ATIS STANDARD

ATIS-0100025

A METHODOLOGY FOR ESTIMATING AVAILABILITY OF ACCESS IP ROUTERS IN TERMS OF CUSTOMER FACING LINE CARD AVAILABILITY

TECHNICAL REPORT

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ATIS-0100025, *A Methodology for Estimating Availability of Access IP Routers in Terms of Customer Facing Line Card Availability*

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ATIS-0100025

Technical Report on

A METHODOLOGY FOR ESTIMATING THE AVAILABILITY OF ACCESS IP ROUTERS IN TERMS OF CUSTOMER FACING LINE CARD AVAILABILITY

Alliance for Telecommunications Industry Solutions

Approved June 2009

Abstract

This Technical Report proposes a methodology for estimating the availability of IP-based Access Routers in terms of lost customer facing router line cards as a unit for access availability. The purpose is to stimulate interactions between service providers, equipment vendors, and suppliers in the development of appropriate reliability/availability SLAs.

FOREWORD

The Alliance for Telecommunication Industry Solutions (ATIS) serves the public through improved understanding between carriers, customers, and manufacturers. The Network Performance, Reliability, and Quality of Service Committee (PRQC) -- formerly T1A1 -- develops and recommends standards, requirements, and technical reports related to the performance, reliability, and associated security aspects of communications networks, as well as the processing of voice, audio, data, image, and video signals, and their multimedia integration. PRQC also develops and recommends positions on, and foster consistency with, standards and related subjects under consideration in other North American and international standards bodies.

The mandatory requirements are designated by the word *shall* and recommendations by the word *should*. Where both a mandatory requirement and a recommendation are specified for the same criterion, the recommendation represents a goal currently identifiable as having distinct compatibility or performance advantages. The word *may* denotes a optional capability that could augment the standard. The standard is fully functional without the incorporation of this optional capability.

Suggestions for improvement of this document are welcome. They should be sent to the Alliance for Telecommunications Industry Solutions, PRQC, 1200 G Street NW, Suite 500, Washington, DC 20005.

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1 SCOPE & PURPOSE

Availability is a key measure in Service Level Agreements (SLA) between service providers and their customers, as well as their vendors and suppliers. Metrics for estimating IP packet layer availability [Y.1540] and service level availability [ATIS-0100020.2008] have received considerable attention in various standards bodies.

At the same time, service providers need to constantly evaluate network element reliability; hence, availability metric estimation for network elements plays a critical role in SLA interactions with equipment vendors and suppliers. IP-based networks and related evolving technologies -- such as Multi-Protocol Label Switching (MPLS) -- are expected to form the basis for Next Generation Networks (NGN) and Services. The specifics of SLA interactions between service providers and IP equipment vendors are driven by the following:

- Degree of reliability and availability of individual network elements (e.g., Line Cards, Routers, etc.).
- Degree of redundancy built into the network design (e.g., redundant line cards).

Thus, the development of an appropriate availability metric, and subsequent techniques for metric estimation, can be very beneficial to service providers. An Technical Report, T1.TR.78-2003, proposed a metric for assessing the access availability of routers in IP-based networks by characterizing fractional availability of access routers in terms of lost ports that can be further weighted by some factor (e.g., port bandwidth).

This Technical Report proposes a methodology for estimating the availability of IP-based access routers in terms of customer facing router line card availability. This is based on what a customer experiences during network failure occurrences. If such failures result in downtime for the customer facing Line Card, then the Line Card is considered to be unavailable regardless of the actual failure. The purpose is to stimulate interactions between service providers, equipment vendors, and suppliers in the development of appropriate reliability/availability SLA's.

It should be noted that this methodology can also be applied to other types of packet network technologies. For example, it can be utilized to assess the access availability of line cards in Frame Relay switches.

2 NORMATIVE REFERENCES

The following standards contain provisions which, through reference in this text, constitute provisions of this Technical Report. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this Technical Report are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below.

[Y.1540] ITU-T Recommendation Y.1540 (2007), *IP Packet Transfer and Availability Performance Parameters*.[1]

[ATIS-0100020.2008] ATIS-A010020.2008, *Quantifying the Impact on IP Service Availability from Network Element Outages*.[2]

[T1.TR.78-2003] T1.TR.78-2003, *Access Availability of Routers in IP Networks*.[2]

[ATIS-0100008.2007] ATIS-0100008.2007, *DPM Metric for Transaction Services such as VoIP*.[2]

3 DEFINITIONS

3.1 Short Duration Outage: For the purposes of this document, a Line Card outage of duration less than one minute is considered to be a short duration outage.

