Navigating the Home Wi-Fi Experience

Part 1: Real-World Data on the Growing Congestion of Home Wi-Fi and Potential Responses

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Introduction

The average number of Wi-Fi devices per household continues to grow with consumers becoming more dependent on Wi-Fi than ever before for the delivery of data and video. A Wi-Fi home network can significantly lower installation and operational costs for a broadband and video service provider and, in theory, the subscriber can integrate their own devices into the home network on their own. However, subscriber-owned devices can also significantly increase customer care calls. It’s estimated that almost one third of all service calls occur when a subscriber cannot attach a device to the broadband network or the network connection is deemed to be too slow.

Many factors need to be considered to resolve connectivity issues. As customers add IP video devices to their home Wi-Fi networks, diagnosing whether the problem is with a device configuration, the home network itself, or even interference from a neighbor’s network increases the complexity.

Multiple Wi-Fi devices in a home create new challenges with airtime congestion as multiple access points (AP) fill the spectrum and interfere with each other. Wi-Fi is a non-deterministic network protocol subject to temporary interferences from other Wi-Fi networks and electronic devices. Since the gateway is without the knowledge of when devices will want to access the broadband network or each other, these devices are always sending and receiving signals from the gateway when they are active.

As consumers rely more and more on Wi-Fi for their connectivity and content delivery, service providers and the industry as a whole must ensure that the best tools and technology are available to manage services within the connected home. This paper, the first in a series focused on Wi-Fi networks in the home, will review:

• Types of data carried across the home
• Impact of multiple device usage in the home and why it is important to manage Wi-Fi devices
• Data on what is actually happening in the home network
• Solutions to help manage the connected home and improving the consumer experience.
The Challenges to Delivering Premium Wi-Fi

With today’s technology, service providers can offer IP-based, multi-room subscriber access to both unicast and multicast content using broadband gateways and in home Wi-Fi networks. Content such as movies, music, and television programs can be delivered by the service provider over a managed network or via the Internet.

Wi-Fi uses radio waves – just like cellular phones, TV, and radio – to create wireless connections between computers, printers, gaming devices, cameras, home entertainment systems, televisions, tablets, media players, and smartphones. Wi-Fi network technologies are defined by the IEEE 802.11 standard to ensure secure, reliable, fast wireless connectivity.

A Wi-Fi network connects electronic devices to each other, to the Internet, and to wired networks which use Ethernet technology. Each active device competes for use of the limited Wi-Fi network bandwidth in the home, so the more devices that are connected and actively in use, the more traffic. As the amount of traffic gets close to the throughput limits of the network, congestion can happen. This is true even for the latest version of 802.11ac gateways and devices coming onto the market. Congestion occurs when there is more traffic than can be carried successfully by the network.

The Growing Number of Wi-Fi Devices in the Home

Globally the number of mobile devices per household — other than smartphones with a mobile data plan — is predicted to increase by more than eight percent annually through 2016. Over 60 million Wi-Fi only devices (mostly tablets) will be added each year to households around the world. The numbers of video-specific Internet- connectible devices, such as TVs, set-top boxes, digital video recorders (DVRs), video players, game consoles and cameras, will also grow as manufacturers make connectivity a default feature in most devices.

In 2012, approximately 1.5 billion Wi-Fi enabled devices were shipped. While not all devices use the same amount of bandwidth, there are more devices active in the home network than ever before.

As an example taken from actual deployments in the Northwestern US in 2013, ARRIS analyzed data to determine how many and what types of devices were connected from each gateway. The study determined that:
• For all homes the average home had 4.2 Wi-Fi devices
• The average home with at least one device had an average of 6 Wi-Fi devices connecting to the Internet via a wireless gateway.
Those six devices compete for airt ime on the Wi-Fi network, even when a device is not actively sending or receiving data, because the network still communicates with all associated devices in the background.

Figure 1: Actual data collected by Carol Ansley, Sr. Director IP Engineering, ARRIS

What were the consumers using?
• 18% Apple devices
• 7% Intel and HP devices
• 5% Android smartphones
• 3% Kindles/e-Readers - while they don’t consume a lot of bandwidth, these devices do share the network
• Smartphones by Samsung and Motorola Mobility combined for 5%
A surprise was Swann security monitoring solutions. Their wireless monitoring equipment was as prevalent in the home as Nintendo game systems for this snapshot in time. The remaining 55% included many other types of Wi-Fi devices.
A study published in July of 2013 revealed that more smartphone and tablet users are using TV-channel apps over their in-home Wi-Fi networks. Researchers discovered that 14% of smartphone/tablet users surveyed have used a TV-content app and nearly 75% of these users are satisfied with this experience.\(^5\)

The growing numbers of Wi-Fi enabled devices presents new challenges for delivering acceptable Wi-Fi network performance, particularly maintaining quality of service and subscriber satisfaction for IP video services.

