Proactive Customer Maintenance

Going Beyond Proactive Network Maintenance With Data, Analytics, and a Laser Focus on Customer Experience

A Technical Paper prepared for SCTE•ISBE by

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Introduction

The year is 2019 and service providers now have more data on every aspect of our business than ever before. Specifically, every piece of equipment in our network and customers' homes can be measured for performance and often issues can be solved or mitigated through remote action. It is not only interesting but is becoming necessary for service providers to leverage this data in new and novel ways to identify problems, make decisions and act proactively to solve problems. This capability to solve customer impacting equipment issues in real-time, or "proactive customer maintenance," is rapidly moving from a competitive advantage to business as usual.

Data analytics plays a key part in this process, which can include advanced modelling techniques like machine learning and artificial intelligence. However, the most effective solutions are often born from a combination of deep technological insight, rapid data enablement, and simple but powerful logic to empower the right action at the right time. Whether the output is a remote command, work recommendation, or even a proactive customer notification, speed to solution is the single most important aspect of a value-add system for proactive customer maintenance.

This paper will cover the general strategy of delivering proactive customer maintenance, that is, proactive and real-time efforts focused on providing ongoing excellent performance for every customer in our network, leveraging data and automation. It will cover the background and history of such efforts at Cox Communications Inc. (CCI) as well as current efforts. Finally, it will discuss the part that data analytics and emerging technologies plays in these efforts. Where noted some descriptions of these efforts has been left intentionally vague due to IP concerns, but concepts and results will be shown.

Background

This section will provide some context on a few key concepts which will become important in the future sections of the paper.

Historically, and especially in the analog days, service providers had to rely on the customer to notify them of issues with their service. Multi-customer issues could be correlated from multiple customer contacts in common areas (i.e. outages), often via "buzz" in the operations center. Information would propagate through this system until the right fix agent was identified and sent. This process is high cost, incredibly inefficient, and difficult on customers. The desires to consolidate operations, reduce costs, and improve the customer experience have all driven the need for proactive monitoring and more timely notification of issues. The ultimate state for both the service provider and customer would be to identify every issue as, or even before, it causes an impairment and fix it proactively. In the cases where a physical technician is needed the desire is to identify the right person, the first time, at a time that works for the customer.

A control loop is a fundamental mechanism for maintaining a critical process value at a desired set point. A closed loop system is one that requires no human or manual intervention to maintain the process value, rather it is done automatically. There are three main components of a control loop: The sensor, the controller, and the actuator. Often a closed loop control system exists within a very small area, such as between equipment on a manufacturing floor. But the elements of a closed loop system can exist physically very far from one another and still meet the definition if their operation depends on each other and they operate automatically without human intervention. Many of the examples in this paper are examples of the latter, where the three elements of the control system all exist in different parts of the network but can still work together to maintain a critical process value.

Partial service mode is a DOCSIS resiliency measure where a modem is operating without the full set of channels defined in the Receive Channel Set (RCS) and/or Transmit Channel Set (TCS). A channel may be missing in this way either due to the modem being unable to acquire the channel during bonding, or because communication on that channel was lost during operation. This can either be due to a physical network impairment (like an RF trap) that must be removed by a technician or due to a temporary impairment caused by (for example) noise ingress. Partial service mode is considered a resiliency measure because the modem will continue to operate in this state but with a limited total bandwidth compared to what the modem can normally use (whether it is provisioned to use that bandwidth is a different matter altogether). Generally, when a channel is unusable, the modem and Cable Modem Termination System (CMTS) negotiate to not use that channel; however, in practice there have been observed states where the CMTS is sending frames to a downstream channel that a modem believes is not enabled, thus causing frame errors. In these cases, partial service mode is no longer a resiliency feature but is actively causing degraded service.

Modem performance is defined as the regularly measured operating state of several key performance indicators of a modem compared to their engineering specifications. Some examples of key performance indicators are DOCSIS Channel Downstream Receive Power (DS RX) and DOCSIS Channel Downstream Signal-to-Noise Ratio (DS SNR). DS RX is a measure of the received power in dB on each bonded downstream DOCSIS channel while DS SNR is a measure of the clarity of the signal as received by the modem. Both measurements have specifications as defined in the DOCSIS spec as well as (potentially tighter) specs defined by the outside plant and/or engineering teams. The intention of any proactive maintenance activity aimed at improving modem performance is to reduce the number of out of specification measurements in the network.

