# BVCC General Meeting

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**Components of a Home Network**

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# Components of a Home Network

- **A visit to the Network section of BestBuy and similar stores can be overwhelming**
  - **So many choices**
  - **What do all these different devices do and what do I really need?**
  - **Do I need a $900 WiFi Router?**
  - **Should I just go with what my Internet Provider can supply or buy my own?**

## Basics

- **Every home network must have a Modem – the interface between your Internet Provider, with an Ethernet interface for your local network.**
- **Every home network should have a WiFi router**
  - **allows one Ethernet interface and one IP address from your ISP to service many devices, either via wired Ethernet connection or via WiFi**
  - **serves as a "firewall" to prevent others from probing ports on your devices from the Internet.**
- **Can be two separate devices or a single combined device**

If you get both from your ISP, odds are they will be in one box – cheaper and easier for them to maintain. Devices from your ISP will likely involve a monthly rental charge, and the devices are less likely to be the latest technology.

If you decide to buy one or both of these devices, you have greater flexibility. Generally speaking, a combo device is more convenient but also has more opportunity for software/firmware bugs and may have fewer features than with a separate router, and also will cost more to replace should your ISP upgrade their transmission system and require you to upgrade your modem.

# Basics

- **Other Network Devices:**
  - **Switches – useful when you have more devices needing a wired Ethernet connection than Ethernet ports available – allows full-duplex concurrent transmit/receive and multiple devices connected to the same switch can talk directly to each other while other devices transmit/receive data through the switch on the path to the router.**
  - **WiFi Extenders – various technologies for extending WiFi coverage to marginal areas of a house. A 2nd router can even be configured as an Ethernet-cable-connected WiFi extender. Can be a cheap alternative to try; but may not solve the problem, and not nearly as convenient as a mesh-router system.**
  - **Hubs – can provide a cheaper alternative to a switch, but MUCH poorer performance (half-duplex: only one device connected to the hub can transmit at a time) Not recommended. Spend a little more and get a switch.**

## Ethernet Cables

- **The standard for wired network connections**
  - **4 twisted pairs with RJ45 connector on each end**
  - **Most now rated for 1 Gbps, or higher, but some older cables only supported 100 Mbps or less. 100 Mbps used 2 of the 4 pairs, 1 Gbps uses all 4 pairs (2 for each direction)**
  - **a computer uses different pairs for transmit and receive (full duplex)**
  - **Can purchase cables in specific lengths, or create cables in custom lengths (requires special tools and testing equipment)**
  - **House can be wired for Ethernet. Higher speeds require better quality cable: CAT6 will support 10 Gigabit up to 55m; CAT6a supports 10 Gigabit to 100m.**

Normal cables – cable pairs are connected identically at both ends of the cable

Crossover Ethernet cables – now rarely used, but can be purchased or made. Allows two computers to be directly connected with an Ethernet cable without another device between. The transmit and receive pairs are interchanged at one connector end so the transmit pair from one computer gets connected to what the other computer uses as the receive pair. Not needed for connect to router/switch/hub because those devices expect to receive on the pair(s) used at the other end for transmission.

The twisting of the individual pairs prevents cross-talk between the pairs and prevents the cable from acting like an antenna at the high frequencies involved.

# Ethernet Cables

- **The tight and consistent twisting of the pairs in an Ethernet cable is what permits transmission of data at high frequencies without having the pairs act as an antenna, creating and being subject to RF interference**
- **Wall mount connectors are available for custom wired Ethernet installation in a house.**
- **RJ45 couplers can be used to join two Ethernet cables into a longer cable (in a suitable environment)**
- **Given the proper tools and skill, a broken RJ45 connector can be replaced.**