**Mixed Devices on a Single Wi-Fi Network Cause Congestion**

Since Wi-Fi devices are certified and are based on the 802.11 standards, setting up a home network is a relatively simple task. However, this does not mean that each device will receive the full bandwidth when other devices are sharing the network, or even its fair share of the network bandwidth. The Wi-Fi network standards under 802.11 are designed to ensure that older devices will still function on a newer network. See the Wi-Fi Generations table on page 16 to understand the wide range of capabilities between the equipment built under older version of the standards, and the latest versions.
When there is a mixture of devices from different 802.11 generations on the network, the data rates seen by all devices will tend toward the lowest common denominator. For example, consider a home with a gateway containing an 802.11n access point and 6 devices attached. If even one of them is an 802.11b device, the net data rate drops by about 17% when all devices are active.

![Figure 3: Actual data collected by Carol Ansley, Sr. Director IP Engineering, ARRIS](image)

Analyzing multiple homes and installations, ARRIS has determined that typical Wi-Fi throughput, received by devices within subscribers’ homes, fell into three categories:

- a third receiving 1 Mbps – most likely because they are older 802.11b devices. Consumers using these clients will potentially undervalue the Wi-Fi service in the home.
- a third receiving 25-65 Mbps, which is a good experience.
- a third receiving 130 Mbps or greater. These clients are mostly likely 802.11n devices.

It’s important to note that the throughput of these devices is directly related to their Wi-Fi gateway, device, and home network instead of the service provider’s network connection. However, if a subscriber is purchasing high bandwidth connectivity, and is only receiving a small fraction of that, the service provider is the first to be blamed, not an older device or an out-of-date router in the home.
A service provider does not have control over which devices are used in the home or connected to their broadband service networks. However, as the real world performance numbers illustrate above, the service providers could benefit from tools that enable them to help consumers manage and reap the benefits of in-home Wi-Fi.

**Hardware Trends – Home Gateway Components Affect Bandwidth**

In the US and many other parts of the world, multiple wireless bands can be used for Wi-Fi. The most common band is the 2.4GHz band which has been in use since the first Wi-Fi systems were developed. Another band at 5Ghz was opened with the 802.11a specification, and is still supported by 802.11n and the latest specification, 802.11ac. Many of the latest generation of home gateways support dual-band radios that is the capability to transmit on the 5 GHz band and also the 2.4 GHz band. Other gateways, usually older version, may be limited to single band support.

Since the 2.4 GHz band has been used longer and has less bandwidth compared to 5 GHz band, it tends to be crowded or congested in many situations. As a result, home gateway configurations using 5 GHz will often yield better performance. Thus, those gateways with dual-band concurrent capabilities provide more capabilities to manage the residence’s wireless environment and accommodate the widest mix of in-home client devices.

While single-band devices are outselling dual-band devices today, it is projected that dual-band devices will outsell single-band devices from 2014 and beyond. These dual-band devices will provide more options for service providers and consumers to better manage in-home networks.

Another component of the home gateway to consider is the antenna and electronics configuration used to receive and send Wi-Fi signals. An access point with a single receiver and transmitter using a single antenna is referred to as a 1x1 system. If the AP has two transmitters and two receivers using two antennas, then it is referred to as a 2x2 system. 3x3 and 4x4 systems have three and four transmitters, receivers, and antennas respectively.

The use of higher numbers of Wi-Fi antennas and electronics provide more bandwidth and more coverage, enabling more reliable connections. The most common configurations on the market today are either 2x2 or 3x3.
ARRIS tested actual throughput with gateways using 2x2 and 3x3 antennas using 2.4 GHz and 5 GHz bands. The results are in the following chart.

![Better Coverage and Speeds from 3x3:3 Radio](image)

Figure 4: Results from ARRIS Wi-Fi Testing Comparing 3x3 and 2x2 Products

Blue represents the 3x3 configuration and the green the 2x2. In most test environments, the 3x3 antenna performed better. The results are even more compelling with a 3x3 antenna using the 5 GHz band. For maximum throughput, ARRIS recommends gateways that feature dual band support and 3x3 antenna/electronics.
Wi-Fi Issues Affect IP Video Streams

A broadband service provider offers broadband connectivity directly to the home. Typically a home gateway is provided that combines a modem or other broadband network access device and coordinates the use of that bandwidth by multiple devices in the home. A wireless gateway includes an embedded router and wireless access point to support a Wi-Fi network for the home. The bandwidth that is available from the service provider and the bandwidth of the in-home Wi-Fi network are often different. In some cases, the home Wi-Fi network bandwidth may be higher than the bandwidth provided by the provider to the home.

