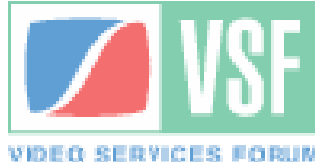


**Video Services Forum
Test and Measurements Activity Group
Report**



Recommended Video over IP Metrics

Summary

The Video Services Forum, Inc. (VSF) Test and Measurements Activity Group (AG) was created to identify and describe metrics required to accurately characterize packet-based network performance for streaming video transport over Internet Protocol (IP). This report includes metrics which are shown to assist with the following needs for a video over IP transport system:

1. Monitoring
2. Troubleshooting
3. Equipment performance compliance to standards and specifications
4. Verifying and measuring delivered service statistics
5. Equipment analysis and debug in the design through production life cycle phases

Each metric is accompanied by a description of why the metric is included, a brief description of its application to a video over IP transport system, and the location or application where the usefulness of the metric is recognized.

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Video Services Forum Test and Measurements Activity Group Report

1. Introduction

The Video Services Forum, Inc. (VSF) authorized Activity Group No.: 2005-1, titled: Test and Measurements in mid 2005. The Test and Measurements AG's goal is to identify and describe metrics required to accurately characterize packet-based network performance for streaming video transport over IP including networks incorporating Forward Error Correction (FEC) techniques. A goal in the process of identifying, describing, and recommending the metrics is to encourage the development of test devices which can measure the metrics.

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The Video Services Forum, Inc. (www.videoservicesforum.org) is an international association dedicated to video transport technologies, interoperability, quality metrics and education. The VSF is composed of [service providers, users and manufacturers](#). The organization's activities include:

- providing forums to identify issues involving the development, engineering, installation, testing and maintenance of audio and video services
- exchanging non-proprietary information to promote the development of video transport service technology and to foster resolution of issues common to the video services industry
- identification of video services applications and educational services utilizing video transport services
- promoting interoperability and encouraging technical standards for national and international standards bodies

The VSF is an association incorporated under the Not For Profit Corporation Law of the State of New York. [Membership](#) is open to businesses, public sector organizations and individuals worldwide. For more information on the Video Services Forum, contact Brad Gilmer, Executive Director, Video Services Forum, +1 404 310 4434, brad@gilmer.tv.

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1.1 Metric Applications

Video over IP transport metrics are useful for a number of system applications such as:

- Reducing Capital Expenses (CapEx) by selecting competitive equipment based on appropriate technical analysis and measurement.
- Reducing Operating Expenses (OpEx) of deployed systems by monitoring for correct system operation. Through monitoring appropriate metrics at proper transport locations, system faults can be identified, isolated, and repaired faster and with lower costs.
- Proof of transport system standards compliance. Monitoring video streams and transport systems with appropriate metrics for compliance to technical standards reduces incidences of equipment interoperability issues.
- Proof of quality delivery for business and competitive reasons. Monitoring delivered video stream quality with appropriate metrics provides a valuable database of performance metrics that can be used to justify corporate claims of best in class service, growth statistics, reliable advertising delivery, etc.
- Equipment design and performance verification. Equipment performance analysis and debugging throughout the design, prototype, and production process requires the use of appropriate metrics.
- Managing a service provider relationship. Metrics help a customer test a contracted carrier network link at the customer-provider demarcation point for performance and fast problem resolution without finger pointing.

This document includes metrics which are shown to significantly assist with requirements for a video over IP transport system. To summarize, the general requirements addressed are:

1. Monitoring
2. Troubleshooting
3. Equipment performance compliance to standards and specifications
4. Verifying and measuring delivered service statistics
5. Equipment analysis and debug in the design through production life cycle phases

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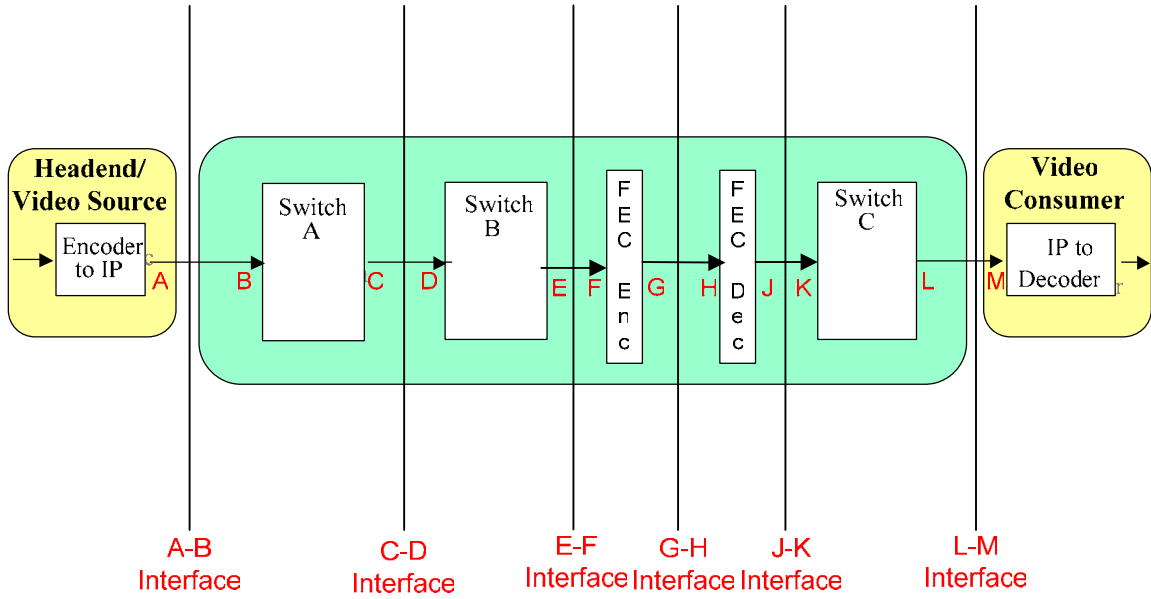
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2. Systems Overview

A system model is helpful in considering and defining Video over IP metrics. A generic, simplified Video over IP system is represented in Figure 1 with video streaming behavior such as:

- Video is typically compressed and encapsulated for ingest into the IP transport system as depicted at interface A. These functions may be part of an IPTV head-end facility, a Video on Demand server farm, a local ad insertion site, a contribution feed from a sporting event or other program origination site. Other video source locations can also be envisioned.
- Switch A represents edge switches or routers that aggregate multiple video sources such as off-air encoders, video servers, etc. For simplicity, the term “switch” throughout this document is used to represent either a layer 2 or layer 3 packet forwarding device. This stage typically results in a multi-stream aggregate data flow available for forwarding at interface C-D. Switch B represents one or more devices that may be part of a mesh of switches deployed over a geographic region for redundancy and connectivity such as shown in Figure 2.
- Certain links such as the G-H interface may have an unacceptable native packet error rate. The effective stream error rate performance for such links can be improved using FEC techniques. Using FEC, a source stream and an accompanying stream of repair packets are assembled in an FEC Encoder for forwarding across the link such as interface G-H with an unacceptable packet error rate. At the receive end of the link, an FEC Decoder utilizes the source stream and repair packet stream to improve the effective stream packet error rate such that the stream forwarded at interface J-K is similar to that at interface E-F in that the source stream is present without the repair packet stream.
- Switch C represents one or more edge devices that forward streams to individual stream consumers via edge equipment such as but not limited to Digital Subscriber Line Access Multiplexer (DSLAMs), Quadrature Amplitude Modulation (QAM), or FiberToThe X (FTTx) technology. In some cases the edge switches may directly forward streams to the stream consumers via Ethernet or other layer 2 protocols.

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**IP Network Core and Edge
Figure 1**

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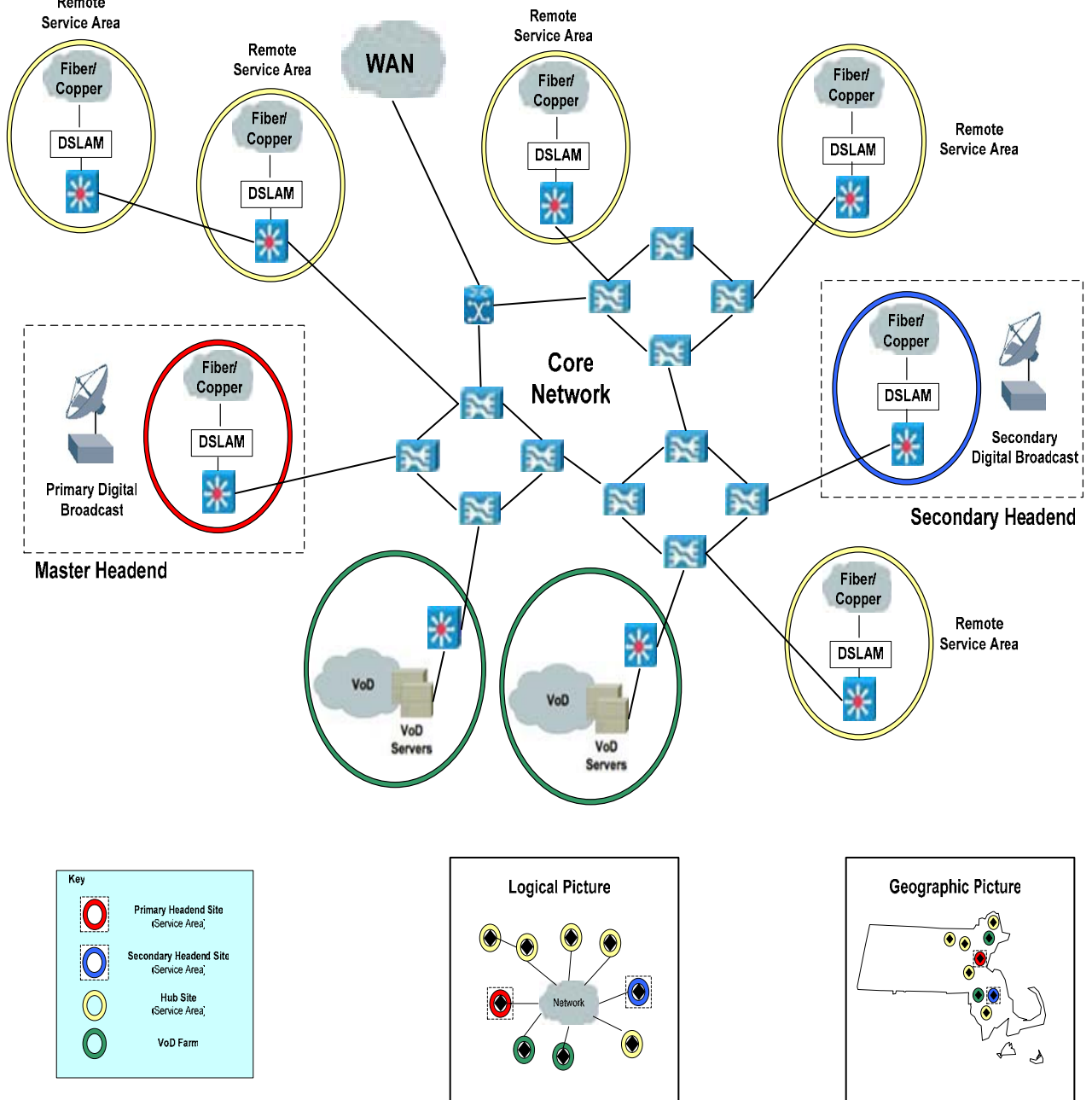


Figure 2
Regional Network Example

With the above system model and its transport focus, the metrics included in this document focus on measuring Jitter, Loss, and Delay – the impairments of interest in a video over IP transport network. Other IP stream metrics are included as well as certain stream payload metrics at the ISO 13818 Transport Stream level that facilitate identifying, characterizing, and troubleshooting certain stream behaviors.

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2.1 Monitoring

Monitoring is a continuous series of measurements on a stream or system often used to detect and locate fault conditions when they occur. A recommended strategy is to continuously measure and verify stream quality at the network ingest (encoder) A-B Interface location using Payload metrics, Transport Stream metrics, and IP Transport metrics (jitter and loss). Combining and comparing these measurements with continuous measurements of network Transport metrics throughout the IP network allow the rapid detection of faults, determination of whether a fault is payload or transport related, and the location of the fault permitting the dispatch of appropriate resources for repair procedures. It also allows warnings to be issued before actual user faults are sustained. See the Troubleshooting section for more details.

2.2 Troubleshooting

To minimize OpEx, it is important to rapidly detect, locate, and dispatch appropriate repair assets when a fault occurs in a deployed video transport system such as in Figure 2. This troubleshooting sequence is greatly facilitated with the availability of appropriate metrics and measurements. The following figures illustrate some example impairments which can be rapidly detected, isolated, and identified with the ready availability of stream measurements.

Figure 3 shows an example of a number of video flows being monitored at key switch locations. Metrics shown here include Media Delivery Index (MDI) for tracking cumulative jitter and loss on each flow throughout the network as well as transport stream parameters such as per Packet ID (PID) and per flow bit rates. An impairment occurring at the source causes measurements throughout the network to indicate the same fault. Although perhaps a somewhat difficult bookkeeping task, the fault location can be readily identified.

