**Joe Mayes: All right. In this block, we’re going to look at wireless technologies in 802.11 and other systems.**
Overview

Standards, technology, capabilities

- Wi-Fi
- Bluetooth
- WiMAX
- LTE / HSPA / EvDO

**002 Specifically, we're going to look for Wi-Fi, Bluetooth, WiMAX, LTE and other related cellular systems, and we're going to look at the technologies and capabilities and why people use one over the other, and why they cause havoc with each other at times.
**Wi-Fi vs. Bluetooth vs. WiMAX vs. “Data”**

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<td>Network access without the physical cable drop</td>
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<td>Metropolitan area networks</td>
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<tr>
<td>Up to 600 Mbits/sec</td>
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<td>Broadband everywhere without the cable infrastructure</td>
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**003 So, first one. Wi-Fi, Bluetooth, WiMAX, data networks, cellular data--they've got different characteristics. Wi-Fi systems, generally used for local area networks. You can actually shoot Wi-Fi between buildings, or in the case where I did, between mountaintops. I worked with a wireless--I worked with a public utility district, a PUD--that's a Western U.S. term, much more than on the East Coast--but I worked with a PUD out in the ranchlands and rangelands of Eastern Washington State, and they were spread over about 200 miles, and we connected their electrical substations**
sometimes with wireless connections; 802.11 we shot-- 802.11-- for eight to ten miles at a time.

So you can do local area networks or you can do the point-to-point wireless, but generally speaking 600 megabits per second is the fastest published data rate. The actual ability to move data through it is closer to 200 to 300 megabits per second because although the-- it's like the Ethernet-- although you can put signals out at a signaling rate of 600 megabits per second, some of it is supervisory signaling; some of it is wait times; and the effective data rates are about half of that system. But it can go-- generally speaking, Wi-Fi systems can go between 100 and 300 feet from an access point in a building or in an open area.

Where if you look at Bluetooth instead, how far does Bluetooth reach? Anybody have an idea?

Student: It’s like 30 feet or--

Joe Mayes: Yeah, about 30 feet.

Student: Max.

Joe Mayes: There is a Bluetooth standard that's built to go 100 feet, but almost no one uses that one. And the reason most people don't use that one is most of these portable devices are battery operated, and it takes a lot more power to shove the longer distance, so they don't use the high-power Bluetooth. So-- because most of the
time you’re trying to talk to a handset or you’re trying to talk to a keyboard or something else very near to you. So you can go lower power and make the batteries last longer.

Data rates up to 3 megabits a second, but if you’re the same kind of typist I am, I can’t run a wireless keyboard and overload that 3 megabits a second; I don’t type that fast.

Another difference, Bluetooth is different from Wi-Fi in that Bluetooth using frequency hopping spread spectrum, and Wi-Fi does not. Wi-Fi uses direct sequence spread discover, and we’ll compare those when we look at it.

Metropolitan area networks. Metropolitan area networks, the biggest advantage— or the biggest example of those is WiMAX. Has anyone heard of WiMAX? WiMAX was a system that was going to be Sprint’s next-generation data wireless network, and WiMAX is a protocol 802.11.16, and was made to shoot over one to three to five miles, and was going to be the way to go wireless to your home. The technology does work, but other technologies, particularly some of the cellular technologies, overtook that space. By the time WiMAX was out in production and being pushed out, the cellular networks were already pushing out 4G cellular, and 4G cellular gave you the same data rates without building a new infrastructure, because the cellular providers are going to build their infrastructure
anyway. So WiMAX is kind of like-- it had a lot of promise, but not much implementation. I lived very near one of the test markets for WiMAX, and it did work. But since people didn't own the equipment already, it was like trying to build an entire new network system, and it just never quite got off the ground.

Student: Would that be from providers? So like AT&T or Comcast or somebody could put up a network in a city and say, "You want our internet. Now you don't need to have your own access point at your house; you can just connect this way." Or for like the city itself to have a network.