4 ACRONYMS & ABBREVIATIONS

ATIS	Alliance for Telecommunications Industry Solutions
CPE	Customer Premise Equipment
DPM	Defects per Million
IP	Internet Protocol
ISP	Internet Service Provider
ITU-T	International Telecommunication Union -- Telecommunication Standardization Sector
MPLS	Multi-Protocol Label Switching
NGN	Next Generation Network
SLA	Service Level Agreement

5 OVERVIEW

Service providers need to constantly evaluate network element reliability; hence, availability metric estimation for network elements plays a critical role in interactions with equipment vendors and suppliers. An ATIS Technical Report, T1.TR.78-2003, proposed a metric for assessing the access availability of routers in IP-based networks This metric expresses average access router availability in terms of customer facing router ports, weighted by some factor (e.g., port bandwidth or number of customers), which are lost due to an element outage over a specified period of time. The use of customer facing ports as a unit enables the determination of fractional loss of any given router.

The current and future ability of operational systems that can effectively track the status of customer facing ports, further weighted by some factor (e.g., port bandwidth), is a critical question. The advantage of such systems is that the granularity offered in tracking ports is significant; accurate

[1] This document is available from the International Telecommunications Union. < http://www.itu.int/ITU-T/ >

[2] This document is available from the Alliance for Telecommunications Industry Solutions (ATIS), 1200 G Street N.W., Suite 500, Washington, DC 20005. < https://www.atis.org/docstore/default.aspx >

estimation of router availability is greatly enhanced by such systems. On the other hand, there are considerable challenges in the use of customer ports to assess access availability:

- In a large IP backbone network, the number of customer facing ports could be excessively large, requiring significant development in tracking systems with additional downstream analytical capabilities.
- Port weighting can be done by some factor that is arbitrarily chosen. For example, port bandwidth may be convenient in some cases, whereas the number of customers may be more appropriate in others. Regardless of the choice of factors, additional strains on operational complexity are introduced as a result.

A service provider may therefore find it advantageous to consider router Line Cards as a unit for estimating the access availability metric. While Line Card use for metric estimation offers a lesser degree of granularity, it does offer the following advantages over customer ports:

