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5G and 6G Technologies: Market Outlook and Investment Implications

Our Expert:

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- Director, Advanced Technology and Innovation at T-Mobile US, Inc (April 2010 – May 2024)
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*Herkole Sava, PhD, has **25+ years in the wireless industry**, starting in 1997 after earning a doctorate at the University of Edinburgh. He has led **software and systems teams in mobile and fixed wireless access**, helped launch **the first U.S. 4G WiMAX deployment at ClearWire**, and guided **strategic shifts to LTE and 5G**. His expertise spans technology strategy, product innovation, and partnerships, earning industry recognition. Sava is currently CTO and SVP MD at a wireless infrastructure company, driving AI integration into wireless networks.*

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President & CEO of TelcoBridges (May 2024 to present)

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KEY TAKEAWAYS

Overview of 5G and 6G Technologies

- Strong consumer value (faster mobile broadband) but limited enterprise returns.
- Ultra-low latency and IoT visions remain niche; adoption slower than expected.
- Operators already spent tens of billions on spectrum and $10–14B/year on upgrades.

Market & Capital Structure

- U.S. consumer market dominated by three nationwide operators.
- Spectrum and infrastructure costs are sunk; focus now is on amortization.
- “5G deployed” ≠ full enterprise features (coverage vs. capability gap).

Revenue & Returns

- ~85%+ of revenue still from consumer subscriptions; ARPU lift modest.
- Mixed investor outcomes: T-Mobile outperformed, AT&T/Verizon lagged.
- Fixed Wireless Access (FWA) emerging as a real new growth stream.
- Enterprise use cases: robotics, AVs, remote surgery, private networks (mostly stalled).

6G & AI Outlook

- 6G will be evolutionary (building on OFDM), not a full reset.
- Three investor angles: operational efficiency, edge/compute hosting, and capacity gains.
- Monetization will be gradual—execution proof points required.

Risks

- Hyperscalers capture outsized value, leaving operators with utility economics.
- Failure to diversify beyond connectivity = low-growth trap.
- Vendor consolidation and geopolitics create supply risks.

Positive Signals to Watch

- Sustained FWA subscriber growth with healthy unit economics.
- Operator partnerships around AI/edge workload hosting.
- Published AI gains (OPEX savings, capacity boosts).
- Carrier–cloud strategic alliances or M&A.

Investor Checklist

- Track FWA unit economics (ARPU, churn, margins).
- Confirm capex stabilization (shift toward maintenance).
- Demand evidence of AI monetization (real pilots, not PR).
- Assess competitive spectrum/coverage positions.
- Watch hyperscaler edge expansion and telco tie-ups.

TRANSCRIPT

Max Hi Herkole, my name is Max and I'll be leading this call on behalf of VISASQ/Coleman Research today. As you know, the purpose of this discussion is to learn about the mobile 5G, 6G market, including key players and trends in the industry. So before we begin, I just want to remind you that we are in no way soliciting any non-public information or any information that is considered confidential and related to any company or organization that you are currently, or have ever been affiliated with. If you believe the answer to any question involves any non-public information, please tell me right away and I'll take us in a different direction. And do you have any questions for me before we begin?

Herkole No, I'm good. Thank you again, very nice to talk to you and looking forward to our discussions.

Max Awesome. So, Herkole Sava, PhD, would you mind just providing a short overview of your background and experience as it relates to the mobile telecom market please?

Herkole Sure. So I've been in wireless market for more than 25 years now. So I started in 1997 after finishing my doctorate degree at the University of Edinburgh. For eight or 10 years I was in Montreal working for an ODM OEM company, designing and leading software and system teams for mobile system, particular fixed deployment with variety of technologies, IP over TDM, TDCMA, WiMAX and so on and so forth. And we had some state of the art products there that made a significant improvement on fixed wireless access around the world.

