristics of the node or TG. They can be the level of security, the cost of connection time and the available bandwidth. The characteristics field contains a range of allowed values.

DOI: 10.13009/EUCASS2017-316

The WF CoS APPN field allows the Routes-Selection Service (RSS) to assign a weight to this allowable route component (node or TG). RSS uses WF to determine the relative desirability of a route component. WF can contain a constant value or the name of the function used by RSS to determine the weight.

Ethernet networks use the Resource ReSerVation Protocol (RSVP) protocol. It is a network resource reservation protocol. The main idea of the protocol is that the source node before sending data requiring a certain non-standard quality of service (for example, a constant bandwidth for transmission of video information) sends a special message in the RSVP protocol format over the network. This path message contains information about the type of information transmitted and the required bandwidth. It is transferred between the routers all the way from the sending node to the destination address, and the sequence of routers in which it is necessary to reserve a certain bandwidth is determined.

The use of this approach in the on-board networks is not permissible, since this imposes certain delays in data transmission. In addition, as a rule, the on-board network of a spacecraft operates in orbit most of the time and data transmission routes should be determined at the stage of its design and configured before launching the spacecraft into orbit. The fact is that reconfiguration of data transmission routes is possible during the flight, but it is extremely undesirable, since it introduces certain risks to the network operation.

Also in the literature there are many works that are devoted to the construction of the shortest routes of data transmission in networks. But in these cases, the authors consider only one criterion for finding optimal routes. It is a distance. In the case of designing on-board networks, such parameters can be much larger. These include delay in data transmission and jitter, and so on.

Work in which algorithms or methods of generation data transmission routes with regard to the quality of service requirements for on-board networks would not be found. Therefore, in this article, we will consider a method that can be used to solve a given task.

5. Method for generation data transmission routes for space on-board networks with QoS

At present time there is not information about tools which are able to generate data transmission routes and network settings for space on-board systems where SpaceWire standard is used as a communication protocol. Current tools and methods are oriented for others data transmission protocols and applications. In this article authors present a new method for generation of data transmission routes in SpaceWire on-board systems. The presented method can be used for SpaceWire on-board systems where different traffics are transmitted and where need to provide various QoS. Also the method generates data transmission routes for systems with duplication of routes. It helps to improve reliability of the system.

When the new on-board network are being developed, it is important to understand that network performance depends on data transmission routes configuration. It is crucial that the network has the uniform loading, there are no congestions in the network in which a lot of different data streams compete for network resources. The presence of congested sections of the network leads to the fact that there are large latencies for the data.

In view of the fact that there are a lot of data streams in modern on-board networks, it is required to provide different data transmission characteristics for different streams, it is practically impossible to estimate the interference of traffic on each other during data transmission without the use of specialized computing facilities and methods. Currently, some methods are proposed for estimating the delays in data transfer in the SpaceWire network [11,12], and therefore they must be used for making estimates in the construction of data transmission routes.

Added to this, for a space on-board networks, an important factor is the possibility of constructing duplicate data transmission routes, which can be used in the event of failure of any components within the network. Therefore, in the network settings, the ability to transfer data between sources and receivers should be supported after disabling of failed network elements.

The method of data transmission routes generation for space on-board networks can be constructed on the basis of a search of variants in the design space exploration for different types of traffic transmitted in the developed on-board network. But without certain optimizations, the number of options will be a brute force. Therefore, the search should be shortened taking into account the criteria and restrictions that are imposed on the basis of the peculiarities of the transmission of each data stream separately. The developed method of routes generation takes into account such features of the SpaceWire standard as wormhole routing, the group and adaptive group routing.

During the carrying out studies on data transmission routes generation for on-board networks, it is important to investigate how such transmission characteristics as delay, jitter and etc. are changed. It is necessary to assess how the delay in data transmission in the switches changes, where several different types of data streams compete in one output port.

Depending on the assigned tasks for data transmission in the on-board network, the evaluation of these or other parameters may be different. For certain cases, it is sufficient to estimate the average data transmission delays for each of the data streams, in other cases, the guarantee parameter of the upper bound of the data transmission delay is

DOI: 10.13009/EUCASS2017-316

critical. In this case, it is necessary to use precise methods for estimating the delays of data transmission in the network. So the authors of the article [12] proposed an exact method that allows estimating the delay of data transmission in the SpaceWire network in the worst case. The use of the proposed idea makes it possible to estimate the characteristics of the network operation at the design stage, which has the great interest in the design of the modern on-board SpaceWire networks. The next figure shows the main steps of the presented method.

