Using Big Data To Fine-Tune The Nation's Largest Public Wi-Fi Network

A Technical Paper prepared for SCTE•ISBE by

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Table of Contents

List of Figures

List of Tables

1. Introduction

How does one go about optimizing the most extensive public Wi-Fi network in the nation? That was the task we were asked to perform. Comcast XfinityWiFi network is a vast Wi-Fi overlay network, with close to 21M access points. These Access Points are deployed outdoors, inside small and medium businesses, and in subscriber's homes. The purpose of this ongoing project is to improve the customer experience of the XfinityWiFi network and increase the overall traffic usage, and increase the data offload of Xfinity Mobile users over the XfinityWiFi network.

The fundamental impact when customer faces a bad experience on Wi-Fi is that they may decide to turn off Wi-Fi on their mobile devices and may use valuable LTE data. While they may do so while outdoors, our data shows that sometimes these customers will continue to use LTE data while in their own homes and would not connect to their home Wireless Gateway provided by Comcast.

Some of the challenges facing the optimization of XfinityWiFi network, apart from the sheer size, were the fact that no central or distributed controller manages and coordinates the system from a Wi-Fi perspective. The Access Points are not aware of each other and have no communication path between them. The network was never designed for complete coverage or even to allow seamless roaming between Access Points. Also, over 98% of the network comprises of residential Access Points that act as a Home Hotspot (HHS). We had minimal control over what Wi-Fi configuration changes can be applied to these devices.

The first step we took was to break the optimization of a nationwide network into smaller, more manageable zones. We took several of such zones and used them to prove the methods, processes, and tools. We broke the process into multiple iterations, using traditional RF planning, measurements, and predictive tools to test after each iteration. Thus, establishing a baseline and iterative improvements as we progressed.

In parallel, the CommScope team developed a Big Data pipeline to ingest data from multiple sources of measurement; Multiple Network telemetry data, Access Point telemetry, enriched with geographic information data. This Big Data Analytics platform is turning discrete sources of data into powerful insights and recommendations.

This paper will describe in detail the methods, processes, and tools we developed to address this challenge and the results observed so far.

2. Testing and Methodology

Working with Comcast's XfinityWiFi team, we agreed to address the problem of optimization of this nationwide network by breaking it into smaller geographical areas. The logic behind this approach is the fact that it is local radio interferences and environmental conditions that impact Wi-Fi Access Points (AP).

Comcast team selected several outdoor areas, with different characteristics, all had a mix of outdoor, and indoor APs; the indoor APs were a combination of the residential home hotspot (HHS) and business hotspot (SMB). Each of the selected areas had a Primary and Secondary zone. Manual testing were conducted in the primary zones.

We used different approaches for the optimization per designated primary zone:

1. Tuning Zone – No physical change to an existing outdoor network. (e.g., No adding of new Access point). Only modifications allowed were configuration changes.
2. Densification Zone – Allow changes to the existing outdoor network by adding new outdoor Access Points. Include configuration changes.
3. Greenfield Zone – A complete redesign of the outdoor access point deployment. Include configuration changes.

We established a Test Methodology and perform identical RF testing in each of the Primary zones. Third-party testers were using a combination of mobile clients (iOS and Android) to perform walking and stationary tests. Conducting standard RF measurement and Over the Air packet capture tools (Ekahau, Omnipeek, Accuver (Android only)). They measured RSSI, SNR, Noise Floor, and Throughput test while walking and in stationary locations. The tests establish baseline conditions in each Primary zone. The same testing repeated after each iteration and produced a detailed test report. A team of CommScope experts analyzed the raw data, and results and suggested modifications for the next iteration.

Figure 1 Breaking up the problem – optimization zones (Primary Zones are highlighted)

The main tools used in the iteration process, based on the limitations of the network design, were fundamental Wi-Fi configuration changes such as RF channel planning, channel width, transmit power, and modification of Wi-Fi cell size. In the Densification and Greenfield zones, we were able to add AP to ensure better coverage, and in the Greenfield even created an overlap between the outdoor AP.

Note, no changes were made to any of the indoor hotspots, residential or SMB.

Below is a visual description of the activity (connected clients and tonnage of usage) of the network during several months before the COVID-19 pandemic.

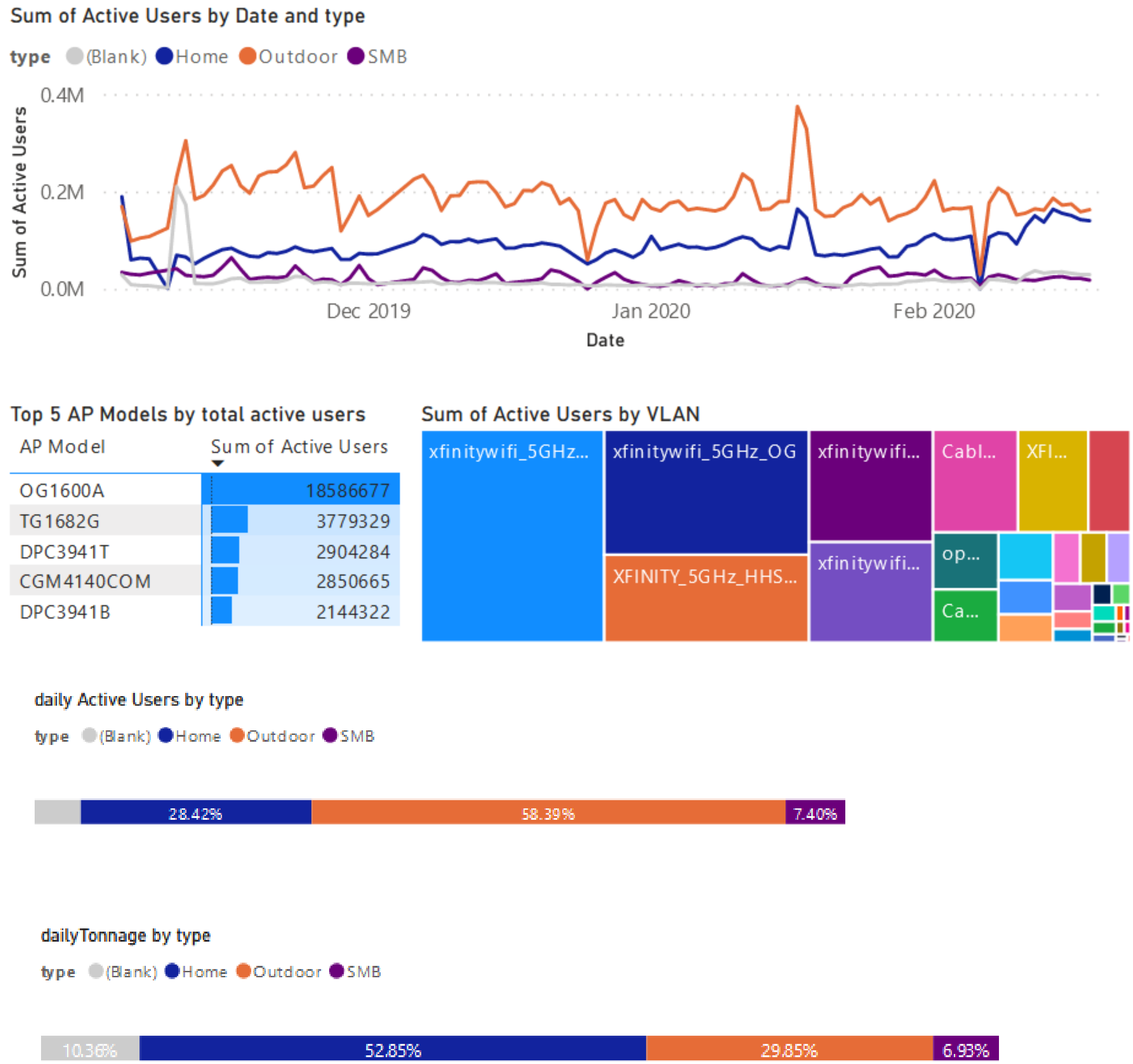

Figure 2 High-Level view of the usage of XfinityWiFi network

2.1. Manual vs. Automated Methodology

The problem with the method and testing methodology described above is that it does not scale. It relies on testers walking the areas, and a manual process that cannot be scaled nationwide.

