Using ODM 3.0 to Fix Customer Impairments

Overall DOCSIS Metric

A Technical Paper prepared for SCTE by

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1. Introduction

1.1. Background

Detecting network issues and solutioning them has served as a complex challenge for telecommunication firms across the globe for decades. In a post-pandemic world, with connectivity at the forefront, reliability becomes the key focus. Overall DOCSIS® metric (ODM) helps build a reliable network with its rapid detection of network impairments and added clarity of where and what action is required.

ODM's first version was developed for upstream (US) SC-QAM 64-QAM deployment and proactive network maintenance (PNM). The algorithm was effective but biased towards upstream metrics. ODM+, the second version of the algorithm, was developed to enhance detection by integrating downstream KPIs (key performance indicators) and DOCSIS (Data Over Cable Service Interface Specification) 3.1 spectrum. The third iteration of the algorithm, ODM 3, focuses on connectivity and stability. ODM 3 combines DOCSIS 3.0/3.1 HFC (hybrid fiber-coaxial) parameters and applies a scoring to each weighted KPI by service impact. These scorings are utilized to detect connectivity impairments and grade overall node health within the network.

Each KPI is polled via SNMP (Simple Network Management Protocol) and IPDR (Internet Protocol Detail Record). KPI's include Rx (receive), Tx (transmit), SNR (signal-to-noise ratio), CER (correctable rrror ratio) and MER (modulation error ratio) 2nd percentile. Each KPI carries an individual scoring based on defined thresholds. A single KPI can have multiple thresholds to capture severity of impact.

A modem will be considered failing if its CM (cable modem) score is equal to or above 75. Once the pass/fail scoring for each modem on the network is completed, the node is scored based on pass/fail percentage of customers, nodes below a 90% passing customer threshold are considered actionable for PNM activities.

1.2. Purpose of the White Paper

The purpose of this white paper is to explore the ODM algorithm, its history, development and benefits. ODM was developed to identify both customers and areas where network impairments are present. With assigned scoring, technicians are able to identify which customers must be prioritized. Equipped with this prioritization and the clear identification of which KPI's within ODM are impaired, technicians are able to quickly resolve issues. With over 600 tickets generated, ODM has observed a 96% success rate.

2. Scope and Limitations

The ODM 3 algorithm is reliant on modem data polled every 15-60 mins. Multiple data sets exist to remove discrepancies and provide back-up data if primary data feeds fail.

Self-corrective and weather-related incidents may cause an increase in "no fault found" closure of IMTs which can impact the accuracy of ODM 3. Further development is currently underway to remove such cases.

3. Overview of HFC Networks

3.1. SC-QAM Channels and Signal Characteristics

DOCSIS 3.0 and 3.1 allow for visibility of many KPIs via MIBs (management information base). Many are utilized by ODM: downstream Rx, upstream Tx, downstream/upstream SNR, downstream/upstream CER. Each of these are polled hourly via an SNMP platform and the data is stored within a cloud service.

3.2. Orthogonal Frequencies and Technical Visibility

DOCSIS 3.1 allows the use of additional frequencies and better impairment visibility. ODM utilizes: orthogonal frequency-division multiplexing (OFDM) Rx power, (orthogonal frequency-division multiple access) OFDMA Tx power, OFDM Rx MER 2nd percentile and OFDMA MER 2nd percentile. The transmit levels at the time of polling will be obtained as is, as such OFDMA mini slots will not be utilized within the ODM model. Each of these are polled hourly via an SNMP platform.

4. Initial Iterations of ODM

4.1. Overall DOCSIS Metric Inception and Execution

With various activities of service monitoring and PNM in place focused on individual service impacting KPI's, the requirement for an overall metric became necessary. ODM's purpose was to qualify nodes for US SC-QAM 64-QAM activation & create a basic PNM process while ensuring service impacting situations may be identified and addressed.

The 2nd iteration, ODM+, expanded to include DS SC-QAM and OFDM KPI measurements including MER 2nd percentile, Rx power and SNR; with an objective to stabilize connectivity for modems and to score the health of a node. During testing several versions were evaluated to determine the accuracy by utilizing accessibility within a confusion matrix (Figure 1), each model was given different weights and total score thresholds.

