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Optimizing Value from Service Provider Wi-Fi in a Converged World

A Technical Paper prepared for SCTE by

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1. Introduction

Increasingly, subscribers want access to their broadband services at home, on the go and at their destinations. The value proposition of service provider Wi-Fi is to give subscribers access to their services when they are away from home at all types of destinations. In the absence of service provider Wi-Fi, subscribers must deal with authenticating to destination Wi-Fi on a case-by-case basis by asking for authentication codes, using their mobile data plans, or foregoing the use of their applications. Cisco estimates that the number of public Wi-Fi hotspots globally will quadruple from 2018-2023 [1]. Shaw operates a service provider Wi-Fi network in its cable footprint that is available free of charge to broadband wireline and wireless subscribers. This paper examines how subscribers use the service provider Wi-Fi network and seeks to answer some key questions around the value of the network, both to subscribers and to service providers.

2. Service Provider Wi-Fi Network

Shaw's service provider Wi-Fi network is made up of three types of access points (APs)—service provider APs expressly installed for service provider Wi-Fi connectivity, business Wi-Fi APs that are installed in business customer premises, and home hotspot APs installed in subscriber premises. Service provider Wi-Fi traffic is backhauled over fibre or coax to a wireless access gateway and into the core network.

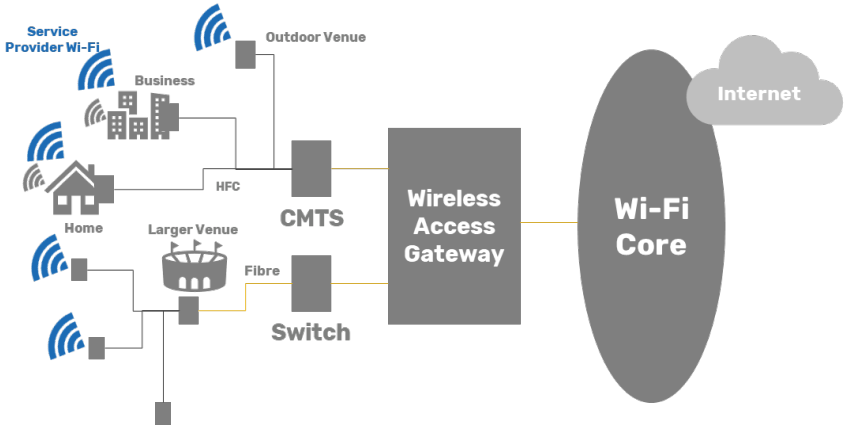

Figure 1 – Service Provider Wi-Fi Network

2.1. Types of Access Points

Service provider APs come in indoor and outdoor units with different backhaul options. The service provider network initially targeted the install of outdoor units that could be mounted on aerial infrastructure with power and backhaul provided via the hybrid-fibre coax (HFC) network. These APs are used to cover public areas such as parks or shopping districts. Indoor units were targeted at public spaces such as community centres and shopping malls and were backhauled via the HFC network or fibre optics, depending on the existing network infrastructure.

Figure 2 – Service Provider Wi-Fi Access Points

Business Wi-Fi APs are used for business Wi-Fi services, and secondarily used for service provider Wi-Fi. One or more SSIDs are set up for the business' use and service provider SSIDs are also broadcast for service provider subscriber use. These APs are used to allow clients of Shaw Business customers to use service provider Wi-Fi without needing to ask the business for authentication codes.

Home hotspot describes residential subscriber modems used for service provider Wi-Fi. In this case one or more SSIDs are set up for the subscriber and additional SSIDs are broadcast for service provider subscriber use. Similarly to business Wi-Fi, these APs allow service provider Wi-Fi users access to Wi-Fi in residential homes without needing to ask for authentication codes.

2.2. Network Access

Access to the service provider network is granted to all broadband and wireless subscribers. In terms of access, one difference is that the home hotspot network is only available to wireless subscribers. There are various methods of authenticating onto the network. Broadband subscribers can connect to the service provider network at an AP and enter their credentials into a splash page. Additionally, subscribers can add the MAC addresses of devices via a web portal, a feature that allows devices to be registered without being in range of the network. Wireless subscribers are automatically authenticated through their SIM cards. Once a device is authenticated it will automatically attach to the network when the device is in range. Broadband subscribers are allocated a 30Mbps downstream and 5Mbps upstream Wi-Fi speed tier, while wireless users have a 100Mbps downstream and 10Mbps upstream Wi-Fi speed tier.

2.3. Reporting Platforms

Shaw collects reporting data from several sources. Data is anonymized and aggregated to gauge performance of the Wi-Fi network.

Both APs and wireless access gateways send RADIUS accounting records with session data. The RADIUS accounting functions allow records to be sent at the start and end of sessions indicating the resources used during the session [2]. This analysis specifically looks at stop records, which are only sent at the end of a session.

To gather application-level statistics a deep-packet inspection (DPI) system was used. This system has a catalog of application signatures to which user traffic is mapped. The DPI system was also used to gauge bitrate statistics at the modem level for Wi-Fi APs backhauled over DOCSIS. This system takes 256ms data consumption samples and summarizes them into one-minute bitrate statistics. These statistics include average, mean, median, 95th percentile and peak throughput.

2.4. Subscriber Feedback

Shaw has undertaken consumer surveys of broadband and mobile subscribers to gauge the sentiment towards service provider Wi-Fi and to verify whether subscriber perceptions match the intended value.

81% of broadband subscribers and 86% of dual broadband and wireless subscribers who responded were aware that they had access to service provider Wi-Fi. Service provider Wi-Fi was ranked third in terms of factors impacting a subscriber's decision to keep their broadband services with Shaw, with 80% responding that it was impactful.

57% of respondents noted that they frequently or occasionally use service provider Wi-Fi, which ranked higher than other sources of Wi-Fi such as restaurants, coffee shops, and retail stores. Given the same options for connecting to Wi-Fi, 81% rated the quality of service provider Wi-Fi as good or very good, a higher percentage than all other options.

Overall, 86% of broadband subscribers and 95% of wireless subscribers who responded to the survey answered that they find value in service provider Wi-Fi.

3. Network Usage

Service provider Wi-Fi is meant to provide subscriber value. Anecdotally however, there had been reports that subscribers authenticating to the Wi-Fi network were unable to connect to the Internet. Additionally, there was a concern that individuals not subscribed to Shaw services were accessing the network. This section explores these issues, general network usage and performance and whether the network was being used as intended. The data presented in the following sections was gathered in 2019 and 2020, before the start of the COVID-19 pandemic.

3.1. Monthly Consumption

Average monthly Wi-Fi consumption was calculated per device for both wireline and wireless subscribers. As shown in Figure 3, average monthly Wi-Fi consumption was nearly identical for the two groups at approximately one gigabyte per month. One gigabyte is a small amount when compared to wireline monthly consumption but is comparable to wireless monthly consumption.

