## ATIS-0100030.2012

# MEAN TIME BETWEEN OUTAGES – A GENERALIZED METRIC FOR ASSESSING PRODUCTION FAILURE RATES IN TELECOMMUNICATIONS NETWORK ELEMENTS

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ATIS-0100030.2012, *Mean Time Between Outages – A Generalized Metric for Assessing Production Failure Rates in Telecommunications Network Elements*

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American National Standard for Telecommunications

# Mean Time Between Outages –
# A Generalized Metric for Assessing Production Failure Rates in Telecommunications Network Elements

**Alliance for Telecommunications Industry Solutions**

**Abstract**

The Mean Time Between Outages (MTBO) metric provides the frequency of all telecommunications network element failures (hardware and software) attributed to equipment supplier – including customer impacting short duration outages. By contrast, the traditional Mean Time Between Failure (MTBF) metric only addresses total failures that lead to element replacement. The MTBO metric has been accepted as a key industry metric by the QuEST Forum/TL9000 organization.

# Foreword

The information contained in this Foreword is not part of this American National Standard (ANS) and has not been processed in accordance with ANSI's requirements for an ANS. As such, this Foreword may contain material that has not been subjected to public review or a consensus process. In addition, it does not contain requirements necessary for conformance to the Standard.

The Alliance for Telecommunication Industry Solutions (ATIS) serves the public through improved understanding between providers, customers, and manufacturers. The Network Performance, Reliability, and Quality of Service Committee (PRQC) 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.

ANSI guidelines specify two categories of requirements: mandatory and recommendation. 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.

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.

This version of ATIS-0100030 replaces ATIS-0100030.2010, *Mean Time Between Outages – A Metric for Assessing Production Failure Rates in IP Routers*. The historical version of ATIS-0100030.2010 can be accessed by sending a completed ATIS Research Request Form, which is located at < http://www.atis.org/docstore/ATIS_Research_Request.pdf >. To request the historical version of ATIS-0100030.2010, please return completed form to ATIS via email to < doccenter@atis.org > or via fax to 202-347-7125, Attn: Kerrianne Conn.

At the time it approved this document, PRQC, which is responsible for the development of this Standard, had the following leadership:

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# 1   Scope & Purpose

Telecommunications Service Providers (SPs) face the challenge of needing to continuously upgrade the network and grow network capacity, while providing a service that meets stringent customer reliability expectations. While telecommunications companies have significant experience providing reliable telephone service, the challenge for an SP is more difficult because changes in Internet technology -- particularly router software -- are significantly more frequent and less rigorously tested than was the case in circuit-switched telephone networks.  SPs cannot wait until the technology matures – a large SP has to meet high reliability requirements for critical applications like financial transactions, Voice over IP (VoIP), Internet Protocol Television (IPTV), streaming video, telepresence, and on-line gaming using commercially available technology. The most critical driver for high reliability requirements is that these applications are very sensitive to short interruptions (~1 second) that arise from component glitches with self-restoration. Such outages are different from hardware failures which require component replacement whose frequency is captured in the traditional Mean Time Between Failure (MTBF) reliability metric.

An initial examination of the inability of the MTBF metric to adequately address short duration outages was undertaken in [ATIS-0100025] and the first publication of ATIS-0100030[1]. The focus of this effort was on the SP edge router, which is recognized as the key element of modern day Internet-based SP networks. Routers comprise a wide range of components such as line, control, and switching cards, as well as power supplies and cooling units – typically from multiple equipment suppliers -- leading to the possibility of several types of failures with different customer impacts. The Mean Time Between Outage (MTBO) metric was introduced as a practical method to characterize the impact of all outages, including short duration outages, by defining MTBO in terms of failure frequency of Customer Facing Line Cards.

