Killer App Alert!

IEEE 802.11ac 5 GHz Wireless Update and Structured Cabling Implications

Killer app alert! The newly published IEEE 802.11ac Very High Throughput wireless LAN standard[1] has far reaching implications with respect to cabling infrastructure design. Users can expect their current wireless speeds to appreciably increase by switching to 802.11ac gear with 1.3 Gb/s data rate capability that is available today. And, 256-QAM modulation, 160 MHz channel bandwidth, and a maximum of eight spatial streams can theoretically deliver 6.93 Gb/s in the future! For the first time, the specification of high performance cabling supporting access layer switches and uplink connections is critical to achieving multi-Gigabit throughput and fully supporting the capacity of next generation wireless access points.

Key cabling design strategies to ensure that the wired network is ready to support 802.11ac wireless LANs addressed in this paper include:

- Specifying category 6A or higher performing horizontal cabling in combination with link aggregation to ensure immediate support of the 1.3 Gb/s theoretically achievable data rate deliverable by 802.11ac 3-stream wireless access points (WAPs) and routers available today

- Installing a minimum of 10 Gb/s capable balanced twisted-pair copper or multimode optical fiber backbone to support increased 802.11ac uplink capacity

- Utilizing a grid-based zone cabling architecture to accommodate additional WAP deployments, allow for rapid reconfiguration of coverage areas, and provide redundant and future-proof connections

- Using solid conductor cords, which exhibit better thermal stability and lower insertion loss than stranded conductor cords, for equipment connections in the ceiling or in plenum spaces where higher temperatures are likely to be encountered

- Recognizing that deploying Type 2 PoE to remotely power 802.11ac wireless access points can cause heat to build up in cable bundles
  - — Siemon's shielded class E_A/category 6A and class F_A/category 7_A cabling systems inherently exhibit superior heat dissipation and are qualified for mechanical reliability up to 75°C (167°F), which enables support of the Type 2 PoE application over the entire operating temperature range of -20°C to 60°C (-4°F to 140°F)
  - — Shielded systems are more thermally stable and support longer channel lengths (i.e. less length de-rating is required at elevated temperatures to satisfy TIA and ISO/IEC insertion loss requirements) when deployed in high temperature environments
  - — A larger number of shielded cables may be bundled without concern for excessive heat build-up within the bundle

- Specifying IEC 60512-99-001 compliant connecting hardware ensures that contact seating surfaces are not damaged when plugs and jacks are unmated under 802.11ac remote powering current loads

What's in a name?

The latest 802.11ac wireless LAN technology goes by many names, including:

- 5 GHz Wi-Fi – for the transmit frequency

- Gigabit Wi-Fi – for the short range data rate of today's three spatial stream implementation

- 5G Wi-Fi – for 5th generation (i.e. 802.11a, 802.11b, 802.11g, 802.11n, and 802.11ac)

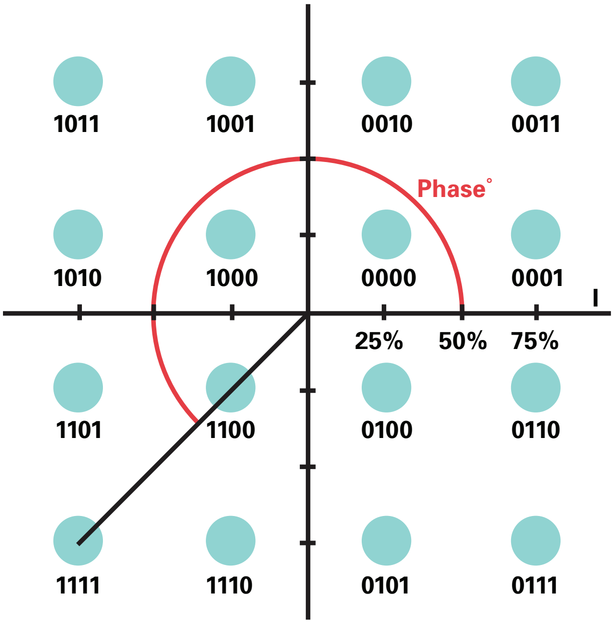
- Very High Throughput Wi-Fi – from the title of the application standard

