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PRESENTATION

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Welcome, everyone, to the Intel Network Builders webinar program. Thank you for taking the time to join us today for a presentation titled: "5 Reasons Why Broadband Providers are Deploying Virtual BNG and CGNAT". Before we get started, I want to point out some of the features of the BrightTALK tool that may improve your experience.

There's a Questions tab below your viewer. I encourage our live audience to please ask questions at any time. Our presenter will hold answering them until the end of the presentation. Below your viewing screen, you will also find an Attachments tab with additional documentation and reference materials, including a number of websites and documents mentioned in this presentation. Finally, at the end of the presentation, please take the time to provide feedback using the Rating tab. We value your thoughts and we'll use the information to improve our future webinars.

Intel Network Builders webinar series takes place live twice a month, so check the channel to see what's upcoming, and access our growing library of recorded content. In addition to the resources you see here from our partners, we also offer a comprehensive NFV and SDN training program through Intel Network Builders University. You can find the link to this program in the Attachments tab, as well as a link to the Intel Network Builders Newsletter.

Intel Network Builders' partners have been working to accelerate network innovation by optimizing their solutions on Intel technologies. These industry leaders are recognized in our Winners' Circle program, and netElastic is a Titanium partner. Learn more about our INB Winners' Circle program by clicking on the link in the Attachments tab.

Today, we're pleased to welcome David Williams from netElastics. David has been a telecom service provider executive for over 25 years, from DSL to fixed wireless, and now fiber-to-the-home. David brings a service provider perspective to his current role as Senior VP Sales and Marketing at netElastic Systems. Prior to netElastic, David was president of MegaPath Managed Services, and GM of MegaPath Wholesale, where he and his team delivered broadband services to customers throughout North America. Earlier in his career, David held executive roles at a large national broadband provider, and a regional fixed wireless ISP. David has a degree in computer science from CSU Chico.

Welcome, David, and thank you for joining us today. Over to you.

David Williams

Oh, thank you very much for that introduction, and thanks everyone for attending today. Before we dive into the five reasons why broadband providers are not just considering, but actually deploying, virtual BNG and CGNAT solutions, I just want to introduce you to our company, and then cover some of the industry trends that are driving all this growth.

First, netElastic, we're a software company based in Silicon Valley, and we focus exclusively on service provider virtual routing technologies, including virtual routers, broadband network gateways, and CGNAT. Our focus is on performance, and getting the most out of the hardware that we're deployed on, maximizing the resources that are used for our software, and that helps improve total capacity and scalability, and also helps drive down costs.

We're very proud to be a part of the Intel Network Builders program, and through our close collaboration with Intel is how we're able to deliver on market-leading performance.

We've got customers deployed all over the globe. This is just a small sampling that includes some tier one, tier two, and tier three service providers that are actually using our solution. There's obviously much more than this, and really every continent around the world. So, we've got customers in Africa and Europe, Middle East, Asia, Australia, New Zealand, and then of course throughout the Americas. And they really range in all kinds of different sizes.

Before we get into the five reasons, again, I wanted to look at some of the industry trends, and if we just look at bandwidth growth by the numbers, we've got 29, 786, and 42. You probably think to yourself what those represent, but I'll give you the answers. 29 is the annual global traffic growth rate that we're seeing right now. It actually was up higher when the pandemic began. As you can imagine, everybody shifted, but has settled back to pre-pandemic levels. But 29%, almost 30% annual growth is still a significant number, and obviously, that is a global number, but that same percentage impacts service providers even at the local level.

786 is that total global bandwidth in terabits according to TeleGeography. That's a big number, especially when you start adding 29, 30% to it every year, and service providers need to address and adapt to help with their portion of that total bandwidth.

And then the last number, 42, is the fixed data traffic growth. So, historically, over the last, say, decade, mobile traffic has been really the driver of growth, and that's as smartphones got more popular, everyone started using data. Now, they're pretty ubiquitous, and with the increase in residential traffic, fixed data has actually been the driver there.