A zombie modem is a modem which is connected to the CMTS on layer 2 (MAC layer) but has lost connection on layer 3 (IP layer). To the CMTS, a modem in this state will appear to be connected but will lose all internet connectivity, including the ability to be polled over Simple Network Management Protocol (SNMP). To the customer, this will appear as a total loss of service. Depending on the cause of the layer 3 loss, connection may be able to be recovered with a hard reboot (for example, due to a software error or encryption key corruption in the modem) or it may not (for example, due to a mis-handled protocol change request from the CMTS to the modem). In both cases a zombie modem is very likely to cause customer impact, and in the latter case without proper identification will likely result in similar troubleshooting efforts to a totally inoperable modem (necessitating replacement).

The ROCK (Resetting Obvious Channel Knockouts)

As noted in the background section, partial service mode is a resiliency feature of DOCSIS that in practice does not always behave as expected. In many cases, especially those involving channel knockouts due to noise ingress, missing channels do not get re-bonded after the event is cleared. This behavior may cause a service impact if the CMTS and modem have not properly negotiated the loss of that channel. Of principle concern are cases where the CMTS will continue to send frames to the modem over channels that the modem believes have been turned off.

The baseline rate of modems in partial service mode on CCI's network prior to conversion to Converged Cable Access Platform (CCAP) and with 32 downstream DOCSIS channels was between 1% and 1.5%. After conversion to the CCAP platform and expanding to 48 downtream DOCSIS channels, the rate jumped to between 3% and 4%. Experimentation has shown that rebooting these devices has no significant affect, however a series of re-initialization commands can be run on the CMTS that have a 60-80% chance of restoring a modem to its full channel bonding state. At scale this capability can be leveraged to bring the network back down near the baseline rate of 1-1.5% of modems in partial service.

The ROCK is a closed-loop control system that CCI uses to find and fix modems in partial service mode. The sensor part of the system is taking scheduled polling data from all devices at a 2-hour interval and identifying modems which are missing at least one channel. The control function waits until the most convenient time for the customer to experience a small service impact (this is usually at 4AM local time which is both in the maintenance window and the measured time of least usage/activity across CCI's network). The ROCK then iterates through all identified modems, issuing the necessary series of commands to the CMTS to re-initialize the modem. Any modems that do not recover are put in a holding list so that they are not continually affected every morning. This holdout list generally represents the baseline, are likely due to physical channel impairments, and can help prioritize proactive labor in the cable plant. Figure 1 below shows the control loop diagram for the ROCK system. Figure 2 shows a timeline of channel behavior on a single modem before and after being fixed. Channel 855, which is increasing frame errors (uncorrectables) at a steady rate goes from an impaired state to normal operation after action is taken.