Our proposed solution was to augment manual RF testing with measurements collected from the network. This includes using Netscout network probes reports and collecting relevant data from outdoor AP. This approach obtained data from network assets, independent of testers walking the areas. And thus, has the advantage of looking at real customer data vs. test client's data. To collect and make use of all this data, we created a Big Data Analytics platform and pipeline to ingest, and analyze different sources of data, cross-correlate multiple measurements into a comprehensive view. And use the manual testing process to "verify" our automated network results and insight.

The main goal of the big data approach and tools is to show how we will be able to answer the following questions:

- How to optimize and automate the process of "making XfinityWifi network better"?
- How to identify where and how the currently deployed network should be augmented?
- Help identify where Comcast should deploy the new XfinityWifi network/APs to offer more offload opportunities to Xfinity Mobile customers.
- Identify Bad Client Experience events, characterize and group them into subcategories
- Show some correlation between Netscout records and Wi-Fi RF (SNMP logs) records relating to the Bad Client Experience events and subcategories.

Several Machin Learning methods and algorithms were used on the existing data. Clustering, anomaly detection and co-occurrence were used to analyze the existing network; Identify areas of over coverage, under coverage, patterns of client movement across the network deployed in the zone and more.

2.1. Current Sources of Data for Analytic system

All the traffic in the XfinityWiFi network traverses the network over softGRE tunnels that are established between the Access Point (AP) and the Wireless Access Gateway (WAG). By placing Netscout probes in the network close to the WAG, which monitors all TCP traffic inside the tunnel; The Comcast team was able to collect and report in 5-minute intervals several TCP measurements.

In addition to the TCP traffic reports generated by the network probes, we collected measurements from the outdoor APs that represent the Wireless performance. The outdoor Wireless Access Points reported a vast number of Wi-Fi RF and network statistics in 15-minute intervals.

We enriched the information provided by Netscout and the APs with geographic information about the AP location, either by GPS coordinates or other GIS data.

Table 1 Sources of Data

Devices	Information	Source
Device location	Geo Location	Google Earth map (KMZ) and GPS coordinates
Outside plant location	Geo Location	Google Earth map (KMZ)
Ruckus Outdoor AP	Usage and Statistics	Netscout and SCI/Druid
OG1600 Outdoor AP	Usage and Statistics	Netscout and SNMP logs
Indoor HHS	Usage and Statistics	Netscout only
Indoor SMB	Usage and Statistics	Netscout only

The above different sources of data accumulated to 250+ days of data, 4000+ geographic locations, 10k-100k records per site per day. 10 TB of compressed data/month. 4 disparate data sources (csv, json, mib, log, kmz). With different types of triggers, event-based, 5 minutes, 15 minutes, and daily time windows.

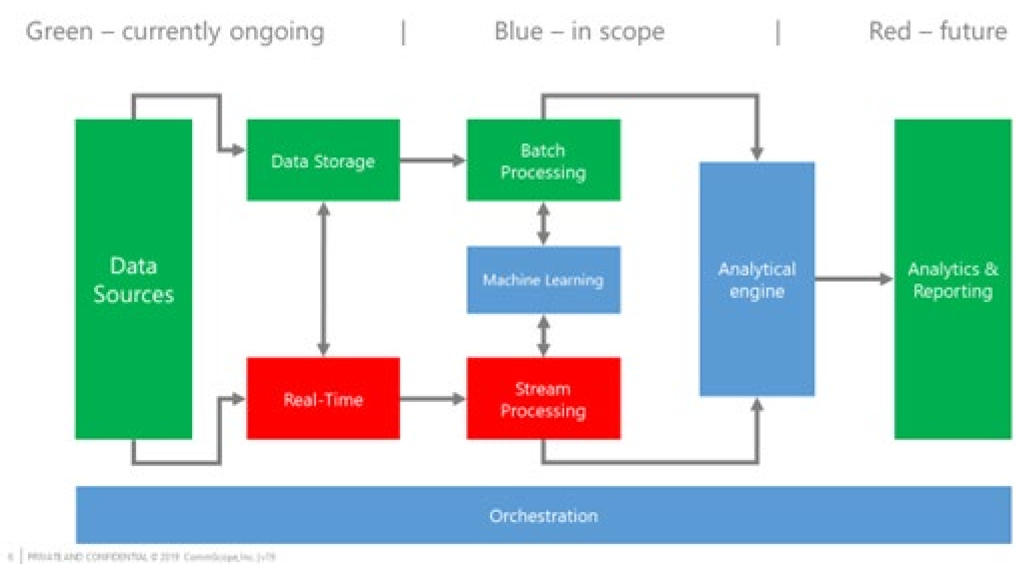

Figure 3 High-Level description of a big data analytics platform

3. Defining and Measuring User Experience

One of the main objectives of the project is to improve the overall Wi-Fi customer experience. But how do we define good customer experience? Customers usually do not know or care about any of the RF parameters that govern wireless communication. Often, the user's subjective assessment of the quality of the service boils down to a few essential characteristics.

- Connection reliability, is the connection easy? Is it fast? Is it repeatable?
- Latency, do I get a snappy response from the network?
- Throughput, is there an adequate minimum throughput guaranteed?

Our challenge is how to quantify these subjective assessments, by translating them into parameters we can measure and control.

From the network side, we can measure many aspects that enforces the above assessment of quality:

- Packet loss and packet retransmission
- Airtime utilization
- Throughput
- Latency
- Consistency

Assuming we can measure, how do we know what constitutes Good or rather Bad Customer Experience? For that, we need to understand the use case and expectations from the service this network provides.

3.1. Use Case for XfinityWiFi network

There are fundamentally two distinct use cases for the XfinityWiFi network. It may serve as a well-known “Guest Network” for visitors that come into your home or business. In this case, residential or business owners do not have to create a unique guest network and remember the credentials that would allow the visitor to join the network. All the access points broadcast the same SSID name (aka. Network name), and all Xfinity customers can join them for free. These users tend to be stationary users with mobile or handheld devices and laptops.

The second use case serves customers that are mainly outdoor; these are pedestrians with mobile or handheld devices. As such, the XfinityWiFi Network aims to create a continuous coverage in designated outdoor areas. And serve these pedestrian users’ data applications such as web browsing, video and audio streaming, IP voice application such as WhatsApp, Facetime, etc.