So, overall, just a lot of growth in the overall traffic utilization, and if we get down to more of the residential aspect of things, the virus and the whole pandemic really changed the way we all use the internet, and our customers do. So, huge rise in residential internet traffic, we've seen this over the last couple of years, and one of the things that they've really brought up was the disparity between some of the urban and suburban markets and their access to quality broadband, and some of the more outlying areas and rural markets, and that's not just in the US, but I see it globally. So, a lot more service providers are springing up. Existing ones are expanding. More fibers being pulled. DSL has gone the way of dial-up, and even cable providers are now moving to fiber infrastructure to bring better service to customers, but also saying they're delivering more bandwidth for upstream to help support some of that telemedicine-- or not telemedicine, that's a good one, but work-from-home and remote education. We're also seeing a big expansion in wireless ISPs that are helping bridge that gap between fiber infrastructure in some of the more remote locations, and new types of service providers entering the market. Utilities are adding fiber to their existing rights of way, and even municipalities building fiber infrastructure in their communities, where maybe some other traditional service providers just aren't addressing the market for them. And all of that's being assisted by significant funding, both in the US and globally. Governments are putting money in to help support that expansion and help meet the needs, and all of that's driving infrastructure upgrades for service providers. They need to build out the infrastructure inside their network to support all this growth.

Some other service providers we see-- or challenges, rather, that we see is just the nature of the applications, and over the last, say, two to three years, so this really started three or four years ago, but really took off in the last two years, some of it related to the pandemic, but others just in the new technologies that are coming out. In addition to distance learning and work-from-home that we mentioned, the shift from traditionally IPTV and other forms of delivery of TV services to completely over-the-top streaming is quite prevalent now. A huge influx of IoT devices in the home, everything from Ring doorbells to surveillance cameras and automated switches and thermostats and things like that. So, a lot more new types of applications that are putting demands on local broadband. And we're also seeing, because of all of those new applications, that fixed broadband speeds are increasing. So, just in the last several years, it's been almost 2.5 times increase in the amount of bandwidth, and on a global average, 110-meg sounds pretty small, particularly where here in the US where we see it's common to get 500-meg to a gig at a residential home, but when you get into outlying areas and rural markets, it's much more difficult to deliver. But it's growing dramatically, and as more fiber-to-the-home gets deployed, that is expected to go up quite a bit.

Another challenge is that, particularly for the larger carriers that are looking at moving to a more distributed edge and how they do that, and the reason they want to do that, moving from more centralized POP infrastructure to a more distributed edge strategy, is to really push more of that content, video caching, any of the content that the residential subscribers are consuming, as close to the customer as

possible to improve the quality of the experience. It also allows them to deploy new types of low latency[00:10:41] applications. I'll talk a little bit more about that in an upcoming slide. And then the last challenge is really just IPv4 exhaustion. That's not a new issue, but it's something that still continues to be a factor, particularly with newer ISPs, broadband service providers, as they don't have some of the legacy IPv4 address space as some of the early providers did.

So, that brings us to the first reason why we're seeing service providers actually deploy virtual BNG and CGNAT solutions. So, the first reason is flexibility. So, that ability to have more flexibility in the decision-making process, and the deployment and management aspects of delivering infrastructure to the network. So, flexibility with virtual BNG and CGNAT solutions are really about being able to focus on the network functionality that you need to deploy in the network and keep that separate from the hardware decisions that those services will run on.

It also allows network functionality to be more easily moved throughout the network. It's a virtual solution, so it's going to be deployed on hardware at various points within the network. So, we talked about moving to the distributed edge, that you might start with a more centralized solution.

The next is really just the flexibility to scale up or down, and that means scaling up vertically or scaling out horizontally. With a virtualized solution, it becomes very easy to do that, for service providers to address whether it's growth, or just the expansion of their network, or increase in the rate plans that they're delivering to their subscriber base. It becomes very easy to achieve.

And then the other aspect is just the financial flexibility, to invest as you need to, instead of looking at maybe your three- to five-year network plan and making that investment, and then having to grow into it before you maximize what you expected to get out of that investment. With a virtual solution, you can really pay-as-you-go or invest as your business expands, and that creates a lot of flexibility. I'll talk a little bit more about that as we go.

When we look at scalability in a virtual solution, what we're talking about is being able to scale the capacity of the network infrastructure that you need to deploy, and augment that as you need to over time. So, an example of vertical scaling might be a small deployment for maybe a new market, new POP, or new part of the town that has just for a small subset of subscribers. You assign a VM with the appropriate resources to meet that particular use case, and then as that market grows, and you need to expand that, you just increase the size of the VM, upgrade the license to take advantage of the additional capacity, and then eventually, if you've exhausted the size of the hardware, you can actually just add additional NICs into the server and get a traditional IT upgrade process there, until you eventually max out the size of the servers that you're running on. But these become very simple, routine IT operations as opposed to a major forklift operation to get additional size.