When a service provider delivers managed IP video to a subscriber, an IP video stream is sent to a set-top box (STB). That STB may be connected over several different home networks, but here we consider delivery over W-Fi.

If the video delivery suffers packet loss, the subscriber may notice an effect known as macro-blocking (see image below), where some of the video appears normal and other parts on the screen appear to be bumped out of place or lumped together.

![Macro-blocking Image](image.png)

Typically, an occasional error of this type that resolves itself quickly does not cause a service provider to receive a high number of calls at customer service.

When a subscriber watches an IP video stream over the broadband network from a site on the Internet, that stream is not managed by the service provider. If the service provider that offers broadband is also providing an IP video stream directly to IP connected devices, those streams may be managed.

Adaptive Bitrate (ABR) streaming is the most common method used to deliver IP video streams to Wi-Fi devices. The ABR protocol determines the receiving device’s bandwidth and capacity, then adjusts the bitrate quality of the stream accordingly. ABR is known as a greedy protocol, as it increases its consumption of bandwidth until it finds...
Each device using unmanaged ABR tends to request video streams at the highest quality that they can receive, with the result that network bandwidth, such as the in-home Wi-Fi network, can quickly be exhausted.

When multiple devices are consuming video delivered by ABR, or even a single device is sharing the in-home Wi-Fi network with another device streaming data, problems can occur. For example: as devices compete to bring their data over the network, the gateway/router attempts to serve them all. With the resulting network congestion, all devices may suffer packet loss, and degraded service.

Managed or not, the delivery of IP video over ABR can suffer packet loss. Packet loss may cause a frozen picture with varying degrees of audio impairment. Packet loss may also cause the audio to be out of sync with the video. Empty buffers may be caused by packet loss resulting from network congestion. In instances when buffers are empty, instead of macro-blocking, the consumer may see a black screen. ARRIS CTO of CPE, Charles Cheevers, calls this the “Armageddon of video delivery over Wi-Fi.”

Subscribers have little patience for poor quality of service and even less patience when their screens go dark. In fact, their patience for any viewing issue lasts approximately three seconds. After that they will attempt to reconnect or change channels. If the problem isn’t resolved, the subscriber’s satisfaction reduces dramatically for each second of delay.

While there are potentially easy fixes, most consumers do not understand the technical nuances regarding devices that compete for bandwidth or how to set up their home networks for maximum efficiency. A successful service delivery architecture should not require them to become Wi-Fi experts.
Solutions for Minimizing Wi-Fi Congestion

Service providers need new tools and traffic engineering to mitigate Wi-Fi weaknesses and to lower the mean-time-to-repair (MTTR) of wireless issues to ensure a quality of experience equivalent to having a wired connection. To remain competitive, service providers must take the lead by:

- Assisting customers with Wi-Fi network and device installation
- Helping to optimize network throughput at service installation and as new devices join the network
- Ensuring that IP video is delivered at the appropriate speeds and quality for each IP-connected device

By anticipating problems before they happen, and reducing errors with better installation of devices into the home network, the consumer’s overall experience with operator-provided Wi-Fi products and services should improve.

Self-Installation with a Wi-Fi Helper

Service providers could help their subscribers set up and manage the devices in the home for better satisfaction using a home gateway. A “Wi-Fi Helper” website, app, or similar tool could guide the customer through the installation with an installation wizard.

As an example, consider a consumer that receives a new home gateway device. The documentation with the gateway could direct the consumer to a website for installation assistance. When the consumer uses their smartphone to connect to that
website, it helps guide the consumer through installation and authentication of the new device. Behind the scenes, the website could also generate a *birth certificate* for the device that can be done by the operator.

The birth certificate is key to the long-term monitoring of each home device for which it is associated. It can record installation conditions such as the Wi-Fi bands activated by the subscriber, or even the number and type of devices, MSO-owned and consumer-owned, that are attached as well as their service capabilities. Through continued monitoring by the service provider of the factors recorded in the birth certificate, the provider may ensure that the network is configured for successful service delivery and maximum throughput. If factors change from the initial birth certificate configuration, or if some factors were problematic in the original consumer installation, the service provider may proactively contact the consumer to improve the configuration.

