ABU DHABI – How It Works: Internet Networking
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UNIDENTIFIED MALE: Now, we're going to wait to a couple more minutes to give enough time for folks who are coming back from lunch.

UNIDENTIFIED FEMALE: Good afternoon, everyone. This is the How It Works on Internet Networking. And we have Alain Durand from the Office of the CTO presenting. Alain?

ALAIN DURAND: Thank you. Can you hear me okay? Thank you.

So, my name is Alain Durand, I work in the Office of the CTO. And as I said, we are not the lawyer guys, so we're supposed to be the good guys of the bad guys. It depends which side of the fence you are.

So today, I'm going to talk about the basic of networking, naming, addressing, routing. This is meant to be an introduction level class. So if you know [about the] TCP/IP, you can ignore this.

This tutorial is really aimed at people who participate in the community here. I'm not necessarily very familiar with the underlying of the technology or maybe they have known about it years ago and they have forgotten and need a refresher. So I'm trying to keep it as simple as possible, but no simpler.

Next slide, please. Oh, I'm doing it. Oh, okay.

The agenda for this tutorial is in four parts. The first one is what I call networking by number. It's like painting by number, trying to understand very, very simply how things are layered. And when we'll go into more details about naming, addressing, and routing, and at the end of the day, there will be three things that I will like you to remember and we'll get [there].

No? I think you're going to have to do it for me.

Networking by number. You may have heard about the 7-Layer OSI model. It was very famous in the '70s and the '80s to explain networking. It's still used as a conceptual model but we are going to describe Layer 0 to 9 of a 7-Layer model, right? So we extend this a little bit on both side.

Next slide. Let's start.

So when we are building network, it start by really the physical. We need to have a pipe to move a data. So moving the data, they have two fundamental different technologies, either wired technology or wireless technology. And they have different properties.

So a wired could be a copper line of fiber. This is something that you put in the ground most of the time. It means that you need to dig a trench and depending on where you are, it may be expensive because you may really need to have authorization from maybe the city or the county or the country, depending where it is. And you have to open up roads and you need to stop traffic in those roads when you're doing this. That's an expensive proposition.

When you put an antenna for wireless, you just put an antenna and [about the DO 2] is done and you cover immediately a very large surface. So if you are in a rural area or if you're in a place where it's quite open, with a single antenna, you can cover quite a lot of surface. If you want to cover the same thing with fiber, you have to bring fibers everywhere so it's really, really expensive. So that's the difference here.

The second difference is in terms of bandwidth with how much bandwidth can you bring [for those] media. With the fiber today, I've seen networks that do 100 gig per second, 200 gig per second, 400, people are going to one terabyte per second or thinking of going to one terabyte per second.

On wireless, while typically you will get maybe 1 meg, 2 meg, 10 megs if you are lucky. I know that people who are trying to push the envelope a little bit further to go maybe up to 1 gig but it's still not quite there yet.

So there's really a difference. Several of those of magnitude in between the bandwidth, you will get the wireless from what you get on the wire line.

And then you had some of an interesting consideration like you see this antenna there on top of this historical building? Not really nice. Yeah. Ugly. And when you put an antenna in a residential area where you have nice houses, people just don't like it. They really don't. They say, "Put this antenna somewhere else. Not here." And then they complain that they don't have good service, right?

So what I have seen in some countries is that they paint the antenna, they pain it green or blue or – I've seen some place where they put like a fake palm trees' branch on the antenna so that thing is like – I don't know – 50-meter high and it looks like a palm tree, a 50-meter high palm tree I've never seen before. So it's a little bit prettier but it reminds that this is early and people don't like it.

So that's why in some of affluent neighborhood, people go for trouble of digging trenches and [doing] fiber cover because this is simply nicer.

Sometimes fiber is not underground but it's on poles like on the telephone poles. We can put the fiber there but it really depend on the environment. If it get like really windy, there could be problems and the wires will be brought down by the storm. And when you have fibers, sometimes you also have problems, you have problems with rabbits or any kinds of little animals that like to dig in the ground, and the rabbits putting its teeth in the fiber. We have seen that many times. Rats cut the fiber. Or you have a problem with a backhoe. There's a construction happening. There's somebody who wants to dig a trench because they want to. They don't really pay attention to what was on underground and the backhoe just got to cut the fiber.

So nothing is really foolproof. But those are really the two different technologies that we have to play with.

So, next slide, please.

All right. So now that we have a media, we can try to send information. So we are going to send light in the fiber. So in wireless, that will be a signal on different type of frequency. So I'm going to talk more about wire line and fibers.

So if I have one fiber, it's a point-to-point fiber, right? It goes from let's say here to the hotel, from here to central office somewhere. We can send information from there to there, no more. That's what it is.

So in the early days, it was simply a laser that was sending light and you send light, it's a one, you don't send light, it's a zero. Very, very simple. But you can have one communication there. If you want to have more communication on the same fiber, the trick that was used was to use colors.

So for example, what is your favorite color?

UNIDENTIFIED MALE: Red.

ALAIN DURAND: What is your favorite color?

UNIDENTIFIED MALE: Blue.

ALAIN DURAND: And what is your favorite color?

UNIDENTIFIED MALE: Green.