And then of course, once you max out the size of a single compute node, horizontal scaling allows you to really scale that out as much as you want. And these are very small numbers, just for examples, but you could start with each compute node quite a bit larger than what's shown in this example.

I mentioned the distributed edge. Some of the larger carriers are really focused on how they start to move from a centralized architecture into a more decentralized architecture, and what we're seeing is they're starting that journey by replacing their traditional fixed capacity or high-cost platforms with a virtualized solution. So, that puts them in a position to make some changes down the road, while still giving them some of that flexibility that a virtual solution introduces, even maintaining their existing network architecture. And then when they are ready, they can then move portions of that capacity to the edge, along with things like video caching, CDN network, and other services very close to the customer, which will improve performance, offload pretty dramatically the traffic that's carried across their metro aggregation network, and improve the quality of the residential subscribers' experience overall. And that's not really possible with a traditional hardware-based platform. For instance, you can't take a line card out of a traditional router and say I want to move that to this edge. You really need to start over with a whole new chassis, multiple line cards, and all of that. But you can do that with a virtual-type solution, so that's a big advantage, particularly for the larger carriers.

So, when we talk about a virtual solution, what does that really mean? So, it is software deployed on standard x86-based white box hardware that's readily available. But virtualized routing solutions are architected generally in a software-defined networking architecture, from a software standpoint, and certainly the netElastic solution is. So, we separate the control plane and the data plane so they each can be scaled independently, and we can manage the amount of hardware resources that are assigned to each depending on the use case.

So, in the case of the data plane, which is in charge of forwarding all of the traffic, we scale at 10-gig per CPU core, so you can scale it down quite a bit, if you're, say operating in a small instance, for a very remote location, all the way down to a single 10-gig interface, with very little hardware resources applied to it, all the way up to 700-gig and more with 100-gig NICs and multiple CPU cores assigned. So, it becomes very flexible so that you don't have to over-assign the resources. You can scale the size of the VM accordingly, and as needed, as the use case expands.

The control plane is similar. It scales instead of on the amount of data and capacity of the traffic being moved around, but it scales on the number of subscribers that need to be supported, the number of routes, and things like that. So, subscribers could be, say, 1,000 or 2,000 subscribers in a very small use case, to over 100,000 subscribers in a larger use case, where in that larger use case you'll have more cores assigned to support that. The same thing with routing, a few static routes off to your core will require less control plane resources than if we're doing peering for the entire global internet routing tables. All of that just makes it very simple to scale and efficient.

CUPS is another—CUPS, stands for Control Plane and User Plane Separation, is another architecture that's somewhat related, but it's moving the data plane to a switch, but also part of the control plane, and we did do some work on that and have some experience with that approach, but we still find that the complete x86 server-based approach requires less hardware and is more efficient from a cost perspective, as well as more flexible than some of those other architectures.

Reason number two is agility. The dictionary defines agility as the ability to move quickly and easily, and service providers really benefit from that ability to do that exact thing. Unless you're growing your business with a crystal ball, or have an exact view into how your network is going to grow over time, chances are that your best plans are not going to be 100% accurate. You may have certain markets that grow faster than your plan, other markets that are going to grow more slowly than you expected, and new opportunities that are going to come up. So, the ability to react and make changes to your network quickly is part of that agility story that is very attractive, and that can be delivered with a virtualized solution. Virtualized BNG and CGNAT solutions are based on software after all, and so the concept of being able to introduce new revenue-generating services, new feature capabilities, in that software becomes much more simple and straightforward to deliver than, say, trying to design a new capability into an ASIC-based switch or line card. Also, just things like implementing CGNAT become something more of turning on a switch rather than having to deploy new hardware and platforms.

And then lastly is just the supply chain issues. A recent customer of mine said that it would take 18 months to get additional routers that he was currently using for his access side. So, he also mentioned that if he was able to use some of his connections, he could probably get that down to 10 months. So, that is not agile, and service providers, particularly those that are growing or trying to remain competitive in more competitive markets, need to be able to react much more quickly than that. If you're putting your growth plans on hold for a year, it's just not a good conversation to have with the CEO and CFO.

So, let's look at a real-world example of some of these reasons. WebSprix is a customer of ours. They're based in Ethiopia. I picked that because they're really doing some great stuff in a market that really hasn't had broadband service until recently. They've got 115 million people, yet only 500k have access to the internet, so a very small segment of the population, and up until a few years ago, the government controlled the telecom infrastructure, but they started to deregulate it, and that's when WebSprix got into the game, and they claimed to be the first privately-owned broadband service provider in that country. And they're really focused on really just bridging that digital divide and bringing broadband service to people that had never had it before.