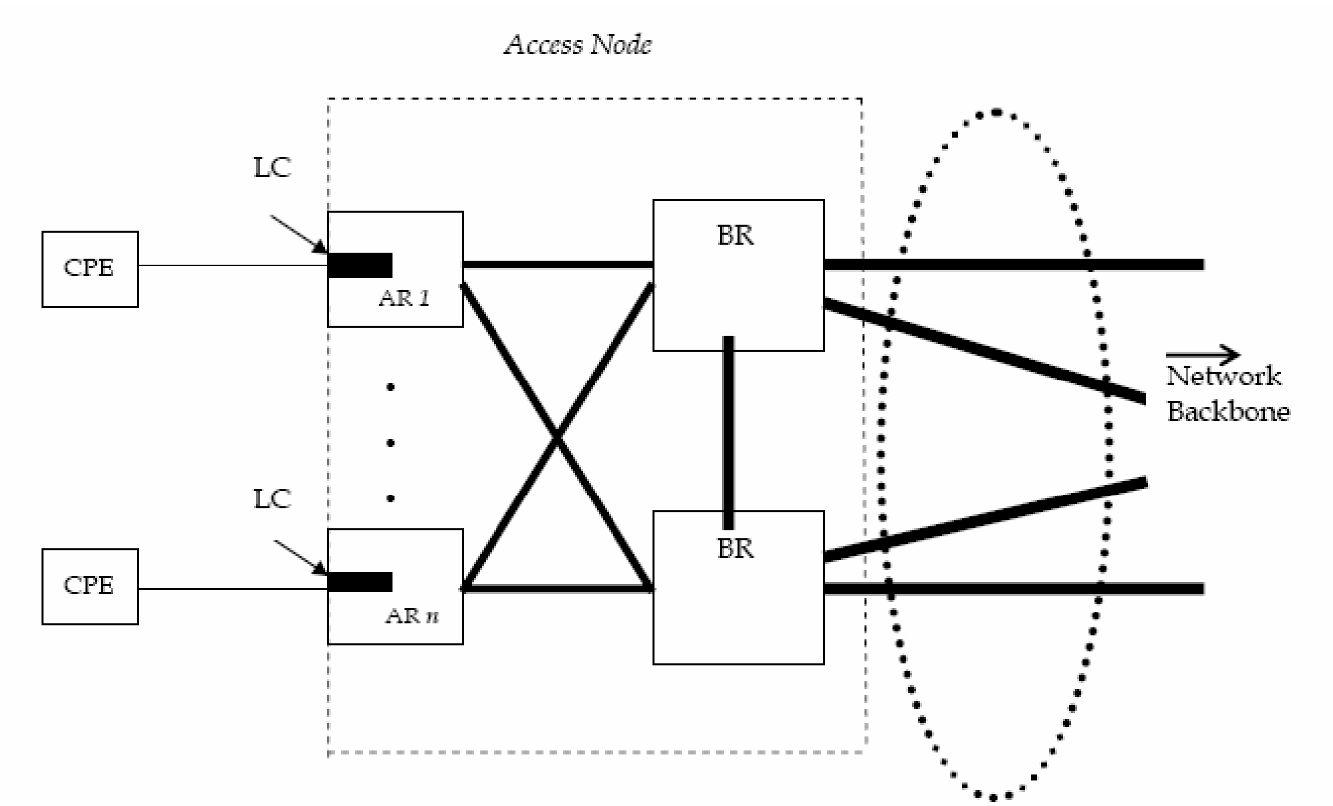
- A very common cause for customer port failure is failure of the Line Card itself. And subsequently, port failure is typically resolved by replacing the entire Line Card.
- Tracking the status of router Line Cards offers a simplified approach towards development of operational systems having acceptable levels of complexity. The number of Line Cards is significantly less than the number of ports for tracking purposes. Further, Line Cards need not be weighted by some arbitrary factor.

This document describes a system for tracking router Line Card status to estimate this metric. However, this method can be applied to ports as well. The choice – and expense – of developing the proper estimation process, whether utilizing Line Cards or ports, is left up to individual service providers.

6 IP Network Elements

This clause describes a fairly general IP Access Network. This network comprises all elements responsible for delivering transactions from the Customer Premise Equipment (CPE) at a customer location into the IP network backbone.

One common component to all these elements is the Line Card that houses Customer Ports. These Line Cards are on the “drop side” of an Access Router, where facilities from a customer’s CPE terminate on individual ports on the Line Cards. A failure in any element in the Access Network may result in downtime for individual ports on the Line Cards or on the entire Line Card on the Access Router. Such failures prevent delivery of customer transactions to the backbone.



KEY	
AR:	Access Router
BR:	Backbone Router
LC:	Customer Facing Line Card

Figure 1 : Access Network Elements

There are five element types in a typical IP Access Network topology (Figure 1) whose failure can cause downtime for Line Cards[3] directly or indirectly. Elements whose failures directly impact downtime are:

1. *Line Card on the customer facing side*. Any failure in the electronic or optical components of the Line Card that causes traffic interruption will result in Line Card downtime.
2. *Access Routers that form an edge on an Internet Service Provider (ISP) backbone network*. Line Card downtime can be caused by a failure in a router component or from a total router failure.

Line Card availability estimation can then be done (see Clause 7) based on these failures for each combination of {Router Class, Line Card Type}. A *Router Class* is a set of identical access routers from a single vendor. The use of such sets can enable metric estimation for different router vendors. For example, if a network has routers from two separate vendors and each vendor produces two unique

[3] Only transport layer failures that directly impact customer facing Line Cards are considered for this document as shown in Figure 1 (access and backbone routers, their components, and facilities linking them). Failures of non-transport layer elements (e.g., service/application layer elements) are not considered.

types of routers, then the total number of access routers in the network can be grouped into four Router Classes – one for each (vendor, router type) combination. The metric can then be estimated for Line Card type within any given Router Class.

