Wireless Technology and Standard : Wireless Technologies

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Now that we've understood the importance of wireless technology for the future of developing our networks, it's important to get as quick as possible into that techie side and understanding what lies beneath the beautiful story of wireless. In order to understand that, we need to understand that Wireless as a concept , even as the word if you want to take it singularly, and then independently can mean almost anything if not applied. It basically means a transmission of electromagnetic waves. Now, depending on how you make that transmission, you can categorize your rules of transmission in different standards, in different types of networks.

By looking at just a few of them, we can begin with the PAN and the WPAN - the Personal Area Network. The standards that lie within this category are those that are built for low power transmissions, and for networks that usually require low data rates of transmissions. You have already pretty much use the standard of Bluetooth - that you can use to share a contact on your phone, or to transmit or receive small files. In a very similar way, the IEEE 802.15.4 standard is constructed for taking data over long distances even to 1 km, from different kinds of sensors or smart meters, and being able to aggregate this data over a wired connection to the backhaul of the Internet.

The second category which is bolded up because this is going to be the one where we're going to focus our attention for the rest of this session, is the LAN -- the Local Area Network. Now, the most important name here is the IEEE 802.11. This is the standard, so this is the set of rules that governs how to transmit electromagnetic waves in our local area networks and communications. Everything from the frequency that we're using, to data rates that we can have, to the power that is allowed to transmit this type of signals, is governed under this standard. You're going to hear more and more on variations at the 802.11 as we move along the presentation.

The wide area networks are basically categorized into big categories. The standards like WiMAX in IEEE 802.16 that are constructed for Metropolitan Area Networks for ready transmitting wireless in the city-wide to the LAN, which we're already use to in terms of GSM, CDMA satellite, going to LTE 3G, and all the standards we have today.

Before being able to understand the complex intricacies of how we're able to transmit the signal on the LAN and how the 802.11 standard actually works, it's important to understand the medium of what we're sending the signal on.

Now for sending data in wireless, we use electromagnetic waves. These electromagnetic waves are around basically all the time. Depending on the level of frequency that we use, we categorized them into different frequencies, like microwaves, like infrared waves, and use them for specific technologies.

Wireless technologies use these electromagnetic waves. Understanding them at the very most physical basic level gives you an understanding of how Wireless technology works at the core.

Now, let me ask you something to begin with, what types of communication medium do we have in wired networks? Well, usually that's copper and fiber. Both these - in most situations are pretty easy to control. You have an insulator that controls them, you have these straight wired connections so you can control the signals very easily. If you want to use one wire to transmit, and another wire to receive, that's left you to create the flexibility of the Layer 1 design. So, really by using two wires, one transmit, and one receive, you can easily achieve full duplex, for example, in a wired transmission. And completely separate your data rate from transmitting, from your data rate from receiving – so upload and download.

Now, what communication medium do we've in wireless? Well, to put it plainly --the earth's stratosphere, which does not offer us any kind of control for the signal, so once we send out a signal, it really goes somewhere around us in the atmosphere. We cannot control the path that that signal is going to take. We're going to deal with that signal reflecting or being absorbed on different kind of surfaces, and all sorts of different challenges that we need to take into account when transmitting wireless signals.

Where does this story start - about transmitting electromagnetic waves into the atmosphere? Well, the most important side and where it starts is the frequency, which is measured in hertz. Now, if you look at the definition of frequency on Wikipedia or in any basic Physics book, we're going to find that there are a number of occurrences of a repeating event per unit of time. Of course time is relative to how you want to measure it, specifically for that technology.

Now, frequency is very important inside wireless transmissions. The reason for that is that frequency is directly connected to that data rate - the bandwidth, the throughput that you can have per transmission. Basically the higher your frequency of a transmission, the greater the speed you going to have.

