MARRAKECH – How It Works: Internet Networking
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ICANN55 | Marrakech, Morocco

UNIDENTIFIED MALE: Today is March 6th, Sunday, 2016, and the session is How It Works: Internet Networking in Oliveraie.

UNIDENTIFIED MALE: We're going to get started in just a second. We're just getting the presentation uploaded, so please bear with us and enjoy your morning in the meantime.

UNIDENTIFIED MALE: All right, we're going to go ahead and get going here. This is the second session of today's How It Works sessions, and this is with Alain Durand doing Internet naming, addressing, and routing. We'll be doing this again tomorrow, so if there are friends and family that want to join this that aren't able to do it today, please let them know, because we'll have a repeat session on this tomorrow. With this, I'm going to turn this over to Alain.

ALAIN DURAND: Thank you, Steve. Good morning. I just arrived yesterday, so I might not be totally awake. I expect that Steve will keep me awake and answering some of my questions during this presentation. This is an introduction to How It Works: streaming, addressing, and routing, so if you already know everything about that, I'm not going to teach you anything. So if you have other things to do – enjoy the sun, whatever – that's fine.

The intent is to provide a little bit of common knowledge to our community. Sometimes I hear that IP means intellectual property. Well, that's not what we're going to talk about here. If I press the right button, maybe. Here we go.

Four parts in this tutorial. The first one is talking a little bit about the technology, what is the underlying technology. I call this networking by numbers, so I try to make it easy. Second one, we'll talk about naming, what do we mean by names? Then we go into addressing, what does it mean to have an address? And the third one is about routing. The most technical one is the routing part, but I'll try to make sure that it's relatively simple.

I will actually make this interactive, so if you have any questions, feel free to ask. [foreign]

UNIDENTIFIED MALE: I'm sorry. If you do French, we do have a remote participant, so please convert that to English, as well, for the record. Thank you.

ALAIN DURAND: So, networking by numbers. As you may know, in the ISO layer, there were seven layers, so we just have augmented them to nine to reflect the reality. Actually, ten. I'm going to start at zero, because we are good mathematicians. We start counting at zero, not at one.

If you look at the first layer, it's how do we get the information moving. There are fundamentally two types of technologies that have completely different style of constraint. First one is about wired, and the other is about wireless. Wired, you are talking about copper or fiber networks, and wireless you're talking about spectrum and antennas.

When you put some wire in the ground, you need to open up the ground, and that's an expensive process in most places – not everywhere – and you have to get licenses to do that. There are public utility works, and digging a trench in the street is not always easy, but you get quite a lot of bandwidth from that fiber when you get it.

On the other side, wireless, it's very easy. You just have to put an antenna and you cover a large area. In sparsely populated areas, this is great. Now, I live in a residential neighborhood, and nobody wants to see an antenna next to his house. It's a bit of a conundrum here.

You can get more and more bandwidth now with 3G, 4G, up to 5G next, but the amount of bandwidth you get from wireless is orders of magnitude lower than what you get from a wired network.

This is like ease of deployment versus bandwidth, what type of regulation you have, and what type of neighborhood issues you may run into. Those are the two fundamental types of networks. Next slide.

Now that you have a physical media, like this piece of fiber. You need to send information over this media. When you want to send some information, it's zeroes and ones.

On the fiber, you may want to share the fiber with somebody else. How do you do that? Well, the simple way to do that is to simply send light in your fiber with different colors or different wavelength. You can send in green and receive in green on the other side. If Steve here wants to send some information on the same fiber, he has to choose another color. Steve, what color will you use?

UNIDENTIFIED MALE: I'll use blue.

ALAIN DURAND: Blue. Blue lasers are a little bit more difficult to build; it's more expensive.

UNIDENTIFIED MALE: That's why I chose blue.

ALAIN DURAND: Okay, fine. So you will have the expensive network. High quality QOS and all of it. Perfect. Kathy, what's your favorite color?

UNIDENTIFIED FEMALE: It's also blue.

ALAIN DURAND: Oh, that's a problem. Two blue networks? It doesn't work, okay? There has to be some kind of an agreement, that maybe you have a different shade of blue. Maybe you have a dark blue and Steve has a light blue, okay? Different wavelengths. And then we can send all of this traffic on the same fiber. That's how you share fiber.

This is point to point, so if a fiber starts from this hotel and goes to, I don't know, downtown, that's all it goes. When we go from downtown Marrakech to, let's say, I don't know, Paris – if it goes to Paris – we can change the colors. We don't have to use exactly the same color, as long as the colors are different.

So we can map the colors. For example, you will be blue from here to downtown Marrakech, and then you can go to green from Marrakech to Paris. It doesn't matter.

That's what we're going to do; we're going to create fiber paths. We're going to make sure that if I want to send information… Let's say I want quote unquote fiber connectivity between here and my office in Washington DC, I'm not going to have one fiber that goes from here to Washington DC. It's impossible to do that; it would cost just way too much.

So we're going to use a fiber from here to downtown. Maybe it would be another fiber from downtown Marrakech to, let's say, Paris. Another fiber from Paris to New York, and another fiber from New York to Washington. Actually, there would be more than that, but I'm trying to make it simple.

We're simply going to interconnect those fibers. As I said, maybe you will be blue from here to downtown Marrakech, then green, then it could be red. It doesn't matter as long as the colors stay

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different from other people and each endpoint of a fiber knows what to do with it.