In 2008, I moved to the United States. I joined a company called ClearWire, not sure a lot of people know about it, but that was the first 4G WiMAX deployment, mobile deployment in the United States. It was a joint venture between Sprint, Intel and the cable companies that invested in the company. It was the very first 4G mobile deployment of WiMAX around the world. For the first two years I was with the technology team and helped on the development of technologies and deployments around the United States in major market like Florida, Baltimore, DC, Seattle, et cetera.

In 2010, then I was moved to the CTO office because the company had a fork in the road and had to take a strategic decision in terms of going LTO versus WiMAX too. So the CTO and the CEO created a team of three people that were tasked with deciding the next frontier and where the company should have gone from the technology strategy and the business as well. So those three years, 2010, 2011, 2012 were quite formative and quite rewarding because those years established the TDLTE and the 5G as we know it now from a technology perspective in terms of massive MIMO systems, how the TDD should work, the largest channel bandwidth, the matching of the traffic between the mobile network and the internet, which led to the acquisition of ClearWire from Sprint and then Sprint from SoftBank.

The reality is that SoftBank wanted to acquire ClearWire, but they couldn't because Sprint has 51%. So they had to acquire the Sprint in order to get the value of ClearWire. And not only we defined a direction of technology there, but we developed the largest ecosystem for the LTE, which was banned 41 by bringing China, India, Japan, and US together and realizing the potential of those markets. With regard to the LTE and future 5G. From 2013 2020, I was with Sprint as part of the CTO office. Again, working on technology strategy, new product innovation. Again, a lot of work there in terms of taking the LTE into the next step with features related to HPUE. Then dual connectivity between 5G and 4G with the equal coverage, etc.

And so I've always worked on the advanced technologies strategy direction of the company partnership ecosystem, what's the next step and the next direction of the industry. And I continue that work with T-Mobile focused on fixed wireless, focused on immersive technologies, certain other proprietary technologies that go beyond the scope of this. But that has been my career on the wireless technology for more than 25 years.

Currently, I am the CTO and SVP MD for a wireless infrastructure company working on AI for the wireless infrastructure industry and trying to bring that segment of the industry up to date and take advantage of the latest technology development and make it as efficient as possible. I've been fortunate to work for organizations that my work and my initiatives have been recognized and valued. So I've been very fortunate on that. In 2017, I was awarded the Mobile World Congress Honorary Award for my work on HPUE. ClearWire CEO gave me the CEO award for the work that I did on Band 41 and directional strategy of the company Sprint recognized me for the work on 5G. So I've been very fortunate to work with good people and with good companies in the past. But that's in nutshell my experience on mobile industry.

Overview of 5G and 6G Technologies

Max Awesome, thanks for sharing. So I'd like to start with just an overview and market outlook of 5G 6G, and I want to start from the basics. So what does 5G and 6G mean, and why are they different?

Herkole Sure. So the wireless technology usually follows the standard defined by the three GBP organizations and every 10 years they come with a major definition of those standards or upgrade on those standards. And that's why you see 1G, 2G, 3G, 4G, 5G, and 6G. So whenever you see a new numerology in front of a G, it means that it's a major upgrade, at least from a three GBP perspective. So the 5G was deployed around the beginning of 2020, LTE was 2010 and so on and so forth. Going back with 3G, 2G and 4G. 5G in itself, it's an upgrade from the LTE. I would say it's an evolution. The 4G in itself was long-term evolution. I think that evolution is continuing. It's based more or less on the same premises as LTE in terms of the physical layer and the wavelength over the air, which is OFDM base signal.

It's an IP core network. It goes into a channel boundary with an additional features like only any other technology, but fundamentally, it's the same technology. The 6G is in very early days and I want to emphasize that, it's in early days' vision and discussion right now. But it seems to be on the evolutionary path as well. A couple of weeks ago, the three GBP ran a working group took a decision they will stay with the physical layer definition of OFDMA, so cyclic prefix, OFDMA for the 6G as well. So from a fundamental technological perspective, 5G and 6G and 4G are within the same vein of technologies. Obviously there's differences in enhancements in terms of performance with the event of massive MIMO and B forming and other technologies, but they fall into this group of technologies around the OFDM and IP core networks.