*Wi-Fi Repeaters and Tools for Optimization*

In many homes today, Wi-Fi repeaters help optimize Wi-Fi service. They enhance connectivity and eliminate dead spots. Looking at the home of the future, Wi-Fi Helper tools could be created to help consumers determine whether or not repeaters are needed and where they should be placed. The Wi-Fi helper website or smartphone application described in the previous section could be enhanced to show a consumer where to install repeaters as that consumer walks through their home.

![Figure 6: Repeater Installation Example for Optimal Wi-Fi Coverage](image-url)
Upgrading to an 802.11ac Wi-Fi router and network will add more bandwidth within the home and may minimize airtime congestion, yet will not solve all the connectivity issues. There will still be temporary interferences and coverage issues as the number of devices grow and the distance from the router (or well-insulated walls) can negatively affect overall bandwidth.

As self-help and cloud-based automation tools improve, they may dramatically improve productivity and scalability in support services. Currently tech support providers estimate one-in-five service calls can be solved by consumers and as many as 50% of operator trouble calls concerning mobile device performance can be solved through self-help channels. (8)

**Monitoring Home Networks**

It is more important than ever to monitor the connected home’s networking capabilities. Wi-Fi devices could be identified by their individual performance history. The Wi-Fi Helper tools could extend into the network and cloud for further support to the subscriber. These tools could monitor Wi-Fi connections and assign service capabilities by data type such as Home Networking, Security, MSO Hotspots, or a Guest Network.

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*Figure 7: Using Multiple SSIDs to Manage Different Networks*
The tools could also define and consistently monitor performance thresholds. Red and green status alerts were used in the past. Yet there is a need for a yellow alert to notify subscribers when changes are occurring and pre-emptive actions could be taken to create a better Wi-Fi home experience. For example:

- **Green**: 24 hours without problems within the home network. All Service Level Agreements (SLAs) are met.
- **Yellow**: Temporary issues with performance. These may occur when guests are visiting with their devices, or perhaps there is a threshold level met at the same time every day. Consumers may not even be aware of these issues. Pre-emptive solutions would be employed such as an email alerting the consumer to potential issues.
- **Red**: SLAs are not met. RF performance is degraded or there is a significant decline in network performance.

Pre-emptive actions also could be taken when devices are added to the home or moved from room to room. Features could include (based on subscriber preferences):

- Opt in for Wi-Fi issue mitigation automatically
- Email or text notifications if significant changes are noticed in the home network
- Alerts when Wi-Fi configurations change

The end result is that by service providers reaching out to consumers in a proactive manner, subscriber satisfaction would increase and churn would be reduced. In addition, some service providers may also use these tools to increase the average-revenue-per-household.

**IP Video Wi-Fi Armageddon? Just Say No!**

The growing numbers of Wi-Fi enabled devices present new challenges for Wi-Fi home networks in general, and particularly for delivering IP video, maintaining quality of service and subscriber satisfaction. After looking at the real world performance of Wi-Fi devices today, service providers can minimize Wi-Fi congestion and subscriber frustration by careful evaluation of gateway hardware, and increasing their engagement with consumers.
This is accomplished using gateways with dual-band concurrent radios and 3x3 antennas, as well as new Wi-Fi Helper tools for the installation and ongoing management of Wi-Fi devices in the home.

Along with new network and cloud tools to constantly monitor and take pre-emptive actions, service providers can help create a better consumer experience as more Wi-Fi devices proliferate the home environment. Using all these tools, the Wi-Fi Armageddon is prevented.

Related Readings

- **Improving Home Networking Satisfaction with a Unified Home Gateway**
  This paper looks at the multiple overlapping home network technologies in the Gateway and how the Gateway can take an active role in determining how to best utilize the networks for optimum performance and increased power savings.
- Listen to the NCTA 2013 panel presentation: **Air Quality Control: Approaches for Improving Wireless Broadband User Experiences**
Wi-Fi: Generations

Each generation of Wi-Fi certified products is tested to ensure that they work with previous generations of Wi-Fi products that operate in the same frequency band. That backward compatibility ensures that an older device can still operate over a network managed by a newer wireless access point. The bandwidth or maximum data rate within the home is limited by the access point. The bandwidth received from outside the home is limited by the service connection provided by the service provider. The Wi-Fi Alliance chart below displays Wi-Fi generations, their frequency band(s) and maximum data rate.