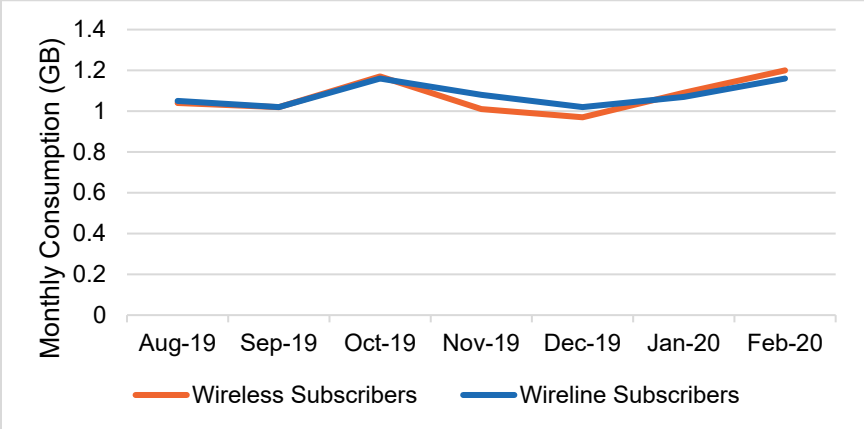

Figure 3 – Average Monthly Wi-Fi Consumption

Monthly Wi-Fi consumption averages hide the large disparities between subscribers. Although these disparities are observed in the wireline network, they are more pronounced in the Wi-Fi network, as shown in Figure 4.

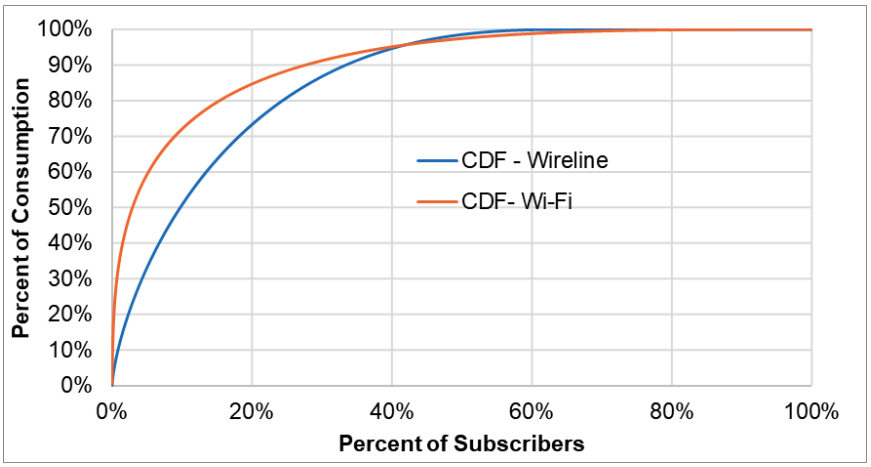

Figure 4 – Wi-Fi and Wireline Consumption Cumulative Distribution Function

This chart shows the cumulative distribution function (CDF) of Wi-Fi and wireline consumption. It can be observed that 20% of subscribers on the wireline network account for approximately 75% of consumption, while 20% of subscribers on the Wi-Fi network account for approximately 85% of consumption. There is no pronounced difference in the number of subscribers who account for little or no consumption, which would be expected if users were authenticating but not connecting to the Internet.

Figure 5 shows that there is an even spread in the percent of devices using Wi-Fi for a specific number of days per month. The data shows that 4.5% of devices access the network only a single day per month, while 4% of devices access the network every day of the month. This pattern fits with destination use because the number of days a subscriber visits destinations, such as restaurants, varies person to person. In contrast, subscribers access the wireline and wireless networks all or most days of the month.

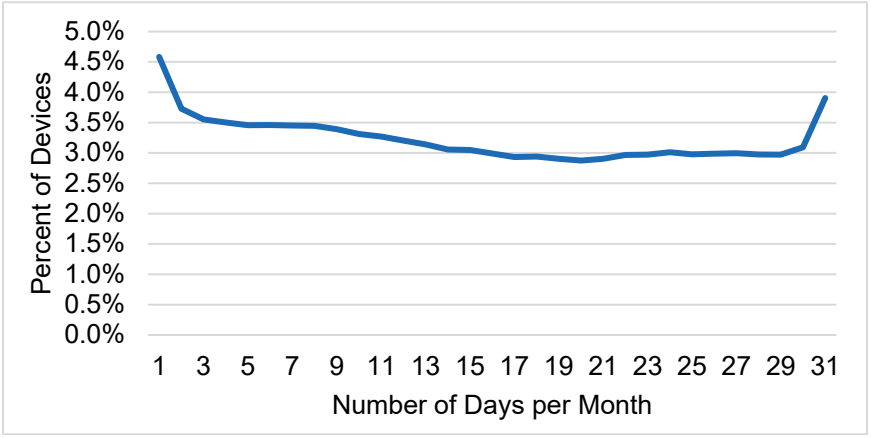

Figure 5 – Wi-Fi Days of Use per Month

Wi-Fi consumption was also compared to wireline and wireless consumption for individual subscribers. While wireline consumption is much higher, there is a correlation between high wireline consumption and high Wi-Fi consumption, as demonstrated by Figure 6. Wireline consumption is shown on the Y-axis in

gigabytes while Wi-Fi consumption is shown on the X-axis in megabytes. Note the logarithmic scales on both axes. The size of the bubbles indicates number of subscribers.

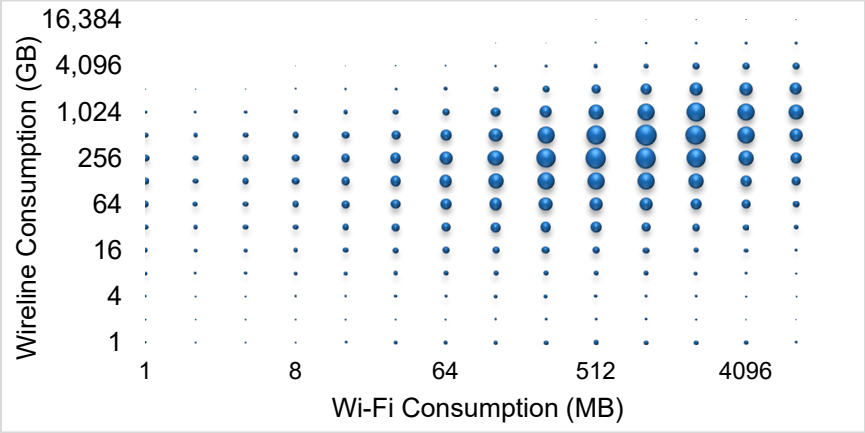

Figure 6 – Wi-Fi vs Wireline Consumption

This result points to Wi-Fi consumption being complementary to—rather than a substitute for—wireline consumption. There is not a significant number of subscribers with heavy Wi-Fi consumption and low wireline consumption.

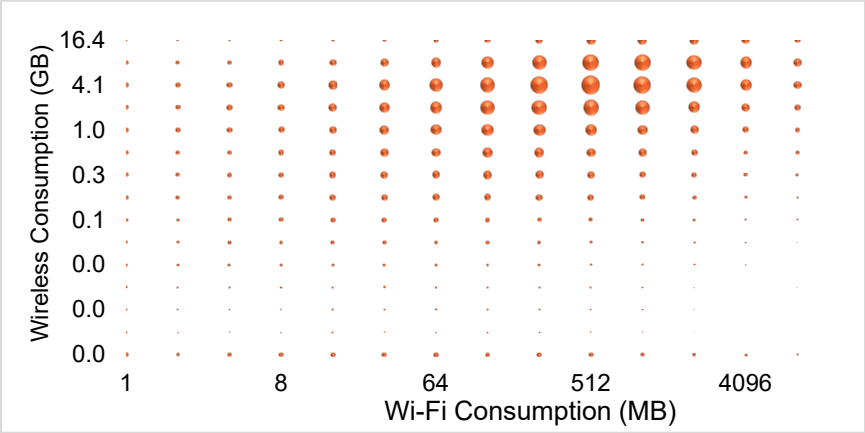

Figure 7 – Wi-Fi vs Wireless Consumption

Monthly consumption for wireless subscribers who used the service provider Wi-Fi network was also analyzed. The result showed a similar correlation to the wireline/Wi-Fi comparison in that subscribers who had high monthly wireless consumption tended to also have high monthly Wi-Fi consumption.