No matter what you call it, the fact is that the increasing presence and capacity of mobile and handheld devices, the evolution of information content from text to streaming video and multimedia, combined with limits on cellular data plans that encourage users to "off-load" to Wi-Fi are all driving the need for faster Wi-Fi networks. As Wi-Fi becomes the access media of choice, faster wireless LAN equipment will play an important role in minimizing bottlenecks and congestion, increasing capacity, and reducing latency but only if the cabling and equipment connections can support the additional bandwidth required. The Wi-Fi Alliance certified the first wave of production-ready 802.11ac hardware in June 2013 and adoption of 802.11ac is anticipated to occur more rapidly than any of its 802.11 predecessors. Today, 802.11ac routers, gateways, and adapters are widely available to support a range of 802.11ac-ready laptops, tablets, and smart phones. In fact, sales of 802.11ac devices are predicted to cross the 1 billion mark (to total 40% of the entire Wi-Fi enabled device market) by the end of 2015![2]

A Technology Evolution

The enhanced throughput of 802.11ac devices is facilitated by an evolution of existing and proven 802.11n[3] Wi-Fi communication algorithms. Like 802.11n, 802.11ac wireless transmission utilizes the techniques of beamforming to concentrate signals and transmitting over multiple send and receive antennas to improve communication and minimize interference (often referred to as multiple input, multiple output or MIMO). The signal associated with one transmit and one receive antenna is called a spatial stream and the ability to support multiple spatial streams is a feature of both 802.11ac and 802.11n. Enhanced modulation, wider channel spectrum, and twice as many spatial streams are the three key technology enablers that support faster 802.11ac transmission rates while ensuring backward compatibility with older Wi-Fi technology.

Quadrature amplitude modulation (QAM) is an analog and digital modulation scheme that is used extensively for digital telecommunications systems. Using this scheme, a four quadrant arrangement or "constellation" of symbol points is established with each point representing a short string of bits (e.g. 0's or 1's). Sinusoidal carrier waves that are phase shifted by 90° are modulated using amplitude-shift keying (ASK) digital modulation or amplitude modulation (AM) analog modulation schemes and are used to transmit the constellation symbols. Figure 1 depicts a rudimentary example of a 16-QAM constellation for demonstration purposes. Note that there are four points in each quadrant of the 16-QAM constellation and each point equates to four information bits, ranging from 0000 to 1111. The 64-QAM scheme utilized by 802.11n equipment carries 6 bits of information per constellation point and the 256-QAM scheme utilized by 802.11ac equipment carries an amazing 8 bits of information per constellation point!



Amplitude	Phase	Data
25%	45°	0000
75%	22°	0001
75%	45°	0011
75%	68°	0010
25%	135°	1000
75%	112°	1001
75%	135°	1001
75%	158°	1010
25%	225°	1100
75%	202°	1101
75%	225°	1111
75%	248°	1110
25%	315°	0100
75%	292°	0101
75%	315°	0111
75%	337°	0110

Figure 1: Example 16-QAM Constellation and Correlating Symbol Bit Information

802.11ac devices will transmit exclusively in the less crowded 5 GHz spectrum. This spectrum supports higher transmission rates because of more available non-overlapping radio channels. It is considered “cleaner” because there are fewer devices operating in the spectrum and less potential for interference. One disadvantage to operating in this spectrum is that 5 GHz signals have a shorter transmission range and have more difficulty penetrating building materials than 2.4 GHz signals. Designing a flexible cabling infrastructure that can accommodate the addition of future WAPs and enable rapid reconfiguration of coverage areas can save headaches later. Figure 2 depicts a recommended zone cabling approach utilizing enclosures that house consolidation points (CPs) with spare port capacity to facilitate connections to equipment outlets (EOs) that are positioned in a grid pattern. In addition, because most WAPs are located in the ceiling or in plenum spaces where higher temperatures are likely to be encountered, the use of solid conductor cords, which exhibit better thermal stability and lower insertion loss than stranded conductor cords[4], are recommended for all equipment connections in high temperature environments. Refer to ISO/IEC 24704[5] and TIA TSB-162-A[6] for additional design and installation guidelines describing a grid-based cabling approach that maximizes WAP placement and reconfiguration flexibility.