# TCP/IP

- **Transmission Control Protocol/Internet Protocol – used for all network traffic local and internet**
  - **Data travels in independent blocks of bytes, typically limited to about 1500 bytes, called packets**
  - **Each packet contains source IP address & port, destination IP address and port**
  - **To communicate with another device, a packet is sent to establish a logical connection or "socket" to that device by using the IP address and desired port (service related) of the other device.**
  - **When the packet reaches a router or a switch, the destination IP address determines how to "route" the packet to an output path that either gets it to its intended destination, or gets it one step closer to its intended destination.**
  - **Every physical transmission path can be shared by packets associated with many different logical connections.**

Checksums and packet sequence numbers allow checking individual packets for transmission errors and verifying all packets are received correctly. While smaller packets might increase transmission overhead, larger packets increase odds of an error and expense of re-transmission.

TCP/IP was designed to allow redundancy and to handle lost, duplicated packets or packets delivered out of order. Network conditions may cause Individual packets to be routed by different paths. Packet sequence numbers allow receiver to arrange packets in correct order. The intended receiver of a packet must return an acknowledgment of successful receipt within an allotted time frame or re-transmission will be attempted.

# TCP/IP

- **IP Addresses**
  - **w.x.y.z, where each part is a number from 0 – 255**
  - **Some ranges reserved for private subnets, devices not directly connected to Internet**
    - **192.168.x.y - 256 subnets w 256 addresses ea**
    - **172.16.0.0 – 172.31.255.255 – 16 subnets w 65536 addresses ea**
    - **10.x.y.z – 10.255.255.255 – 1 subnet with 16777216 addresses**
- **MAC Addresses**
  - **A hex value xx:xx:xx:xx:xx:xx (each part between 00 – FF) that uniquely defines the manufacturer and each specific Ethernet or WiFi interface on all network-connectable devices.**
  - **Can be used by routers that assign IP address to always assign the same IP address to a specific device.**

# Modems

- **Modem – short for modulator/demodulator (from radio terminology) converts a signal to and from a format suitable for long-distance transmission**
  - **Typically provided by Internet Service Provider – must match the requirements of specific ISP system; can also be purchased**
  - **System upgrades by ISP may require modem to be changed**
  - **Modems that support Internet over cable TV system coax are totally different than and incompatible with modems that support Internet over phone lines**
  - **Has one interface that connects to the ISP communication service, another Ethernet interface the connects to a user router device. (Direct connect to a single computer will also work, but not recommended for security reasons.)**
  - **Typically no user configuration possible for a modem, but there may be an internal IP address that can be queried by the user (my Cox modem will return signal status info to a web browser on my home LAN from address 192.168.100.1)**

In order to be able to "talk" to the modem from your LAN, the modem must have an internal IP address that is outside the subnet range defined for user devices connected to your router. Typical router default subnet definition is to use 192.168.0.0 – 192.168 0.255, or some other low number for the third part. The Cox modems now use a high value "100" which shouldn't conflict, but this was not always the case. If there is a conflict, Internet access through the modem still works fine; there is just no way a computer on your LAN can talk directly to the modem itself.

Can buy a DOCIS 3.1 modem for $120 or get from Cox for $5/month. Break even point: 2 years.

# Mobile Hotspots

- **Many smart phones can be configured to act as a mobile hotspot. When used in that mode, the smart phone is in effect acting as a combination modem/WiFi-router, but with very limited features and very limited WiFi range. Usually the number of WiFi devices that can be accommodated is low (5 or 10), and of course there is no Ethernet port for a wired connection.**
- **It is possible to find devices that will connect to a WiFi hotspot and provide an Ethernet port. When sufficiently desperate (e.g., 3 day Cox outage), you can actually hook such a combination to a home WiFi router in place of the home ISP modem and get [degraded] home network Internet service. It forces your mobile phone to be fixed at a location near the WiFi router, so only tolerable as a short-term solution. Don't try to stream movies, or you can easily exceed your phone data plan; but email and ordinary web surfing shouldn't be a problem.**