By having a good understanding of the above use cases, we can provide a good foundation for defining the Key Performance Indicator (KPI) that will be measured, their expected values and acceptable range.

3.2. Key Performance Indicator

Netscout data provided by the Comcast team collected and reported in 5-minute intervals the following TCP measurements:

DHCP Time- Measure how quickly a customer can get an IP from the network by recording the time it takes to complete a DHCP complete DORA (discovery, offer, request, and acknowledgment) exchange.

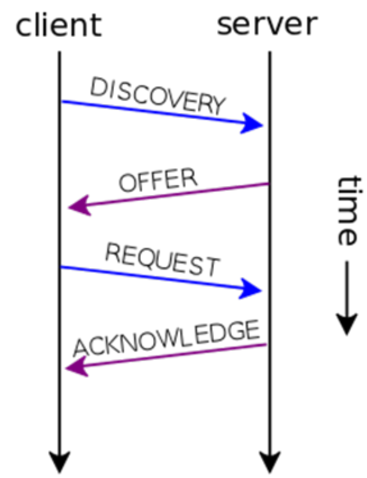

Figure 4 DHCP DORA 4-way exchange

Client Latency- Measures the initial TCP 3-way handshake between client and server and calculates the client-side latency (time elapsed between the Syn-Ack and Ack)

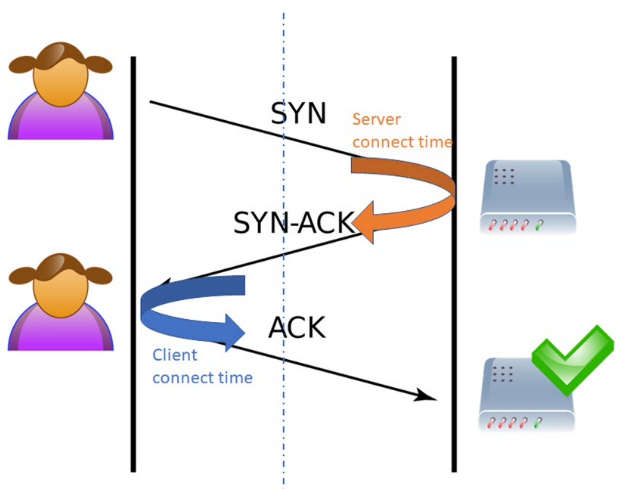

Figure 5 TCP 3-way handshake

Average Throughput- records the TCP throughput in each direction (Upstream and Downstream) within a 5-minute measuring interval. Throughput is calculated by dividing the sum of bytes in each direction by the number of milliseconds of activity in the corresponding direction.

TCP Retransmission- Number and percentage of TCP packets that were retransmitted in each direction i.e, from the client towards the server, and from the server towards the client.

While the first two measurements (DHCP Time and Client Latency) only represent a brief snapshot in time, the other two are ongoing and provide much more detailed measurement of all active TCP sessions between the client and the network.

The Average Throughput report is also used to sum the total of traffic (Tonnage) that traverse the network over a period.

In addition to the TCP traffic reports generated by the network probes, we collected measurements from the outdoor APs that represent the Wireless performance.

The outdoor Wireless Access Points reported a vast number of RF and network statistics in 15-minute intervals. Below are some of the relevant measurements collected.

Table 2 Example SNMP information elements provided by the Access Point

Group	Information Element	Description
Client information	Client IP address	
	Client MAC Address	for all clients associated with the AP
	Client State	Authenticated, Associated, Authorized, Secure or Unsecure
	Client RSSI	the last Received Signal Strength Indicator (RSSI) of the wireless client device.
	Min RSSI	the minimum RSSI of the wireless client device through the 15-minute interval.
	Max RSSI	the maximum RSSI of the wireless client device through the 15-minute interval.
	Client Last Transmit Rate	the transmit rate of the last MPDU sent to the client
	Client Last Receive Rate	the receive rate of the last MPDU sent from the client
Active Wi-Fi Channel quality statistics	Min Noise Floor	the minimum noise floor (dBm) on the serving channel across the measurement interval.
	Max Noise Floor	the maximum noise floor(dBm) on the serving channel across the measurement interval.
	Median Noise Floor	the median noise floor (dBm) on the serving channel across the measurement interval
	Activity Factor	percentage of airtime the radio was actively utilizing the channel across the measurement interval
	Channel Utilization	percentage of time the medium was utilized on the channel across the measurement interval

	Retransmission	percentage of packets that had to be retransmitted during the measurement interval
	Busy by Other Radio	percentage of each second that the transmitter is busy by another Radio
	Average Tx Mod Rate	a weighted average of the Tx modulation rate for data MPDU in Mbps
	Average Rx Mod Rate	a weighted average of the Rx modulation rate for data MPDU in Mbps
Radio based statistics	Radio Tx OK	number of successfully transmitted MSDU (data MPDU)
	Radio Tx Fail	the number of hardware Tx errors and excessive retries for MSDU (data MPDU).
	Radio Rx OK	number of Ethernet frames forwarded to stack by wifi MAC
	Radio Rx Fail	number of data MPDU missed by sequence number gap
	Tx MCS	the number of Data MPDU transmitted for each MCS (modulation and coding scheme).
	Rx MCS	the number of Data MPDU received for each MCS (modulation and coding scheme).
SSID based statistics	SSID Tx OK Bytes	per SSID number of bytes in successfully transmitted MSDU (data MPDU).
	SSID Tx OK	per SSID number of successfully transmitted MSDU (data MPDU).
	SSID Rx OK Bytes	per SSID number of bytes in Ethernet frames forwarded to stack by wifi MAC.
	SSID Rx OK	per SSID number of Ethernet frames forwarded
	SSID Successful Auth	per SSID number of wifi clients successfully authenticated
	SSID Auth Failure	per SSID number of wifi client's authentication Failures

4. Identifying Bad WIFI Client Experience (Bad WCX)

To provide a better user experience, we had to define what does "good user experience" means. And therefore, what are the bad cases we wish to identify, eliminate, or correct.

DHCP Time and Client Latency only represent a brief snapshot in time; however, they provide insight into the Connection reliability and the perceived latency. We were aiming for a fast Authentication (802.1x or Open SSID), and fast DHCP response (less than 1Sec). These parameters of Authentication and DHCP response, are entirely under the network operator control. As a rule of thumb, we also defined expectable latency as less than 150ms.

In order to measure latency, throughput, and reliability on an ongoing basis, we used the following criteria's as "good user experience":

1. Less than 4% of TCP packet retransmission,
   Measurements conducted by Comcast identified 4% as the threshold where clients start noticing network delay and slowness.
2. A minimum downstream throughput in the coverage areas,
   We were aiming at HD Video quality inside cell coverage (>5Mb/s) and SD Video quality at cell edge (>3Mb/s).
   Note, Outdoor AP may serve up to 100 active clients per Radio, 50 per SSID.

Evidence of Bad WIFI Client Experience (Bad WCX) can be gleaned from records of a high percentage of TCP packets retransmission. Another proof of Bad WCX is slow average throughput for lengthy sessions. We should look for a combination of indications from the Netscout reports of the same client MAC at the same 5 min bin.

