ELECTRONICS AND ELECTRICAL ENGINEERING
ISSN 1392 – 1215 2011. No. 1(107)
ELEKTRONIKA IR ELEKTROTECHNIKA

T 121 SIGNAL TECHNOLOGY
SIGNALŲ TECHNOLOGIJA

The Worst or Average Availability: Option for the SLA Contract

I. Rados
Department of Transmission Systems, Croatian Telecommunications d.o.o. Mostar,
Kneza Branimira bb, 88000 Mostar, Bosnia and Herzegovina, phone: +387 36 33 66 56, e-mail: ivan.rados@hteronet.ba

Introduction

The development of the photonic technologies enabled high transfer over optical fibers. The key technology for this development is WDM which enables hundreds of wavelength channels which transfer data in Gb/s speeds to be multiplexed in one signal suitable for transfer over the optical fiber. As a result of huge quantity of the transferred data, network failures can cause big financial losses as well as the reputation of the service provider. For that reason the application of the different protection methods in the WDM ring structure enables network operators to even in the circumstances of failure (i.e cable cut off) provide to its users normal performance or in other words quality service. Service Quality requests are usually defined by a contract (SLA- Service Level Agreement) between the operators and its users as well as the penalties which need to be paid by the operator in cases when the quality is not on the level which was defined in the SLA contract.
Surveillance of the service is generally introduced over connection availability which is a probability that the connection will be correct in some moment in time. The availability of the connection depends of the availability of the network components alongside (optical fibers, optical add/drop multiplexors and switches...). In order to provide quality service to its users introduced over availability and defined by the SLA contract, operators apply different protection methods. In this paper we shall focus on the protection of the wavelength channel in the ring WDM network.

Defined availability in the SLA contracts usually refers to the average connection availability. However, the question is what the average availability means for the services user and if that is good enough to be protected against loss of incomes. If we assume, for example, that the average availability is 99%, it means that still 1% of unavailability remains which for the big users who are transferring big data quantities (i.e. order Tb/s) can mean significant loss of incomes and perturbation of the service quality.

Authors in the [1] researched guaranteed availability using shared protection in the national and continental networks. They concluded that the high availability (0,99999) can be guaranteed in the national networks while not in the continental ones because of the possibility of occurrences of concurrent double failures. The availability in some time period as well as the duration of failures were researched by the authors in [2] and concluded that the possibility of failure duration has direct and significant influence on the penalties which are defined by the SLA contract, which need to be paid by the operators to the users of their services. Ling Zhou and W.D. Grover analysed in [3] how “security margin” influenced availability which is guaranteed by the SLA contract and concluded that bigger “security margin” is needed as the period of the SLA contract is shorter. In the reference [4] authors analysed availability of the connection which is guaranteed by the SLA contract and proposed a model which provides improvement of availability to operators with minimal network investment. Authors compared dedicated and shared protection from the aspect of availability guaranteed in the SLA contract and proposed the usage of shared protection for the same level of the guaranteed availability because of the better usage of the network capacities. D. Schupke proposed the way by which it is possible to reach guaranteed availability with minimal network investment in the way of allocating network resources to individual connection when it is necessary or in other words depending on the failure scenario. In the reference [5] authors dealt with the analysis of the reliability of the telecommunication system depending on different regimes of repair which also has an influence on the guaranteed reliability. In this paper, we shall introduce the term “the worst availability” and compare average and the worst availability in order to be able to conclude what big users should request from the operators through the SLA contract.

Availability theory

Let the G network consists of N nodes and N links connecting those nodes. Availability $A_{st}(G)$ between two terminals is a probability that there is at least one path which is composed of correct links and nodes between *s* and *t* in G. If the nodes are ideal, let x_{lk} means availability of the link where l is link and $k = 1,2,\ldots,N$ and let vector $\times$ means assembly of the availability of links

$$\times \equiv (x_{l1}, x_{l2}, \ldots, x_{lN}). \qquad (1)$$

The aim is to calculate availability between two terminals s and t which is presented by a polynomial function of $\times$ elements

$$A_{st}(\times) = A_{st}(x_{l1}, x_{l2}, \ldots, x_{lN}). \qquad (2)$$

To complete algebra formulation two operators on polynomial shall be introduced:

1. This $\otimes$ operator is applied to the tandem connection of two or more elements in which the same reason (cause) can cause the failure of some or all elements in the series.