That's how we create connectivity, by patching those fibers together. At the end points, complete end points like between here and my office, we will not see this fiber any more. All we'll see is essentially layer to network, and we would think, "Oh, we're just next to each other." It just happens there is a lot of latency because speed of light is a constant, so maybe it would be like 70 milliseconds, 100 milliseconds, but it would be fundamentally no different than if his computer was on the same desk as my computer there.

The speed on this thing, if you go fiber today, you can get up to maybe 100 Gb/s, which is quite a lot. We started, of course, much lower. What is standard now is gigabit Ethernet is very easy to find. Ten gigabit Ethernet is relatively easy to find almost everywhere, and we have multiple of the above.

25 gig and 40 gig are things that are used in datacenters. Service providers tend to use like 10 gig or 100 gig. More than 100 gig is still research, but certainly that will come at some point. As I say, you can have multiple of the above. If you want 200 gig, you take two paths of 100 gig, and you bridge them together, and that gives you 200 gig.

Moving up the stack, as I said when I was creating this layer 2 network, it was the same as if Steve's laptop would be on the same network as my laptop, and Kathy's laptop would be sharing exactly the same thing.

If Steve and I are playing games, you know, some of the games like point and shoot or whatever, are really high bandwidth. They send a lot of messages. Kathy wants to do her work, because she's a hard-working person. She doesn't want to see our traffic. It's just a nuisance. You simply want to send your e-mail to your boss; that's all you want to do.

The world is not flat. There's no reason to have all those communications sharing exactly the same network, so what you can do is create subnets. Steve and I can create our own subnet. You can create your own subnet and connect to wherever you want – connect with mail servers and whatever – and those would be different networks. So we're going to create some topologies. For example, we can say the network here in the room is one network. The network in my office in Washington DC is one network.

But we can also say that we want to have topologies that are virtual topologies, and that's when we use VPN. We can now say that Steve and I are on the same virtual network because we like to play those games together, and maybe Steve is traveling. He would be in Dublin and I would be somewhere in Australia, and we still want to play together, so we will create the VPN. Kathy would create a VPN to go to the office, because she wants to connect to the office server and look at the content of her e-mail.

That's how you use VPN to create virtual topology on top of something else. Essentially, at this point, when we're talking about layer 3, we're talking about IP. Again, IP is the Internet protocol, not intellectual property in this discussion. Maybe next floor up, that's a different story.

Okay, moving up a layer. Now I have put all my fibers together. I've created those networks and I can send packets from one to the other. Now we want to use this network to do something. Having connectivity for connectivity's sake is not going to help me much. I want to communicate.

I want to say hello and I want to send data, but again, I'm very far away. Maybe I'm still in Australia, like I was a week ago, or in New Zealand, and I want to talk to Steve who was somewhere else last week or two. I want to make sure that he receives my message. That's an interesting question. I don't see Steve, and I want to send Steve a message.

Steve, can you hear me?

UNIDENTIFIED MALE: Ack.

ALAIN DURAND: Oh, what just happened?

UNIDENTIFIED FEMALE: He acknowledged.

ALAIN DURAND: He acknowledged my message. I heard that he has acknowledged my message, so I know for a fact that Steve can hear me. Steve knows that he can hear me, because he responded to my message. What he doesn't know is if I have received his ack. He doesn't know if the communication from him back to me works or not. So what do I have to do? I have to respond to his ack. I'm going to say ack. At this point, we know that the communication works. It's established.

That's called the three-way handshake in TCP. There's a diagram here that shows exactly how it works. Once the communication started, we're going to send data. Data is chunked into small packets, typically it would be 1500 bytes or less, and sometimes it will be lost.

So I'm going to say "Steve, packet number one."

UNIDENTIFIED MALE: Ack.

ALAIN DURAND: Packet number two.

UNIDENTIFIED MALE: Ack.

ALAIN DURAND: Packet number three.

Nothing. That means that Steve has not heard packet number three. What am I going to do? It's easy, send it again. "Packet number three."

UNIDENTIFIED MALE: Ack.

ALAIN DURAND: Now Steve has packet number three. I also know now that Steve had a hard time to receive packet number three. Why is that? Well, maybe the packet was dropped somewhere, there was a mistransition. That's possible, but most likely there was a router in-between that dropped the packet because there was some congestion.

Congestion means there's too much information coming and routers can't keep up with all the packets, which means that I cannot speak that fast. If I were to speak maybe slower, things will be easier. So I will say "Packet number four."

UNIDENTIFIED MALE: Ack.

ALAIN DURAND: Wait. Packet number five.

UNIDENTIFIED MALE: Ack.

ALAIN DURAND: Packet number six. Again, congestion. Can't hear it. I'm going to speak even slower. And like that, I'm going to adapt the bandwidth to what is available. At some point, I will try to go a little faster. That's what TCP does, it really adapts transmission rate to what is available.

There's another protocol used on the Internet called UDP, for User Datagram Protocol. This is simply sending packets. There is no ack. I don't know if a package gets there. I don't know if it gets lost or not. I have no control whatsoever.

Why is it interesting? Because sometimes I just want to send one packet and I don't care that much if it's there or not and I'm not going to transmit it again if it doesn't go there.

An example of that is voice. When I talk, I want to transmit something. In the middle of the sentence if something is dropped, Steve would rather like to hear click, click, click or some kind of silence than hearing the word maybe two seconds later. Because if I start a sentence, "Start a sentence, if I..." This is completely impossible for him to understand, so it's better for him to hear [inaudible] sentence.