They did start looking at a virtualized solution from day one. They were attracted to the benefits of a virtual solution, and they tried some of the virtual offerings from the traditional router vendors, but they struggled with some of the performance and scalability once they took it out of the lab and into the real world. So, they started looking around for alternative solutions and found ours, which was built from the ground up to be a virtual high-performance platform, and they were immediately impressed with the performance and the stability of that solution. So, as they continue to build out that market and rely running that on our virtual BNG and CGNAT solution, about a year later, when their growth rate really started to improve, they were able to expand over time to four additional cities, and the experience, once they got ready for that expansion, was that they were able to go through a procurement process, all the way to delivery, deployment, and turn up literally in about a week. So, that gets back to that agile reason that I mentioned before, and that's quite a bit different from having to place orders for hardware-based platforms months in advance, and then hope it arrives at the time the rest of your infrastructure is in place. So, they've had good success, and we look forward to their continued growth.

Reason number three is the transition to IPv6. I mentioned the IPv4 shortage, and exhaustion is one of the issues that service providers are dealing with, and from an industry standpoint, we're still in transition. I've been in the industry for many years, and we were talking about IPv6 in the early 2000s, and we're still not there. In fact, Google reports on their IPv6 trend tracker that still less than half of the traffic is running on IPv6 globally. Now, certain markets and certain countries are further ahead than others, obviously, but either way, we're still not completely transitioned. So, BNG's virtual needs to incorporate some transition technology into them to help support this for service providers as they grow.

Adding to that is just the cost of IPv4 addresses. So, there are still plenty of service providers that have been around a long time, and were able to acquire lots of IPv4 addresses to support their growth, but many of the new entrants just simply can't go and get big blocks of public IPv4 addresses to support their growth. So, a whole secondary market has emerged to help those that need IPv4 addresses and those that have excess space to buy and sell, and the broker that helps facilitate many of those transactions tracks and reports out what the going rate is, and we can see over the last couple of years it's doubled, and even tripled in some transactions, currently hovering around $50 per IP address. So, if you're a service provider having plans to grow to 5,000 subscribers, 20,000 subscribers, a million subscribers, $50 per IP in a purchase is just not really sustainable. It's a very high cost versus putting in some sort of translation mechanism to reduce the amount of public IPv4 space that you need. Now, certainly CGNAT is not a great thing. It's a necessary evil, if you will, just because there aren't enough IPv4 address spaces. And then having a suitable path, such as dual stack, to support the transition to IPv6 is important.

When we talk about CGNAT, it's important to look at how it's implemented and architected within the BNG environment. They work very closely together for the IPv4 traffic, and the traditional way of delivering that translation on, say, a traditional proprietary hardware router would be a separate application line card that will run the translation services. So, the traffic will actually come into one of the line cards, get forwarded off to the application card, get translated, then back to the line card, out to the internet. Another way to do that would be to have a dedicated BNG router, and then a separate dedicated CGNAT appliance, where you're moving it from your BNG to the next hop, which would be the CGNAT, for translation, and then off to the internet. In both of those cases, you're talking about additional hardware, additional software, additional maintenance contracts, and additional support and management. With a virtual BNG, we approach it differently. We integrate it directly into the same control plane that BNG with routing and AAA, and all the other services, it just becomes another microservice within the control plane, and all of that is then programmed out to the data plane in the same packet processing pipeline. So, if the traffic is coming through, and is IPv4, it'll get translated during that same process, and if it's IPv6, it'll just skip that. But the bottom line is it reduces the resources that are required, improves performance, eliminates a hop, and then it scales along with the BNG as that grows. So, when you're looking at virtual BNG, look for something that has that capability, and this is one of the key reasons that service providers have been deploying ours.

A real-world example of that is Praction Networks. They're a customer of ours in India. They're a tier two smaller ISP with 20,000 subscribers. And the exact example that I was talking about with the CGNAT on the previous slide, they were using one of the traditional hardware-based routers from one of the larger router vendors, so they were using that services router for their BNG and they had a separate appliance for their CGNAT translation activity. And they were running at a scale, particularly on their CGNAT, so that

was their real pain point. So, they were looking at our solution, at our standalone CGNAT router, and during their testing, they also took the opportunity to test the BNG feature sets as well. So, they ended up replacing both their ASR, as well as their CGNAT appliance, all into one virtual BNG with an in-line CGNAT, and that's worked out really well. It addressed their current scaling needs, and then put them in a position where they can easily augment that scale as their business continues to grow.

