Whitepaper

Ittiam

Reliable Video Streaming over Wi-Fi (Part 1)

Optimal Network Configurations

Nov 2015

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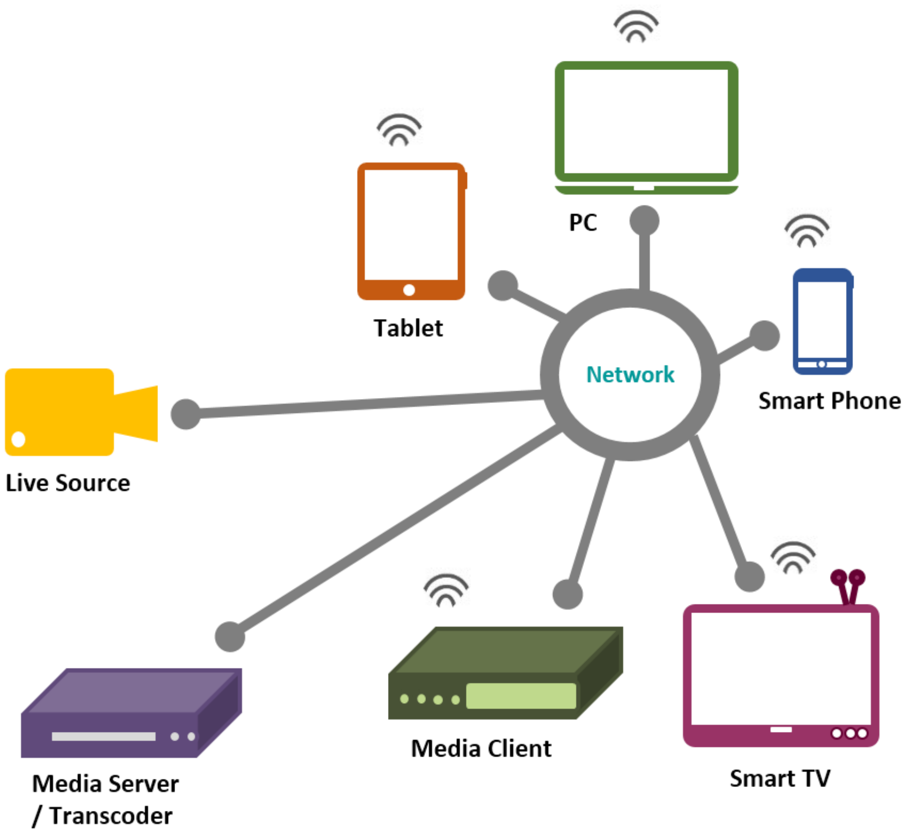
Abstract

Video streaming over wireless networks is quite susceptible to any changes in network conditions. Media servers, transcoders, network cameras or DVRs streaming to embedded or mobile clients over wireless networks are often affected by the quality of the connection. **Congestion, fluctuations in bandwidth, high signal interference** and varying distance between network nodes can make streamed video quality inconsistent and unreliable. How does one counter this?

The solution is twofold – one preventive and the other corrective. The preventive approach is to try and **ensure that network impairments do not happen** in the first place. And for this, one must fully understand the network nodes and equipment, including the streaming end points. The corrective approach equips the streaming end points with **mechanisms to correct impairments** introduced by the network. These solutions are covered in Part 1 and Part 2 of this white paper series.

This is Part 1, which aims at providing **insights into popular Wi-Fi standards**, optimal frequencies for transmission, recommended antenna configurations and router settings for an enhanced video streaming experience.



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Introduction

Wi-Fi being a wireless technology brings in various advantages like mobility, scalability, easy installation, flexibility and is also cost effective. However, video streaming applications have additional careabouts without which the network may become unusable. Video streaming requires a steady flow of media packets within a stipulated time across end points. Since the channel conditions are time-varying, unbound and largely unpredictable, video streaming may prove to be challenging.

Video Streaming Challenges over Wi-Fi

A. Inadequate Bandwidth

Available bandwidth is an important consideration for video streaming. Wi-Fi networks offer lower bandwidth (max 300Mbps for 802.11n) as compared to wired Ethernet networks (Gigabit Ethernet - up to 1000Mbps). Further, **applications cannot utilize the maximum available bandwidth** due to air-time utilization by other wireless participants and re-transmissions. Newer standard 802.11ac is targeted to increase this theoretical bandwidth limit comparable to Gigabit Ethernet. However, this is to be achieved by overcoming practical limitations.

