# The Failure of a Regulatory Threshold and a Carrier Standard in Recognizing Significant Communication Loss

**Andrew P. Snow**
**J. Warren McClure School of Communication Systems Management**
**Ohio University**
**asnow@ohio.edu**

**Abstract.** This paper investigates a regulatory reporting threshold dealing with telecommunication outages, and the use of a carrier industry standard in measuring the significance, or impact, of outage events. The FCC reporting requirement investigated is the 30,000/30 minute threshold, wherein any outage potentially affecting at least 30,000 customers for at least 30 minutes is an FCC-Reportable outage event. As outages below the threshold are censored, the natural question is whether a threshold is masking important events and impact? As local wire-line telecommunication switch outages are also reported in ARMIS for any local switch outage lasting 2-minutes or more, we have the opportunity to investigate communications loss above and below the FCC mandated threshold, at least for local switch outages. Although outages are due to failures in transmission facilities, signaling, tandem switching, and local switching, ARMIS reported local switch outages offer a proxy that provides insights into the relevancy of the current threshold. Over 18,000 local switch outage events are examined in this work. Impact for those local switch outages above and below the threshold are computed two ways (1) use of an ANSI accredited Standards Committee T1 metric called the Outage Index, and (2) use of a benchmark metric defined here, called Prime Lost Line-Hours. Key findings are that the current regulatory threshold masks serious communications loss, and that the industry communications loss metric (Outage Index) distorts impact above and below the regulatory threshold. This point is demonstrated by further considering five 9-11 switch outages in New York City. The appropriateness of the threshold and the industry metric are called into question, and further research is indicated, including economic research into threshold optimality.

## I. Introduction

In response to several celebrated telecommunication outages in the late 1980's and early 1990's, the FCC started requiring wire-line carriers to report certain network outages in 1992 [1]. These outages are referred to as FCC-Reportable outages. Although the reporting rules require reporting different type outages, such as fire, special facilities (airports and military), and E911, the largest number of reported outages meet a particular threshold requirement. This threshold is any outage capable of potentially affecting at least 30,000 customers for at least 30 minutes.[1]

The policy issue relating to this threshold deals with whether it is too high or too low. Set too low, excessive and unimportant reports are filed; set too high, censoring, or

[1] The threshold was initially set at 50,000 and 30 minutes, but the order was changes within months of rule initiation. This would be but a transient item of interest had not Standards Committee T1 used 50,000 in the definition of the Outage Index at that time.

masking, of serious outage events is present. To illustrate censoring, if the threshold were 1,000,000 or more affected for at least 24 hours, there would be almost no reports. One might incorrectly infer that the network is very reliable and that users are not susceptible to telecommunication outages.

One way to investigate the threshold issue is to tally the number of reports above and below the threshold. This is a reliability perspective, and tells but part of the story. It is important to know that an event occurred, but it is more important to understand the impact of the outage. The impact of the outage is a survivability perspective. To fully understand the threshold issue, both reliability and survivability perspectives must be considered.

This work is an empirical assessment of 18,482 local telecommunication switch outages, from a reliability and survivability perspective to see if there is masking of significant communications events and loss by the FCC threshold. However, the latter perspective relates to *how* the impact is measured, and *how well* an industry metric portrays outage impact.

So the policy threshold issue also relates to how impact is measured, as an outage event affecting 40,000 users for 10 days is different from 40,000 affected for 10 minutes. Standards Committee T1 Telecommunications proposed, and industry uses, an outage impact (survivability) metric, called the *outage index* [2]. Any assessment of threshold relevance must also include any shortcomings in this metric to see if it distorts impact above or below the threshold. Other work has demonstrated that the outage index metric is open to criticism for being too carrier-centric in its view of outages [3, 4].

The threshold investigation in this paper is not an economic investigation of whether the threshold is set at the optimal societal point. This consideration, although important, is not in the scope of this paper. However the results presented here do provide information to assist in such an analysis.

## II. Research Questions

In this work we examine two questions:

R1: *Censoring* - How many outage events and how much communication loss is censored by the FCC-reportable threshold?