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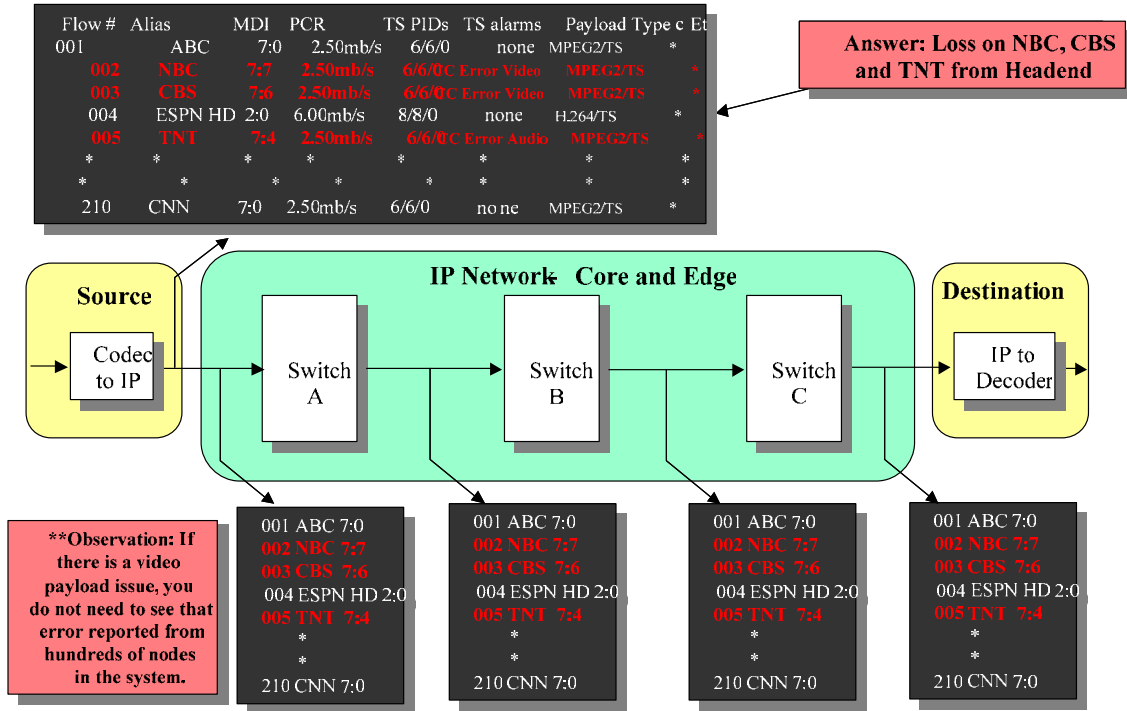


Figure 3. A simple video transport model and troubleshooting example using metrics to detect and locate impairments. Where and what is the problem?

Figure 4 shows an example of a number of video flows being monitored at key switch locations. Metrics shown here include MDI for tracking cumulative jitter and loss on each flow throughout the network as well as transport stream parameters such as per PID and per flow bit rates. A periodic loss impairment occurring within the network causes measurements downstream from the fault location to indicate the fault and the likely location of the fault.

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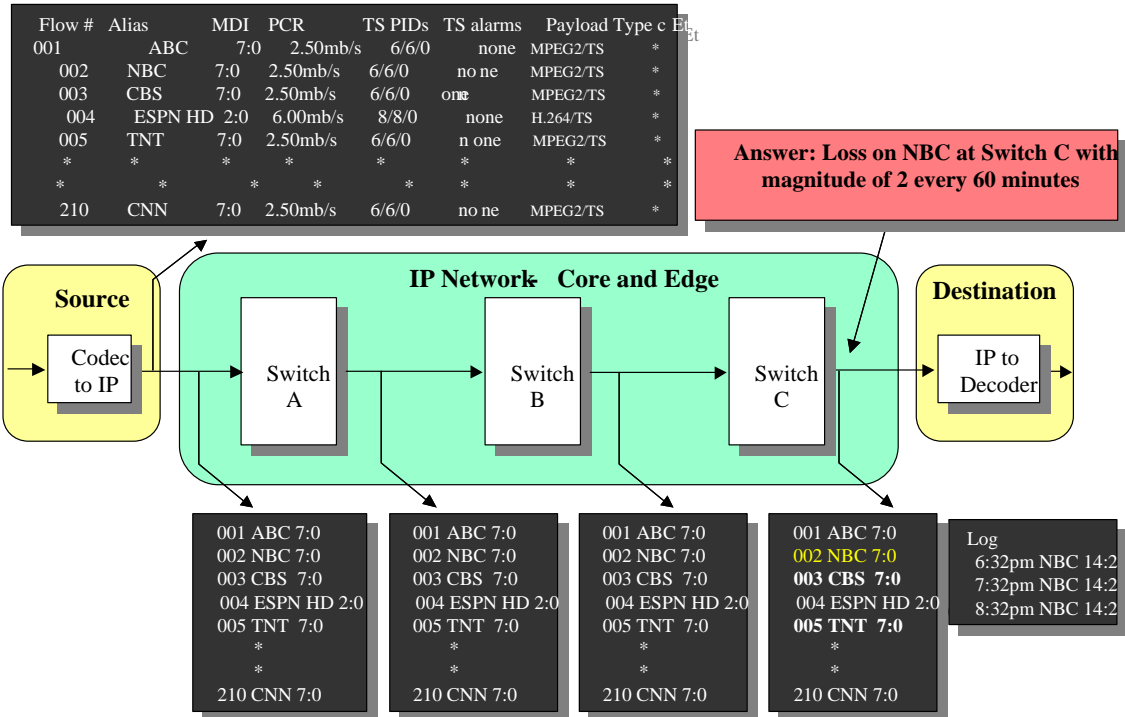


Figure 4. A simple video transport model and troubleshooting example using metrics to detect and locate impairments. Where and what is the problem?

Figure 5 again shows a number of video flows being monitored at key switch locations. Example metrics include MDI for tracking cumulative jitter and loss on each flow throughout the network as well as transport stream parameters such as per PID and per flow bit rates. A cumulative jitter variation occurring within the network causes measurements downstream from that location to indicate the cause and the likely location of the event causing the cumulative jitter variation. In this case, monitoring appropriate metrics on a distribution network can provide an early warning of possible transient congestion events or oversubscription before a flow suffers packet loss allowing preventative measures prior to users being impacted.

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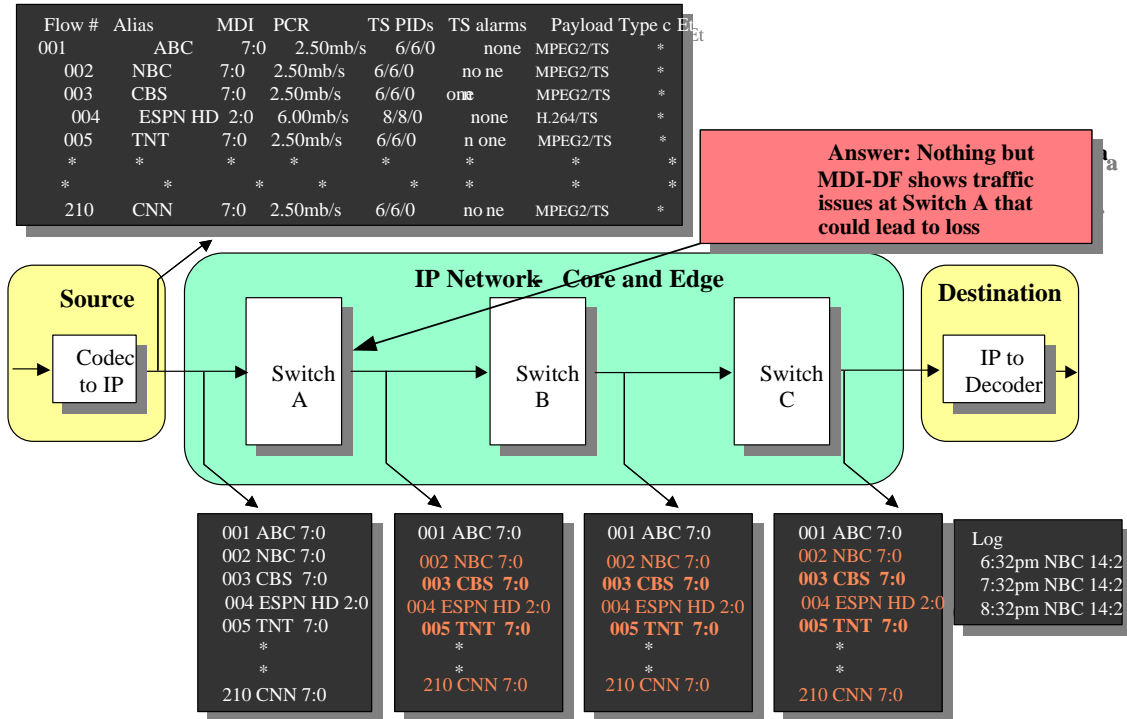


Figure 5. A simple video transport model and troubleshooting example using metrics to detect and locate impairments. Where and what is the problem?

2.3 Equipment Performance Evaluation

Reducing CapEx by selecting competitive equipment based on appropriate technical analysis and measurements is critical to meeting cost goals when deploying new systems. Improper selection of transport gear causes delays in reaching operational status and often wastes engineering resources troubleshooting issues that are often of a transient and difficult to locate nature. The use of appropriate test and evaluation procedures along with the appropriate metrics permit competitive performance evaluations and comparisons of transport gear. It also aids in the setup and configuration of the gear and enhances its operational effectiveness. As the recommended metrics highlight, loss and jitter are the primary impairments of concern in selecting and configuring the transport system.

For example, use of the MDI delay factor (DF) metric for cumulative jitter and the Media Loss Rate metric permits the evaluation of network devices for stream capacity and delay factor footprint testing of a device for stream capacity given input stream burstiness or delay factor. This footprint can be graphically shown using the following example MDI Characteristic Curves. This evaluation process is detailed in “Switch Testing for Streaming Media Applications” [1].

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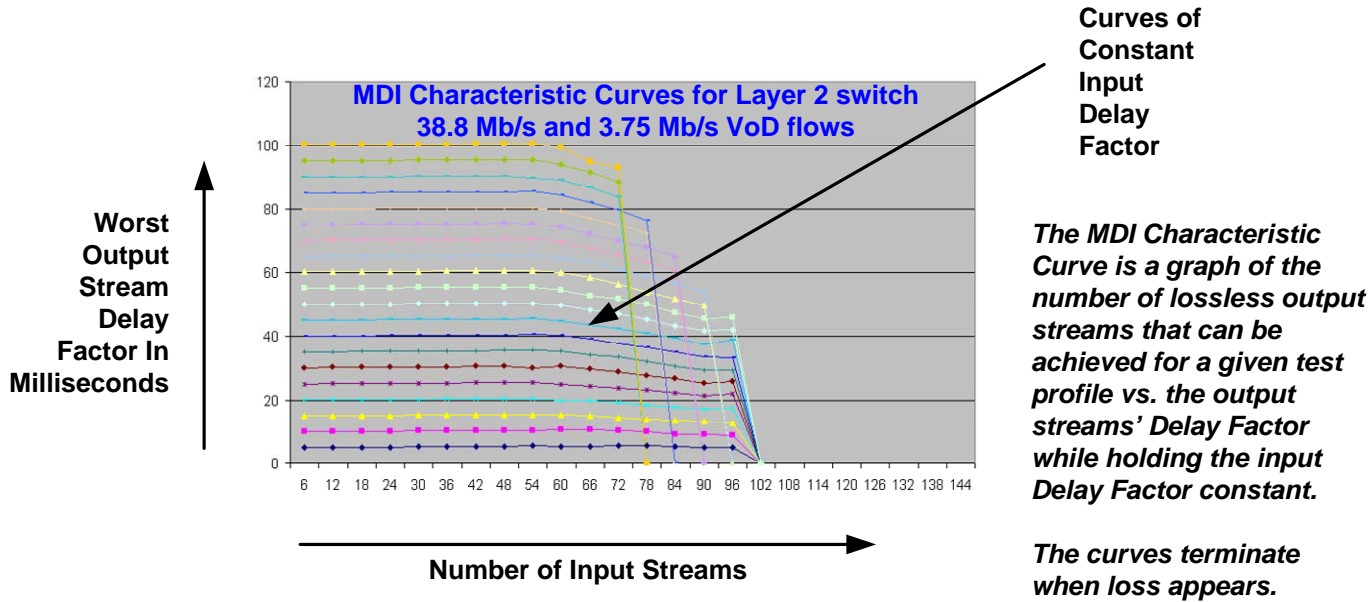


Figure 6. Example Equipment Evaluation using MDI Characteristic Curves

2.4 Verifying and Measuring Delivered Service Statistics

A service provider often needs to demonstrate the level of delivery system quality for streaming media. This can be required for meeting internal improvement objectives as well as for business and competitive purposes. Monitoring delivered video stream quality with appropriate metrics provides a valuable database of performance measurements that can be used to demonstrate corporate service quality, growth statistics, unimpaired advertisement delivery.