B. Interference

This is one of the biggest problem faced by Wi-Fi applications. The key concerns is that it causes an **increase in packet loss and hence increased re-transmissions**. Interference from other wireless devices affects the signal quality and prevents Wi-Fi networks from achieving its full capacity.

C. Variable Channel Conditions

While mobility is a major advantage of wireless networks, it also **increases variation in the channel and signal conditions between the transmitter and receiver**. Signal strength in relation to distance between the transmitter and receiver is subjected to inverse-square law (Ex: distance grows by 2x → signal strength drops by 4x). This affects the available bandwidth and eventually the achievable video quality.

Wi-Fi Network Set-up Recommendations

Wi-Fi networks are characterized by several parameters one can control. Knowledge of these **network parameters can help network administrators** to tweak the right ones to suit various application scenarios. This will enable the users to optimize the network capabilities, improving the overall performance. The following sections talk about these parameters and provides recommendations to enable reliable video streaming over Wi-Fi networks.

A. Choice of Wi-Fi Standard

There are 5 well known 802.11 wireless family standards and are mentioned below in the chronological order of its advent. Modulation schemes used, media access method adopted, number of antennas supported etc., are the typical differences seen across these standards.

Wi-Fi Standard	Max Bandwidth (in Mbps)	Frequency (in GHz)
802.11a	54	5
802.11b	11	2.4

802.11g	54	2.4
802.11n	600	2.4 or 5
802.11ac	7000	5

Table 1 - Wi-Fi Standards

The bandwidth numbers above represents theoretical maximums, however re-transmissions, acknowledgments, collisions will bring down the usable bandwidth. The real throughput is essentially half of the advertised speed.

Additionally, one should know these standards while choosing network devices for ensuring compatibility across these devices.

- 802.11g is backward compatible with 802.11b.
- 802.11a is **not** compatible with 802.11b/g.
- 802.11n is interoperable with 802.11b/g and 802.11a as per legacy/mixed/greenfield modes. This means, an 802.11n AP [11] can support 802.11n/a/g/b end points.
- 802.11ac is backward compatible with 802.11b/g and 802.11a/n.

Recommendation

A few examples of popular video streaming applications and recommended wireless standards for the same are shared below. Bandwidth requirements for these applications may change with the number of channels/users. In such cases, the appropriate Wi-Fi standards can be chosen based on Table 1.

Application Class	Bandwidth Requirement	Standards
Surveillance	< 1Mbps	802.11a/b/g/n/ac
Surveillance	4-8 Mbps	802.11g/n/ac
SD Video Teleconference	8-12 Mbps	802.11g/n/ac
In-Flight Video On Demand	8-12 Mbps	802.11g/n/ac
HD Video Teleconference	12-20 Mbps	802.11n/ac
Live video streaming	8-30 Mbps	802.11n/ac

Table 2 - Application Specific Bandwidth Requirements

B. Selecting the Right Wi-Fi Frequency and Channel

Two signaling frequencies are popularly used today by Wi-Fi networks:

- **2.4 GHz** - This spectrum range referred to as the 2.4GHz band represents frequencies between 2400MHz to 2500MHz in the ISM[11] band. 802.11b/g/n networks operate in the 2.4 GHz band.
- **5 GHz** - This spectrum range referred to as the 5GHz band represents frequencies between 5150MHz to 5825MHz operating in the U-NII [11] band. However the range actually changes from region to region. 802.11a/n/ac networks operate in the 5 GHz band.

Attenuation and Range: Higher frequency signals have higher attenuation through obstacles than lower frequency signals. Also higher the frequency lower will be the range of the signal itself.

Interference and compatibility: 2.4GHz is a crowded frequency as many devices operate in this range and causes lot of interference. This also means one can be compatible with lots of devices using 2.4GHz but compatible with fewer devices using 5GHz. However, in the near future, this can prove to be wrong.

For each signaling frequency, there are multiple channels available for communication.

- **2.4 GHz** - There are 14 channels designated, each 22 MHz in width spaced 5 MHz apart (with the exception of a 12 MHz spacing before channel 14).