Wireline subscribers can register multiple devices on the Wi-Fi network, with limits set depending on which broadband tier they are subscribed to. Although there is potential for subscribers to allow people outside their household to access the network, this is not seen in the data. 70% of accounts have only one or two registered devices, which roughly matches the number of people per household.

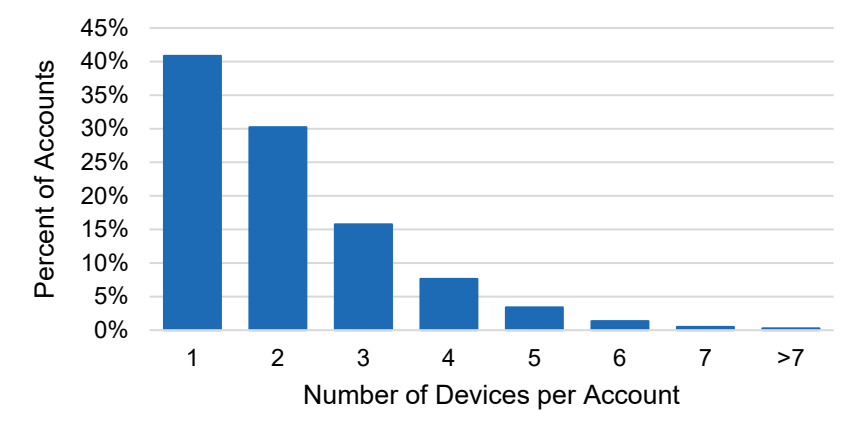

Figure 8 – Number of Devices Registered per Account

3.2. Bitrate Statistics

Average and 95th percentile bitrate is measured in the downstream and upstream every minute for a month for each DOCSIS backhaul modem. From those measurements the monthly 95th percentile bitrate is taken and graphed.

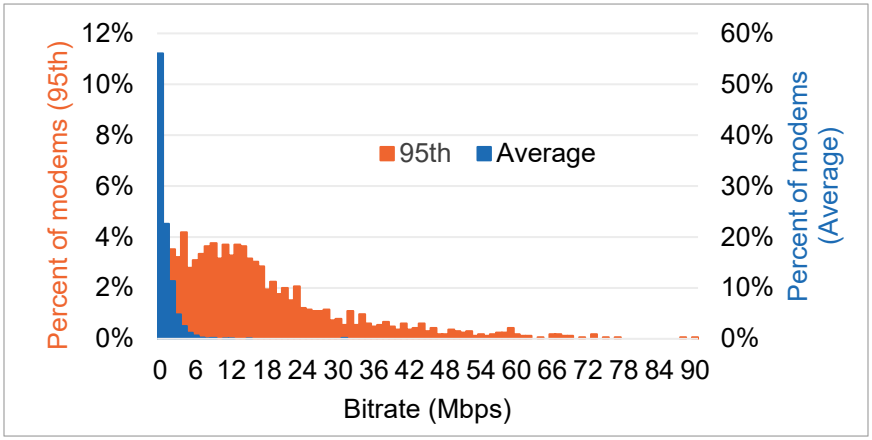

Figure 9 – Downstream Average and 95th Percentile Bitrate

On average, downstream backhaul modem bitrates are below 5Mbps, while the 95th percentile bitrate is more distributed.

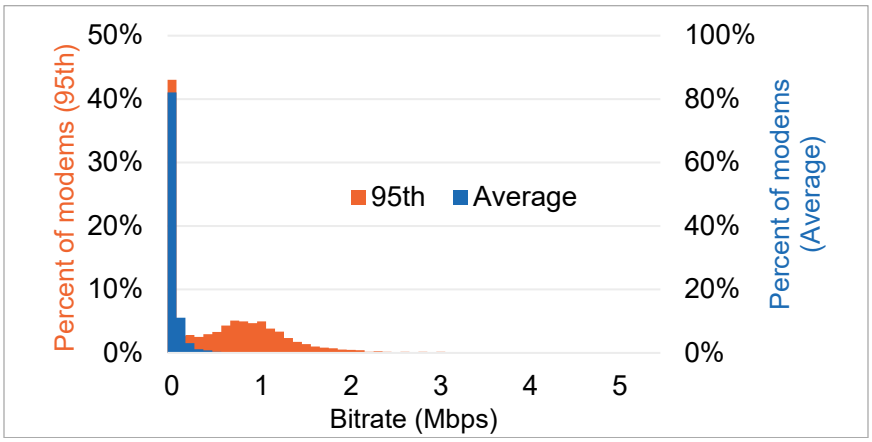

Figure 10 – Upstream Average and 95th Percentile Bitrate

The average upstream bitrate of the backhaul modem is below 1Mbps with the distribution of 95th percentile bitrates centered at approximately 1Mbps. These graphs show that the bitrate limitations placed on subscribers do not hinder their use.

3.3. Application View

The top applications ranked by consumption on the Wi-Fi network can be observed and contrasted with those on the wireline network using DPI systems.

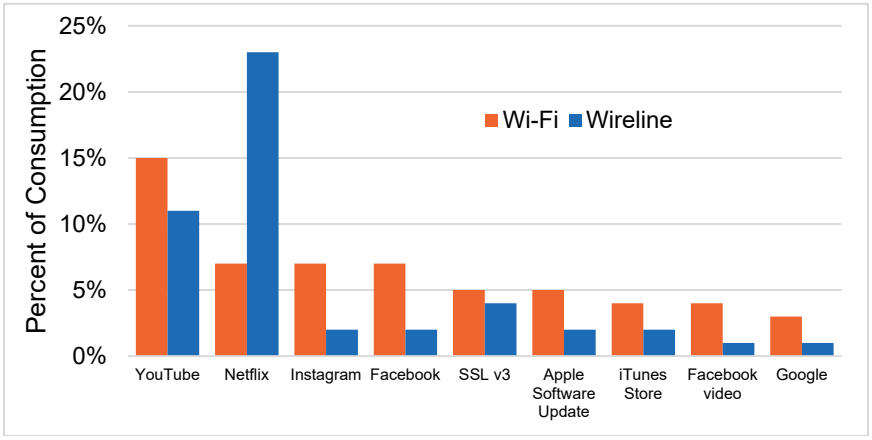

Figure 11 – Wi-Fi and Wireline Application Usage

Streaming media dominates data consumption for both wireline and Wi-Fi. In both cases, the top two applications are YouTube and Netflix. However, the order of these two applications is reversed for wireline and Wi-Fi, likely due to the nature of these applications. YouTube videos are generally shorter and can be more easily watched on a small screen at a destination connected to Wi-Fi, whereas Netflix is geared toward longer programming and is more commonly watched on a larger screen at home. Social media applications also account for a higher percentage of Wi-Fi consumption than wireline consumption as demonstrated by Instagram and Facebook.

As illustrated in Figure 12, while video dominates consumption, social media—specifically Facebook and Instagram—is used by a higher percentage of subscribers.