R2: *Distortion* – Does Standards Committee T1 outage metric distort the impact of outages above and below the FCC-reportable threshold?

## III. Required Regulatory Telecommunications Outage Reporting

Here we describe a threshold related industry outage report, called an FCC-reportable outage, and local switch outage reports required by the FCC of price cap regulated local carriers in ARMIS. The former reporting threshold is our research issue of interest, while the latter reporting offer us local switch outage data above and below this threshold.

### *A. FCC-Reportable Outages*

There are a variety of reports required with different thresholds, the size portion relating to potentially or actually affected customers [1]:

- General outages causing local switch isolations (at least 30,000 users and 30 minutes)
- Outages caused by Fire (1000 lines, 30 minutes duration)
- Special Outages (any size and duration national security/emergency preparedness (NS/EP)
- E911 outages (tandems, any size, 30 minutes duration; E911 facility, 30,000 users, 30 minutes duration)

As most of the FCC-reportable outages are in the first category, this is the threshold we choose to investigate - outages that affect at least 30,000 users for at least 30 minutes. Note that this is an "and" as opposed to an "or" threshold requirement. Both the magnitude and duration thresholds must be met to have a reportable incident.

These type outages occur because of failures in transmission, signaling, switching, and power equipment/infrastructure. Switching includes both local and tandem switches.

### *B. ARMIS Switch Outages*

ARMIS requires price cap regulated local carriers to report local switch outages in FCC Report 43-05, Table IV.A, Occurrence of Two Minutes or More Downtime. Among other things, this Table provides for each switch outage over 2-minutes, the number of access lines served, the date/time of the outage, and the duration of the outage. This data offers an opportunity to investigate outages above and below the FCC-reportable threshold. For the years 1993 through 2001, 18,482 outages were collected from ARMIS to perform the threshold analysis.

## IV. Outage Impact Measurements

Here we discuss an outage metric often used by the FCC (Lost-Line-Hours), a metric defined by ANSI certified Standards Committee T1 (Outage Index), and a benchmark metric that combines the strengths of the FCC and ANSI metrics, yet removes their weaknesses.

### *A. Lost Line Hour*

The lost line hour (*LLH*) metric has been often used by the FCC in the past, and is simply the product of the access lines of the failed switch multiplied by the duration of the outage. The result is a simple metric that is easy to understand and compare to other switch outages. For example, if a switch with 10,000 lines is down for 30 minutes, the *LLH* is 5,000, or an outage comparable to a 5,000 line switch down for 1-hour. Likewise, if a switch with 2500 lines is down for 120 minutes, the *LLH* is also 5,000. The weakness of the *LLH* is that it does not account for periods of little or no customer activity on the switch. For instance, if an outage happened at 3:00am on a Saturday, is the impact the same as if these outages were at 10:00am on a Monday? If the switch fails and no one is trying to use their line, is there an impact? In addition, the metric does not distinguish between say an E911 call and an IntraLATA call.

### *B. Outage Index*

The outage index (OI) was created by Standards Committee T1, which is accredited by ANSI and sponsored by the Alliance for Telecommunications Industry Solutions (ATIS) [5]. More specifically, it was developed within T1A1 Technical Subcommittee: Performance, Reliability, and Signal Processing by Working Group T1A1.2 Network Survivability Performance [6]. Although the motivation for the metric was originally a way to measure FCC-reportable outages [7], it is touted as being a universal metric that can be used above and below FCC-reportable thresholds [2]. Although not formally adopted by Committee T1 as a standard, but in approved Technical Reports, the outage index has become an adhoc standard as it has been put to use by a number of carriers and by the Network Reliability Steering Committee (an ATIS sponsored committee that analyzes FCC-Reportable outages). The outage index accounts for the importance of the lost telecommunication service (type call), the magnitude of the outage, the day/time of the outage, and the outage duration. In [2], the outage-index was generalized for voiceband services in wireline, wireless, PCS, CATV, and Satellite networks. The outage-triple approach was adopted, allowing an outage episode to be characterized as a single impact metric by incorporating service, duration and magnitude weights, as follows:

$$I(O) = \sum_{j=1}^{N} W_{S_j} W_{D_j} W_{M_j}$$

where $j=1,....,N$ are the services impacted by the outage, $W_S$ = Service Weight, $W_D$ = Duration Weight, and $W_M$ = Magnitude Weight.