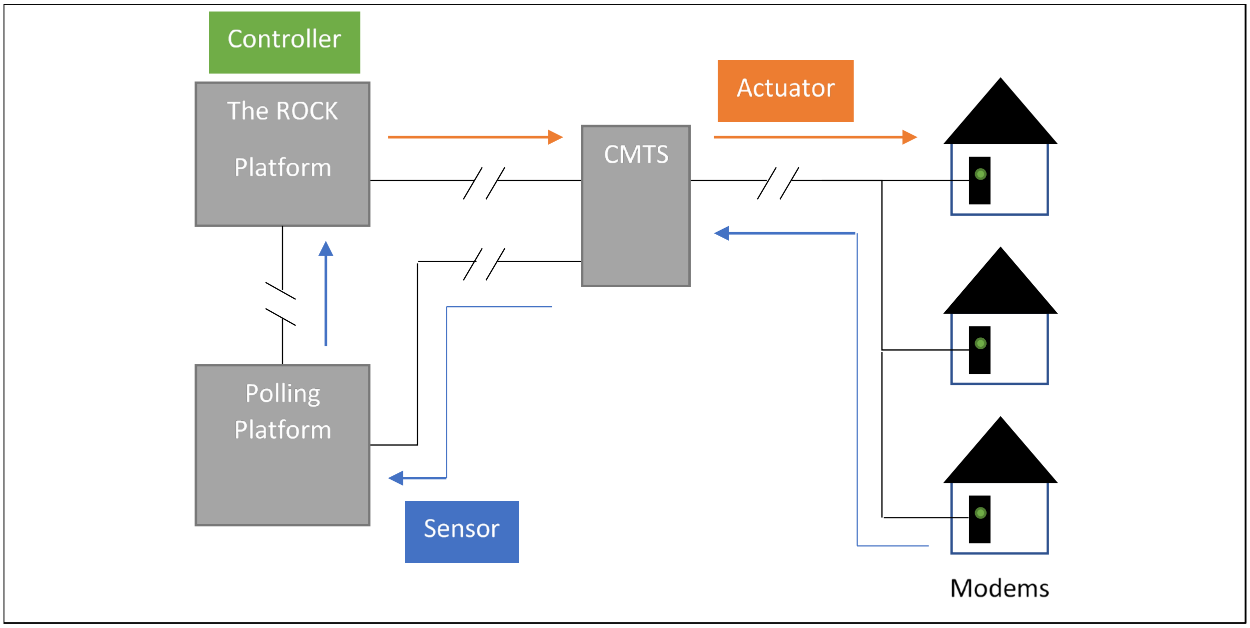

Figure 1 - The ROCK Control Loop Diagram

Figure 2 - The ROCK Fixing a Modem With a Single Channel Impairment

The ROCK program was implemented over five weeks in April 2019 using a staggered regional roll out schedule. Figure 3 shows the immediate impact in each region after the program was started. The average regional improvement (excluding California, which had previously been piloted and started at a lower baseline) was 52%, with the total improvement by the end of the rollout being 50% or roughly 120,000 modems. The intention of the ROCK is to maintain the baseline of impaired modems; in parallel a data analytics effort is underway to understand the root cause of the fixable impairments and feed that information back to the device vendor(s) for a hopeful bug fix or feature add.