ALAIN DURAND: We are very lucky because red, green and blue. We're fine. You guys can send your traffic and all I need to make sure is that when you send in red, the person on the other side is going to listen to the red. When you send it in green, the person going to listen to the green and when you send in blue, it will receive on the other side in blue. If you have chosen red together, it doesn't work, right? So [I may] need somebody who's going to make sure that the colors are different and also I'll spread out some more evenly because if they are too close together, there may be confusion, right?

So that's how it works of a very, very basic layer. We have a fiber and we have a laser, different lasers that can change the tune of the frequency of the light. So that's the same thing with wireless. We have an antenna and you get antenna signal, slightly different frequencies and that creates a channel specifically for you. So that's a way we can share a fiber with multiple people. So next slide.

All right. That's great to send data from here to the central office. But if I want to send data from here to let's say my office, I live in Washington, D.C. in the US., I'm not going to draw a fiber straight from my office to here. That will take months and even years to get the [boat] to do that and it will be atrociously expensive. You just don't do that, right?

So how do we do this? Well, the answer is we get different fibers for different element of a path and we connect them. So we are going to say, "To go from here to the central office, you chose red so we are going to send in the red." But from the central office to maybe central office in a neighboring city, we are going to use another fiber that goes from one central office to the other but on that one, maybe we need to change color because that was already used by somebody else. So we are going to translate the red into something that is available, maybe a purple.

And at that second central office when we go maybe to an undersea cable, we may have to change again to yellow or to whatever color is available as long as each side of the fiber understand that this is the same thing, we are fine.

So by putting side by side or end to end those little pieces of fibers, we create what's called a fiber path and then I can now send my data from here to, well, let's say my office or wherever I have [essentially] created that fiber path.

So to connect those fibers together, this is not just like I have a fiber, I plug it there, another fiber I plug it there. That doesn't really work like that. You need to be able to switch dynamically so that maybe I can use that fiber there but if we have been sharing, if you like you use a green color and you want to go to another country, not necessarily in the U.S. but to the city where you're from, then we will electronically switch your traffic to the other fiber.

So if you think of it as a telephone in the early days like 1910, 1920, there was a switchboard where you physically connect one piece of copper to another piece of copper. And when we fast-forward to the '70s with the electronic switchboards, [that does this] for you. So that's exactly what this is.

I mentioned a specific bandwidth associated to a fiber, so typically you will find like 100 gig now, some of the fast fibers. If you want more than that, the trick is to take two fibers. And then speed of data, alpha data on the left, alpha data on the right and then that way you can get 200 gig. If you want to go faster, you take four fibers and split in four.

We know how to do that [2x10], after that, things get a little bit [heavy]. Two, that's easy. Four, gets difficult but it's kind of cost effective. Ten, usually it's better to use the next technology. For example, if you are using like only 10 gig, we can multiply it to 20 gig or 40 gig. After that, it's better to use directly in an interface that does 100 gig.

Oh by the way, I forgot to mention, if you have any questions for me, please interrupt me. I would like this to be more interactive. So we'll make it for more interesting session. Question?

UNIDENTIFIED MALE: What will –

ALAIN DURAND: We need to use a microphone because the remote participant. Thank you.

UNIDENTIFIED FEMALE: Sorry, if can specify your name and your affiliation, please. Thank you.

UNIDENTIFIED MALE: Yes. My name is [inaudible] and I am running my IT company over here in Abu Dhabi. So my question is actually what is the maximum distance point to point one fiber path? So that data can be traveled easily. I know there is a both side data switches but what is the standard distance for a single path of the fiber cable?

ALAIN DURAND: It depends. It depends with technology you are using. It depends with the speed you're trying to use it and it depends if you use repeater on it. So I've seen people doing very easily at 100 gig, 600 kilometers, no problem. More than that, it gets a little bit more difficult.

UNIDENTIFIED MALE: So that's been the fiber under the sea. We are using after 600 kilometer. We are using like Twitter or something.

ALAIN DURAND: Yeah.

UNIDENTIFIED MALE: Okay. Thank you.

UNIDENTIFIED MALE: My name is [inaudible] from SaudiNIC. My question is how the colors, I was following you online, I didn't understand how the colors related to fiber. How –

ALAIN DURAND: So the colors – I want to share the fibers among multiple people – actually of a fiber strand, not the fiber path, right? Just the point to point fiber. So I am going to say this, our friend here, [Ahmad].

UNIDENTIFIED MALE: Yes.

ALAIN DURAND: Like thread, our friend here, what's your name again? I'm sorry. [Ethan] like green and our friend Abdul Aziz like blue. So for this communication, I'm going to use red. For this communication, I'm going to use green and for this communication I'm going to use blue. So that way the three of them can use the same fiber at the same time.

UNIDENTIFIED MALE: Anyone with the one color?

ALAIN DURAND: Yes.

UNIDENTIFIED MALE: Just to comment that the main idea for fiber optic is to transmit the light with the speed of the light from one point to another point. The speed of light will almost significant [as virtual light] for transmitting of the signal from the source to the destination.

So if you send to multiple flashes by the same color, it will be with some frequencies. The destination will detect that this is according to maybe some character, maybe as a message.

ALAIN DURAND: So yes, essentially that a color is a wavelength. Right? This is not different than radio frequencies. You can have like 100 megawatts, 110 megawatts, 120 megawatts when you listen to the radio like FM radio and that's the same thing with color. So you can tune your lasers to actually send the light at this particular frequency and on the other end, you can tune the receiver to receive the light at that frequency. We have a question in the back.

You guys are really great to ask questions. Thank you.