For traditional voice in the wireline Public Switched Telephone Network (PSTN), the service weights range from *1* to *3*, depending upon whether local, toll, or emergency services are impacted by the outage. For traditional voice calls in the wire-line PSTN, the service weights are discrete "importance factors" given by:

- IntraLATA Intraoffice Service - *1*
- IntraLATA Interoffice Service - *2*
- InterLATA Service - *2*
- E911 Service - *3*

The *magnitude weight* ranges from *0.0* to *16.67* and a defined function relates the number of users impacted by the outage (magnitude) to a magnitude weight value. In addition, before determining the weight, the magnitude is multiplied by a Time Factor (*TF*), where $TF = 1.0$ for daytime, $TF = 0.3$ for evening, $TF = 0.2$ for weekends, and $TF = 0.1$ for late night (the exception is that TF is always *1.0* for an E911 service outage).

The *duration weight* ranges from *0.0* to *2.5* and a defined function relates the duration of the outage to a duration weight value. Both magnitude and duration weights approach their respective maximums asymptotically. Note that in the limit, the outage index weighs outage size almost 7-times more important than duration [3]. In addition, the magnitude weight reaches 90% of its asymptotic value at 4,000,000 users affected, while the duration weight reaches 90% of its asymptotic values at about 8-hours.

The outage index overcomes the *LLH* weakness by applying a Time Factor to the magnitude (to reflect switch traffic) which is based upon the day/time of the outage. For instance if a 10,000 line switch fails during the prime business day, say 2:00 pm on a weekday, the magnitude weight for non-E911 service outages is derived using a magnitude of (10,000)*(1), $M \cdot TF$, or 10,000. However if this same switch were to fail at 3:00 am on Saturday, the magnitude weight is derived using a magnitude of (10,000)*(0.1), or 1,000. The time factors for various days of the week and hourly times are defined in [2]. In the outage index, if the outage straddles different time periods with different time factors, the largest time factor is used.

To determine the outage impact for a particular time-period, we simply sum the outage-indices of all the outages occurring during that time-period (e.g. day, month, quarter, year).

### *C. Benchmark Metric - Prime Lost Line Hours*

Because of the imbalance between magnitude and duration weights in the outage index, and the discontinuous and non-linear nature of the outage index weights, concern has been evidenced and documented that the outage index skews perception of outage impact [3, 4]. For this reason, another metric is needed to check the validity of this measure in examining threshold relevance. The *PLLH* metric combines the line-hour metric and the time factor used in the outage index:

$$PLLH = LLH \cdot TF_{AVG}$$

Here, the *average* Committee T1 time factor over the outage period is used. By applying the time factor, the metric more accurately reflects usage. Since *TF* for the prime business day is 1, this results in a "prime business day equivalent lost line hours" metric which gives equal importance to magnitude and duration. However, *PLLH* does not reflect the type service(s) impacted by the outage. The *PLLH* is a benchmark metric against which to assess the reasonableness of the outage index. To determine the outage impact for a particular time-period, we simply sum the *PLLH* of all the outages occurring during that time-period (e.g. day, month, quarter, year).

## V. Methodology

In this investigation, 18,482 ARMIS reported local switch outages from 1993 through 2001 were used. Each event was first categorized as above or below the FCC-reportable threshold. Next, both the *OI* and the *PLLH* are calculated for each outage. *OI* and *PLLH* were summed by category. This methodology is summarized below in Table 1. Five of these events were due to 9-11. Because of the long duration of these outages, and their small number compared to the 18,482 outages over a nine year period, the same methodology was applied to the outages, less the 9-11 outages.

