The Real Bottleneck of the Future:

Wired or Wireless

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Introduction

Whenever you move your eyes now days you will see news and ads talking about products or technologies that can make your digital life more easy and "speedy".

And, as a Humans, we like to compare mostly with speed, my car is very fast, my internet speed is very fast, etc.

And with rapid technology innovations; you feel everything is going to be perfect, but what if our progress was focusing on some things and forgetting others.

Herein is the source of this paper: I will focus on how some innovation progressions in Wi-Fi technology can't be done without the support of other systems. We will explore the future of Wi-Fi, with Wi-Fi 7 as the next step, and how we may reach a point where wireless is not the bottleneck of our networks. This key point must be taken in our consideration when we design a wireless network, and it should be considered today rather than waiting for the future. The main focus of the article is the introduction of potential issues and some discussion of possible solutions for the future.

Where are We Standing?

Mobility is something valuable for us and accessing data while we are not attached to a cable, which limits our movements, especially in new demanding offices or in our houses. In addition to general mobility, the number of connected devices continues to increase. The first phase of increase was multiple devices per user. This phase was significant and resulted in the requirement of high-density design for many deployments. The next phase, which we are in and quickly expanding, is the phase of the connected things or the Internet of Things, much of which utilizes Wi-Fi. Many organizations will connect thousands or tens of thousands of these "phase two" devices at single locations, requiring a very different approach to the design of supporting systems behind the Wi-Fi network.

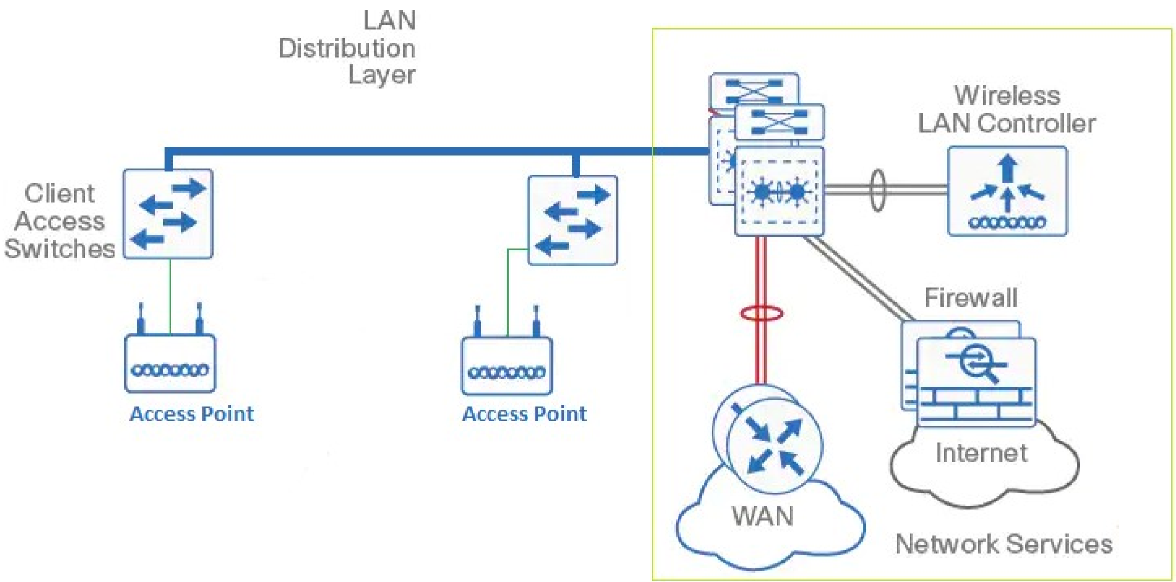
The Wi-Fi industry has evolved since Wi-Fi generation 1 (the 802.11-1997 standard amended by 802.11b in 1999). Now we have seen the new Wi-Fi 6 and even the extended version which has enabled the 6 GHz band with 1200 MHz of potential bandwidth. The following table shows the evolved technologies and standards of Wi-Fi and related speeds, while mapping the Wi-Fi Alliance "tech" to the IEEE amendments and capabilities:

Tech	Standard	Speed*	MIMO	Deployed
Wi-Fi 1	IEEE802.11b	11Mbps	N/A	Yes
Wi-Fi 2	IEEE802.11a	54Mbps	N/A	Yes
Wi-Fi 3	IEEE802.11g	54Mbps		Yes
Wi-Fi 4	IEEE802.11n	288Mbps @20Mhz 600Mbps@ 40Mhz	Up to 2	Yes
Wi-Fi 5	IEEE802.11ac	300Mbps@ 20Mhz 800Mbps@ 40Mhz	Up to 4	Yes
Wi-Fi 6	IEEE802.11ax	1.1Gbps@20Mhz 2.2Gbps @40Mhz	Up to 8	Yes
Wi-Fi 6E	IEEE802.11ax	1.1Gbps@20Mhz 9Gbps @80+80Mhz	Up to 8	Government Regulations adoption status
Wi-Fi 7	IEEE802.11be	~45Gbps@320Mhz	Up to 16	studies

