EN

STEVE CONTE: Okay, we actually got a couple more people here. Welcome. I hope you enjoyed your lunch. We're going to get started. This is the How It Works session on Naming, Addressing, and Routing, and we have Alain Durand from ICANN's office of the CTO to present.

And do you want to take questions during or do you want to take questions after? During, so feel free. At all the How It Works sessions, we encourage dialogue, so feel free to raise your hand. I've got a second mic. I will run out to you and give you the microphone and we'll have a dialogue about anything that you might have questions or comments on.

With that, I pass it over to Alain.

ALAIN DURAND: Thank you, Steve. We have plenty of seats in front so I would like to encourage you to move closer, please. So that way, we don't have to run with the microphone to the back of the room. Thank you very much.

Note: The following is the output resulting from transcribing an audio file into a word/text document. Although the transcription is largely accurate, in some cases may be incomplete or inaccurate due to inaudible passages and grammatical corrections. It is posted as an aid to the original audio file, but should not be treated as an authoritative record.

All right, thank you very much. Yes, please come forward. Sorry if I'm scaring you. So thank you for being here after lunch. I know it's a difficult time.

This tutorial is about naming, addressing, and routing. It's part of the How It Works series. It's kind of a primer of fundamentals on networking. It can be a refresher for you if you have been doing networking before, and it was many years ago. Originally, I thought of this as how to explain the basics of the technology to people who come to ICANN meetings and that have more policy focus but don't necessarily understand the bits and bytes.

So if you are already an expert in networking, you will not learn anything. So a 101 class is not a class for experts.

All right, so, I'm going first to talk about networking by numbers. It's like painting by numbers. I try to make it easy and so that you can understand the basic concept of networking, and then I will talk about naming, addressing, and routing.

As Steve said, please feel free to interrupt me any time with any questions. If we have to spend the entire tutorial on the first two slides, that's okay.

So I'm sure you have heard about the 7-layer OSI model. It was the basic introduction class to networking for many, many, many years. So we are going to talk about the layer 0 to 9 of the

7-layer ISO model. What it means is that we have some [inaudible] a little bit on both sides.

So the layer zero is a physical layer. It is when you're building a network, what you need to do physically that you have a network. So you have two technologies. You have wired technologies and wireless technologies, and they are very different, they have different purposes, they have different ways of being used, different characteristics, but at the end of the day, that's what is going to bring [your] network to wherever you want it to.

So wired technology, you have copper, fiber, and this is all about bringing your cable to where you want the network to go. So when you bring your cable, if you're in the city, you have to dig a trench and you may have to go through roads and through buildings or through bridges and things, and it can be quite expensive.

Also, depending on the local regulation, you may need to get some authorization to dig through the street to dig on the sidewalks and it may or may not be easy to do.

But mostly, it's expensive so it's usually cost effective if you can bring, for example, a fiber to a building where there's a large apartment complex and when all the tenants in the apartment complex can use a fiber.

If you want to do this in a rural area, where there are like small villages, if you want to bring the fiber to all the houses in the villages, it's going to be an extraordinarily expensive proposition.

So that's why in places like, for example, South Korea, in Seoul, you have a lot, a lot, a lot of very large apartment complexes and the penetration of fiber is amazing because, well, you dig a trench once, you pay the cost once and then you have everybody connected. That's really what it is.

In more rural areas, like for example, in rural America where I live, you don't have fiber there. You may have copper. Sometimes you have a hybrid. For example, some cable networks have a hybrid of fiber and co-ax called the HFC for Hybrid Fiber Co-Ax. And sometimes you have a fiber inside of a copper cable. You have a co-ax cable and inside of it, there is one strand of fiber so that your service provider can start with copper, and at some point, may switch over to fiber if it wants to. It doesn't add a lot of cost to the physical piece of cable by the meter, but it's ready for the next gen of technology.

On the other side, you have wireless. So wireless is great because you put one antenna and then you cover a very large area. So in rural places, this is fabulous. You just put something once and everybody's covered, almost everybody.

The main problem is that the type of bandwidth that you can get from the wireless has nothing to do with the type of bandwidth you can get from a fiber. Like a fiber, we are talking about maybe 10 gigs is like a piece of cake, 100 gigs today is common. You can get 400 gigs. People are talking about 1 terabyte per second. That's the type of speed we are talking about.

Wireless, if I get 1 meg, 10 meg, I'm happy. People are talking maximum to 1 gig in the most advanced 5G network. But if you look at the most advanced 5G network compared to the most advanced fiber, you're comparing 1 gig to 1 terabyte. So there are three orders of magnitude, like 1,000 times. So if you scale down the technology to things that are more cost effective, you still have this factor of 1,000 between fiber and wireless. So that's number one.

Number two is wireless are wavelengths in the air and they are absorbed by the vegetation. So if you are in a place where there are a lot of forests, yeah, it doesn't work that well. If you are in a place where there are mountains, it doesn't work that well. If there are big trees and things, it doesn't work that well. If there are a lot of magnetic perturbation storms and things, you can have problems, all kinds of issues like this.

In the city, there's another issue. If you look at this, right here on top of this nice historical building, people don't like this. They

don't want to see this in cities. They consider this ugly and if you put this in an affluent neighborhood in the suburbs, people don't want this either. They want the nice, fast connectivity, but they don't want to see the antenna.

So what I have seen in many places is people hide the antenna. They paint it green or they add palm branches to it. I have seen one. It was absolutely fabulous. I am not going to name the country, but it's an island in the Indian Ocean, so that narrows it down. And what they had was a big pylon, which was maybe 50 meters tall, like 150 feet tall. And it looked like a pine tree. I've never seen a pine tree that tall, never, and it was next to nothing: buildings, apartments, and houses. And there was not a single other pine tree next to it, so okay, it looks less ugly. But that's essentially what it is.

And also you have an issue about spectrum because you need sometimes a spectrum of wireless technology is licensed and unless you do Wi-Fi and you also need to make sure [that you have the right spectrum].

So these are really the two things to consider, like bandwidth, how much bandwidth are you going to get, and what are the environmental concerns? Do I need to dig a trench? Do I need to worry about trees and things? Do I need to worry about the density of populations?

Yes, please. Microphone, we have remote participants and we need to make sure that people can hear you, so please state your name.

ALICE BAIN: Alice Bain, Grenada. In terms of the wireless technology, is it based on line of sight or do you know the maximum distance that technology has advanced due to let you project wherever? What is the furthest distance?

ALAIN DURAND: Well, line of sight is kind of better. It's not always necessary, but it's better. If not, you have to go through obstacles, right? And an obstacle like a tree, a rooftop, or something like that is going to absorb some of the wireless spectrum. So if you have more of that, you go less distance.

Now at the end of the day, the question is speed and distance. The further out you go, the less bandwidth, less speed you're going to get. So in things like 5G, for example, they are talking about integrating both high speed and narrow coverage plus lower speed and very wide coverage all together on the same antennas.

So for example, if you have some small IoT device that doesn't need much bandwidth, they could be covered on a very, very

wide area. There could be tons of them. But if you have also phones, like people's phones that require a lot of bandwidth, then on the spot, you can deliver that bandwidth.