2. This operator $\oplus$ is applied to the parallel connection of two or more elements in which the same cause can cause the failure of some or all elements.

Let S represent an assembly of all polynomials which can come into existence by the combination of operators $\otimes$ and $\oplus$ so that the minimal value of the polynomial is 0 and the maximal is 1.

For polynomials $f, g, h \in S$ following axioms are applicable [9]: $f \otimes f = f$, $f \oplus f = f$, $f \otimes 1 = f$, $f \oplus 0 = f$, $f \otimes 0 = 0$, $f \oplus 1 = 1$, $f \otimes g = g \otimes f$, $f \oplus g = g \oplus f$.

If the operator $\otimes$ is applied on the serial structure, for instance of two elements whose failures are totally independent, the availability of such structure is equal to the product of availability of each single element

$$A_s = x_1 \otimes x_2 = \prod_{i=1}^{2} x_i = x_1 . x_2. \qquad (3)$$

It is generally applicable for the parallel structure of two elements

$$A_p = x_1 \oplus x_2 = x_1 + x_2 - (x_1 \otimes x_2). \qquad (4)$$

If the failures of elements are totally independent the following applies:

$$A_p = x_1 \oplus x_2 = x_1 + x_2 - (x_1 . x_2). \qquad (5)$$

If x_1 *and* x_2 are mutually exclusive which means that $x_1 \otimes x_2 = 0$, we have

$$A_p = x_1 \oplus x_2 = x_1 + x_2. \qquad (6)$$

Let P_{st} be the assembly of all individual paths P_i between s and t in the network G.

The path value $v(P_i)$ is defined as a product of availability of links alongside

$$v(P_i) = \otimes\{x_{lk} : k \in P_i\} = \otimes \prod_{k \in P_i} x_{lk}. \qquad (7)$$

The availability between two terminals $A_{st}(\times)$ is in that case the parallel sum of path value $v(P_i)$ over all individual paths from s to t

$$A_{st}(\times) = \oplus v(P_i), P_i \in P_{st} = \oplus \sum_{P_i \in P_{st}} v(P_i). \qquad (8)$$

We can develop a parallel sum using Poincare's formula. Where E_i marks the event where all links on the path P_i are correct, then the availability $A_{st}(G)$ is a probability that at least one event E_i occurred

$$A_{st}(G) = P(E_1 \cup E_2 \cup \ldots \cup E_i). \qquad (9)$$

Since i paths can incorporate joint links, events E_i are generally not mutually exclusive, however regardless of that Poincare's formula can be applied to the above equation because in each element of the formula cross section of the event is used.

By using operators $\otimes$ and $\oplus$ this formula can be written as

$$A_{st}(G) = \oplus \sum_{i=1}^{k} E_i = \sum_{i} P(E_i) - \sum_{i<j} P(E_i \otimes E_j) +$$
$$+ \sum_{i<j<l} P(E_i \otimes E_j \otimes E_l) - \cdots + (-1)^{k+1} \cdot P(E_i \otimes E_j \otimes$$
$$\cdot P(E_i \otimes E_j \otimes \ldots \otimes E_k). \qquad (10)$$

The availability can be calculated by using the expression

$$A = \frac{MTTF}{MTTF + MTTR}, \qquad (11)$$

where *MTTF (* Mean Time To Failure) is mean time till the failure occurs and *MTTR* (Mean Time To Repair). Mean time of repair

$$MTTF = 1/\lambda, \qquad (12)$$

where λ is a failure rate which is usually expressed in *FIT* (Failure in Time, 1*FIT*=1 failure in 10^9 hours).

Availability can be calculated on the basis of the collected data while the new systems use a probability model .