[HAL SAMAR]: Thank you very much. This is [Hal Samar] for the record. Do you believe that – you already mentioned the microwave and after that the fiber maybe over DWDM or another technologies. Due to the huge demand of the diversity, new and backhauling capacity for the new mobile backhoe technologies, do you believe that still fiber is enough for getting that huge number of data or that we'll still need to start to looking for a new technology to carry the data? Because I believe that we are maybe in Middle East exactly we are suffering from the backhauling capacity. We'd be [inaudible] for transmit data from our area to Europe or the source of the data. So do you believe that we can have some kind of address for this issue that we are suffering from?

ALAIN DURAND: So, I'm not familiar with the details of your issue. But what I have seen is backhauling is usually not in the 100 gigs. It's more a 10-gig circuit that is being used. Now, not all fibers can go to the maximum speed, right? Some fibers because they are old or they use a slightly different fiber technology can be limited in what speed they can achieve. But what I can say is using the best fibers and the best technologies and fibers that are clean, not dirty. I can give you an anecdote.

I used to work for a very large service provider in the U.S. and we were starting to deploy 100 gig. It was in 2008, the very, very beginning of 100 gig. And we plug that in, it didn't work, like it got like, I don't know, 5 gig, 10 gig of it and people were wondering what's wrong. So we got all the engineers to debug the hardware, debug the software, everything is fine until we realized that there was grease on the fiber. Somebody had put a [inaudible] on the fiber itself at the end of the fiber and that was covering the fiber with grease and that was blocking the light, as stupid as that. And because of that, the fiber was unable to transmit that 100 gig. So it took like weeks to find this.

So sometimes there's a problem as stupid as this that makes it go slow. Now, what's the max? I have seen people doing 200 gig, 400 gig now. One terabyte is on [Verizon] now. The question is, is this standardized or not standardized, is getting harder and harder to standardize the next generation. The law of physics are becoming difficult.

But for backhauling, if the fiber is in good condition, no fingerprints in it, if it's not old and if the equipment on the other end is recent enough, there should be no problem.

Next question.

[LAWRENCE]: My name is [Lawrence]. You mentioned earlier that wireless – on the wireless end, we might not have as much speed as we have when we're using fiber. Fiber, we can have between 10 gig to 100 gig and I think for wireless, it could be lesser. Could you address the reason why this could be possible? Because from where I come from, I think a lot of the network runs on wireless. In other words, microwave connections. Definitely, from what you're saying, if fiber is deployed, we will have better speed. So, what can be done or from an industry perspective, what's the advice on how to maybe maximize more speed? Is there a possibility of a hybrid in between wireless technology and fiber?

ALAIN DURAND: Yeah, it's always an hybrid. What people do and we are talking about the backhauling thing, is you deploy 3G, 4G, now 5G. It goes to the antenna wireless because as I mentioned earlier, one antenna, you cover a very large area, right? It's much cheaper to deploy. But from the wireless antenna to the service provider, that's usually when you use fiber, so that's a mix of the two.

So in some new environments that are being [think] about, there's also satellite that can play a role. For example, somebody can have a wireless environment in a very remote area and it's not cost-effective to get a fiber over there. So then shooting up the sky to a satellite bouncing there and going down to the base station might actually be a good economical solution to this problem.

Dave.

DAVE PISCITELLO: This is Dave Piscitello from ICANN. So, there are two discussions about having wireless. There's wireless from the subscriber to the carrier and then there's also wireless infrastructure that could be anything from point to point projected wireless, which can achieve all sorts of different speeds depending on how much signal strength you're allowed to legally use and what kind of topology you can build.

So it's not necessarily the same spectrum, it's not necessarily the same technology that we use with 3G, 4G or even 802.11 variants. So there's probably a lot of room for experimentation and growth in those kinds of topologies as well.

ALAIN DURAND: And actually, I have seen some deployment a number of years ago where the service provider was using Wi-Fi with special antenna but with directional antenna to go and bring connectivity to an island. They were in Mali and they're trying to connect to this distant area and it just worked. Well, I'll say I'm not sure it was in Mali this one but it was one of the neighboring countries in Africa. And to go to an island, it was maybe like 20 kilometers and it was just fine with Wi-Fi.

So there are multiple ways to mix and match all sorts of different technologies. Can I keep going?

So at that point, we have the fiber path, right? We had connected and bridged fibers together and I can send data from Point A to Point B. Next slide, please.

All right. Now, I will need to do networking. So in the good old days when we were doing networking, I'm talking about the '80s, we had this thick cable. We call it a thick Ethernet cable that was going inside of a building from building to building. And when you wanted to connect to the network, we had some what we call vampire transceivers. That were things that we're attaching to the thick cable and you have the drop from there and you connect it back to the computer. It was an interesting terminology. That's what it was.

And all the computers in the campus were on the same network. Interesting thing that happened, for example, I remember one day people came to see me and said, "Well, you know we have this automatic backup solution that is going to go on all the computers, backup the data to the central disc and we run this in the middle of the night because nobody is working in the middle of night, we can use all the bandwidth we want." Okay. Great. "And we realized this morning that nah, it did not finish on time. At 7 a.m. it was still running and was still a long time. What's happening?"

So we put some analyzer on the network and we realized that there was a lot of X Window traffic if you guys remember X Window, X11, it was like 20 years ago. It was the first graphics workstation when you had like a mini computer and a desktop that has only the screen and the keyboard and it was just playing the graphics on it.