<table>
<tr><td colspan="2" rowspan="2"></td><td colspan="2">ODM CM Score</td></tr>
<tr><td>Good</td><td>Bad</td></tr>
<tr><td rowspan="2">Accessibility</td><td>Good
≥98%</td><td>ODM CM Score aligns well
High accessibility with Low ODM CM score</td><td>False-Positive
High accessibility with High ODM CM score</td></tr>
<tr><td>Bad
<98%</td><td>False-Negative
Low accessibility with Low ODM CM score</td><td>ODM CM Score aligns well
Low accessibility with Low ODM CM score</td></tr>
</table>

Figure 1- ODM Confusion Matrix

Through testing, KPI weights were adjusted to ensure ODM was able to capture actionable issues. Testing found that when overall score threshold is low and optimized weights are used (<75 score per modem), a decrease in both false-positives and false-negatives is observed. Figure 2 shows this decrease in false-positives with optimized weights.

A similar analysis was conducted for only false-negatives. False-negatives showed a lower percentage when the optimized weights were used. Figure 3 shows the decrease in false-negatives with optimized weights. It is noted in both scenarios that the dramatic decrease/increase in accessibility as ODM score lowers indicates potentially other factors impairing accessibility in addition to the existing KPIs.

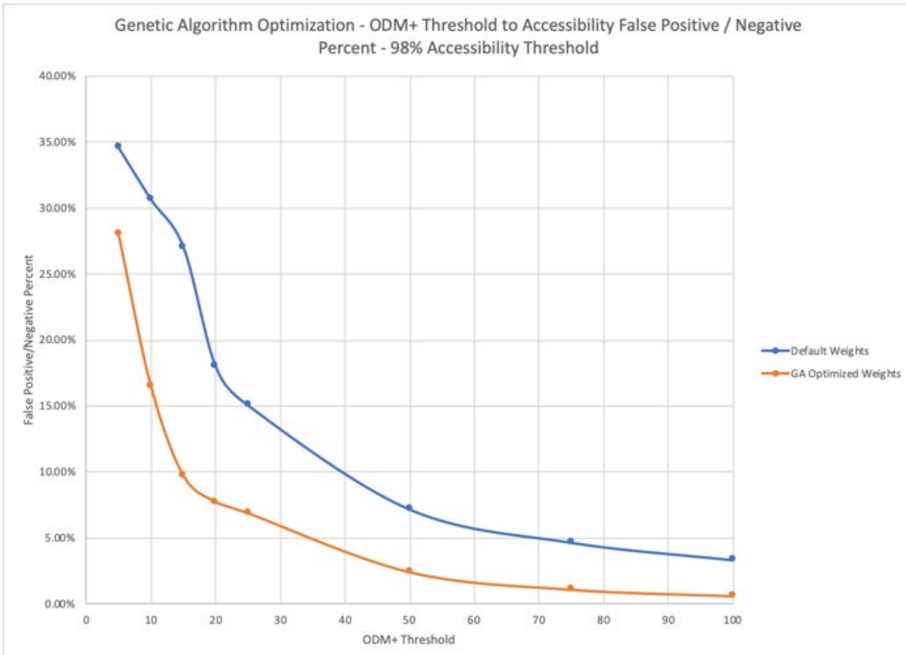

Figure 2- Decrease in false-positives with optimized weights

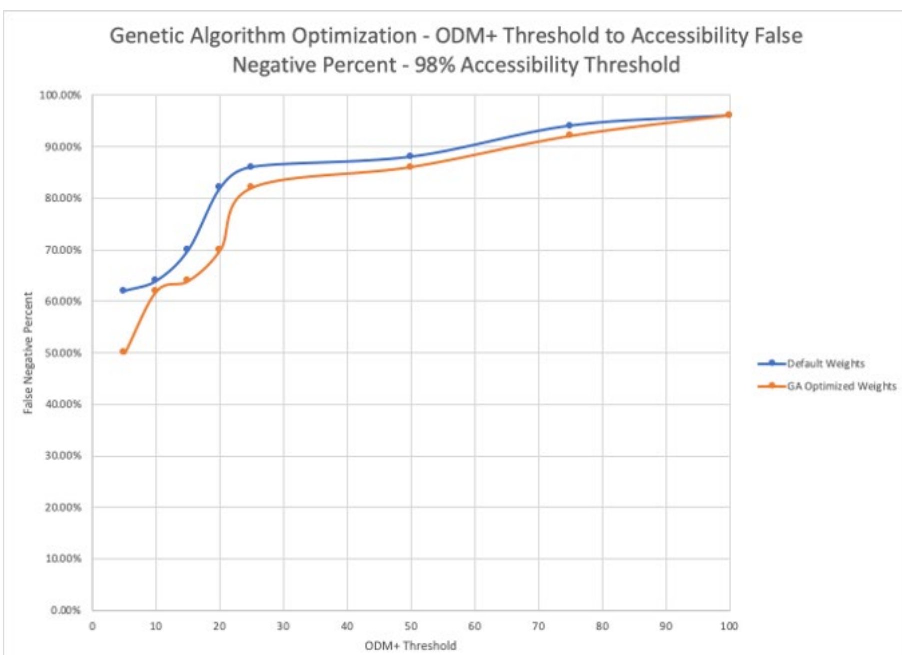

Figure 3- Decrease in false-negatives with optimized weights

5. Network Lab Testing

5.1. Testing Tools and Methodology

A lab environment encompassing 24 DOCSIS 3.1 modems of various chipsets was utilized, each with 4 Internet Protocol television (IPTV) set top boxes to mimic production as closely as possible. At the CMTS, a noise generator was placed along with attenuator pads for adjusting transmit and receive levels. Separate testing was done for SNR, Tx power