4.1. Criteria's of Bad WIFI Client Experience (Bad WCX)

1. Percentage of Server Retries ≥ 4% AND Number of packets retries > 2 (packets)
2. Percentage of Client Retries ≥ 4% AND Number of packets retries > 2 (packets)
3. Video sessions that are longer than 2 minutes AND average downstream throughput less than 3Mbps

4.2. Types of Bad WCX events

Looking at the total Bad WCX events based on the above criteria, we can group them into different types of events, which may require different resolutions.

1. Moving Client
   - records identify client on Multiple AP during the 5 min bin
2. Client on a Single AP, Single VAP/VLAN.
3. Client on a Single AP, Multiple VAPs/VLAN.

Note – in order to create this classification of events; we would need to add within the 5min bin all records of the client that experienced a Bad WCX within that 5min bin.

4.2.1. Example of identifying type of Bad WCX

As seen in Table 3 below. At 11:45 The client 48:BF:6B:92:FB:D8 is connected to an OG1600 with AP_MAC_Address of a8:9f:ec:da:b2:6a, experienced a Bad WCX while connecting to the 5GHz xfinitywifi VAP. However, the same client also registered on the 2.4GHz VAP during the same time. And exchanged most of the traffic on this VAP. This is a case of **Client on a Single AP, Multiple VAPs/VLAN**

At 13:50 and 14:05 the same client experienced 2 Bad WCX events. These are cases of the **client on a Single AP, Single VAP/VLAN.**

At 16:10 we see the same client registered on multiple AP, experiencing 2 Bad WCX events. On TG34862G with AP_MAC_Address 88:ef:16:dd:b0:01. And on TG862G AP_MAC_Address cc:a4:62:af:68:d4. This is a case of **Moving Client**

Table 3 Example of classification to the type of Bad WCX

Time Line	5 Min	MAC Address	AP Model	VLAN		TCP_retries_From_Server	From Server Packets Count	%TCP Server Retransmission	TCP_retries_From_Client	To Server Packets Count	%TCP Client Retransmission
11:45	6/15/2020 11:45	a8:9f:ec:da:b2:6a	OG1600A	xfinitywifi_5GHz_OG	612	3	23	13.04%	0	50	0.00%
11:45	6/15/2020 11:45	a8:9f:ec:da:b2:6a	OG1600A	xfinitywifi_2_4GHz_OG	602	6	1,218	0.49%	3	2,046	0.15%
12:30	6/15/2020 12:30	a8:9f:ec:da:b2:6a	OG1600A	xfinitywifi_2_4GHz_OG	602	12	290	4.14%	0	255	0.00%
13:20	6/15/2020 13:20	a8:9f:ec:da:b2:6a	OG1600A	xfinitywifi_5GHz_OG	612	12	3,773	0.32%	6	3,692	0.16%
13:20	6/15/2020 13:20	a8:9f:ec:da:b2:6a	OG1600A	xfinitywifi_2_4GHz_OG	602	8	88	9.09%	2	64	3.13%
13:50	6/15/2020 13:50	a8:9f:ec:da:b2:6a	OG1600A	xfinitywifi_2_4GHz_OG	602	22	187	11.76%	2	210	0.95%
14:05	6/15/2020 14:05	a8:9f:ec:da:b2:6a	OG1600A	xfinitywifi_2_4GHz_OG	602	3	27	11.11%	3	29	10.34%
14:50	6/15/2020 14:50	a8:9f:ec:da:b2:6a	OG1600A	xfinitywifi_2_4GHz_OG	602	26	473	5.50%	8	503	1.59%
15:00	6/15/2020 15:00	a8:9f:ec:da:b2:6a	OG1600A	xfinitywifi_2_4GHz_OG	602	42	871	4.82%	8	642	1.25%
15:05	6/15/2020 15:05	a8:9f:ec:da:b2:6a	OG1600A	xfinitywifi_2_4GHz_OG	602	40	335	11.94%	7	291	2.41%
15:10	6/15/2020 15:10	a8:9f:ec:da:b2:6a	OG1600A	xfinitywifi_2_4GHz_OG	602	31	377	8.22%	17	294	5.78%
15:30	6/15/2020 15:30	a8:9f:ec:da:b2:6a	OG1600A	xfinitywifi_5GHz_OG	612	5	3,211	0.16%	5	4,059	0.12%
15:35	6/15/2020 15:35	a8:9f:ec:da:b2:6a	OG1600A	xfinitywifi_2_4GHz_OG	602	8	130	6.15%	1	69	1.45%
15:55	6/15/2020 15:55	a8:9f:ec:da:b2:6a	OG1600A	xfinitywifi_2_4GHz_OG	602	58	850	6.82%	17	793	2.14%
16:00	6/15/2020 16:00	a8:9f:ec:da:b2:6a	OG1600A	xfinitywifi_2_4GHz_OG	602	21	506	4.15%	15	714	2.10%
16:05	6/15/2020 16:05	a8:9f:ec:da:b2:6a	OG1600A	xfinitywifi_5GHz_OG	612	9	980	0.92%	7	986	0.71%
16:05	6/15/2020 16:05	a8:9f:ec:da:b2:6a	OG1600A	xfinitywifi_2_4GHz_OG	602	22	157	14.01%	3	63	4.76%
16:10	6/15/2020 16:10	88:ef:16:dd:b0:01	TG3482G	xfinitywifi_2_4GHz_HHS_BWG	102	6	81	7.41%	1	100	1.00%
16:10	6/15/2020 16:10	cc:a4:62:af:68:d4	TG862G	xfinitywifi_2_4GHz_HHS_BWG	102	3	9	33.33%	0	8	0.00%
17:10	6/15/2020 17:10	80:b2:34:3d:52:e5	DPC3941T	xfinitywifi_5GHz_HHS_BWG	103	3	19	15.79%	1	18	5.56%
17:10	6/15/2020 17:10	a8:9f:ec:da:b2:6a	OG1600A	xfinitywifi_2_4GHz_OG	602	6	29	20.69%	0	11	0.00%
17:15	6/15/2020 17:15	a8:9f:ec:da:b2:6a	OG1600A	xfinitywifi_2_4GHz_OG	602	9	86	10.47%	0	74	0.00%

4.1. Correlating Bad WIFI Client Experience with WIFI SNMP Data

Utilizing telemetry, currently in the form of SNMP polls or Ruckus SmartCell Insight (SCI) reports. Allows us to make measurements without the need to have testers on the ground. Furthermore, collecting data in small intervals, over a long period enable us to identify trends in behaviors. And avoid any transient events that may impact test results of a specific day.

The main trends we were looking for were Channel Utilization, Activity Factor, Wi-Fi Retransmissions, and calculated Average Modulation Rate.