Unavailability U is probability complementary to availability, i.e. U=1-A. In reporting about system/network performances, unavailability U is often expressed as *MDT* (Mean Down Time) in minutes per year, i.e.

$$MDT = 365 * 60 * 24 * U \quad [\text{min}/\,year], \qquad (13)$$

As an SDH network generally consists of cable sections and nodes, optical fiber failure rate is calculated separately from node failure rate. Optical fiber failure rate is calculated according to the equation

$$\lambda = n / MT \; [l / hkm], \qquad (14)$$

where n is a number of failures over monitoring time, M the length of installed cable in km and T monitoring period in hours.

Availability analysis of WDM ring

Since the installation of more SDH line systems between two nodes is very expensive, as the capacities of optical cables exhaust considerably, the need for high transmission capacity system requiring only two fibers has arisen. Such are WDM systems based on wavelength multiplexing which uses the wavelength channel protection. In this section we shall analyse the availability for WDM ring, which uses the wavelength channel protection. In this type of protection the switching is carried out on wavelength channel level so that the protection capacity is one wavelength. There are two types of protection: OCh dedicated protection ring *(OCh*

DPRing) and OCh shared protection ring *(OCh SPRing)*. In this paper, we shall analyse OCh dedicated protection ring.

OCh dedicated protection ring

This type of protection requires two fibers in a ring. Each wavelength channel is being routed on the working path along one side of the ring and the corresponding dedicated wavelength channel, along the opposite side. Bidirectional wavelength requirements are supported by two wavelength channels; one in each direction. Both wavelength channels with bidirectional wavelength requirement can be routed along the same side of the ring in different fibers by using the same wavelengths.

The alternative can be in routing the working wavelength channels on different sides of the ring, so that one fiber of a two fiber ring merely transports the working traffic while the other fiber transports the protection traffic only. In the case of a link or node failures on the working path protection switching happens on the wavelength channel level (OCh layer).

Two types of dedicated protection are possible: 1+1 and 1:1. In ring network which uses the 1+1 wavelength channel protection, the wavelength channel is the source node and is being duplicated and concurrently delivered in both directions of the ring.

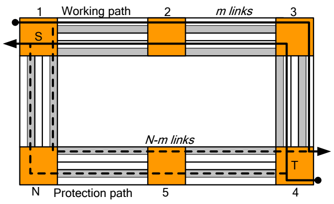

Fig. 1. 1+1 wavelength channel protection under conditions without a failure

Under ordinary conditions in terminal node, the receivers get two signal copies (with a different delay) and choose the best one. In the case of a failure on the working direction, the receiver chooses the signal that it gets from the protection direction.

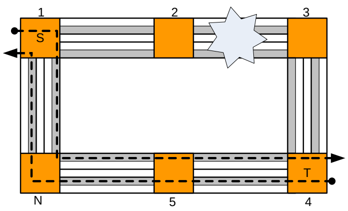

Fig. 2. 1+1 wavelength channel protection in the case of a failure on working path

This is so called single ended protection because the switching is carried out only on one (receiving) side. It is important that the working and protection direction do not have components in common, in order that one failure would not cause total communication break down, and this means that the component failures on the working and protection direction are fully independent.

For each wavelength channel of working direction, a corresponding wavelength channel on protection direction is reserved and therefore, we are talking about an 1+1 wavelength channel protection (8).

In 1:1 protection, the wavelength channel on the front side is not permanently duplicated so that the switching is performed on both ends which requires a protocol to coordinate this dual-ended switching. From the availability aspect, the same availability expression applies as for the 1+1 protection.

Since the nodes are generally connected by optical links, irrespective of their architecture, in this section we shall analyze the availability for links without protection and nodes with active components.

Link availability

In order to determine the wavelength channel availability between two nodes we need to know the availability of links and nodes.

In this paper the unprotected optical link is comprised of the optical cable and mux/demux as can be seen in the picture 1. In order that the connection be functional, all components of the optical link must be correct. The most often cause of an optical link failure is the breakage of optical fiber. Since, in the case of the cable breakage, mostly all the fibers break, we shall suppose that the failures of fiber and cable are fully dependent so that, instead of the availability for fiber, we shall take the availability for cable.