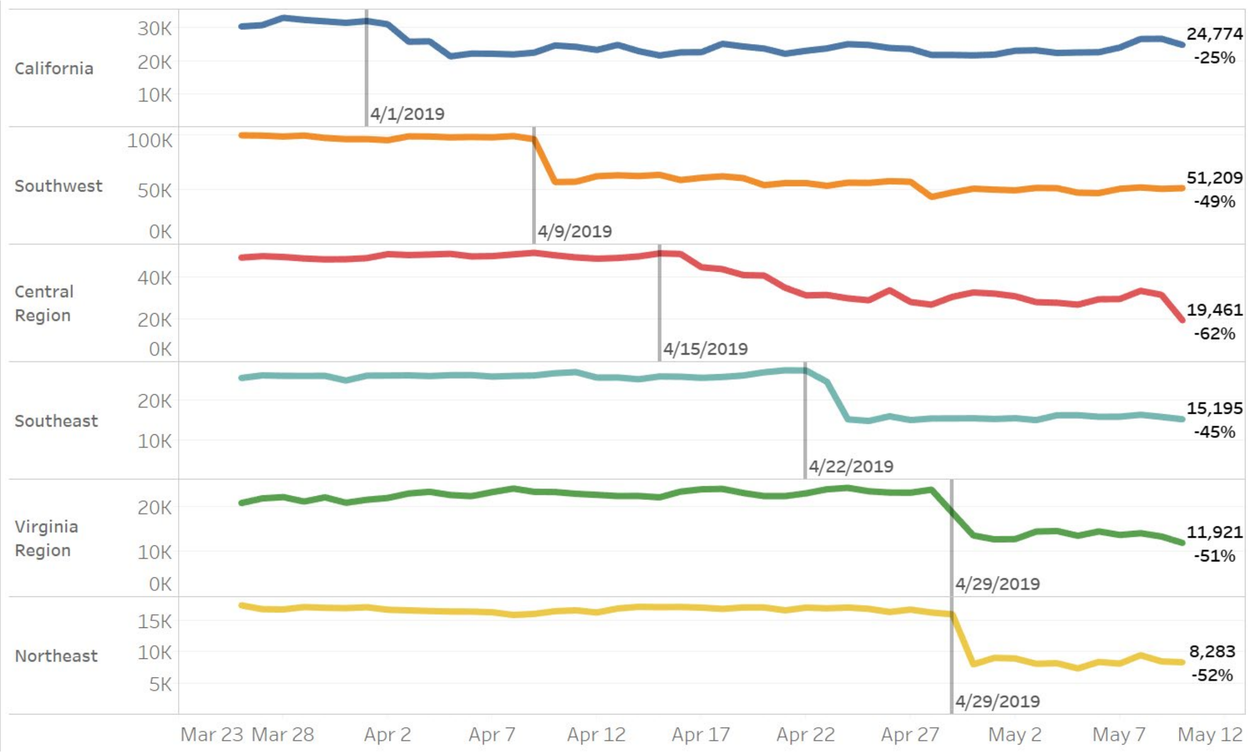

Figure 3 - Regional implementation of the ROCK

Project NEO (Nightly Equipment Optimization)

As noted in the background section, a proven key performance measure of modem performance is DOCSIS Channel Downstream Receive Power (DS RX). Every bonded downstream channel must fall within a certain power range as given by the DOCSIS spec. Essentially, the higher the received power (up to a reasonable level) the better the modem will perform. DS RX at the modem is a function of several factors, but it is strongly correlated with transmit power at the edge quadrature amplitude modulator (edge QAM), which is configured through the CMTS. The CMTS does not have the ability to measure the receive power of any given modem let alone an aggregate, but it can be measured and aggregated from the modems themselves through scheduled polling. Due to non-ideal elements in the cable plant which change properties with temperature, drift over time, and generally can move the performance away from the designed center point, modem channel receive power will have a certain amount of variance over the course of a year and across the radio frequency (RF) spectrum.

Using scheduled DS RX polling data, the optimal transmit power for every channel can be calculated with the intention of bringing as many modems into specification as possible. Classically this would have to be tuned in the plant by a field technician which is difficult and prohibitively expensive. This adjustment can be made on a very fast basis, as quickly as DS RX data can be polled, or at a slower pace (monthly for example). The calculated adjustments are such that the total error of every channel is minimized across all modems actively bonded to that channel while also meeting some key requirements of the cable plant. The first is that no two adjacent channels can be more than 3dB of transmit power apart, and the second is that an individual channel cannot be adjusted more than an upper limit.

The result is an optimized cable plant without requiring physical adjustments to physical elements. This results in less variance over the spectrum and over the course of the year (due to temperature swings) which will result in a net improvement to customer experience and lower care and field services costs. Finally, it bubbles actual plant issues to the top which can then be proactively addressed, further optimizing the plant and allowing proactive work to be the most effective. Figure 4 shows the simplified control loop diagram of NEO.

