802.11ac: The next Wi-Fi generation
Gigabit Speed Wi-Fi

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Executive summary

The 5th generation of Wi-Fi is here, knocking at our door. IEEE 802.11ac also known as Gigabit Wi-Fi is the latest standard built upon 802.11n by increasing data rates, network robustness, reliability and RF bandwidth utilization efficiency.

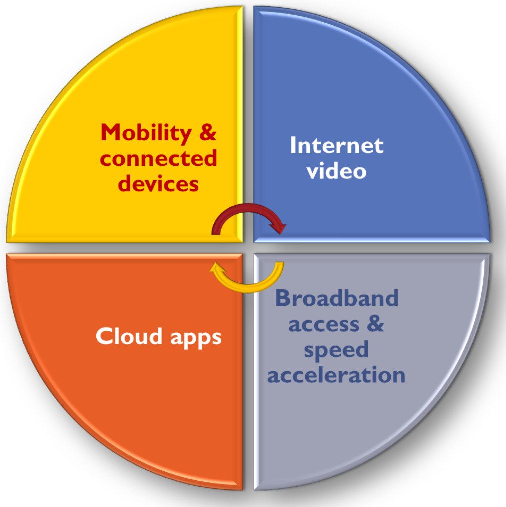
802.11ac is the first Wi-Fi standard that has been conceived listening the roar of the mobile community and high speed internet users. At same time, there is a significant increase in broadband speed available for end-users and number of devices connected at home with many mobile applications requiring higher speed Wi-Fi.

802.11ac is designed to meet the throughput and quality of service requirements of high speed internet, high-definition video and wireless voice applications. 802.11ac provides wireless data rates in excess of 1 Gbps per radio, which rivals with traditional hardwired speeds. More generally, 802.11ac provides better coverage and reliability, higher client capacity and increased battery life for mobile devices.

This paper will share the basics of this 5th Wi-Fi generation standard and it will give some key points to better understand the current and future challenges this new standard combined with AirTies' technology that will help to deal with.

Why do we need faster Wi-Fi?

The answer is concentrated in the 4 main following trends:



Mobility & connected devices

The world is becoming mobile; the number of mobile connected devices at home is exploding. By 2014, the number of mobile-connected devices will exceed the world's population and by 2016 tablets will generate almost as much traffic as the entire global mobile network did in 2012.

It's the end of one era and the beginning of another, by 2015; IDC and Gartner forecast show that annual shipments of tablets are set to outpace those of all PCs on a full-year basis.

The number of fixed connected devices is also increasing at home boosted by the connected TVs, gaming consoles and Blu-ray players.

Globally, the average household had 4.7 devices/connections in 2012; the average household will have 7.1 devices/connections by 2017 [1].

Translation in Wi-Fi language of the trend can be summarized by higher capacity demand (to support the huge number of devices connected simultaneously), whole home coverage (for a flawless experience of mobility at home) and better energy efficiency (to optimize the battery life of mobile devices).

Internet Video

TV and consequently video has only been available within the walled garden of free-to-air, satellite or cable broadcasters up to now. Looking at the current trend, future can be predicted as a shift of free-to-air TV broadcast toward live video streaming over the internet mainly boosted by the high economic value of selling radio frequencies to mobile operators.

Getting your live TV channels from the internet and watching them anywhere in the house on your tablet will probably be one of the most convenient ways of watching TV in coming years. Estimations show that by 2017, smartphones and tablets will reach 40% share of connected devices [2].

By 2017, IP Video will account for 73% of the internet traffic1 heavily boosted by fast growing services such as live TV, catch up TV & Video-On-Demand.

Home Wi-Fi network needs to support the trend with higher speed, multi-video stream capability, higher coverage and higher capacity.

Cloud applications

Global IP traffic will growth 3-fold between 2012 and 2017, mainly boosted by more internet users, more connected devices, richer media content and faster broadband speeds.

Users are running bandwidth-hungry apps such as Apple iCloud and Google Drive over-the-air synchronization services, high-definition video streaming services such You Tube, Web conferencing, social networking apps, facetime/skype video calling and music streaming apps, to name just a few. These new apps consume far more bandwidth than the low-speed data transfers of yesterday. At the end of the day, consumers will desperately ask to power up their wireless network to enjoy the full benefit of this new era of apps.