This document generalizes the MTBO metric definition as an industry standard applicable for any type of network element and provides additional illustrative examples for metric development and assessment for the following:

- Set of Software Controlled Devices (power amplifiers in the UMTS nodeB)

- Ethernet Virtual Connections (eVC)

- Radio Network Controller (RNC)

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[1] This version of ATIS-0100030 replaces ATIS-0100030.2010, *Mean Time Between Outages – A Metric for Assessing Production Failure Rates in IP Routers*.  The historical version of ATIS-0100030.2010 can be accessed by sending a completed ATIS Research Request Form, which is located at < http://www.atis.org/docstore/ATIS_Research_Request.pdf >. To request the historical version of ATIS-0100030.2010, please return completed form to ATIS via email to < doccenter@atis.org > or via fax to 202-347-7125, Attn: Kerrianne Conn.

# 2   Normative References

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

[ATIS-0100025] ATIS Technical Report ATIS-0100025 (2009), *A Methodology for Estimating the Availability of Access IP Routers in Terms of Customer Facing Line Card Availability.*[2]

[Telcordia SR-332] – Telcordia Document Number SR-332 (2011), *Reliability Prediction Procedure for Electronic Equipment.*[3]

[TL9000-Hbk] QuEST Forum TL9000 *Quality Management System, Measurements Handbook*, Release 4.5 (2010).[4]

# 3   Definition

For a list of common communications terms and definitions, please visit the *ATIS Telecom Glossary*, which is located at < http://www.atis.org/glossary >.

**3.1   Mean Time Between Outage**: Ratio of Time Period of Operation and the Total Number of Outages Observed over that Period.

# 4   Acronyms & Abbreviations

| | |
|---|---|
| AR | Access (Edge) Router |
| BFD | Bi-directional Forwarding Detection |
| BR | Backbone Router |
| CPE | Customer Premise Equipment |
| eVC | Ethernet Virtual Connection |
| IP | Internet Protocol |
| ISP | Internet Service Provider |
| LC | Line Card |
| LTE | Long Term Evolution |
| MTBF | Mean Time Between Failure |
| MTBO | Mean Time Between Outage |
| P-MTBF | Predicted MTBF |
| PSTN | Public Switch Telephone Network |
| RNC | Radio Network Controller |
| SLA | Service Level Agreement |

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[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 >

[3] Telcordia documents are available from Industry Direct Sales, Telcordia, 8 Corporate Place, PYA 3A-184, Piscataway, NJ, 08854-4156, or: < http://telecom-info.telcordia.com >.

[4] This document is available from < http://www.tl9000.org/handbooks/measurements_handbook.html >.

| SPOF | Single Point of Failure |
|------|-------------------------|
| SP | Service Provider |
| UMTS | Universal Mobile Telecommunications System |
| UTRAN | UMTS Terrestrial Radio Access Network |
| VoIP | Voice over IP |

# 5   Overview

The motivation for the derivation of the MTBO metric and its application for IP-based routers is described in [ATIS-0100025] and in the first publication of ATIS-0100030.2010 as follows:

- *Internet Service Providers (ISP) Challenge* -- While traditional PSTN-based telecommunications companies have significant experience providing reliable telephone service, the challenge for an ISP is more difficult because changes in Internet technology -- particularly router software -- are significantly more frequent and less rigorously tested than was the case in circuit-switched telephone networks.

- *Pivotal Role of Routers and Variations in Router Component Reliability* – The key component of an ISP network is the router; hence the immediate focus on router reliability. The field reliability of modern provider edge routers, which have a large variety of interface cards, cannot be accurately characterized by a single downtime or reliability metric because it requires averaging the contributions of the various router components that may hide the poor reliability of some components.

- *MTBO Positioned as a Practical Application of Traditional MTBF* – Failures in router elements go beyond the traditional view of failures whereby *only element failure leading to total replacement is considered for MTBF*. In reality, there are other transient modes of failure such as software glitches that also lead to downtime for customer facing line cards. MTBO counts all failures that affect customer downtime besides physical replacement.