In those cases, like real-time protocols, UDP is enough because we don't need this overhead of retransmission. Sometimes it is only one packet that I'm going to send and one packet back. I don't need to establish this communication; it's just too expensive.

DNS is an example of that. I send a question: Steve, what's your name?

UNIDENTIFIED MALE: What's my name? Steve.

ALAIN DURAND: Thank you, Steve. Simple question, simple answer. I don't need to have a complex overhead of setting up communication, because maybe Steve will answer the same question a million times in a second. So in order to make it more efficient, we're simply going to have no control and simply ask the question and get the answer back. If I don't get my answer, what will I do? I will ask the same question again.

It's important when someone designs an application to think about this step and pick up the right protocol. That's the nice thing about the ITF and all the work that has been done. We have multiple protocols, and sometimes the real question is which one do we want to use? We have to think about what is the application, what are the requirements, and use the correct protocol accordingly.

An example of a bad choice for file transfer. A number of years ago, 15 years ago maybe, folks who were developing protocol selections – files – decided "Oh, we're just going to be on the same local network. It doesn't matter. There's no packet loss, no congestion. We'll go fast. We'll use UDP."

A few years later, what happened? Oh, we have those VPNs. We want to expand the network and it's going to go to the other side of the planet. Now all of a sudden, nothing works. Why? Because they had the wrong protocol. They needed a protocol that will be establishing the connection and making sure there was a transmission. That's why it's important to get those choices right.

Up one layer, session five. This is when you want to do some streaming. What's interesting about streaming is you don't care if it's lost, you're not going to retransmit, but what you want is to make sure the packets will all arrive roughly at the same time in-between packets.

If I have voice, I don't want to have one packet then a silence of five seconds and then another packet. I would rather like to have all the packets arriving roughly at the same interval. I also need a protocol to talk to the source and say, for example, "This is the movie I want to see. Please send it to me." That's what those real time protocols are doing.

Moving up the stack, I was saying "This is the movie I want to see," so I need to describe this. Back in the day, there was no protocol to do that. I was sending something that was free text form, and the server on the other side had to really understand what I was sending. Sometimes they did, sometimes they did not. Or if my particular implementation was doing something, somebody else who was writing another piece of software will not interact with my server. That was a bit of a problem.

There have been attempts at defining standards to do that. The most commonly used today are XML and JSON. The syntax in JSON is a little bit easier to read for humans, so that's one of the most popular ones so far. How you do that? Well, you simply describe things. For example, in the menu, you can have some files, you can have some popups and different items. You simply describe them; it's relatively easy to read.

Layer seven; that's when people start to really care, people that are not simply geeks or engineers. This is not my son but it could be. All he wants to do is play his game. None of this networking stuff is really important to them. What we need to keep in mind is that people who are using the Internet don't care about the underlying layer. They simply don't. What they want is to get access to the news, access to their games, access to Facebook, whatever it is. That's what we really need to focus on. That protocol is HTTP, for Hypertext Transfer Protocol. A version of it, that is a secure version, HTTPS, where you have some authentication with certificates.

I said that we have nine layers, I'll move on. Financial, layer eight. If what you're trying to build is not going to bring back some revenue, you may have a problem. Sometimes this is a philanthropic effort, and that's fine, but if it's a commercial effort and what you build doesn't have any return on investment, then you're not going to build it for very long.

How do you price those things? There are a bunch of different books and theories that have been written about that. For example, what people are doing is they buy big fiber and then they slice it into smaller chunks and lease services. That was a business model 10, 15 years ago. Now, there are people who try to go and run services over the top, use the infrastructure that has been deployed by service providers, and that's how they do their business.

The point here is when you're in this business, you need to have some kind of financial plan on how things are going to work. You always adapt your financial plan or your network to the circumstances, because things are not static, things are changing.

There's a layer on top of that. That's a political layer. That's the galaxy; you're there, and over there, there are some regulations that you need to comply with. You cannot simply run a business and not comply with regulation, because you will lose your ability to do so very quickly.

Dealing with the local politics and the real stuff that goes with it is an important thing, and those regulations are different in different places. There are things that you are allowed to do in one place that you're not allowed to do in another place, and vice versa. So if you have a business that is multinational, you need to reflect on that and deal with the local constraints.

There are also global constraints, and that's why we are here at ICANN, to talk about this process of how to [inaudible] what we want to do here on the Internet. It's this multi stakeholder process.

That's essentially all those seven layers expanded from zero to nine that are the fabric of the Internet. Any questions so far? Mother with an apple pie. Okay, next.

A couple of meetings ago, I flew somewhere and had violent, violent toothache. Something that I'd eaten didn't go very well and got stuck in my teeth. It was really hurting and maybe it was actually worse than bad. Maybe I had a cavity that has gone really bad. It was really, really hurting, so I needed a dentist – bottom line. How am I going to find a dentist in a country where I know nobody? I just arrived. Luckily, I know people, and maybe those people will help me.

A little parenthesis first: what's a name? I need the name of a dentist to help me, but what is a name? if I look at the dictionary, a name is a word or a set of words by which a person, an animal, a place, or a thing is known, addressed or referred to.

