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Network management – International network management

Assessing the impact of resource discontinuity in transport networks on service availability

ITU-T Recommendation E.412.1

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ITU-T Recommendation E.412.1

Assessing the impact of resource discontinuity in transport networks on service availability

Summary

ITU-T Recommendation E.412.1 provides two indexes for assessing the impact of resource discontinuities in transport networks. These two indexes are called the "service outage index (SOI)" and the "service affected index (SAI)" on the availability of services for users. They can be used to guide a network operator to arrange the OAM resources so that better services can be provided. (The word "service" is used in its normal sense and not as a defined term or defined ITU service).

Source

ITU-T Recommendation E.412.1 was approved on 14 December 2007 by ITU-T Study Group 2 (2005-2008) under the ITU-T Recommendation A.8 procedure.

Keywords

Service affected index, service outage index.

FOREWORD

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CONTENTS

Introduction

The service outage index (SOI) and service affected index (SAI) are defined based on service lost or potential service lost, and these two indexes together can be used to assess the operational status of a transport network from the viewpoint of service lost, where SOI indicates the percentage of service lost compared to the total service; while SAI indicates the percentage of affected service (due to protection degradation) compared to the total service.

These two indexes can be used when an operator wants to know the overall operational quality of a transport network, and these two indexes together can quantitatively express the healthy condition of the transport network. Based on the values of these two indexes, the operator can take measures to provide more reasonable transport resources to provide better services.

These two indexes can also be used for early warnings. When there are limited backup resources for a transport network, by calculating these two indexes with the assumption of each line failure, the operator can find out which line(s) will cause more service loss than others. If some lines with the <SOI, SAI> values exceed a predefined threshold, an early warning message will be sent to the operator so that they will have a higher priority to be provided with backup measures.

These two indexes are mainly calculated based on a network management system, from which the network topology, fault information and service information can be obtained.

These two indexes are applicable for all kinds of network topologies, but the SAI index is not applicable for those transport networks that do not provide protection mechanisms. In other words, a transport network without any protection schemes will have a constant value of SAI.

ITU-T Recommendation E.412.1

Assessing the impact of resource discontinuity in transport networks on service availability

1 Scope

This Recommendation provides an overview of the assessment indicators for the operational status of transport networks with protection schemes. It is the scope of this Recommendation to provide an overview of:

- The service environments of transport networks for network operational assessment.
- The assessment of operational status of the transport network for a specific time point, which is used to indicate the robustness of a transport network.
- The assessment of potential risks for outage of a transport network for a specific time point, which is used to indicate the extent of the services affected in a transport network.
- The quantitive failure measuring approach using the above indexes.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T G.805] ITU-T Recommendation G.805 (2000), *Generic functional architecture of transport networks*.

[ITU-T M.3320] ITU-T Recommendation M.3320 (1997), *Management requirements framework for the TMN X-Interface*.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 customer [ITU-T M.3320]: An organization which has a business relationship with a service provider for the provision of network services. A customer may encompass one or more end users of telecommunications services.

3.1.2 service provider [ITU-T M.3320]: A general reference to an entity who provides telecommunication services to customers and other users either on a tariff or contract basis. A service provider may or may not operate a network. A service provider may or may not be a customer of another service provider.

3.1.3 transport network [ITU-T G.805]: The functional resources of the network which conveys user information between locations.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 (O, A, P, R) quaternion: SOI and SAI are time-variable, discrete values. Using straight lines to connect successive sample values, continuous functions of SOI(t) and SAI(t) can be created. Based on SOI(t) and SAI(t), failure measure approach, (*O, A, P, R*) quaternion are defined where,

– ***O***: **O**utage component. It is the component to measure the failure's total extent of service lost.

– ***A***: **A**ffected component. It is the component to measure the failure's total extent of potential risk.

– ***P***: **P**rocess component. It is the component to describe failure process. It consists of function curves of SOI(t) and SAI(t) which are drawn in one coordinate system.

– ***R***: **R**emark component. It is the component for recording some important necessary information.