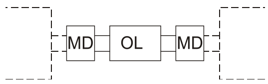

Fig. 3. Unprotected link

The availability for link without protection $(x_{lk_{np}})$equals to the availability product of individual components

$$x_{lk_{np}} = x_{lk}.x_{MD=}^2 x_l.x_{MD=}^2 x_l.(x_{MD})^2. \qquad (15)$$

Node availability with active components

An optical switch with add/drop possibilities is used as the active component. In the case that the node is used as terminal one, the wavelength channel passes through the transmitter and optical switch.

For the instance of n the wavelength channel in terminal node, the availability is

$$x_{nt,n} = x_{TX}^n \cdot x_{OSW} \cdot x_{RX}^n . \qquad (16)$$

If the node is a pass-through (x_{np}) one the wavelength channel passes from east to west side of optical switch so that the availability is

$$x_{np} = x_{OSW} . \qquad (17)$$

The Availability of terminal nodes is same either the 1+1 protection or 1:1 is concerned because the optical switch can act both as the divider and switch.

Ring availability

If a wavelength channel on the working path passes the *m* number of optical links between terminal nodes, the availability for the working path is equal to the availability product for optical links and nodes through which this wavelength channel passes [6]

$$v_{st}(P_0) = \otimes \prod_{k,m \in P_0} x_{lk} x_{nm} = \left[\otimes \prod_{k \in P_0} x_{lk} \right] \left[\otimes \prod_{m \in P_0} x_{nm} \right] =$$

$$= (x_{nt})^2 \cdot (x_{np})^{m-1} \left[\otimes \prod_{k \in P_0}^{m} x_{lk} \right]. \qquad (18)$$

In the case of a failure on the working path P_0, the wavelength channel passes the *N-m* of optical links and the *N-m-1* of nodes on the protection path P1 so that the availability for the protection path is (10)

$$v_{st}(P_1) = \otimes \prod_{k,m \in P_1} x_{lk} x_{nm} = \left[\otimes \prod_{k \in P_1} x_{lk} \right] \left[\otimes \prod_{m \in P1} x_{nm} \right] =$$

$$= (x_{nt})^2 \cdot (x_{np})^{N-m-1} \left[\otimes \prod_{k \in P_1}^{N-m} x_{lk} \right]. \qquad (19)$$

The availability for the wavelength channel between the s and t nodes is completely determined by these two paths, so that the availability for the wavelength channel in the case of 1+1 protection is calculated as the availability of two branches, failures of which are fully independent

$$A_{st}(\times, m) = v_{st}(P_0) + v_{st}(P_1) - \left[v_{st}(P_0) \otimes v_{st}(P_1) \right], \quad (20)$$

$$A_{st}(\times, m) = (x_{nt})^2 \cdot (x_{np})^{m-1} \cdot \left[\otimes \prod_{k \in P_0}^{m} x_{lk} \right] +$$
$$+ (x_{nt})^2 \cdot (x_{np})^{N-m-1} \cdot \left[\otimes \prod_{k \in P_1}^{N-m} x_{lk} \right] -$$
$$- \left\{ \begin{array}{l} (x_{nt})^2 \cdot (x_{np})^{m-1} \cdot \left[\otimes \prod_{k \in P_0}^{m} x_{lk} \right] \\ \otimes (x_{nt})^2 (x_{np})^{N-m-1} \cdot \left[\otimes \prod_{k \in P_1}^{N-m} x_{lk} \right] \end{array} \right\}. \qquad (21)$$