Joe Mayes: Mm-hmm. Yeah. I was in Pasco-Richland-Kennewick, Washington, the Tri-Cities, and what they did there was the infrastructure was put in by the power company, and then they wanted to lease that infrastructure out to someone to operate a wireless system over it, and that was kind of the model that was supposed to happen. And it worked in rural areas where there weren't any other way-- or there wasn't another way to connect, because you could put these systems up relatively inexpensively. But not enough traction, and most of the major companies that were heavily involved in this have just kind of devolved.

But what did come up instead were cellular networks. Right? Cellular networks running 3G or 4G, and
that's where we're looking at the long-term evolution and some of the other systems that got us the data rates that we're now getting in our 4G systems, where we now can watch streaming video on a cell phone. For all those people who really like to watch their TV two and a half inches wide.

**Wi-Fi, or Wireless Fidelity.**

**004 So Wi-Fi, or Wireless Fidelity.**
**Wi-Fi Standards**

IEEE – The Institute for Electrical and Electronics Engineering defines the following standards for wireless networks.

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<th>Standard</th>
<th>Description</th>
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<td>802.11</td>
<td>Base standard which covers basic wireless transmission methods like frequency hopping spread spectrum, direct sequence spread spectrum, and infrared</td>
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<td>802.11a</td>
<td>Operates at 5GHz, 6 – 54 Mbps</td>
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<tr>
<td>802.11b</td>
<td>“Wi-Fi” standard, operates at 2.4 GHz, 5.5 and 11 Mbps</td>
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<tr>
<td>802.11g</td>
<td>Operates at 2.4 GHz, 6-54 Mbps</td>
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<tr>
<td>802.11n</td>
<td>Operates at 2.4 and 5 GHz, up to 600Mbps</td>
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<tr>
<td>802.11ac</td>
<td>Draft standard; proposed for 5 GHz; data rates up to 1Gbps</td>
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**005 We talked a little bit about wireless standards here, the original 802.11 standard. The 802.11 original standard was one or two megabits, and it was direct sequence spread spectrum, or frequency hopping spread spectrum. It only took me two weeks to learn how to say that. It’s much more difficult to say than you’d think until you try it. And you could also do it on an infrared.**

So the original standard was kind of like a catchall, the anyway-you-want system. And that became one of the issues is that people didn’t settle on one of those three methods; by the time they went to 802.11b, which
unfortunately was the next system, not the A-- B got approved before A did-- so 802.11b operates only in direct sequence spread spectrum, no frequency hopping, no infrared. Raised the data rate to 11 megabits, and that was the first system that got wide, wide, wide acceptance, which is why we now, even today, see that as a standard, even though that standard goes back to 1999.

802.11a came along right afterward. 802.11a operates up to 54 megabits per second, but it operates on a different radio frequency. So if you want to support both on your laptop, your laptop has to be a dual-band laptop. It has to support 5 GHz and 2.4 GHz. Systems that do that are very good. However, to run two radios instead of one, you need more power, it drains batteries faster, and that's why it's been very slow to adopt on portable devices because they've got so much smaller battery and battery life is so much more critical.

802.11g uses the same technology 802.11a uses, and that's why it got up to 54 megabits, but it does it in the original spectrum. So you can do it with the original radio. All it is is a different way of formatting the signal, and later on in this block we'll talk about that in more detail.

And of course, since we already want things to be faster, we later on came up with 802.11n, which goes up to 600 megabits, but it divides the radio signal up and takes three antennas to operate.
And then we wanted to go ever faster, so 802.11ac recently came out and was ratified, and proposed for 1 gigabits per second of signal. And basically 802.11ac, if you think of a radio signal being this side, and we worked on 802.11 and then 802.11b and 802.11g, 802.11n, we're all this wide. When they wanted to double the speed again, they finally said, "The only way we can do that is to use up twice the frequency range." So instead of a 20 MHz-wide signal, they turned it into a 40 MHz-wide signal, to use twice as many-- to get twice the data rate.

And one of the things you'll see is 802.11ac can only work in the 5 GHz range, because there's not even enough room to double the signal and make it operational in 2.4 GHz. So 802.11ac hasn't gotten a lot of traction yet. Back to that same idea, it's not backward-compatible with 802.11g or 802.11b
Wi-Fi Standards – 802.11b

The de-facto standard in wireless

Low cost of cards and access points resulted in swift acceptance

**006 802.11b did become the de facto standard. Low-cost cards, access points-- I mean, you can get-- I'm going to grab something here. Let me make a change.