# WiFi Routers

- **This is where technology seems to change the most rapidly and where the widest number of confusing options are available.**
  - **Frequent new WiFi standards to support faster speeds**
  - **More expensive WiFi routers likely support more WiFi communications at the same time reducing contention**
  - **10/100 Mbps vs 1000 Mbps (Gigabit) Ethernet ports. Any new router should support Gigabit Ethernet ports these days. If you don't need it today, you will before the router is retired.**
  - **New configuration options and features**
  - **Mesh routers – if you have trouble covering your entire house with good WiFi performance using only one WiFi router, you may want to look at multiple-unit mesh router systems. They are more expensive, but do a much better job than alternatives.**
  - **Routers tend to be built with planned obsolescence – their power supplies start getting weak after a few years and it is not unusual for a router's WiFi range to degrade over time. If performance no longer seems acceptable and the router is 3 or 4 years old, it's probably time for an upgrade.**

## What Does a Router Do?

- **Does a handshake with the modem through its up link or WAN port to obtain an Internet (non-private) IP address assignment from your ISP, and to also obtain a DNS (domain name server) IP address from your ISP**
- **Does a handshake with any user device connected to the router by wire or WiFi to negotiate transmission speed, assign a LAN (private) IP address to the device (called DHCP service, possibly based on MAC address of the device), and to pass along a DNS IP address and "Gateway" to the user device – for home networks these will be the first device address in the subnet range, the address of the router itself (like 192.168.0.1 if using default subnet 192.168.0.x)**

WAN = Wide Area Network (Internet connection)

A "Gateway" is a device address within the local network to which packets are sent that are destined for devices outside the local network. Since it is the router that has connections to both the Internet and the local network, the gateway in a home network is the LAN address of the router, typically something like 192.168.0.1. Local network devices don't need to know how the gateway is connected to the outside world, only that it is connected.

# What Does a Router Do?

- **Packets sent from one user device on the LAN to another device on the LAN will be received by the router and forwarded to the correct LAN interface to reach the target device.**
- **Packets sent from a user device on the LAN to an Internet address will pass through the router with modification and sent on its WAN interface through the modem to the Internet so they appear to come from the Internet address assigned to the WAN interface on the router, and communications received back from the remote site to the router will be modified so they are sent back to actual LAN device that initiated the communication.**
- **The router acts as a "Firewall": packets received on the WAN interface from the Internet that are not associated with a communication initiated from your LAN are normally blocked, unless an explicit configuration definition has been made on the router to tell it to which LAN IP address and port the packet should be routed. The are also some ways in which an application can dynamically enable a router to open up a path for an Internet request to pass through the router.**

# What Does a Switch Do

- **A switch is sort of like a router, with no WAN port, and no IP address assignment capability (DHCP).**
- **The switch "learns" what IP address are reachable through each of its connected ports, and if a packet is received on one port it is re-transmitted on the appropriate port to reach its target.**
- **The same port can be both transmitting and receiving at the same time and all ports can operate in parallel as long as the total rated throughput of the switch isn't exceeded**
- **The packets are buffered in the switch so transmission on individual ports is not constrained by slower devices on ports not involved in that transmission**
- **Comes with various number of ports and throughput capacities. I have one with 5 ports, the Training Center has a 24 port version.**
- **Solves the problem of how to put more wired devices on the LAN than the Ethernet ports on a typical router; or how to run multiple wired devices in a room remote from the router without running a cable for each device**
- **For home use look for a 10/100/1000 Ethernet switch. They are only slightly more expensive than a slower 10/100 switch and will have a longer useful life with new devices.**

Switches can be "managed" or "unmanaged".

The ones at retail stores are most likely the unmanaged variety, as they require no configuration, are cheaper, and should be quite adequate for normal home use where additional wired ports may be the only issue.

The managed variety are more intended for corporate environments, where it may be desirable to monitor, control, or prioritize traffic passing through the switch.