Although in the equation brackets we have the product of the same two members, we use one member not the square because of the earlier mentioned axioms $f \otimes f = f$ which are valid for the operator $\otimes$ so we have

$$A_{st}(\times, m) = (x_{nt})^2 \cdot \{ \ (x_{np})^{m-1} \cdot \left[\otimes \prod_{k \in P_0}^{m} x_{lk} \right] +$$
$$+ (x_{np})^{N-m-1} \cdot \left[\otimes \prod_{k \in P_1}^{N-m} x_{lk} \right] - (x_{np})^{N-2} \cdot \left[\otimes \prod_{k \in P_0, P_1}^{N} x_{lk} \right] \}. \quad (22)$$

If the links do not have protection

$$A_{st}(\times, m) = (x_{nt})^2 \cdot \{ \ (x_{np})^{m-1} \cdot (x_{MD})^{2m} . \left[\otimes \prod_{k \in P_0}^{m} x_{lk} \right] +$$
$$+ (x_{np})^{N-m-1} \cdot (x_{MD})^{2(N-m)} . \left[\otimes \prod_{k \in P_1}^{N-m} x_{lk} \right] -$$
$$- (x_{np})^{N-2} . (x_{MD})^{2N} \cdot \left[\otimes \prod_{k \in P_{0}, P_1}^{N} x_{lk} \right] \}. \qquad (23)$$

If we assume that optical links have the same length, their availability is the same, i.e. $x_{lk} = x_l, \forall k$.

In this case, the availability between the s and t nodes is

$$A_{st}(\times, m) = (x_{nt})^2 \cdot \{ \ (x_{np})^{m-1} \cdot (x_{MD})^{2m} . (x_l)^m +$$
$$+ (x_{np})^{N-m-1} \cdot (x_{MD})^{2(N-m)} . (x_l)^{N-m} -$$
$$- (x_{np})^{N-2} \cdot (x_{MD})^{2N} . (x_l)^N \ \}. \qquad (24)$$

Worst terminal pair availability

In order to get the worst availability with regard to the number of links it is necessary to do derivation of this expression 24 for availability by *m* and level with zero

$$\frac{d}{dm} \{ \ (x_{np})^{m-1} \cdot (x_{MD})^{2m} . (x_l)^m +$$
$$+ (x_{np})^{N-m-1} \cdot (x_{MD})^{2(N-m)} . (x_l)^{N-m} -$$
$$- (x_{np})^{N-2} \cdot (x_{MD})^{2N} . (x_l)^N \ \} = 0. \qquad (25)$$

After simple derivation we have the following expression

$$\left[(x_{np})^{m-1} \cdot (x_{MD})^{2m} . (x_l)^m - (x_{np})^{N-m-1} \cdot (x_{MD})^{2(N-m)} . (x_l)^{N-m} \right] \times$$
$$\times \left[m(x_{np})^{-1} + 2m(x_{MD})^{-1} + m(x_l)^{-1} \right] = 0. \qquad (26)$$

After putting in order we have:

1. *m*-1=*N*-*m*-1; follows *m*=*N*/2;
2. 2*m*=2(*N*-*m*); follows *m*=*N*/2;
3. *m*=*N*-*m*; follows *m*=*N*/2.

This applies to the even number. As m has to be whole number, this expression cannot be applied to the odd number *N* and therefore the following is used *m*=*N*-1/2.

In order to examine whether it is about minimum or maximum we shall have to determine the second derivation of this expression and establish if it is > 0 or < 0

$$\left[(x_{np})^{m-1} \cdot (x_{MD})^{2m} . (x_l)^m - (x_{np})^{N-m-1} \cdot (x_{MD})^{2(N-m)} . (x_l)^{N-m} \right] \times$$
$$\times \left[m(x_{np})^{-1} + 2m(x_{MD})^{-1} + m(x_l)^{-1} \right] = 0. \qquad (27)$$

By a simple calculation, it can be proved that the second derivation >0 and that it is about the minimum or in other words about the worst availability which is got for m=N/2 for the even number of nodes and m=N-1/2 for the odd number of nodes.