Network elements whose failures may indirectly impact Line Card downtime are:

3. *Facilities and supporting elements such as cross-connects, which link Access Routers to Backbone Routers*. To increase the availability of the Access Network, an ISP usually provides redundancy by connecting each Access Router to two Backbone Routers at the same access node using two independent sets of uplinks[4] (Figure 1 depicts a typical access node with several Access Routers and two Backbone Routers). This permits customer traffic to enter the backbone in the following failure scenarios:
   - A failed uplink.
   - A failed card supporting an uplink.
   - A failed Backbone Router at the access node.

   If all facilities linking an access router to a backbone router fail, then all Line Cards at the access router will experience downtime.
4. *Backbone Routers linked to Access Routers*. As shown in Figure 1, if both Backbone Routers at an access node fail (a rare event), then all Line Cards on the Access Routers at this node lose connection to the backbone.
5. *Facilities linking Backbone Routers at an access node, to backbone routers at other backbone nodes*. Such facility failures decrease the available bandwidth from Access Routers to the backbone. Note that if all Backbone Router uplinks at an access node fail (a rare event), then all Line Cards on the Access Routers at this node lose connection to the backbone.

Impacts on Line Cards from such failures are extremely rare, as service providers typically have redundancy in the backbone (all elements that may indirectly cause Line Card downtime). Full redundancy in terms of facilities dual homing the access routers to pairs of backbone routers are intended to serve this purpose.

In summary, the access Line Card acts as a common denominator for all of the above failure types. Any one of these failures results in downtime for the impacted Line Cards. The goal of this document is to describe how the Line Card unavailability contribution from these failure types attributed to vendor related defects can be estimated.

7 AVAILABILITY METRIC FOR ROUTER LINE CARDS

Increasing variety of access routers and access line cards justifies an approach where average availability is evaluated separately for each {Router Class, Line Card Type} combination (see Clause 6). Consider a set of access routers of the same class with J types of access line cards which are monitored for failures during time interval of length T. For each customer impacting failure $i, i = 1, \ldots, L$, the number n_{ij} of type j cards affected and its duration t_{ij} is recorded. In case of redundancy, the failure of the active (primary) line card is not counted if the failover to the backup card was hitless. Otherwise,

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[4] An uplink is a facility (e.g., DS3, OC-3, OC-48) connecting any access router to a backbone router.

only failures of active cards are counted. The average unavailability of type j access line card is calculated as:

$$U_j = \frac{\sum_{i=1}^{L} n_{ij} t_{ij}}{N_j T}$$

where N_j is the total number of type j active cards. The average unavailability can be expressed as:

$$U_j = \frac{R_j}{M_j} \tag{1}$$

Where:

$$R_j = \frac{\sum_{i=1}^{L} n_{ij} t_{ij}}{\sum_{i=1}^{L} n_{ij}} \tag{2}$$

is the average repair time, and:

$$M_j = \frac{N_j T}{\sum_{i=1}^{L} n_{ij}} \tag{3}$$

can be interpreted as the average time between router failures impacting customers on access line cards of type j. Metric M_j can be considered as an extension of the traditional field hardware MTBF. For the field MTBF, only individual line card failures which require card replacement are counted in the denominator. In M_j, all card failures outside the maintenance window including those caused by reset, software bugs, and all impacted cards of type j in case of entire router failure are counted. This distinction is important since the metric needs to accurately represent the impact on customers resulting from all types of card failures, not just total card failures. For example, each time that a line card is reset, this causes a protocol re-convergence event resulting in short duration packet loss.

Metrics R, M, and U can be also defined for the entire population of access line cards without differentiating failure by LC type. Denote:

$$N = \sum_{j=1}^{J} N_j, \quad n = \sum_{j=1}^{J} \sum_{i=1}^{L} n_{ij}, \quad t = \sum_{j=1}^{J} \sum_{i=1}^{L} t_{ij}.$$

Then:

$$R = \frac{t}{n}, \quad M = \frac{NT}{n} \tag{4}$$

and the average unavailability:

$$U = \frac{R}{M}. \tag{5}$$

The value of using M_j in addition to the average unavailability is demonstrated by the following example.