3.2.2 service affected index (SAI): Service affected index, which considers the extent of a transport network being affected, is a metric to measure potential service risks for a certain failure. SAI represents the weight ratio of affected services over total services.

3.2.3 service outage index (SOI): Service outage index, which considers the extent of a transport network being destroyed, is a metric to measure actual service losses for a certain failure. SOI represents the weight ratio of lost services over total services.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

ASON Automatically Switched Optical Network

DWDM Dense Wavelength Division Multiplexing

IP Internet Protocol

MAX Maximum

MIN Minimum

PDH Plesiochronous Digital Hierarchy

SAI Service Affected Index

SDH Synchronous Digital Hierarchy

SOI Service Outage Index

SP Service Provider

VIP Very Important Person

5 Conventions

None.

6 Overview of service environments of transport networks

6.1 Evolution of transport networks

Transport networks are the bases of more and more services, and they provide reliable end-to-end connections (circuits) for service layer networks. Transport networks have been evolving from PDH, SDH to DWDM, and these networks still coexist in current networks. As ASON technology has been developed, more requirements for communication capacity of the transport networks are supposed to be provided.

6.2 Services environment of transport networks

Transport networks can be divided into several layer networks, and end-to-end leased circuit services are the most popular services provided to customers, upon which multiple kinds of services can been supported, such as PCM, IP or other data services.

With the evolution of transport networks and all the services that transport networks provide to customers, the relationship between transport networks and service layer networks has become closer. Therefore, the operational quality of transport networks has much more influence on the service-provisioning capabilities of service layers. In order to improve the service level that service providers (SPs) provided to the customer and meet the increasing requirements for communication quality, the operational status should be assessed for SPs to know the extent of the services being, or to be, affected so that measures may be taken to reduce the service unavailability with a reasonable direction and order.

The following clauses describe the detailed indicators for the assessment of the operational status of transport networks, which can be used for early warning for transport network operators.

7 Assessment indexes for the operational status of transport networks

7.1 Conventions for the concept of circuit operational state of a transport network

Generally, it is assumed that circuits (in this Recommendation, the concept of circuit is the service provided by the transport network) in a transport network have two states: ON and OFF. In fact, in cases where there are good protection and restoration mechanisms in a transport network, there are multiple routings for circuits, and services would not be lost unless all of their routing schemes (including prime and spare schemes) have failed. The state of a partial failure of the routing scheme is different for the ON state and OFF state. In such situations, although service is not in an outage state, there are less protection schemes than their original state; the reliability for the service(s) is decreased. That is, they are in a risk state and the carried services may be lost if the spare routing scheme fails. This state is denoted as an AFFECTED state in this Recommendation. Consequently, there are three states for a service in transport networks: ON, OFF and AFFECTED. Based on these three states, the service set can be divided into three sub-sets: ON service set, OFF service set and AFFECTED service set.

The following two subclauses analyse the relationship between these three service sets and service features, and define two assessment indexes: service outage index (SOI) and service affected index (SAI).

7.2 Service outage index (SOI)

7.2.1 Concept

The service provided by a transport network to a service network is the end-to-end connection (circuit), thus the assessment indexes should be defined based on the circuits (that is the services) that have been provided.

The service outage index is an indicator used to express the extent of a transport network to be in an outage condition, which is used to assess the robustness of the operational status of the network in a quantitative way. This indicator represents the ratio of the lost services over the total services provided by the network.

7.2.2 SOI expression

In order to precisely express the extent of the impact on the network due to circuit unavailability, the following are considered to be key factors:

a) Number of unavailable services.

b) The service (circuit) type (such as SDH or E1).

c) The bandwidth of the service (circuit bandwidth).

d) The related VIP level of the service.

e) The service importance that is related to time.