# What About Ethernet Hubs?

- **NOT RECOMMENDED.**
  - **They are simplistic, devices, significantly slower when supporting concurrent activity from multiple devices. Used to be significantly cheaper than switches a decade ago, but now nearly the same price.**
  - **Doesn't look at packet content. Just repeats (re-transmits) content received on any port on all other ports. One device transmitting makes the box 100% busy; no device can both transmit & receive at the same time; and all connected interfaces see all the packets for other devices on the hub. This also means if any connected device can only operate at a slower speed, all devices connected to the hub are forced to operate at that slower transmission speed.**

# WiFi Extenders

- **The WiFi Extender becomes an independent WiFi Access Point – causes problems if you need continuous mobile device connectivity while moving around in the house**
- **Need to establish a connection to an existing WiFi router via**
  - **WiFi – uses up part of your router WiFi bandwidth. Needs to be close enough to both router and area with bad coverage for good signals. Not always possible.**
  - **Ethernet signal over house power lines – limitations**
  - **Signal over coax – in theory can use house coax system, but hardware for this hard to locate**
  - **Signal over Ethernet cable – one can actually configure some routers to act as a glorified switch with WiFi access point by disabling some of the router features. Generally requires research and experimentation as instructions are usually inadequate. More routers will work for this if a separate subnet with limited access to the main subnet is acceptable. This is how we provide WiFi Internet access in our meeting room at HCC from the Internet service in our Training Center.**

## WiFi Extenders

- **Have tried all but the coax-connected extenders – too much expense and effort to test that. The WiFi-connected is the cheapest to try. Typical Ethernet-over-power works like an Ethernet cable: you still need to hook some other device like a WiFi router at the remote end to provide a WiFi access point.**
- **YMMV, but I never found the 2nd WiFi access point approach completely satisfactory. Many mobile devices were unable to transition without disruption, but it worked until I could find something better. Mesh routers have so far been the best solution for my house.**

Doesn't help that most WiFi-connected WiFi extenders are small direct-plug-in units designed to be installed at electrical output level -- typically about 1 ft above baseboard, so that line-of-sight signal transmission must travel through any furniture in the room.

If your problem is a building with walls that block most of a normal WiFi signal (like Highlands Crossing Center), then WiFi Extenders may only work if they can be arranged to take advantage of line-of-sight through windows and doorways. And Extenders based on power-line transmission are also less likely to function in a commercial building (like HCC) because of interference from motors and other devices and blockage by independent transformers.

## Router Options
## Throughput

- **Routers (and switches) are computers with specialized hardware running specialized operating systems (typically some variant of Linux)**
- **WiFi and Ethernet interfaces impose an upper bound on performance, but internal processor and memory speed place a lower limit on total data throughput of the device**
- **Number of WiFi transmitters/receivers constrain how many different WiFi devices can be transferring data at same time**
- **Within the same brand, the naming scheme and pricing tend to imply the capability**

Obviously want a router powerful enough to allow you to utilize the Internet service you are paying for.

If you do a significant amount of data transfer between different devices within your own house (for example, a heavily used network file server, or doing backups of one computer onto another), it may be useful to have a router that is able to sustain much higher data transfer rates than your connection to the Internet.

If most of your devices in the house connect via WiFi, routers than can support multiple concurrent WiFi transfers can significantly reduce contention and improve throughput.

Weak WiFi signals in some parts of a house, can force slower transmission speeds to affected devices, which can in turn reduce overall LAN performance.

# Router Options
# Evolution of WiFi Standards

- **802.11b – 2.4 GHz, 11 Mbps – 1 Mbps**
- **802.11.a – 5 GHz, 54 Mbps – 6 Mbps**
- **802.11g – 2.4 GHz, 54 Mbps – 1 Mbps**
- **802.11n (WiFi 4) – 2.4/5 GHz, 300 - 600 Mbps**
- **802.11ac (Wi-Fi 5) – 2.4/5 GHz, 433 Mbps - 6.8 Gbps, beamed**
- **802.11ax (Wi-Fi 6) – 2.4/5 GHz, 10 Gbps, device scheduling**
  - **Max data rate higher than typical: signal degradation with distance, re-transmission because of errors, interference with other devices (other WiFi, microwave ovens, Bluetooth, cordless phones)**

Typically, a modem can fall back to earlier standards to support slower devices or when a signal is too weak to support faster transmission.