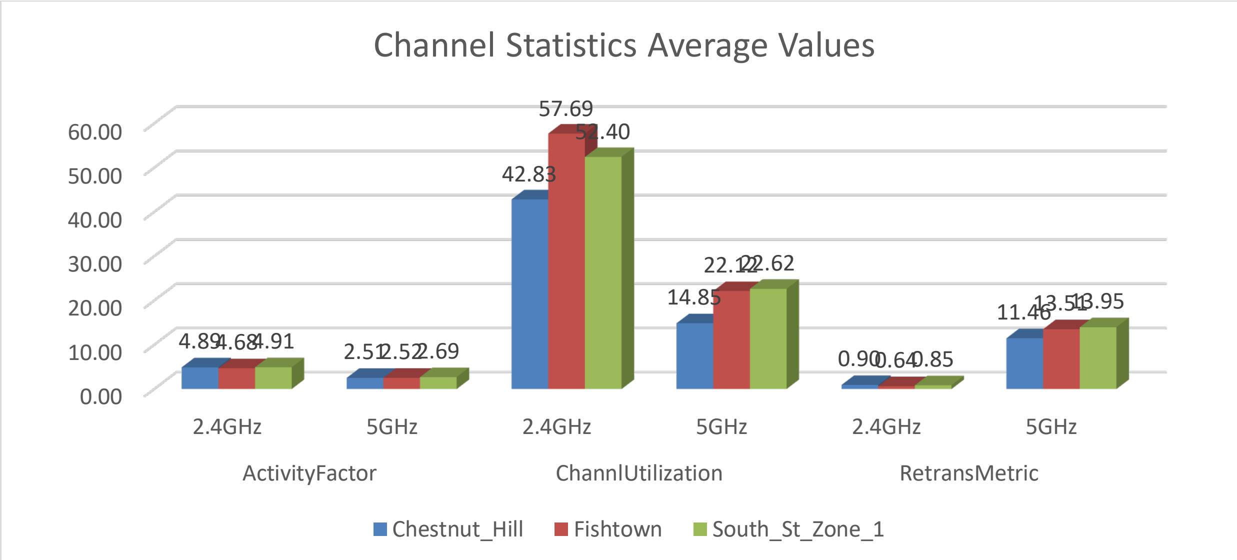

Figure 6 Average Channel Health Statistics

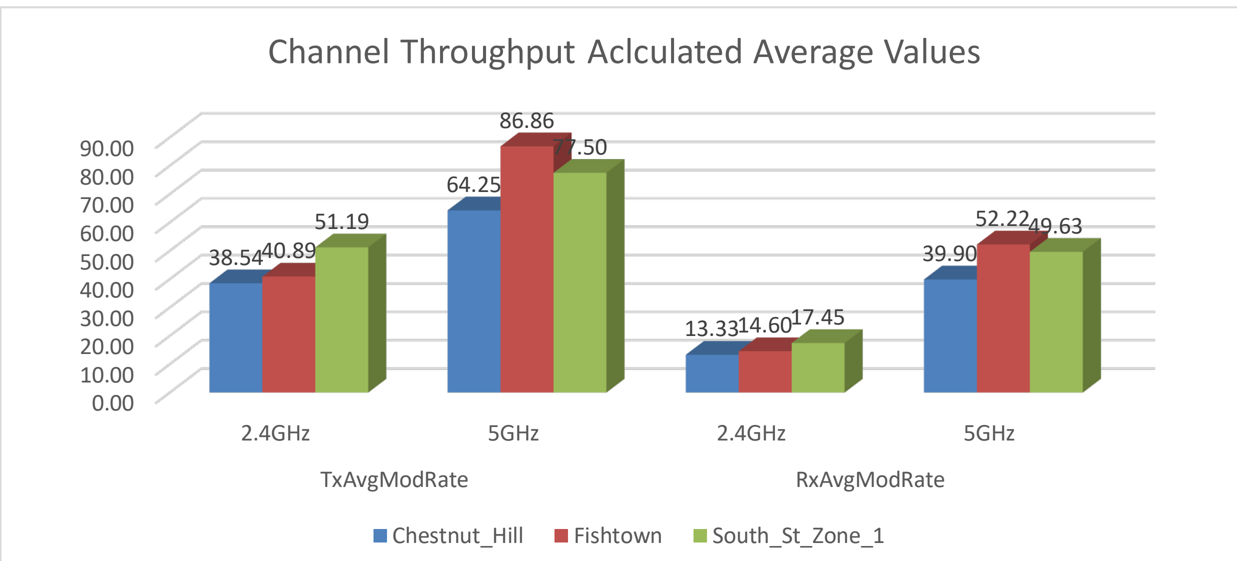

Figure 7 Average Calculated Channel Throughput

For each of the areas, we also identify the outliers AP. This insight helped in the channel planning, as well as with decisions about turning 2.4GHz radio off entirely in some cases.

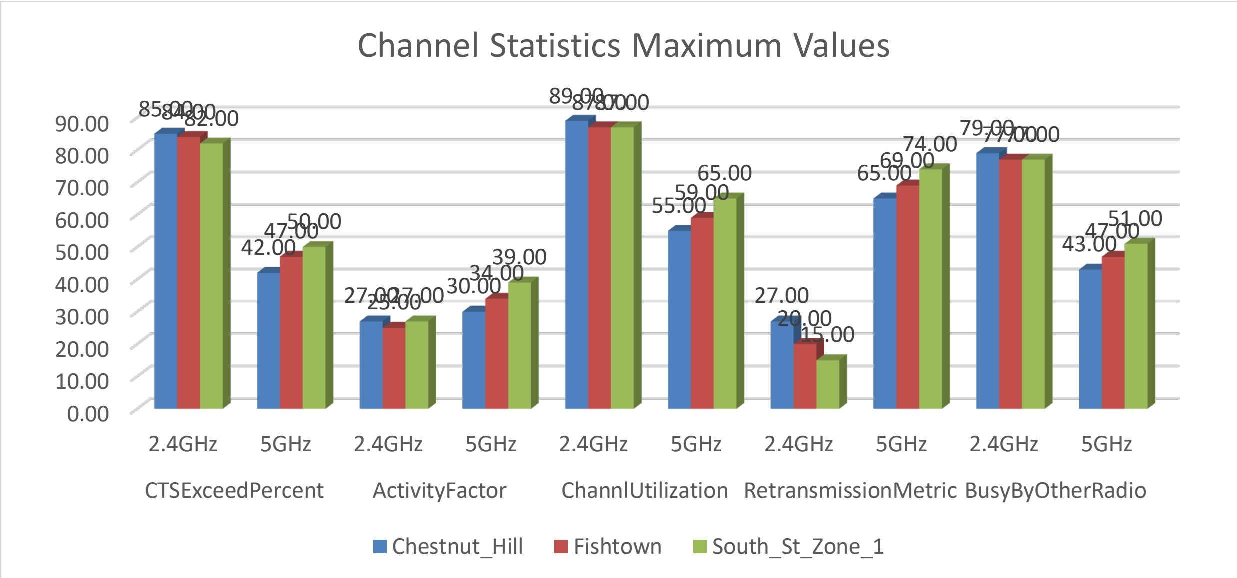

Figure 8 Outliers of Channel Health Statistics

One of the indications that would provide insight into the way client interact with the AP, in terms of good Signal to Noise Ratio (SNR), Signal Strength Indicator (SSI), and throughput; is the distribution of Data MPDU across the different Modulation and Coding Scheme (MCS) indexes.