Reason number four is just performance overall. So, as I mentioned before, I've been in the ISP world since the late '90s, and we actually used, my first startup ISP, Linux-based routers for some of our routing needs. So, software-based routing has been around for a long time. What's really been different is in the last, say, 10 years, but really, in the last five, the performance and scale of virtual BNG, and virtual routing solutions, has improved tremendously. And we've been really focused on that capacity, scale, and the overall performance that our solution can deliver. And just a few years back, we were delivering up to 120-gig of total capacity per server, but working very closely with Intel, and being part of the Intel Network Builders program, we've continued to collaborate with Intel and leverage the innovations that they've delivered to the marketplace, along with our software. So, you can see the transition and growth progression that we've seen with the performance we're able to get out of a single server. So, in 2018, we were able to increase that to about 180-gig capacity. Just a couple years ago, we hit over 300-gig, and then more recently, with Intel 3rd Generation Xeon scalable processors, and 100-gig and 200-gig E810 network adapters have been able to push that up over 700-gig of total capacity per server. So, it just shows continued progression, and software is not introducing latency. It's very fast, and the capacity is there. So, the performance, it's there now, so you no longer have to make that tradeoff between a proprietary hardware-based platform and a virtual-type solution.

And then lastly is the most obvious one, which is lowering costs. Service providers continue to have to deliver more bandwidth to their subscribers to be competitive, and meet all these new changing demands, and most virtual solutions have lower licensing costs than traditional hardware-based platforms. You combine that with the fact that virtual BNG and CGNAT solutions can run on standard COTS hardware, so white box servers, from any vendor that you want, whether it's retail vendors or ODM-type manufacturers, it's completely vendor neutral. So, you can shop around, make a choice for one cycle, make a different choice for another, becomes that flexibility, but that allows you to lower your cost, both on the licensing side, but also on the hardware side.

And then you're able to completely eliminate the cost of separate hardware for the CGNAT translation. So, it's literally a very small incremental license cost to enable CGNAT versus having to purchase a whole different appliance or line card into a traditional platform.

And then there's the operational savings that you get from just modern software. So, the tooling and things like that that help improve operations. An example of that is with netElastic's BNG and CGNAT, we've got a built-in BNG Manager application that is offered alongside of the BNG. It gives complete visibility to all the BNGs throughout the network, and operations can see the health and status of every BNG throughout the network. They can drill in and look at individual interfaces, see how their capacity is holding up, trend that out over days, months, weeks, or up to a year, set alerts and alarms for when certain portions of the capacity get to a certain stage that they want to take some action, maybe augment and increase.

The other aspect of that is that with role-based access, you can give portions of that tool's access directly to low-level support staff, who then have the ability to go look at individual subscriber experience. When a customer calls, they're on the direct line with a support agent, that person can be empowered to actually look at how things are working. Are they getting the right attributes applied for their QoS and the rate plan? Is the routing all applied correctly, and what's the actual traffic that they're getting across their network? So, that can help expedite the time to recover any issue that may be going with the customer, make sure that their experience is that, and do that at a very low level within the organization without having to get the engineers involved.

Also, very familiar, CLI, and then modern APIs, NETCONF APIs and REST APIs to be able to add additional automation, integrate with existing tooling that may be important with the operation, and all of those things combine to make it easier to manage, and that helps drive down operational expenses.

So, those are the five reasons that we're seeing service providers select and deploy virtual BNG solutions. So, it's flexibility, that ability to not be tied to a particular hardware, and to be able to scale as they need to; the ability to add agility to the decision and deployment cycle, being able to react to market changes very quickly; having integrated in-line CGNAT, as opposed to a separate CGNAT appliance or separate process; just the performance of the solution; and then obviously, the overall lower costs of a virtualized solution versus proprietary hardware.

If you look at some of the industry surveys, this one's by ResearchGate on the right, the reasons that we're seeing in the field map pretty closely to what some of the industry surveys about network virtualization, in general, were hoping to deliver, what they hoped or expected network virtualization to deliver. So, it tracks pretty darn well to those same things: flexibility, cost savings, agility, and scalability.

So, I hope that's been helpful to understand what's really happening in the real world, why people are actually not just considering, but actually deploying and relying on virtual broadband network gateways and CGNAT throughout the world, and if you do have additional questions, or want to get more information about some of our solutions, I invite you to visit our website, particularly our Resources page. There's lots of case studies, benchmark white papers, and other things that might be helpful to you.