Broadband access & speed acceleration

The fixed Broadband speed is in permanent acceleration, global average speed will go from 11Mbps in 2012 to 39 Mbps in 2017 (3.5-fold) [3] boosted by fiber and VDSL deployments. A faster broadband service enables more and better end user experience and creates new hungers for HD video downloading, HD movie streaming or bandwidth demanding new services.

802.11ac Overview: How does it go so fast?

802.11ac represents more of an evolutionary than revolutionary step up from 802.11n; this new generation Wi-Fi standard relies substantially on algorithms already worked out during the development of 802.11n. The good point is that all the bodies have learned about mistakes in the standardization and in the implementation of the 802.11n where even today, more than 5 years after draft 2.0 of the 802.11n, we still use only a subset of 11n features. 802.11ac is a good baby born; breaking the 1Gbps wireless speed is definitely an exciting accomplishment. This is only the first phase of the 802.11ac standard; the revolution is on its way with a theoretical maximum speeds close to 7 Gbps. 802.11ac is built on a set of key enhancements designed to drive data rates very high and to improve coverage quality and network capacity dramatically:

- 5 GHz band
- Wider channel bandwidth: 80 and 160 MHz
- More spatial streams: up to 8

[1] source: Cisco VNI annual report 2012-2017
[2] source: Cisco VNI annual report 2012-2017
[3] source: Cisco VNI annual report 2012-2017

- More efficient modulation: 256-QAM
- Beam forming
- Implicit beam forming
- Multiple User MIMO (MU-MIMO)
- Backward compatible to 802.11a and 802.11n which also use the 5GHz band
- Battery life

5GHz band

2.4GHz is an extremely crowded frequency band; it can be compared to the peak hour traffic jam in the main cities of the world. 802.11ac operates in the 5GHz band only and given the massive capacity advantage of the 5GHz spectrum, the cumulative benefit of this strategic decision will be huge. We are shifting the Wi-Fi focus away from the 2.4 GHz junk band.

The first advantage of the 5GHz band is the number of non-overlapping channels available compared to the 2.4 GHz band. The numbers of non-overlapping channels vary by country (local regulations) and by channel widths.

The below table gives a comparison for European Union and for the US of the non-overlapping 20 MHz channels available for 2.4 GHz and 5GHz. Activities are going on in the US that will increase the number of available channels in the 5GHz band and other countries will follow.

Non-Overlapping channels	2.4 GHz	5 GHz
European Union	3	19
US	3	21

When looking at the situation from the product point of view, most of the first generation 802.11ac products will come out with a dual band configuration with 802.11ac for the 5GHz and 802.11n for the 2.4GHz to ensure an optimum backward compatibility with the already deployed wide range of Wi-Fi devices.

Most of the electronic devices such as smartphones, tablets or PCs already have embedded 5 GHz capable Wi-Fi. Smartphones and laptops based on the first generation of 802.11ac chipsets are already in the market and a new wave of tablets will leverage 802.11ac as part of their support for high-definition video.

The adoption of the 802.11ac in consumer electronic goods will be much faster than the 802.11n due to better definition of the standard, tremendous increase of HD video consumption and an extraordinary growth of the number of mobile devices.

Wider channel bandwidth: 80 and 160 MHz

The increase of the channel bandwidth is an easy way to gain speed. 802.11n technology is using 20 MHz or 40 MHz channel bandwidth, 802.11ac uses additional 80 MHz channel bandwidth in its current phase of deployment, the 802.11ac standard has defined a channel bandwidth of 160MHz as an option.

Immediately, increasing the channel bandwidth to 80 MHz yields 2.16 times faster speed and 160 MHz will offer a further doubling.

This is exactly as if the 4-lanes highway that you drive in every morning to go to your office is transformed into an 8-lanes highway.

More spatial streams: up to 8

Spatial Multiplexing (MIMO) is a feature that enables multiple simultaneous data streams in the same channel.