As an example, my name is Person, John Person, or I could be a famous person. For example, if you're famous, give money to some charity, maybe you will have a building in a university that will have your name, or you have done a lot of things for your country and they build a new city and they give your name to that city, things like that.

If you think about the name, if I know your name, I know who you are. I know the reputation that comes with it. If I go to Alain City in Alain's country, that means, yeah, that guy has done something, probably something right, because they gave a name to… Or maybe not; they just decided to put my name there.

But essentially, if I know the name, I know Steve's name, I know who he is. I know Kathy's name, I know who she is. That's the important thing I would like you to remember today. There are three things I want you to remember, that's the first one. If I know your name, I know who you are. So we can think of a name as a handle. It's a word or a set of words by which a person, an animal, a place, or something is known.

Steve, you have a name, Steve. But if nobody knows about the name Steve, it doesn't matter.

UNIDENTIFIED MALE: It matters.

ALAIN DURAND: It matters to him; doesn't matter to us. Now, if Steve tells us his name… What's your name, Steve?

UNIDENTIFIED MALE: Steve.

ALAIN DURAND: Now we all know Steve.

UNIDENTIFIED MALE: I'm Steve.

ALAIN DURAND: Steve is the most famous person in the room right now. So it matters to all of us. I can now relate to him. We can talk, we can exchange things. We can talk to someone or we can talk about someone. I can talk to Steve, or I can talk to you and tell you all the things I know about Steve. Those are two different things – talking to someone or talking about someone – but in both cases, we're using a name. We're using the name Steve, and I can use the name and pass it as a referral. Kathy, maybe to save you time, we can talk to your manager, I think Steve did a good job.

UNIDENTIFIED FEMALE: Yes.

ALAIN DURAND: Now she can use that handle and talk to a person that is not in the room right now. We can pass these things around. This is a handle to talk about something. It's a really important thing.

Steve, I have a bit of a problem with my teeth. I need a dentist. What's the name of your dentist?

UNIDENTIFIED MALE: I used to use Dr. Daniels, Jack, but I was in New Zealand recently and I found a great doctor with fine medicine, and I use Dr. Thompson now.

ALAIN DURAND: Dr. Thompson?

UNIDENTIFIED MALE: Yes.

ALAIN DURAND: Okay, I'll go for Dr. Thompson. Now I need to find Dr. Thompson.

Names have scopes. My name is Alain. In my family, I'm the only Alain. That's easy. I have no brothers, no sister, but I have cousins, and when you talk about Alain, yeah, they know this is this guy who is working overseas; we don't see him very often. They know who I am. There's no conflict.

However, when I was in elementary school, Alain was a very common name and there were multiple kids with the same Alain first name. So when the teacher was saying… We had a teacher who was a little bit difficult to deal with, and she was saying "Alain, go to the blackboard" and the five of us were looking at each other, like "Which one?" Then she would get really mad, because nobody was answering her question, nobody was going to the blackboard. She was repeating the same thing, "Alain, go to the blackboard" and nobody could go there, because we had no idea which one.

So we need to identify the scope of this. Maybe if she had said "Alain Durand, go to the blackboard," yeah, I know it's me. "Alain Michel, go to the blackboard." That's the other guy, okay.

So when you need to disambiguify things, it means that you need to add a scope to those things so that you know exactly what you're talking about or we you talking about.

But having the name is not enough. Okay, Dr. Thompson, right? It's a big city around here. I have no idea where Dr. Thompson is, and my tooth is really hurting now. I have to find Dr. Thompson.

Thank you, Steve, it's great to have a name, I appreciate that very much, but I cannot go to see Dr. Thompson because I have no idea where he lives. What's his address?

UNIDENTIFIED MALE: He's at 125 Root Canal Road.

ALAIN DURAND: Root Canal Road, okay. That's certainly a good place to have my tooth looked at.

We need to map the name Dr. Thompson to an actual street address. This is what we call name resolution. Going from a name to an address. Here, we go from Dr. Thompson to 125 Root

Canal Road. We can go from www.icann.org to the IP address of an ICANN server. This is actually this process that's called name resolution.

There are a bunch of issues about that. That's why we have ICANN meetings, and to talk about the high level issues that have been discussed in the last few years – things like internationalization. How do we use named that are written for different languages with different alphabets? How do we do security and authentication on this thing? That's DNSSEC. How do we expand the root zone? That's the gTLD program. You know all of those things; I'm not going to spend a lot of time there.

All right. Now, 125 Root Canal Road, that's the address of the dentist. Let's look into this a little further. What's an address? An address is the particulars of a place where someone lives or an organization is situated. An example is they exchange their address and they agree to keep in touch.

I know your address, I know where you are. The second thing that I want you to remember today. I know your name, I know who you are; I know your address, I know where you are. In those gangster movies, he says, "I know where you live." That's what it is. If I know your name, you're Joe Montana, that's fine. I know you live on the 125 Root Canal Road, I know where you live, and if you don't pay me every week, I'm going to find you. That's what it is.

A little bit of a detour in the city where I live now. The most famous place is not where I live. I don't live in that building, but there are famous people who live there. The most famous place in Washington DC is at the address 1600 Pennsylvania Avenue Northwest, Washington, DC, 205000-003, USA. That's a postal address.