Another question? Okay, next slide.

Yesterday, we spent like 15 minutes on the first two slides so that's perfectly okay. Sorry, actually stop the clicker. This is [inaudible].

STEVE CONTE: Is this the slide you want?

ALAIN DURAND: Yeah. All right, so let's talk about fiber for a second. I'm sorry. I'm total confusion. I've done this too many times.

So at the beginning of [the day], you have a fiber. What's a fiber? Well, it's essentially a piece of glass and you send the light through the piece of glass and the light [follows] the glass. If you really look at this, it's kind of funny because it can bend but it just follows. The way it works, it just bounces around the side of the walls of the fiber.

So you send light and your receive light. So you send white light and you receive white light on the other end. So essentially, you have one person that can send, transmit, usually with a laser

and one person that can, on the other side, receive the light with a receiver. And if you want to talk on the other side, you have another strand of fiber that goes in the other direct direction. So we are always talking about fiber pair, one in a direction, one in the other direction.

So that's nice and great, but let's say that we want to share the same fiber not with just one person, but let's say three different persons because if there are multiple people in the city who want to choose the fiber, we're not going to put multiple fibers, as many fibers as there are people. It makes no sense, right? We need to do something slightly different.

So the idea is instead of sending white light, maybe we can send different colors of light. So for example, what is your favorite color?

UNIDENTIFIED FEMALE: Orange.

ALAIN DURAND: Thank you very much. And your name is?

UNIDENTIFIED FEMALE: [Sarah Dar].

ALAIN DURAND: Thank you for your cooperation, orange. What is your favorite color?

UNIDENTIFIED FEMALE: Yellow.

ALAIN DURAND: And what is your favorite color?

UNIDENTIFIED MALE: Blue.

ALAIN DURAND: So we have orange, blue, and yellow. What is your favorite color?

UNIDENTIFIED MALE: Yellow.

ALAIN DURAND: Right. Now, that's a bit of a problem because two of them want to have yellow so I'm going to say, "I'm sorry, we can't have yellow. Can you have something else? Do you have another second favorite color?"

UNIDENTIFIED MALE: Blue.

ALAIN DURAND: Blue. You have blue, right? That doesn't work. Give me another one.

UNIDENTIFIED MALE: Okay, red.

ALAIN DURAND: No, it doesn't work so can I give you green?

UNIDENTIFIED MALE: Okay.

ALAIN DURAND: All right. So that's what it is. We do a negotiation on that, okay? So when you talk, you're going to send what color?

UNIDENTIFIED FEMALE: Orange.

ALAIN DURAND: When you talk, you're going to send?

UNIDENTIFIED MALE: Yellow.

ALAIN DURAND: When you talk, you are going to send?

UNIDENTIFIED MALE: Blue.

ALAIN DURAND: And when you talk, you are going to send?

UNIDENTIFIED MALE: Green.

ALAIN DURAND: There we go. No problem. On the other side, if I want to listen to you, I listen to orange. I turn my receiver to only receive the orange part.

So that's no different than radio, right? If you listen to FM radio, somebody talks on channel 88.5 or 88.9 or 91.2. You just have a different frequency. The colors are different frequencies, different wavelengths, right? So that's how we are going to share the fiber, so we can have one fiber shared by many different people. Simple. Next slide, please.

All right, so we're talking about Layer 2 now. By the way, I live in Washington, D.C. in America so that's important for the next part of the talk. Let's say that I want to run a fiber between this ICANN meeting and my office in Washington, D.C. I want to have communication, so I'm not going to have a single piece of fiber that will go all the way from Washington, through the ocean, through wherever it lands in Africa to Europe and to Europe, through Europe and here. It's just too expensive. If I'm here for a week, anyway it will take several years to get this done so that is not going to work, right?

So how do I do that? Well, the way is to piece these bits of fibers together. So maybe there is a piece of fiber that goes from here to the center of Abu Dhabi. There's maybe a fiber that goes – I'm making this up – from Abu Dhabi to Dubai, maybe another fiber that goes from, let's say, Dubai to Paris and another fiber that goes from Paris to New York, and one from New York to Washington. I am going to piece them together. Okay?

And the same as before, as we were using colors. Remember your favorite color is?

UNIDENTIFIED FEMALE: Orange.

ALAIN DURAND: Thank you. So you want to use orange on the fiber from here to the central office and that's okay because we all agree that she can have orange. But on the fiber from here to Dubai, maybe somebody else has orange. Right? Maybe somebody here that's not in this conference, from somewhere else. So that's a conflict, right? And it's going to be really difficult to negotiate all that.

So we're going to say you can start with orange, but arriving in the center of Abu Dhabi, I'm going to translate orange into something else that is not used by anybody else, and you don't need to know. That's fine.

When it goes to Dubai, I'm going to translate this, maybe it was yellow, and translate it into a green because nobody else is using green, and this all the way to Washington where somebody maybe has to use purple because that's the only thing that's available. As long as you tell the person on the other side, "I'm going to send orange, but you're going to receive purple. Just think that I'm sending purple," then that's okay.

So we will do this chaining with active elements and by doing that, we create what we called a fiber path. And then there are two ways of sending the rest of the network on this. We can use this directly or using a protocol that's called a framing protocol, like [SONET] and a bunch of others in order to make sure that we explain that we are going to send for certain duration, when we

are going to pause and send for another duration and we're going to pause.

It used to be all the time like this, but in modern deployment, it's not used anymore. That's why I'm not talking much about it.

So I already talked about speed. So let's say that you have a fiber that can do 100 gigs per second, a super-fast fiber. But that's still not enough for you. You want 200 gig. How do you do that? Why, you take two of them and you put them together. So what you have on a router is a splitter, essentially, that's going to send half of the traffic on one fiber and the other half on the other fiber, and on the receiving side, you have a [exact reverse] splitter that is going to merge [the two] traffic.

So doing two times the bandwidth of one fiber, very easy. Four times, still fairly easy, and the cost of doing four times is about four times the cost of doing once, more or less. When you go to more than that, like ten times or 20 times, it gets really, really expensive because you need to have electronics that goes through all the different optics that goes through all the different channels and making sure that you have consistency between all of them and that you don't send half of a packet on one side and half of a packet on the other. Maintaining the consistency of a system is difficult.

So most of the time, you need to jump to the next generation if you need more. So if you had started, for example, with 10 gigabytes like ten years ago, it was like the classic thing, and people multiplied by two, by four, 40 gig. They wanted really 100 gig, they had a really hard time to do 10 times 10. They tried [it worked] in some cases but it was really hard. They had to wait until the next generation of technology that brought [natively] 100 gig. And that's what is happening now with 200 gig, 400 gig. We can do that. One terabyte per second is still in the works. So next slide, please.

All right, so now we are going to create a network with this. And as I said, the world is not flat. We have learned that a certain number of years ago. The Greek, apparently, knew that. And why is this important? I'm going to talk about some anecdotes here and try to not use the same as yesterday for the people who have been here before.

There are some network equipment that are not necessarily of the same quality of the others. Some are better and some are much worse than the others.