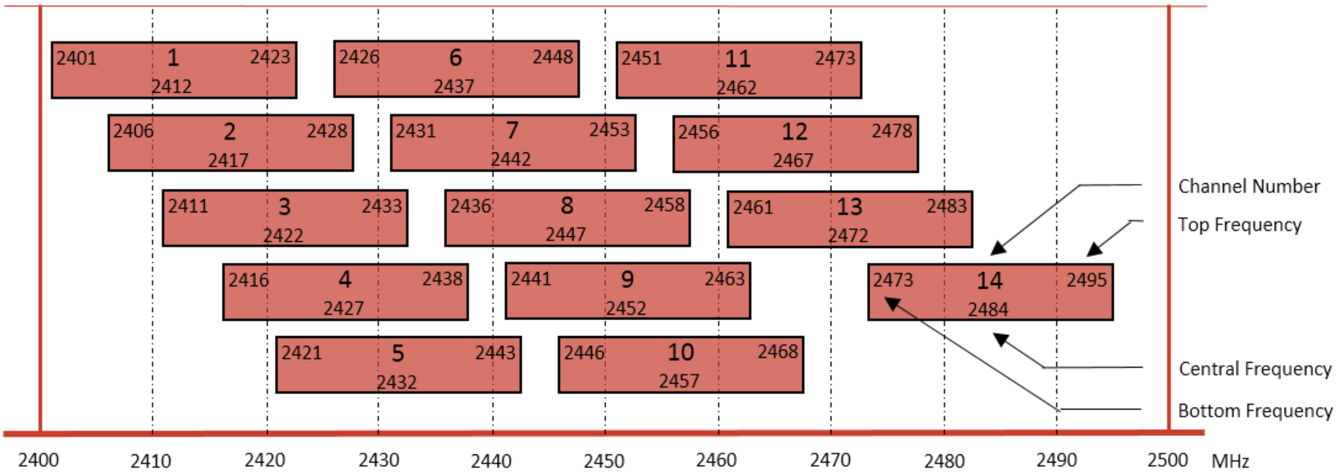

Figure 1 - 2.4GHz Channels and Frequency Spectrum

- **5 GHz** - Countries apply their own regulations to the allowable channels, allowed users and maximum power levels within these frequency ranges. They are subjected to change or can be revised anytime. Comprises of 26 channels, with a bandwidth of approximately 20 MHz each.

Channel	Frequency (MHz)	Channel	Frequency (MHz)
36	5180	**108**	5540
38	5190	**112**	5560
40	5200	**116**	5580
42	5210	**120**	5600
44	5220	**124**	5620
46	5230	**128**	5640
48	5240	**132**	5660
52	5260	**136**	5680
56	5280	**140**	5700
60	5300	**149**	5745
64	5320	**153**	5765
100	5500	**157**	5785
104	5520	**161**	5805

Table 3 - 5GHz Channels and Frequency

Recommendation

- Choice of channel
  - If two AP's are operating in the same channel/frequency and are within range, they cause interference introducing errors, re-transmissions and delays, reducing throughput and sometimes causing the network to drop.
  - This can be avoided by **making sure adjacent APs (in the same/different network) are operating on non-overlapping channels**. 2.4GHz band has a maximum of 3 non-

overlapping channels whereas as 5GHz has higher number of non-overlapping channels (Channel availability varies by country).

- Channel auto select
    - Many WLAN vendors have automated the channel assignment process. Such algorithms are known to swap the channels more number of times than necessary increasing the amount of disconnects and deteriorating the user experience.
    - Manual assignment of channels according to the channel usage of neighboring APs is the recommended choice in case of such issues.
- Wide channels
    - Combining two adjacent channels optimizes bandwidth and is referred to as **wide channels** (802.11n/ac). By combining two 20MHz channels we get a wider 40MHz channel that can transmit more data, resulting in faster Wi-Fi speeds. 802.11ac additionally supports 80MHz and 160MHz wide channels increasing the maximum theoretical achievable bandwidth multiple folds, and hence **usage of wide channels is recommended**.
    - However, if there are lot of neighboring Wi-Fi networks, they may cause higher interference with wide channels. In such cases, some routers may automatically switch back to 20MHz.
    - Usage of wide channels in 5GHz band can be more favorable as the interference is usually lower.

C. Selecting and Configuring the Antenna

The AP/router antenna is responsible for converting electric power into radio waves and vice versa; also transmission and reception of these radio waves. The speed and coverage of the Wi-Fi link is directly dependent on the antenna capabilities. Based on the requirement one may see a need to replace default antennas that come with the AP/router.

There are two main types of Wi-Fi antennas:

- **Omni directional** – Provides 360˚ donut-shaped radiation pattern to provide widest possible signal coverage both in indoor and outdoor wireless applications.
- **Directional** – Focus the wireless signal in a specific direction resulting in limited coverage area and longer range in the direction of the signal.