So that's how I would characterize 5G and 6G from a technology perspective. From a marketing perspective, obviously 6G is not deployed today, it's at inception stage. 5G has been deployed around the world and there's certain specificity, we can go on in more details if required, but it is a technology that has been deployed since 2020. So it

has been in the market for almost five years now in major geographies like United States, China, Europe, Asia, and other parts of the globe.

Max Okay. So perfect. So let me see if I can wrap some of what you said with some plain English terms. So correct me if I'm wrong. So when you say it's an IP core network, you're referring to the fact that from the tower to other towers or to other nodes, it's just fiber, it's just IP core.

Herkole Correct.

Max And then when you say it's the same physical infrastructure, then we're still talking about towers, right? For 4G, 5G, 6G. Okay. And then the difference in the Gs it's how compact and how high the wavelengths are between a device and a tower, is that right?

Herkole Not necessarily. When I was referring to the physical layer is the type of modulation that the signal that send over the air. In 3G for instance, those were WCDMA. In LTE, they were DMA based. In 5G they continue to be of DMA based with certain enhancements and certain new features. But it's a totally different waveform that is in 3G, and that's the major difference from a physical layer perspective between the 3G and the 4G and beyond.

Max Got it. So it's an improvement in waveform and then the difference between 5G, 6G will continue to be a different improvement in waveform?

Herkole Correct. Again, with the fundamentals of it being aligned with OFDM and what is today on the 5G, which is amazing decision point because that has implication on cost and upgrades that I'm sure we can talk in this discussion more.

Market and Capital Structure

Max Got it. Can you help us frame just as a starting point, what the capex build was globally for 5G, and then how many people have 5G? You said it's deployed in the United States, does that mean every single tower and every single device has 5G or not? And then how does that track to how much was spent so far?

Herkole So in the United States, from an expenditure perspective, when you're deploying a technology, you usually acquire a new spectrum and then you have to deploy new radios on the towers and other works are going. If I look at the three major operators in the United States, which is T-Mobile, Verizon and AT&T, Verizon spend roughly 51 billion to acquire the C band spectrum around 3,511 licenses in the United States, that's just to acquire the spectrum. AT&T spent a little bit less, they spend 27 billion, but they just spent 23 billion to acquire spectrum from EcoStar. So both Verizon and AT&T already spent around $50 billion to acquire spectrum.

In the case of T-Mobile it was a little bit different because T-Mobile merged with Sprint and they got access to the Band 41 spectrum for their 5G deployment. And then if you look at the capex, yearly capex expenditure of those companies, particularly if you take the case of T-Mobile because they have been ahead on the 5G journey compared to Verizon and AT&T. So their figures tells you a little bit more for the last three years. They have spent roughly 10 to 14 billion a year for capex. So if you just put together the amount of dollars spent to spectrum and deployment, you're getting roughly to $100

billion, which is a very high number. But those are the numbers that we're talking in the United States. I would expect that the other geographies more or less would be the same.

Obviously the cost structure is different because in the US when you acquire spectrum, you auction for a spectrum and you pay for it in some other geographies the spectrum is leased, and you don't pay for it. Obviously the size of the economy and the cost structures are different, but those numbers are solid in the United States to give us a picture of how much would cost of deploy a 5G network per the first state of the 5G, which is the major update of 4G to 5G network. Obviously after four or five years when you have deployed the network, then you go into maintenance mode or more surgical deployment and upgrade into the network and the numbers may go, definitely will go down.

But in terms of coverage, for instance, T-Mobile today covers 330 million pops in the United States with their 600 megahertz and around 320 million pops with their Band 41, which is 2.5. I think Verizon is around 290, 300 million for their C Ban deployment. I think AT&T is below those numbers, so they have some catch up to do. But a full deployment of technology in the US we can say is roughly $100 billion per operator in the last four or five years.

Max Got it. And then just a couple more questions on this to frame this properly. So can you first explain when the large operators buy by spectrum, is that forever, or is that a predetermined amount of time that they can own that spectrum? And then for the annual capex after, is that just putting devices on existing towers at existing pops? That means point of presence, right? Is that basically a tower?