So those that work, usually work by saying, "Oh, I'm going to send something," like [an Ethernet network], "I'm going to send something for a certain duration and then I am going to pause. Then I'm going to send something for a certain duration. If

somebody is trying to talk at the same time, I'm going to stop and we are going to decide who is going to talk and maybe it will be me, maybe it will be somebody else."

This is all fine when everybody is playing the game by rules, but it's just like in school at recess. Not every kid is playing the game by the rules. So if you have an unruly child that wants to have more candies than the others, then there is no candy left for the other kids. It's kind of the same on the network. If you have an unruly computer that does kind of crazy things and does not respect the protocol, then it's going to talk all the time on the network and there will be no space left for the others.

So things like that happen a lot. For example, you have something called an [ARP] broadcast. Somebody says, "Oh, I want to know who is on the network," and you send the message and it sends to every single node on the network and all the nodes respond saying, "This is me. This is my address. That's my name." That's great, but that generates one message to go to everybody and let's say you have 1,000 machines on the network, you have 1,000 messages come back.

Now, if you do that once, that's kind of okay. If you do that once per second, that's much less okay. If you do that once every tenth or hundredth of a second, then you can essentially melt the network. Now, if it's not just you that is doing this but

everybody in the room is doing this at the same time, that entirely melts the network.

So we had incidents of the first kind that I was describing, impolite, unruly children or people who are sending inadvertently broadcast storms and that melted the network, so people were not very happy about that. So they said, "We need to segregate the network. We need to make sure that it's not going to be too big." So maybe 100 machines, that's okay, 1,000 machines, that's too much, something like that. And we are going to say, "We want to make sure that if we are an enterprise or even at home."

Let me take a better example at home. I'm going to say there's a network for me, my computer for work. The kids also want to use the network. I don't want them to mess up with my work traffic because work is really important and if the kids do something stupid, I still want to be able to work. So I'm going to separate the networks. So that's the whole idea, is that we're going to separate and isolate network, separate, isolate, segregate, all those words mean the same thing. We are going to separate the networks and interconnect the networks.

So when we are talking about Layer 3, it's about now creating those interconnections between networks, and that's where the IP technology comes from. IP stands for Internet Protocol. I

know that in the ICANN community, a lot of people think that IP stands for Intellectual Property, right? No. It stands for Internet Protocol. If you are talking about intellectual property, you should be very specific and say, "IPR," Intellectual Property Rights.

So next time somebody talks about IP, say, "You mean IPR, right?" Because IP, this is something different. So next slide, please.

Okay, now we have a network. We can use the network to do something useful and start to talk. So I'm going to talk to Cathy and when I talk to Cathy, we have two protocols on top of IP that we can use. One is called UDP and one is called TCP. UDP is simply, I'm going to send the data – it's called a datagram – and maybe she will receive it, maybe she won't and I don't care. That's really what it is.

TCP is about making sure that I know that she's receiving the data. So if I want to say something to Cathy and say, "It doesn't matter much to me," say, "Okay, I'm leaving now and I don't want to even respond to me," that's perfect. I can leave and bye-bye. She may or may not like this. But if it's an important discussion like, "Cathy, when is my paycheck coming?" I want to know that she has my questions and she's going to get back to me. So that's why we have two different types of protocols here.

So let's talk about the one where we want to have some reliable connection. So the first thing is to establish this connection and when we are going to send data. Here's a problem. I want to talk to Cathy. I want to make sure that she hears me because she is [in another] room. Remember networking can be on the other side of the planet. I want to make sure she hears me. She wants to make sure that I hear her. Okay?

So the first [thing that] we are going to do is I am going to initiate a connection and send a message to Cathy. I will say, "Hello, Cathy." At that point, what do I know? Nothing. All I know is that I sent a message. That's it. What does she know? Nothing. Now she is going to receive a message. Message arrived. You are going to respond to me.

CATHY PETERSEN: Ack.

ALAIN DURAND: Thank you, Cathy. At that point, what just happened? She has received my message so she knows that she can hear me. She is going to send me a message saying that she can hear me. Does she know I can hear her? No, she has no clue. Right? She's sending this message to me. I receive the message. "Ack" means acknowledge.

I receive a message. What does it mean? It means that she has received mine if she is able to respond to it. So I know that she can hear me. That was much better. She knows she can hear me. I know she can hear me. But she doesn't know that I can hear her so I have to send her another message, "Ack," and when she is going to receive it, then she will know that I have received her message. Now she knows that I can hear her and I know that she can hear me, so we both know that we can hear each other and there is no point to go any further than that.

So that's called the three-way handshake, the TCP Three-Way Handshake, to make sure that we all know we can hear each other.

Now, we can start sending data. The first thing I could do is to send a bunch of data and say good-bye, but now I have no clue if she has received them or not. And most importantly, I don't know if she has received them in order. So the first thing I am going to do is to take my messages and put a number in them, like Message 1, Message 2, Message 3, so if she receives Message 3, Message 2, and Message 1, she can reorder them and make sure that now things are in order.

But let's say I'm going to send Message 1. Cathy, message 1.

CATHY PETERSEN: Ack.

ALAIN DURAND: Thank you. Now I know she has received Message 1. I can send another one, but now I'm going to send message 2, 3, 4, and 5.

CATHY PETERSEN: Ack.

ALAIN DURAND: Now I know, actually she should say Ack 5. Sorry.

CATHY PETERSEN: Ack 5.

ALAIN DURAND: Because that way, I know she has received 1, 2, 3, 4 and 5. She's sending the acknowledgement for the last one. Now I'm going to go a little bit faster and I'm going to say, "Message 6, 7, 8, 9, 10." Nothing. It just means that she has not received it after a while and I have to try again.

So why has she not received it? That's an interesting question. I send the message through the network. Can you come up with an idea [or scenario] as of why the message didn't go through? Do you have an idea? Any suggestions?

UNIDENTIFIED FEMALE: Won't you explain in the beginning, the colored send is not what was being received?

ALAIN DURAND: Okay, that's one idea. We have another.

UNIDENTIFIED MALE: A break in the actual physical connection that links you to her.

UNIDENTIFIED MALE: A break in the connection.

ALAIN DURAND: Yeah, like a fiber is cut or something like that. That's a good idea. Any other ones?

UNIDENTIFIED MALE: From time to time, the Internet connection can be dropped or congestion in the traffic.

ALAIN DURAND: Traffic congestion. Thank you very much. All those three are correct. One more?

UNIDENTIFIED FEMALE: Oh, it's the same, saturated.

ALAIN DURAND: Yes. So all those three things can happen. There could be breakage in the protocol, like you said, the colors mapping and something got wrong, somebody messed up. It could be a physical break in the network, like a cable cut or fire in the building or anything like that, misconfiguration. That would be the same as what you are talking about. Or it could be too much traffic. For example, on a typical service provider, a router that aggregates traffic from users, you may have, say, 5,000 users but there is enough bandwidth only for 2,000 so if they don't speak all at the same time, everything is okay, everything is fine. If they all talk at the same time, at peak hour at the end of a soccer game, then there's not enough traffic – congestion.

