Raj Singh: Welcome to the Six Five Summit. I'm going to talk to you about 5G networks and Edge computing. My name is Raj Singh. I run the processor business here at Marvell. And as you will see, Marvell is a leader and has been for many years in both 5G and wireless communication for infrastructure throughout the world. We have marquee names like Samsung and Nokia who we partner with to bring 5G technology to the market, and most recently, Fujitsu in Japan and Facebook connectivity as well and others. We provide complete end to end platform solutions, and we provide them in a way that enables our customers to bring this very innovative technology to the market in a robust qualitative and early to market methodology.

For the last 15 years, we've been providing products for wireless connectivity for back haul, for radio networks, for transport processing, for base band and most recently for L1 beam forming processing in radio as well. Today from Merchant Silicon, we truly are the number one provider of silicon and software in the world. And by our last count, we have shipped over a hundred million units into the marketplace. And over 2.2 billion people are now connected to networks using our technology and our software and our hardware. And this is, of course, rising. Some of the very large networks in the world in India and China and Japan and Korea and even here in the US based on Marvell Technology.

And if you look at 5G networks, they are evolving into something quite interesting and quite complex. And we see later on, there is a real necessity of why that evolution took place and how the market and the industry is capitalizing on that, how Marvell is playing to that and enabling the ecosystem. And if you look at this diagram, what you will see is, of course, there's the traditional radio heads, 2D, 2R, 44R. But there's also now a proliferation of massive my one radio heads, 16T, 32T, 64T. This is driven by the need for capacity and the need for speed where you're able to steer multiple beams of my one and to specific devices to increase capacity or guarantee certain qualities of service. And in the same metamorphosis of the network, we're also seeing mobile edge computing happening at the edge of the network, rather than at the core, so that the very edge of the network's now more intelligent as is fare edge. And in the near edge, what used to be conventionally in a collapsed base station, central office type locality. You're getting not just traditional virtualized chassis based systems, but also servers with PCI cart with inline and other acceleration to provide one acceleration. The far edge remains the province of CU's and L2 L3 and the wrecks. But the combination of these is very exciting because for the first time in 35 to 40 years, it's changing the topology of the network.

And why did this happen? Well, if you look at the diagram up top where a traditional rap, historically you could maybe have some INCs and other control thing, but historically you had a radio tower. You had radios at 2T, 2R, maybe 44R, really interesting. Even with the LTE, the connection from that to base band unit at the cell side or co-located in the central office was an optical fiber on CPRI, so the common public radio interface, which of course was somewhat customized for each vendor with the vendor extensions to match their particular need. But at 20 megahertz at 2D 2R, the combination requirement for traffic is about seven gigabits per second plus. If you to extrapolate that to 5G where the bandwidth is not 20 but a hundred, and then 10 potentially 32 at age of 16 layers, you have 300 plus gigabits per second. And a single

fiber will maybe handle eight to 10, so it's problematic to have 30 of these fibers going to a single radio head.

And the backbone similarly grew from 225 to seven. Now seven is in the range of ethernet traffic being able to manage that. But if you look at the way you solve that, the way 3DPP did, definition of five use standards said, "Yes, you can have standard DUs and yes, there's a split eight that lets you either use ethernet or optical fiber on the front com. But the smarter money is to do more of the processing in the radio head, such that a lot of the sweeps and other things that you need to throw away at the beginning, reduce the amount of traffic going from the radio head to the DU." And of course, as you can see here, it went from 314 to 25. Now 25, you can have them on ethernet all day long, and of course the mid haul is seven and the back hall is seven as well. These are very manageable portions.

And that was the beginning of how the split came. This is a conventional number two split. Oran came along and said, "Well, if that's the case, the true nirvana is to provide a defined protocol between the DU and the RU such that vendor ABC can inter-operate with rate of a DUs can interoperate with radios from vendor XYZ and everything was good." And that gives flexibility, it gives choice, it increases competition and innovation, and that's all goodness. So the splits were a necessity. Oran used the splits specifically that the RU DU interface and codifying that in a way which define both the messaging, the protocol, the signaling, the compression decompression mechanism and the timing, so that things would work in a more cohesive way, which is a very good thing for the industry.