Support of a standard means the modem can connect to other devices that support the same standard. It does not mean the devices can communicate at the max data rate supported by the standard.

That two devices can communicate at some peak speed, doesn't necessarily mean they can sustain that as an average speed. There may be internal bottlenecks (processing speed, memory, contention with other devices) that constrain the average speed of a sustained transmission.

May pay a premium for the top standard. Doesn't make sense unless you have an actual need for it.

# Router Options
# Ethernet Port Speed

- **10/100 Mbps ("Fast Ethernet") vs 10/100/1000 Mbps (Gigabit)**
  - **Older routers, computers, & really cheap new routers may only have 10/100 Ethernet interfaces. All newer computers should support Gigabit Ethernet.**
  - **Makes sense to pay a little more for Gigabit Ethernet ports to fully support newer devices you will acquire. Two gigabit-capable computers wired directly to a gigabit router can communicate with each other at 1000 Mbps, even if your ISP Internet connection is considerably less than that.**
  - **Lack of support for 10/100/1000 ports implies a lack of processing power, which implies throughput limitations for WiFi as well.**

"Fast" is relative. 100 was fast compared to 10.

If you have some really old Ethernet cables, they may not support Gigabit Ethernet. The higher speed requires 4 functioning pairs in the cable, not just 2, and the pairs must be twisted tighter and with higher quality control to reduce cross talk and other interference at the higher frequencies required for gigabit Ethernet.

Most 10/100/1000 ports on routers and switches have LED lights that indicate whether the port is connected at 100 vs 1000, which may be used to detect a cable problem or a connection to an older device that doesn't support 1000 Mbps.

# Router Options
# Mesh Routers

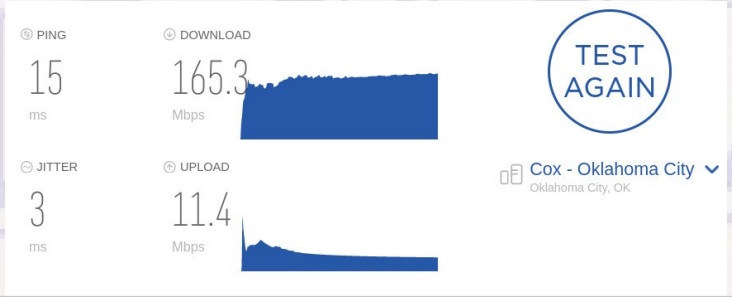
- **Mesh Routers allow multiple router devices (primary & 1 or more satellites) to act as a single device and cover a wider area well**
  - **Unlike WiFi Extenders, the communication path between primary and satellites is outside and does not take up normal WiFi bandwidth**
  - **Unlike WiFi Extenders or multiple routers, the hand off of a device among primary and satellite mesh routers is transparent to the end-user WiFi device**
  - **Mesh routers are more expensive. ~$300 for two-unit WiFI 5 system vs $100 - $150 for pretty good ordinary routers; have seen WiFi 6 mesh system at ~$900. Can make sense if you have tried cheaper alternatives and are not satisfied with the results.**

# Do I Have a Performance Problem

- **Streaming Video has undesirable pauses**
  - **could be problems with service, your ISP Internet speed, or with your home Network**
- **Measured Download/Upload speeds don't agree with what ISP claims I should have**
  - **Search for a "speed test" – most ISPs provide one (can use non-ISP test, but could be slower); Upload is always much slower (except for some more-costly business plans)**
    - **Wired Ethernet should get best results. Newer WiFi device near router will be best WiFi results. Use that mobile WiFi device to test WiFi results in other important locations in the house.**