Well, what was happening was very simple is that at 5 p.m. people who are leaving and they have the screensaver that was starting on the desktop on the screen and they thought it was just fine, the screensaver. But the screensaver was actually on the display that was a remote display. The program was running on the main computer displaying on this remote desktop machine and going of other network and that was using quite a lot of bandwidth.

So when we handled the researcher, we're all doing the same thing. All of this was essentially maxing out the network. That was the problem. So that's when we start to realize that we need to segment the network so that if something messy happened in one part, it doesn't impact the other part. So we had over things like Ethernet broadcast storms, it's like a sandstorm for the network. And sometimes there's a device that send all kinds of weird things. If all the computers are on the same network and one of them start to misbehave like this, it's bad, really bad.

So the lesson was we need to create topology for isolation to make sure that if something wrong happened in one part of a network, the rest can still work.

So this is what we call Layer 3 or IP. So that's when I have my joke. IP does not stand for Intellectual Property. It is Internet Protocol. So if you want to be able to talk about the two differently, IP means Internet Protocol, the other one is IPR, Intellectual Property Rights, okay? So in this community, it's an important distinction to make. So, next slide, please.

Transport – okay, now I have my network. Okay. It's good to have a network but I want to use it to send data. So let's say that I want to send data to Kathy. I want to send data to her and I want to make sure that she gets the data. So there are two different protocols in the [inaudible], one is called UDP and one is called TCP. There are a bunch of others that does not really remain that matters.

The easiest one is UDP. I send data to Kathy. I have no idea if she can still read it or not. Maybe she did. Maybe she did not. Maybe she was awake. Maybe she was asleep. Maybe there was a problem. I have no idea.

The other one is TCP to try to address this. I want to make sure that when I send data, she receives is. First, I need to establish a connection with her. So I'm going to send a message. Kathy, I would like to talk to you.

KATHY: Ack.

ALAIN DURAND: I've received something back from her. She said ack. That means to me that she has received my message and send it back to me. I know that she can hear me. I know that I can hear her. But there are still ones that are missing. Can you figure it out?

No? Well, she doesn't know that I can hear her, right? I send the message to her, she heard me. She sends the message back to me, I can hear her. I know that but she doesn't know that I can hear her, so I have to send a message back to her. Ack. That way now she knows and we can start. She doesn't need to send anything back because I already know that she can hear me. So that's fine.

So this is called a freeway handshake. Free messages to establish that she can hear me, I can hear her, and I know that she can hear me and she knows that I can hear her. So now we're going to send data. So I'm going to send a bunch of data.

KATHY: Ack.

ALAIN DURAND: I sent a bunch of data. She sent the ack message. Ack means acknowledge. And I know that she has received this data. I'm going to send another bunch of data.

KATHY: Ack.

ALAIN DURAND: She got this. I'm going to send another bunch of data. Nothing. That data was lost. Or maybe she received it, she sent the ack, I never got the ack, there's something happened. So because it was lost and I want to make sure that I sent it, then she received it, I have to send it again. Kathy, here it is again.

KATHY: Ack.

ALAIN DURAND: This time, she got it. You see? With this system of ack or no ack, if she doesn't receive it, I know that she got this thing.

And the other interesting thing that we can do is to make sure that traffics arrive in order. So I'm going to send packet 1, 2, 3, 4, 5 6 and you're going to respond with –

KATHY: Ack.

ALAIN DURAND: Add a little bit more. You may want to say that you have received only some of them.

KATHY: Ack, I've received four.

ALAIN DURAND: She got received number four. So in that, she says that she means that she has received 1, 2, 3 and 4. I have sent 1, 2, 3, 4, 5, 6 so I know that I need to send again 5 and 6. I messaged 5, I messaged 6.

KATHY: Ack, I've received six.

ALAIN DURAND: And now I know it's okay. I can start again. So why was the message lost? Any idea why a message could be lost? Microphone. Oh, could you just please pass the microphone around?

UNIDENTIFIED MALE: Not me.

UNIDENTIFIED MALE: There's several different reasons. You might have a noisy transmission medium that drops or creates part of the errors, which is sort of very old school. You don't see that very much in fiber. You could also have information that's misrouted or takes a route that doesn't deliver within the hot count. So there's lots of different reasons.

ALAIN DURAND: So all those things can happen but there's one thing that is even more frequent than that that happens is that the network was congested. There was too much traffic. So when the traffic goes, it goes from some routers, right? And maybe there are like five pipes going in and two pipes going out.

The ways dimension is that the two pipes going out usually have less bandwidth total than the five pipes going in. That's how you make money actually. You over supply the service.

Well, when everybody is sending traffic together, it's not going to go out. Something will be dropped. When only one or two people are talking at the same time, statistically, that's fine and your two pipes going up are just okay. But whenever we talk together, no, there is congestion and what does a router do when there's congestion? It drops packets. When packets are dropped, they don't go through.

So that's 99% of the case what is happening when there's a traffic that doesn't go through. Now, some other cases like Dave mentioned where it's more complex, some routing issues and all those but most of the time, this is simply congestion.

So when she did not receive my packet four and five, I should interpret this as a signal that I was sending too much data too fast. I have to slow down. So instead of sending full speed, I'm going to stop, pause and only start slow again. So I'm going to send seven and eight.

KATHY: Ack, I've received eight.

ALAIN DURAND: Okay. I can maybe try a little faster, 9 and 10.