Considering the above factors, the service outage index can be defined using the following equation:

$$SOI = \frac{\sum_{y \in F(x)} p_y \times r_y \times c_y \times f_{y(t)}}{\sum_{z \in U} p_z \times r_z \times c_z \times f_{z(t)}} \times 100 \qquad (1)$$

where:

a) ***x***, stands for the failure component to be measured. And ***F(x)*** is the OFF-service set of ***x***.

b) ***y*** and ***z***, stand for a certain service provided by this transport network.

c) ***p***, stands for the service type factor, and it is the weight component of the service type. It is assigned due to service types that are borne by the circuit. For example, "leased circuit" is a service type.

d) ***r***, stands for the service rate factor, and it is the weight component of the service rate. It is assigned due to different circuit rates (it can also be based on prices of the corresponding bandwidths).

e) ***c***, stands for the customer level factor, it indicates the importance (the VIP levels) of the customers.

f) ***f(t)***, stands for the distribution function of traffic importance associated with time. Generally, the working time is more important than the off duty time for most customers.

g) ***t***, stands for time, which indicates the measuring time moment.

h) ***U***, stands for the total service set. Namely, it is the set of all the services provided by the transport network.

i) ***SOI***, has the value range of $0 \le SOI \le 100$ (it is amplified 100 times for easy distinguishing).

If no customer level factor or time factor is considered, equation 1 can be simplified as follows:

$$SOI = \frac{\sum_{y \in F(x)} p_y \times r_y}{\sum_{z \in U} p_z \times r_z} \times 100 \qquad (2)$$

According to the definition of this index, when a specific time is given, the quantitive index can be calculated and used to judge the (almost) real-time operational status of the transport network.

SOI can be used to quantitively express the actual influence of failed components on services provided by the transport network.

7.2.3 Assessment procedure

This clause provides a brief introduction of the assessment procedures of the service outage index of a transport network.

In order to calculate the SOI of a transport network at a specific time, the following two basic steps may be followed:

1) For that specific moment, analyse the set of the services (circuits) that are in outage (unavailable) state from the fault detected on the transport network.

   With the analysis from the faults of the transport network, get the transport systems that are involved in the network. With the information of the route protection scheme, the OFF-service set that is borne by these transport systems can be calculated. That is, determine ***x*** and ***F(x)*** in equation 1.

2) Analyse the circuit sets whose services break off, and calculate the service outage index of the network using equation 1 or equation 2.

Before the SOI can be calculated, the values of the following factors should be determined:

– The weights for all possible service types provided by this transport network should be pre-assigned, that is to determine the factor ***p*** for each provided service.

– The weights for all possible circuit bandwidths (service rates) provided by this transport network should be pre-assigned, that is to determine the factor ***r*** for each provided service.

– If the customer factor is considered, the weight for each customer importance should be pre-assigned, that is to determine the factor ***c*** for each service. If this factor is not considered, factor ***c*** can be assigned as a constant with the value of 1.

– If the time-related factor is considered, the distribution function ***f(t)*** of traffic time importance should be predetermined. If this factor is not considered, function ***f(t)*** can be assigned as a constant with the value of 1.

In order to calculate the SOI value at a specific time, for each service that is in the outage state, calculate both the cost of service lost due to circuit failure and the total amount. Finally, divide this value by the sum of all the provided service weights, using either equation 1 or equation 2, and the SOI value can be obtained.

7.3 Service affected index

7.3.1 Concept

Due to all kinds of protection mechanisms of transport networks, when a fault occurs in a network, there will be a set of services that do not break off, but their circuit protection may have been degraded, and they are more likely to suffer from service break offs.

The service outage index described in clause 7.2 does not cover this concept, and thus a new index should be defined to express the extent of potential risk to the network.

7.3.2 SAI expression

The service affected index (SAI) can be defined using equation 3:

$$SAI = \frac{\sum_{y \in A(x)} p_y \times r_y \times c_y \times f_{y(t)}}{\sum_{z \in U} p_z \times r_z \times c_z \times f_{z(t)}} \times 100 \qquad (3)$$

where:

a) x, y, z, p, r, c, $f(t)$, t and U have the same meaning as for ***SOI***.

b) $A(x)$ is the AFFECTED-service set of x.

c) ***SAI*** has the value range of $0 \le SAI \le 100$ (it is amplified 100 times for easy distinguishing).