*Speeds here are reflecting the highest data rates of the standard and not throughput. Values may vary depending on the many parameters of the RF link or channel

UTP Categories	Data Rate	Max. Length	Cable Type	Application
CAT1	Up to 1Mbps	--	Twisted Pair	Old Telephone Cable
CAT2	Up to 4Mbps	--	Twisted Pair	Token Ring Networks
CAT3	Up to 10Mbps	100m	Twisted Pair	Token Ring & 10BaseT Ethernet
CAT4	Up to 16Mbps	100m	Twisted Pair	Token Ring Networks
CAT5	Up to 100Mbps	100m	Twisted Pair	Ethernet, Fast Ethernet, Token Rings
CAT5e	Up to 1Gbps	100m	Twisted Pair	Ethernet, FastEthernet, GigabitEthernet
CAT6	Up to 10Gbps	100m	Twisted Pair	GigabitEthernet, 55m up to 10G
CAT6a	Up to 10Gbps	100m	Twisted Pair	GigabitEthernet, 55m up to 10G
CAT7	Up to 10Gbps	100m	Twisted Pair	GigabitEthernet, 55m up to 10G
CAT8	Up to 10Gbps	100m	Twisted Pair	GigabitEthernet, 55m up to 10G

For most wireless deployments, they were designed with an architecture based on the common use case of a star network, which is represented in the following diagram:



The cable system is playing a vital role here, since it is responsible of the followings:

1. Energizing the APs by providing PoE from the source to function.
2. Connecting the APs to the controllers and providing management and control.
3. Connecting the user to the ultimate destination - either Internet or local network resources.

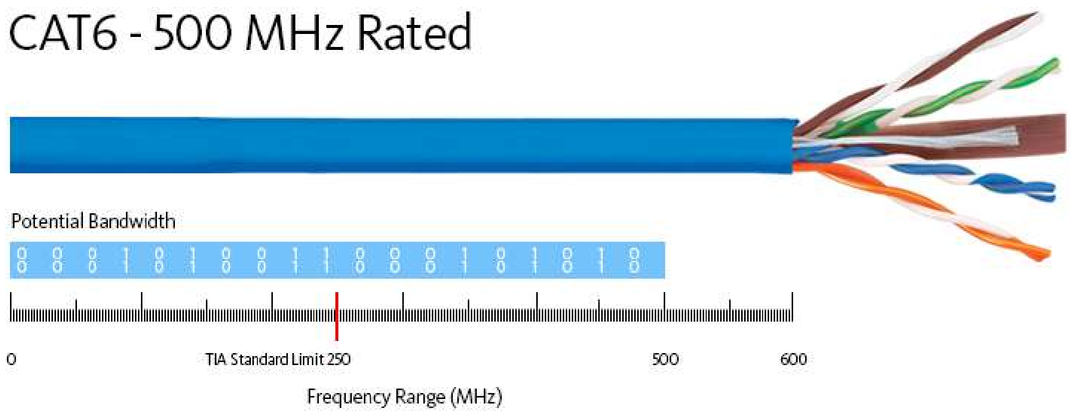
But what about Wireless mesh networks, with dual or triple band – the new Wi-Fi 6E, we have a very good wireless backhaul to the DS layer - Distribution System Layer - here is the switching network that can let users access the Datacenter or Cloud Services - where the new 6 GHz band can do a perfect backhauling service and still have 2.4 GHz and 5 GHz, as well as other portions of 6 GHz, for users to access the network.

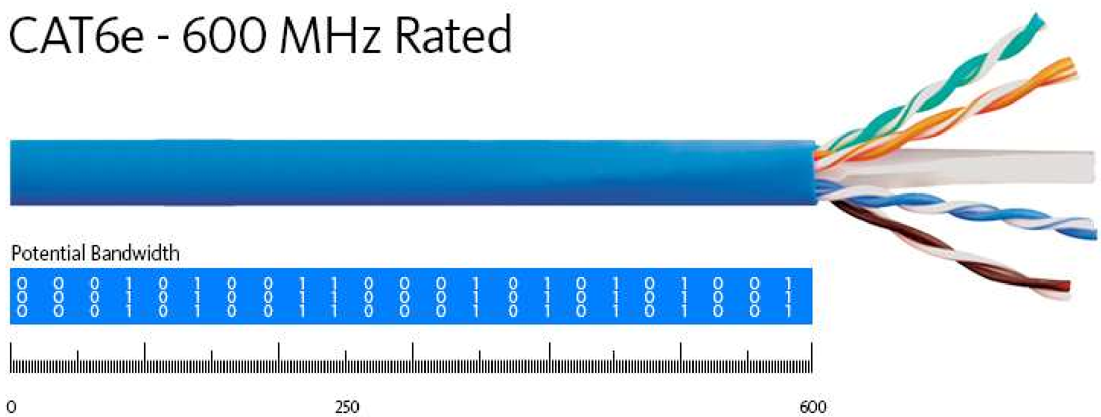
The good news is that much more frequency space is coming to our WLANs, but have we asked ourselves about the near future and the consumption of more bandwidth from new services such UHD, 4K, 8K, VR and low latency games, and more dwell time in offices or houses needing more Wi-Fi access.