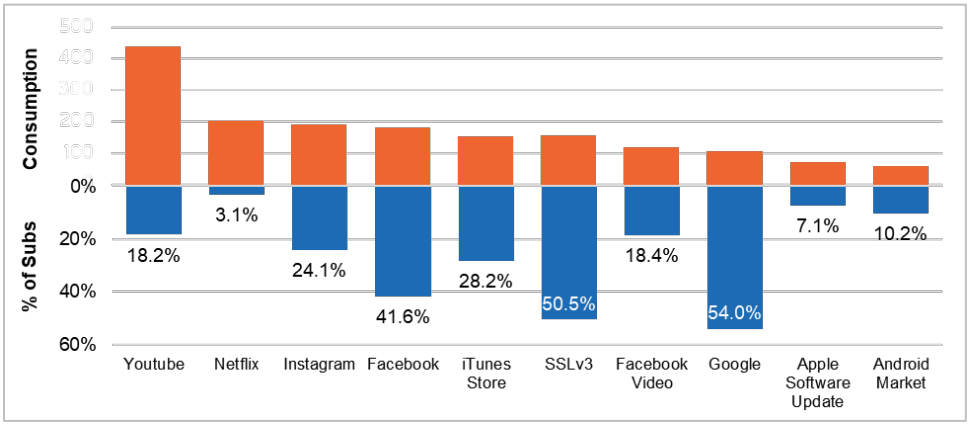

Figure 12 – Application Penetration and Consumption

When organized by application type and ranked by consumption, the top three categories are streaming media, web browsing, and messaging and collaboration (Figure 13).

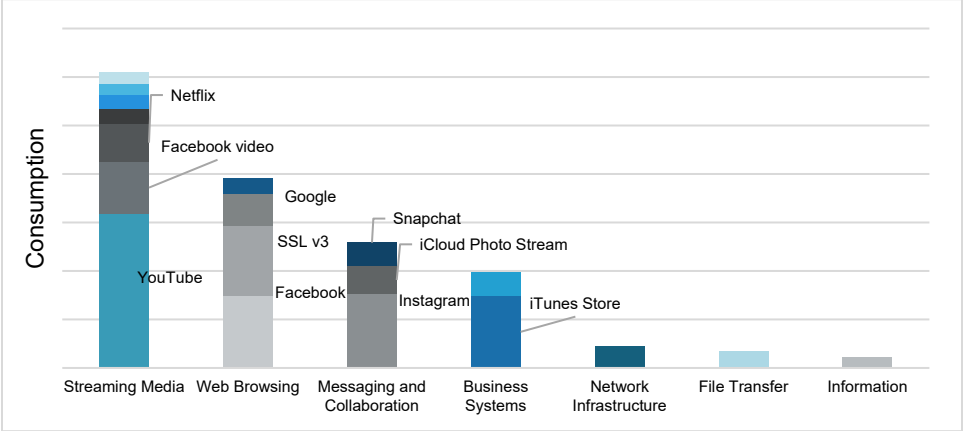

Figure 13 – Consumption by Application Type

3.4. Time of Day Trends

Wireline and wireless services have very different consumption patterns over the day. Wireline consumption peaks in the evening when subscribers are at home, while wireless consumption peaks in the late afternoon. Figure 14 shows that Wi-Fi time of day statistics are similar to wireless, but slightly delayed in time. This delay is likely to allow subscribers to get from home to their destinations where Wi-Fi is present.

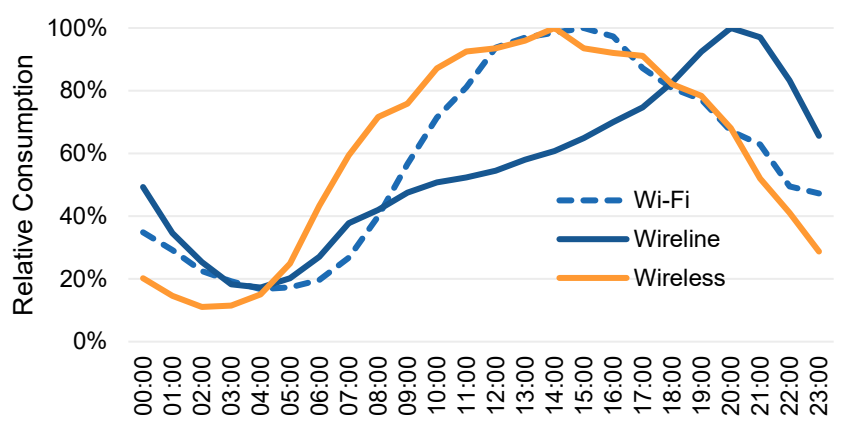

Figure 14 – Wi-Fi, Wireline and Wireless Network Time of Day Trends

Aggregate network consumption analysis points to subscribers deriving value from the Wi-Fi network and the network being used as intended. Per-device consumption, as well as time-of-day and monthly usage patterns, point to the Wi-Fi network being used to offload wireless data at destinations. The distribution of monthly Wi-Fi consumption per user was similar to the distribution of monthly wireline consumption per user. The correlations between Wi-Fi and wireless or wireline consumption demonstrates that subscribers have high consumption on both networks. Bitrate statistics and application usage suggest that devices connecting to the Wi-Fi network are mostly small-screen portable units. The number of devices per account roughly matches the number of people per household, indicating that there was no wide-spread sharing of access to non-subscribers.

After researching aggregate network usage, specific users and venues were analyzed for a more in-depth perspective.

3.5. Venue Examples

Wi-Fi APs are installed at many different types of venues, as shown in Figure 15. While most venues were similar in terms of consumption, transportation (transit platforms and similar venues), hotels and Shaw Wi-Fi Zones have higher consumption per AP.

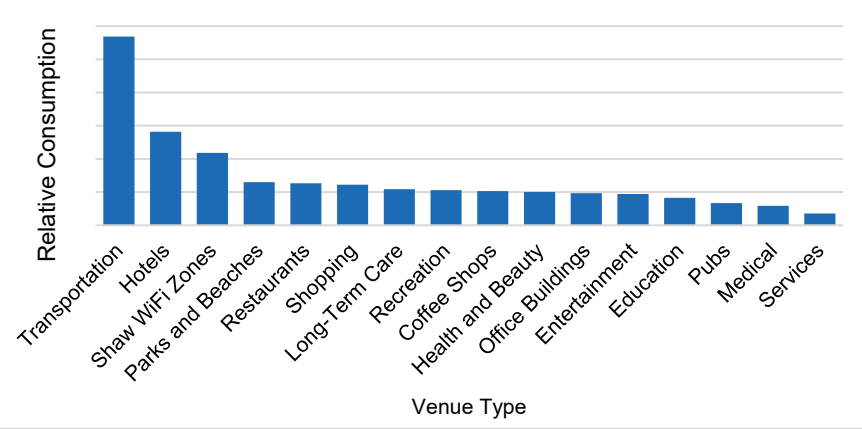

Figure 15 – Wi-Fi AP Consumption for Different Venue Types

One of the Shaw Wi-Fi Zones has previously been identified as potentially having poor performance, so an in-depth analysis was undertaken for that venue. Specifically, this venue is located close to a main thoroughfare and there is anecdotal evidence that subscribers in their cars would connect to Wi-Fi as they passed by or stopped at a stop light, disrupting any wireless session they may have had. Monthly consumption and unique device count were collected for each AP in the venue.