Directional antenna can be used only for point-to-point communication, providing longer range but incurring considerable reduction in coverage area. Typically used for LOS [11] coverage; the angular coverage is less and cannot cover wider areas.

Omni directional antennas must be used for better coverage and access in a dynamic system where the transceiver is not fixed.

Antennas generally have greater coverage at the expense of range and greater range at the expense of width of coverage area.

Gain and HPBW

Antenna gain determines the amount of power transmitted in the direction of peak radiation to that of an isotropic source. The higher the gain, the narrower the beam width (coverage area) and reduces the coverage near the antenna significantly. Half-power beam width (HPBW) is the specification of the antenna's coverage area. It is measured relative to the points at which the antenna's radiation drops to half the peak value. The higher the value the better the coverage area.

Generally omnidirectional antennas have gains not exceeding 12dBi, while directional antennas have gains up to 30dBi. **Based on usage and topology of the network, antennas with suitable gain and HPBW value should be selected.**

Spatial Streams

The 802.11n/ac standards support the usage of multiple transmit and receive antennas based on the **multipath propagation phenomena**, essentially multiplying the capacity of the wireless communication. This allows a device to transmit independent and separately encoded data signals, called streams, from each of the multiple transmit antennas at the same time.

The maximum spatial streams achievable shall be the minimum of the number of transmit antennas and the number of receive antennas. Whenever more than one receivers/inputs and more than one transmitters/outputs exist, multiple spatial streams can be achieved. This is referred to as **MIMO** (multiple-input and multiple-output). **MIMO offers multiple folds of data throughput capacity at the same available bandwidth.**

802.11n/ac should therefore be considered for video applications having high bandwidth requirement. Many devices like smart phones, tablets supports MIMO and can efficiently improve the quality of video solutions with the use of these devices.

D. Configuring the Access Point(s)

For routers/APs, there are a few configurable parameters that affect the channel conditions significantly. These are explained next.

Transmission Data Rate

Ideally, data transmission must use as less time as possible, so the air is clear for the next transmission. This can be achieved by increasing the data rate as per 802.11. Although this increases the capacity to transmit more data in a given time period, the effective range of transmissions decreases as the available power is used for sustaining the higher data rate. Devices closer to the transmitter can demodulate but as the devices go further away they cannot demodulate the signal and these signals will be viewed as noise. This increases re-transmissions as data is not properly received, and hence not acknowledged. In summary, the higher the configured data rate, the more susceptible the transmitted data is to noise.

Yet lowering the AP's data rate can actually have the opposite desired effect. Packets are now in the air longer, which means there is a greater chance of losing those packets because they take longer to be received, making them more susceptible to periodic interference.

802.11 Extension	Supported Data Rates
802.11a	6, 9, 12, 18, 24, 36, 48, 54 Mbps 6, 12, and 24 Mbps are mandatory
802.11b	1, 2, 5.5, 11 Mbps
802.11g	1, 2, 5.5, 11, 6, 9, 12, 18, 22, 24,33, 36, 48, 54 Mbps 1, 2, 5.5, 11, 6, 12 and 24 Mbps are mandatory 22 and 33 Mbps are typically not supported
802.11n	1, 2, 5.5, 6, 9, 11, 12, 18, 24, 36, 48, 54, 121.5, 130, 144.44, 270, 300, 405, 450 Mbps
802.11ac	200, 400, 433, 600, 867, 1300 Mbps

Table 4 - Data Rates supported by IEEE 802.11 standards

The intent is to create an environment which **uses relatively high data rates suffering relatively low re-transmissions**. This should be considered while manually configuring the data rate. Otherwise we can let the routers decide the data rate automatically (if supported) where the metrics like RSSI [11] and SNR will be used for dynamic decision making.

- Often, signal **measurements by the APs can be unreliable** and data rate predicted may not give the expected results. In such a case, favorable data rate shall be deduced manually by measuring throughput/quality for various data rates.
- It is often seen that using a **data rate at an immediate lower value than the default maximum** helps. This results in a good trade-off between throughput and the rate of re-transmissions.
- Similarly, one can **disable the lowest data rates on the APs** since these would result in high transmission times and would be more prone to interference.