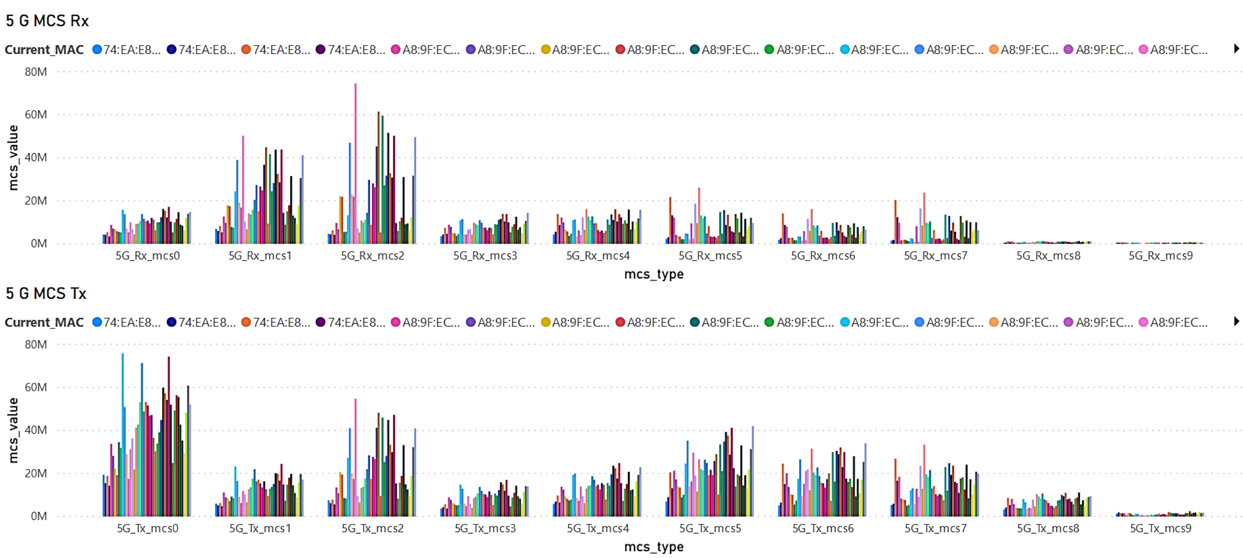

Figure 9 5GHz Radio Data MPDU distribution across MCS

5. Current Results and Findings

5.1. Baseline state

First, we needed to establish the percentage of sessions with Bad WCX out of all client sessions.

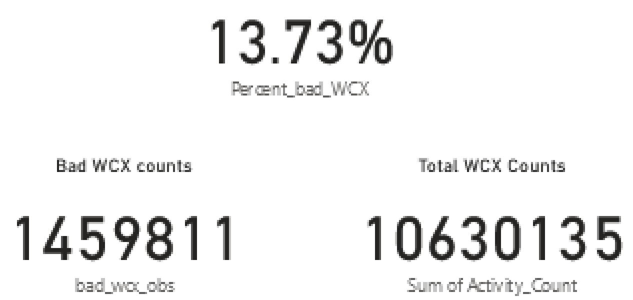

Figure 10 Percentage of sessions with Bad WCX out of all client sessions – Baseline state

Looking at the breakdown of Bad WCX based on the three types defined above. We can see that moving clients represent the smallest group of bad experience events. Even when looking at outdoor AP exclusively, this non-intuitive fact holds.

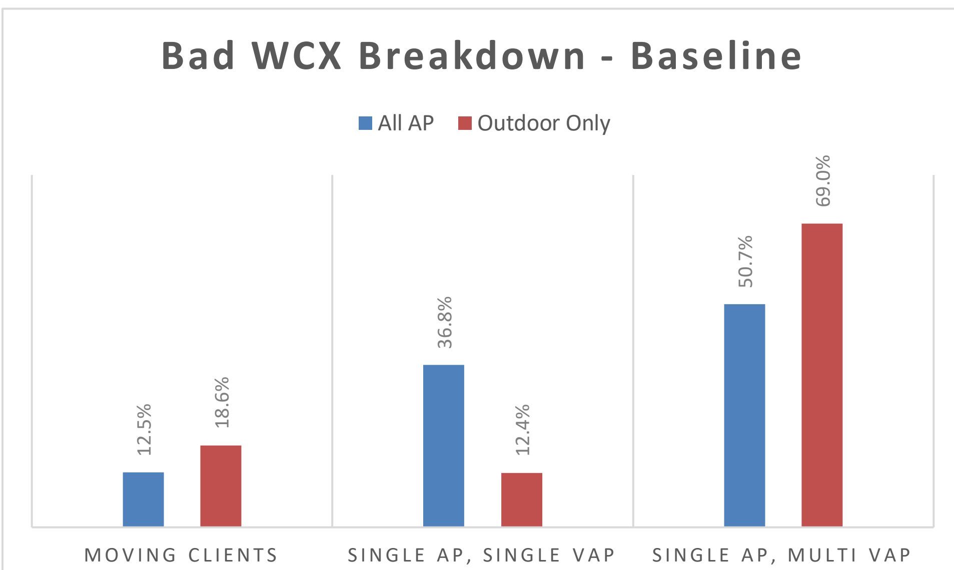

Figure 11 Bad WCX breakdown per type – Baseline state

A second insight is that there is no real difference in the Bad WCX due to TCP retries when we look at the percentage of retries compare to all TCP packets in that direction. As expected, the traffic patterns are heavily skewed in favor of downstream. In other words, much more traffic is going from the server towards the client. At first glance, this may be non-intuitive, given the differences in transmit power and receive sensitivity between the client and the AP.