Metrics needed for this category should be tracked over particular time periods of interest and logged as needed for report generation. User demand, usage metrics and quality of experience (QOE) metrics such as channel change times are included in this category. Also included is impairment time binning such as the number of impairments in a 24 hour period and number of impaired seconds are also included in this category.

2.5 Equipment Analysis and Debug

Video over IP equipment and networking equipment intended for use with video over IP, like any other complex electronic systems, should be tested and debugged during the prototyping development phases. Furthermore it should be tested to assure that design performance objectives are met. System tests are often complex and require extended efforts due to the inherent flexibility of the gear. This type of equipment is often designed to be used in a wide variety of system applications and with a wide variety of payload types. Each of these stages of testing and analysis rely on many of the metrics described in this document for documenting performance levels and to assist in

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understanding the operation of the gear for redesign or reconfiguration when performance levels are unsatisfactory in an application.

3. Metrics Selection Criteria

Some metric types are more appropriate than others in assessing system performance and investigating and troubleshooting particular issues. This can depend on where the measurements are performed in the system and the system design; e.g., broadcast, switched broadcast, VoD, broadcast contribution, etc. It can also depend on the quality or phenomenon being investigated such as loss or jitter events, whether FEC is used at the measured location, whether impairments occur in the payload originating from an encoder, or whether an impairment is related to transport protocol layers only.

The following is a list of several types of metrics that are often utilized for the applications discussed in Section 2:

- **Payload (video compression)**
 - Compression standard compliance and coding artifacts.
- **Video Transport Stream**
 - Transport standard compliance, stream construction, table rates and PCR loss.
- **IP Transport Network**
 - IP Packet jitter, loss and delay.
- **Transaction**
 - Response time and reliability.
- **Display (video decoding)**
 - Artifacts, color accuracy and user visual acceptance.

This document focuses on the IP transport network. Video compression encoding and decoding phases are considered out of scope for this document. To meet the troubleshooting objective, there is a need to include some measures of the video transport stream to separate payload and encoder impairments from transport impairments. Also, video transport stream protocols can provide stream information to assist in determining IP transport performance. Many impairments result in an impaired picture display – the use of the recommended metrics in the appropriate combinations help to locate and discover the cause(s) of the impairments. This document provides some guidance in the application of the metrics but is not intended to be an exhaustive training tutorial.

Most IP transport networks now employ Quality of Service (QOS) mechanisms. For troubleshooting, one needs not only the metrics for loss and jitter but measures of utilization per flow type, per QOS marking, per VLAN, tracking all flows over time, encoded vs delivered dynamic bit rates, dynamic and logged stream inventory, dynamic MPTS stream content information and logged inventory, FEC parameter statistics, and various stream identifying information.

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The following criteria were used in evaluating, comparing, and selecting metrics included in this document.

3.1 Satisfies a Perceived or Demonstrated Requirement

Consideration was given to why a metric is important and should be included. The objective of the metric, how the metric could be implemented, where the metric may be applied in the system model, and an example application of the use of the metric were considered.

3.2 Metric Quality

Metric quality from the perspective of selecting the optimum metric for an application was considered. A metric's efficiency in capturing a behavior and its convenience and economy of calculation and use from a system perspective were considered. For example, where it applies, a metric should be "codec" agnostic, meaning the metric should work well in correlating the network impairment and the visual experience regardless which codec (MPEG2/4, VC1, wavelet...) is used. Also, the metric should be agnostic to the FEC algorithm, meaning whatever FEC algorithm is used, the metric should provide sufficient information to monitor, diagnose, and optimize the parameters of various FEC algorithms. It is also desirable that metrics should exhibit high correlation between the measured or computed data with an actual user's visual experience when possible and reasonable.

3.3 Cost Effective

Since one of the goals of identifying, describing, and recommending the metrics is to encourage the development of test devices which can measure these metrics, it is important that the metrics selected be open and non proprietary, relatively easy to capture and compute, and, if otherwise comparable in capability, should require minimal amount of storage for computation.

4. Recommended Metrics

This section lists and describes the recommended metrics. Included is a full description of the metric, how to calculate it, why it is important and where one might use it, a comparison to other metrics if appropriate, etc. Additionally, references to RFCs, ISO standards, or other readily accessible documentation which provide information about the metric are included.

Categorizing the recommended metrics puts their relevance in context. The categories specified in this section, as well as the individual metrics themselves, are summarized in the following Table.

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Loss Category	Media Loss Rate (MLR) (RFC 4445)
	IP Packet loss
	Packets Out of Sequence
	Packet Reordering with Defined Windows
	Frequency of N consecutive Lost Packets
	Sequential Loss frequency
	Mean time between Loss Periods
	Loss Distance
	Loss Period Length (RFC 3357)
	IP Loss Ratio
	Time between loss
	Ingress ≥ 2 loss in column
	Ingress 3- or 4-corner loss
	Number of Lost Packets in a Block of n Packets of Size N
	Blocks with loss
	Unrecoverable count
	Recoverable count
	Short duration block loss
	Long duration block loss
	Distribution of N consecutive Lost Packets
Duplicate Packets within a window N	
Jitter Category	Cumulative Jitter (RFC 4445)
	IP Packet Jitter/Packet delay variation/1-point Packet Delay Variation (ITU-T Y.1540)
	Mean Network Delay with Median, Maximum, and Minimum Variation Values
Loss and Jitter Category	Media Delivery Index (RFC 4445)
Delay Category	End to End delay distribution
Other Network Categories	Packet size variation
	Packet size distribution
	FEC OH%
	Decodable with Applied FEC
	Loss > protection
Payload Category	Packet stream bit-rate
Non Metric Category	FEC Block latency
	Block Size

4.1 Loss Category

IPTV which employs compressed video techniques is very sensitive to loss occurring during transport. Each loss event often causes a visible artifact when the stream is decoded and displayed. There are various ways to measure and quantify loss events for different uses. For example, to derive a QOE evaluation, one may need to know how often a loss event occurs; ie, whether it happens just once per minute, or several times a

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day, etc. If a link is configured with FEC, the length of loss in consecutive packets, the number of packets received without loss, etc. is important to determine if the FEC implemented can repair the loss. Troubleshooting links with loss may require more statistics about loss as might analyzing FEC or other equipment during design, analysis, or evaluation. Furthermore, various protocols stacks in common usage for video over IP may require one or more techniques to detect and track loss events. These various purposes help explain why there are a number of metrics in this category.

4.1.1 Parameter Name: Media Loss Rate (MLR) (RFC 4445)

4.1.1.1 Definition and Measurement Units

The Media Loss Rate is the number of media packets lost per second as described in “A Proposed Media Delivery Index”, RFC 4445 [2]. If the video stream is encapsulated in MPEG Transport Streams as described in ISO 13818-1 [3], then a media packet is defined as a Transport Stream packet. If the video stream does not use Transport Stream encapsulation, then the media packet is the UDP/IP packet, possibly with an RTP layer, that encapsulates a group of video bits, possibly variable in number, of the video stream.

The unit of measure is an integer number of packets per second.

4.1.1.2 How to Measure

Media packet loss is detected by monitoring flow sequence numbers if using RTP or an encapsulation protocol that incorporates a sequence number. Monitor the continuity counter if ISO 13818-1 Transport Streams are used with a protocol stack that has no sequence numbers. For the Transport Stream case, the rules for incrementing the continuity counter such as disregarding null mpeg packets, not incrementing media packets with a set discontinuity indicator, etc. must be taken into account to correctly determine media packet loss.

Reporting the minimum, maximum, and average value of MLR over a measurement period is desirable. It is desirable to permit setting threshold values for MLR and logging when MLR exceeds the set threshold for monitoring applications. It is desirable that MLR be measured for all streams present on a link simultaneously to assure timely and reliable fault detection and for fault type characterization. It is desirable that a running total of the number of lost media packets over the life of the measurement be captured as well as the total number of lost packet values over intervals such as 15 minutes and 24 hours as these are useful in assessing acceptable transport system performance, for competitive equipment evaluations, and for product development purposes.

4.1.1.3 Why This Metric is Important

As described in section 4.1, IPTV using compressed video techniques is sensitive to any loss occurring during transport. Each loss event often causes a visible artifact when the stream is decoded and displayed. Loss measurements on live streams are required to

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determine the dynamic performance of the transport system and no other metric is included here to detect and measure loss events for streams that employ protocol encapsulations such as UDP/IP that have no sequence numbers that can be utilized for loss detection. Since it is expressed as a rate, it is convenient to use as a measure for continuous live streams where it is important to dynamically detect a loss event and determine its magnitude for fault detection and isolation.

4.1.1.4 Metric reference documents

Refer to “A Proposed Media Delivery Index”, RFC 4445, for additional information and a description of MLR.

4.1.1.5 Recommended Measurement Location

Referring to Figure 1, MLR is a useful metric to detect and quantify media packet loss at all identified interfaces. The per flow MLR on interface G-H should be assessed in conjunction with its accompanying FEC repair flow.

4.1.1.6 Applications for this Metric

Detecting and quantifying media packet loss has applications in performance monitoring for deployed systems, troubleshooting deployed and prototype systems, assuring equipment performance compliance to standards and specifications, verifying and measuring delivered service statistics, and during equipment analysis and debug in the design through production life cycle phases. It is the principal impairment that is of interest as a result of a fault in a video over IP transport system.

4.1.2 Parameter Name: IP Packet loss

4.1.2.1 Definition and Measurement Units

IP Packet Loss is the number of IP packets lost over a pre-defined measurement period. The measurement period must be noted with the reported value.

The unit of measure is an integer number of packets.

4.1.2.2 How to Measure

IP packet loss is detected by monitoring flow sequence numbers if using RTP or another encapsulation protocol that incorporates a sequence number. However, if a protocol stack is utilized that does not include sequence numbers, then packet loss should be determined by counting packets at an ingest locations at different points on the network and comparing those counts to downstream locations per flow. This approach may best suit test and lab networks as well as out of service networks where flows can be interrupted periodically for performing measurements.

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It is desirable to permit setting threshold values for IP packet loss and logging when IP packet loss exceeds the set threshold for monitoring applications. It is desirable that IP packet loss be measured for all streams present on a link simultaneously to assure timely and reliable fault detection and for fault type characterization. It is desirable that a running total of the number of lost IP packets over the life of the measurement be captured as well as the total number of lost packet values over intervals such as 15 minutes and 24 hours. These are useful in assessing acceptable transport system performance, competitive equipment evaluations, and product development purposes.

It is suggested that the following factors be taken into consideration when computing this metric.

1. Loss Period: The loss period for packet loss should be pre-defined.
2. Inter-packet arrival times: There should be threshold inter-packet arrival times. If a packet is received outside this window, it should be considered lost.
3. Duplicate Packets: If duplicate packets are received within the specified inter-packet arrival time, the packet will be considered received.
4. Corrupted Packets: If a corrupted packet is received it should be considered lost.
5. Fragmented Packets: If a packet is received fragmented and cannot be reassembled it should be considered lost.

4.1.2.3 Why This Metric is Important

Compressed video transport systems are highly sensitive to lost packets. Lost packets usually cause a user viewable impairment. Loss measurements are required to determine the dynamic performance of the transport system.

4.1.2.4 Metric reference documents

Please refer to RFC 2860 "A One-way Packet Loss Metric for IPPM"

4.1.2.5 Recommended Measurement Location

Referring to Figure 1, IP packet loss is a useful metric at all identified interfaces. The per flow IP packet loss on interface G-H should be assessed in conjunction with its accompanying FEC repair flow.

4.1.2.6 Applications for this Metric

Detecting and quantifying IP packet loss can be applied as a tool for performance monitoring of deployed systems, troubleshooting deployed and prototype systems, assuring equipment performance compliance to standards and specifications, verifying and measuring delivered service statistics and during equipment analysis and debug in the design through production life cycle phases. It can also be used to quantify Service Level Agreement (SLA) performance for a service offering. It is the principal impairment that is of interest as a result of a fault in a video over IP transport system.

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4.1.3 Parameter Name: Packets Out of Sequence

4.1.3.1 Definition and Measurement Units

This metric is a count of the number of out of sequence packets. If a packet received with a sequence number smaller than the preceding packet in a flow that packet is considered to be out of sequence.

The unit of measure is an integer number of packets.

4.1.3.2 How to Measure

Store sequence number of first packet of a flow. If the next packet received has a greater sequence number store the new sequence number. The metric should continue to store the sequence numbers of incoming packets discarding the previous. Each time a packet is received with a sequence number smaller than the stored number the counter for this metric should be incremented.