and Rx power levels. Each test was set for 15-minute intervals with increasing impairments until complete failure was observed across all modems. This lab testing generated the first set of thresholds used in ODM 3 development; these thresholds were further validated with production trials.

Production trials were performed with field technician assistance, these trials verified each impaired KPI within the algorithm denoted the point of corrective action required. Through continuous feedback, multiple sessions with field technicians were completed to improve the weighting and prioritization method.

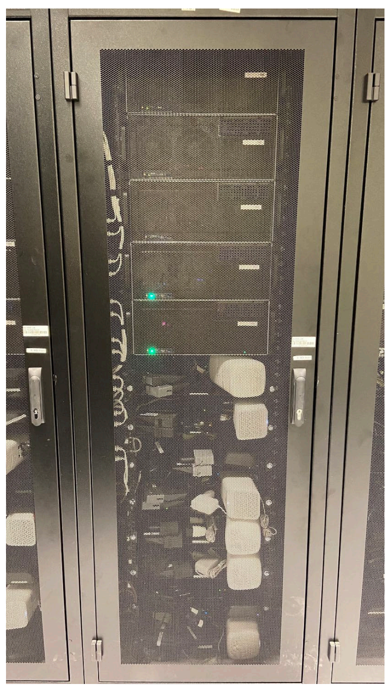

Figure 4- Automation Lab

5.2. Characterization Method and Data Capture

Within the lab, multiple data sources were utilized to correlate customer experience to ODM3. Visual inspection was performed on video feeds during impairment threshold testing to replicate customer experience when using the service. To ensure accuracy of data and efficient collection, automation scripts were built to modify KPI levels and collect service metrics, this was visualized on internal reporting tools for analysis. Key infliction points observed in the visualizations were used to adjust weightings to further increase accuracy.

6. Analyzing the Algorithm

6.1. Developing a Modular Solution

Each individual KPI is collected throughout the day. The final days polling is then run through the ODM 3 algorithm to provide each nodes scoring. Currently, the daily averages of these metrics are being utilized, however, a methodology to use data with min/max values will be released by next year.

When a given metric is pulled into the algorithm, depending on its severity of impact, the ODM 3 algorithm will apply a score. The score is higher, depending on how severely the KPI breaches the thresholds and in some cases which frequency is being impacted.