Numerical results

As shown before, the same expression applies for the availability of OCh dedicated and OCh shared protection. In order to calculate the availability for a WDM system one needs to know the nodes and optical links availability. For availability calculation, in general, one needs to know the intensity of failures for the individual components, the data of which are shown in Table 1, and are taken from different literature and previously published works.
NOTE: W is the number of wavelength channels

Table 1. Availability data for optical components (W=64)

Component/Device	Symbol	Failure rate
Line Amplifier	LOA	3200
Multiplexer	MUX	25xW
Demultiplexer	DEMUX	25xW
Optical Switch	OSW	1000
Fix Transmitter	TRX	186
Fix Receiver	RX	70
Cable (per km)	OC	100

Table 2. MDT (min/year) for a node with active components

	MDT
MTTR=6 h	$\lambda = 64$
Terminal	3.22
Pass-through	0.000018

We shall calculate availability for the even and odd number of links of the working path for N=11and N=12 nodes in order to establish whether numerical results correspond to theoretical analysis. We shall also take different lengths of links in order to analyse their influence on the availability. For MTTR of the equipment and cables, 6 and 12 hours is taken which is usual in practice.

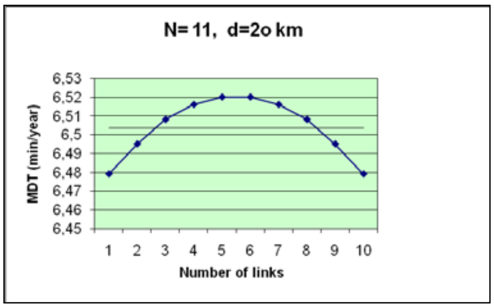

Fig. 4. MDT (min/year) for N=11 and d=20 km

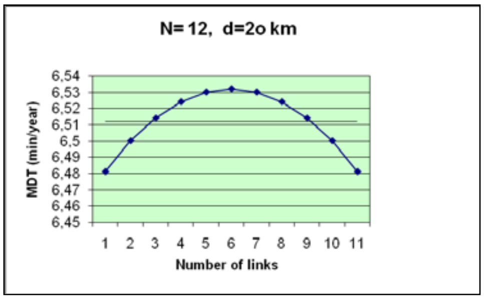

Fig. 5. MDT (min/year) for N=12 and d=20 km

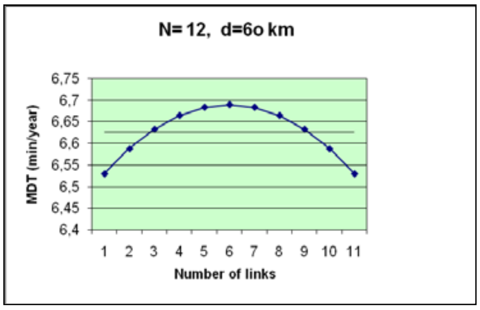

Fig. 6. MDT (min/year) for N=12 and d=60 km

As can be seen from the above graphs, the worst availability obtained is in accordance with the earlier derived expression for the number of links of the working path which is for N=11 m=N-1/2=5 (MDT=6.520) and for N=12 m=N/2=6 (MDT=6.532) for the same length of the link. It is also visible that by increasing the number of nodes, the unavailability increases by app. 0.18 % with the same length of the links (N=11 i N=12, d=20). Increase in the length of links has even more significant influence on unavailability because for the same number of nodes N=1, with increase of the length of the links from 20 to 60 km, the unavailability increased by 2.34 %.

If the differences between the average and the worst availability are examined, it can be noted that the difference grows with the number of nodes and the length of links. For example, for N=11 and d=20 km the difference between the average and the worst availability is 0.26 % and for N=12 and d=60 km the difference is 0.95 %. With the increase in the number of nodes with d=60 the difference is over 1%.

Conclusions

Analyses of the results on the WDM ring shows that the worst availability is obtained in accordance with the earlier derived expression for the number of links of the working path and that is m=N/2 for even number of links and m=N-1/2 for odd number of links of the working path. It is also noticeable that the unavailability increases with the increase of the number of nodes in the ring and even more with the increase of the length of the optical links. Also with the increase of the number of nodes and length of the optical links, the difference between the average and the worst availability increases which can go over 1% depending on the number of nodes and length of the links. If taken into consideration that those big operators have the revenues of a few dozen billion Euro, than the difference is not at all negligible and it is not all the same for them whether the average or the worst availability is guaranteed in the SLA contract.