4.1.3.3 Why This Metric is Important

An IP network can have problems that result in packet re-ordering. Most networks have a small window to receive buffers at the destination (usually for de-jitter purposes); consequently, these errors will typically impact the decoding of live streaming video, resulting in video macro-blocking, and if severe, temporary loss of video if packets are decoded out of sequence. There are technologies available to reorder packets received out of sequence but these are often not used for cost and complexity reasons. Based on application, this metric could be used to determine viability of layering in the reorder technology.

4.1.3.4 Metric reference documents

From the IETF Working Group for IPPM the Internet Draft Document “Packet Reordering Metric for IPPM”

4.1.3.5 Recommended Measurement Location

The metric count is useful at all identified interface points identified in figure 1; however, it should be noted that in networks where packet transfers for IP flows can occur across multiple parallel paths, this metric only has significance over the complete end to end path.

4.1.3.6 Applications for this Metric

The use of this metric can help isolate and identify some of the following network anomalies that can lead to the generation of out of sequence packets.

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1. If a flow is setup on two or more parallel paths with differing transfer times, packets traversing the slower path may arrive out of order.
2. When a network entity has multiple processors serving a single network port, variations between the processors could cause packets to be sent out of sequence to the destination.
3. In multi-queue, QOS enabled networks packets in a flow could be classified, serviced and buffered at varying depths in different queues leading to out of sequence packets.

4.1.4 Parameter Name: Packet Reordering with Defined Windows

4.1.4.1 Definition and Measurement Units

This metric is a count of packets that arrive out of sequence in relation to a pre-defined a defined window of packets.

The unit of measure is an integer number of packets as an incrementing counter.

4.1.4.2 How to Measure

To successfully measure this metric a packet window should be defined. This could be a user defined value N as an integer number of packets. This value can be derived at some value greater than the network de-jitter buffer tolerances for the end to end network transfer time variation. Reasons for this include determining how far outside the network accepted tolerances for jitter out of sequence packets are arriving. Each time a packet is received where the sequence number is lower than previously received sequence number the difference in the sequence numbers is taken. This difference is compared to the defined value "N". Once the comparison is made one of two counters should be incremented. One counter should be incremented each time the difference is less than or equal to N. The other counter should be incremented if the difference is greater than N.

4.1.4.3 Why This Metric is Important

Input buffers provides the ability to buffer MPEG TS packets, allowing packet reordering, reduction of network introduced jitter and adaptive rate recovery. The size of the buffer, however, will have a direct relation to the delay of the stream. Maximum buffer size will have the best protection against network jitter, but will also give the longest delay. Another technology is the use of FEC. FEC is an open standard for correcting common problems seen when transmitting live video over an IP network. FEC will give increased robustness of transmission and extend network reach on high loss links. This scheme is usually customizable, depending on what hardware manufacturers you use. A common configuration will likely include a balance between bandwidth overhead, latency and robustness.

4.1.4.4 Metric reference documents

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From the IETF Working Group for IPPM the Internet Draft Document “Packet Reordering Metric for IPPM

4.1.4.5 Recommended Measurement Location

The metric count is useful at all identified interface points identified in Figure 1; however, it should be noted that in networks where packet transfers for IP flows can occur across multiple parallel paths, this metric only has significance over the complete end to end path.

4.1.4.6 Applications for this Metric

The use of this metric can help isolate and identify some of the following network anomalies that can lead to the generation out of sequence packets.

1. If a flow is setup on two or more parallel paths with differing transfer times, packets traversing the slower path may arrive out of order.
2. When a network entity has multiple processors serving a single network port, variations between the processors could cause packets to be sent out of sequence to the destination.
3. In multi-queue, QoS enabled networks packets in a flow could be classified, serviced and buffered at varying depths in different queues leading to out of sequence packets.
4. Providers using devices with configurable FEC can use the information from this metric to determine how much FEC overhead should be configured on network Encoding components.

4.1.5 Parameter Name: Frequency of N consecutive Lost Packets

4.1.5.1 Definition and Measurement Units

This metric is the number of events of loss period length (see parameter 4.1.9) of value N that occur over a user settable measurement period.

The unit of measure is an integer count of packets per second.

4.1.5.2 How to Measure

The user should be able to pre-define a burst threshold setting of “n” packets. Let C_n denote the total number of burst losses of size “n”. At measurement initiation, initialize all C_n to 0. The measurement equipment should monitor for loss periods as defined in RFC 3357. Each time the loss period length is greater than “n” packets increment C_n by 1.

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4.1.5.3 Why This Metric is Important

Knowing the distribution of burst loss sizes may be useful for optimizing the FEC settings used for video stream protection. The total number of packets lost may be very high, but only by knowing the individual burst loss sizes can you determine how heavy the FEC scheme needs to be to protect the video traffic. For example, if there are many losses of up to 5 packets in a row but very few beyond that, a lightweight FEC scheme may provide adequate protection even if there are many of these small burst losses.

4.1.5.4 Metric reference documents

Refer to RFC 3357 “One-way Loss Pattern Sample Metrics” for additional information about loss period length.

4.1.5.5 Recommended Measurement Location

Referring to Figure 1, per flow loss period length frequency is a useful metric to characterize media packet loss at all identified interfaces. The per flow loss period length frequency on interface G-H in conjunction with knowledge about the FEC algorithms and repair flows will indicate whether a loss event will be repaired by the deployed FEC.

4.1.5.6 Applications for this Metric

Detecting and quantifying packet loss has applications in performance monitoring for deployed systems, troubleshooting deployed and prototype systems, assuring equipment performance compliance to standards and specifications, verifying and measuring delivered service statistics, and during equipment analysis and debug in the design through production life cycle phases. It is the principal impairment that is of interest as a result of a fault in a video over IP transport system. Loss period length frequency is an indication of an impairment severity. It is used with other metrics to assess the level of FEC that may be required on an interface to achieve a desired packet error rate. It is used with other metrics to assess whether the level of deployed FEC on a link is adequate to repair a measured impairment. Thus, it is also useful for network planning.

4.1.6 Parameter Name: Sequential Loss frequency

4.1.6.1 Definition and Measurement Units

The metric measures the number of times in a given time period for which two or more sequential packets are lost in the network

The unit of measure is an integer count of packets per second.

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4.1.6.2 How to Measure

To effectively measure this metric the user/tester must predefine a specified time period within which events Sequential Losses are observed a counter—say “B1” should be defined. During the defined time period, increment the B1 counter 1 count whenever there is a received packet followed by two consecutive lost packets. At the end of the period divide the number in the bin by the number of seconds in the period to get the frequency of sequential packets lost per second.

4.1.6.3 Why This Metric is Important

This measurement helps define the pattern of network packet loss with respect to defining the rate of burst losses. Since FEC is defined more by Period and Distance, this measurement is more to define network stability during actual performance than FEC choice

4.1.6.4 Metric reference documents

RFC 3357 “One-way Loss Pattern Sample Metrics”

4.1.6.5 Recommended Measurement Location

This measurement can be made at any node in the network. While its main value is evaluating network performance at the egress of the network, it can have value in defining the segment of the network that has the greatest contribution to this loss pattern. For this application, measurements would be made at different network node points, with the problem segment being defined as the segment between the two most varied results.

4.1.6.6 Applications for this Metric

The prime value of this parameter is defining the network loss pattern performance such that the most effective FEC process can be determined to recover the network induced loss.

4.1.7 Parameter Name: Mean time between Loss Periods

4.1.7.1 Definition and Measurement Units

This metric defines Loss distance as a mean value of the spacing between loss periods in measurement in time and not an absolute value.

The unit of measurement is in milliseconds or seconds.

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4.1.7.2 How to Measure

This metric can be measured by establishing a running counter to record time increments. The testing equipment should monitor flow or flows for packet loss. Create an incremental counter bin - Bl. Create an additional bin to store sampled time values - Bt. When a packet loss is detected as being a “Loss Period” (RFC 3357) 1) Increment Bl one count once the Loss Period has ended 2) Store time value in Bt, 3) Divide time value in Bt by loss count in Bl, and 4) Display result as Loss/T where T is the time counter measure unit. Continue to run test with increasing Loss and Time values as desired. This is a running test. There is no time limit to the test period. Reset bin count and clock value as desired to begin new test.

4.1.7.3 Why This Metric is Important

Defining network loss patterns over time as a mean value allows a view of average network performance and stability as opposed to the worst single event perspective of an absolute value.

4.1.7.4 Metric reference documents

RFC 3357 “One-way Loss Pattern Sample Metrics

4.1.7.5 Recommended Measurement Location

This measurement can be made at any node in the network. While its main value is evaluating network performance at the egress of the network, it can have value in defining the segment of the network that has the greatest contribution to this loss pattern. For this application, measurements would be made at different network node points, with the problem segment being defined as the segment between the two most varied results.

4.1.7.6 Applications for this Metric

The prime value of this parameter is defining the network loss pattern performance such that the most effective FEC process can be determined to recover the network induced loss.

4.1.8 Parameter Name: Loss Distance

4.1.8.1 Definition and Measurement Units

The loss distance metric captures the spacing between loss periods. It is defined as the difference in sequence numbers of two successively lost packets which may or may not be separated by successfully received packets.

The unit of measure is an integer and has no units.

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4.1.8.2 How to Measure

Analyze received sequence numbers in all packets of a stream. When the first packet is considered lost by the system the loss distance is set to 0. After the first loss, each successive packet lost after the receipt of packet will be used to generate loss distances. For example, consider the scenario where packets with sequence numbers 2-6 are considered lost, packets 7-10 are received, and then packets 11-14 are lost. In this example there are two loss periods; one starting with packet 2 and then another starting with packet 11. The loss distance is the difference (5) between last lost packet of the first loss period (6) and the first lost packet of the subsequent loss period (11).

4.1.8.3 Why This Metric is Important

The loss distance metric helps characterize the importance of loss events in a flow. It can be used with other parameters to determine the level of FEC overhead required for reconstructing packets in the presence of loss for a given FEC algorithm. Thus, for a given FEC algorithm and level of deployed FEC, measuring loss distance will indicate for a particular loss impairment event and for a particular loss distance, whether correction can be guaranteed.

4.1.8.4 Metric reference documents

RFC 3357 “One-way Loss Pattern Sample Metrics”

4.1.8.5 Recommended Measurement Location

Referring to Figure 1, per flow loss distance is a useful metric to characterize media packet loss at all identified interfaces. The per flow loss distance on interface G-H in conjunction with knowledge about the FEC algorithms and repair flows will indicate whether certain loss events will be repaired by the deployed FEC.

4.1.8.6 Applications for this Metric

Detecting and quantifying packet loss has applications in performance monitoring for deployed systems, troubleshooting deployed and prototype systems, assuring equipment performance compliance to standards and specifications, verifying and measuring delivered service statistics, and during equipment analysis and debug in the design through production life cycle phases. It is the principal impairment that is of interest as a result of a fault in a video over IP transport system. Loss distance is an indication of impairment severity. It is used with other metrics to assess the level of FEC that may be required on an interface to achieve a desired packet error rate. It is used with other metrics to assess whether the level of deployed FEC on a link is adequate to repair a measured impairment.

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4.1.9 Parameter Name: Loss Period Length (RFC 3357)

4.1.9.1 Definition and Measurement Units

The loss period length metric captures the number of consecutive packets lost in a loss period. Since this metric represents the burstiness of each loss period, it indicates which loss periods are more influential on a stream than others from a quality perspective.

The unit of measure is an integer count of packets in a loss period.

4.1.9.2 How to Measure

Analyze received sequence numbers in all packets of a stream. A counter 'n' should be created. This counter should be incremented by one each time a lost packet is identified, before the successful receipt of the next packet. The Loss Period will be the total count of lost packets between successfully received. When the next packet is received successfully, the loss period is defined to be zero.

4.1.9.3 Why This Metric is Important

The loss period length metric helps characterize the importance of loss events in a flow. It can be used with other parameters to determine the level of FEC overhead required for reconstructing packets in the presence of loss for a given FEC algorithm. Thus, for a given FEC algorithm and level of deployed FEC, measuring loss period length along with other metrics will indicate whether a detected loss impairment event will be corrected.

4.1.9.4 Metric reference documents

RFC 3357 “One-way Loss Pattern Sample Metrics”.

4.1.9.5 Recommended Measurement Location

Referring to Figure 1, per flow loss period length is a useful metric to characterize media packet loss at all identified interfaces. The per flow loss period length on interface G-H in conjunction with knowledge about the FEC algorithms and repair flows will indicate whether a loss event will be repaired by the deployed FEC.

4.1.9.6 Applications for this Metric

Detecting and quantifying packet loss has applications in performance monitoring for deployed systems, troubleshooting deployed and prototype systems, assuring equipment performance compliance to standards and specifications, verifying and measuring delivered service statistics, and during equipment analysis and debug in the design through production life cycle phases. It is the principal impairment that is of interest as a result of a fault in a video over IP transport system. Loss period length is an indication of an impairment severity. It is used with other metrics to assess the level of FEC that may

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be required on an interface to achieve a desired packet error rate. It is used with other metrics to assess whether the level of deployed FEC on a link is adequate to repair a measured impairment.