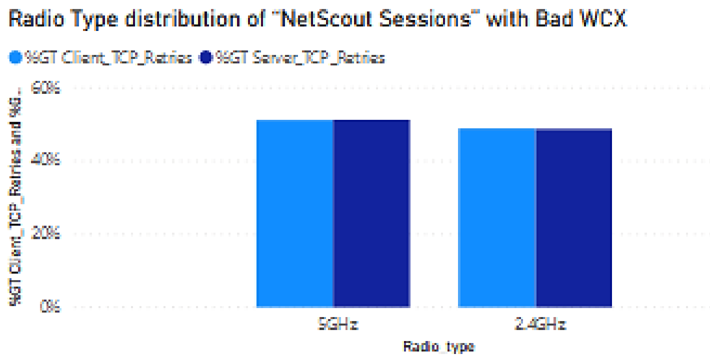

Figure 12 Bad WCX distribution per Radio – Baseline state

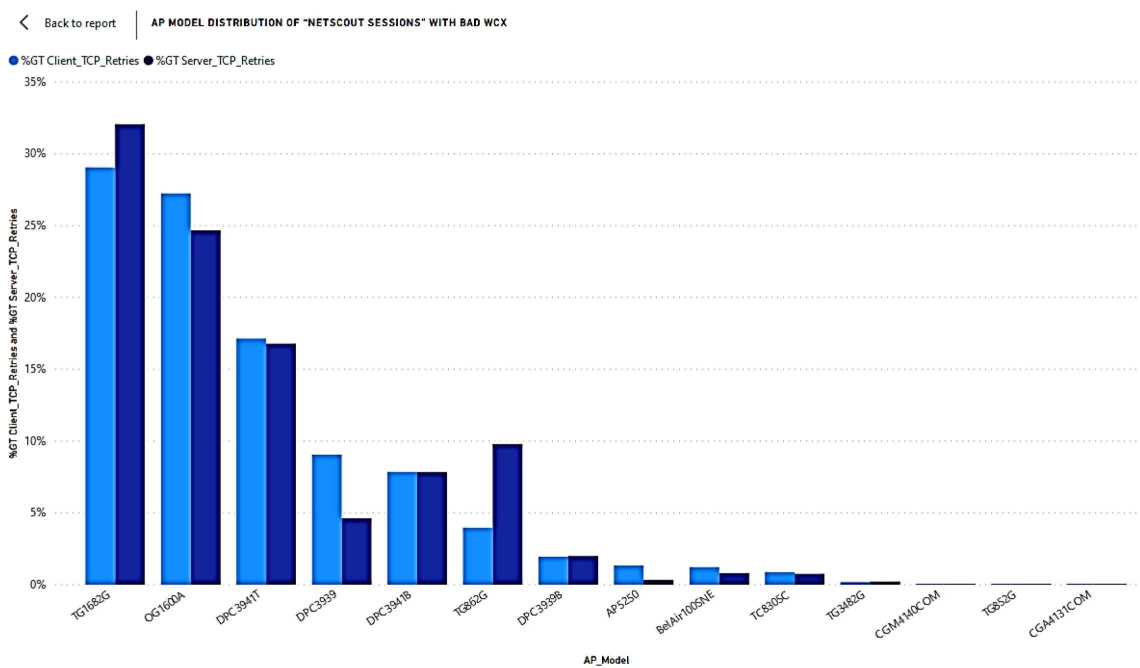

Figure 13 Bad WCX distribution per AP Model – Baseline state

5.1. Current state

For each of the areas, CommScope has defined several iterations of configuration changes and for the areas that allowed, added coverage by additional outdoor AP or a complete redesign. While COVID-19 shelter-in-place impacted our ability to conduct many of the iterations and significantly reduced the number of observations (client activity, sessions of outdoor activity, etc.). We were able to drive many of the changes based on the insights we gathered by the big data analytics systems.

Using cross-correlation between our defined criteria of Bad WCX, AP SNMP, and telemetry reports. We were able to drive the following improvements on the network. Note the significant improvement in the outdoor AP (OG1600), and the smaller improvement in the average of all models.

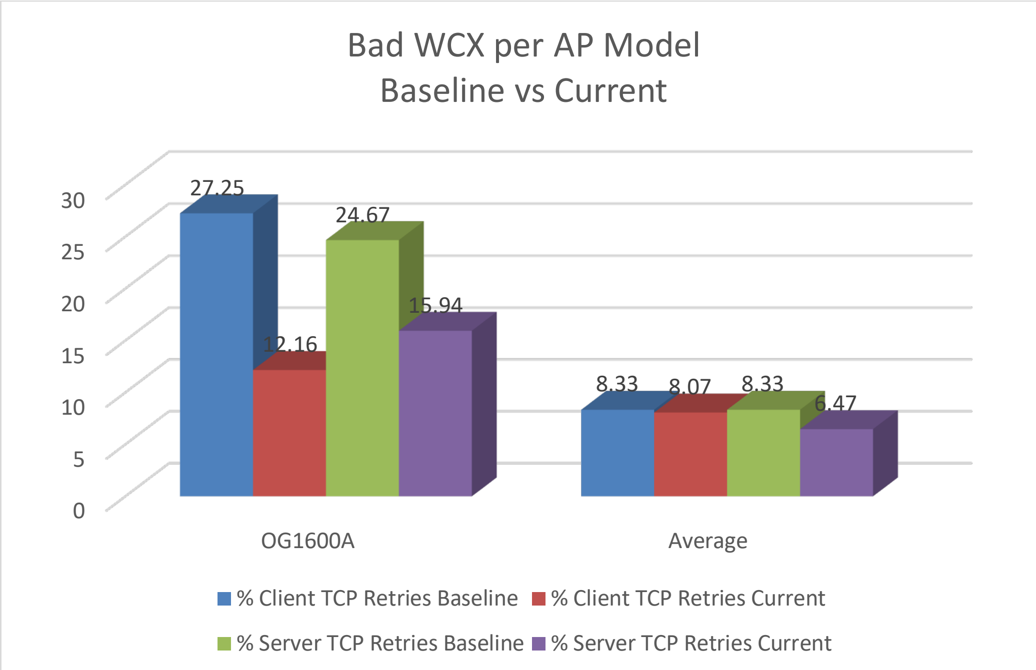

Figure 14 Bad WCX distribution per AP Model – Baseline vs. Current

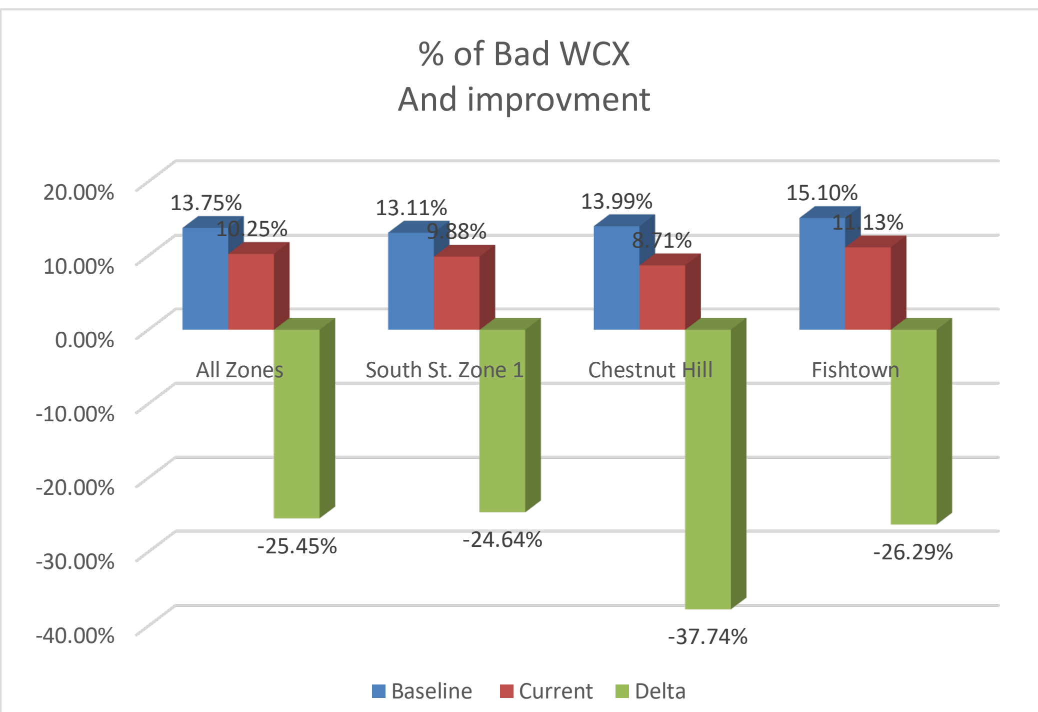

Figure 15 Percentage of sessions with Bad WCX out of all client sessions and improvement