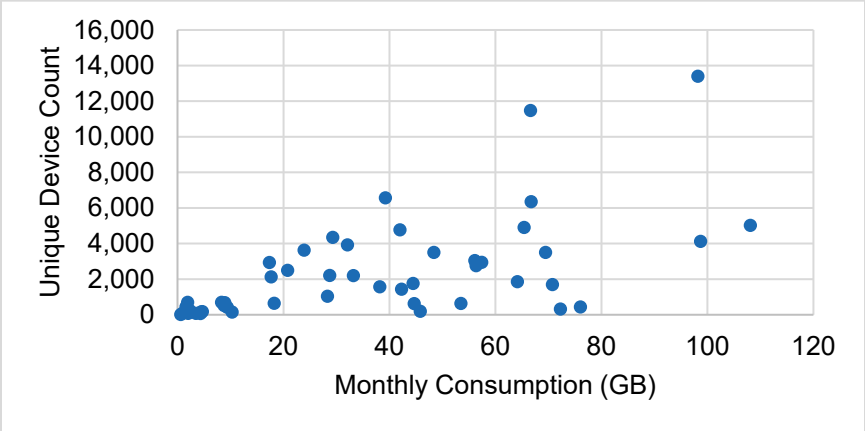

Figure 16 – Unique Device Counts vs Consumption for One Venue

As can be observed, there are large differences in consumption and unique device count between APs. APs with a high number of unique devices also have a high monthly consumption, as opposed to low monthly consumption, as might be expected with APs close to traffic lights. The correlation appears to be that APs close to popular locations such as restaurants and coffee shops have more unique devices and higher monthly consumption, while APs close to more lightly visited locations have fewer unique devices and lower monthly consumption.

One specific AP with a high number of unique devices and a large amount of consumption close to a popular restaurant and busy intersection was further analyzed. The device with the highest monthly consumption for that AP was 4GB, pointing to casual usage.

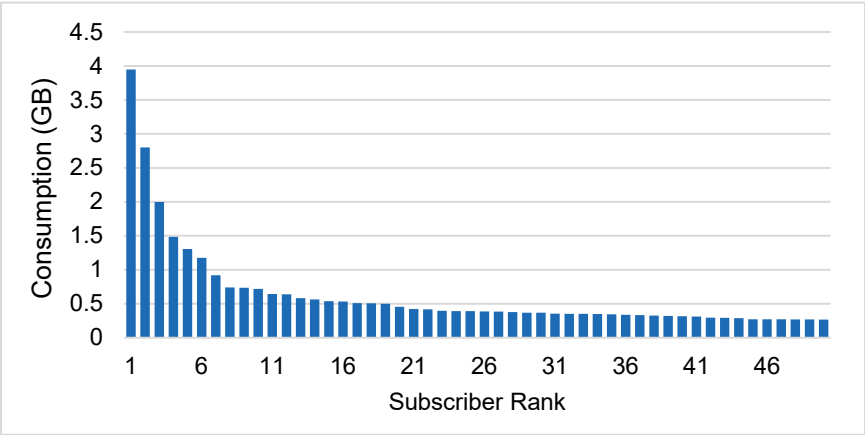

Figure 17 – Consumption of Top 50 Devices for One AP

As shown in Figure 18, the application distribution of this particular AP differed from the aggregate statistics. Video represented less consumption, with YouTube ranking tenth and Netflix ranking outside of the top ten applications. However, similarly to the aggregate statistics, social media ranked high on the

list. The top application by consumption for this AP was SSLv3, which is likely encrypted web browsing. The application mix points to short duration usage, as might be expected in a restaurant.

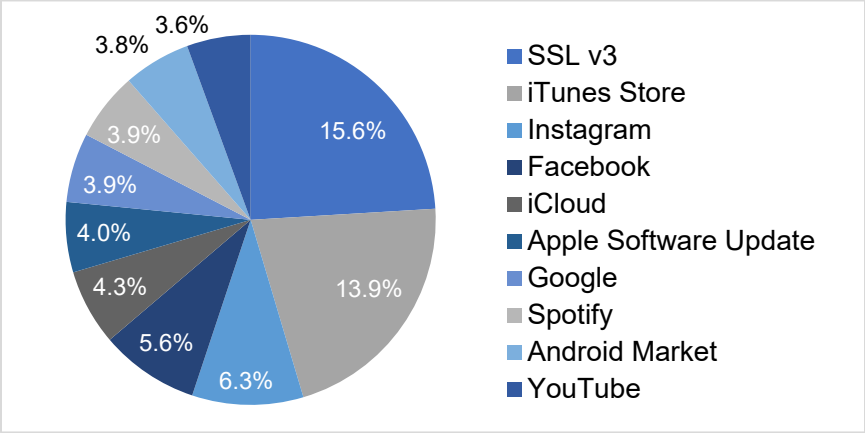

Figure 18 – Top 10 Applications for one Access Point

Five-minute throughput samples can be used to estimate bitrate over a longer duration. Max bitrates over five-minute durations tend to be low, indicating that few devices are being used to transfer large files or watch high quality video.

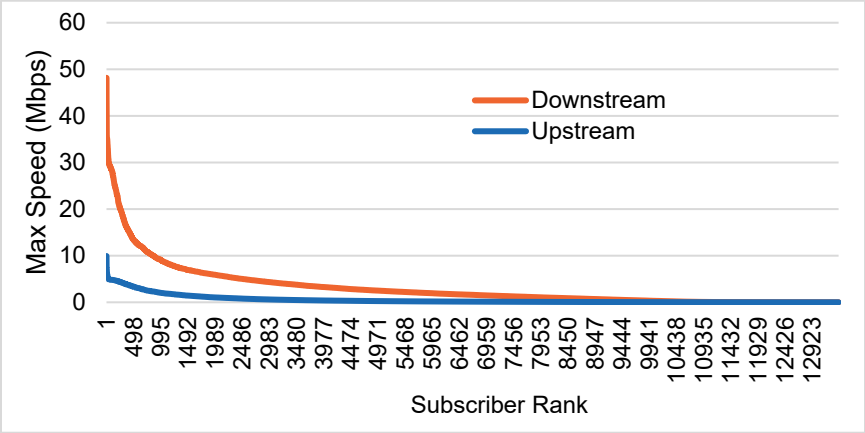

Figure 19 – Max Speed for All Users on one Access Point

While no evidence of a poor subscriber experience was found based on the data collected, it was determined that venue data can be used to prioritize the addition of new sites and potentially to reposition or remove APs that are being underutilized in their current locations.

3.6. Heavy Users

A dashboard was created to focus on a small number of heavy users whose monthly Wi-Fi consumption was greater than 100GB. In Figure 21, Wi-Fi consumption is plotted on the Y-axis and wireline consumption on the X-axis. The size of the circles denotes how many devices are linked to the account. Available data include device level statistics, as well as location and application-level information. Circles in pink have greater Wi-Fi consumption than wireline consumption and vice versa for circles in blue.

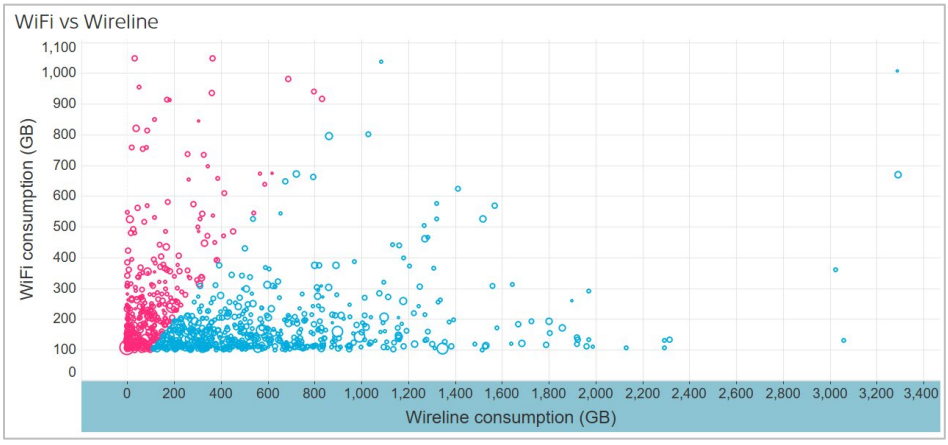

Figure 20 – Wi-Fi vs Wireline Consumption for Heavy Users

It was found that most consumption came from one or two connected devices, even for accounts with many connected devices. For most cases, consumption came from one or a small number of locations. This points to heavy but normal use of the Wi-Fi network, analogous to what is seen in the wireline network.