Consequently, the initial focus of MTBO development in the first publication of ATIS-0100030.2010 is exclusively from a router perspective – customer facing line card downtime is the driver for MTBO estimation. Typically, a service provider Operations organization applies the MTBO metric across different routers and switches, including redundant configurations. In a redundant configuration, a line-card failure is counted against MTBO only if there is no failover to the redundant card. As one could expect the MTBO goal (target) for the redundant configuration is much higher than that for a configuration without redundancy. For example, if the MTBO goal for single point of failure (SPOF) configuration is 100,000 hours, and the coverage factor is 0.99, then for a configuration with redundancy the MTBO goal will be 100,000/(1-0.99)=10,000,000 hours.

In fact, the MTBO concept can be applied to any and all forms of telecommunication network elements, including elements with redundancy. Given that the rapid pace of current telecommunications technologies spanning wireline and wireless networks is inevitable, it makes sense to try and manage equipment supplier product reliability that includes transient failures in addition to the more traditional type of MTBF physical replacement scenario. The following examples illustrate the applicability (and advantage) of the MTBO concept:

1. *Any Software Controlled Device:* For example, a transmission power amplifier in the UMTS nodeB or the LTE eNodeB will be turned off when its temperature exceeds some threshold, and then turned on when its temperature decreases to a normal level. The number of such temporary outages with automatic recovery can be counted against MTBO. In particular, a defective amplifier may have smaller MTBO in comparison with its predicted hardware MTBF. In such cases a proactive replacement in the maintenance window can be issued that will prevent the production failure.

2. *Set of Software Control Devices:* The UMTS elements such as nodeB and RNC, the LTE elements such as eNodeB, etc., consist of a set of devices (subsystems), some of which are redundant. Failures of these devices (subsystems) may cause partial or complete service interruption for customers. The MTBO metric can be calculated per device like in the previous example, or per element where device outages can be generally weighted according to their customer impact. Equal weighting is applied if we do not differentiate between partial and complete outages.

3. *Ethernet Quality Assessment:* The MTBO metric can be applied to the quantification of quality of the Ethernet connection between two routers based on the number of timeouts of a specific protocol like Bi-directional Forwarding Detection (BFD). The intent is to test for frequency of short duration outages of the Ethernet connection.

This revision provides a generalized definition of the MTBO metric (Section 6). It retains the application of the metric to the Customer Facing Line Cards (Section 7). It then provides descriptions of applying the metric to additional situations described above (Section 8).

# 6  Generalized MTBO Definition

In modern telecommunication networks, many electronic and media (e.g., Ethernet) components have short-time outages with automatic recovery. These outages may remain undetected because of their short duration (of the order of one second) but they have severe impact on services like VoIP/LTE, Telepresence, and any video application. The outage detection and respective outage time measurement can be done using fault detection alarms, BFD protocol, SLA protocol, etc. These measurements are used for the MTBO calculation in given time interval *T* as follows:

$$MTBO = \frac{T \times (Total\ Number\ of\ Components)}{Number\ of\ Outages}$$

# 7  MTBO & Network Production Failure Rate – Use of Customer Facing Line Cards

A typical IP router consists of line cards (LC) carrying traffic and shared equipment (e.g., router processor, switching elements, and cooling devices). Each of these components has predicted Mean Time-Between Failure (P-MTBF) offered by the equipment supplier using traditional Telcordia methodology [Telcordia SR-332], [TL9000-Hbk]. The P-MTBF metric is traditionally used to compare the predicted and production (or measured) failure rates of hardware elements in routers comprising service provider edge networks.

However, hardware failures leading to element replacement are not the only reasons for service disruption. Line cards and router processors operate under control of complex software systems (including packet transmission protocols) that may also experience failures leading to temporary downtime for these elements. Consider a set of identical Customer Facing Line Cards. For these cards, all outages caused by hardware and software, including the entire router failures, are counted. This count is used to calculate the production line card failure rate in a given time period (e.g., monthly) and the respective mean time between failures is referred to as MTBO.