Herkole Yeah, POP stands for number of population on a particular geographical area.

Max Okay. Okay.

Herkole So the spectrum in the US is auctioned, obviously it's conditioned there and I think the latest discussion in terms of EcoStar and FTC conditions are a vivid example of that. But when you acquire the spectrum, you acquire it forever. And when you meet those conditions, you own it. There are certain rules that you can sell it and you can do, but even the exchange of spectrum usually has to go and get the approval of the FCC. So two entities can agree to each other to exchange spectrum and purchase spectrum, but the FCC has to be the final say on it and approve it. So it's a mixture of full ownership with certain regulatory rules in terms of changing that ownership and financial transactions that go with it. The other part of your question was?

Max What's the annual spend after? So if you've bought the spectrum and then you said there's an annual spend of 10, 15, what is that annual spend on?

Herkole So that annual spend basically spent on the equipment, on the radios that go on the tower, the installation of those towers, the equipment that goes on core network. They go in the fiber to connect the tower with the data centers and the core network. So is the establishment of the technology from the tower to the data centers or to the core network that the mobile network operators have their position.

Revenue and Returns

Max Got it. Perfect. Super helpful. And then how do operators typically monetize this investment? Because you said it yourself, it's pretty significant. What is the revenue model once you've spent that kind of money?

Herkole So the majority of historically, and it continues to be the case, the wireless networks have served to a large degree the consumer market. So it has been a cutthroat industry basically in terms of acquiring customers from your competitors. Because the number of population to large degree is capped, it's not growth substantially. So you may have certain increases in number of smartphones or devices per single customer, but those things are relatively minor. So the majority of the revenues more than 85% I would say of the top three wireless operators in the United States, they come from the consumer space. That has been the major source of revenue.

So you design the plans in certain way that they're attractive for the consumers by either bundling them with certain services offering high speeds or unlimited tonnage. So to date, I think it is mostly driven by the consumer space. There's been a little bit of development on the enterprise side of it, but that, as I say, in terms of revenues, those numbers are relatively modest to the overall revenues of a mobile network operator. Not only the US I think, but globally as well. So that's the major source of the revenue for the wireless operator, so far I would say.

Max Awesome, thank you. Moving on to 5G, more specifically in terms of our agenda here. For the average consumer, I mean just to level set, when you say it's been the consumer, you're referring to the monthly subscription we pay for ourselves, that's right?

Herkole Correct. The smartphone again, by consumer, let's simplify to a smartphone because that's what we mostly use as a mobile device exclusively.

Max Perfect. And did the experience... How did the experience change for a consumer on their smartphone for the steps between 4G and 5G?

Herkole Obviously there were certain improvements because with the 5G you got more spectrum and larger channel bandwidths, which allowed for larger, better capacity. So you get higher speed nowadays compared to the LTE by the virtue of new spectrum being deployed. And some advancements in spectral efficiency with the massive MIMO. So there is an improvement in terms of throughput and latency on 5G versus the LTE. Those are more noticeable compared to the 3Gs, because that's a completely different technology. But you still see, if you look at the comparative data or historical comparative data that companies like Ookla or RootMetrics provide that are crowdsourced data, you would see that the speeds have increased substantially and the latencies to some degree have reduced, especially if you have a standalone core for the 5G network. So there is an improvement in user experience as you go from a 4G to the 5G.

Max Got it. And you alluded to it being mostly a consumer thing for now. Was that always the expectation, or was it always the view that consumers would be the primary and vast majority of monetization? Or was there an expectation that 5G would unlock enterprise use cases? Can you talk to us a little bit about this enterprise use case for mobile?