So at the beginning of the days of networking, the first two problems were dominant. We thought that it was a configuration problem or a cut in the network. Today this doesn't happen very often. There's an outage. It happens maybe once a year, once every two years. But congestion, that happens every day, every minute almost. So that's the number one reason for problems like this.

So if a network is congested, it means that there is too much traffic. So remember I was sending, "6, 7, 8, 9, 10," right? I was speaking very fast. Maybe if I were to speak a little slower, there will be a chance that things will be okay. So I'm going to try again. Instead of saying, "6, 7, 8, 9, 10," I am going to say, "6… 7… 8… 9… and 10."

CATHY PETERSEN: Ack 10.

ALAIN DURAND: That worked. Okay? Now I know that "6, 7, 8, 9, 10" is too fast. "6… 7… 8…" is okay. Maybe I can try somewhere in the middle, so I can go a little faster, like, "11.. 12.. 13."

CATHY PETERSEN: Ack 13.

ALAIN DURAND: So this time, that was still okay. I can go even faster, like, "15, 16, 17." Nothing. So I know now by trial and error, where the limit is and that's how I can figure what is the maximum bandwidth I can use in the network.

So this algorithm has been created by Van Jacobson many, many years ago and it's called the TCP Congestion Mechanism

from Van Jacobson. He has his name on this algorithm. So the next slide, please.

All right, now the next layer [in the OSI model] is called Layer 5: Session. That's when I'm going to start describing a little bit what I'm going to send. So this thing is only used in the real-time media and this is going to say, "We are going to use this type of [codec]. We are going to encode the audio this way, we are going to encode the video this way, and this is the URL of a server where you can actually do this thing." So this is essentially a protocol that is going to carry information about what is happening. It's not used a lot outside of real-time streaming. Next.

When you really want to be more specific about what is the data, you need to create a structure to the data to say, "This is exactly what I am going to talk about." The example here is about a menu. Let's say that I want to communicate to a client that there is a menu that you can use on a cell phone, for example. So a menu has a structure. It could have different values, different pop-up things, and different functions to apply to this.

Many years ago, there was some private encoding of this so the client and the application had to know exactly what it was and when you were creating a new application, it was something new. When people moved to ASN.1, it was quite popular in the

'80s and '90s, like binary encoding of the description of what it is. Binary encoding is great for machines. It's really bad for humans because it's very hard to read. So we had to compile the text form into a binary form and sometimes there were errors in that compiler and it was really, really hard to debug.

So all of this to save a few bytes, nobody cares about saving a few bytes now, but [networks] are really, really fast so it's more important to make sure that it's easier to debug.

Actually, that's an important thing, an important part to this. When you operate a network, the number one cause of outage is complexity. The number one cause of outage, because something was too complex, somebody messed up something at some point because they didn't follow all the rules or the rules were too difficult to understand, there were some things that were not clear and that's why things [break]. In 99% of the cases, you can trace outage back to some kind of extra complexity.

So when you create a network, you have to be really, really careful to put the complexity when you need it because that's absolutely required to achieve what you want to do, but if you start to put more than that, then you create weaknesses in your network and that will be sources for outage.

So moving from binary presentation to text here actually simplifies things a lot because now – video stopped. Did I step on something?

UNIDENTIFIED MALE: Make it up.

ALAIN DURAND: All right, I am going to make it up. That's okay.

So when you have a text representation of what it is, a human can go and read this, and it's much easier to understand. It simplifies the entire system. So when you reduce the complexity, you reduce the risk for outage and you actually reduce the number of outages. You have a network that operates in a much more efficient way and at the end of the day, things work much better.

So while we see if this projector is working, why don't you just lift the screen up and everybody can see it. This is all nice and well, but at the end of the day, at this moment here, you have built a network but you have no users. I know that I can talk to Cathy, but that's about it. She is gracious enough to send me "Ack" from time to time when she receives my messages, but I don't have an application and nobody is going to pay somebody

to receive an "Ack". I know that Cathy is a really nice person, but still, this is not enough. She is not going to pay for this, right?

Users want real applications, real benefits, and those applications [run at] what we call Layer 7. So a type of application is a kid that has an iPad and is watching YouTube. That's an application because if the kid is happy, the parents are happy and if a parent's happy, they are going to pay the bill to the service provider. This is as simple as that. If a kid is complaining that the YouTube download is too slow, parents are going to say, "Yeah, yeah." Then he's going to complain again, again, and again, and you know what will happen the next month? The parents call the service provider, "Please increase my bandwidth," and the kids stop complaining. Parents are happy. This is really how it works.

So I am using this extreme example to show that all of the bandwidth, all of the networking usage are driven by applications. If people have the application they want, they will use the network and a service provider will actually make money from this and application vendors will make money, and this entire system will work and people will be happy using the network.

So that's the number one thing to keep in mind. If there is no application, if there is no need for what you are building, you are wasting your time.

That was the seventh layer on the OSI model, so we [create another two].

The next one is eight. Eight is financial. That goes back to my previous point about the parents paying the bill to make the kid happy. This is all driven by the money at the end of the day. If you cannot bill it, don't build it. It was an expression, an idiom, that we were using at a big company that I used to work for before being at ICANN. It was a big service provider in America. If you cannot bill it, don't build it. If you cannot make sure that people are going to pay for this, then you don't have a market. You're not going to create this thing. Okay?

So for the longest time, for example, that company was looking at some new services and we had some market studies that showed that people were not willing to pay for it. Technology was there. People were not willing to pay for it. Okay, we had a prototype or two and it stopped there. It would have been a commercial failure to launch it at that time. A few years later, studies show that, yeah, people are actually willing to pay for stuff like this, and then that's okay. Remember that one. If you cannot bill it, don't build it.

And on top of that, there's another layer, what we call Layer 9, which is the political layer. Politically is to be taken at the purest form of a term. It means how do we agree together as a collectivity, as a community, on how to make decisions? And ICANN is an example of that. We have a multistakeholder process where different communities get together and try to sort out different conflicting interests. It's a really important forum and it's part of a network life. Without this, people will essentially not build any of these things because both interests will not align.

So we started from zero and we went all the way to nine. I know there were initially only seven layers, but those extra layers help to understand the overall picture.

Now think of those layers as attraction models, right? This is a presentation of this. It does not mean that all the layers are built exactly this way and that there are no other layers. For example, do you know about MPLS? Who has heard about MPLS here? One person, two persons. Okay, so which layer is MPLS? We have a candidate here in the back.

UNIDENTIFIED MALE: I'm not a technical.

ALAIN DURAND: Anybody knows about MPLS? Two? Layer 2? Well, MPLS can run.

UNIDENTIFIED FEMALE: [Inaudible]

ALAIN DURAND: MPLS, Multi-Protocol Layer Switching. You never heard about this one? It's something used by a service provider to create, for example, VPN, Virtual Private Networks. And it's something that sits above Layer 2 because it's using the framing that I was discussing before, but it sits below Layer 3 because I'm going to run IP on top of it. So if it's above Layer 2 and below Layer 3, which layer is it? 2.2, 2.5, 2.7, right? So that's why those things are okay. They are conceptual models that help us try to represent things, but don't get too hung up on this, okay? Because, yeah, sometimes we have things like this.