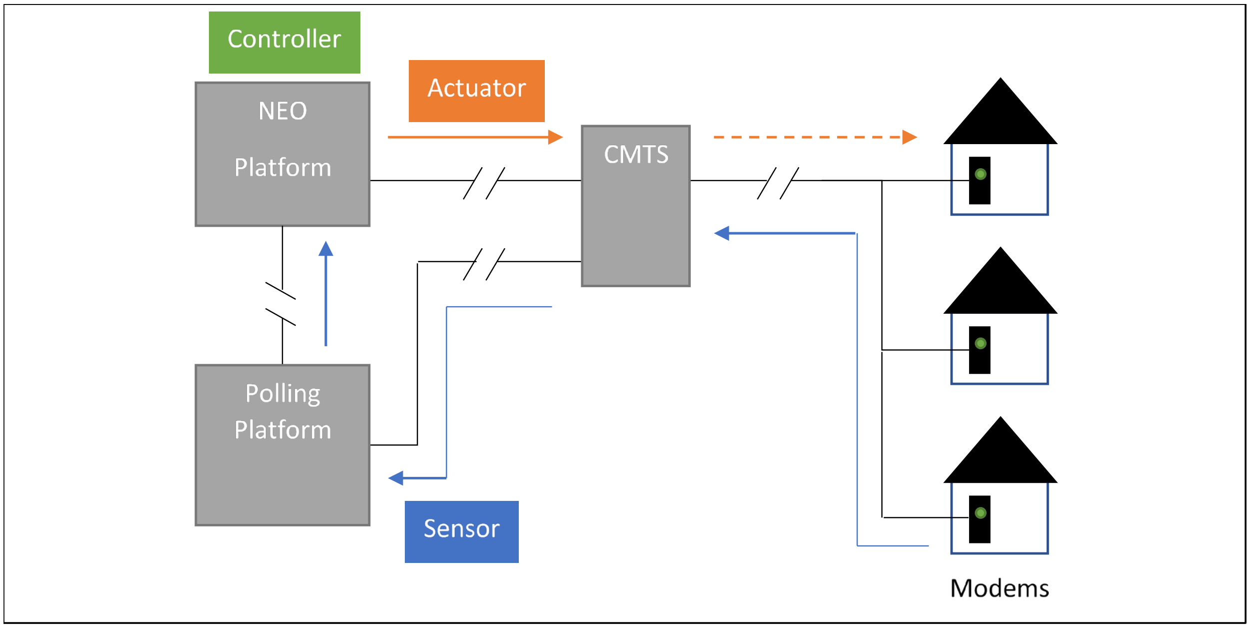

Figure 4 - NEO Control Loop Diagram

Experimental results are shown below in Figures 5 and 6 where a small area of the network (roughly 1600 modems) was optimized using NEO. Prior to the change these modems were reporting roughly 52k out of spec DS RX measurements and 18k out of spec DS SNR measurements per poll. After the adjustment the same modems were reporting 45k and 15k out of spec measurements, respectively. This represented an improvement of 13% and 16% out of spec measurements in DS RX and DS SNR respectively. A hidden added benefit of the process is that by optimizing DS RX, there is also a benefit to DS SNR performance.