Now within Marvell, we have also adopted this. We've said, "Look, there's a way to do this both in conventional networks," conventional networks aren't good deploy. 95% of networks deployed today are conventional networks are the chassis based, but there is a desire on both for geopolitical reasons and for government intervention as well as the operators to have more flexibility and to have a more open system. And ORAN certainly provides that. So we are now providing silica in the radio head for the lower L1 for 5G that's shipping Silicon today for a number of our customers. We're providing the full base band silicon as well as upper base band silica and L2 processing for the digital unit, the distributed unit, and then this central unit for the upper L2 L3 and the back haul interface.

Now this takes care of conventional chassis based things. What it does not do is address what happens if you want to use cult servers either in the near edge of a far edge, use sample offload. We've taken a view that yes, you can do offload and we can do that. But the much better way of doing cult based server implementations and it's a much harder way, is to have true inline processing of data. And as most of you know, wireless inland processing is harder, but it's much more effective because you can have more capacity. You don't have the constraints of not being able to do calm or cataract creation or many other advanced techniques that are prevalent in the industry. Because one of the things that we're very keen to do at Marvell, and we have done with our customers, is that whether you're doing Oran or you're doing VRAN, you're doing conventional chassis based things or you're doing pizza boxes, that you should not be losing functionality.

You should not be going backwards. You should have future parity. You should have the same performance level that you need to do this.

And with that in mind, here's an example of the kinds of things we do in the radio unit, in the base station unit, in the central unit. And in each case, we have a number of different pieces of silicon and appropriate software associated with it that deals with each one of these, both for L2 control in the central unit, connectivity. In the DU, we have both L2 transport, base band processing, five. We can do custom A6 for certain of our customers and the radio unit has a massive MIMO as well as connectivity and DNP as well.

So if you go past this, what are we doing in enabling it? We partnered with a company called Analog Devices on the east coast, which is a world leader in RF technology to complete our new design for a 7.2 split massive MIMO. Before this was announced, that this would now be shipping in Q3, Q4 of this year, all the massive MIMO designs that were SOC based where the provenance of tier ones when you're our customers, but all of the ones that were in the public domain for the startups and other companies to inhabit, required people to use [inaudible] . The box is much bigger. It displayed a lot more heat and needed different mounting mechanisms and were more expensive. We for the first time in conjunction with analog devices are offering a solution to the marketplace which is licensable that provides the SOC based design at 32R.

[inaudible] provides a software for lower L1 being forming and of course, all the RS software, which analog devices justfully set. We're providing a single pizza box integrated to you, which has L1 and L2 integrated and L3 integrated all 10 including IP set on the back haul and then encrypter or on the front haul. All of our base band silicon, whether it's complete base band in line or L1, upper L1, has frontal connectivity built into the SOC, has timing built in recipe, Oran compatible one has some compression decompression built in as well. And you can see it.

The last one on this list is of course the one which says this is an inline acceleration and I spoke about earlier, which we believe to be the way of the future. We've enabled this with a number of our customers in a way that gets them to market and gives them very high capacity in a single car, allows them to do advanced techniques that I said like comp and carrier aggregation, both across FTD bands and interband and intraband and across FTD and TDD. And as spectrum becomes more fragmented and it becomes more sparse, this becomes a very important thing for us to do.

So in summary, what we've been doing over the last decade and a half is enabling large parts of the ecosystem in the wireless infrastructure space to be able to quickly and effectively go to market with solutions that are deployable, that are robust and have fine lines of reliability and are at par with what customers are used today. The innovation from 5G, of course, also is that 5G is not something that is just for devices or handsets or tablets or cell phones. It's much more than that, has industrial components. It'll power smart cities and smart grids and vehicular traffic and communication in augmented reality, in gaming, in remote medicine. These are all very key components of a low latency, always on, very high speed network. That's what 5G is, and has great promise to literally change the effect of society in the future.

Thank you for listening. I really appreciate your time.