Is this going to work or not? Okay, I guess that the answer is no. So let's move to the next slide. I just want to see what it is.

All right, so now that we have this – this is our introduction part of a tutorial – let's move to the big [inaudible] of this thing, the [important] part of it, like naming, addressing, and routing.

So all of this started from a real problem I had one day when I was traveling into an ICANN meeting. I had woken up with a

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major toothache, like really major and I went to see Cathy in the morning and I said, "Cathy, I really have a problem. I couldn't sleep all night. It was really bad. I need to present something tomorrow to the Board. You need to help me, Cathy. Okay? I need to see a dentist. I know that you have lived here in the city for a number of years before, can you recommend me the name of a dentist?"

CATHY PETERSEN: Sure. My dentist's name is Dr. Al [inaudible].

ALAIN DURAND: Thank you. So now, I know that I have to find a dentist. I know that there's a dentist in the city. I know that the dentist's name is Dr. Al [inaudible]. Okay? So that's a start and we are going to follow this journey to finding Dr. Al [inaudible].

So we have the name and what's a name?

UNIDENTIFIED MALE: A unique identifier.

ALAIN DURAND: Maybe. That's actually correct. But when I have a question like this, "What is X?" my answer is "Open up a dictionary." So I went to the Merriam-Webster Dictionary and I looked, "what is a

name?" The answer is – I'm going to read it here – usually, it's on the screen over there, "A name is a noun, a word, or a set of words by which a person, an animal, a place, or a thing is known, addressed, or referred to."

In other words, if I know your name, I know who you are. That's what it is. That's the very first thing I really want you to remember from this tutorial. If you forget about everything else today, there we be three things totally to remember, this is the first one. If I know your name, I know who you are. Okay? What's the first thing to remember?

ALICE BAIN: If you know my name, you know who I am.

ALAIN DURAND: Yes. I know your name, I know who you are. Okay? All right? Question?

ALICE BAIN: In the village I live in Grenada, there are two Alice Bains.

ALAIN DURAND: Great point. I'm going to just bring this. Thank you very much. But you will have to bear with me one slide before I get there.

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So when I have a name, there are two things I can do with it. I talk to Cathy. Cathy, what was the name of your dentist again?

CATHY PETERSEN: Dr. Al [inaudible].

ALAIN DURAND: Okay, so notice in this conversation that we had, we used names. How many names did we use?

UNIDENTIFIED FEMALE: Two.

ALAIN DURAND: Which ones?

UNIDENTIFIED FEMALE: Al [inaudible].

ALAIN DURAND: No, that was one. That's one name. Al [inaudible]. What was the second name that we used?

UNIDENTIFIED FEMALE: Doctor.

ALAIN DURAND: No, that's a title. That's not a name. What was the second name?

UNIDENTIFIED MALE: There was no second name.

UNIDENTIFIED MALE: Dentist.

ALAIN DURAND: No, dentist is a noun, it's not a name. You don't know? No. I said, "Cathy." Yes. I talked to Cathy about Dr. Al [inaudible]. Okay? Those are the two different usages of the name. I can talk to Cathy about Dr. Al [inaudible]. That's very, very important and we will see that in our context. We can talk to or we can talk about, and when we talk to, it's [said to initiate] a conversation. When we talk about, it's called a referral. Okay?

So you said that when you were young, there were two people who had the same name as you had in your village, right?

ALICE BAIN: Yes, there is. There still is.

ALAIN DURAND:	So when you went to school in the village – right? – and the teacher was talking to you, what would happen?
ALICE BAIN:	Well, they used my second name.
ALAIN DURAND:	Exactly, because there was a conflict. Nobody knew which one to talk to. I had exactly the same problem. When I was in school, there were six kids which name was Alain. Right? Six. And the teacher we had sometimes was a little bit angry at us because we were doing some kind of mischief and she would say, "Alain, go to the blackboard," and you know what happened? I'm sure you know what happened in that case. What will happen?
UNIDENTIFIED MALE:	All Alains.
ALICE BAIN:	Everybody stand up. Everybody sit down and look at each other.
ALAIN DURAND:	Exactly. Everybody sat down and looked at each other. Nobody wanted to go because we knew what would happen. And you know what happened next? You know? Want to guess?

UNIDENTIFIED FEMALE: I think she had some numbers on the Alains [one].

ALAIN DURAND: Yes. So the first thing actually she did was to get angrier. She said, "Alain, go to the blackboard," and nobody responded, of course, because it was like even more frightening. Then she would say, "Alain 2, go to the blackboard." Who is Alain 2 this week because you know sometimes it's one or the other. So she had to do exactly what you said, which is use the last name or use the full name of a person. Right?

So you remember this thing because we might have some ambiguities on some short names, sometimes you need to use the full name and that's really important.

All right. Now I know that I need to talk to Dr. Al [inaudible]. I hope this is the only one in the city, but assuming that, I have no clue where it is. I have no clue if it is next to the building here, two miles away. Do I need to take a taxi? I don't know where it is. So I go back to Cathy. Again, I use Cathy, talking to Cathy about Dr. Al [inaudible].

Cathy, can you use your Rolodex and tell me what is the address of Dr. Al [inaudible]?

CATHY PETERSEN: Absolutely. His address is 125 Root Canal Road, D.C.

ALAIN DURAND: It's actually a good location for a dentist on Root Canal Road. Now, what she has done is to map the name into an address for a Rolodex. If you were there in the tutorial yesterday on DNS – or was it this morning again or is it later, Steve? The tutorial on DNS.

STEVE CONTE: DNS Fundamentals will be at 5:00, I believe, today.

ALAIN DURAND: Okay, so plug for this tutorial, a great tutorial by Steve and if you want to know how to map a name to an address, that's exactly what the DNS does. So what Cathy did with her Rolodex now is made automatic by computers if you map a name into an address because that's really what it is.

                         This process of mapping a name to an address is called name resolution. There is a nice picture on the screen, but I'm sorry you will not see it. You may have to download it from your computer.

All right, so now I have an address. Okay, what's an address? Anybody? A unique identifier, right?

ALICE BAIN: For a location, yeah.

ALAIN DURAND: A unique identifier for a location. Yes, we are getting better here. So I did the exact same thing. I went back to the dictionary. All right? Dictionary, an address, "the particulars of a place where someone lives or an organization is situated." Okay. If I know your address, I know where you are. That's the second thing I want you to remember, okay?

The first thing I wanted you to remember was?

ALICE BAIN: We can talk to or we can talk about.

ALAIN DURAND: It was if I know your name, I know?

ALICE BAIN: Who you are.

ALAIN DURAND:	Right. If I know your name, I know who you are. If I know your address?

UNIDENTIFIED MALE:	I know where you are.

ALAIN DURAND:	Exactly. I know where you are, the second thing to remember. The rest, important, but those two, very important.

All right, so I told you I live in Washington, D.C. in America. There is a little house in Washington, D.C. It's not very big actually. It's painted white. It's in the middle of Washington, D.C. There's a nice a park. There is a nice garden in front. It's called the Rose Garden. It has a nice view. Sometimes a helicopter lands in front of it.