<table>
<thead>
<tr>
<th>Wi-Fi Technology</th>
<th>Frequency Band</th>
<th>Maximum data rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>802.11a</td>
<td>5 GHz</td>
<td>54 Mbps</td>
</tr>
<tr>
<td>802.11b</td>
<td>2.4 GHz</td>
<td>11 Mbps</td>
</tr>
<tr>
<td>802.11g</td>
<td>2.4 GHz</td>
<td>54 Mbps</td>
</tr>
<tr>
<td>802.11n</td>
<td>2.4 GHz, 5 GHz, 2.4 or 5 GHz (selectable), or 2.4 and 5 GHz (concurrent)</td>
<td>450 Mbps</td>
</tr>
<tr>
<td>802.11ac</td>
<td>5 GHz</td>
<td>1.3 Gbps</td>
</tr>
</tbody>
</table>
References

(1) Wi-Fi Alliance: Simple Home Network 2013
   http://www.wi-fi.org/discover-and-learn/simple-home-network

(2) Wi-Fi Alliance: Discover and Learn 2013
   http://www.wi-fi.org/discover-and-learn

(3) Gartner Says Home Networks Will Drive Success of the Connected Home
   http://www.gartner.com/newsroom/id/2437115

(4) Data collected by Carol Ansley, Senior Director IP Engineering at ARRIS Group, Inc.

(5) Parks Associates, consumer analytics research: TV Channel and Network App Users (July 2013)
    http://www.parksassociates.com/blog/article/pr-jul2013-ae-millennials

(6) Wi-Fi Generations Chart from Wi-Fi Alliance: Discover and Learn 2013
    http://www.wi-fi.org/discover-and-learn

(7) Data collected by Sr. Director Marketing and Product Management at ARRIS Group, Eli Baruch’s team.


(9) Glossary definitions are from sources including:

   ABI Research at http://www.abiresearch.com/
   Wi-Fi Alliance at http://www.wi-fi.org/knowledge-center/glossary
   About.Com http://hometheater.about.com/od/hometheatervideobasics/qt/Macroblocking-And-Pixelation-Similarities-And-Differences.htm
## List of Acronyms

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPE</td>
<td>Customer Premises Equipment - communications equipment that resides in the customer's premises.</td>
</tr>
<tr>
<td>IPTV</td>
<td>Internet protocol television (IPTV) - the process of providing television (video and/or audio) services through the use Internet protocol (IP) networks.</td>
</tr>
<tr>
<td>Macroblocking</td>
<td>Macroblocking is a video artifact in which objects or areas of a video image appear to be made up of small squares, rather than proper detail and smooth edges. The blocks may appear throughout the image, or just in portions of the image. The causes of macroblocking are related to one or more of the following factors: video compression, data transfer speed, signal interruption, and video processing performance.</td>
</tr>
<tr>
<td>Mbps</td>
<td>Megabits per second - A measurement of digital bandwidth where 1 Mbps = 1 million bits per second (1,000,000 bits per second).</td>
</tr>
<tr>
<td>MHz</td>
<td>Megahertz - One million hertz, or cycles per second.</td>
</tr>
<tr>
<td>MPEG-2</td>
<td>MPEG-2 is a frame oriented multimedia transmission system that allows the combining and synchronizing of multiple media types.</td>
</tr>
<tr>
<td>MPEG-4</td>
<td>MPEG-4 is a digital multimedia transmission standard that was designed to allow for interactive digital television and it can have more efficient compression capability than MPEG-2 (more than 200:1 compression).</td>
</tr>
<tr>
<td>MPEG-2/4</td>
<td>Meaning one, the other or both MPEG-2 and MPEG-4.</td>
</tr>
<tr>
<td>MTTR</td>
<td>Mean-Time-to-Repair is an estimated time period (typically rated in hours) of the time it takes to repair or return an assembly from a failed condition to an operational condition.</td>
</tr>
<tr>
<td>OTT</td>
<td>Over-the-Top - OTT content is characterized as online video from services and service providers that is distributed over a number of channels including fixed (e.g. to computers, connected CE, tablets) and mobile (e.g. smartphones and tablets) broadband - it is not associated with a pay-TV service provider subscription.</td>
</tr>
<tr>
<td>RF</td>
<td>Radio Frequency - those frequencies of the electromagnetic spectrum normally associated with radio wave propagation. RF sometimes is defined as transmission at any frequency at which coherent electromagnetic energy radiation is possible, usually above 150kHz.</td>
</tr>
<tr>
<td>SLA</td>
<td>Service Level Agreements - an agreement between a customer and a service provider that defines the services provided by the carrier and the performance requirements of the customer.</td>
</tr>
<tr>
<td>SSID</td>
<td>Service Set Identifier - A unique 32-character network name, or identifier, that differentiates one wireless LAN from another. All access points and clients attempting to connect to a specific WLAN must use the same SSID. The SSID can be any alphanumeric entry up to a maximum of 32 characters.</td>
</tr>
</tbody>
</table>