**Table 1. Methodology**

| INPUT | CALCULATE | OUTPUT |
|---|---|---|
| • Switch outage event ($E_i$) from ARMIS<br>• Magnitude ($M_i$), or access lines, of switch suffering outage<br>• Outage duration ($D_i$)<br>• Time of day ($T_i$) outage started<br>• Day of Week outage started | • Outage Index ($OI_i$) for switch outage event<br>• Prime Lost Line-Hours ($PLLH_i$) for switch outage event | • Identify switch outage as above or below the threshold<br>• Associate impact (*OI* and *PLLH*) as above or below the threshold<br>• Sum events above and below threshold $\sum E_{Above}$ and $\sum E_{Below}$<br>• Sum impact above and below the threshold $\sum OI_{Above}$ & $\sum OI_{Below}$ $\sum PLLH_{Above}$ & $\sum PLLH_{Below}$ |

## VI. Summary Results

The total communication outage events and communication loss is summarized in Table 2. As a result, we conclude that the five 9-11 outages appear to be outliers, as they account for about 29% of the total impact. We also conclude that although the outage index handles these outliers nicely, the price paid is an order of magnitude underestimation of communications loss impact.

**Table 2. Summary of Communication Loss**

| MEASURE | WITH 9-11 OUTAGES | WITHOUT 9-11 OUTAGES | REDUCTION |
|---|---|---|---|
| Events | 18,482 | 18,477 | 0.03% |
| Outage Index | 1,848 | 1,797 | 2.76% |
| Prime Lost Line Hours | 43.4 M | 30.9 M | 28.80% |

Next, we summarize "above" and "below" threshold results in Lines vs. Duration graphs, using the 30,000 and 30 minute threshold to create four different quadrants (Figure 1 below). Quadrants I, II, and III represent outage events below the threshold while quadrant IV represent FCC-reportable outages (uncensored events above the threshold). In each quadrant, the number of outages, the summed Outage Index, and the summed Prime-Lost-Line-Hours are depicted.

The same data is displayed, less the 9-11 switch outages, in Figure 2, to see how this small number of long duration outages affects the threshold results.