The Implications of Speed

In 802.11n and 802.11ac, channels that are 20 MHz wide are aggregated to create the “pipe” or “highway” for wireless transmission. 802.11ac technology allows radio transmission over either four or eight bonded 20 MHz channels supporting maximum throughput of 433 Mb/s and 866 Mb/s, respectively. In addition, 802.11ac can accommodate up to eight antennas and their associated spatial streams for an unprecedented maximum theoretical data speed of 6.93 Gb/s! Note that, unlike full duplex balanced twisted-pair BASE-T type Ethernet transmission where throughput is fixed in both the transmit and receive orientations, the speed specified for wireless applications represents the sum of upstream and downstream traffic combined. Figure 3 summarizes the key capability differences between 802.11n and 802.11ac technology.

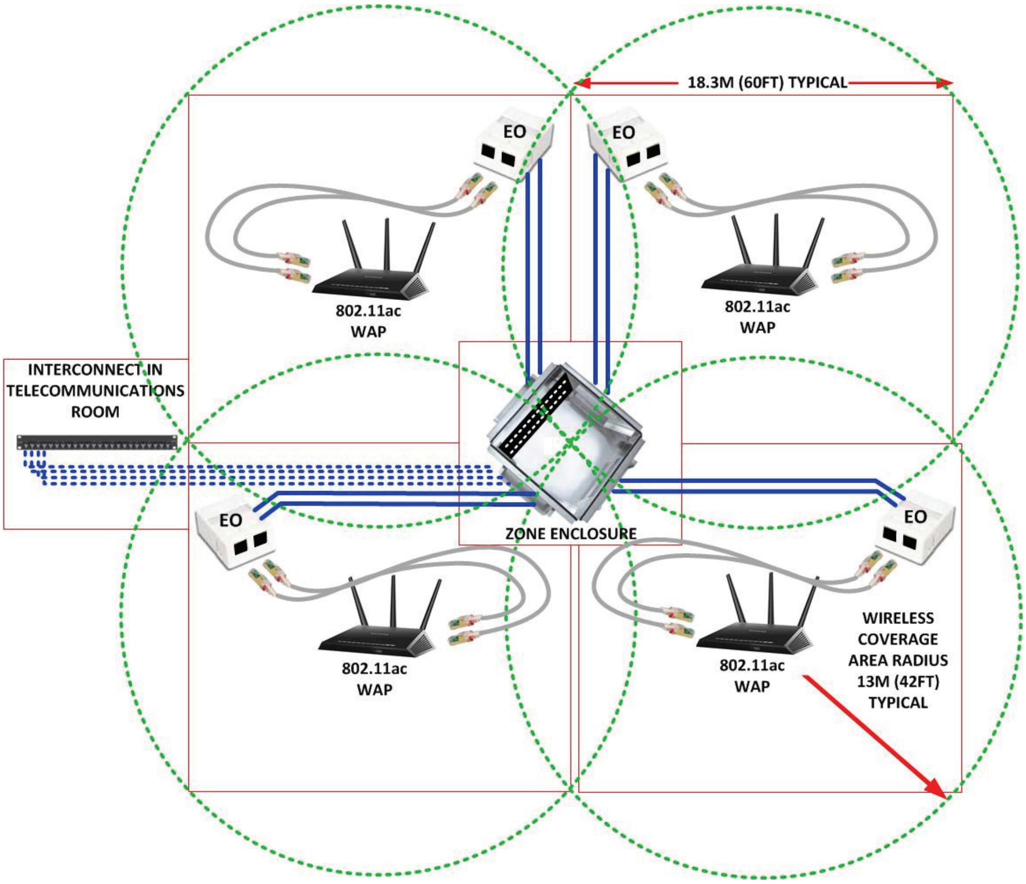


Figure 2: Example Grid-Based WAP Zone Cabling Deployment Design

	802.11n	802.11ac
Transmit Frequency	2.4 or 5 GHz	5 GHz only
Channel Bandwidth	20 or 40 MHz	80 or 160 MHz
Modulation	64-QAM	256-QAM
Maximum Number of Spatial Streams	4	8
Theoretical Maximum Data Rate per Stream	144 Mb/s	866 Mb/s
Theoretical Maximum Data Rate	576 Mb/s	6.93 Gb/s