KATHY: Ack, I received 9 and 10.

ALAIN DURAND: Yeah. 11 and 12. Nothing. 11 and 12, that speed was too fast so I can backtrack, nine and 10 was sent, okay.

So our TCP has this adaptation to the bandwidth and can maximize what the bandwidth is. So when you're competing with other people in the network, everybody is playing that game and if everybody is playing it fair, things are fine. Sometimes people are not playing it's fair. Things are not so fine. But overall, it works.

Questions?

UNIDENTIFIED MALE: Sorry. You said adaptation with the speed of the packets. So how long it is happening and what the procedure was that or the technique because it was that adaptation in this manner to optimal speed of that transmission?

ALAIN DURAND: So what we do is called exponential back off and we start to a minimum and then as soon as we detect the packet lost, we start at the minimum and then we double the speed. And if it [inaudible] fine, we double again until things are not fine and then we backtrack.

Well, that's the overall idea, okay? In practice, it's a little bit more fine tuned than this. So it's called a TCP congestion control [inaudible] Van Jacobson award many years ago and there had been many variations on this but that's the gist of it. Next slide.

Okay. Now, I have a network, I know how to send data, I know how to make sure that Kathy will receive my data. So, what can I do with that? Well, one thing is to describe what I'm going to send. For example, if I want to stream a movie, I want to describe what is the codec for the movie, what is the audio codec or the video codec. I may want to describe what's the length of the movie, where are the servers, things like that.

Other question over here?

UNIDENTIFIED MALE: What you are using [inaudible]

ALAIN DURAND: We need to use the microphone for remote participants.

UNIDENTIFIED MALE: For streaming, do you use TCP or UDP? I think you have TCP rather than UDP for handshaking.

ALAIN DURAND: For streaming, most of the time we're going to use UDP. The protocol here is called RTSP for Real-Time Streaming Protocol. So that's a protocol that is used on top of the transport protocol that is going to describe the session. So the data is not going to go for that protocol. This is only to describe the session. Makes sense?

UNIDENTIFIED MALE: Yeah.

ALAIN DURAND: So why that's actually an interesting segue, I just spent the last 10 minutes explaining why TCP was so much better than UDP and now I'm saying that for streaming, we use UDP, okay. Why?

UNIDENTIFIED MALE: Sometimes you use [inaudible] we take some [inaudible].

ALAIN DURAND: We really need to use the microphone, I'm sorry.

UNIDENTIFIED MALE: Sometimes, are [inaudible]. Maybe you are having that streaming of football match and you see some delays. This may be due to using the UDP not TCP. For TCP, it will take a longer time in order to receive.

ALAIN DURAND: Not exactly but you are getting there. So, let's say that I want to download a file. If I want to download a file, that is, I don't know, my thesis, my dissertation or letter that I sent to somebody. It's very important that all the blocks arrive in order, right? So that if somebody is going to read the letter, it makes sense, because if all the words are mangled together, it doesn't make any sense and it's useless, right? So it's very, very important to do that.

Now, if I send a movie to you or if I talk on a voice over IP type of things, it doesn't really matter that much because the ear or the eyes are – some are able to reconstruct the scene. Sometimes there's a glitch on the picture, on the movie or in the audio and that's kind of okay. You can still reconstruct what is happening for the context. Then it all depend of how many of those glitches you have, right?

So, if you have a little, that's fine. If you have a lot of them and you say, "I'm not going to watch this movie. No way." So, for some type of content specifically streaming, losses are not so bad. But what you want to make sure is that the order is important also. Like if I say, "1, 2, 3, 4," you don't want to hear "4, 3, 2, 1." That would be bad. So I'm going to put the emphasis on the order but not so much on having losses or not losses, right? And it's better for me more effective to send very small packets for audio that will contain some of this information and if essentially 9 out of 10 makes it, that's good enough. So that's why we use UDP for those things. Next slide, please.

In the OSI model, there was a Layer 6 called Presentation. This is a little bit the same thing as the Session Layer that I discussed before but it's to provide more structure to the content. And it used to be done as a fixed text description of what it was, difficult to understand for a computer. When folks moved to something to what was called ASN.1, that's like a binary packed description of what the content is. It's easy for computer to read. It's difficult for human to read. It is error-prone for programmers to code this because they don't really see what it is.

In the recent years, people moved to describing content using XML and now the new kids, people that could be at my age or less use the something called JSON or many other formats that had been invented where they used what they called a dictionary or an example here to describe a menu, like a Window menu. So the level of description has really gone up and you can describe very complex things now using this.

So next layer. Next slide, please.

That's where the [inaudible] we start. Everything you have done so far is building pipes. The reason you are building pipes is because there are people who want to use it and they are going to pay you for that. And this is a kid there. If a kid that's six-year-old can use a tablet and watch a YouTube movie, you're good. If it can't because your network has bad quality and drop too many packets and it's overloaded, whatever it is, then you are doing a bad job as a service provider. End of story. It's very, very simple. So, next slide.

That's what I meant. If a kid can watch his YouTube movie, the parents are going to pay the bill for Internet connection. They may even ask for a faster connection because the kid is complaining that is not going fast enough, right?

So when you build a network, there's something that's always important to remember. It's the service that you're selling, right? The service is not the pipe, the service is not IP, the services of a kid to be able to watch his YouTube movie, that's what it is. And if you cannot build the service, I mean, somebody is going to pay for it, then don't even build the network because it's not going to work. You cannot sustain your business model like this.