Herkole Absolutely. Yeah. So that wasn't necessarily the vision for 5G. 5G, the vision was be a three-leg stool, basically. So it was the enhanced mobile broadband, which was one side of it. The second one was ultra reliable low latency connectivity. And the third one was the massive connectivity. So far after five years, I think it is fair to say that the only one leg of the stool, the enhanced mobile broadband, which is smartphone connectivity, has seen most of the benefits of the 5G, and the other tools are lagging far behind for a variety of reasons that I'll be more than happy to delve into if you're interested. But as of now, I think it's fair to say that most of the deployments on the 5G around the globe deal with the EMBB or the consumer space.

Max Got it. Can you talk a little bit about why those two schools haven't panned out?

Herkole Yeah, absolutely. So there's a couple of main threads that represented to the industry as to why those things have not been materialized. And I'll give you my personal opinion on why too. It starts first with the definition of the requirements and what you're trying to design as a system or part of three GBP. And my personal opinion is the three GBP quite often looks at the theoretical stuff, theoretical points and driving use cases or vertical industries for the requirements that may not be exactly a match for those industries, or not absolutely required.

And let me share you a real story, which I found quite stunning. A couple of years ago I was in a conference in Silicon Valley and we had their representative from one of the major global OEMs, car OEMs, they have a research center there. And he was making a presentation and he was giving his opinion about the 5G. And he was telling a story that, well around 2016, '17, we had these companies from the telco space, they come and talk to us. They were the OEM on the chipset. And they were saying, oh, what kind of requirement you want and what you want to do and we're trying 5G and trying to use this for autonomous driving, and we provide them some requirements.

Then they came a year later, they presented our requirements. We told them that these are not very meaningful to us, we want to do something else. And then they came after the 5G was defined and they told us that we don't know the industry very well, but those are the real requirement for automotive industry. So this was like eye-opener to me, I was like you need to define requirements that are practical, that can be deployed cost-effectively, and has a real value for the vertical industries. I am not convinced that the 5Gs was defined that the early days met those three conditions and I think it's suffering for that.

The other thing is that the consumer space is quite different than the enterprise, both in terms of requirements, reliability of the network and the cost associated with it. Because with those additional services in terms of reliability, performance, et cetera, that come with enterprises comes a different cost structure, that's different than cost structure for the consumer. And that requires some learning from the enterprise and some negotiation that it's much more challenging than just the consumers pay that cannot do without a smartphone.

And the other reason is that those enterprises take a long time to get convinced and to change their organization to adapt those kind of things when it comes particularly to the private networks for the cellular network. So there's a multitude of factors I think that have made the two legs of the ultra reliable connectivity and massive connectivity not as advanced as the industry would have liked. There's inside voices within the industry that trying to make the argument that, well, maybe not too much was invested in 5G in terms of standalone and some advanced features that have prevented those kinds of use cases. And there is a validity on that argument as well, but I don't think that that's

the most striking factor on those two legs of the stool. Why they're not where the industry would've liked when they defined the vision for 5G and the requirements for 5G.

Max Got it. Can you just give some examples of the use cases that the 5G industry had in mind for enterprises? It's robots, basically, moving around a factory that don't have to be plugged into an ethernet port to get connectivity. It's remote surgeries. What are some of the visions that the industry had that didn't pan out just to help the audience understand that?

Herkole Yeah, you're touching a couple of industries that have been of interest to 5G and we'll talk about more. So one has been the health industry. So there's a lot of, in the early days claiming out or trying to do robotic long distance surgery with a surgeon somewhere and then the operating theater somewhere else. Having 5G connection in ambulances. Even having implants on the patient that had sensors to collect data, has been other things. And then the operation of the hospitals and the sensors in that environment in order to have a more efficient running of it.

So the most advanced deployment that I've seen with any of those cases is somewhere in Singapore with a national university hospital there and they presented something in Barcelona last year that seems to be impressive. Obviously that's early days, but that has been the most advanced there.

There's a lot of work in terms of 5G in terms of claiming for autonomous driving, including the robots and other things. Robots are very complex one, because those require very large throughputs and very low latency. And technologically 5G can achieve those, but the cost factor to achieve those, to deploy those kinds of networks is much, much higher than a public network as we know today. Because to ensure reliability of few milliseconds of connection with hundreds of megabits per second on a certain location, it requires a very high performing network that it's quite different in terms of architecture, in terms of density and other parameters that go into the design of a network, and the public network that connects to the smartphone.