802.11n standard stopped at 4 simultaneous spatial streams for a channel width of 40 MHz but when looking at the reality of the devices deployed on the field today, design constraints and economics have kept 802.11n products at one, two or three spatial streams.

802.11ac standard expand that to 8 spatial streams for both 80MHz channel width and 160 MHz channel width for a 100% speed increase compare to 4 spatial streams.

Design constraints and economics that kept 11n products at 3 spatial streams max are still valid for the 11ac. Nevertheless as we are talking now about new generation chipsets at the edge of the technology, AirTies is launching the smallest 4x4 Wireless Access Point to the market powered by 802.11ac technology to reach 1.7 Gbps speed for the first time in the world.

More than 4 spatial streams is definitely a goal for the future. Number of spatial streams is directly linked to the number of radios included in the product which limit the benefits of spatial multiplexing to high performance devices.

Portable devices like tablets and mobile phone will stay limited to a single or two streams because of power consumption limitations.

More efficient modulation: 256-QAM

802.11ac is using a denser modulation scheme and an enhanced coding. 802.11ac jumps from 64 Quadrature Amplitude Modulation (QAM) in 802.11n to 256 QAM.

The greater the QAM number, the faster the data rate of the wireless link is or in another words more data can be encoded in the same packet size. The 802.11ac standard also specifies more aggressive error correction codes that have fewer redundant bits and is expected to improve rate-versus-range performance and link reliability when operating at a distance.

The improved modulation can be compared in having a bigger car, carrying more people in one car at the same speed of a sport car.

Beam forming

Beam forming is now a standard in 802.11ac, this is the typical great feature already available in the 802.11n standard as an option but never widely adopted due to the lack of unique standard definition leading to vendor incompatibilities. 802.11ac standard has paid more attention to the specification of the feature and has defined a standard beam forming implementation that will facilitate interoperability and increase the effective range of 802.11ac based systems. The feature is based on an exchange between the transmitter and the receiver (sounding) in order that the beam former precisely steer its transmit power toward the receiver. This feature will have a deep impact on coverage quality improvement.

With 802.11ac beam forming feature, not only the wireless Modem/Access Point but also clients (tablet, laptop, TV, tablet) need to be 802.11ac compliant in order to benefit from the beam forming feature.

But what happens if the client devices is 802.11n 5GHz only?

Implicit beam forming

802.11ac standard is totally backward compatible with 802.11a & 802.11n which means that 802.11n, 802.11a and 802.11ac clients (tablet, laptop, TV, tablet...) can simultaneously connect to the same 802.11ac Wi-Fi network.

By construction (need to have a standardized dialogue between the Modem/Access Point and clients), only 802.11ac devices can take the full benefit of the beam forming feature.

AirTies is proud to announce the implementation of the implicit beam forming feature in its 802.11ac products. Implicit beam forming is a unique feature that enables 802.11n or 802.11a devices to take benefit of the beam forming feature.

The AirTies 802.11ac Modem/Access Point performs a smart analysis of the return signal from its 802.11n or 802.11a clients and according to this analysis, steer its transmit power toward these clients exactly in the same way as for an 802.11ac client.

All your existing devices will take the advantage

The figure below gives a visual understanding of the beam forming feature.

Wi-Fi current situation

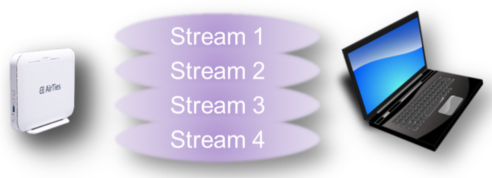
Wi-Fi with 802.11ac & beam forming feature of using your new AirTies 802.11ac wireless Modem/Access Point.

If your 802.11ac Modem/Access Point does not include implicit beam forming feature, your existing 802.11n or 802.11a devices will still continue to operate but with the same level of performance as with a 802.11n Modem/Access Point.

Multi-User MIMO (MU-MIMO)

MIMO capabilities were introduced in 802.11n. Radios spread a user's data into a multiple spatial streams, transmitted through multiple antennas, propagating over the air along different paths. When all streams reach the client, the data are recombined. With 802.11n, a device can transmit multiple spatial streams at once but only to a single device and this is called Single-user MIMO (SU-MIMO).