So this financial element is always going to be there. Sometimes if you're at level this and talk about some other services on the network, you see, "Oh, but the services are free. I can use search engine free. I can use a browser free. I can use an e-mail something free." Well, most things are never free. What you pay for it is not money but information that you provide to that service provider and that is going to be used to send you advertisements or to send you whatever it is.

See, the service looks free, it means that you have a product. So that's something to always keep in mind. There's always, always, always a Financial Layer. Next slide, please. Thank you.

And on top of that, there's a Political Layer. Your political has to be understood in the good sense of a term. Political means it's a process by which people get together and agreed to make decisions. Sometimes everything is nice, sometimes a little bit messy but that's what it is in the end. It is how as a community are we going to make decisions? That's what political is.

So in the realm of the Internet, well, there are policies like do you use domain names, which top-level domains are being created? That's what the ICANN meeting is about, to get committees together in this multistakeholder process and get everybody to talk and figure out how we're going to do this together. So that's one thing important here is how we're going to do this together.

So, now I have described the Layer 0 to 9 of the OSI 7-Layer model. So, you know how to count from 1 to 7 now, it start at 0, ends with 9.

Next slide, please. How are we doing on time?

UNIDENTIFIED FEMALE: We're doing all right. Pretty good.

ALAIN DURAND: Okay. Perfect.

All right. So we are going to embark now in a journey and it's kind of a true story. In one of the previous ICANN meeting, I woke up one day with massive, massive raging toothache. It really, really hurt. I don't know what happened. I mean, the crown fell off or something like that. You have a question?

MUHAMMAD: It's Muhammad [inaudible] from Egypt. Actually, I didn't see the Data Link Layer. I missed the top or it's not in your presentation or it's Layer 2, Data Link Layer between the Physical and Network Layer.

ALAIN DURAND: I talked about the Layer 2 when we were putting a fiber path together.

MUHAMMAD: Ah, you put in the Physical Layer, sorry. You put it on the Physical Layer?

ALAIN DURAND: Oh, yeah, I might have skipped a slide and I apologize for that.

MUHAMMAD: Ah, okay. Okay.

ALAIN DURAND: But the slides are online.

MUHAMMAD: Okay.

ALAIN DURAND: The Data Link Layer, the Layer 2 is actually less and less used in many environments. Somebody was mentioning DWDM as like directly shooting IP over the fiber, over dock fiber. The different school of thoughts, is it useful, not useful, it's a continuous debate. Does that answer your question?

So, going back to my story, so I woke up one day with this massive, massive toothache and I really needed to do something. So I went to see wonderful Kathy here and I said, "Kathy, it hurts. I know that you have been living in this city for a long time before and I need your help. I need to find a dentist. So, can you tell me who is your dentist?"

KATHY: My dentist's name is Dr. Al [Ayin].

ALAIN DURAND: Thank you. So, now, I am going to go in a quest to find Dr. Al [Ayin] and get him to help me with my tooth. That's where I start. I have the name of this person. Next slide.

Okay, what's the name? So, I'm a big fan of dictionaries. It's what I go to when I want to make sure that I understand what we're talking about. And I have so many discussion with my children. They say something. I say, "Do you really understand what you're talking about?" They say, "Yeah. Yeah." "Well, what does this name mean?" And they say something, "No, that's not really true. Let's do this exercise. Open up a dictionary and find out."

So what is a name? Well, according to the Merriam-Webster Dictionary, the name is a noun, it's a word or a set of words by which a person, an animal, a place or thing is known address referred to. Example, my name is Alain Durand. There are some other definition could be famous person, a big race, etc.

So here's the very first thing I want you to remember. Forget all my Layer 0 to 9. One, the first thing I want you to remember is if I know your name, I know who you are. If you know my name, Alain Durand, that's me, you know who am I. Very simple. Next.

So, if the definition it says a word or set of word by which a person, an animal, a place or thing is known. So, with name, we can do two things essentially. I can talk to Kathy. Kathy, how are you doing today?

KATHY: I'm doing good.

ALAIN DURAND: Good. Thank you. So, I started a conversation with Kathy. Okay. Steve, good afternoon. Have you seen Kathy around today?

STEVE: Well, yes.

ALAIN DURAND: We were talking about Kathy. You see those two different things? Talking to or talking about. Those are the two different things we can do with the name. So by the way Kathy, what's again the name of your dentist?

KATHY: Dr. Al [Ayin].

ALAIN DURAND: So that's an example where I did both things together. I talked to Kathy, I used her name and she was giving me information about somebody else. Something really, really important that can do those two things. Next slide.

Names have scopes. So another story, I'm sorry I have many stories. When I was a kid in school, like maybe 10, 12-year-old, my first name, Alain or Ala in French was very common. Lots of kids had my name. So maybe we're like five or six in the classroom. The teacher was saying sometime, she was angry at one of us and she was saying, "Alain, come to the whiteboard (or the blackboard at the time)." And then five of us were looking at each other. "Which one is she angry at today?" Because it was rotating, sometimes it was me, sometimes it was somebody else.

And then she got even angrier because we did not respond, right? So she had to say, "Alain Durand, go to the blackboard." Okay, now I know I am in trouble. I can go. I have to go there, right?

So, if you use a name and there's conflict, it means that the scope is not complete. You need to expand the scope of the name to make sure that the name is complete, okay? So, next slide.