Similarly, if no customer level factor or time factor is considered, the above equation can be simplified as the following:

$$SAI = \frac{\sum_{y \in A(x)} p_y \times r_y}{\sum_{z \in U} p_z \times r_z} \times 100 \quad (4)$$

SAI can be used to quantitively express the potential risks of service loss to the transport network at a specific time.

Clause I.1 shows an example on how SOI and SAI are used.

SAI can also be calculated for individual lines, which can be used for early warning for network management purposes. A management system can calculate the SAI for each line between two adjacent nodes, and calculate those SAI values which cross some predefined threshold that will be a warning to the operator, as such circuits carry more risk than others. If they fail, more services will be lost.

Clause I.2 shows an example on how to use SOI and SAI for early warning on circuit lines.

7.3.3 SAI assessment procedure

In order to calculate the SAI of a transport network at a specific time, the following two basic steps may be followed:

1) For that specific moment, get the set of the services that are affected (services are still available, but the corresponding protections are degraded) from the analysis of the fault detected on the network.

   With the analysis from the faults of the transport network, get the transport systems that are affected in the network. With the information of the protection of the route, the AFFECTED-service set that is borne by these transport systems can be calculated.

2) Analyse the affected services set, and calculate the service affected index of the network using equation 3 or equation 4 in order to grasp the potential risks to the transport network.

Factors **p**, **c**, r, **f**(**t**) in equation 3 and equation 4 should be pre-assigned, and they can follow the same approach as described in clause 7.2.3.

In order to calculate the SAI value at a specific time, for each service that is affected by some other failure component, calculate their cost if the service breaks, and get the sum value for the affected services. Finally, divide this value by the sum of all the provided service weights, using either equation 3 or equation 4, and the SAI value can be obtained.

8 Failure measuring approach of (*O, A, P, R*) quaternion

As SOI and SAI represent the extent of services lost and services affected, respectively, ***SOI(t)*** and ***SAI(t)***, which are obtained by ***SOI*** and ***SAI*** values, can continuously describe the extent of services lost and services affected by failure x on the time axes. Therefore, definite integrals of ***SOI(t)*** and ***SAI(t)*** can be used to measure the total impact of the failure during the whole failure period.

Consequently, based on ***SOI(t)*** and ***SAI(t)***, the measuring approach of (***O, A, P, R***) quaternion is defined as follows:

O: **O**utage component. It is the component to measure the failure's total extent of service lost. It is calculated by the definite integrals of ***SOI(t)*** from t_1 (start time of ***x***) to t_2 (end time of ***x***):

$$O = \int_{t_1}^{t_2} SOI(t)dt$$

A: **A**ffected component. It is the component to measure the failure's total extent of potential risk. It is calculated by the definite integrals of ***SAI(t)*** from t_1 (start time of ***x***) to t_2 (end time of ***x***):

$$A = \int_{t_1}^{t_2} SAI(t)dt$$

P: **P**rocess component. It is the component to describe the failure process. It consists of function curves of ***SOI(t)*** and ***SAI(t)*** which are drawn in one coordinate system. By this component, many other useful data can be observed besides the changing failure process. For example, *MAX(SOI(t))*, *MAX(SAI(t))*, *MIN(SOI(t))*, *MIN(SAI(t))*, etc.

R: Remark component. It is the component for recording some important necessary information. For example, it can note information of related failures, which have resulted in non-zero SOI values together with the failures being measured.

Appendix I

Usage examples for assessment indexes

(This appendix does not form an integral part of this Recommendation)

In this appendix, examples for the usage of the assessment indexes are shown.

I.1 Examples for SOI and SAI applications

1) Topology and service examples

In this example, suppose that the transport network is a SDH ring with six nodes, marked from N1 to N6, as shown in Figure I.1. In this example, there are two services provided to two customers: service A is an E1 (2M) connection between N1 and N2 for customer 2 providing voice services; service B is a 4M connection between N4 and N6 for customer 1, mainly providing data transfer services.