4.1.10 Parameter Name: IP Loss Ratio

4.1.10.1 Definition and Measurement Units

IP loss ratio (IPLR) is the ratio of total lost IP packet outcomes to total transmitted IP packets in a population of interest such as for a flow over a selected period of time.

The unit of measure is expressed as a value between 0 and 1.

4.1.10.2 How to Measure

IP packet loss is detected by monitoring flow sequence numbers if using RTP or an encapsulation protocol that incorporates a sequence number. If a protocol stack is utilized that does not include sequence numbers, then packet loss can be determined by counting packets at an ingest location and comparing those counts to downstream locations per flow. This approach may best suit test and lab networks and out of service networks where flows can be interrupted periodically for performing measurements.

It is desirable to permit setting threshold values for IP packet loss ratio and logging when IP packet loss ratio exceeds the set threshold for monitoring applications. It is desirable that IP packet loss ratio be measured for all streams present on a link simultaneously to assure timely and reliable fault detection and for fault type characterization. It is desirable that measurements of IPLR be captured over intervals such as 15 minutes and 24 hours as these are useful in assessing acceptable transport system performance, for competitive equipment evaluations, and for product development purposes.

4.1.10.3 Why This Metric is Important

IPLR is traditionally an out of service measurement using test equipment at each end to characterize the network. It may also be applied to an in service link for a specified duration. It is convenient measures of performance comparison between links and as a measure of improvement that FEC realizes between links that do and links that do not utilize FEC.

4.1.10.4 Metric reference documents

ITU-T Recommendation I.380 Internet Protocol Data Communication Service - IP Packet Transfer and Availability Performance Parameters

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4.1.10.5 Recommended Measurement Location

Referring to Figure 1, per flow IPLR is a useful metric to characterize media packet loss at all identified interfaces. The per flow IPLR on interface G-H should be assessed in conjunction with other flow metrics and the FEC algorithms to get an accurate representation of IPLR on system performance.

4.1.10.6 Applications for this Metric

Detecting and quantifying IP packet loss has applications in performance monitoring for deployed systems, troubleshooting deployed and prototype systems, assuring equipment performance compliance to standards and specifications, verifying and measuring delivered service statistics, and during equipment analysis and debug in the design through production life cycle phases. It is the principal impairment that is of interest as a result of a fault in a video over IP transport system. Representing packet loss as IPLR is a traditional way to display link quality.

4.1.11 Parameter Name: Time between loss

4.1.11.1 Definition and Measurement Units

The mean-time identified between block loss events. This could be time between packet loss events, or time between blocks with loss.

The unit of measure is seconds or milliseconds.

4.1.11.2 How to Measure

For packet loss events, record the time stamp each time the packet loss counter increases within a block. Take the difference between this and the last loss. Add this to the running average.

4.1.11.3 Why This Metric is Important

This is specific to FEC. It will allow us to calculate the mean time between errors as it relates to blocks.

4.1.11.4 Metric reference documents

None

4.1.11.5 Recommended Measurement Location

Time between is a useful metric to measure at all identified interfaces.

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4.1.11.6 Applications for this Metric

Detecting and quantifying time between loss has applications in performance monitoring for deployed systems, troubleshooting deployed and prototype systems, assuring equipment performance compliance to standards and specifications, verifying and measuring delivered service statistics, and during equipment analysis and debug in the design through production life cycle phases. Time between losses gives a good measure of how bad a network is over time. It is used with other metrics to assess the level of FEC that may be required on an interface to achieve a desired packet error rate. It is used with other metrics to assess whether the level of deployed FEC on a link is adequate to repair a measured impairment

4.1.12 Parameter Name: Ingress \geq 2 loss in column

4.1.12.1 Definition and Measurement Units

This metric is an integer count that a specific loss pattern has occurred within a single FEC block. An "Ingress \geq 2 loss in column" loss pattern is defined to occur when two or more data packets are lost in the same column of the same FEC block. While it is possible for multiple instances of these loss patterns to occur in the same FEC block, this parameter increments at most once per FEC block. Therefore, this parameter records the number of times at least one "Ingress \geq 2 loss in column" loss pattern occurred in the same FEC block.

The unit of measure is an integer.

4.1.12.2 How to Measure

A monitoring device measures this by scanning all FEC blocks (both data and FEC parity packets) looking for instances of this loss pattern as defined. The integer counter increments by one each time an "Ingress \geq 2 loss in column" loss pattern occurs in an FEC block. There may be more than 1 instance of this loss pattern per FEC block but only the first loss pattern detected increments the counter. Initial counter values are 0. The counter is incremented for each occurrence for a user settable time interval.

4.1.12.3 Why This Metric is Important

For CoP3R1, this parameter tallies the number of times a loss pattern occurs that satisfies the necessary conditions to result in unrecoverable packets. For CoP3R2, this parameter is not useful since this condition is necessary but not sufficient to cause packet loss. A utility to measuring these occurrences is that this occurrence should coincide precisely with a CoP3R1 FEC decoder reporting irrecoverable packets. In the absence of measuring this event, it is impossible to prove that packets declared irrecoverable by the FEC decoder were actually irrecoverable, versus potential implementation or operational faults in the FEC recovery algorithm. Measuring this event type and comparing it to the

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reported irrecoverable packets per the FEC decoder is a measure of the health and accuracy of the FEC decoder. If the decoder fails to recover a packet and this loss pattern has not occurred, there is a fault in the FEC decoder.

4.1.12.4 Metric reference documents

Refer to CoP3R1 specification for additional information about this FEC algorithm.

4.1.12.5 Recommended Measurement Location

Referring to Figure 1, this per flow metric on interface G-H in conjunction with knowledge about the FEC algorithms and repair flows will indicate whether certain loss events will be repaired by the deployed FEC.

4.1.12.6 Applications for this Metric

Detecting and quantifying packet loss has applications in performance monitoring for deployed systems, troubleshooting deployed and prototype systems, assuring equipment performance compliance to standards and specifications, verifying and measuring delivered service statistics, and during equipment analysis and debug in the design through production life cycle phases. It is the principal impairment that is of interest as a result of a fault in a video over IP transport system. "Ingress ≥ 2 loss in column" is an indication of impairment severity with respect to FEC. It is used to assess the level of FEC that may be required on an interface to achieve a desired packet error rate and, further, to assure that a deployed implementation of FEC is performing correctly by comparing this monitored metric with the "uncorrectable error count" reported by the FEC decoder implementation.

4.1.13 Parameter Name: Ingress 3- or 4-corner loss

4.1.13.1 Definition and Measurement Units

This metric is an integer count that a specific loss pattern has occurred within a single FEC block. A "3-corner" loss pattern is defined to occur when a data packet is lost, and both FEC parity packets (one for the row and one for the column) are lost as well. A "4-corner" loss pattern is defined to occur when any two packets are lost in a column, and two additional packets are lost in a separate column, and the four total lost packets are located in exactly two rows. While it is possible for multiple instances of these loss patterns to occur in the same FEC block, this parameter increments at most once per FEC block. Therefore, this parameter records the number of times at least one 3 corner or one 4 corner loss pattern occurred in the same FEC block.

The unit of measure is an integer.

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4.1.13.2 How to Measure

A monitoring device measures this by scanning all FEC blocks (both data and FEC parity packets) looking for instances of this loss pattern as defined. This increasing integer counter increments by one each time either a 3 corner or a 4 corner loss pattern occurs in an FEC block. There may be more than 1 instance of this loss pattern per FEC block but only the first loss pattern detected increments the counter. Initial counter values are 0. The counter is incremented for each occurrence for a user settable time interval.

4.1.13.3 Why This Metric is Important

For CoP3R2, this parameter tallies the number of times a loss pattern occurs that satisfies the necessary conditions to result in unrecoverable packets. A utility to measuring these occurrences is that this occurrence should coincide precisely with a CoP3R2 FEC decoder reporting irrecoverable packets. In the absence of measuring this event, it is impossible to prove that packets declared irrecoverable by the FEC decoder were actually irrecoverable, versus potential implementation or operational faults in the FEC recovery algorithm or equipment. Measuring this event type and comparing it to the reported irrecoverable packets per the FEC decoder is a measure of the health and accuracy of the FEC decoder. If the decoder fails to recover a packet and this loss pattern has not occurred, there is a fault in the FEC decoder.

4.1.13.4 Metric reference documents

Refer to CoP3R2 specification for additional information about this FEC algorithm.

4.1.13.5 Recommended Measurement Location

Referring to Figure 1, this per flow metric on interface G-H in conjunction with knowledge about the FEC algorithms and repair flows will indicate whether certain loss events will be repaired by the deployed FEC.

4.1.13.6 Applications for this Metric

Detecting and quantifying packet loss has applications in performance monitoring for deployed systems, troubleshooting deployed and prototype systems, assuring equipment performance compliance to standards and specifications, verifying and measuring delivered service statistics, and during equipment analysis and debug in the design through production life cycle phases. It is the principal impairment that is of interest as a result of a fault in a video over IP transport system. “Ingress 3- or 4-corner loss” is an indication of impairment severity with respect to FEC. It is used to assess the level of FEC that may be required on an interface to achieve a desired packet error rate and, further, to assure that a deployed implementation of FEC is performing correctly by comparing this monitored metric with the “uncorrectable error count” reported by the FEC decoder implementation.

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4.1.14 Parameter Name: Number of Lost Packets in a Block of n Packets of Size N

4.1.14.1 Definition and Measurement Units

This metric captures the number of packets lost in a block of n consecutive packets, where each packet is N bytes in length. Since FEC codes typically work on a source block basis, the statistics on the number of packets lost between the sender and the receiver for the blocks of n packets provides valuable information about the performance of an FEC code on the FEC protected stream.

The unit of measure is an integer count of lost packets in a block of n packets, where each packet is N bytes in length. This metric is to be reported for each block of n packets in the stream for the duration of the measurement.

4.1.14.2 How to Measure

Send a stream of test packets (each N byte in length) from a sender. At a receiver based on sequence numbers in the sent test packets, measure for each consecutive block of n sent test packets (for a relevant value of n) how many packets within the block were lost, and gather statistics on this. A full set of statistics could be the number of lost packets in each block for all blocks in the test stream of packets. A condensed set of statistics could be, for example, for each value of $i = 0, 1, 2, \dots, n$, the number of blocks in the stream in which i packets were lost. Note that the full statistics provides more detailed information about the losses within blocks in the stream than the condensed statistics, e.g., more information about packet loss variability among consecutive blocks. Both the condensed statistics as well as the full statistics provide enough information to determine, for specific FEC codes with specific settings of the FEC overhead, statistics on how many blocks would not be able to be completely recovered within the stream.

The receiver can generate statistics for various values of n for the same stream of test packets. This might be important to do to help to determine how long the FEC source block should be to provide a given level of protection with a given FEC overhead. For example, it could be the case that with $n = 110$, if the FEC code is evaluated with a 10% overhead ($k = 100$) then the mean time between blocks that could not be fully recovered is 20 minutes, whereas if $n = 220$, with the same FEC code and 10% overhead ($k = 200$) then the mean time between blocks that could not be fully recovered is 12 hours. This would provide meaningful information on the trade-off between latency introduced by using FEC (essentially the length of time to play-out k packets) versus the quality of the FEC decoded stream for a given FEC overhead.

4.1.14.3 Why This Metric is Important

FEC codes typically work on a source block basis, e.g., some number k of source packets are grouped together into a source block and then some number n-k repair packets are generated from the source block of k source packets so that there are n packets in total that are sent for the source block, for example $k=100$ and $n=110$. The statistics on the

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number of packets lost between the sender and the receiver for the blocks of n packets provides some valuable information about the performance of an FEC code on the FEC protected stream for relevant values of N , e.g., $N = 1316$ bytes. For example, suppose the condensed statistics report that 95% of the blocks have no packets lost out of the 110, 3% of the blocks have 1 packet lost out of the 110, 1% of the blocks have 2 packets lost out of the 110, 0.5% of the blocks have 3 packets lost out of the 110, 0.1% of the blocks have 4 packets lost out of the 110, ..., 0.001% of the blocks have more than 10 packets lost out of the 110. This is valuable information as, for each FEC code with a specified FEC overhead, one can infer a lot about the quality of the stream that would play out at the receiver after FEC decoding.

4.1.14.4 Metric reference documents

None

4.1.14.5 Recommended Measurement Location

Referring to Figure 1, a per flow count of lost packets in each block of n packets, each packet of length N bytes, is a useful metric to characterize media packet loss on all identified interfaces. The measurement on interface G-H in conjunction with knowledge about the FEC algorithms and repair flows will indicate statistics on whether loss events will be repaired by the deployed FEC. The measurement on other interfaces will indicate how well a link might benefit from deploying a proposed FEC code.