ATIS Technical Report ATIS-0100025 [ATIS-0100025] described the use of a normalizing factor in determining the service availability impacts due to a variety of network element hardware and software outages. The use of Customer Facing Line Cards as the normalizing element was described in [ATIS-0100025] and the MTBO was briefly presented as a component of estimating service availability impacts arising from various outages. The rationale for utilizing Customer Facing Line Cards is repeated in this clause.

The Customer Facing Line Card is a common component to all elements that can cause service outages. These Line Cards are on the "drop side" of an Edge (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 (Edge) Router |
| BR: | Backbone Router |
| LC: | Customer Facing Line Card |
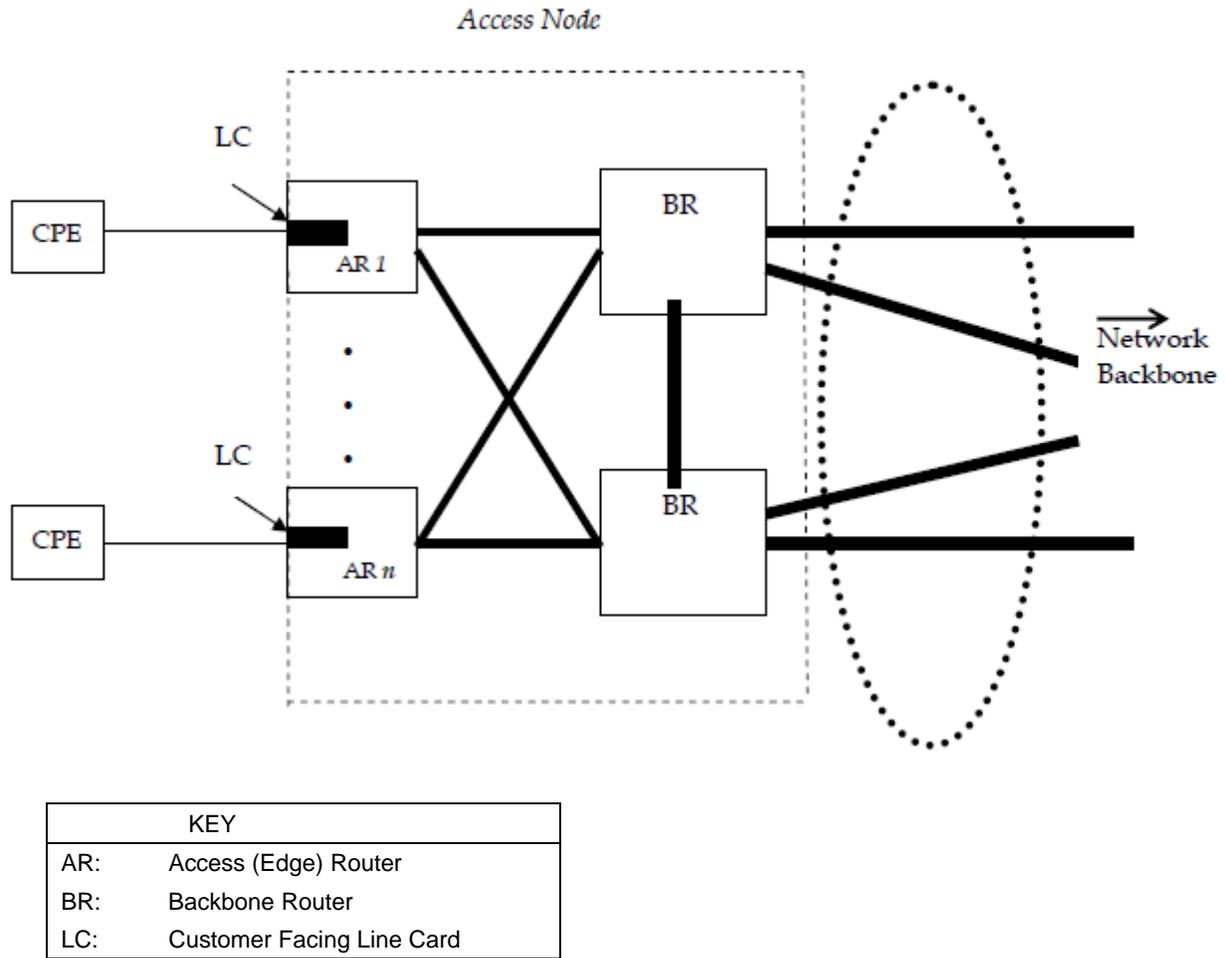
**Figure 1: Access Network Elements**