Figure 3: 802.11n versus 802.11ac Technology Comparison

Channel Bandwidth	Number of Spatial Streams	Maximum Speed	Target Device or Application
First Wave – Products Available Now			
80 MHz	1	433 Mb/s	Dual-band smart phone, nextVoIP handset, or tablet
80 MHz	3	1.3 Gb/s	High-end laptop
Second Wave – Products Available Mid 2015			
80 MHz	2	867 Mb/s	Netbook/low-end laptop
160 MHz	3	2.6 Gb/s	High-end laptop
Possible Future Implementations			
160 MHz	4	3.5 Gb/s	Outdoor or low coverage areas
160 MHz	8	6.9 Gb/s	Specialized

Figure 4: Example 802.11ac Implementation Configurations

Because of the variables of channel bandwidth and number of spatial streams, 802.11ac deployments are highly configurable. In general, the lower end of the throughput range will be targeted for small handheld devices with limited battery capacity such as smart phones, the middle of the throughput range will be targeted towards laptops, and the highest end of the throughput range will be targeted at specialized and outdoor applications where there is less device density compared with indoors. Figure 4 provides examples of currently available first wave and second wave (available mid 2015) 802.11ac implementation configurations with target devices indicated. Possible future 802.11ac implementations are also shown, but these implementations may not be available for years, if at all. While this may seem surprising, consider that there are no 4-stream implementations of 802.11n even though the technology is standardized. Wireless LAN provider Aruba Networks suggests that manufacturers will leapfrog 4-stream 802.11n products in favor of 802.11ac products. The bottom line is that end-users can reasonably expect their current wireless speeds to at least double by switching to 802.11ac gear that is available today and more than quadruple when second wave products become available.