4.1.14.6 Applications for this Metric

This metric can be used to characterize a link's loss characteristics to help assess the level and best FEC code that may be required on an interface to achieve a desired packet error rate. It can be used in deployed systems on either in or out of service links when evaluating and selecting FEC equipment. It is used with other metrics in selecting the optimum type of FEC code that may be required on an interface to achieve a desired packet error rate. It is used with other metrics to assess whether the level of deployed FEC on a link is adequate statistically to repair measured impairments.

4.1.15 Parameter Name: Blocks with loss

4.1.15.1 Definition and Measurement Units

This metric counts the occurrence that one or more data packets cannot be recovered by the FEC decoder. Regardless of how many packets cannot be recovered, the counter increments by at most 1 per FEC block.

The unit of measure is an integer.

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4.1.15.2 How to Measure

For each FEC block, a monitoring device will scan the data packets and look for loss patterns that cannot be recovered. When such a pattern is detected, the monitoring device increments the integer counter by one and ceases any further analysis related to this parameter in the current block. If the FEC decoder is reporting this value, it counts how many FEC blocks had at least 1 unrecoverable packet.

4.1.15.3 Why This Metric is Important

This parameter is useful for determining at a high level the quality of the FEC protected IP flow. When this value increases it is an indication that video corruption did occur. The full magnitude of any single instance cannot be known using this metric, but some operators may not need to know how 'bad' the disturbance was as long as they know that such an event occurred. This logged event could be used to correlate the loss to customer complaints at a later time. In this case, knowing that '5 packets were unrecovered in a burst of 3 and a second burst of 2' may be unnecessary for example. Knowing that some loss occurred may be sufficient.

4.1.15.4 Metric reference documents

Refer to the FEC definition documents for the type of deployed FEC.

4.1.15.5 Recommended Measurement Location

Referring to Figure 1, this per flow metric on interface G-H in conjunction with knowledge about the FEC algorithms and repair flows will indicate whether certain loss events will be repaired by the deployed FEC.

4.1.15.6 Applications for this Metric

Detecting and quantifying packet loss has applications in performance monitoring for deployed systems, troubleshooting deployed and prototype systems, assuring equipment performance compliance to standards and specifications, verifying and measuring delivered service statistics, and during equipment analysis and debug in the design through production life cycle phases. It is the principal impairment that is of interest as a result of a fault in a video over IP transport system. "Blocks with loss" is an indication of impairment severity with respect to FEC. It is used to assess the level of FEC that may be required on an interface to achieve a desired packet error rate and, further, to assure that a deployed implementation of FEC is performing correctly by comparing this monitored metric with the "uncorrectable error count" reported by the FEC decoder implementation. It can be used to correlate such events with video viewer impairment reports in order to isolate and repair network distribution faults.

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4.1.16 Parameter Name: Unrecoverable count

4.1.16.1 Definition and Measurement Units

This metric is an integer count of the number of data packets in a block that cannot be recovered after FEC decoding attempts are complete.

The unit of measure is an integer.

4.1.16.2 How to Measure

A monitoring device measures this by counting the total number of packets that were either received intact or were recovered by the FEC reconstruction process, and subtracting that value from the block size (full FEC table size $L \cdot D$.)

4.1.16.3 Why This Metric is Important

This counter represents the number of packets that are lost following FEC processing and will result in video stream corruption. This value would be used to calculate the effective IPLR of the FEC protected network.

4.1.16.4 Metric reference documents

Refer to the deployed FEC algorithm definition documents for details about which and how many packets can be recovered by that particular FEC algorithm.

4.1.16.5 Recommended Measurement Location

Referring to Figure 1, this per flow metric on interface G-H indicates how many packets cannot be repaired by the deployed FEC.

4.1.16.6 Applications for this Metric

Detecting and quantifying packet loss has applications in performance monitoring for deployed systems, troubleshooting deployed and prototype systems, assuring equipment performance compliance to standards and specifications, verifying and measuring delivered service statistics, and during equipment analysis and debug in the design through production life cycle phases. It is the principal impairment that is of interest as a result of a fault in a video over IP transport system. “Unrecoverable count” is an indication of impairment severity with respect to FEC. It is used to assess the level of FEC that may be required on an interface to achieve a desired packet error rate and, further, to assure that a deployed implementation of FEC is performing correctly by comparing this monitored metric with the “uncorrectable error count” reported by the FEC decoder implementation.

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4.1.17 Parameter Name: Recoverable count

4.1.17.1 Definition and Measurement Units

This metric is an integer count of the number of data packets in a block that were recovered after FEC decoding attempts are complete but were not received by the FEC decoder.

The unit of measure is an integer.

4.1.17.2 How to Measure

A monitoring device measures this by counting the total number of packets that were not received by the FEC decoder but could be recovered by a designated FEC algorithm's reconstruction process.

4.1.17.3 Why This Metric is Important

This counter represents the number of packets that were recoverable by the FEC equipment. This value would be used to calculate the effective IPLR of the FEC protected network. It provides a metric on the efficiency of the FEC recovery algorithm and provides a metric to compare effectiveness of FEC algorithms.

4.1.17.4 Metric reference documents

Refer to the FEC algorithm definition documents deployed or being considered for deployment for details about which and how many packets can be recovered by that particular FEC algorithm.

4.1.17.5 Recommended Measurement Location

Referring to Figure 1, this per flow metric on interface G-H indicates how many packets can be repaired by the selected FEC algorithm.

4.1.17.6 Applications for this Metric

Detecting and quantifying packet loss has applications in performance monitoring for deployed systems, troubleshooting deployed and prototype systems, assuring equipment performance compliance to standards and specifications, verifying and measuring delivered service statistics, and during equipment analysis and debug in the design through production life cycle phases. It is the principal impairment that is of interest as a result of a fault in a video over IP transport system. "Recoverable count" is an indication of impairment severity with respect to FEC. It is used to assess the level of FEC that may be required on an interface to achieve a desired packet error rate and, further, to assure that a deployed implementation of FEC is performing correctly by comparing this

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monitored metric with the “correctable error count” reported by the FEC decoder implementation.

4.1.18 Parameter Name: Short duration block loss

4.1.18.1 Definition and Measurement Units

This metric is an integer count of the number of brief stream outages detected on a stream utilizing FEC over a user settable time interval. A brief stream outage is defined as greater than $n+1$ sequential packets dropped, where n is the FEC block size, but less than 65536 sequential packets dropped. A brief stream outage can also be defined in terms of the equivalent time durations of these events based on the given stream’s bit-rate.

The unit of measure is an integer.

4.1.18.2 How to Measure

A monitoring device measures the count of short duration block losses by incrementing an event counter by one for each brief outage. The brief outage event is calculated using the difference between the last RTP sequence number received before the outage, and the first RTP sequence number received after the outage consistent with the definition for the short duration block loss above.

4.1.18.3 Why This Metric is Important

Service providers are often interested in how frequently service outages occur and how to measure their severity. Counting FEC blocks lost is useful when analysis of loss events is based on blocks rather than packets. A brief service outage may be shorter than a second, or last for many seconds.

4.1.18.4 Metric reference documents

Refer to the deployed FEC algorithm definition documents for details about which and how many packets can be recovered by that particular FEC algorithm.

4.1.18.5 Recommended Measurement Location

Referring to Figure 1, this per flow metric on interface G-H indicates how many short duration block loss events have occurred during a user selected time interval on this FEC protected link. It may also be applied to any link that is being evaluated in terms of block loss such as links being considered for use with FEC.

4.1.18.6 Applications for this Metric

Detecting and quantifying packet loss has applications in performance monitoring for deployed systems, troubleshooting deployed and prototype systems, assuring equipment

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performance compliance to standards and specifications, verifying and measuring delivered service statistics, and during equipment analysis and debug in the design through production life cycle phases. It is the principal impairment that is of interest as a result of a fault in a video over IP transport system. “Short duration block loss” is an indication of impairment severity with respect to FEC processing units. It is used to classify packet loss events lasting longer than an FEC block time.

4.1.19 Parameter Name: Long duration block loss

4.1.19.1 Definition and Measurement Units

This metric is an integer count of the number of long stream outages detected on a stream utilizing FEC over a user settable time interval. A long stream outage is defined as greater than 65536+1 sequential packets dropped or greater than the RTP sequence number range. Sequential lost blocks are counted as one event. Note that the total number of blocks lost cannot be reliably determined but the expected number of packets lost in a long outage can be estimated and compared to the expected sequence number of the packets when the stream restarts. A long stream outage can also be defined in terms of the equivalent time durations of these events based on the given stream’s bit-rate.

The unit of measure is an integer.

4.1.19.2 How to Measure

A monitoring device measures the count of long duration block losses by incrementing an event counter by one for each long outage. The long outage event is calculated using the difference between the last RTP sequence number received before the outage, and the first RTP sequence number received after the outage consistent with the definition for the long duration block loss above.

4.1.19.3 Why This Metric is Important

Service providers are often interested in how frequently service outages occur and how to measure their severity. A long duration block loss typically lasts for many seconds and would represent a severe loss condition.

4.1.19.4 Metric reference documents

None

4.1.19.5 Recommended Measurement Location

Referring to Figure 1, this per flow metric on interface G-H indicates how many long duration block loss events have occurred during a user selected time interval on this FEC protected link. It may also be applied to any link that is being evaluated in terms of block loss such as links being considered for use with FEC.

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4.1.19.6 Applications for this Metric

Detecting and quantifying packet loss has applications in performance monitoring for deployed systems, troubleshooting deployed and prototype systems, assuring equipment performance compliance to standards and specifications, verifying and measuring delivered service statistics, and during equipment analysis and debug in the design through production life cycle phases. It is the principal impairment that is of interest as a result of a fault in a video over IP transport system. “Long duration block loss” is an indication of impairment severity with respect to FEC processing units. It is used to classify packet loss events lasting more than an FEC block time.

4.1.20 Parameter Name: Distribution of N consecutive Lost Packets

4.1.20.1 Definition and Measurement Units

A timestamp indicating the length of the burst loss was N packets.
The unit of measure is an integer count and timestamp.

4.1.20.2 How to Measure

Let $T[i]$ be a timestamp and $L[i]$ be an integer. At initialization set i to 0. For every burst loss thereafter increment i setting $T[i]$ to be the start time of loss and $L[i]$ denote the length of loss in packets.

4.1.20.3 Why This Metric is Important

This metric is different than 4.1.5 Frequency of N consecutive Lost Packets in that it allows you to completely model all errors for later testing. This can be very useful in troubleshooting the design of equipment. In many cases testing on a live network is not an option. This is critical to allow testing of equipment in a non production situation while simulating real world conditions.

4.1.20.4 Metric reference documents

None

4.1.20.5 Recommended Measurement Location

Referring to Figure 1, starting measurement on interface L-M and working back towards interface A-B is the most direct way to isolate network loss.

4.1.20.6 Applications for this Metric

This metric can be useful for network planning and troubleshooting.

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4.1.21 Parameter Name: Duplicate Packets within a window N

4.1.21.1 Definition and Measurement Units

A counter of the number of times duplicate packets are received within a window of N seconds.

The unit of measure is an integer counter

4.1.21.2 How to Measure

Keep an N second buffer of packets. Compare packets received to the buffer. If the packet matches one in the buffer increment the counter.

4.1.21.3 Why This Metric is Important

This metric is important to show a specific type of problem on the network. Duplicate packets would not be detected under most circumstances. Detecting duplicate packets in many cases can point to mis-configuration or defective equipment.

4.1.21.4 Metric reference documents

None

4.1.21.5 Recommended Measurement Location

Referring to Figure 1, starting measurement on interface L-M and working back towards interface A-B would be the best way to isolate where the duplicate packets are occurring.

4.1.21.6 Applications for this Metric

This metric can be useful for network troubleshooting.

4.2 Jitter Category

Jitter, the variation of a stream's IP packet arrival times from nominal, is important because it can be a precursor to packet loss in the transport system. If a stream's jitter exceeds the limits of a device's queuing capabilities to accommodate the deviation from nominal, buffer overflow resulting in packet loss will occur. It is important to note that jitter itself does not impair the video transport; the video is impaired only when jitter reaches magnitudes that cause transport system device buffer overflows and/or end device buffer overflows or underflows.

There are various ways to measure and quantify jitter for different uses. For example, to characterize a newly installed transport network, one may choose to capture and timestamp all packets received for a select duration and derive various statistics for the

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system. This might be used to modify equipment configurations, routing paths, select alternate providers for leased links, etc. Likewise, such statistics can be successfully used to characterize a device in lab testing during development. For live continuous monitoring of large numbers of streams in production networks, a simple, scalable cumulative jitter measurement such as delay factor can be used to detect transient burst conditions that may cause transient loss.

4.2.1 Parameter Name: Cumulative Jitter (RFC 4445)

4.2.1.1 Definition and Measurement Units

Cumulative Jitter (CJ) is a metric which describes the effect of a stream's packet delay variation over a multi-packet measurement interval -- an indication of its maximum burstiness. CJ is a direct measure of the sum of positive and negative delay variations over an interval and reflects the size of the de-jitter buffer required to avoid overflow or underflow. CJ is expressed as Delay Factor (DF) in RFC 4445 and is the maximum difference, observed at the end of each packet, between the arrival of media data and the drain of media data over a measurement interval of 1 second. The drain rate of media data is taken as the nominal stream bit rate. The DF is expressed as the number of milliseconds required to drain (or fill) the worst case dynamic flow rate imbalance over a 1 second period at the nominal bit rate.