This is a hierarchical structure. You have to read it from the end, from the right, and move to the left. In the USA, this is the United States of America, that's a country. DC for District of Columbia. DC is not exactly a state, but it's kind of a state for that purpose here. Then, DC is divided in four quadrants: northwest, southwest, southeast, northeast, so this is in the northwest quadrant, and it's on the street called Pennsylvania Avenue, and the number on the street is 1600. That's this hierarchy.

Not all address structures have this geography architecture built into them. For example in America, you have toll free numbers where you dial a number and you don't pay for the communication. Most of those numbers start with 1-800, so when you dial this number, you have no idea where the person is. It could be in Kansas, it could be in Arizona, it could be in New York, or it could be in India for that matter.

Cell phone numbers are the same thing. It used to be "I know your number, I know the area code, I know where you live." Now you have a cell phone, you could be traveling anywhere in the world.

IP addresses are exactly the same way. IP addresses have been delegated by the IR to different organizations, but addresses can be moving and they are not necessarily done in geographical aggregation. Simply by looking at an IP address, seeing the first bits of an IP address, 129 does not mean this is something that is in France. It could be somewhere else in Europe or somewhere else in the world. Now we see more and more fragmentation of this.

There are people who have done some reverse engineering to this and built a database of geolocation, so you can look it up and it says this address is actually there, but by simply looking at the address itself, there's nothing in the structure of the address that tells you what this address is.

All right. So same thing as names, addresses have scopes. If I meet Steve in DC and I say let's meet at 1600 Pennsylvania Avenue Northwest, he knows exactly what I'm talking about. If I go and talk to Kathy and I say "Oh, let's meet in Paris," where are we going? Because there's a little town outside of Washington DC in Virginia that's called Paris. There are maybe 300 people living there. Last I checked, there were 29 cities in the US whose name were Paris, so which one am I talking about? Same thing, we need to have a scope associated to this. If I say Paris, Virginia, there's only one. Paris, France, there's only one.

Same thing, addresses can be used as handles. I can put an address and use it directly. I can write a postcard, put an address on the postcard, ship the postcard, it will go there. Or we can pass it as a reference, as Steve just did.

Steve, what is the address of your dentist,

UNIDENTIFIED MALE: 125 Root Canal Road.

ALAIN DURAND: Dr. Thompson lives at 125 Root Canal Road. He just gave this to me as a reference.

But having an address itself is not enough to communicate. I need some kind of infrastructure behind it. For example, I'm going to send a postcard to this famous address that I mentioned previously, 1600 Pennsylvania Avenue Northwest, Washington, DC, 20500, USA. From anywhere in the world, I can send a postcard there. From here, if I did, it will arrive.

Why? Because there's a postal service that is in place. There's a postal service here in Morocco, there's a postal service in the US, there are a bunch of services that are linked together. They will know how to route the postcard. Maybe the postcard will go from here to Marrakech with a mailman in his little truck. Maybe from Marrakech to Casablanca, it'll go in a bigger truck. Maybe from Casablanca to somewhere else, it will go on a plane or on a boat. There are multiple ways to carry this postcard.

But in the end, it will arrive there. Why? Because there are agreements that are in place with the different post office organizations to make it all work and all interconnected. This infrastructure underneath and all those agreements between the different players are really what make the system work.

Now we'll talk about Internet addresses. There are two protocols that exist today. One is IP version 4, one is IP version 6. If you wonder about IP version 5, that was something experimental that was abandoned, so it doesn't exist any more; we went to six. Fundamentally, they are the same thing.

The difference between the two is IP version 4 can address things using a field of 32 bits, so you have 3.2 billion usable addresses. 32 bit is 4.9 billion, but there are a bunch of them that are not usable because they're multicast or reserved. So in total, you have 3.2 billion, and we have more than 3.2 billion people on the planet, so you see there is a bit of a discrepancy here.

That’s why we built this protocol IP version 6. That’s 128 bit, and you see on the screen here the number of addresses that are in 128 bits. It’s not four times bigger; it’s much bigger than that. I don’t even know how to pronounce this number. It’s fundamentally irrelevant. The point is that there are enough addresses for the next 50 years, and then my kids will have to figure out what to do next.

You have all heard about IPv4 address exhaustion. Exhaustion doesn’t mean the IP address gets tired. They don’t get tired; they’re just numbers. It means that we don’t have any new ones to allocate. The IR are the one who allocate addresses to the members who are service providers or end users, and they go to IANA – or they went to IANA – to replenish their well. Well, IANA ran out of new things to give to them back in 2011, a few scraps in 2012, and now each of the IR have exhausted their own pools and they have essentially nothing left to give to their members.

The Internet is still growing, so what’s next? Well, the real problem that we face here is that IPv4 and IPv6 are not compatible. It’s a technical limitation. If you look at the plug, for example, on the left-hand side, this is a power supply for my Macintosh, and if I go to New Zealand where I was two weeks ago, the socket is different in the wall. You just can't plug in; you need an adapter. That's really what we're dealing with.

Today, IPv6 isn't a substitute for IPv4; it doesn't work together. At some point, it might be, or at some point, it will be, depending on your perspective, but today, it's not. So we cannot simply say, "Oh, abandon the IPv4 ship, move onto the IPv6 ship and business is fine." No, because you have all this legacy stuff. So we need to do something. That's what I was essentially saying here. We will have to support IPv4 and IPv6 for quite a long time.

UNIDENTIFIED MALE: Is there no adapter between those?