And every four years, there is a contest to decide who is going to live in there, so you put your name in the ballot and randomly, something comes out. The address of that place is 1600 Pennsylvania Avenue, Northwest, Washington, D.C., 20500, U.S.A. That's the address. If you look at this address, there is a structure to it. It goes from the end to the beginning.

At the end, it says, "U.S.A." That says [that's] the country, United States of America. The previous part was a number, the zip code.

I'm not going to look at this one now. The one before was D.C. D.C. stands for District of Columbia. In North America, most of the states will be Virginia, Texas, California. Those are states. The District of Columbia is not exactly a state, but for this purpose, it will be similar. Okay? So that's essentially the region where it is.

Before that, there is Washington. That's the name of the city in the state. Before that, there is Northwest because Washington D.C. is split into four quadrants: northwest, southwest, northeast, southeast. Before that, you have Pennsylvania Avenue because that's the name of the street, and 1600, that's the number. Okay? On the street. So this is this hierarchy, geographically organized. It's one type of address.

Now a phone number, is a phone number an address? Yes? No?

UNIDENTIFIED FEMALE: No.

ALAIN DURAND: Well, I kind of yes and no. It's an address on the telephoning network system. It's not an address for a person because if I have a number like my phone number is 703-623 and something that follows it. I don't want you to wake me up in the middle of the night. If you have my number, my phone number, you can

call me – so, yes – but you have absolutely no clue where I am. Today, I am here in Abu Dhabi. Last week, I was in Dubai. Next week, I will be home in Washington, D.C. The week after, I will be in Singapore. Right? You have no clue where I am because by simply looking at the phone number, it doesn't give you information about who I am, the same way when you are looking at the address, postal address, you know exactly where it is. Okay?

In the old days, when you were looking at a phone number, if you were looking at the first digit of a phone number, you will know where that person was. It was 703 was the area code. That was located for Virginia, which is right next to Washington, D.C. and you know that person lives there, and it was okay because it was a phone line, a physical phone line and a physical telephone attached to it that was not moving. Now that this is my phone, that goes everywhere and it actually does go with me everywhere. But oh fabulous, wow.

The same thing with IP addresses, if you look at the IP address, can you know where the machine is? Yes and no. If you look at the structure of the IP addresses, there is nothing that tells you where that machine is. Now, people have built tables to say, "Oh, I have observed that this address actually is in Dubai, but this address is in Abu Dhabi, this address is in Washington or New York," but people have built those tables. It doesn't come

with the structure of the address, the same way that if I look at the address on the top, I know exactly where it is. So some addresses are built geographically. Some are not. Next slide, please.

So same thing with names, you are telling me that you had two people with the same name when you were young at school and people still live. Sometimes you have conflict. For example, if you live in Paris, in France, do you know where Paris is? Where is it?

ALICE BAIN: In France.

ALAIN DURAND: Okay, well, in North America, there are 29 cities – not five – 29 cities that are called Paris, and one of them is in Virginia, as I said, next to Washington where I live. And I have jokes with my kid when I say, "Let's go to Paris for lunch." So no, we are not hopping on a Concord to fly faster than any other planes to go to Paris, France, and have lunch and come back. We're simply taking the car and we drive for half an hour.

So if I only say "Paris," that's just not enough. I need to say, "Paris, Virginia," or "Paris, Texas," or "Paris, France." Okay, next.

The same thing as when we use names, we could use names to talk to somebody or to talk about somebody. Same thing with the address, when I was talking to Cathy, "Cathy, what is the address of Dr. Al [inaudible]?"

CATHY PETERSEN: 125 Root Canal Road, D.C.

ALAIN DURAND: Thank you. So we were talking about the address, okay? We didn't go there. Now I need to go there. I need to hop in a cab and go there. Let's do that. Next. Thank you.

So let's go back to this White House, a small house in Washington. Let's say that you want to send a postcard there. You write the postcard, you write the address, you put a stamp, pop a stamp the right postage on it, put it into the mailbox at the post office and I can guarantee you that after a few days, maybe more, it will arrive there. I cannot guarantee you that you will receive a message back, but I can guarantee you that it will arrive there.

Why? Because the post office here has some agreement with some other post offices in the world and they will agree to send the letter over there. Sometimes it's a joint agreement between the post office in the city or the country where you are with a

post office in America, and it goes there directly by plane. Sometimes it takes some intermediary. Maybe we send the mail to Paris, France, and then Paris, France, post office has an agreement with New York and they will send the mail over there and then New York will know, "It's in Washington. I'll put it on the train."

But it works because there's an agreement between the systems and we come back to this later. Now how do I go to 125 Root Canal Road? Next slide.

All right, routing. Same thing, I went to the dictionary and tried to find the definition of routing. So routing is "a way or course taken in getting from a starting point to a destination." It is, "How do I get from Point A to Point B? What intersection do I have to use? Do I need to turn left or turn right?" That's what routing is.

So if I have a route to you, I know how to go to you. Okay? I know where to go, how to go there.

What's the first thing to remember?

ALICE BAIN: The name.

ALAIN DURAND: What's the first thing to remember?

ALICE BAIN: If I know your name, I know who you are.

ALAIN DURAND: Great. Thank you. What is the second thing to remember?

ALICE BAIN: If I know your name, I know where you are.

ALAIN DURAND: That was the first one. The second one?

ALICE BAIN: Where, the second one is where.

UNIDENTIFIED MALE: Yeah, but you are saying, "If I know your name."

ALICE BAIN: Oh, I know where you are.

UNIDENTIFIED MALE: That's the address.

UNIDENTIFIED FEMALE: If I know your address, I know where you are.

ALAIN DURAND: Now, number three, third thing to remember. What's the third thing to remember?

UNIDENTIFIED MALE: The first is, I think it's the name.

ALAIN DURAND: The third one.

UNIDENTIFIED MALE: Your location.

ALAIN DURAND: Okay, so the third one is if I have a route to you, I know where to go. So let me repeat this. If I know your name –

ALICE BAIN: I know who you are.

ALAIN DURAND: If I know your address –

ALICE BAIN: I know where you are.

ALAIN DURAND: If I know your route –

UNIDENTIFIED MALE: You have to go.

ALAIN DURAND: Yes, three things to remember. Everything else, forget it. Next slide. All right. So let's say that you have a car and you want to go to 125 Root Canal Road, and you know nothing about the city. What do you do? And you have no GPS. What do you do?

Well, you turn the engine on, you start the car, you get out of the parking garage and you follow the directions, right? There is going to be a sign that says, "Root Canal Road," turn left, you go to roundabout, another sign that says "Root Canal Road, second exit on roundabout," etc. That's what you do. If nobody had put any signs, maybe you'll not find your way. Right?

So it's an important concept that somebody has to put those signs on the network in place before you can actually use the network. Right? So it is a process. We are going to create those signs. We will start from the destination and we are going to say I

am connected to a service provider and I'm going to tell my service provider, because I have a contract with them, "I'm here. If you receive traffic for me, send it to me." Okay?