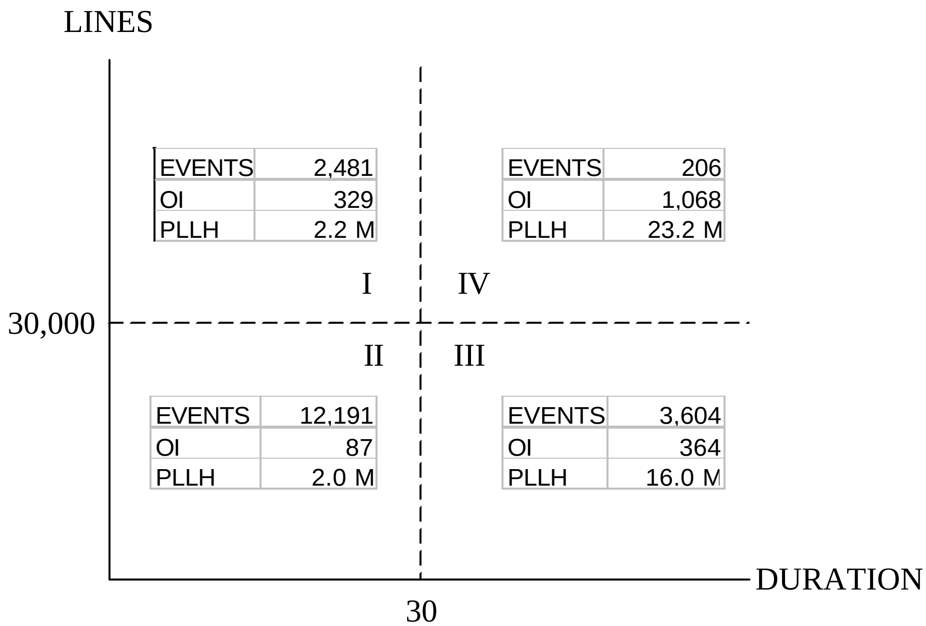


**Figure 1. Outage Characterization Above and Below the Threshold**

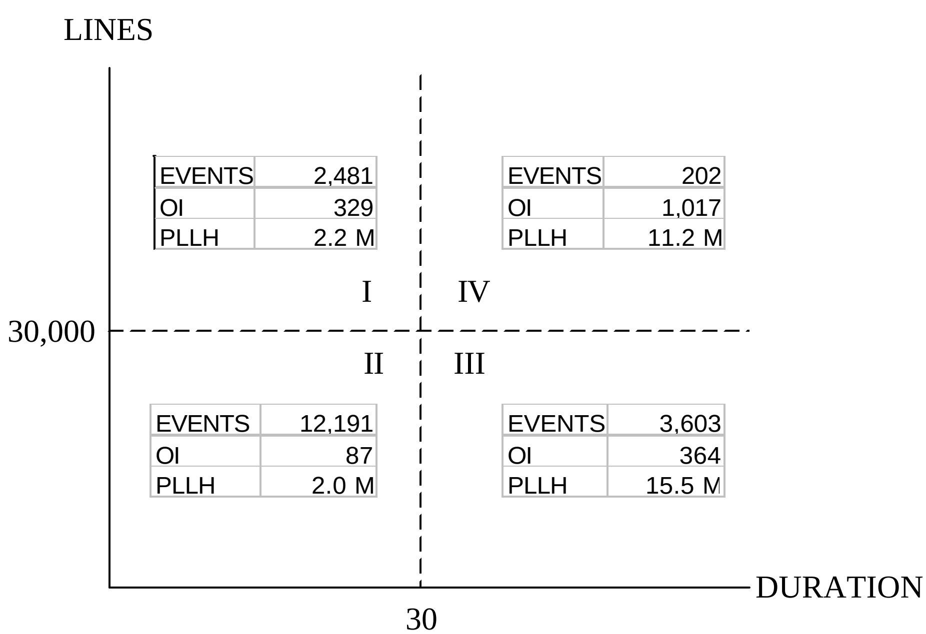


**Figure 2. Outage Characterization Above and Below the Threshold (Less Five Switch Outages as a Result of 9-11**

From a comparison of Figures 1 and 2, we once again see that the five 9-11 events are outliers, principally because of their long duration, as seen in Table 3 below.

**Table 3. Local Switch Outages in NYC due to 9-11**

| OUTAGE | LINES | DURATION (HRS) | OI | LLH | PLLH |
|---|---|---|---|---|---|
| 1 | 6,140 | 209.5 | 0.2 | 1,286,023 | 495,119 |
| 2 | 35,369 | 209.5 | 6.7 | 7,408,037 | 2,852,094 |
| 3 | 41,671 | 189.5 | 9.2 | 7,895,960 | 3,039,945 |
| 4 | 50,043 | 145.1 | 13.3 | 7,261,239 | 2,662,454 |
| 5 | 63,211 | 150.1 | 21.9 | 9,490,078 | 3,479,695 |
| | | **TOTAL** | **51.3** | **33,341,337** | **12,529,307** |

## VII. Findings

The research questions are addressed in this section, based upon the empirical data. Major findings, limitations, and implications are also discussed.

***R1: How many failure events and how much communication loss is censored by the FCC-reportable threshold?***

The percentages of events and impact depicted in Figures 1 and 2 are summarized in Table 4. Impact here is in *PLLH.* First, we conclude that the threshold is *efficient*, in that significant impact is captured with a very small fraction of the total outages. Second, we conclude that *considerable impact is censored* by the threshold (almost half). If the very long duration 9-11 outages (outliers) are removed, we see that almost 2/3 of the impact is censored by the threshold.

**Table 4. Outage Events and Impact Above and Below the Threshold**

| | **PERCENTAGE OF TOTAL OUTAGES** | **PERCENTAGE OF TOTAL IMPACT (W/O 9-11)** |
|---|---|---|
| **ABOVE THE THRESHOLD** | 1.1% | 55.8% (38.4 %) |
| **BELOW THE THRESHOLD** | 98.9% | 44.2% (61.6%) |

***R2: Does the Standards Committee T1 outage metric distort the impact of outages above and below the FCC-reportable threshold?***

*OI* and *PLLH* are normalized and depicted in Figure 3. Here we see that there is not much difference between the *OI* and *PLLH* above the threshold, initially suggesting little distortion. However, if we look below the threshold we see that the impact of outages involving switches smaller than 30,000 lines our for at least 30 minutes or more is underestimated by about a factor of two. Likewise we conclude that for switches of 30,000 lines or more out for less than 30 minutes, the impact is overestimated. This reinforces the bias of the *OI* towards large outages, and away from long duration outages.