Okay. But we now have the name of the dentist, that's great but I don't know where that dentist is, right? So, Kathy, could you please go to your Rolodex and tell me what is the address of this Dr. Al [Ayin]?

KATHY: Dr. Al [Ayin]'s address is 125 Root Canal Road.

ALAIN DURAND: Thank you. That is a good address for a dentist. So what did she do? What did Kathy do? Well, she went to a database on a Rolodex that maps the name of the dentist to an address.

If you were in the tutorial this morning, the DNS Fundamentals, that's what it is. The DNS maps a name to an address. DNS can do many, many other things but these [menus age] today is to map a name to an address, right? That's exactly what it is. This process is called name resolution. Put the name in, get an address out. Next slide, please.

Now, we are going to talk about addressing. So, really that's answering the question where is your dentist? Next slide.

Well, guess what, I went back to the dictionary and try to see what an address means. Now, particulars of a place where someone lives or an organization is situated. That's interesting.

First thing, remember, I asked you to remember, you know it [was]. If I know your name –

UNIDENTIFIED FEMALE: I know who you are.

ALAIN DURAND: Thank you. The second thing I'm going to ask you to remember is if I know your address, I know where you are. Okay. The name is who, the address is where. Next.

So, there's some structures in an address. So I told you I live in Washington, D.C. in America and there is a small house painted white and that is quite famous and every four years there's kind of a fight to figure out who is going to live in there for the next few months or years.

The address is 1600 Pennsylvania Avenue Northwest, Washington, D.C. 20500-0003, USA. That's the complete postal address. You can't send a postcard there. It will go. So there's a hierarchy in this. And you have to read it from the end to the beginning.

So, the top level would be USA, that's the country. Forget about the zip code for a second. The next thing is D.C., D.C. stands for District of Columbia. That's not a state in America but it's kind of the equivalent of a state for this particular purpose. There's a lot of fights to know if it's going to become a state or not but anyway that's the detail. But that gives you a small allocation [inaudible] just America. Now, we know it's in the District of Columbia. So, Washington is the only thing in the District of Columbia, so it's kind of redundant here.

Next one, Northwest is interesting. The city of Washington, D.C. is split into four corners: Northwest, Southwest, Northeast, Southeast. So this is in the Northwest quadrant. Then Pennsylvania Avenue, that's the name of the street. 1600, that's the number on the street.

If you ask somebody how to go to this address, they will take you there, right? And this is an example where addresses are geographically organized but it's not always the case.

For example, in America, there are phone numbers that you can dial and you don't pay. The person on the other side will pay for you. It's usually like hotline support or something and you don't want the customer to pay for the call. You will pay for it. So this is one 1-800 number. But when you dial this number, let's start with this, you have no idea where the person on the other side of the line is. Sometime it will be in the same city, sometime not, sometime in the same state, sometime not, sometime not even in the same country. Maybe somebody in India or somewhere else that is going to pick up the phone.

So by looking at the phone number, you have no clue. You cannot know where the person on the other side is. But that's also the same in America at least for cell phone numbers. When you have a phone number and you move around, you can call me on my phone number, I'm here. I have an American phone number. But if you dial a number, I'm here, right? So then looking at the number doesn't tell you where I am. It just tells you where the phone is registered. That's it.

IP addresses, the same thing. There's no national structure on the IP address. There's no regional structure either. It's just a number that has been allocated. Now, there are people who have been trying to reverse engineer this and to create geo location databases where you input an address and you figure out where it is but it's not the property of the address itself. In the way it's structured, it is a property of people spending a lot of time and money to create this database and figuring out where things are. Next.

So, I mentioned previously that name had scope and talked about the classroom incidence but addresses have scope, too. If you live in Washington, D.C. and you say, "I want to go to 1600 Pennsylvania Avenue," and you give this address to a taxi driver, he will take you straight to the White House. But if I give 1600 Pennsylvania Avenue to a taxi driver in Chicago or in London, they will have no clue where it is, right?

Another example, if you live in Europe, Paris, there's one Paris in France, right? If you live in America, there are 29 cities which name is Paris. And I have a running joke with my children. There is a very, very small town in Virginia where I live, maybe like, I don't know, 10 houses. It's called Paris. And sometimes I say, "Well, let's go to Paris and then have lunch." It's 11 in the morning, they say, "Are you kidding me?" "No, no, we just drive there." It's like half an hour drive and we come back. Like there are many Paris. There are many Berlin. There are many Baghdad. There are many different – it's just amazing, a lot of conflicts there.

So, what's important here is again, there's a scope. If I talk Paris, France, I know it's Paris in France. If I say Paris, Virginia, that's the one where the joke is – running joke with my children, right? Next.

So, similar to names, I can use an address directly. For example, I want to go the dentist. What's the address again of the dentist, Kathy?

KATHY: The address is 125 Root Canal Road, D.C.

ALAIN DURAND: Thank you. So, again, she gave me the address as a reference. Now, I can give the address to a taxi driver that's going to take me there. Okay. Same thing that we saw with the names. We can use to establish a communication or to have referral to something else. Next.

Yeah, but it's great with all this but I have the address but I'm still not at the dentist and my tooth is still hurting. So, obviously, this is not enough. I need to – I have a taxi or something that's going to take me there. So let's understand this better.