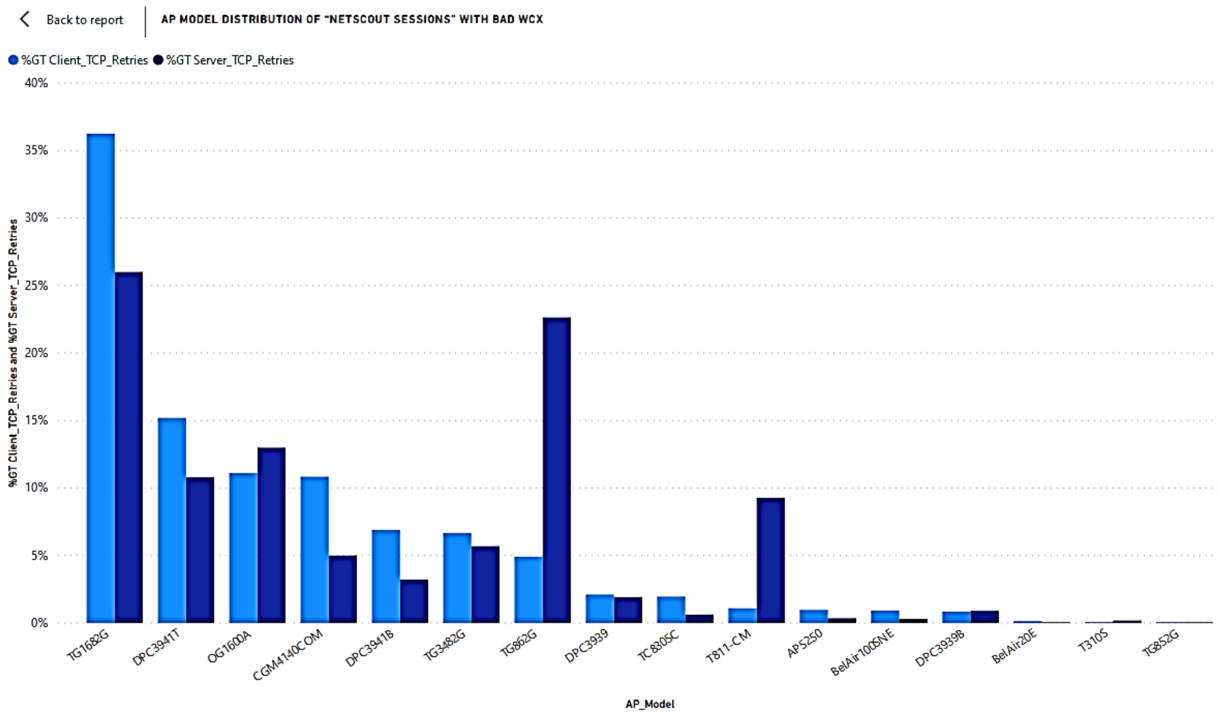

Figure 16 Bad WCX distribution per AP Model – Current state

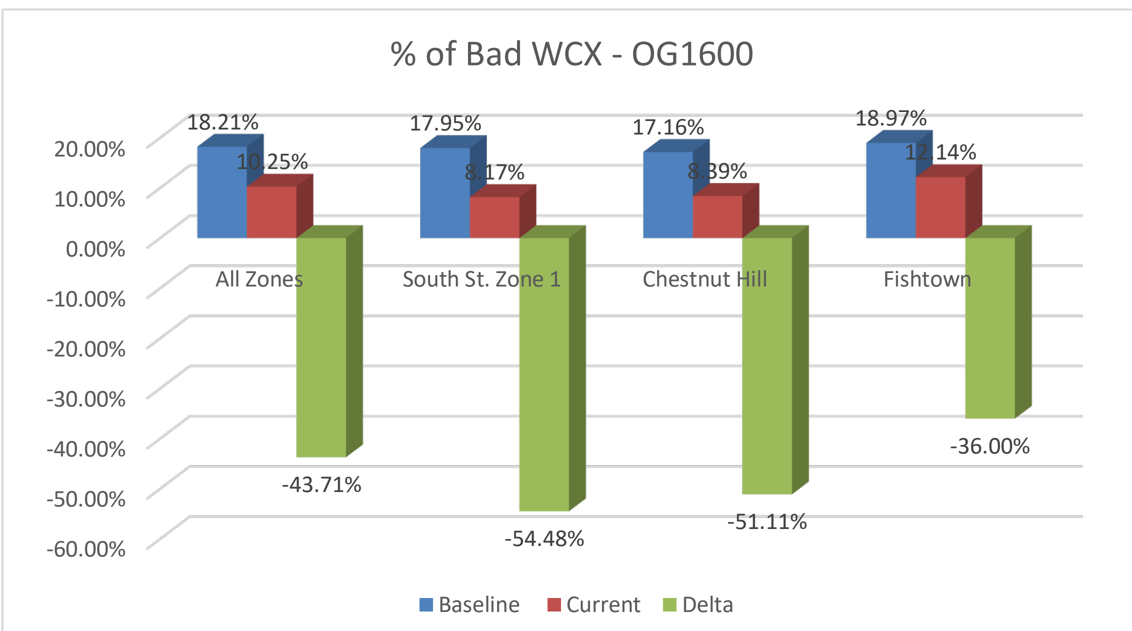

Figure 17 Percentage of sessions with Bad WCX out of all client sessions and improvement – OG1600s

6. Conclusion

Utilizing an automated big data analytics system that collects, correlates, and provides insight into users' experience, even for a nationwide network, is achievable.

Bringing together the right subject matter experts in the areas of data science and Wireless; Operators can use the insights generated by the big data analytic system to identify possible causes of bad user experience. Through recommendations and applying the right actions and implementation, we can eliminate or significantly reduce the number and frequency of these bad user experience events. Paving the way to a more optimized network that can serve more customers and provide significant data offload opportunity for an LTE usage.

Future enhancement of this platform includes more sources of data (e.g., indoor Access Points) and real-time telemetry, which will increase the ability to predict where optimization and intervention are needed. The platform and architecture developed to provide the foundation for a machine learning platform. Such machine learning capability would be able to establish thresholds, identify anomalies, and automate the identification and prediction of user experience. Future enhancement is to close the loop by turning the insights and recommendations provided by the system into an engine that would apply the right configuration changes to the network and continue to optimize the performance.

Abbreviations

AP	Access Point
bps	bits per second
DHCP	Dynamic Host Configuration Protocol (aka IP allocation)
FEC	forward error correction
GIS	Geographic Information Systems
GPS	Global Positioning System
HFC	Hybrid Fiber-Coax
HHS	Home Hotspot
Hz	hertz
ISBE	International Society of Broadband Experts
KPI	Key Performance Indicator
MAC	Media Access Control
Mbps	Megabits per second
MCS	Modulation and Coding Scheme
MPDU	MAC Protocol Data Unit
MSDU	MAC Service Data Unit
SCTE	Society of Cable Telecommunications Engineers
SMB	Small or Medium Business
SNMP	Simple Network Management Protocol
SNR	Signal to Noise Ratio
SSI	Signal Strength Indicator
SSID	Service Set Identifier (aka. Network Name)
RF	Radio Frequency
RSSI	Receive Signal Strength Indicator
VAP	Virtual AP (aka SSID)
WAG	Wireless Access Gateway