Each KPI CALL (ex: US_TX0, US_TX1) scoring is aggregated into their respective KPI buckets: US SCORE, DS SCORE, OFDM SCORE and OFDMA SCORE. As visually indicated by the US Score sample below this summation provides the modems individual score and determines if a modem is passing or failing.

Sample:

$$US\ SCORE = \sum_{i=1}^{n} \frac{tx\_score}{i} + \sum_{i=1}^{n} \frac{snr\_score}{i} + \sum_{i=1}^{n} \frac{cer\_score}{i}$$

Where:

tx_score = US TX = $\begin{cases} x, if\ TX < 30.5\ dBmV\ or\ TX > 52.5 \\ 0\ dBmV, otherwise \end{cases}$

snr_score = (US SNR0 = $\begin{cases} x, if\ SNR \geq 25\ dB\ or\ SNR \leq 28 \\ 0\ dB, otherwise \end{cases}$) +
(US SNR1 = $\begin{cases} x, if\ SNR < 25 \\ 0\ dB, otherwise \end{cases}$)

cer_score = (US CER0 = $\begin{cases} x, if\ CER \geq 0.0057\ AND\ CER \leq 0.01 \\ 0, otherwise \end{cases}$) +
(US CER1 = $\begin{cases} x,\ if\ CER > 0.01\ AND\ CER \leq 0.03 \\ 0, otherwise \end{cases}$) +
(US CER2 = $\begin{cases} x\ , if\ CER > 0.03\ AND\ CER \leq 0.1 \\ 0, otherwise \end{cases}$) +
(US CER3 = $\begin{cases} x,\ if\ CER \geq 0.1\ AND\ \leq 1.0 \\ 0, otherwise \end{cases}$)

This is a sample of one of the modular sections of the algorithm, the SC-QAM upstream component, where x is the proprietary variable for the weighted scoring per threshold (KPI CALL). Each modular component is calculated as the data is iterated.

$$cm\ score = \sum_{i=1}^{n} \frac{us\_score}{i} + \sum_{i=1}^{n} \frac{ds\_score}{i} + \sum_{i=1}^{n} \frac{ofdm\_score}{i} + \sum_{i=1}^{n} \frac{ofdma\_score}{i}$$

Based on the above sample set, each bucket of calculations is aggregated to derive the CM scoring.

$$ODM = \left(\frac{\sum_{i=1}^{n} pass}{\sum_{i=1}^{n} pass + \sum_{i=1}^{n} fail} \right) x\ 100$$

The final ODM 3 score is a percentage of modems passing their individual modem score. Wherein 90% or greater is a passing node.

To summarise, each upstream and downstream channel is scored for each KPI, and the sum of the KPI scores represents the customer's overall CM score. The CM score for the customer can be used to determine single customer impairments, direct service trucks as required and inform frontline of any area issues detected by the ODM algorithm.

If the CM score is greater than the 75 threshold, that individual modem is failing. If passing customers is greater than 90%, the node is classified as passing and no action is required.

7. Implementation of Algorithm and Cloud-Based Systems

7.1. Proof-of-Concept (PoC) Development

A dashboard was built using production modem IPDR data within the company's internal visualization and automation platform. This dashboard assesses and validates each metric against the defined scoring values determined by lab testing for each KPI CALL. This PoC was shared with maintenance team members to ensure results as indicated were in line with their findings and that each indication of failure noted was actionable in the field.

7.2. Cloud Solution

Previous versions of ODM utilized an on prem system of automation. As cloud services became readily available, its efficient data processing and automation capabilities were utilized.

Applying the standards set for each KPI scoring for thousands of modems must be done in an efficient manner to ensure optimal load on the cluster, as such the code was written in modules to ensure efficiency, ease of updating and rapid validation. Sections were separated into four modules, downstream SC-QAM, upstream SC-QAM, OFDM and OFDMA. Each can be run at the same time, separately or in any order necessary. After the modules are completed the final merge and calculation of an ODM score can begin. This entire process takes on average ~130 seconds for a full day's data.