The unit of measure is in milliseconds.

4.2.1.2 How to Measure

Track the maximum and minimum size of a virtual buffer (VB) required to accommodate flow rate variations over a 1 second period. $DF = (VB_{max} - Vb_{min}) / (\text{nominal Flow Rate})$. See RFC 4445 for details.

4.2.1.3 Why This Metric is Important

The burstiness of a stream greatly affects the lossless forwarding performance of network devices such as switches and routers. Longer and more frequent bursts of packets in a stream reduce the number of simultaneous streams that can be forwarded without loss. See VSF May 2005 paper "Switch Performance with SD & HD Video over IP Streams with Cumulative Jitter" [4]. Cumulative jitter deviation is an indication of likely queue utilization in network devices and therefore reflects transient congestion events in a transport network. CJ can be used as a warning indicator of Quality of Service issues in a transport network as a precursor to loss.

4.2.1.4 Metric reference documents

See RFC 4445 for more details.

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4.2.1.5 Recommended Measurement Location

Referring to Figure 1, DF is a useful metric to detect and quantify flow burstiness on all identified interfaces. Comparing flow DF values as a flow traverses various network interfaces assists in the location of transient flow congestion issues.

4.2.1.6 Applications for this Metric

Stream burstiness measurements can be used as an indicator of impending loss in a transport system monitoring application. Monitoring per flow DF on strategic interfaces in a distribution network will indicate upstream location dynamic congestion. The per flow DF on any interface should be assessed in conjunction with an accompanying flow MLR measurement to determine whether flow burstiness is due exclusively to transient congestion or whether loss is present. Detecting and quantifying stream burstiness has applications in performance monitoring for deployed systems, troubleshooting deployed and prototype systems, assuring equipment performance compliance to standards and specifications, and during equipment analysis and debug in the design through production life cycle phases. It is also an important measure of whether a decoding device has sufficient size de-jitter buffer to successfully decode an arriving stream.

4.2.2 Parameter Name: IP Packet Jitter/ Packet delay variation/1-point Packet Delay Variation (ITU-T Y.1540)

4.2.2.1 Definition and Measurement Units

The time difference between the actual arrival times and the intended arrival times of a packet. If the intended inter-arrival pattern is periodic, then these times can be implied from the "smoothed" inter-arrival times processed by the receiver. If the intended inter-arrival pattern is aperiodic, then we assume that the intended arrival times are also carried in the packet header (such as the RTP time stamps) and that the receiver and source clocks are synchronized in some fashion. The statistics can be collected raw as a time series, or summarized in the forms of max, min, average, or the difference between percentiles (99.9-th percentile value minus 0.1-th percentile value). The resolution of the time calculation should be 100 micro-second or better. If arrival time exceeds M it is considered loss.

The unit of measure is the min/max/average in milliseconds.

4.2.2.2 How to Measure

When the stream is periodic:

The receiver shall contain 8 bins. Bin "Ap" will contain the average time period from one packet to the next. It is calculated by monitoring the packet count "C" for period "S" and storing "S/C" in bin "Ap". Bin "Ct" will be an incremental counter recording the

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total number of packets processed. Bin "Rl" will store the time stamp for the last packet received. Bin "Rx" shall store the receiver time stamp for the current packet received. Bin "T" will store the total aggregate variation. Bin "Mx" will store the maximum variation. Bin "Mn" will store the minimum variation. Bin "Av" will store the mean variation. When a packet is received "Rx" is stored in "Rl" and the current timestamp is stored in "Rx". The value in bin "Rx" is subtracted from the value in bin "Rl" this value is then subtracted from the value in bin "At" and stored in bin "Dn". The current value of "Dn" is added to the value in bin "T". The current value of "Dn" is compared with the value in bins "Mx" and "Mn". If the value is greater than the current value in "Mx", the new value is placed in bin "Mx". If the value is smaller than the current value in bin "Mn", the new value is placed in bin "Mn". The new value in bin "T" will be divided by the new value in "Ct" and the result will replace the value in bin "Av". This test requires that a minimum of two packets be tested, but establishes no maximum time or packet count for the test. To start a new test, clear the values in all bins and set them to zero. This test provides an average variation, a maximum variation, and a minimum variation.

When the stream is aperiodic:

The receiver shall contain 8 bins. Bin "Ad" will contain the average offset between the packet Timestamp and the receiver time. Calculated by monitoring the Timestamp for packet count "C" and adding the current offset between the packet timestamp and receiver time in "S" and storing "S/C" in bin "Ad". Bin "Ct" will be an incremental counter recording the total number of packets processed. Bin "Rx" shall store the receiver time stamp for the current packet received. Bin "T" will store the total aggregate variation. Bin "Mx" will store the maximum variation. Bin "Mn" will store the minimum variation. Bin "Av" will store the mean variation. When a packet is received the current timestamp is stored in "Rx". The value in bin "Rx" is subtracted from the actual receiver time this value is then subtracted from the value in bin "Ad" and stored in bin "Dn". The current value of "Dn" is added to the value in bin "T". The current value of "Dn" is compared with the value in bins "Mx" and "Mn". If the value is greater than the current value in "Mx", the new value is placed in bin "Mx". If the value is smaller than the current value in bin "Mn", the new value is placed in bin "Mn". The new value in bin "T" will be divided by the new value in "Ct" and the result will replace the value in bin "Av". This test requires that a minimum of two packets be tested, but establishes no maximum time or packet count for the test. To start a new test, clear the values in all bins and set them to zero. This test provides an average variation, a maximum variation, and a minimum variation.

4.2.2.3 Why This Metric is Important

This parameter would be used instead of IPDV 2-point Delay variation when 2 point measurement is not an option.

4.2.2.4 Metric reference documents

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None

4.2.2.5 Recommended Measurement Location

Normally measured at the LM interface to the receiver, but, can be measured anywhere along the stream if necessary. This measurement can be made at any node in the network. While its main value is evaluating network performance at the egress of the network, it can have value in defining the segment of the network that has the greatest contribution to this loss pattern. For this application, measurements would be made at different network node points, with the problem segment being defined as the segment between the two most varied results.

4.2.2.6 Applications for this Metric

The prime value of this parameter is defining the network delay performance such that the most effective buffer size can be determined to recover the network induced packet arrival variation when 2 point measurement is unfeasible

4.2.3 Parameter Name: Mean Network Delay with Median, Maximum, and Minimum Variation Values

4.2.3.1 Definition and Measurement Units

The Average and Peak to Peak delay variation of packet transit time over a network

The unit of measure is the min/max/average in milliseconds.

4.2.3.2 How to Measure

For any two points on a network establish a transmitter and receiver. This transmitter and receiver pair can either generate packets or process existing packets in a given stream. For absolute network delay measurements the transmitter and receiver will have synchronized clocks. For deviation and relative measurements the clock can be isolated as long as they have an accuracy of 10parts per million. The transmitter shall time stamp every packet in the stream and place the value in the header. The receiver shall contain 8 bins. Bin "Ct" will be an incremental counter recording the total number of packets processed. Bin "Tx" will store the Transmit time stamp for calculation. Bin "Rx" shall store the receiver time stamp for calculation. Bin "T" will store the total aggregate delay time. Bin "Mx" will store the maximum transit delay. Bin "Mn" will store the minimum transit time. Bin "Av" will store the mean transit delay. Bin "Md" will store the median transit time. The receiver shall read every packet in the stream and record the time stamp value in a bin "Tx". When the time stamp is read in the header at the receiver, the value of the clock in the receiver is recorded in bin "Rx". The value in bin Tx is subtracted from the value in Rx and defined as "Dn". The current value of Dn is added to the value in bin T. The current value of Dn is compared with the value in bins "Mx" and "Mn". If the value is greater than the current value in Mx, the new value is placed in bin Mx. If

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the value is smaller than the current value in bin Mn, the new value is placed in bin Mn. The value in Mn will be added to the value in Mx and divided by 2. This value will replace the current value in bin Md. The new value in bin T will be divided by the new value in Ct and the result will replace the value in bin Av. This test requires that a minimum of two packets be tested, but establishes no maximum time or packet count for the test. To start a new test, clear the values in all bins and set them to zero. This test provides an average network delay, a median network delay, a maximum network delay, and a minimum network delay between any two points.

4.2.3.3 Why This Metric is Important

Defining network loss patterns over time as a mean value allows a view of average network performance and stability as opposed to the worst single event perspective of an absolute value.

4.2.3.4 Metric reference documents

None

4.2.3.5 Recommended Measurement Location

This measurement can be made between any two nodes in the network. While the prime value of this parameter is to define the end to end delay performance, segment delay can also be measured using this test between the two nodes defining the segment of interest.

4.2.3.6 Applications for this Metric

The prime value of this parameter is defining the network delay performance such that the most effective buffer size can be determined to recover the network induced packet arrival variation.

4.3 Loss and Jitter Category

As described in sections 4.1 (loss) and 4.2 (jitter), IPTV using compressed video techniques is very sensitive to any loss occurring during transport and excessive jitter in an operational network is a precursor to a loss event. Combining these metrics results in a metric that indicates the principal impairments possible from an IP transport network.

4.3.1 Parameter Name: Media Delivery Index (RFC 4445)

4.3.1.1 Definition and Measurement Units

The Media Delivery Index (MDI) is the combined metric of Delay Factor, a measure of cumulative jitter, and Media Loss Rate. These are metrics 4.2.1 and 4.1.1 described above. It is a single metric that captures two common classes of impairments, Loss and Temporal Distortion that can occur within IP networks.

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4.3.1.2 How to Measure

Delay Factor and Media Loss Rate measurements are detailed in RFC 4445.

4.3.1.3 Why This Metric is Important

As a single metric that captures Loss and Temporal Distortion, the only two classes of impairments that can occur within IP networks, it provides an at-a-glance metric of the health of a delivered stream. This facilitates automated monitoring and alarming. It is economical to compute and scalable for the hundreds to thousands of simultaneous streams present on emerging networks carrying video streams. This is important since transport network impairments such as queuing limitations can affect multiple streams in difficult to predict ways requiring simultaneous monitoring of all streams present.

4.3.1.4 Metric reference documents

None

4.3.1.5 Recommended Measurement Location

Referring to Figure 1, MDI is a useful metric at all identified interfaces. The per flow MDI on interface G-H should be assessed in conjunction with its accompanying FEC repair flow.

4.3.1.6 Applications for this Metric

Many applications require continuous monitoring of large numbers of streams such as is typical in production networks. MDI can be used to continuously and simultaneously monitor streams for principal impairment types that can be caused by video over IP networks. Combining jitter and loss metrics in MDI is also useful in characterizing streams at the network ingest interface, interface A-B in Figure 1, to determine whether the transport network has the appropriate queuing resources to accommodate the ingest stream ensemble while simultaneously verifying that the ingest streams are without loss. MDI is also useful in evaluating network devices as described in section 2.3.

4.4 Delay Category:

4.4.1 Parameter Name: End to End delay distribution

4.4.1.1 Definition and Measurement Units

Average one way network latency calculated over a period of time. (two points of measurement)

The unit of measure is in milliseconds.

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4.4.1.2 How to Measure

Send packet with synchronized timestamp. At receive end compare packet timestamp to actual time. Return the difference.

4.4.1.3 Why This Metric is Important

It is extremely useful for users to know what delay is across the entire circuit. It is also very useful for them to be able to determine where this delay comes from. This measurement can help the user determine how a given link may be used (for example, whether it is useful for a live event or not). It is also useful for system designers to know what sort of instantaneous delays exist in the system so that they can design and configure equipment on the network appropriately.

4.4.1.4 Metric reference documents

None

4.4.1.5 Recommended Measurement Location

Referring to Figure 1, end-to-end delay distribution should be measured between two matching points in the system. Example: A measurement between A and M gives total system delay. A measurement between F and J gives the FEC and network delay. A measurement between G and H gives the network delay only.

4.4.1.6 Applications for this Metric

This metric can be used to troubleshoot equipment, determine suitability of a particular link to a specific end-user application such as live interview. It can be used to determine where delay is being introduced into a path.

4.5 Other Network Categories:

4.5.1 Parameter Name: Packet size variation

4.5.1.1 Definition and Measurement Units

These metric measures the maximum and minimum packet sizes in a flow.

The unit of measure is an integer number of octets representing the maximum and minimum size measured packet.

4.5.1.2 How to Measure

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Create two bins. One bin will contain the maximum packet size and the other bin will contain the minimum packet size in the test stream. Monitor all packets in the stream for packet size. In the event that a packet size is in excess of the number in bin 1, replace the number in bin 1 with the size of the current packet. In the event that a packet size is smaller than the number in bin 2, replace the number in bin 2 with the size of the current packet. There is no time limit on this test; the test may be run as long as desired. Reset the numbers in the bin to restart the test when desired.