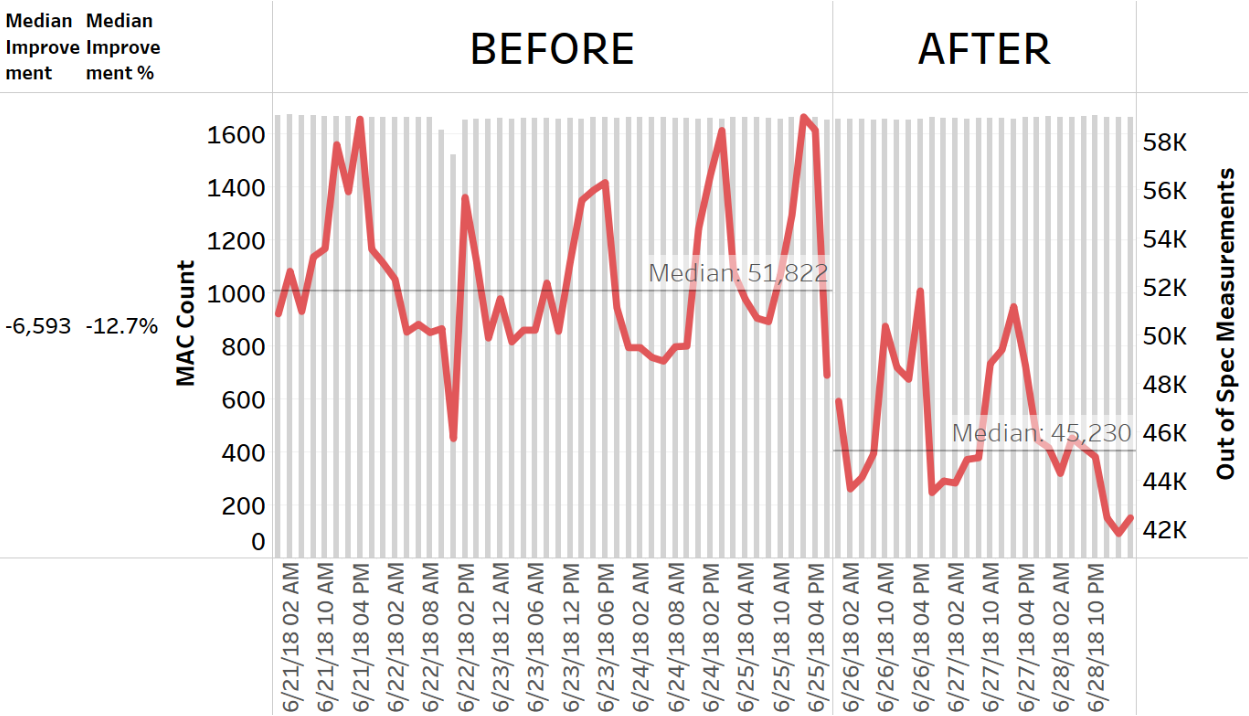

Figure 5 - NEO Improvement to Downstream Receive Power Out of Spec

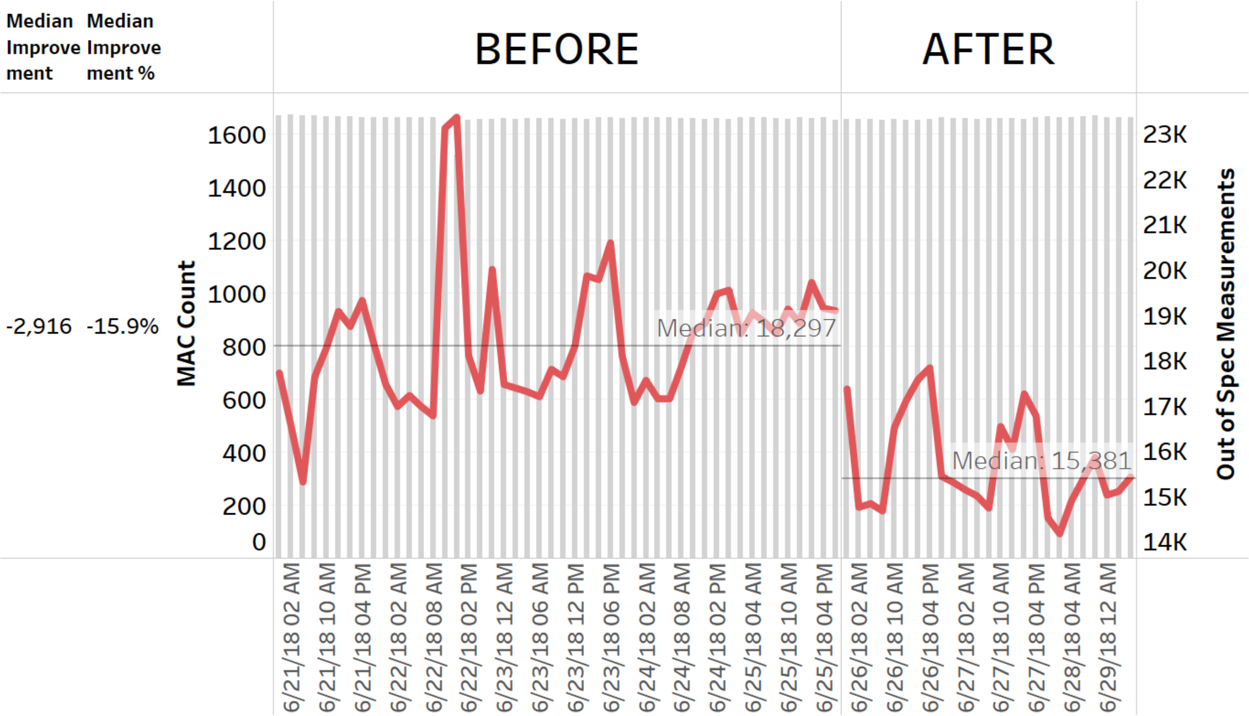

Figure 6 - NEO Improvement to Downstream SNR Out of Spec

The BOOMSTICK (Kills Zombies, 'Nuff Said)

As noted in the background section, a zombie modem is a device that has entered a state where it is still powered, is still connected to the CMTS on the MAC layer (layer 2) but has stopped responding on the IP layer (layer 3) due to an internal modem software crash or missed profile change from the CMTS. A modem reboot may solve the issue in some cases if the state is identified, but because the modem has stopped responding to IP requests it cannot be proactively reset over SNMP. However, there is action that can be taken on the CMTS side which will take the modem out of this state once identified. The added benefit of performing this action is that it will solve zombie states that are not fixable with a modem reboot (such as ones due to a missed protocol change request from the CMTS). Because the zombie state represents an immediate service impact, the desire is to identify and fix these modems as near real-time as possible to prevent or limit customer impact.