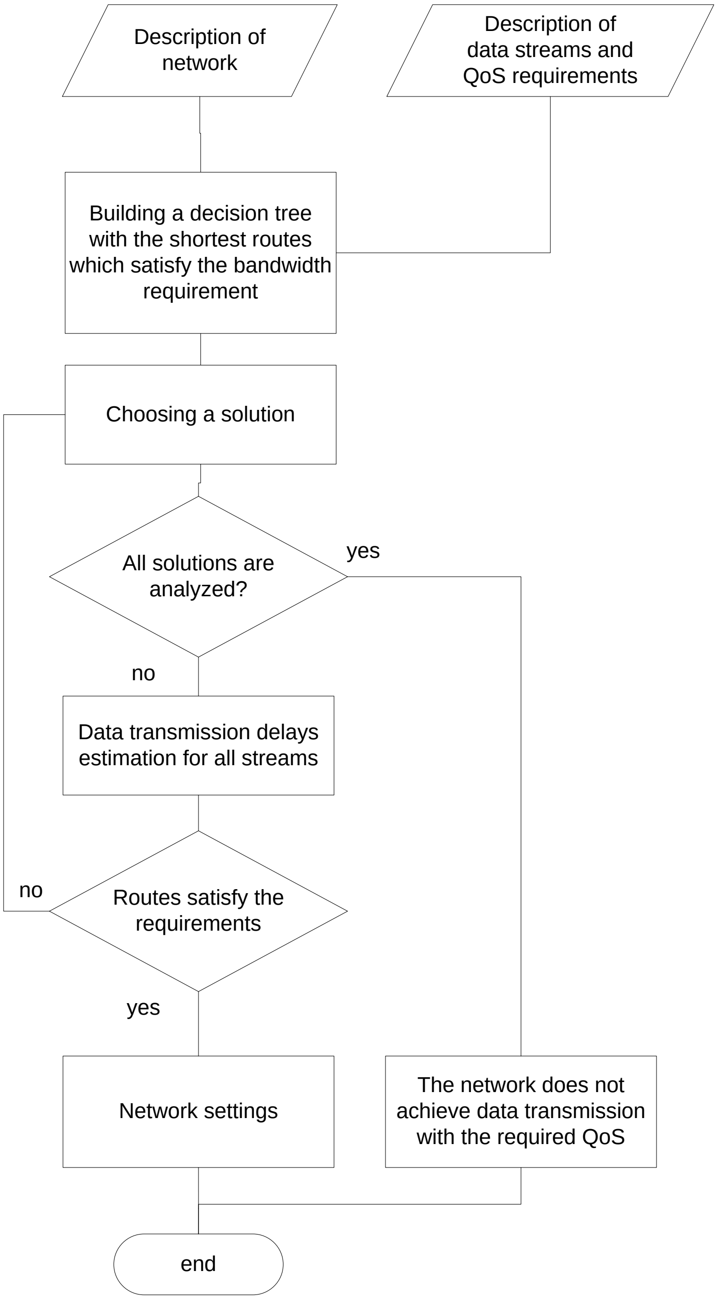


Figure 9: Main steps of the method of data transmission routes generation

As the input data, the follows information about the network is used: network topology, description of switches and terminal nodes, links between them. It is also necessary to provide a description of the transmitted data streams: specify the source and destination nodes, the characteristics of the transmitted data, the type of data, the packet size, priority. QoS requirements include requirements for bandwidth, data transfer delays, and jitter. The network designer can select any combination of these QoS parameters.

The main idea of the presented method is to build the initially shortest routes for all data streams, taking into account the bandwidth requirements. Then, with the help of the chosen mathematical approaches, the timing characteristics of the data transmission are evaluated, taking into account the routes. As a final solution, a combination of routes is proposed for which all the requirements for QoS are satisfied for each data stream. In the case when requirements are

DOI: 10.13009/EUCASS2017-316

not attainable for all data streams, information about data streams for which it was not possible to find a satisfying route is provided. In the case of a successful routes search for all data streams, the settings of the routing tables of the on-board network are generated.

6. Conclusion

This article discusses the reasons for the need to develop methods and algorithms for searching data transmission routes in the on-board SpaceWire networks in accordance with the requirements for the quality of the service transmission of different data streams. The requirements and features of transmitted data streams in on-board data networks are described. Also, a method is proposed for the data transmission routes generation on-board space networks, taking into account QoS requirements.

Acknowledgements

The research leading to these results has received funding from the Ministry of Education and Science of the Russian Federation under the contract RFMEFI57816X0214.

References

[1] ECSS Standard ECSS-E-ST-50-12C, "SpaceWire, Links, Nodes, Routers and Networks’", European Cooperation for Space Data Standardization, July 2008.
[2] Gorbachev S., Sheynin Y. Integrated Modular Spacecraft Avionics. Architecture and SpaceWire-based Implementation. The 16th IFAC Symposium on Automatic Control in Aerospace, June 14-18, 2004, St. Petersburg, Russia. 2004, v. 2, pp. 240-245.
[3] Parkes S., Nomachi M., Sheynin Y. SpaceWire Missions and Architectures. 60th International Astronautical Congress, 2009.
[4] Sheynin Y., Suvorova E., Syschikov A., Sedov B., Matveeva N., Raszhivin D. Toolset for Onboard Networks Design and Configuration. // Proceedings of the 29th Congress of the International Council of the Aeronautical Sciences. St. Petersburg, Russia, 7–12 September 2014, pp.1-8.
[5] Volkov P.L., Gorbachev S.V. Application of regional-logical addressing for the organization of cluster SpaceWire networks / Intellectual and multiprocessor systems - 2001. Materials of the international scientific conference. Taganrog-Donetsk. 1-6 October 2001. P. 141-144.
[6] I. Korobkov “Adaptive Data Streaming Service for Onboard Spacecraft Networks”, Proceedings of 17th Conference of Open Innovations Association Finnish-Russian University Cooperation in Telecommunications (FRUCT), 2015, pp. 291-298.
[7] CCSDS 766.1-B-2 Digital Motion Imagery Recommended Standard.
[8] Shnurenko O.E. MPLS technology and its practical application, the journal "Conference Collections of SIC" Sotsiosphera ", No. 23, 2013, 50-54 p.
[9] SNA Network Implementation Guide Version 2 Release 1, 2014, link: http://www.ibm.com/systems/z/os/zos/webqs.html
[10] A Guide to Integrated Network Technologies. 4th edition M .: Publishing house "Villamé", 2005. - 1040 p.
[11] Ferrandiz Thomas, Frances Fabrice, Fraboul Christian. Worst-case end-to-end delays evaluation for SpaceWire networks. Discrete Event Dynamic Systems, 2011, vol. 21, n° 3, pp. 339-357.
[12] Ferrandiz Thomas, Frances Fabrice, Fraboul Christian. Using Network Calculus to compute end-to-end delays in SpaceWire networks. (2011) SIGBED Review, vol. 8 (n° 3). pp. 44-47.