ALAIN DURAND: Yes, I've built some adapters. These are called NAT, for Network Address Translators. The same way we have a NAT that shares an IPv4 address locally and translates it to a global address, we have some NAT that translate an IPv6 address to an IPv4 address.

UNIDENTIFIED FEMALE: Or the reverse.

ALAIN DURAND: Or the reverse, yes. The reverse is much more difficult, simply because it's a bigger space. To go from a small space to a bigger space is more difficult to do the mapping.

The funny thing is, let's say that I'm a wireless service provider and I have millions of cell phones. I can decide to use IPv4. [inaudible] IPv4 to a global [inaudible], or I can say, "I like the new technology, I'm going to use only IPv6 and with this [inaudible] NAT, I'm going to translate from IPv6 to IPv4." The curious thing is that the pool of IPv4 addresses you need in that NAT is exactly the same size that you translate from v4 to v4 or from v6 to v4. That has been a serious break into the adoption of IPv6.

At the end of the day, it's interesting to have IPv6 if you have somebody to talk to that has IPv6. If I have my IPv6 network at home and Steve, you have an IPv4 network at home, we're going to go through one of those NAT and [inaudible] is the same. But next year, Steve will have an IPv6 network and the service provider will have IPv6 and the applications are IPv6 and the wind is blowing in the right direction. Maybe we can use IPv6.

What happens is you have a last mover advantage to go to IPv6, and that has been a serious issue. We still see a lot of momentum building and some large service providers have been adopting technologies to deploy IPv6 in a number of countries over the world, so those two thing are going to be at play for a while. What do you do in the meantime? You need more IPv4 addresses.

You have two things you can do. First thing is… My statement is actually not correct here. Three out of the five IR have enacted policies that allow transfers. If I'm correct, AFRINIC does not have such a policy and LACNIC was contemplating one but they haven't voted it. In those transfer policies, terms and conditions may vary, what you are allowed to transfer from one place to another place. Some of the policies were based similarly to allocations on needs. There's an evaluation of what you need and then you get this. In some regions, they started by eliminating the need-based policies for transfers, but they put it back in in order to allow for transfers between regions.

Those are technicalities; the larger point is if you live, for example, in Europe and you want to get some addresses, you can transfer addresses from somebody else. There is a market for that, and you can buy the right to transfer addresses. Addresses are numbers. You don't buy a number. What you buy essentially is a right to register this number to your name. That's all you do. And you can get it from somebody who was not using this address block in your same region, or if you can go in another region and then transfer it into your own region.

I had some statistics, but I'm not going to display them because they're a little bit old. I did another study more recently that I presented at APNIC two weeks ago. In the last two years, there were about 38 million IP addresses that have been transferred within the ARN region. There were about 10 million IP addresses that were transferred in the APNIC region and about 18 million in the RIPE region in just a period of two years. That's a lot. It was expected, because we've run out of quote unquote free IP addresses, so now people are trying to grow their network, and there's a market for that.

[inaudible] this one. And back to the third segment, which is routing. I have, remember, this raging toothache. I know that Dr. Thompson – my dentist, or Steve's dentist – Steve told me it's on 125 Root Canal Road, and I'm here in this hotel. How do I go to 125 Root Canal Road? That's the question we're going to try to answer now.

What's a route? You can say route or route depending if you are more British English or American English. If you're French, you say route. That's a noun. It's a way, a course taken in getting from a starting point to a destination. The third thing I want you to remember. First one was I know your name, I know who you are. I know your address, I know where you live. I know your route, a route towards you, I know how to send data towards you. I know how to. First one is who, where, and how. Those are the three different things. If you remember only one thing in my tutorial… But that was three things.

So, how will that work? Remember, I have this network. I have this network over there. I'm at the source. My destination is this Route Canal Road, 125. I can simply follow signs, but how are those signs put in place at each intersection? We have to build that, and the way this is going to be built is from the destination back to the source.

There's a router that is connecting this dentist here at this destination, and it knows that this destination is there because it's connected directly to it. At the beginning, the only element who knows how to reach that node. So what is it going to say? It's going to tell all its neighbors, "Hey, I know how to get to this destination. If you want to send traffic, send it to me." Do we have a laser pointer? Here we go.

This router here knows, "I know how to reach the destination." It's going to advertise it to the neighbors, this one and this one. Once it has advertised it, this neighbor here knows "Oh, if I want to send traffic to the final destination X, I can simply send it to this guy." And it's going to do what? Exactly the same thing: re-advertises information to all its neighbors. The information is going to be propagated to a bunch of other routers.

This one already has received the announcement from the first router. This one will come from a second router; it's kind of a duplicate. It's going to look at them both and say, "Oh, this is more direct. This one here, I have to make a stopover somewhere. Not good." Like if I want to go from Paris to here, I could take a direct flight or I could make a stopover in Casablanca. I would like to go direct, and we're going to do that and propagate this information. At some point, everybody will know about it.

This is how you build this routing infrastructure. The important thing here is this is a cooperative system. Same story as my post office stuff. It only works because everybody believes it works. It only works because all the people who are participating in this have decided to collaborate and cooperate.

Now that I've built this, when I'm going to send traffic, all I'm going to do is to follow the directions. I'm at the source here. Source sends to the first router. First router: "I've heard that these guys know how to send the packet. These guys know how to send the packet. These guys know how to send the packet."