Example: Consider a set of 400 access routers of a given class (from a single vendor) and let $T = 1000$ hours. Each router has two cards of type 1, three cards of type 2, and five cards of type 3. In case of single card failures, $n_{ij} = 1$ if Line Card of type j failed and $n_{ij} = 0$ otherwise. In the case of entire router failure, $(n_{i1}, n_{i2}, n_{i3}) = (2,3,5)$. In this example, assume constant failure duration $t_{ij} = t_j$ of type j cards and a constant duration of the entire router failure. The failure duration is measured in hours. The number of failures for the entire router and each card type with their duration is given in Table 1. The failure parameters in Table are referred to as Scenario 1. We also consider Scenario 2, where the only difference with Scenario 1 is the increase in the number of routers failures from 1 to 5.

Table 1: Scenario 1 -- Number of failures and their duration

Failure	# Failures	Duration
Router	1	0.1
LC Type 1	30	0.8
LC Type 2	6	1.5
LC Type 3	2	0.5

The reliability metrics for two scenarios are given in Table 2. The results in columns *R* and *M* for Line Card Type $j, j = 1,2,3$ and for All Cards are calculated using (2), (3) and (4) respectively. The unavailability for LC Type $j, j = 1,2,3$ and for All Cards is calculated using (1) and (5) respectively. The Defects per Million (DPM) [ATIS-0100008.2007] is a commonly used metric that is obtained by multiplying the respective unavailability by 1,000,000.

Table 2: Reliability Metrics

LC Type	Scenario 1				Scenario 2			
	R	*M*	*Availability*	DPM	*R*	*M*	*Availability*	DPM
1	0.76	25,000	99.9970%	30.25	0.63	20,000	99.9969%	31.25
2	1.03	133,333	99.9992%	7.75	0.50	57,143	99.9991%	8.75
3	0.21	285,714	99.9999%	0.75	0.13	74,074	99.9998%	1.75
All Cards	0.73	83,333	99.9991%	8.75	0.44	45,455	99.9990%	9.75

Note that for All Cards, DPM are below 10 in both scenarios, implying a high availability exceeding 99.999% (five nines), while the average time between customer impacting failures M in Scenario 2 is almost half of that in Scenario 1. Therefore, DPM -- in contrast with average time between customer impacting failures -- is not sensitive to the frequency of short failures of the entire router. If an ISP were only tracking DPM and router outages increased from one outage per 1000 hours to five outages per 1000 hours, it might miss the significant decrease in reliability as seen from the customer's perspective.

The metrics in the All Cards row hide a low average time between failures and high DPM for LC Type 1 in both scenarios. The average time between customer impacting failures by LC type amplifies the difference between the two scenarios. For example, for Type 3 the average time between failures M_3 decreased almost by a factor of four in Scenario 2 in comparison with Scenario 1. This example illustrates the importance of measuring reliability metrics by type of access line cards. It also illustrates the significant impact that even short duration outages of an entire router have on reliability.

8 ESTIMATION PROCESS FOR ACCESS LINE CARD FAILURES

The recording and estimation of the failures for Access (customer facing) Line Cards is described in this Clause. Line Card failure modes include the following:

- Hardware or software malfunction of individual Line Card, as well as Card reset with automatic recovery ⇔ 1 Line Card failure.
- Failure of entire router ⇔ all Line Cards on that router assumed to have failed.
- Failures of all uplinks from access router to backbone routers ⇔ all Line Cards on that router assumed to have failed.

The following failure modes are excluded:

- A failed Card(s) that has no customers provisioned on it (requires confirmation from appropriate records).
- A Card outage occurs during maintenance window (requires confirmation from service provider trouble tickets).
- In case of active (primary) card failure, switchover to the redundant Line Card occurs instantaneously.

A three step process can capture all failures as follows:

1. *Automated Scripts from Vendor*: Such scripts for elements such as Line Cards can accurately track short duration failures where Line Cards self-recover from errors such as parity errors. These scripts permit estimation of Line Card downtimes.
2. *Service Provider Network Management System (including router Syslog)*: In the event that the element in question -- such as Line Cards -- crashed, the vendor-provided automated scripts cannot record the failures. In such cases, the service provider Syslog system can record the failure event.
3. *Service Request Notification*: In some cases, the element may not have crashed, but an outage may have occurred requiring user intervention for recovery. For example, all user interfaces on a Line Card may have gone down, resulting in the generation of a Service Request Notification from the service provider to the vendor.

These rules can be implemented in an automated system from which the appropriate availability metrics can be estimated.