Vendors and manufacturers are pushing the speed of innovation, more technologies, and techniques to access the spectrum, with less paced innovation in the wired side.

Do you think the multigigabit wired cables can support an access point with future Wi-Fi 7 capabilities for higher bandwidth that may reach up to 45 Gbps, this is the question for which we must find an answer?

An example of current wired technologies and comparison between CAT6 and CAT6e are presented next:





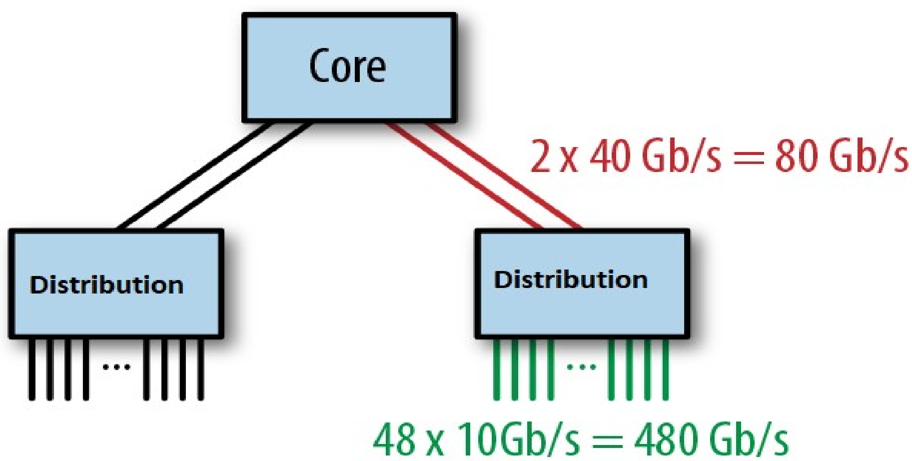
Indeed, there is some progress in reaching higher bandwidth in wired cables but does this progress cover the gap with access bandwidth of emerging technologies of Wi-Fi when multiple APs are deployed that must be connected to the wired infrastructure?

The table below lists some capabilities of both previous cables:

Features/Specs	CAT6	CAT6e
Potential Bandwidth (per sec)	1Gbps	1Gbps
Data Transmission	1000 BASE-TX	Exceeds 1000 BASE-TX
Frequency Range Minimum	0 - 250 MHz	0 - 250 MHz
Frequency Maximum	500 MHz	600 MHz
Performance Distance	328 Feet	328 Feet
Alt. Distance	10Gb 180ft	10Gb 180ft

Conceptual and Mathematical Analysis

The ideal network design approaches the 1:1 oversubscription but entirely depends on the applications, traffic patterns, and capacity needed by the network devices. But what if we have other values or the traffic pattern has changed for any reason. The oversubscription is illustrated in the picture below:



The ratio for the input traffic and the output traffic will be: 480:80 or 6:1

So, the ratio of the subscription will be 6:1, which is it far away from the best case of 1:1 and here we face a bottleneck for the network and will have congestion on the uplinks from the distribution switch and then the buffers of the switch will fill and the ASIC will be overloaded. Imagine we have an AP with assumed rate of 45 Gbps, we all know that in Wi-Fi we can utilize only is about 0.35 to 0.50 of the data rate so in our case we will say we have 15.75 Gbps available to utilize as data traffic for one user on one AP – in Wi-Fi the used throughput is less than the rated data rate of the standard due to the overhead of contention and management traffic. Also assume we have 3 access points and those access points are connected to a 24 port switch with 10 Gbps access ports.

We will have 3*AP*15.75 Gbps = 47.25 Gbps of total traffic on the switch that will be forwarded to the core switch and on to the internet, let assume. With only 3 access points we have this amount of traffic, now how about if we have 50 or 100 access points in a facility such a university or an airport, we will have significant reduction in throughput with access points based on copper CATxx cables (I am assuming the user is utilizing the full bandwidth).