If we want to say it another way, this guy has said, "I know how to go to Kathy." This guy is going to say, "I know a guy who knows how to go to Kathy." This one is going to say, "I know a guy who knows a guy who knows how to reach Kathy." This is how it builds up. Then I'm going to the first guy who said, "I know a guy who knows a guy who knows a guy…" And then we're going to reduce this, hop by hop – this is what routing is: hop by hop – until we arrive to the place that says "Oh, I know who Kathy is. I know where she is. It's right there. She's right there. That's easy."

So this is a cooperative system again. We rely on the next hop to do the right thing. There's no contract on the packet. It relies essentially on goodwill of all the participants to do the right thing. Goodwill is good, except that sometimes bad things happen. We can have a bad actor there – somebody, a bad guy, who says "I am going to pretend I am Kathy." Remember, this is all about announcements. If a bad guy talks louder and screams from over there that "I'm Kathy," maybe half of you would believe that information. You have no way to know; he's just the loudest.

How do you deal with that? There's a system that has been proposed, called the RPKI, for Resource Public Key Infrastructure, that says, "We're going to put some kind of a certificate associated to the destination address, and we're going to validate the announcement with the certificate, and if it matches, that's a legit announcement. If it doesn't, I will drop it."

When the bad guy over there screams, "I am Kathy," that doesn't match the certificate, drop this announcement.

This is an interesting technology. However, it has some issues. There have been a lot of discussions about how do we organize this certificate system? Is it a centralized or a decentralized system? There is still ongoing discussion.

This will provide the validation of the origin. We know that this is correct and we know that this is not correct. But that does not prevent somebody in the path here to do some weird things, only protect the origin. A number of service providers, when I ask them "What do you think of this?" have been telling me, "Yeah, that's nice, but that doesn't really solve our problem." This is still work in progress, something to follow.

All right. Now I've arrived. I know who you are, I know where you live, and I know how to get there. I can go and get my tooth examined.

That's the last slide. Questions?

UNIDENTIFIED MALE: Hold on a second. I'll bring you the mic.

ALAIN DURAND: Steve, how much time do we have?

UNIDENTIFIED MALE: We have officially [inaudible] minutes, but if we want to let them have more lunch, we have 30 minutes.

ALAIN DURAND: Okay.

UNIDENTIFIED MALE: What is the problem of the implementation of IPv6? Why does it take so long? Is this a problem of routers, or is it a problem of the manufacturers of the routers, that they don't want to push it so fast? Where is the real problem, that it takes so many years?

ALAIN DURAND: I started to work on IPv6 in 1992, and every year since then, I've said it will be deployed in the next two years. Routers, they all do IPv6, all the new ones. I use to work for a router vendor before working for ICANN, and all the stuff has been IPv6 since 2000. Most of the major router vendors, like Cisco, Juniper, [inaudible], they all have IPv6. All there.

Software: operating system by Microsoft, it's there. Apple is there. [inaudible] is there. The software that works on top of that may or may not be there. Example: webservers, yes, they can do IPv6. Skype? Not so. That's a problem, but you could say that's a minor problem; you just have to invent a new messaging system or voice system, and plenty of them exist.

At the end of the day, it's an economical problem. It costs money to do this, and there's no immediate return on investment. You cannot make money by having IPv6, essentially. It's not just ROI; it's just "Can you make money with this?" And the answer is no more than with IPv4.

Actually, there's some complexity, and as I mentioned earlier, it only works if everybody does it. At the beginning, if you're the only one, the first one, it's harder to justify for you that you want to do that, so there's this last-mover advantage. That's really the thing. It's not about the technologies, it's not about software, it's not about routers. It's really an economical problem.

Next question?

[AHMED MUSA]: Hello. My name is [Ahmed Musa] from an ISP here in Morocco.

ALAIN DURAND: Where do you live?

[AHMED MUSA]: In Rabat.

ALAIN DURAND: Okay. How do I get there?

[AHMED MUSA]: Take a car, bus, whatever. There is the train, also works, plane.

ALAIN DURAND: Thank you.

[AHMED MUSA]: You can walk also. My question is, of course, about IPv6. In your opinion, is IPv6 ultimately going to replace IPv4 in the future, or they're going to live together?

ALAIN DURAND: That's my crystal ball; it's very opaque. That's the honest answer. I don't know. There are a bunch of hypotheses that have been made, and at this point, it depends on how you view the world. There's one view of the world that says with this market of IPv4 addresses, it costs more money to get IPv4, that will be an incentive for people to go to IPv6, and ultimately it will be all

IPv6, and the market will simply exist for a few years and then… That's one view of the world.

There's another view of the world that says, yes, we can keep this v4 thing going, there's a market. Yes, it costs a little bit more, but if you look at the price of an IP address today, it's about $6 per IP. Compared to the cost of a router, compared to the cost of a spectrum, compared to the cost of passing a house if you're deploying fiber, passing a house is about $2000 or $3000, at least in the US. I'm not quite sure how much it is in Morocco. If you look at the price of spectrum and things, we're talking about very large amounts of money. Even if it goes to $20 or $50, yes, it's a one-time cost. It's a sales problem, it takes money, but it's a one-time cost and it will be the cost of doing business. Do I need v6 for that? Maybe, maybe not. That's another view of the world.

Which of those two views is going to prevail, honestly, your guess is as good as mine. I don't know.

PAUL WILSON: Hi. Thanks, Alain. It's Paul Wilson. I'm the head of APNIC, the IP address registry for Asia Pacific. We're definitely involved with promoting IPv6 through IP address allocations but also through a lot of the training and information work that we do, so we've worked with Alain, with ICANN, and with other RIRs for many years.