Some things are supposed to be amazing. To me this is one of them. This little blue card here-- anyone seen the movie Back to the Future? Right? You remember Doc? He’s holding the video camera and he says, ”A TV studio in a box!” Right? Well, what’s this?

Student: Radio station.
Joe Mayes: This is a radio station on a card, that you can get for nine dollars. I can buy a radio transmitter and receiver for nine dollars. For anybody who’s in traditional radio, who knows what it traditionally took to do that, it’s amazing. Radio transmitter, receiver, on a card that can fit in my wallet, for nine bucks. Amazing stuff. But that’s how it became ubiquitous. That’s how it became an everyday activity. If you look in your laptops-- the military makes you take wireless out of some laptops when they’re used in secret environments, and the chip you take out of the laptop is the size of a postage stamp. And it actually makes connections.

This is actually a wireless cable used on a laptop, and-- one moment. Just to get a sense of scale, here’s a pencil. For anybody who knows radio stuff, this is shielded cable. And if you don’t know what shielded cable is, shielded cable is what your cable TV comes in on, that big rounded shielded cable. This is shielded cable the size of the lead in your pencil, and this is a shielded cable end. It has two connections inside of it, or two connections inside of this. It’s just miniaturized down to be able to fit in a laptop. And that’s why just-- they throw it in the laptop for free. You don’t even pay for them anymore, because it’s so inexpensive to stick that card in, or that chip in. One of the ways that you make everybody have something is you make it so cheap that anybody can
afford it. Everybody can have a microwave now that they're 39 dollars, right? That's the idea.

So. That drove it. When stuff was 500 dollars apiece, you literally could not buy it.

And that's why-- one of the reasons it became a de facto standard is it reached that critical mass where people could really begin to mass produce it inexpensively and drop it into everything. Once it was in everything, then everybody wanted it and everybody already had it, and the snowball kept rolling.
Wi-Fi Standards – 802.11b Stats

**Frequency:** 2.4 GHz

**Speed:** 11 Mbits/sec, realistically ~6 Mbits/sec
- Lower speed at higher ranges (300ft is ~1 Mbits/sec)

**Range:** 150 feet indoors, 300 feet outdoors

**Pros/Cons:**
- Bandwidth is shared between all users on the access point
- Public, unlicensed spectrum = interference from many other devices
- Low cost, available nearly everywhere, but low speed

**007 So 802.11b operates at 2.4 GHz. Anybody know-- can you get a feel of what that is? Right? It’s 2.4 billion cycles per second, 2.4 GHz. Data rate of 11 megabits per second. Realistically, about half of that, right? Five, six megabits per second is how much data actually pushes through it. It can go up to about 300 feet, and what you find is they use multiple methods for encoding the signal. Encoding the signal means how do you put ones and zeroes on a radio wave.

Well, the more complicated your method is, the more ones and zeroes you can put in the same given space,
but the harder it is to read it. So as you get farther and farther away, they have to uncomplicated, or use a less complicated method, and what that does is it drops the data rate.

So 150 feet indoors, 300 feet outdoors. We talked about the fact the bandwidth is shared. If you have a networking background, the difference between a switch and a hub is what? Anybody want to speak up? Go ahead, Neal.

Student: I believe that the hub just pushes everything out broadcast on all the ports, whereas a switch would have one user per port.

Joe Mayes: Correct. So, in a switched environment, every user can have their own bandwidth. In a hubbed environment, you’re all sharing the same bandwidth. In that respect, network access points, wireless access points, are wireless hubs, because everybody’s on the same media, the media being the radio frequency. And everybody has to take turns. Only one person can talk at a time.

Public unlicensed spectrum means there are interference from other devices. You have no control over the fact that your next-door neighbor has an access point operating on the same frequency you do. Matter of fact, what is your control of the next-door neighbors on the same frequency you are, and they’re interfering with your access point? You get two solutions. You can go
take them a pizza and see if they'll change their frequency, or you can just change your own. But if you call the FCC up to say, "That guy's walking all over my signal," the FCC says, "So?"

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