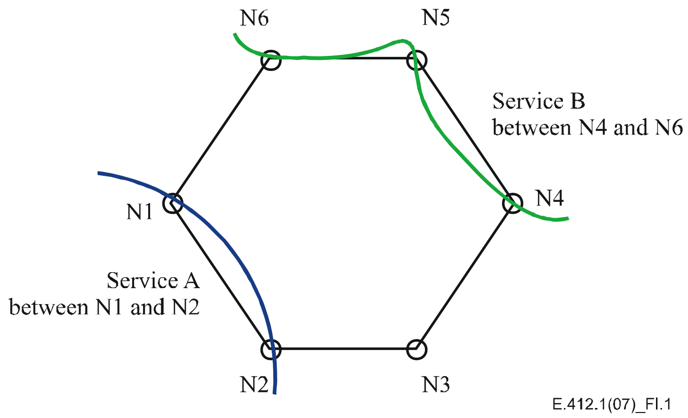

Figure I.1 – Network topology and service examples (SOI = 0, SAI = 0)

Based on the service types, service rate (circuit bandwidth), customer VIP level, and time-related factors, suppose the factor in equation 1 and equation 3 are pre-assigned as per Table I.1:

Table I.1 – Service factor examples

Service	Start and end points	Service type	Service rate	Customer VIP level	Time-related factor
Service A	From N1 to N2	Leased circuit	2M	Gold (government user)	During busy hours (from 9:00 to 21:00), service is more important than any other time period.
		p = 5	r = 4	c = 3	f(t)=2, t∈ [9:00, 21:00] f(t)=1, t∈ [21:00, 9:00]
Service B	From N4 to N6	Data service	4M	Bronze (Normal user)	The same at all times of day.
		p = 3	r = 8	c = 3	f(t) ≡ 1

As shown in Figure I.1, when the transport network is running without any fault, the values of SOI and SAI are both zero.

2) SOI and SAI in one line failure

Suppose there is an optical line failure between N5 and N6, as shown in Figure I.2.

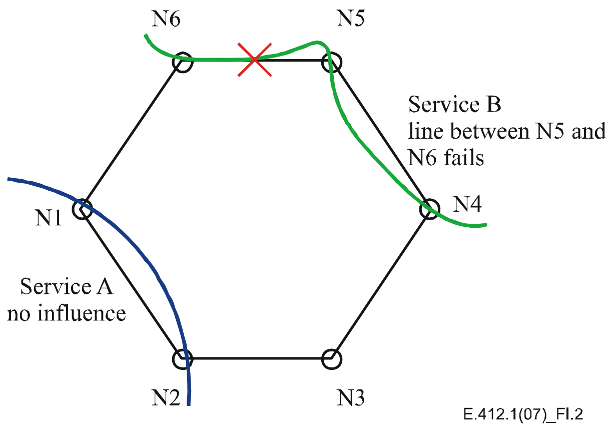

Figure I.2 – Optical line failure between N5 and N6

As this network is a ring with its own protection schemes, one optical line failure does not cause service loss. Using the backup routing between N4 and N6, service B is delivered from N4 through N3, N2, N1 to N6, as shown in Figure I.3.

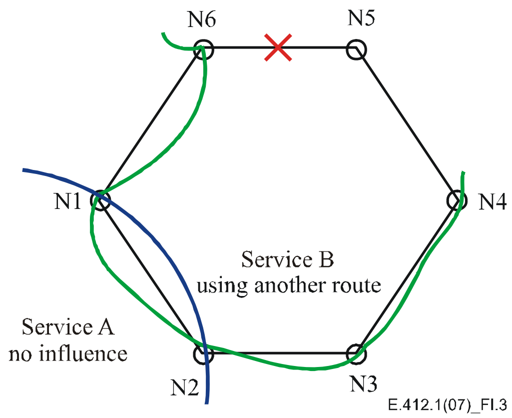

Figure I.3 – Service B using another route (SOI = 0, SAI > 0)

In this case, even though there is no service lost, there are more risks in the network, and if there are other line failures in other places, some services can be actually lost.