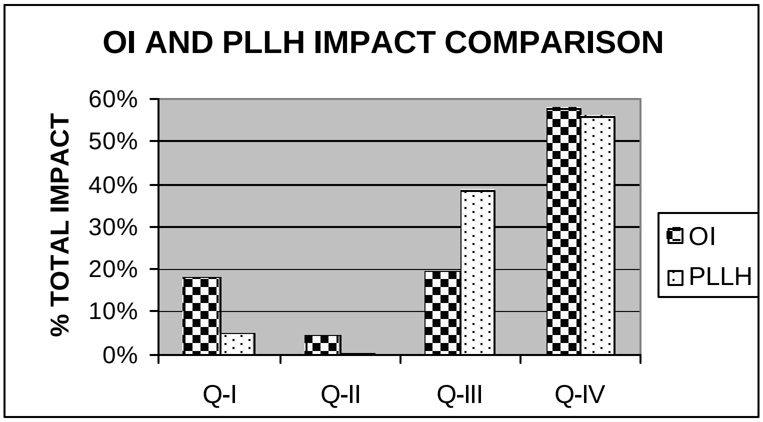


**Figure 3. Normalized Comparison of Impact Metrics**

The same normalized comparison, less 9-11 outages is shown in Figure 4. Without 9-11, the *OI* overestimates the impact above the threshold by about 50%, once again demonstrating the bias of this metric against long duration outages. Also, the amount of underestimation below the threshold for long duration outages (Q-III) is increased.

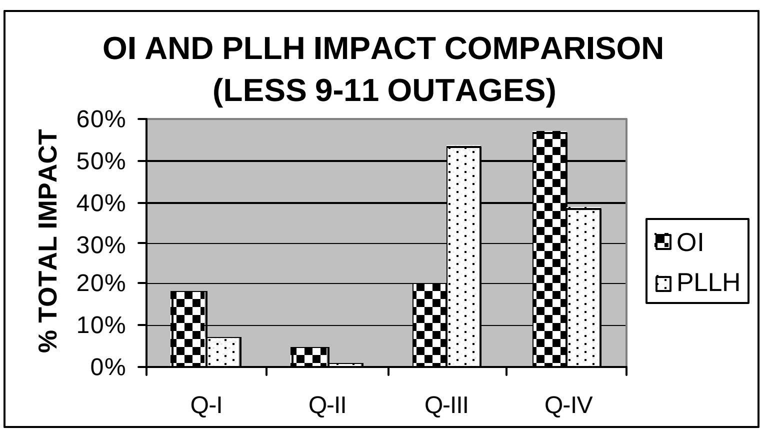


**Figure 4. Normalized Comparison of Impact Metrics Less 9-11 Outages**

The FCC-reportable outage threshold fails to identify very considerable outage impact, particularly those outages lasting more than 30 minutes, but less than 30,000 lines. Likewise, the carrier industry metric fails to accurately portray the impact above and below the threshold. Next, we discuss the research limitations of this work, summarize findings, and discuss implications of the results.

### *A. Research Limitations*

This research has several limitations, which are enumerated and discussed below to place the research in context.