Identification of zombie state is key and cannot be done with a simple check. Conceptually, a modem not responding to an SNMP request but which still shows in a connected state on the CMTS is an obvious zombie, but SNMP polling at a high enough rate to detect these issues isn't feasible. Instead a combination of existing polled data can be used to significantly limit the list of suspected zombies which can then be polled for definitive proof before action is taken. The combination of data that can help identify these modems includes layer 2 connectivity and service flow usage data, both of which are polled from the CMTS.

Generally, a near real-time model can be created which checks for significant changes in both upstream and downstream usage for a modem while also confirming layer 2 connectivity. If the modem shows a significant change in upstream and downstream usage compared to nominal and is still showing connection on layer 2, the modem will be put on a list for a secondary check of layer 3 connectivity using a real-time SNMP poll. If this final check fails, the modem can be fixed using a series of commands on the CMTS which will re-initialize the modem into its proper operating state. Figure 7 shows the control loop diagram while Figure 8 shows an example of three identified zombies using this methodology when compared to a control (non-zombie) modem. A key calculation from the usage data will is shown in red for the three zombie modems, while the control modem never enters this condition.

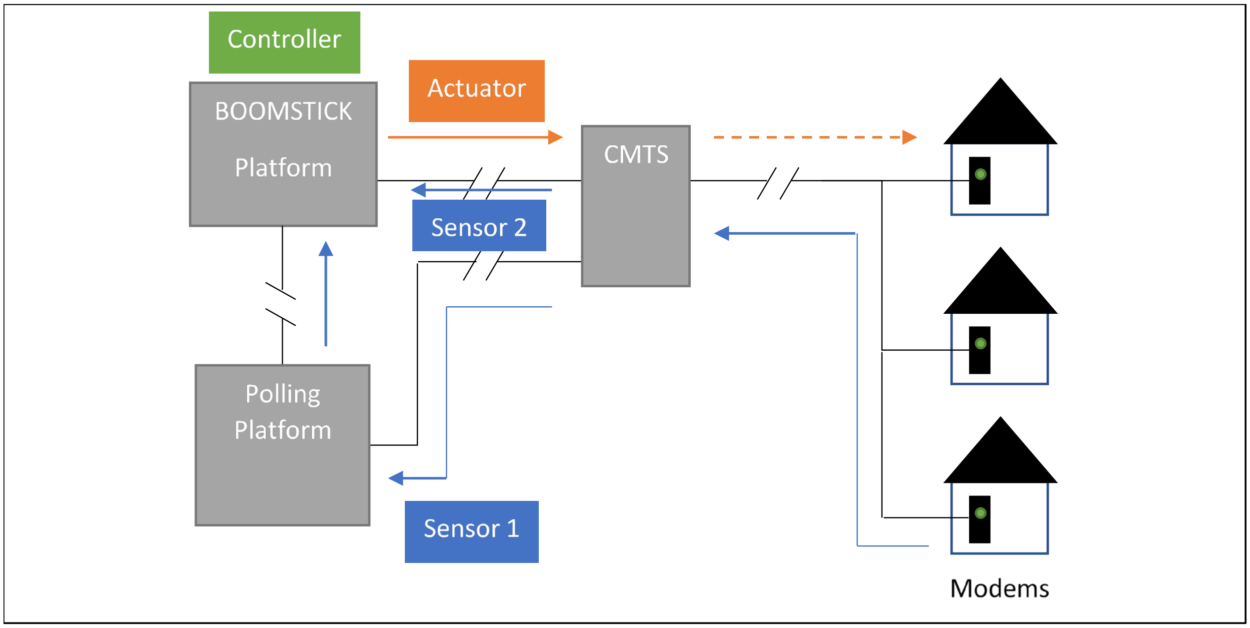

Figure 7 - BOOMSTICK Control Loop Diagram