# Do I Have a Performance Problem
# Cox Speed Test

- **https://www.cox.com/residential/support/internet/speedtest.html**
- **Results for Cox service rated at 150 Mbps download, 10 Mbps upload. Can get slightly better or worse depending on system load. Initial vs steady-state rate changes as ISP system adjusts to your load. In this case, clearly there is no bottleneck for wired devices for Internet access.**
- **Checking for router bottlenecks within the LAN is trickier. Need a server app on one device, a client app on the other, and a large file to transfer that can be timed.**




WiFi Speed test from iPhone6:
Near Satellite router: 171.5/11.2 Mbps down/up
In Office 15' from router: 171.1/11.3 Mbps
Far corner 2nd floor: 138.3/10.2 Mbps
Far corner backyard: 162.4/4.1 Mbps (suspect the "beamed" transmit of router was more effective than non-beamed transmit of iPhone in countering interference from neighbors WiFi)

## Non-Mesh Router Examples

- **Linksys WRT1900ACS – 600 + 1300 Mbps**
  - **4 - GB ports, USB3.0 & eSATA $180**


- **Linksys EA6350-4B -AC1200**
  - **4 – GB ports (max 867 Mbps) $65**

All routers have 1 Gigabit Ethernet WAN port (to connect to modem). 4 – Gigabit Ethernet LAN ports seems to be fairly standard.

Most, if not all, will tell the highest WiFi standard supported (AC = WiFi 5) and the max theoretical data rates of 2.4 & 5 Ghz bands combined – sometimes broken down like 600+1300 (smaller is always the 2.4GHz band), as in AC1900. Expect actual peak throughput to be less.

Multiple visible antennas suggests ability to handle multiple concurrent WiFi transmissions, but specs should clarify.

Cheaper model description admits will not support full 1 Gigabit rates on Ethernet ports, but this probably typical of an AC1200 router whether admitted or not.

## Non-Mesh Router Examples

- **Netgear Nighthawk AC1900 $150**

- **Netgear R6230, AC1200 $50**


All routers have basic customization features. Some also provide "guest" network support (different network password, isolation). Some have parental control features.

## Mesh Router Examples

- **Amazon eero 6 dual band (3-units) $280**
  **Calls itself WiFi6 but only claims 500 Mbps!**
  **Have to go to eero 6 pro at $600 for GB speeds.**

- **TPLink Deco S4 (AC1200) (3-units) $130**

When I got my Netgear Orbi mesh router in late 2019 there were very few choices. Now there are many. Many mesh routers appear to come with fewer Ethernet ports – it looks like the primary unit of the eero only has two, and one of those may be the WAN port.

It also appears that mesh technology can now be found with some slower (and cheaper) routers. I suspect the TPLink S4, which only claims AC1200 status, could also have problems exploiting the full potential of Cox 150 Mbps Internet.

Another important piece of info which is hard to discern from terse descriptions is the number of parallel WiFi communications and how the main device communicates with its satellites – for best performance that should be a different freq band.

## Mesh Router Examples

- **Netgear Orbi tri-band 3Gbps (2 units) $270 (AX4200)**

- **Netgear Orbi tri-band, WiFi-6 4.2Gbps (3 units) $550**
- **Netgear Orbi Ultra, WiFi-6, 6Gbps (3 units) $1000 (also avail in 2-unit $700, and 4-unit $1300)**

Was tired of dealing with problematic WiFi. Find I went to WiFi-6 before I knew what it was.

One of the earlier manufacturers of retail mesh routers with AX (WiFi-6). Can also add additional satellites later.

Main unit and satellites communicate using different channel than WiFi devices so full WiFi bandwidth available to devices.

Has a mobile device app that is useful for firmware upgrades.

Main unit has 3 Ethernet ports plus WAN port. Satellite has 4 Ethernet ports.

Found Windows 10 had a bug in dealing with my laptop WiFi hardware and WiFi-6 (but circumvention found)

Questions?