1. Study includes local switch outages only: The extent to which the local switch outages are a good proxy for all other type outages is not known. As outages below the threshold for failures in signaling, transmission, and power are not reported in the public domain, the true amount of outage impact above and below the threshold is not apparent. However, this does not discount this work as an indicator of potential problems with the threshold and the Standards Committee T1 metric.
2. Switch outage data used are not totally reflective of all communication loss due to switches: ARMIS data used does not include partial switch failures. For instance, if a 100,000 line switch loses 50,000 lines for 10-minutes, it is not a reportable outage in ARMIS. In addition, tandem switch outages are not reported in this venue, unless the tandem also has local access lines. Also, details of outages under 2 minutes are not reported. Lastly, if there were any blocked calls, this impact is not reported in ARMIS. However, as the ARMIS data includes over 18,000 total switch outages, this impact assessment may not be complete, but it is certainly substantial.
3. Switch data includes only Federal price cap local carriers: Non-price cap regulated carriers are not required to file ARMIS reports. However, price cap regulated carriers represent the vast majority of access lines in the U.S.
4. The Prime Lost Line-Hour metric used here is not an alternate metric to the Outage Index: The weakness of $PLLH$ as a metric is that it does not delineate between different telecommunication services. The $PLLH$ is specifically created in this paper as a "sanity check" on the Outage Index to see if it distorts communication loss for local switch outages. From this and other work [3, 4], the outage index cannot be validated as a rational outage impact metric for local switch outages.

### *B. Major Findings*

The findings of this research indicate that:

- There is very significant communications loss due to total local switch failures below the FCC-reportable threshold
- If the ANSI accredited Standards Committee T1 outage index is used, the significance of the communication loss below the threshold is not recognized, and the loss above the threshold is overstated.

### *C. Implications*

The FCC-reportable threshold may not be optimally selected, and this paper presents evidence of considerable censoring of significant outage events and impact. Without an optimal threshold, if carriers took proactive steps to decrease FCC-reportable outages, the outcome could be a misallocation of capital and operational resources. The economic optimality in setting a threshold is outside the scope of this paper, but indicates future research may be in order.

Clearly, the outage index is not as universal as Standards Committee T1 claims. In this paper, the index significantly distorts impact by overweighting the importance of size, and underweighting the importance of duration. Rightfully, carriers focus on restoral based upon the *size* of an outage while users focus on the *duration* of an outage. However, up to 7-times more importance given to outage size over duration seems excessive. In addition, as the outage index is insensitive to outages exceeding 8-hours duration, the metric is clearly more carrier-centric rather than user centric. The industry should consider reexamining this metric to more fairly reflect impact of outages.

A threshold set by regulatory action influenced industry to create a particular outage metric. As the threshold masks considerable impact, and the industry measure distorts impact, the result is *pain below the threshold*, which is considerably underestimated and mostly unreported. Regulators should reexamine the goals of large-scale outage event reporting, especially in light of broadband developments and uneven reporting requirements[2], if they wish to adequately monitor the wellbeing of critical network infrastructure and the level of service continuity offered users. Piecemeal reporting regimens with arbitrary thresholds provide only a partial view of the overall reliability and survivability of critical telecommunication infrastructure. If this issue is not sufficiently addressed for voice communications, how can we possibly hope to assess the same type issues for the Internet or other convergent telecommunication infrastructures?

## VIII. References

[1] 47 CFR § 63.100, Notification of Common Carrier of Service Disruptions

[2] Standards Committee T1 Telecommunications, T1A1.2 Working Group on Network Survivability Performance, "*A Technical Report on Network Survivability*", Report No. 24A, Alliance for Telecommunications Industry Solutions, 1997.

[3] Snow, Andrew P., "A Survivability Metric for Telecommunications: Insights and Shortcomings", IEEE Computer Society Proceedings, Information Survivability Workshop - ISW'98 (October 1998) 135-138.

[4] Snow, Andrew P. and Carol C. Carver, "Carrier-Industry, FCC and User Perspectives of a Long Duration Outage: Challenges In Characterizing Impact", ANSI Committee T1 – Telecommunications, T1A1.2, Contribution Number T1A1.2/99-026, (May 1999): http://www.t1.org/index/0627.htm

[5] Standards Committee T1 Telecommunications, http://www.t1.org

[6] T1A1 Technical Subcommittee, Performance, Reliability, and Signal Processing, http://www.t1.org/t1a1/t1a1.htm

[7] Standards Committee T1 Telecommunications, T1A1.2 Working Group on Network Survivability Performance, "*A Technical Report on Enhanced Analysis of FCC-Reportable Service Outage Data*", Report No. 42, Alliance for Telecommunications Industry Solutions, 1995.

[2] For instance wireline carriers must report while wireless carriers have no obligation to do so.