Suppose that the optical line between N5-N6 breaks down at 10:00, at this time, the two indexes for the operational status can be calculated as the following:

SOI = 0, as the failure of the N5-N6 line does not bear service any more, it does not cause any service loss.

When calculating ***SAI***, the first thing is to find out the AFFECTED service set. As this is a single ring, each optical line is only protected by the other round of the circle, so both service A and service B are affected (there is no more protection for these two services in the current situation). Thus we can calculate the SAI for each of the services using equation 3, as shown in Table I.2.

Table I.2 – SOI and SAI calculation example in one line failure

Service identifier		Service A	Service B
Service Cost: $p \times r \times c \times f_{(t)}$		$5 \times 4 \times 3 \times 2 = 120$	$3 \times 8 \times 3 = 72$
Service status	OFF	--	--
	AFFECTED	√	√
OFF service: $\sum_{y \in F(x)} p_y \times r_y \times c_y \times f_{y(t)}$		0	
AFFECTED service: $\sum_{y \in A(x)} p_y \times r_y \times c_y \times f_{y(t)}$		120 + 72 = 192	
Total service amount: $\sum_{z \in U} p_z \times r_z \times c_z \times f_{z(t)}$		120 + 72 = 192	
SOI value		0	
SAI value		100	

3) SOI and SAI in two line failures

Suppose there are two optical line failures between N5 and N6, N2 and N3, as shown in Figure I.4.

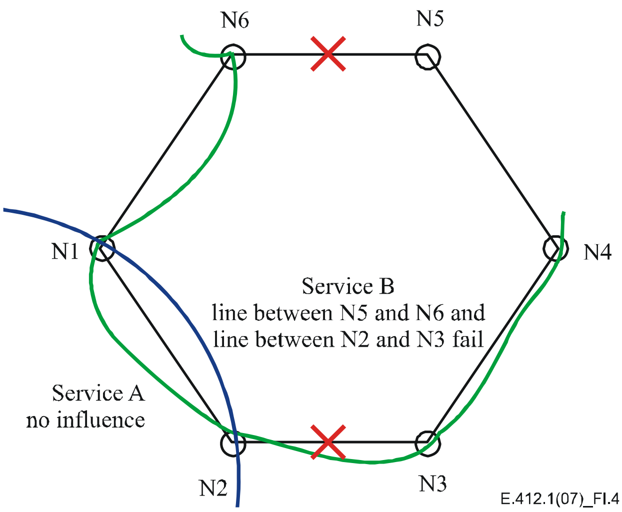

Figure I.4 – Lines between (N5 and N6) and (N2 and N3) fail

As this ring has been broken due to two optical line failures, there are no more routes to bear service B, and service B is lost, while there is no influence on service A, as shown in Figure I.5.

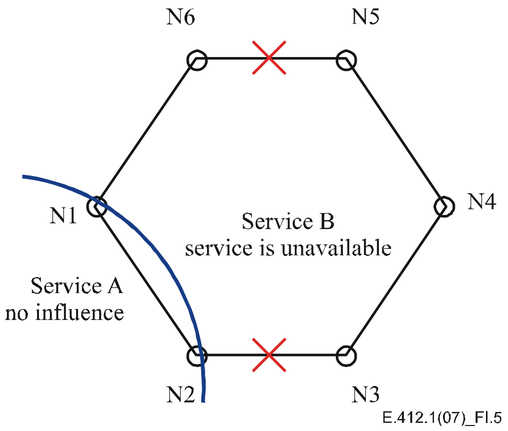

Figure I.5 – Service B is lost (SOI > 0, SAI > 0)

Suppose the measuring time is 23:00. At this time, the two indexes for the network operational status can be calculated as shown in Table I.3:

Table I.3 – SOI and SAI calculation example in two line failures

<table>
<tr><th colspan="2">Service identifier</th><th>Service A</th><th>Service B</th></tr>
<tr><td colspan="2">Service cost: $p \times r \times c \times f_{(t)}$</td><td>5 × 4 × 3 × 1 = 60</td><td>3 × 8 × 3 = 72</td></tr>
<tr><td rowspan="2">Service status</td><td>OFF</td><td>--</td><td>√</td></tr>
<tr><td>AFFECTED</td><td>√</td><td>--</td></tr>
<tr><td colspan="2">OFF service: $\sum_{y \in F(x)} p_y \times r_y \times c_y \times f_{y(t)}$</td><td colspan="2">72</td></tr>
<tr><td colspan="2">AFFECTED service: $\sum_{y \in A(x)} p_y \times r_y \times c_y \times f_{y(t)}$</td><td colspan="2">60</td></tr>
<tr><td colspan="2">Total service amount: $\sum_{z \in U} p_z \times r_z \times c_z \times f_{z(t)}$</td><td colspan="2">60 + 72 = 132</td></tr>
<tr><td colspan="2">SOI value</td><td colspan="2">54.5</td></tr>
<tr><td colspan="2">SAI value</td><td colspan="2">45.5</td></tr>
</table>

As there is service loss, the SOI is not zero any more. From the above table, we can see that one service is lost and the other service is affected.

In this example, we can see that SOI and SAI can be grouped together to describe the running status of this transport network from the service loss perspective. In condition 2 of clause I.1, the <SOI, SAI> has the value pair of <0,100>; and in condition 3, the <SOI, SAI> has the value pair of <54.5, 45.5>, which indicates a worse condition of the network than the operational status of condition 2.

I.2 Example of early warning for circuit lines using SOI and SAI

In this clause, an example is provided to show the usage for SOI and SAI in early warning for circuit lines.

In the same network and services environment as condition 2 in clause I.1, the line between N5 and N6 breaks, as shown in Figure I.2. During this time, suppose we want to know which optical lines bear the most services, we can use the following method to calculate the corresponding SOI and SAI for each of the optical lines for the purpose of comparison.

Table I.2 shows the original SOI and SAI calculation under this situation (<SOI,SAI> = <0,100>). In order to provide early warning for the most risky circuit lines, we can use the following method: for each of the available optical lines within this transport network, assume one of them fails, and then calculate the SOI and SAI corresponding to this optical line; the one with the highest <SOI, SAI> value composition is the most risky one, and should be taken care of more than the others.

Table I.4 shows the calculation result:

Table I.4 – SOI and SAI calculation of each line for early warning

Available optical lines	Supporting borne service		SOI values	SAI values
	Service A	Service B		
N6-N1	AFFECTED	OFF	72/192 × 100 = 37.5	120/192 × 100 = 62.5
N1-N2	OFF	OFF	192/192 × 100 = 100	0/192 × 100 = 0
N2-N3	AFFECTED	OFF	72/192 × 100 = 37.5	120/192 × 100 = 62.5
N3-N4	AFFECTED	OFF	72/192 × 100 = 37.5	120/192 × 100 = 62.5
N4-N5	AFFECTED	AFFECTED	0/192 × 100 = 0	192/192 × 100 = 100

From the above table, we can see that line N1-N2 has the highest SOI and SAI value pairs (<SOI,SAI> = <100,0>), if this line breaks, all the services will be lost. If two lines have the same assumed SOI value, the one with a higher SAI value will be considered to be more risky. The <SOI,SAI> value pair for line N4-N5 is <0,100>, which means that even if this line breaks, there will be no service lost. Compared to the original condition in clause I.1, condition 2, there is no change in the <SOI, SAI> value pair if N4-N5 breaks. This indicates that line N4-N5 is the least risky line under this situation.

In practice, there will be more services and network nodes than those provided in this example. A threshold for <SOI, SAI> will be set for early warnings. When some of the optical lines cross the predefined threshold, warnings will be sent to the operator for preparing backup schemes for such network components.

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