So, Lilian, I know that we're probably going to have some questions. I'll hand it over to you.

Lilian Veras

Thank you, David. Thank you for sharing such great information with us. We do have a few questions that have come in while you were presenting. So, let's get started on those. The first question here asks, will a virtual BNG interoperate with my existing network, or are major topology changes needed?

David Williams

That's a great question, and actually the BNG, and the functionality of broadband network gateway, is really the same whether it's hardware, a traditional hardware-based router, or software. So, a service provider, if you think back to one slide I showed with carriers moving from a traditional hardware-based router to a software-based solution, then eventually moving to the edge, it can be deployed exactly in place. In fact, most of our customers are just replacing existing traditional hardware-based router BNGs with our solution in place, and then taking advantage of that flexibility for the future. So, no real change is required in the architecture.

Lilian Veras

Great, thank you, David. Another question here. How many subscribers are supported on a virtual BNG?

David Williams

So, again, it depends on the scale of the hardware and the resources that you apply to them, but from a software design standpoint, we can support well over 100,000 per software instance. So, depending on how many of those you're doing, but each BNG can handle 128,000 subscribers from our table, but we're generally going to hit some other scaling, the overall capacity of the compute node first. So, most of our customers are doing not more than 50 or 60,000 per BNG node, and then scaling out horizontally after that.

Lilian Veras

Great. Another question we have here, to achieve 700 Gbps performance, do you rely on a special NIC FPGA accelerator, or purely achieve it with latest CPU architecture?

David Williams

That's a good question. So, we're not using FPGAs. We're doing this with a combination of the latest 3rd Generation Xeon scalable processor from Intel, which supports PCIe Gen 4, and that's important because PCIe Gen 4 can support the bandwidth that's possible with the new 100-gig and 200-gig NICs. So, it really opens up and improves the density that we can do on a single server. And then, of course, doing that 700-gig, we're really in that case, in that particular example, we're doing two BNGs on a two-socket server-- And excuse me for a second. No, we're doing two BNGs, one per socket, with 400-gig NICs per socket, to get to that 700-plus. So, it's really closer to 800 in total. So, 100-gig NICs, PCIe Gen 4, and the latest 3rd Generation Intel scalable processors all combine together within our virtual routing solution, now supporting all of that and optimizing it. So, great question.

Lilian Veras

Awesome. Thanks, David. Another question here. Do you have specific hardware recommendations for specific throughputs?

David Williams

We do. So, we've got papers available. You can contact me or any of my colleagues for specifics on what your particular use case is. So, we have customers deploying some very small hardware for very small use cases, even inside of MDUs, all the way up to very large use cases. And so a good rule of thumb is, say, if you're going to do, say, two 10-gig interfaces, so 10-gig in, 10-gig out, that's going to start with around eight CPU cores, and then we'll just add one core per 10-gig as you continue to scale up. And then more specifically, we've got actual CPU model numbers that we'd recommend, and NICs that we recommend, and all those other aspects, but it all depends on the size and scale. We've got papers that go into detail, but we're happy to assist with any sizing.

Lilian Veras

Awesome. We do have time for one last question, and it is a member of the audience who’s asking, is it best to have more slower cores, or less but faster cores?

David Williams

That's a great question. So, it's actually better to have one core per 10-gig, and that core should be, say, 2.4 GHz or better, so in order to achieve line rate, and you can run on a slower core, but you won't get the performance. It'll be slower, and that's-based on the CPU, and not all platforms, and not all NICs, can support mapping multiple cores to help augment that. So, we do really recommend, and it's really tied to how the DPDK is designed, to have one high-performance core, faster core to each NIC. And then was there a follow-on to that?

Lilian Veras

Yes, what about RAM usage?

David Williams

Yes, so RAM usage is fairly fixed and depends on the use case, so depending on how many subscribers. We generally start with around 32-gig for, say, a 20-gig smaller BMP. It can be even less for one gig, really mini BNGs for apartments and things like special use cases, up to, the max is around 64-gig, so that's just for larger use cases. So, it's really only one or the other.

Lilian Veras

Great. Well, David, thank you so much for that great presentation. I ask our live audience to please not forget to give our team a rating for the live recording so that we may continuously improve the quality of our webinars. That's it for now. Thanks, David. This concludes our webcast.

David Williams

Thank you very much.