My service provider, because he's a good guy, is going to send information to all his peers and say, "If you want to send traffic to Alain, send it to me. I know where Alain is. Send it to me." Now this guy says, "Oh, I know a guy who knows Alain. Great. I'm going to send this information to all my peers." And then they will receive something like, "If you want to go to Alain, send this to this guy," for example. And then this one will know a guy who knows a guy who knows how to go to Alain. So routing on the Internet is all about this. It's I know someone who knows someone who knows how to get there and I'm going to trust this.

Why does it work? Because service providers cooperate together. They cooperate the same way as the post office cooperates and you trust the post office to actually do the right things. This is the same thing here. I trust my service provider and the other service provider to actually collaborate and to make this work. Next slide.

So when I am going to send the traffic, now from the source, I have received information that I have to send it there. I'm going to send the traffic to this router here and I'm going to trust that

this router is going to do the right thing. Let's say this is my service provider. My service provider is sending me a bill every month and they like it. They like me to pay the bill. If they stop doing the right thing, I am going to stop paying them and they will not like this. As a consequence, they are going to do the right things. Right? That's really how it works.

And the entire system is going to work because both service providers collaborate with each other. That is why the system works. All right, next up, next slide.

All right, well, now I have arrived. Next. And I could go see my great Dr. Al [inaudible] who can do something about my tooth, and thank you very much, Cathy, for giving me this referral.

CATHY PETERSEN: You're welcome.

ALAIN DURAND: So that's the end of my talk. I'm sure you have many questions, but before you ask your questions, there are three things I want you to remember, right? What's the first one?

ALICE BAIN: If I know your name, I know who you are.

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ALAIN DURAND:	Great. Let's [vary] a little bit. What is the second one?
UNIDENTIFIED MALE:	If I know your address, I know where you are.
ALAIN DURAND:	Great. Thank you very much. Third one?
UNIDENTIFIED FEMALE:	If I know your route, I know how to get to you.
ALAIN DURAND:	Exactly. Forget everything else. Forget my jokes. But those are the three things that I really want you to remember. Questions? Going once.
UNIDENTIFIED MALE:	Thank you. So my question is about some of the fiber optic cable that runs across the ocean. What is your level of involvement? Obviously, you're not laying trenches down there, but what is ICANN's level of involvement and knowledge when it comes to the networking of the cables?
ALAIN DURAND:	None.

UNIDENTIFIED MALE: We have those free maps though.

ALAIN DURAND: Yes. So the question is really who finances and who actually puts those cables in place? So the second question is easier. Who puts the cables in place? You have some companies that lay cables, an extraordinarily complex operation where they build the cable on the boat when they're going on the sea.

Who pays for it is a very interesting discussion. There was a presentation made by Geoff Huston. I can't remember if it was last week at a RIPE meeting or a few weeks ago at the NANOG meeting, but who is paying for it? It used to be that Internet Service Providers were paying for it. They were getting together and they were paying for the cost of the fiber and then they're amortizing this over many years. It appears now that the largest part of the cost is actually bought by the content provider, people like Facebook, Google, Netflix, and others. They are the ones investing massively into new fibers, and those are private agreements. ICANN has absolutely nothing to do with that.

Another question?

ALICE BAIN: I also wanted to add, I know in some instances, you have governments getting involved just to reduce that, areas that don't have connectivity. There isn't a business case for an ISP or a business to lay a cable, an undersea cable. Sometimes you have governments who lay it just to bring connectivity to a population when there isn't a business case. [True], something like a public/private partnership or just full government.

ALAIN DURAND: Yeah, that's a very, very good point. It's not just all private, you're correct. In many cases, because the costs are really significant and the return on investment is not obvious, there is a big role to play for governments there. That is true. Another question?

UNIDENTIFIED MALE: Alain, I have a practical question. So you know that in many countries, their connectivity and the different telecommunication services is delivered to flats, to apartments by fiber optic. So on that last part of the [signal] distribution, they use it to make it a conversion to fiber, the optical [signal] to [electrical signal] and do it by the means of to join it to the [co-axial] cable and so on.

So is it now the router and, let's say, access point that allow [to convert] directly the fiber optic optical signals that belongs to TV, phone communication, Internet communication, digitally convert to the wireless and [inaudible] this way to supply the [inaudible] home appliance signals?

ALAIN DURAND: So it's all a matter of cost of wiring the building. So if a building is brand-new, you may have fiber that will go from the basement of a building to each individual unit because when you build a building, you might as well put the fiber in place. If a building is old, you don't have that and retrofitting the building with fibers may be a really expensive proposal when you may already have either twisted pairs of copper or you may have a cable for cable TV that's already in place. So why not reusing it?

It turns out that the bandwidth on the scope of things on short distance is usually greatly underestimated. On a piece of [co-ax] cable, you can go to a gigabyte per second very easily. So if you are going to deliver may be even 10 meg, 20 meg, even 100 meg, one gig, that's enough if the cable is in good condition. Sometimes the problem is that the old cables that are broken in places are patched together and it's not as good.

UNIDENTIFIED MALE: You can use a couple of cables, but not for long distances.

ALAIN DURAND: That is correct. So for example, I had some computers hooked together at 10 gigabytes per second using copper but on one meter. I will not be able to do ten meters with that at 10 gigabytes. At one gigabyte, I can go 100 meters, no problem. If I want to do more than that with copper, not really. The signal goes really weak and then I have to regenerate a signal and all of that. So for example, DSL, three kilometers, five kilometers, maybe ten and after that the signal gets really, really weak. Another question? Yes, in the back.

UNIDENTIFIED MALE: I don't know if it's a stupid question, but the routing which you were talking of, is it always through cable or can it be through the air without cable? And number two, who controls the movement? Is it ICANN or is it the local government which can shut off the tap, so to say?

ALAIN DURAND: So you had three questions. The first one, you didn't know if it was a stupid question or not. All I know is there are stupid answers, but no stupid questions. So I'm probably going to give you stupid answers.

The second question was it is always fiber or cable or is it sometimes wireless? And it is sometimes wireless. So best example is satellite. You live in a rural area. You may have local distribution through, I don't know, an antenna, 3G, 4G antenna but there is no back hole for fiber. What you can do is take a satellite antenna. You shoot up to the sky, bounce to a satellite, goes to a base station, ground station, and then you have your connectivity this way. Or in some places, they use Wi-Fi signal with directional antennas to go from the continent to an island that may be like 10, 20 kilometers away. That's fairly common.

When you have line of sight with the radios like Wi-Fi directional radio, directional antenna, you can go some pretty long distances within decent boundaries, so that happens. It doesn't have to be fiber [inaudible].

Now the other question is about who controls the network. And well, it depends. That's a stupid answer that I was about to give you. It's certainly not ICANN. That I can tell you. It's not ICANN. And this is under the control of service providers and service providers are under the jurisdiction of the local governments and regulators and things happen.

STEVE CONTE: There's a follow-up here.

UNIDENTIFIED MALE: No, but they have a contract with ICANN, I think, all the registries.

ALAIN DURAND: No. The service providers don't have a contract with ICANN, not at all. They're completely independent. People who have a contract with ICANN, the contracted parties are the people who operate Top-Level Domains like registries or registrants with a register name into those registries. Those are the contracted parties. Service providers are not contracted parties. Questions?