Antenna Power Level

Transmit Power Level of the antenna determines the router/AP's coverage area. When selecting an antenna for the router/AP, appropriate power level should be used based on the desired coverage area. In specific, the following must be paid attention to:

- Antenna Power Level comprises of multiple contributors: Antenna gain, channel width, data rate and spatial streams. The antenna datasheet typically adds all these contributions to publish the Power Level. If not using these features, the **associated contribution must be subtracted from the published value**.
- WLAN equipment in general have automatic power control algorithms. Access points detect power levels of neighboring APs and try to optimize the cell size to create a matrix of barely overlapping cells. However, these algorithms tend to converge on a lower power level than necessary or desired, causing client coverage issues. Often, it is **recommended to adjust the range of the transmit power control so that the minimum value is higher than the default**. Adjust the power levels so that the hidden nodes are avoided and a better balanced connection is established.

Air-time Utilization

There are three types of transmissions in Wi-Fi – data, control and management frames. Ideally, most of the capacity should be used for data transmissions.

- If the network consists of large number of SSIDs[11], a lot of air time will be utilized by beaconing and probe responses. A beacon will be sent several times a second for every SSID. **Keeping the number of SSIDs under five and decreasing the beaconing rate** (100ms to 300ms) significantly reduces management overhead and improves data utilization.
- APs/Clients that support 802.11b sends out standard specific probe requests. **It is best if such devices are not used or the standard is disabled in the devices**. Most computers and mobile devices should not need it, but some legacy equipment may (medical devices, ticketing machines, VoIP phones).
- Interference is also caused by non Wi-Fi devices like microwave ovens, security cameras, zigbee devices, Bluetooth devices, cordless phones, baby monitors, and amateur radio. These devices mostly run in the 2.4GHz band. **Operating in 5GHz band** will resolve the problem. Otherwise it is **recommended to limit non Wi-Fi devices allowed in the coverage area**.

Fragmentation/Aggregation

- **Breaking up the packet into smaller fragments** increases the chance of successful transmission of all the fragments. It is the job of the receiver to reassemble the fragments into the original packet. The tradeoff is more overhead associated with the transmission of each fragment.
- Aggregation is the concept of using a **BLOCK acknowledgement to acknowledge a group of packets**, thereby cutting down on the need to acknowledge every single packet. This helps increase efficiency at the expense of robustness when noise component is high in the network.

Traffic Priority

Other mechanism for improving performance is to assign QoS [11] traffic classes to help **prioritize data within the network**; this may translate to different SSIDs for Voice and Video, which are more delay sensitive. While operating in a multimedia environment, WMM (Wireless MultiMedia extensions) QoS classes (voice, video, best effort) should be used. Each WLAN equipment manufacturer provides **load balancing, band steering and admission control features**, and network administrators/designers must make the best use of these.

Guard Interval

The standard symbol guard interval used in 802.11 OFDM [11] is 0.8 µs. 802.11n added optional support for a 0.4 µs guard interval providing an **11% increase in data rate**. A shorter guard interval results in a higher packet error rate when the delay spread of the channel exceeds this interval and/or if timing synchronization between the transmitter and receiver is not precise. Network administrators/ designers may experiment with a short guard interval to see if it still fits their requirements.

Afterword

Reliable Video Streaming over Wi-Fi (Part 2) will talk about technologies/algorithms that enhance video performance in video streaming solutions over Wi-Fi in Ittiam's products.

Conclusion

In this paper, we provide a high level overview of popular Wi-Fi standards and associated parameters. For an enhanced video streaming experience, we have shared the following recommendations:

- Use devices that supports 802.11n or higher standards
- Operate in 5GHz frequency band
- Use non-overlapping channels for the adjacent APs
- Use APs/routers/end-points equipped with Omni-directional antenna, with a gain less than or equal to 12dBi and 360˚ HPBW horizontal coverage
- Have all devices supporting MIMO, enabling more than one spatial streams
- Configure transmission data rate to a value one lower to the maximum default values
- Configure antenna power level range to have the minimum power one higher to the default minimum
- Configuring WMM appropriately in the APs
- Use 0.4 µs guard interval.

Fine tuning of some parameters based on the network topology may be necessary based on further analysis. Therefore, it is important to understand that what may work in one network/area may not work for another. Know that any network can be improved, but improvements should be made after observing, measuring, analyzing and making decisions based on the outcome to achieve the desired result. Note that, all the configurations mentioned in this paper may not be provided by all vendors/APs.

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Glossary

Abbreviations	Expansions
ISM	Industrial Scientific and Medical
U-NII	Unlicensed National Information infrastructure
AP	(Wi-Fi) Access Point
SSID	Service Set Identification
LOS	Line of Sight
SNR	Signal to Noise Ratio
RSSI	Received Signal to Strength Indication
QoS	Quality of Service
OFDM	Orthogonal frequency-division multiplexing

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