4.5.1.3 Why This Metric is Important

This is not a network performance parameter; however, it is a measure of a traffic parameter that affects network performance. This measurement can help define the load on the network as defined by the disparity of packet sizes. This might affect queue and fabric performance in switches.

4.5.1.4 Metric reference documents

None

4.5.1.5 Recommended Measurement Location

This metric can be measured at any point in the network. Since it defines a traffic parameter, it should be measured at the specific point of interest for traffic issues.

4.5.1.6 Applications for this Metric

If significant packet delay variation or packet loss is experienced on a network, this parameter can define if long packet lengths of competing traffic could be a contributing factor.

In the event of network disparity, this parameter can define the packet size disparity in the traffic. It can't define the effect on the issue, but identify the extent of the disparity.

4.5.2 Parameter Name: Packet size distribution

4.5.2.1 Definition and Measurement Units

Defines quantity of each packet size over a period of time as a percentage of the total

The unit of measure is an incrementing counter.

4.5.2.2 How to Measure

Define a minimum and maximum packet size for the test. Define granularity of packet size differences for test. Create a number of bins to equal the number of packet sizes defined in the granularity - B1-Bn. Create one more bin for total packet count - Bc.

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Monitor all packets for packet size. When packet size is determined, increment bin associated with that packet size one count. Also increment total packet count bin (Bc) by one count. Calculate percentage of all bins with respect to the new total packet count. Repeat process for each new packet monitored. No time frame is defined for this test. This is a running test. Reset bin counters when it is desired to run a new test.

4.5.2.3 Why This Metric is Important

This is not a network performance parameter; however, it is a measure of traffic parameters that affect network performance. This measurement can help define the load on the network as defined by the quantity, distribution, and mix of packet sizes. This might affect queue and fabric performance in switches

4.5.2.4 Metric reference documents

None

4.5.2.5 Recommended Measurement Location

This parameter can be measured at any point in the network where traffic issues are of interest.

4.5.2.6 Applications for this Metric

If significant packet delay variation or packet loss is experienced on a network, this parameter can define if a large number of long packet lengths of competing traffic could be a contributing factor.

In the event of network disparity, this parameter can define the packet size dispersion in the traffic. It can't define the effect on the issue, but identify the extent of the disparity.

4.5.3 Parameter Name: FEC OH%

4.5.3.1 Definition and Measurement Units

FEC overhead % is a measure of the bandwidth occupied by FEC information as a percentage of the overall bandwidth consumed for a particular transport stream (including FEC).

The unit of measure is a percent of total.

4.5.3.2 How to Measure

This value is derived by measuring the bandwidth of the FEC stream and dividing by the total bandwidth consumed by the transport stream and FEC stream and multiplying by 100.

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4.5.3.3 Why This Metric is Important

This metric is important to systems designers and users. This measurement can be used to confirm that theoretical FEC overhead percent matches actual implementation.

4.5.3.4 Metric reference documents

None

4.5.3.5 Recommended Measurement Location

Referring to Figure 1, FEC overhead % should be assessed at interface G-H.

4.5.3.6 Applications for this Metric

Detecting and quantifying FEC overhead percentage has applications in performance monitoring for deployed systems, and in assuring equipment performance and compliance to standards and specifications. It is useful for the end user to know how much of the total link is being consumed by FEC overhead.

4.5.4 Parameter Name: Decodable with Applied FEC

4.5.4.1 Definition and Measurement Units

This metric is defined to mean the instances where at least one packet was lost on the network but the loss pattern is such that the FEC decoder will have 100% packet recovery. It is a subset of the Blocks with Loss metric (4.1.17).

The unit of measure is an integer.

4.5.4.2 How to Measure

For each FEC block analyzed increment this counter by 1 IF and ONLY IF Blocks with Loss metric increments by one AND the Unrecoverable Count metric (4.1.18) is 0 for the same block.

4.5.4.3 Why This Metric is Important

This metric is useful to the network operator so they easily determine the effectiveness of the FEC scheme. It's really more of a 'summary' type parameter, and would not be useful during testing of FEC equipment (where they want to know the loss patterns involved, etc. so they can verify the proper operation of the FEC equipment) but may be very useful to a network operator who simply wants to know how frequently some type of video corruption was avoided due to the presence of the FEC system, without caring about the nitty-gritty details at a packet level.

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4.5.4.4 Metric reference documents

None

4.5.4.5 Recommended Measurement Location

If you are calculating this based on chosen FEC parameters this could be measured at all interfaces. If you are relying on the FEC receiver to calculate this value it would have to be measured at the FEC receiver.

4.5.4.6 Applications for this Metric

Detecting and quantifying the metric corrected blocks has applications in performance monitoring for deployed systems, troubleshooting deployed and prototype systems, assuring equipment performance compliance to standards and specifications, verifying and measuring delivered service statistics, and during equipment analysis and debug in the design through production life cycle phases. Decodable with Applied FEC gives a good picture of how the chosen setting are performing. It is used with other metrics to assess the level of FEC that may be required on an interface to achieve a desired packet error rate. It is used with other metrics to assess whether the level of deployed FEC on a link is adequate to repair a measured impairment.

4.5.5 Parameter Name: Loss > protection

4.5.5.1 Definition and Measurement Units

This metric is a Boolean (T/F) that indicates whether a count of packet loss for a given block exceeds the number of FEC repair packets; i.e., "true" indicates that no FEC decoder could recover block. Note that it is simultaneously possible that Loss>protection is false and that all packets are still not decodable depending on the strength of the FEC code.

The unit of measure is a Boolean (T/F).

4.5.5.2 How to Measure

A monitoring device compares the number of FEC repair packets per block (r) to the number of missing packets per block (m) per stream. If $r \geq m$ then return F, "false". If $r < m$ then return T, "true". Counts of detected blocks and their $m > r$ status over a user settable measurement interval time are recorded.

4.5.5.3 Why This Metric is Important

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For Generic FEC and Raptor FEC algorithms, if $r \geq m$ then the FEC algorithm can always recover the missing packets. For Pro-MPEG CoP3 R2, if $r \geq m$ the FEC algorithm can usually recover the missing packets. A count of the number of T results indicates how frequently unrecoverable loss occurs regardless of the FEC algorithm being applied.

4.5.5.4 Metric reference documents

Refer to the deployed FEC algorithm definition documents for details about which and how many packets can be recovered by that particular FEC algorithm.

4.5.5.5 Recommended Measurement Location

Referring to Figure 1, this per flow metric on interface G-H indicates how many loss events per block are not recoverable no matter which FEC algorithm is selected for this FEC protected link.

4.5.5.6 Applications for this Metric

Detecting and quantifying packet loss has applications in performance monitoring for deployed systems, troubleshooting deployed and prototype systems, assuring equipment performance compliance to standards and specifications, verifying and measuring delivered service statistics, and during equipment analysis and debug in the design through production life cycle phases. It is the principal impairment that is of interest as a result of a fault in a video over IP transport system. “Loss>protection” is an indication of loss severity with respect to FEC processing units. It is used to classify packet loss events that are unrecoverable regardless of the FEC algorithm employed for monitoring applications.

4.6 Payload Category:

4.6.1 Parameter Name: Packet stream bit-rate

4.6.1.1 Definition and Measurement Units

This metric is the actual measured bit rate of the data stream of a group of representative packets in the network.

The unit of measure is number of bits per second.

4.6.1.2 How to Measure

Define a specified time period. Identify packet address or packet identifier set to be measured. Capture every packet with designated identifier(s) during defined time period. Record packet size of each packet captured during time interval. Add all recorded packet

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size measurements for the defined time period to achieve total bytes/period. Divide the total bits/period by the number of seconds in the defined time period to achieve bit rate in bits/sec. Repeat as often as desired and average results over total period intervals exercised during test period.

4.6.1.3 Why This Metric is Important

This is not a network performance parameter; however, it is a measure of a parameter that affects network performance. This measurement can help define the load on the network of an individual data stream.

4.6.1.4 Metric reference documents

None

4.6.1.5 Recommended Measurement Location

Since this is a traffic parameter it can be measured at any point in the network where traffic issues are of concern.

4.6.1.6 Applications for this Metric

The primary significance of this parameter is in evaluating the size or integrity of a defined stream. However, it can be used to evaluate the size of a suspect stream or define the total network load by evaluating all stream rates and calculating the total network load for any given segment.

4.7 Non Metric Category:

4.7.1 Parameter Name: FEC Block latency

4.7.1.1 Definition and Measurement Units

The length of time it takes to receive a FEC Block from start to finish.

The unit of measure is in milliseconds.

4.7.1.2 How to Measure

The value is block size * bit-rate.

4.7.1.3 Why This Metric is Important

This metric can be useful for interpreting the results of other measurements.

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4.7.1.4 Metric reference documents

None

4.7.1.5 Recommended Measurement Location

This can be measured anywhere on the network or just calculated from equipment settings.

4.7.1.6 Applications for this Metric

This is a non metric that is more of an informational calculation used to clarify what the other metrics are showing.

4.7.2 Parameter Name: Block Size

4.7.2.1 Definition and Measurement Units

This parameter is number of packets in a block for a particular applied FEC type.

The unit of measure is an integer in bytes.

4.7.2.2 How to Measure

The value is the block size.

4.7.2.3 Why This Metric is Important

This metric is mainly for informational purposes.

4.7.2.4 Metric reference documents

None

4.7.2.5 Recommended Measurement Location

This can be measured anywhere on the network or just calculated from equipment settings.

4.7.2.6 Applications for this Metric

This is a non metric that is more of an informational calculation used to clarify what the other metrics are showing.

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5. Glossary

Cumulative Jitter – A measurement of total end to end delay variation incurred on a stream of data (i.e. video). It is directly related to and can be expressed as the amount of playback delay that must be provided in order to avoid discarding of any video frames in the stream by the network endpoint.

DSLAM (Digital Subscriber Line Access Multiplexer) – A network device, usually located at a telephone company central office, or within a neighborhood Serving Area Interface (SAI) as part of a digital loop carrier, that receives signals from multiple customer Digital Subscriber Line (DSL) connections and aggregates the signals on a high-speed backbone line using multiplexing techniques. Depending on the product, DSLAM multiplexers connect DSL lines with some combination of Asynchronous Transfer Mode (ATM), frame relay, or Internet Protocol networks.

FEC (Forward Error Correction) - A system of error control for data transmission, where the sender adds redundant data to its messages to allow the receiver to detect and correct errors (within some bound) without the need to ask the sender for additional data.

(FTTx) – This refers to several different forms of optical fiber architectures including:

- Fiber-to-the-Node/Neighborhood (FTTN)
- Fiber-to-the-Exchange (FTTEx)
- Fiber-to-the-Cabinet (FTTCab)
- Fiber-to-the-Curb (FTTC)
- Fiber-to-the-Building (FTTB)
- Fiber-to-the-Home (FTTH) (Fiber-to-the-Premise (FTTP))

Headend – A master facility for receiving television signals for processing and distribution over a cable television system.

IPPM (IP Performance Metrics) – A list of metrics defined by the IETF working group of the same name to characterize IP network performance. The metrics are:

- Connectivity
- One-way delay and loss
- Round-trip delay and loss
- Delay variation
- Loss patterns

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- Packet reordering
- Bulk transport capacity
- Link bandwidth capacity

IPTV (Internet Protocol Television) - A system where a digital television service is delivered using the Internet Protocol over a network infrastructure, which may include delivery by a broadband connection.

Jitter - The variation in arrival time of information (digital signal or packets) from its expected arrival.

MDI (Media Delivery Index) - MDI is represented mathematically as two numbers. One representing the DF or Delay Factor, indicating the buffer needed to accommodate IAT or Inter Arrival Time variances in IP packets. The other number is the MLR or Media Loss Rate, which states the number of Transport Stream packets lost over a time period - usually one second, thereby giving DF:MLR as the mathematical representation of MDI.

MPEG - Moving Picture Experts Group

MPEG 2 - Transport, video and audio standards for broadcast-quality television.

MPEG 4 - Expands MPEG-1 to support video/audio "objects," 3D content, low bitrate encoding and support for Digital Rights Management. Contains newer higher efficiency video standards as an alternative to MPEG-2 Video, notably, Advanced Simple Profile and Advanced Video Coding.

MPTS – Multiple transport streams.

Packet reordering - A packet is considered reordering if it has a sequence number smaller than the sequence number of a previously observed packet.

PID – Packet ID.

PCR – Program Clock Reference

QAM (Quadrature amplitude modulation) - A modulation scheme which conveys data by changing the amplitude of two carrier waves.

QOE (Quality of Experience) – A subjective measure from the user's perspective of the overall value of the service provided. It is user dependent, and can be influenced by the user's end device (for example whether they are using a Standard or High Definition TV).

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VC1 - The SMPTE 421M video codec standard. Deemed as an alternative to the latest to H.264/MPEG-4 AVC. VC-1 contains coding tools for interlaced video sequences as well as progressive encoding.

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