Let's assume that you use a very, very simple micro-controller, a very simple -let's say, radio transmitter. And you transmit data, '1's and '0's at 900 MHz frequency. For that transmission, you get a 1 Mbps speed. Now, without using any fancy mathematics, or any fancy modulation on that signal, if you can take that frequency, and you heighten it to 1.8 GHz , you double it, you effectively double it. Just by looking at the data rate, you're going to be able to tell that you're getting close to 2 Mbps. By increasing the frequency you almost linearly increased the speed at which you're sending.

You might say this is pretty interesting - that means that I could basically just increase the frequency all the time, and by increasing it, I'm going to get higher data rates. Partially that's true, and it has been something that has been done throughout wireless standard history. However, by increasing the frequency, we do get some drawbacks.

One of the first drawbacks is the shorter range. The reason why we have a shorter range if we increase the frequency is because of a default property that the earth atmosphere has. Basically the higher the frequency, the more of the signal the atmosphere is going to be able to absorb. So, I can't really just go to tens of thousands of hertz, because if I do, I'm going to get to ranges that are maybe even a short as 1m and 2m, and that's impractical for the transmission technology that I want to evolve.

By achieving a higher frequency, I get a high reflection rate. So, what happened with the signal with an electromagnetic wave of a certain frequency when it travels through the atmosphere? Sooner or later, you can imagine, that it's going to hits something, it's going to hit a certain surface.

Depending on the physical properties of that surface, it's going to either reflect or refract. Reflecting means the signal basically bounces off that specific surface. Refracting means that there's a portion of the signal that is absorbed inside that surface. By standard laws of physics, you don't have a perfect surface that gives you 100% reflection. So, you're always going to lose a part of the signal, when the signal hits a specific surface.

In order to measure how much you actually lose from the quality of your signal, and implicitly from the date that you've encoded in the signal, we have a specific measurement called a signal-to-noise ratio. This is a very simple fraction, where you divide signal by the noise that is created by the signal traveling to the atmosphere, and through specific surfaces. The higher the signal-to-noise ratio, it means the better the signal. The lower the signal-to-noise ratio, it means you have a lot of noise, so the weaker the signal you're going to have.

By heightening the frequency, you have a high reflection rate, that means that you also have a low penetration rate. Imagine if you're trying to put your wireless signal through, let's say, a 2m concrete wall. If you use a high frequency, the penetration power is going be really low, and you're going to have a high reflection rate. On the one side, you contain the signal in a specific room, but on the other side, you have a really low penetration rate. You can immediately tell that using a big frequency in a city that is, has buildings all around is not very practical. That's why, for example, your radio, your AM transmission that you listen to radio in the morning, really uses shorter frequencies, lower frequencies for example 90 MHz or 100 MHz. Because at this low frequency, you have a high penetration rate and you can listen to your radio in the office, or in the car, or even outside the city by the signal traveling for a long distance.

We already covered the high absorption in the earth's atmosphere. Something really important that you should know from an economical standpoint is that building equipment that requires a higher frequency transmission also is going to apply a higher cost on the production end. Now, this used to be, more sure if I can try to expand the term in the past, than in the present. Really, the costs for producing this kind of radios for transmissions in the LAN have really gone down. From the perspective of frequency, that's not really what adds a lot of cost today - it's more about the complexity of the transceiver; the different streams it can use, in the number of streams that it can use that takes your cost upward; than is the actual frequency. Still, it's something you should have in mind when thinking about the basics of these electromagnetic waves.

We talk about frequency being the most important property of a signal when transmitting in LANs. In what exact frequencies are we transmitting when we want to communicate in the Local Area Network? Here's the catch: if you connect a wire from point A to point B, you're the owner of that wire, independent of if it's copper or fiber, you completely control what you transfer on that wire. Nobody, no authority, no government can come to you and say, hey, exactly where are you're transmitting through that wire if that wire is somewhere inside your home.

With electromagnetic waves, it's a little bit more different, because you cannot control them so specifically. It matters a lot what frequency range you're going to use to make your transmission. Most frequency ranges you have to get approval from certain points in the government, from certain administrations, and pay for that rights in order to transmit at certain frequency.