I think it's worth pointing out that IPv6 is in active deployment at the moment. About 10% of Google's users are accessing Google through IPv6 these days, and that's a huge number. According to APNIC stats, there's around 5% of all Internet users today who are capable of using IPv6. In case you don't know it actually, you're likely to be using IPv6 today, but if you're accessing the ICANN network IM, if you're using a normal computer, a modern computer, you'll be using IPv6. So it actually is in use today.

It's worth bearing that in mind, because we've been talking about IPv6 for 20 years. We've been promoting it for 10 or 15 years very actively, and yet for most of that time, we were bumping along the bottom with very little movement. But right now, we've got a very exponential growth going on.

It's easy to think at the moment that nothing's happened with IPv6 for the last 15 years, and therefore nothing is still happening, but actually, on account mostly of IPv4 address exhaustion, the IPv6 deployment is actually happening now. It is in full production, and as I say, with 10% of Google's users using it, that is a huge amount of IPv6 usage on the Internet.

The question before was how long will IPv4 be around? It's got to be around for quite a long time, and although no one can predict the future, there's likely to be a whole series of tipping points which will make sure that the IPv6 usage and deployment keeps increasing and keeps accelerating, as well, we hope.

There's an issue I think with the statement that v6 and v4 are incompatible, because in one sense, they are incompatible, but in another sense, for instance the computer that you're using at the moment, the browser that you're using at the moment, as I say, you'll be using IPv6 right now in accessing for instance websites that are IPv6 capable, and you won't even know that. So in fact, the compatibility actually exists.

One analogy that I've drawn in the presentations that I've provided is a sort of real-world analogy between the v4 to v6 transition and the transition from gasoline to electric vehicles. At one level, particularly if you're manufacturing a vehicle or maintaining a vehicle, you've got to know the difference between gasoline and electricity. They operate very differently. You can't stick electricity into your gasoline vehicle. That doesn't work; those things are incompatible. But in fact, at another level, the vehicles drive the same way, drive on the same roads, they carry the same passengers. If you're a vehicle owner, you need to know the difference to some extent, but not all the details. If you're a kid sitting in the back seat, you just enjoy the ride, there's no difference at all.

You asked questions about v4 and v6 transition. You can sort of think about them in terms of that transition, for instance. I think it'll be a very long time before we get rid of gasoline vehicles altogether off the roads, but they're going to become less and less relevant as time goes on and I guess they'll be around for a long time, like IPv4 will be. But at some point, I guess, we're going to hit an exponential tipping point and electric vehicles are going to be taking over, and the infrastructure that supports and carries them will become much more dominated by the support for electric than gasoline, as is the case with v4 and v6.

That's just an analogy in terms of understanding this compatibility issue, which can be sort of misinterpreted almost as a kind of mismanagement of the IPv6 design in the first place.

In fact, if IPv4 and IPv6 were designed to be plugin-together-compatible at every level, then the complexity of doing that and the overhead of having to do that and carry that through the Internet through this whole period would have actually been a very big disadvantage to IPv6 and a big [inaudible] with its efficiency and manageability. So in fact, the decision was the correct decision, that these protocols are not directly compatible, because that produces the most efficient IPv6 that we can have, but it does result in this kind of long transition – kind of similar, I guess, again, to the gasoline-electric transition. Thanks.

ALAIN DURAND: Thank you, Paul. I think your analogy with the electric car is a really good one. What's important to keep in mind is when you look at tipping points or things that are happening, there's a difference between the spot market and the long-term view.

A year or two years ago, gas prices were really high and in the US at least, we saw people flocking to order electric cars, abandoning those big SUVs and buying more electric cars. Price of gas went down, people are buying the SUVs again because it's more difficult to justify the extra cost of the electric car. But maybe in two years, the price of gas will go back up and we will buy electric cars again.

That's why we should not simply base long-term estimation on what is happening just right now. You have to look at some of the broader pictures, and electric cars will be the future.

Another question?

UNIDENTIFIED MALE: I just bought a truck, too. Now I'm sad.

UNIDENTIFIED MALE: Any other questions? I think you're standing between them and lunch right now, that's the issue.

ALAIN DURAND: That's the last thing I want to do, so have a good lunch, thank you.

UNIDENTIFIED MALE: I'd like to take a moment and thank Alain, please. Like I said, we will have this again tomorrow. I'm going to pull Alain out of Tech Day to come and do this. We've made deals.

We've given you a piece of paper asking for some feedback. We would love to get some feedback. We're trying to make this a continual thing, but yet keep it interesting and have new sessions. Any feedback you give us, we will read and we will take it to heart, so please, take a moment before you go and enjoy your lunch to give that feedback.

After lunch, we're back here for two more sessions. We have a session on the protocols that are involved with the registration process of domain names. That includes everything from the registrar all the way to the registry and then ancillary services around that, so it should be interesting.

And then a really interesting one this afternoon is the root server operator will be… The gentleman from RSOC will be coming in and talking about root serer operations and talking about the root server system and all that. We had that the first time in Dublin, and it was extremely interesting, so if you have any interest in the root server system, I strongly recommend attending that one, too.

Thank you all. Enjoy your lunch, and we hope to see you back after lunch.

[END OF TRANSCRIPTION]