Table

	MAC_ADDRESS	US_SCORE	TX	US_SNR	US_CER	PTIME	CHANNEL_NAME	FREQUENCY	CER_AVG	SNR_AVG	TX_AVG
1	[redacted]	0	0	0	0	2023-07-11	Logical Upstream Channel 10/11.2/0	32300	0	36.4833	43.4917
2	[redacted]	0	0	0	0	2023-07-11	Logical Upstream Channel 11/10.1/0	25900	0.000508696	33.3043	42.787
3	[redacted]	0	0	0	0	2023-07-11	Logical Upstream Channel 9/9.0/0	21100	0	40.7458	46.9
4	[redacted]	0	0	0	0	2023-07-11	Logical Upstream Channel 11/3.3/0	38700	0	37.6833	44.575
5	[redacted]	0	0	0	0	2023-07-11	Logical Upstream Channel 10/15.1/0	25900	0	42.1	42
6	[redacted]	0	0	0	0	2023-07-11	Logical Upstream Channel 10/11.2/0	32300	0	34.7417	39
7	[redacted]	0	0	0	0	2023-07-11	Logical Upstream Channel 12/8.3/0	38700	0	42.1	46.8

8,393 rows | Truncated data | 13.11 seconds runtime — Refreshed 12 days ago

Figure 5 - This is a sample of US Score

8. Measure of Success

8.1. Measuring Success of ODM

Measuring ODM’s success is both qualitative feedback from technicians and quantitively assessing impairments found in field. Since Jan 1, 2023, approximately 600 IMTs were generated. The IMTs have had a 96% success rate in finding impairments out in field. The incident tickets generated return a variety of impairments ranging in nature from noise-related to hardware failure.

8.2. Production Example

Provided is an example of a submitted ticket for ODM 3, the initial failing score was 62% (failing), within field a hardware fault was identified and resolved increasing the ODM score to 96% (passing). After the impact is resolved the node is monitored for additional days to ensure issues are corrected and the node is stable. In addition to the example provided below, other ODM 3 tickets have identified and resolved: noise floor rolling impedance, power supply impairments, faulty drop impairments as well as high transmit/receive impacts requiring additional filters all within a single day.