4. Network Optimization

Earlier in the year, a network optimization initiative was undertaken to reduce the occurrence of devices connecting to the 2.4GHz network at low signal strength. The intent was to reduce the 2.4GHz coverage to match the 5GHz coverage in order to decrease instances of devices authenticating but not connecting to the Internet and allow more devices to see the 5GHz network sooner as they approached an AP.

Figure 21 – 2.4GHz Coverage Optimization

When looking at the data for a single market, a large reduction in the number of devices connecting to the 2.4GHz network can be observed after the optimization was made. Importantly, there was no drop in consumption for the 2.4GHz network, meaning that the optimization was performing as intended and not preventing subscribers from accessing the network. At the same time there was an increase in consumption on the 5GHz network, pointing to more usage of the network.

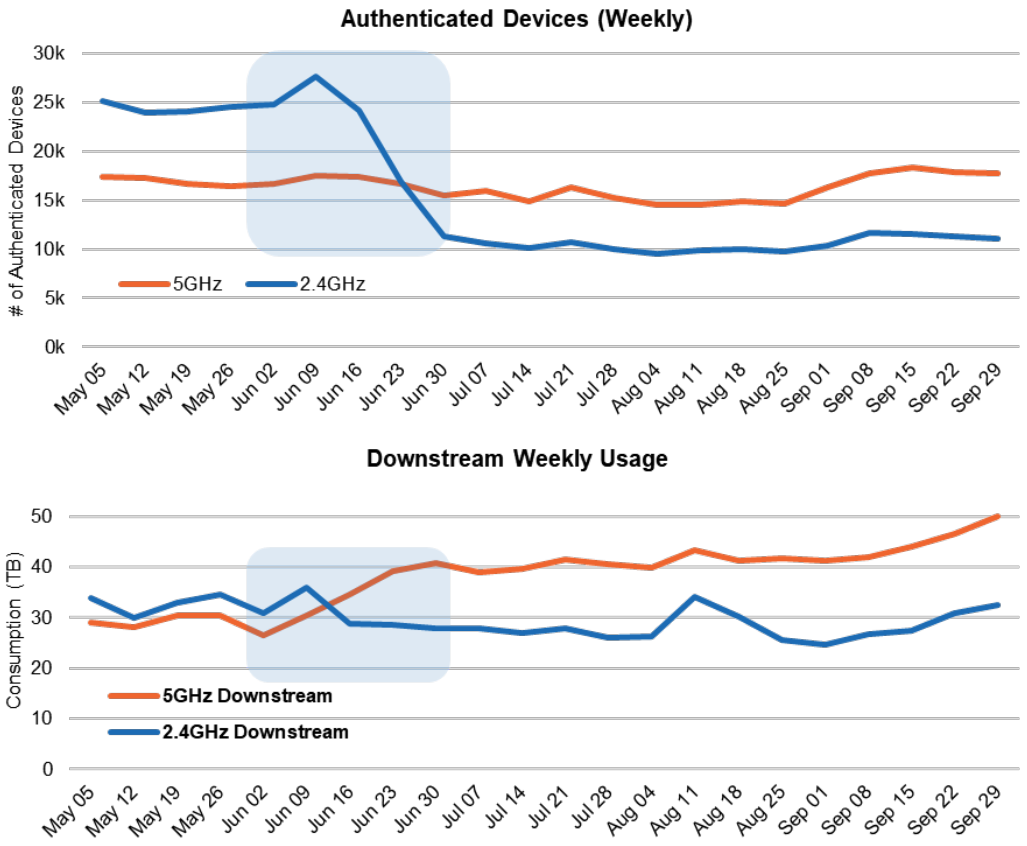

Figure 22 – Impact of 2.4GHz Optimization on Device Counts and Consumption

This optimization covered the area investigated and prevented users from authenticating but not connecting to the Internet. Given its effectiveness, it was eventually rolled out across the entire service provider Wi-Fi network.

4.1. Upgrade Strategy

Initial service provider Wi-Fi APs were Wi-Fi 5 and were reaching their end-of-life, which raised the question of if and how these APs should be upgraded. Wi-Fi 6 provides several new features (Figure 24) which combine to deliver greater capacity and a better performance with a high density of users [3].

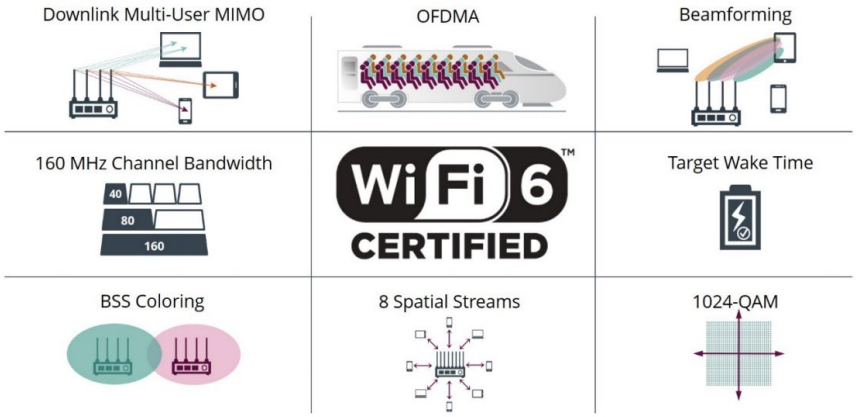

Figure 23 – Wi-Fi 6 Benefits (Source: Wi-Fi Alliance)

The experience analyzing venues revealed that there was significant differences between APs in terms of unique devices and monthly consumption. A methodology was created to separate APs into three different categories—Priority Upgrade, Maintain, and Minimize Support. The categorization was made based on the number of unique devices connected to the AP that consumed over 50MB of data in a month. 50MB was used because it provides tangible data offload and is likely to be above the data threshold that would cause a subscriber to seek out Wi-Fi.

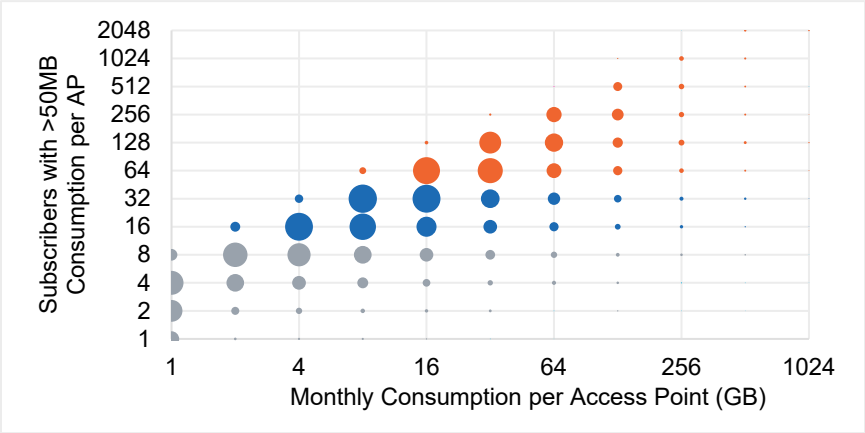

Figure 24 – Devices with >50MB of Consumption per AP

Service provider Wi-Fi APs with more than 64 subscribers with greater than 50MB of consumption were put on the list to upgrade to Wi-Fi 6 as they came to end of life. APs with between 16 and 64 subscribers were to be maintained, while APs below 16 were to have operational support minimized. This upgrade strategy allows investments to be focused where subscribers get the most value while reducing operational costs elsewhere. A simple strategy that uses the total consumption per device could prioritize APs where a single device consumes a large amount of data. Similarly, a strategy that uses total unique devices could prioritize APs where many devices connect but do not consume data.