Although the former practice for the SLA contracts was generally to guarantee the average between the two terminals in the network, yet big users should request from their service providers to have the worst availability guaranteed in order to have as fewer losses as possible in the case that the guaranteed availability is not fulfilled as a responsibility from the SLA contract to be able to charge penalties.

References

1. **Mello D. A. A., Pelegrini J. U., Riberio R. P., et al.** Dynamic Provisioning of Shared–Backup Path Protected Connections with Guaranteed Availability Requirements // OSP 2005. – Boston, USA, 2005. – Vol. 2. – P. 1320–1327.
2. **Mello D. A. A., Quiterio G. S., Schupke D. A., Waldman H.** Specification of SLA Survivability Requirements for Optical Path Protected Connections // OFC 2006. – Anaheim, USA, 2006.
3. **Ling Zhou, Grover W. D.** A Theory for Setting the „Safety Margin“ on Availability Guarantees ina n SLA // Proc. 5th International Workshop on Design of Reliable Communication Networks (DRCN 2005). – Ischia (Naples), Italy, 2005.
4. **Jing Zhang, Keyao Zhu, Hui Zang, Mukherjee B.** A New Provisioning Framework to Provide Availability–Guarantee services in WDM Mesh Networks // ICC 2003. – Anchorage, USA, 2003. – P. 1484–1488.
5. **Trstenský, D., Schwartz, L., Trunkvalter, M., Baroš, R.:** Reliability of Telecommunication System by Various Repair Regime // Advances in Electrical and Electronic Engineering. – Žilina: ŽU, 2004. – No. 2. – Vol. 3/2004. –P. 25–26.
6. **Rados I.** Availability Models for Wavelength Channel Protection in WDM Ring Networks // Electronics and Electrical Engineering. – Kaunas: Technologija, 2008. – No. 8(88). – P. 81–86.

Received 2010 04 20

I. Rados. The Worst or Average Availability: Option for the SLA Contract // Electronics and Electrical Engineering. – Kaunas: Technologija, 2011. – No. 1(107). – P. 19–24.

This paper introduces a new term „the worst availability“. In the introductory part, the reasons why a high availability of the system is important are given as well as overviews of the former papers addressing the problem of the guaranteed availability in SLA contracts. Then, basic terms on availability are introduced with a special view on the parallel structure which can actually be applied to the ring network. The principles re protection of the wavelength channel which are used in the ring WDM networks are described separately. Furthermore the availability of the WDM ring which uses the protection of the wavelength channel is analysed, the expression for the worst availability of the WDM ring derived and the number of links of the working path which provide the worst availability determined. Data on the intensity of failures and mean time for the correction of certain components are taken from different literature. In the analysis, we suggested that it is about the WDM system with 64 wavelengths. At the end, the paper provides the answer to the question why in the SLA contracts, the worst availability needs to be requested and not average availability. Ill. 6, bibl. 6, tabl. 2 (in English; abstracts in English and Lithuanian).

I. Rados. Blogiausios ryšio užmezgimo galimybės paieška taikant SLA tipo sutartis // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2011. – Nr. 1(107). – P. 19–24.

Darbe aptariamas siūlomas naujas terminas „blogiausia ryšio užmezgimo galimybė“. Apžvelgiamos problemos, susijusios su SLA tipo sutartimis WDM tinkluose. Nustatyta blogiausia ryšio užmezgimo galimybė pagal gautų užklausų atsakus įvertinant reakcijos laiką ir gedimų (duomenų praradimo) priklausomybę nuo duomenų intensyvumo. Taip pat pateikiamas blogiausios ryšio užmezgimo galimybės nustatymo būtinumas, palyginti su vidutine ryšio užmezgimo galimybe. Il. 6, bibl. 6, lent. 2 (anglų kalba; santraukos anglų ir lietuvių k.).