Single-User MIMO 802.11n



Multi-User MIMO (MU-MIMO) that will be introduced in the second or the third waves of 802.11ac will allow simultaneous downstream transmission of different user streams in the same channel at the same time. 802.11ac MU-MIMO will allow multiple streams to be assigned to different clients, increasing the total bandwidth that can be transmitted simultaneously.

Multi-User MIMO 802.11ac

To take advantage of the new 802.11ac feature set, deployment of 802.11ac clients will be required. However, MU-MIMO is a challenging technology to implement correctly and won't be available in the first wave of 802.11ac products.

Backward compatible to 802.11a and 802.11n which also use the 5GHz band

This is an extremely important point of the 802.11ac standard; it is fully backward compatible with existing 802.11 standards in the 5GHz band of frequency.

For the end user, introducing a new 802.11ac Modem/Access Point will be flawless. It means that he/she will continue to take benefits of his previous 802.11n/802.11a devices and power up his/her network by introducing new 802.11ac devices such as tablets, smartphones or laptops working in harmony.

For a perfect backward compatibility with existing networks, newer devices and especially newer Modem/Access Point devices will have multiple radios, including both 2.4GHz and 5 GHz Wi-Fi allowing access to older 2.4GHz only 802.11/b/g/n devices.

Battery Life

802.11ac chipsets are the first generation of Wi-Fi chipsets having to face at the brutal expansion of mobile devices. With every new product, manufacturing and technology advances are also improving the efficiency of the Wi-Fi chipset design resulting in power savings.

Some of the first chipset manufacturers for 802.11ac are projecting that their newest chips demonstrate better performance and power efficiency than previous 802.11n chips.

The higher data rates provided by 802.11ac (allowing devices to access the medium, transfer the data and then resume low power state more quickly than previous technologies) associated to the newest chipset manufacturing and technology advances will make 802.11ac devices 6 times more power efficient than similar 802.11n devices.

This is one of the reasons why 802.11ac standard will be adopted by the mobile devices very fast. Just as an example, a typical tablet or smartphone with a single antenna 802.11n 150Mbps Wi-Fi can now support 433Mbps with 802.11ac without any increase in power consumption or decrease of the battery life.

802.11ac summary

802.11ac is a series of incremental improvements to many aspects of the existing standard. While many of the new 802.11ac features are aimed at increasing the speed, there are many other benefits of the 802.11ac technology including improved range; robust coverage, less interferences, higher capacity and optimized HD video streaming.

The key advantages of the 802.11ac over 802.11n can be summarized as follows:

- Gigabit wireless technology about 4 times the performance of the 802.11n (1.7Gbps)
- 5GHz band only for higher capacity, better reliability and quality of service
- Better performance at any distance providing better coverage in home
- More reliable HD video streaming
- Connect more mobile devices to your network with higher bandwidth
- Backward compatible to 802.11a and 802.11n which also use the 5GHz band
- Longer Battery life ideal for mobile devices

The table below gives the feature comparison between 802.11n and 802.11ac.

Features	802.11n	802.11ac	Impact of the feature enhancement
Frequency Band	2.4 GHz & 5GHz	5GHz only	Higher Capacity, Less Interferences
Channel bandwidth	20, 40 MHz	20, 40, 80 MHz 160 MHz Optional	Higher Speed, Higher Capacity
Modulation	64 QAM	256 QAM	Higher Speed, Higher Capacity
Spatial Streams	1 to 4	1 to 8 up to 4 per client	Higher Speed, Higher Capacity, Better Range, Better Coverage
MU-MIMO	No	Yes	Higher Capacity, Better Coverage
Single Stream	150 Mbps	433 Mbps	Higher Speed, Higher Capacity
Maximum streams	450 Mbps (3x3)	1.7 Gbps (4x4)	Higher Speed, Higher Capacity
Beamforming	Not implemented	Yes	Higher Capacity, Better Range, Better Coverage
Implicit Beamforming	Not implemented	Yes (AirTies)	Beam forming feature for 802.11n 5GHz devices also