A solution is needed and new thinking about the backhauling of traffic into and from the core network must be considered. I didn't introduce these questions to have immediate answers, but we must have new types of access points interfaces at some point.

Fiber Optics

Fiber optics access media cables have practically unlimited bandwidth by today's standards, and the primary limiting factor to the speed of transmission is related to the transceivers that form the connections. The table below shows the differences between Fiber Optics and Copper cables:

Bandwidth	60 Tbps and beyond	10 Gbps
Future-Proof	Evolving towards the desktop	CAT7 in development
Distance	12 Miles+ @ 10,000Mbps	300 Ft. @ 1,000Mbps
Noise	Immune	Susceptible to EM/RFI interference, crosstalk and voltage surges
Security	Nearly impossible to tap	Susceptible to tapping
Handling	Lightweight, thin diameter, strong pulling strength	Heavy, thicker diameter, strict pulling specifications
Lifecycle	30-50 Years	5 Years
Weight/1,000 ft.	4 Lbs.	39 Lbs.
Energy Consumed	2W per User	>10W per User

Table 4 differences between Fiberoptics and Copper
(SOURCE: https://www.multicominc.com/training/technical-resources/copper-vs-fiber-which-to-choose/)

So, fiber optics can do the job if we find an access point that support SFP or integrated fiberoptics transceiver, and when we have the speed on APs supporting 50Gbps to 100Gbps, 9ur oversubscription issue will be eliminated, and we will have full speed to the destination service. (Assuming, the rest of the wired network is also designed to handle the load.)

But we still have some problems like:

1. Power delivery to energize the Access Point and the need for additional power sources to do this instead of the network's switches.
2. Fiber optics termination and splicing costs are higher compared to the UTP termination.
3. Additional transceivers for the switch side may increase the cost of deployment.

Power Delivery

Historically, the network switches handled and currently handle the power delivery for the end devices such access points through PoE (Power over Ethernet) technology, and this makes the implementation and deployment easy thanks to the copper UTP cable that uses the copper and unused pairs to do this. But now we have the fiber optics which isolate the circuitry and electrical parameters from connected devices. How can we solve this?

A solution used by Corning SD-LAN (SD-LAN is a technology registered for Corning® utilizing the optical network to transport triple play services mostly for hospitality industries) technology to energize the OTN fiberoptic devices on the same fiber optic cable, and that was a patent for Corning called composite fiber cables

The cable consists of multiple strands of single mode fiber and the same number of stranded for twisted pairs, as each fiber strand connects network end devices, and the twisted pair energize the devices. From the near end -IDF side- we can find a PSU – (Power supply Unit), you can see the picture on the next page. This device can supply each port up to 100w for about 90 meters. So, with the use of this technology we can solve the first issue we mentioned before: powering the devices.

Composite cable by Corning.

Power Supply Unit from Corning® used for SD-LAN technology.

Fiber Optics Deployment Cost

Every day we witness an evolution in many technological areas, and these evolutions sometimes come to the front to solve a problem such reduced cost, decreased deployment time or elimination of some obstacle. And the fiber optics industry has evolved with many technologies used to enhance this area. These include the termination process, now we can find more efficient splicing machines and more professional are trained to support the needs of system deployments.

Also, another type of terminations was introduced; such mechanical termination and the gel filling materials which matches the refraction indexes to connect two fiber strands are quicker and no longer need splicing machines. And we will see more innovative techniques to enhance this process, which can support the evolving of fiber optics industry.

Fiber Optic Transceivers

Fiber optics transceivers also have their own evolution, many thanks to the development in transistors and ICs (Integrated Circuits) that are used in transceivers and take it to the next level of speeds, now we can use SFPs (Small Form-Factor Pluggable).

Here are some of the known Optical Transceivers:

1. SFP (Small Form-factor Pluggable): 1 Gigabit Ethernet speed.
2. SFP+ (Small Form-factor Pluggable Plus): 10 Gigabit Ethernet speed.
3. QSFP (Quad Small Form-factor Pluggable): 40 and 100 Gigabit Ethernet.
4. OSFP (Octal Small Form-factor Pluggable): 200 and 400 Gigabit Ethernet.
5. QSFP-DD (Quad Small Form-factor Pluggable – Double Density): 200 and 400 Gigabit Ethernet.

Conclusion

In the journey of my article, you can find that it is not the first time to discuss a topic such as this, but my opinion here is Standards Organizations must provide enhancements through their processes to issue and declare new capabilities. They should consider the requirement engineering for the new technology or standard that will fit in the system of interest, so it can work in at least 85% of the use cases. This can ease manufacturing and deployment of the technology.

Some access points may have optical fiber interfaces in the market now days – I don't say I am the first to mention that, but I think more should be done in this area, because I believe there is a gap.