There are several element types in a typical IP Access Network topology (Figure 1) whose failure can cause downtime for Line Cards[5] directly or indirectly. Elements whose failures directly impact downtime are:

- *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.

- *Access (Edge) 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.

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

- *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[6] (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:

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[5] 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.

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

o    A failed uplink.

o    A failed card supporting an uplink.

o    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.

- *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.

- *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.

The estimation of MTBO and Production Failure Rates can then be done based on line card failure count caused by failures of customer facing line cards, both uplinks and the entire router 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 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 metrics can then be estimated for any Line Card type within any given Router Class.

The generalized MTBO metric defined above is adapted for each {Router Class, Line Card Type} combination as follows.

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, 2, …, L,* the number $n_{ij}$ of type *j* cards affected is recorded. Two points to note here:

- 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, only failures of active cards are counted.

- In case the entire router is down (due to router failure or due to downstream failures described in the previous clause), then all Line Cards on the router are considered to be down.

Let $N_j$ be the total number of Line Cards of type j in the given Router Class. Then, the MTBO metric for Class *j* type of Router Cards is denoted as:

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

Consequently, the Production Failure Rate metric associated with Line Card of type *j* can be written as:

$$PFR_j = 1/M_j$$

# 8   MTBO Application for Other Cases

MTBO application is illustrated with the following examples.

## 8.1   Set of Uniform Devices

Consider a set of uniform devices/boards such as power amplifiers in the UMTS nodeB.

Let $N$ be the total number of amplifiers and there were $n$ outages of these amplifiers during time interval with duration of $T$ hours. We count outages with automatic recovery as well as those outages where the failed amplifier was replaced to restore the service. Then:

$$MTBO = \frac{NT}{n}$$

One can expect that MTBO does not exceed the predicted hardware MTBF. However, a significant gap between MTBO and MTBF requires an explanation[7].

## 8.2   Ethernet eVC Connections

Consider a set of Ethernet Virtual connections (eVC) between the router co-located with the LTE eNBs (eNodeB) and the router that represents a concentrator node.

The BFD protocol can be used to detect short duration outages of eVCs. An outage starts when three consecutive BFD messages are lost. Let $N$ be the total number of eVCs and there were $n$ outages during time interval with duration of $T$ hours. Then:

$$MTBO = \frac{NT}{n}$$

## 8.3   Radio Network Controller

The Radio Network Controller (or RNC) is a governing element in the UMTS radio access network (UTRAN) and is responsible for controlling the nodeBs that are connected to it. The RNC carries out radio resource management, some of the mobility management functions, and is the point where encryption is done. RNC consists of several subsystems connected in a series. Each subsystem has a redundancy. A customer-impacting failure occurs only when the backup unit does take over when one of the active units fails. Partial and complete RNC failures are counted with the same weight. Let $N$ be the total number of RNCs in the SP network and there were $n$ customer impacting failures during time interval with duration of $T$ hours. Then:

$$MTBO = \frac{NT}{n}$$

> NOTE: The MTBO goal for redundant systems like RNC can be calculated using an appropriate Markov model and predicted hardware MTBF of RNC components.

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[7] Large number of devices (tens of thousands) in modern mobility network presents a challenge for short duration outage measurements and it requires an innovative distributed approach.

**Annex A**
(informative)

# A Estimation Process for Access Line Card Failures

The recording and estimation of the failures for Access (customer facing) Line Cards is described in this Annex. 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 (3) 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.