4.2. Small Cell

Small cells can be used to increase wireless capacity and coverage in localized areas [4]. The coverage area is small compared to a macro cell, as shown in Figure 26.

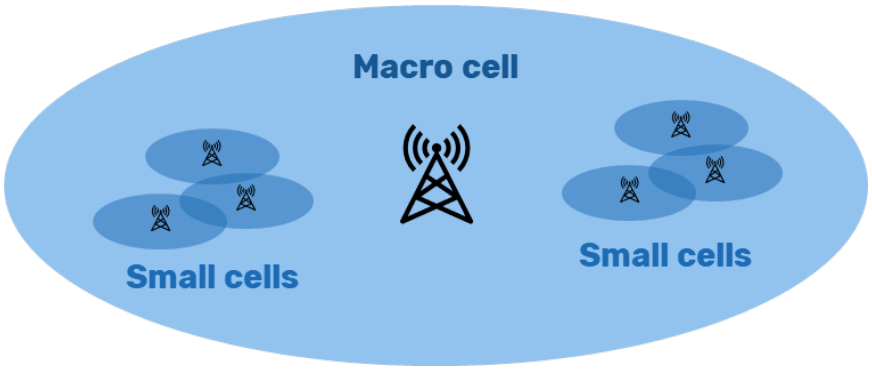

Figure 25 – Small Cell vs Macro Cell Coverage

The coverage area of a small cell will depend on the spectrum used. New mmWave spectrum used for 5G will have RF coverage areas similar to Wi-Fi. mmWave spectrum, or high-bands, represent a large capacity over small coverage areas [5], as shown in Figure 27.

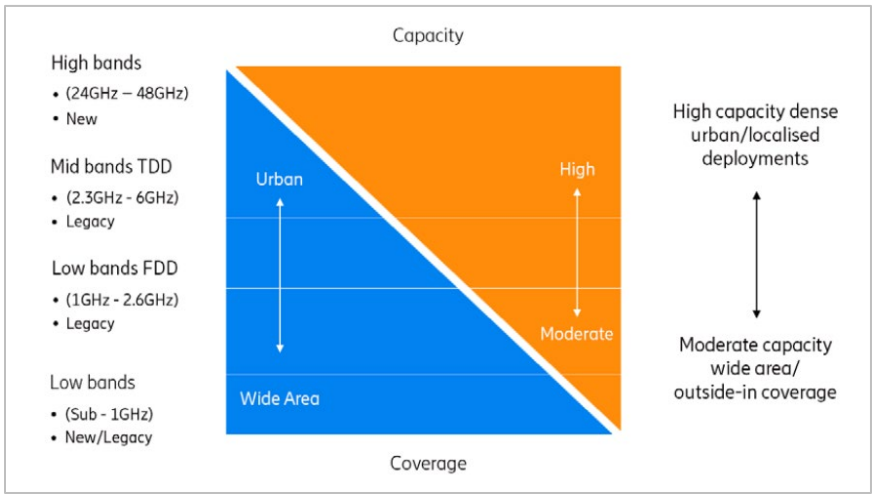

Figure 26 – Capacity vs Coverage for Different Spectrum Types (Source: Ericsson)

These new networks will require space, power, and backhaul. The service provider Wi-Fi network has all of these resources and in the future may be augmented or replaced with 5G small cells.

Shaw has deployed small cells in its wireless network, initially for trials and in advantageous locations. One such location had both service provider Wi-Fi and small cells deployed. The networks were installed separately from each other and individual coverage planning was done. The location of Wi-Fi APs and small cells were similar, however, allowing for a direct comparison. There were 26 Wi-Fi APs and 23 small cells in the facility. It was found that wireless subscribers had four times as much consumption on the Wi-Fi network compared to the small cell network. Figure 28 includes all Wi-Fi traffic and shows consumption per AP or small cell.

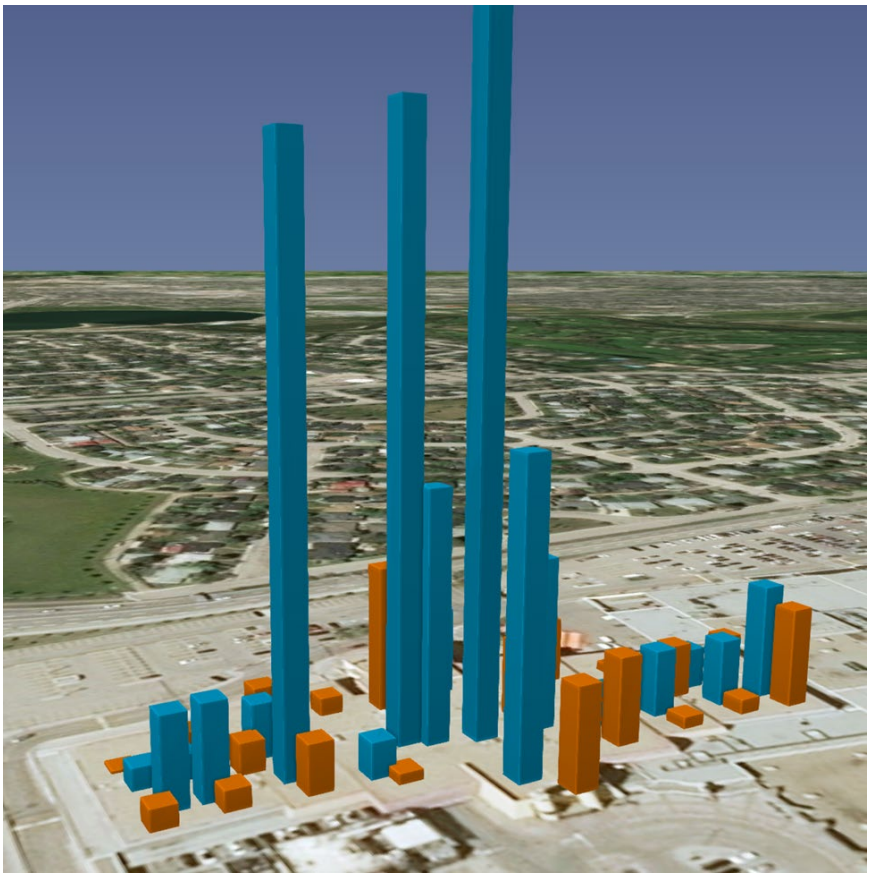

Figure 27 – Consumption for Wi-Fi APs and Small Cells

Wi-Fi consumption is shown in blue and small cell consumption in orange. The venue is a cinema with consumption highly centered in the lobby and the highest consumption at the AP near the entrance. The consumption for this AP was much higher than the others and the representative bar was cut off in the figure to allow the consumption of the other APs to be observed. The low small cell use raises the question of whether it makes sense to deploy both service provider Wi-Fi and small cells in the same locations for offload. However, wireless coverage is still a strong justification for placing small cells, especially for legacy devices that require 3G connectivity for voice.