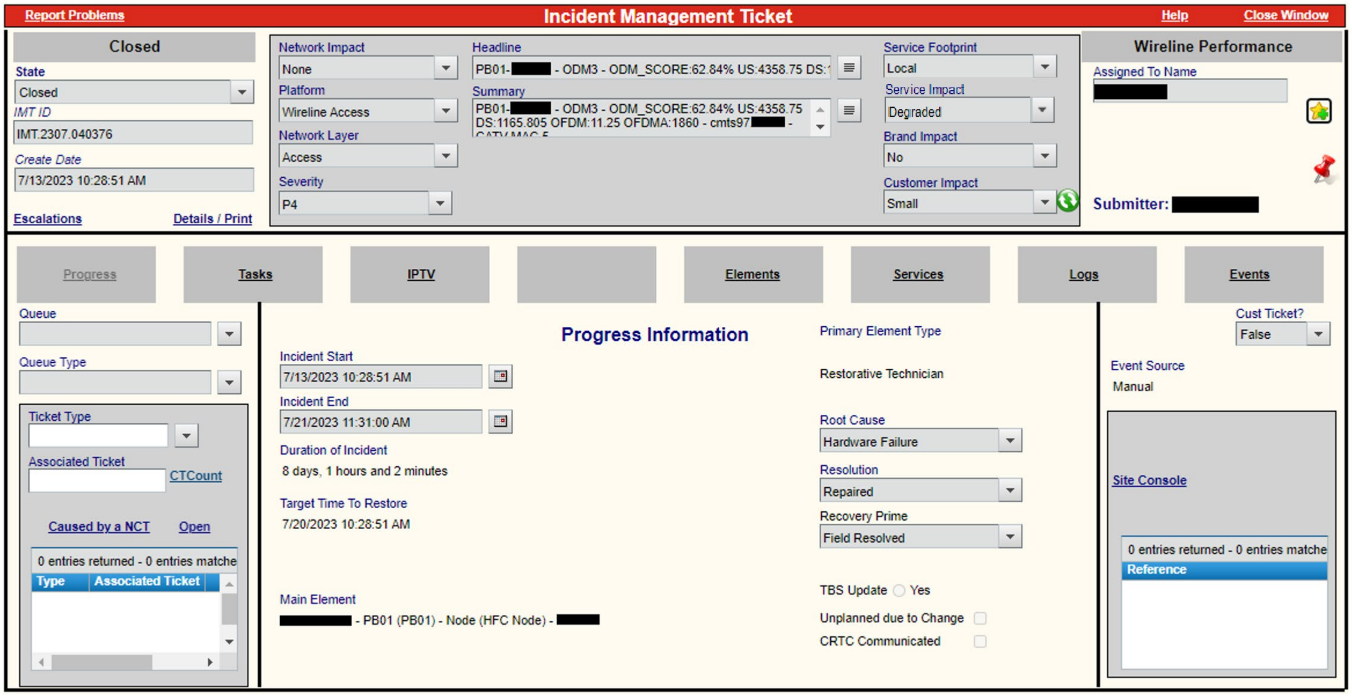

Figure 6- Sample Incident ticket with hardware failure

	PTIME	ODM_SCORE	MDMs_PASSING	MDMs_FAILING	US_SCORE	DS_SCORE	OFDM_SCORE	OFDMA_SCORE
1	2023-07-10	62.99212598425197	80	47	4381.25	1189.77	22.5	1740
2	2023-07-11	62.698412698412696	79	47	4336.25	1141.8400000000001	0	1980
3	2023-07-12	66.66666666666666	82	41	4050	1160.47	0	1548.75
4	2023-07-13	62.295081967213115	76	46	4212.5	1037.65	0	1822.5
5	2023-07-14	93.7007874015748	119	8	1455	884.2100000000002	0	858.75
6	2023-07-15	96.8503937007874	123	4	56.25	808.7299999999999	0	75
7	2023-07-16	96.8503937007874	123	4	75	694.4399999999999	7.01	75
8	2023-07-17	96.06299212598425	122	5	75	747.55	0	150
9	2023-07-18	95.2755905511811	121	6	56.25	680.4000000000001	0	225
10	2023-07-19	95.23809523809523	120	6	93.75	702.2400000000001	0	225
11	2023-07-20	96.03174603174604	121	5	131.25	611.2900000000001	0	150

Figure 7 - Before/After ODM Score Improvement

9. Conclusion

9.1. Summary of Key Findings

ODM 3 has proven its success by consistently identifying actionable network pain points. Since the beginning of 2023, ODM has had a 96% success rate across the almost 600 IMTs generated. Technicians can consistently find, triage and repair impairments. ODM's unique ability to find and determine key impairments has offered technicians ease in solutioning problems found in the field.

9.2. Future Improvements and Areas of Further Research

Weather data integration into ODM3+ (next version of ODM) is one of the next steps to avoid degraded service due to weather fluctuations. Continued testing and analysis on specific weather patterns and impacts to the cable plant will allow for better issue identification in the ODM3+ model, which will further increase accuracy and reduce the 4% “no fault found” tickets. Additional KPI inclusion such as partial service and in-channel frequency response (ICFR) will be integrated into future releases. The process will include continuous feedback from maintenance technicians for new enhancements and accuracy improvement.

Abbreviations

CER	correctable error ratio
CM	cable modem
CMTS	cable modem termination system
dB	decibel
dBmV	decibel millivolt
DOCSIS	Data-Over-Cable Service Interface Specification
DS	downstream
HFC	hybrid fiber-coaxial
ICFR	in-channel frequency response
IMT	incident management ticket
IPTV	Internet Protocol television
KPI	key performance indicator
KPI CALL	The definition for each individual KPI (includes multi-threshold KPIs) to apply a scoring based on each channels value
MER	modulation error ratio
MIB	management information base
ODM	overall DOCSIS metric
OFDM	orthogonal frequency-division multiplexing
OFDMA	orthogonal frequency-division multiple access
PoC	proof-of-concept
Rx	receive
RDK-V	reference design kit for video
SC-QAM	single channel quadrature amplitude modulation
SCTE	Society of Cable Telecommunications Engineers
SNR	signal-to-noise ratio
SNMP	Simple Network Management Protocol
Tx	transmit
US	tpstream

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