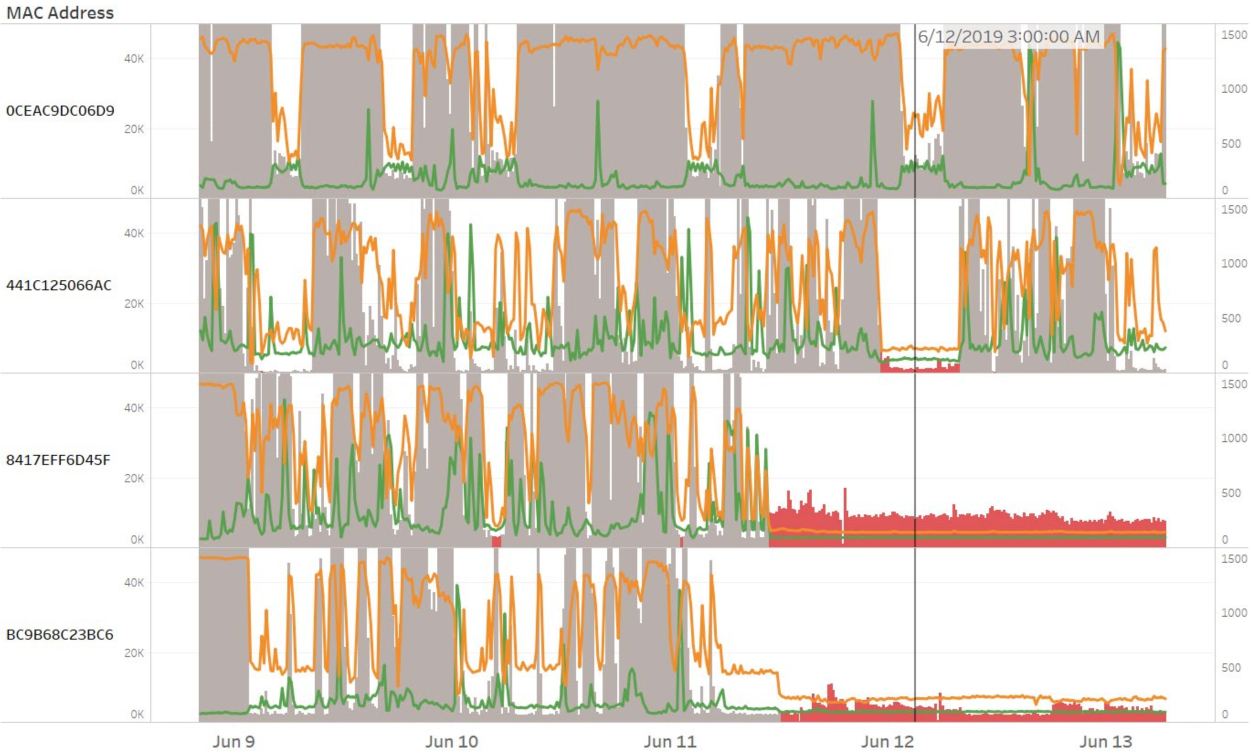

Figure 8 - BOOMSTICK Identification Model Comparing Zombies to a Control

Conclusion

In conclusion, several examples of proactive customer maintenance systems have been introduced. These methods are intended to improve modem performance, and thus customer experience, by measuring key performance indicators on a regular or real-time basis, feeding those into models of varying complexity, and ultimately enabling or taking an action to fix the issue. These are proven methods that have shown significant improvement in the CCI network.

The impact of data engineering, advanced analytical, and modeling techniques on these efforts cannot be understated. However, the genesis of these systems has broadly been a methodology of identifying an opportunity through close partnership between the business and field, rapidly determining feasibility and what action to take, and then utilizing as much existing infrastructure and capability as possible to quickly stand up a solution. Often the modeling complexity is in understanding the problem, and less so in solving it.

Abbreviations

CCI	Cox Communications Inc.
CCAP	Converged Cable Access Platform
CMTS	Cable Modem Termination System
DS RX	DOCSIS Downstream Channel Receive Power
DS SNR	DOCSIS Downstream Channel Signal-to-Noise Ratio
Edge QAM	edge quadrature amplitude modulator
NEO	nightly equipment optimization
RF	radio frequency
RCS	Receive Channel Set
ROCK	resetting obvious channel knockouts
SNMP	Simple Network Magagement Protocol
TCS	Transmit Channel Set

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