But for the Local Area Network standards, the 802.11 standard, we're a little bit more lucky. Luckily, we have the frequency bands. These are called the Industrial, Scientific, Medical bands, which are completely free to transmit in. These are usually the 2.4 GHz and 5 GHz bands. Inside these bands, there are smaller chunks that are described for these three ISM bands. They can differ from country to country, and from continent to continent.

All the equipment that is constructed to be used in a specific continent or country, for ISM band, ie, for LAN transmissions. 802.11 is already built to function on one, if not both of these bands. Now, it's great that we can transmit in these bands because it's free to transmit. I can basically go buy an Access Point, or go buy a radio transmitter, then start transmitting my signal. But you see that advantage can be looked at from a different perspective as a disadvantage; because everybody can transmit in them, they're very occupied.

As you can see from the graph below the 2.4GHz lies in the radio wave transmissions. The 5 GHz, which is actually the 5.4 and 5.7 bands - there's two of them. People generally like to call it the 5 GHz band. But for us technical guys, we need to know exactly in what intervals it is.

So, those are the microwaves. These are heavily being used right now. Any kind of wireless headset, or wireless keyboard, or wireless mouse, or even your microwave oven transmits data in this exact Industrial, Scientific Medical space. Remember when I talked about, if you don't want to confuse transmission rate -upload rate or download rate with receiving rate on a wire, you can just have two separate wires - transmit in one transmit, and in the other one, receive.

Well, in frequencies and in electromagnetic waves, it's not exactly like that, because if you transmit in frequency X at a certain point in time, and another device transmits over that same frequency in that same amount of time, or receives in that same amount of time, you're going to have a collision in the air. The duo electromagnetic waves - don't imagine them as two cars that just bump in the road, but, rather imagine them as two waves that compose themselves by hitting themselves; compose themselves in a totally different wave. That different wave that is created, possibly doesn't have all the data that it initially had, and a very small signal-to-noise ratio - very poor quality of the wave. That means that we have to be very careful in developing our technology of sending data in these frequencies, and somehow make sure that we're separating frequencies in terms of transmission, and not having different technologies bump into each other.

If you compare it to the 900 MHz frequency that in Europe right now it's not available anymore - it used to be available for ISM, but now it's for GSM transmissions. If you compare it to the radio frequency transmissions, the one you use for listening to radio that are a 100 MHz, these are indeed quite high. Since the frequency being high and we cannot have a long distance of sending data. And, since we cannot increase the frequency forever to obtain a higher data rate, we have to do ‘something’ smarter to increase the data rate without increasing the frequency.

In order to separate different data streams in the same frequency - that specific ‘something’ called modulation and multiplexing. It's the idea of using mathematical algorithms that controlled the physical properties of electromagnetic waves in order to bring more data into the same frequency stream. Imagine just pouring '1's and '0's into a frequency stream. If you do it just by default, transforming an analog signal to digital signal, and encoding it into a stream, you're going to be able to encode a specific quantity of data. However, if you think about a compression way of doing this, and a smarter way of representing that '1' and that '0' in a digital form, then you might be able to put more '1's and '0's in the same spatial frequency stream. That's what modulation is about - it's about encoding more digital data media in the same type of frequency band.

Higher bandwidth requires higher modulation techniques. And this is what basically saves us from having to increase the frequency, nor to increase the bandwidth. The smarter the modulation, the more bandwidth we have for that technology.

We have different types of modulation. We have standard Analog Modulation; and you can look at AM which is Amplitude Modulation; FM which is Frequency Modulation. Now, you can tell where that radio that you listen to every morning comes from : FM - Frequency Modulation, or PM – Pulse Modulation.

In digital, you have a whole different set of standards. You might have heard of the QAM, especially QAM64 which has been used for a long number of years’ specifically into LAN standard. And the Spread Spectrum Modulation, like the DSSS, FHSS or OFDM which is the multiplexing side of the encoding, which really have been very, very popular in 802.11.