Okay. I mentioned earlier that you could write a postcard and put the address 1600 Pennsylvania Avenue Northwest, Washington, D.C., USA from anywhere in the world. If from here, it will arrive. If you get an answer on that, different story, but the postcard will arrive. Why? It arrives because there are number of agreements between post systems and when you post it let's say in a mailbox here and they come from the center, the postman will come maybe tomorrow morning, pick it up, he has no clue where to send it to, he bring it to the central post office here in Abu Dhabi. And then somebody is going to see this. "This is, oh, that's for America. Put it in a plane for the U.S." Maybe it will arrive in New York and somebody in New York will look at this and say, "Oh, this goes to Washington," etc.

This works because there are agreements in between post offices to make it work and that's very, very important concept in networking. This entire system only works because people agreed to make it work and cooperate. This cooperation is absolutely critical. Next.

Okay, let me try to get to my dentist now. It's about time because it really hurts. Next slide.

Okay. Back to the dictionary. The route or route depending if you are British or American or whatever your accent is. I have a book in French and American accent so it's hard to say.

So route is a way or a course taken in getting from starting point to destination. How'd you go from Point A to Point B? There are different steps in the middle. So, let's remember my three things. Thing number one, if I know your name –

UNIDENTIFIED FEMALE: I know who you are.

ALAIN DURAND: All right. If I know your address –

UNIDENTIFIED MALE: I know where you stay or live.

ALAIN DURAND: Yes. And next, the third thing, if I have a route to you, I know where to go. I know how to get there. Three simple things I wanted you to remember. I'm going to say them again. I know your name, I know who you are. I know your address, I know where you live. I know your route for you, I know where to go, I know how to get there. Three things. Forget everything else. Next slide.

So, this is a network diagram, all the dots and some routers and I want to talk from the source to the destination. So think about this as I have a car, I want to go from here to my doctor and how do I do that? I start the car, I go out to the first intersection and then what? There is no indication, there's no sign and I have no GPS and I cannot do anything, right? Somebody has to give me indication.

So, the question now becomes how do I get those indications? Who is going to put signs on the road to tell me turn left, turn right or keep straight? So, where this is done is going in reverse before I even start my journey. So the same way that the signs on the road to say, "This is Abu Dhabi, this is to Dubai, this is to get to another country or another city." Those signs are put in place way before I turn my car on in the morning, right? So the same thing here, before I send traffic on the network, somebody has to put those road signs for packets in place.

So, let's say my dentist is connected to the network over here and it's connected to a service provider here. It's going to tell the service provider, please send traffic for me on this link that I had subscribed to you and now I will be happy, right? When the service provider is going to advertise to all his neighbors, "If you want to reach my customer, send the traffic to me."

Now, this guy is going to do exactly the same thing, is going to advertise all his – all the service provider friends, I know how to get there. So, in other words, this one says, "I know how to get there." This one says, "I know a guy who knows how to get there." This one is going to say, "I know a guy who knows a guy who knows how to get there." And we construct the chain like this. And when we flood the network, at some point, all this information will go to the source that says, "This is a path to get there."

So obviously, there's going to be multiple path. They could be a path like this. There could have been a path like that. There could be a path like this. There could be a path like this. You need a simple diagram there, like quite a number of path possible. And the goal is going to simply figure out which one is the shortest.

So there are a bunch of [inaudible] in routing protocols that helps you how to do that. So [inaudible] out of scope for this tutorial that if you are more interested, we – I can use some pointers. The thing to remember here is this is just like the postal system when I was mentioning about sending your postcard. It worked because all the service providers here have decided to cooperate and says, “Okay. I’m going to listen to this guy.” And if he says that it can reach this destination, I’m going to trust him. It’s based on trust. Next slide.

Okay. Now, that all this is done, it’s like I have put all the road signs and I can start my car and go drive and I will say, “I will see a sign that says Root Canal Road, turn right.” I turn right. I’d go to the next intersection that’s around about and I see a sign that says, “Root Canal Road, Second Exit,” I take the Second Exit. I’ll just follow the signs.

So I will send the packet to this guy, would send it to this one, to this one and to this one. Once I send the packet to the first router, I have no idea if my traffic will ever make it or not. I trust it will. Why do I trust it? Because I pay my service provider every month. And if they don’t do a good job, I’m going to stop paying them and I would use another service provider. It’s as simple as that.

This is what it's called next stop routing. I send a little packet trusting that the next stop will divide [inaudible].

Okay. Next slide. So the conclusion of this is, next slide.

I can't find this Dr. Al [Ayin]. He's going to take care of my tooth. So I hope that this little adventure in naming, addressing and routing will have been interesting for you to understand what are the concepts behind this.

So let's repeat those three things that I wanted you to remember. If I know your name –

KATHY: I know who you are.

ALAIN DURAND: If I know your address –

UNIDENTIFIED MALE: I know where you live.

ALAIN DURAND: If I know a route to you –

UNIDENTIFIED MALE: I can get to you.

ALAIN DURAND: Yes. So that was the three things I wanted you to remember. So that's the end of my talk. We have a little bit time left. Oh, we have plenty of time. So, if you have questions, now will be a good time.

If you don't have questions, we can go get a coffee.

Going once, going twice. Well, I think it's coffee time. Thank you all for attending.

KATHY: Thank you everyone. I just wanted to remind you that we have another How It Works session at 3:15 and that would be the How It Works: Root Server Operations. It's always a very packed session. So we look forward to seeing you again and we'll have the same session for How It Works tomorrow. Thanks.

[END OF TRANSCRIPTION]