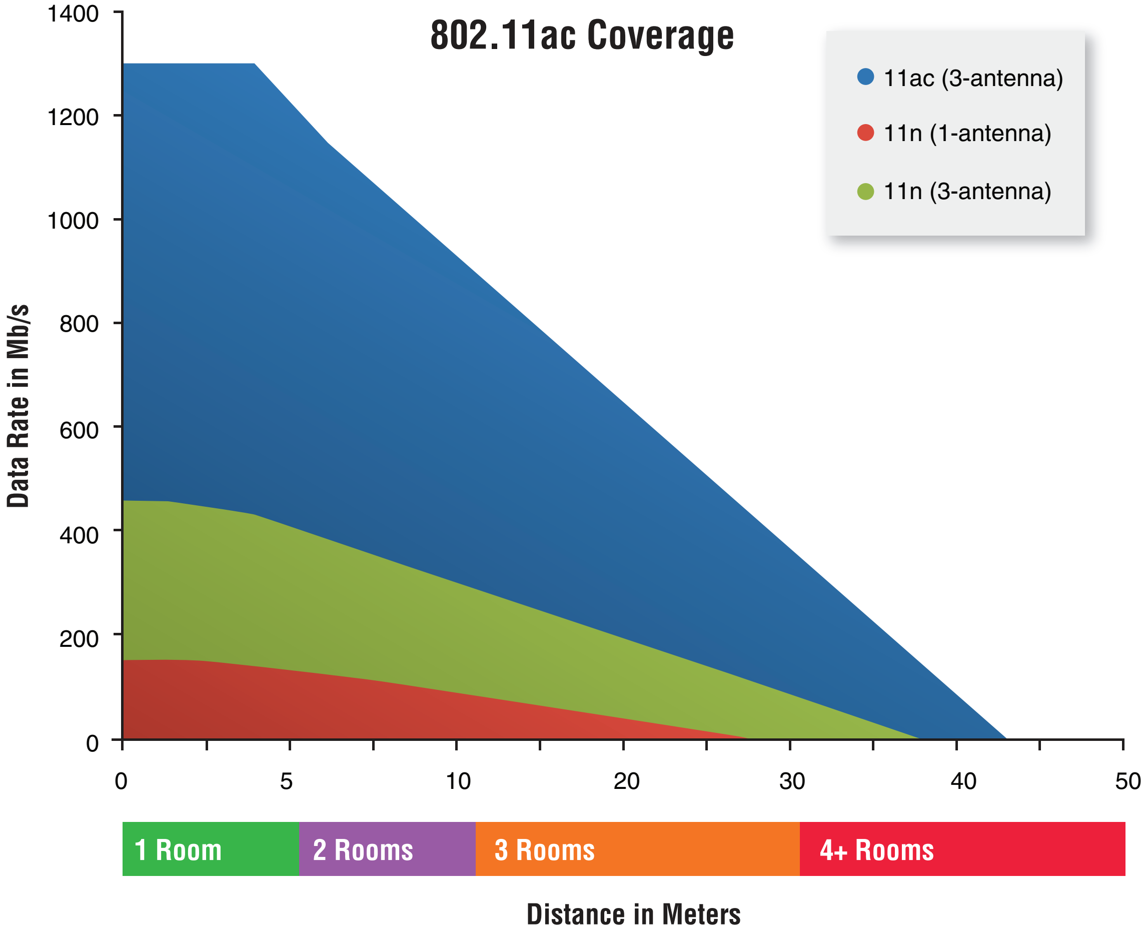


Figure 5: Data Rate versus Coverage Radius (provided courtesy of Broadcom)

When comparing wireless capabilities, it's important to keep in mind that the maximum realizable data rate is impacted by the number of wireless users, protocol overhead, and the spatial distribution of end-user devices from the access point. The image in figure 5 illustrates how data rate decreases as distance from the WAP transmitter increases for a commonly available 802.11ac 3-stream 80 MHz transmitter and 802.11n 1- and 3-stream transmitters. The chart shows that 1.3 Gb/s data rates are theoretically achievable within a coverage radius of 5m (16.4 ft) from an 802.11ac 3-stream WAP. Transfer data collected for first generation wireless products confirms that the 802.11ac 3-stream data rate at relatively close range to a single device is roughly on par with that achievable with a wired Gigabit Ethernet (1000BASE-T) link. In some cases, the 802.11ac wireless data transfer rate was fast enough to saturate the 1000BASE-T copper balanced twisted-pair cabling link provided between the 802.11ac router and the server![7]

Greater than 1 Gb/s wireless data rate capability has serious implications related to wired media selection for router to server and other uplink connections. For example, two 1000BASE-T connections may be required to support a single 802.11ac WAP (this is often referred to as link aggregation) if 10GBASE-T uplink capacity is not supported by existing equipment (refer to figure 2, which depicts two horizontal link connections to each equipment outlet). As 802.11ac equipment matures to support 2.6 Gb/s and even higher data rates, 10 Gb/s uplink capacity will become even more critical. Moreover, access layer switches supporting 802.11ac deployments must have a minimum of 10 Gb/s uplink capacity to the core of the network in order to sufficiently accommodate multiple WAPs.

Power Consumption

Although 802.11ac radio chips are more efficient than prior generation wireless chips, they are doing significantly more complex signal processing and the amount of power required to energize 802.11ac devices is higher than for any previous 802.11 implementation. In fact, 802.11ac WAP's are unable to work within the 13-watt budget of Type 1 Power over Ethernet

(PoE) and must be supported by either a direct DC power adapter or 30-watt Type 2 PoE remote power. (Note that some 802.11ac products may be able to draw power from two Type 1 PoE connections, but this is an impractical and fairly uncommon implementation.) While safe for humans, Type 2 PoE remote power delivery, at an applied current of 600mA per pair, can produce up to 10°C (22°F) temperature rise in cable bundles[8] and create electrical arcing that can damage connector contacts. Heat rise within bundles has the potential to cause bit errors because insertion loss is directly proportional to temperature. In extreme environments, temperature rise and contact arcing can cause irreversible damage to cable and connectors. Fortunately, the proper selection of network cabling, as described next, can eliminate these risks.

The Wired Infrastructure

Existing wireless access devices, client devices and the back end network and cabling infrastructure may need to be upgraded in order to fully support 802.11ac and Type 2 power delivery. In addition, 802.11ac's 5 GHz transmission band requires relatively dense WAP coverage areas and existing 802.11n grid placement layouts may not be sufficient. For both new and existing wireless deployments, now is the time to seriously consider the wired cabling uplink infrastructure.