Technology advancement, as well as business strategies, will dictate whether these networks will be replaced with 5G or whether Wi-Fi will continue to operate in parallel. Licensed-Assisted Access (LAA) is an LTE feature that allows mobile devices to use the unlicensed 5GHz band without having to switch to Wi-Fi. This relieves devices of the burden of deciding which network to prefer and under what conditions to switch from one network to the other. However, Wi-Fi may be the only option for devices without SIM cards such as laptops, or the preferred network in situations where LAA traffic is counted toward a subscriber's data usage. In scenarios where both networks exist, efforts such as CableLabs' Intelligent Wireless Network Steering (IWiNS) project aim to improve the user experience by steering traffic to the most appropriate network given the specific context.

5. COVID-19 Update

As with all networks, the service provider Wi-Fi network was heavily impacted by the COVID-19 pandemic. While wireline networks saw large increases in consumption, wireless networks saw

reductions, owing to stay-at-home orders or similar limitations on movement. Daily consumption on the Wi-Fi network fell approximately 50% in March of 2020 at the start of the pandemic, slowly climbing back to pre-COVID-19 levels over the summer (Figure 29).

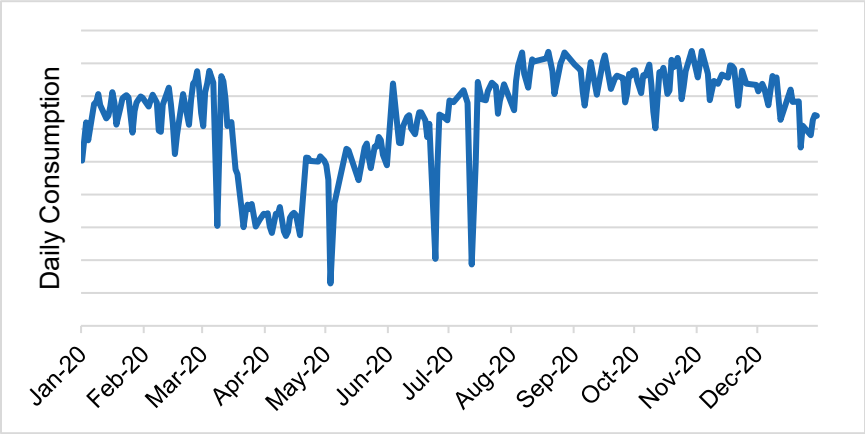

Figure 28 – Daily Consumption During COVID-19

Relative application use did not change significantly, with the notable exception of increased Facebook and decreased Instagram consumption (Figure 30). This makes sense as Instagram is used to document experiences, which are rarer during stay-at-home orders, while Facebook is used to search for news and check in with social networks.

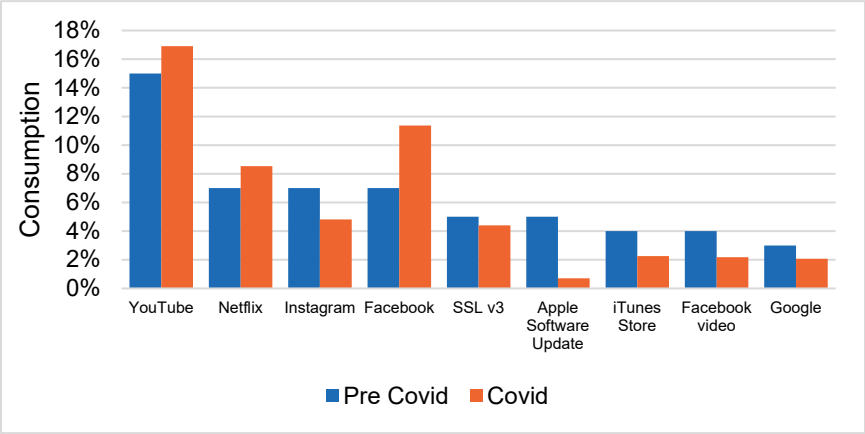

Figure 29 – Application Use During COVID-19

Home hotspot APs saw slightly increased consumption at the beginning of the COVID-19 pandemic in opposition to other Wi-Fi APs (Figure 31). This also makes sense as people stayed home or in their neighbourhoods where home hotspots are more common.

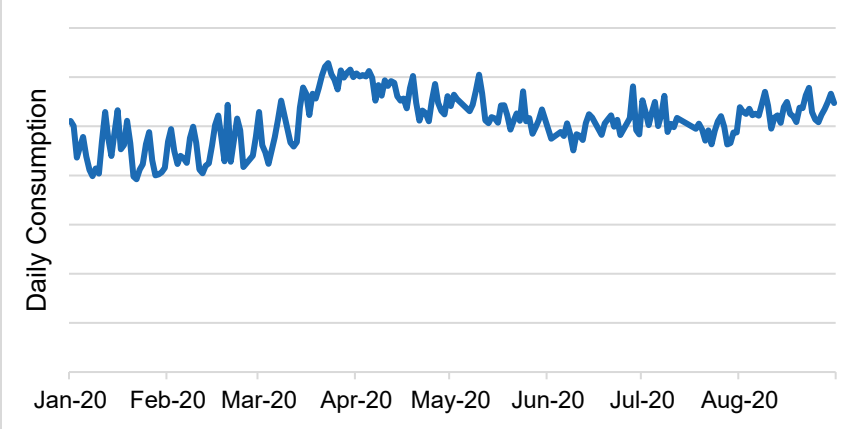

Figure 30 – Home Hotspot Consumption During COVID-19

6. Conclusion

As networks converge and become ubiquitous, consumers will expect to be able to access their broadband services at all times, wherever they are. Service provider Wi-Fi can deliver an important piece of this puzzle, extending subscribers a quality connection at their destinations. In general, service provider Wi-Fi is used as an extension of the in-home wireline network, geared towards shorter durations and smaller devices. The implementation of the service provider Wi-Fi network will have implications on the customer experience. In particular, it was found that devices could authenticate to the 2.4GHz network at low signal levels, but not be able to connect to the Internet. This can cause mobile sessions to end, resulting in frustrated subscribers turning off their Wi-Fi. Matching 2.4GHz and 5GHz coverage reduces this occurrence, leading to a better customer experience. The wealth of AP usage data can inform a network upgrade strategy, but care must be taken to choose metrics that optimize subscriber value. A strategy that uses the number of unique devices that consume 50MB or greater allows for AP upgrades to be targeted where subscribers find the most value. In the future, as small cells and 5G are deployed, the service provider Wi-Fi network will offer a wealth of data to optimize deployments and provide readily available space, power and backhaul.

Abbreviations

5G	Fifth Generation Wireless Standard
AP	Access Point
BSS	Basic Service Set
CDF	Cumulative Distribution Function
DOCSIS	Data over Cable System Interface Specification
DPI	Deep Packet Inspection
GB	Gigabyte
Gbps	Gigabit per second
GHz	Gigahertz
HFC	Hybrid Fibre Coax
IWiNS	Intelligent Wireless Network Steering
LAA	Licensed-Assisted Access
LTE	Long Term Evolution
MAC	Media Access Control
MB	Megabyte

Mbps	Megabit per second
MIMO	Multiple-input and Multiple-Output
mmWave	Millimeter Wave
Ms	Millisecond
OFDMA	Orthogonal Frequency-Division Multiple Access
QAM	Quadrature Amplitude Modulation
RADIUS	Remote Authentication Dial-in User Service
RF	Radio Frequency
SIM	Subscriber Identification Module
SSID	Service Set Identifier
SSL	Secure Sockets Layer
TB	Terabyte
Tbps	Terabit per second

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