UNIDENTIFIED MALE: [Inaudible]

UNIDENTIFIED MALE: You have ten minutes.

UNIDENTIFIED MALE: Okay, so I'm wondering. Most of your graphs and explanations were done based on the fact that ISPs are currently in control, so to speak.

UNIDENTIFIED MALE: [Inaudible]

UNIDENTIFIED MALE: Okay, so most of your explanations were done, and your graphs were done based on the fact that, like the one that says if I know your name, I know who you are and stuff like that. Now with the advent of [destructive] technologies like [WhatsApp] and OTT players, project five years from your experience. Do you see this changing? Do you see these guys bypassing the ISPs somehow? What do you think?

ALAIN DURAND: Talk about a loaded question. It's not a stupid question. It's a loaded question. It doesn't change networking because at some point, you have to send the packet. The packet has to go through some kind of network and arrive somewhere. So the question you're asking, essentially, dives into the relationship between the service provider who has, essentially, a contract with the customers, the eyeballs, and the content provider [of the] over-the-top that has contact with the content.

And let's delve into the network neutrality discussion. So that will be the topic for another session and I'm sure it will be extraordinarily controversial like always on this topic, and I would like not to go too far into it. Now, if you want to talk to me after the session, we can continue this discussion. You had another question.

UNIDENTIFIED MALE: Alain, about DWDM, this is quite applicable for the [inaudible] model, fiber optic [inaudible]. It's used only for the single model, so it's [inaudible] great for us.

ALAIN DURAND: So DWDM is this idea of using the colors of a fiber that I explained. Before that, we were using simple light, white light, and we had to frame the traffic on it. So we were to say, "You're going to speak for this situation [inaudible]," and part of the framing was a little identifier that was saying, "Who is speaking?" So that was Layer 2 framing.

This used to be everything, 100% of deployment. Now it's less and less because instead of buying a frame relay or [SONET] or ATM or any of these things, people tend to buy more directly what we call dark fiber, meaning it's just a fiber and they are going to use our own lasers and just the fibers. Why? Because it's becoming less expensive. Twenty years ago, the mere idea of having a fiber or a fiber path between here and, let's say, Dubai would be crazy, or here and Washington, not even think about it. But now there has been so much fiber put in the ground and in the sea that it's actually possible to do that.

One of the big service providers I worked for in 2005 did just that. They wanted to build a nationwide network all across America, and what they did is they signed a 99-year contract with a provider of dark fiber. And it says, "We are going to [light] the fiber ourselves." That's fine because there was enough of a market for those things, but you could buy it at a much lower cost and if your network is big enough, actually, it is cost effective to do it yourself.

That's why we use those different colors I was talking about and use DWDM. That's why I didn't spend a lot of time talking about [SONET] and frame relay and all those things because they're not used as much as they used to be. They still exist – don't get me wrong – but not as much.

One last question.

ALICE BAIN: Do you think the capacity of wireless would ever surpass or would it always be fiber, the best in terms of capacity? Do you think technology is moving towards that era when you'll have wireless giving you as much as a fiber could ever give you?

ALAIN DURAND: My crystal ball is about as good as yours. Now, joke aside, this is a good question. But I will reframe it differently. I will frame it in

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two parts. The first one is, historically, has it always been the case? And the second part is, is there a point where enough is enough?

So historically, there has always been several orders of magnitude more bandwidth with wire than with wireless, like when we had maybe one gigabyte on fiber, we had maybe two kilobytes on wireless, right? Now this is the same ratio. Historically, this has never changed. So in the future, yeah, I don't know. Maybe somebody will find something that we don't even know yet.

Now the question that's more interesting is the second one. Is there a point where enough is enough? Is there a point where I don't need to increase the bandwidth to the user, for example?

So how much bandwidth do you have in your house?

ALICE BAIN: I can't [inaudible].

ALAIN DURAND: You don't remember. How much bandwidth do you have in your house?

UNIDENTIFIED MALE: Ten megabytes.

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ALAIN DURAND:	Ten megabytes. How much bandwidth do you have in your house?
UNIDENTIFIED MALE:	I'm not sure.
ALAIN DURAND:	Well, I have 75 megs in my house and I received an offer from my service provider. Do I want to upgrade to 150 meg or 500 meg or 1 gigabyte? And I said, well, my kids don't live with me at this moment so they're not doing this YouTube thing I was talking about earlier. I'm traveling a lot. Seventy-five megs is actually quite a lot. I'm okay with that.

Now if I were a big YouTube person, if I was a big virtual reality person, first-person shooter and all of that, I might decide that 75 megs is not enough, so you kind of have to adapt, okay?

Now for a number of years, there was an interesting question raised was, "Will the total bandwidth used on the Internet cap somewhere or will it keep going?"

There are two schools of thought. One is to say, well, it has been going and going and going historically, there is no reason it will ever stop. That's one school of thought.

Another school of thought says, "Well, this is somehow limited by the eyeballs." So that was when we were starting to stream movies. I can only watch one movie at a time. So if my kids are there – I have two kids – me and my two kids, three movies. It takes 20 megabytes per second to stream a movie in HD times three, 60 megabytes per second. I have 75 megabytes. I'm good, right? That was my calculation.

There is no point to go further than that because we can only [watch those three streams]. But now came 4K movies instead of HD. When you have 4K with virtual reality, so this whole thing is increasing.

Okay, so the question is what is the next thing? Right? What is the next driver for bandwidth? Yeah, 4K, more bandwidth. But 4K compared to HD is a little bit more. It's not like a lot more, like times two or something like that, times four. You go from 4K to HK, you double it or quadruple it, depending on which HK you're talking about.

So that's not an order of magnitude when you two times two. It's just a little bit more.

If you go to virtual reality, yes, it's more than that. The real question is what about communication that are designed not for humans but for machines because machines don't have eyeballs? Machines are not limited in the number of movies they

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can watch. A machine can decide to download the entire library of movies into the world and do that every single hour. That will use infinite bandwidth.

We don't know. That's the answer to your question, is we don't know, not because of a prediction that we had in the past, but we don't know because it's really, really hard to imagine today what will be the bandwidth usage by machines.

I think we are getting to the end.

STEVE CONTE: We are out of time, yeah.

ALAIN DURAND: We are out of time?

STEVE CONTE: Yeah.

ALAIN DURAND: Okay, let's talk offline about your last question. So thank you all very much for being here today.

STEVE CONTE: Alain, thank you very much. I got to say really quick, you explain this so much better. I tried this once. I sat someone down. I did the whole thing. If I know your name, I know who you are; if I know your address, I know where you live; and if I know the route, I know how to get there. The next thing, I was hit with a restraining order and I couldn't be 500 feet from this person. So you do so much better than I do with this.

I invite you guys all to stick around. In about 15 minutes, we're going to have a session with RSSAC and they're going to talk about their root server, the Root Server System Advisory Committee as well as root servers, and it's an interesting session. So in about 15 minutes, we'll start up with RSSAC. Thanks.

[END OF TRANSCRIPTION]