Under all circumstances, the equipment outlets, patch panels, and other connecting hardware used in the channel should comply with IEC 60512-99-001[9] to ensure that critical contact seating surfaces are not damaged when plugs and jacks are unmated under 802.11ac remote powering current loads. In addition, the use of Siemon shielded class E_A/category 6A and class F_A/category 7_A cabling systems, which support longer channel lengths (i.e. less length de-rating is required at elevated temperatures to satisfy TIA and ISO/IEC insertion loss requirements) and are qualified for mechanical reliability up to 75°C (167°F), are recommended for Type 2 PoE remote powering applications in locations having an ambient temperature greater than 20°C (68°F). Furthermore, larger numbers of shielded cables may be bundled without concern for excessive heat build-up within the bundle.

Designing a cabling infrastructure to robustly support 802.11ac deployment requires consideration of the switch, server, and device connection speeds commonly available today as well as strategies to support redundancy, equipment upgrades, and future wireless technologies. A grid-based category 6A zone cabling approach using consolidation points housed in zone enclosures is an ideal way to provide sufficient spare port density to support 1000BASE-T link aggregation to each 802.11ac WAP as necessary, while also allowing for more efficient port utilization when 10GBASE-T equipment connections become available. Zone cabling is highly flexible and enables rapid reconfiguration of coverage areas and conveniently provides additional capacity to accommodate next generation technology, which may require 10GBASE-T link aggregation. Additional WAPs can be easily incorporated into the wireless network to enhance coverage with minimal disruption when spare connection points in a zone cabling system are available. This architecture is especially suited for deployment in financial, medical, and other critical data-intensive environments because redundant 10GBASE-T data and backup power connections provided to each WAP can safeguard against outages.

Siemon recommends that each zone enclosure support a coverage radius of 13m (42.7 ft) with 24 port pre-cabled consolidation points available to facilitate plug and play device connectivity. For planning purposes, an initial spare port capacity of 50% (i.e. 12 ports unallocated) is recommended. Spare port availability may need to be increased and/or coverage radius decreased if the zone enclosure is also providing service to building automation system (BAS) devices and telecommunications outlets (TOs). Backbone cabling should be a minimum design of 10 Gb/s capable balanced twisted-pair copper or multimode optical fiber media to support 802.11ac uplink capacity.

Conclusion:

A killer app forces consumers to stop and question legacy views about broadly deployed operating platforms or systems. IEEE 802.11ac is a dual-edged killer app in that it requires both 10GBASE-T and Type 2 remote powering for optimum performance – swiftly making the wait-and-see stance concerning 10GBASE-T adoption in support of LAN applications a position of the past. A properly designed and deployed zone cabling architecture utilizing thermally stable shielded category 6A or higher cabling products engineered to withstand the maximum TIA and ISO/IEC ambient temperature of 60°C (140°F) plus the associated heat rise generated by 600mA Type 2 PoE current loads will ensure that your cabling infrastructure is a killer app enabler.

Footnotes:

[1] IEEE Std 802.11ac™-2013, *"IEEE Standard for Information technology – Telecommunications and information exchange between systems Local and metropolitan area networks Specific requirements Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications Amendment 4: Enhancements for Very High Throughput for Operation in Bands below 6 GHz"*, December 11, 2013

[2] Strategy Analytics' Connected Home Devices (CHD) service report, *"Embedded WLAN (Wi-Fi) CE Devices: Global Market Forecast"*

[3] IEEE Std 802.11n™-2009, *"IEEE Standard for Information technology – Local and metropolitan area networks – Specific requirements – Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications Amendment 5: Enhancements for Higher Throughput"*, October 29, 2009

[4] Siemon white paper, *"Advantages of Using Siemon Shielded Cabling Systems to Power Remote Network Devices"*, 2013

[5] ISO/IEC TR 24704, *"Information technology – Customer premises cabling for wireless access points"*, July, 2004

[6] TIA TSB-194-A, *"Telecommunications Cabling Guidelines for Wireless Access Points"*, November, 2013

[7] APC, *"Five Things to Know about 802.11ac"*, May, 2013

[8] Siemon white paper, *"IEEE 802.3at PoE Plus Operating Efficiency: How to Keep a Hot Application Running Cool"*, 2010

[9] IEC 60512-99-001, *"Connectors for Electronic Equipment – Tests and Measurements – Part 99-001: Test Schedule for Engaging and Separating Connectors Under Electrical Load – Test 99A: Connectors Used in Twisted Pair Communication Cabling with Remote Power"*, 2012

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