Transportation was another area in terms of tracking the goods historically has been an area of interest for the 5G. There's been a lot of interest recently about the sporting events and special events, particularly T-Mobile has been very successful on it with certain events in New York with the regatta there with the boats, golf events and baseball events as well. So special events are getting some traction from the industry as well. There's been some interesting deployments and claims with regard to the ports, because they have a major impact on the global good transportation, particularly a couple of ports in China, but that market, it's quite opaque and you don't know how much was government subsidized there versus the other things.

So there's been some reports about the port in Rotterdam, but that was more like an LTE deployment. So there's an effort from the telecom industry to enter the vertical industries but not at the scale and the revenues that everyone would have wished from a telecom perspective, I would say.

Max Awesome. So I appreciate that, that's really helpful. Okay, so 5G it's mostly been still consumers. So talk to us about what the industry view is on the return of invested capital that has been achieved on the 5G build out. Is the consumer market still so good and you get a bit of pricing power and connectivity and the experience has been so much better that it's been worth it? Or have return on invested capital metrics been lower than expected because there haven't been these revenue streams from

enterprise? How has that math played out? Has the build up been successful, quote-unquote, from a financial perspective?

Herkole I'll address that question in a second, but before then I think another area that 5G is trying to have a leg and develop is the fixed wireless access. So basically providing broadband to the houses or enterprises. That has been relatively much more successful with the vertical industries. If you look at the T-Mobile for instance, today they have more than seven million, eight million with the goal to reach 12 million I think much earlier than they said or planned.

Verizon also has made some progress there, even though they're using millimeter wavelengths and that's quite challenging. But fixed wireless has shown some promise on the 5G, at least at this stage. There's still open questions in our long-term and cost, et cetera, but it's a very aggressive market that the 5G is pursuing in the United States with the fixed wireless in addition to the things that we talked.

Coming back to your question now, in terms of the return to investment, obviously 5G was not designed only to have consumer space as revenue, it was the other two as we discussed. The consumer space has been challenging, because you've got really three powerful companies that are competing more or less for the same people and every quarter the world state is looking at the financial results and see who has more cost paying customers than the other one. So what's the trends and what's the shift there?

But as I mentioned, my understanding is that more than 85% of the revenues for mobile loan to work operators in the United States today come from the consumer space. There's been enhancements on those plans or you bundle services with giving access to Hulu or Netflix, or those kind of additional services. You provide incentives to the apps like T-Mobile has got a T-Life app that gives them incentive on certain things. So you're trying to entice the customer to come to you through the price and additional services on the consumer space. But history has shown that as soon as one of those top three makes a move in the market, the other two will replicate it or try to replicate it within a period of six months.

So it's a very, very competitive market and I think the levels of ARPUs will tell you that that's the case because the ARPU hasn't grown too much from 4G to 5G, and is a very, very competitive market on both consumer and enterprise space. So there's a lot of movement currently in the wireless industry to explore revenues from enterprise and with the advent of AI to see what benefits the AI will bring there. Not from a technology, but a service provider of AI workloads and using the data centers of telecom as a data center for AI workload outside the telecom space. So the diversification of revenues outside the consumer space I think remains one of the desires and challenges of current telecom, wireless telecom business I would say.

Max Got it. So it's fair to characterize it as the returns have been less than expected, given the, A, competitiveness on the consumer side between the major operators? And B, the lack of additional revenue streams that were expected, is that a fair characterization?

Herkole That's a fair characterization and if I want it to be even more simpler than that, so in preparation for this call today, I went and I did a comparative search between S&P500 and the stocks of T-Mobile, Verizon and AT&T. So in the last five years, S&P500 has doubled, more or less. Out of those three vendors, it's only T-Mobile that has beaten S&P500. In the last five years. T-Mobile stock it's 116%, Verizon is down 27%, and AT&T is up 33%. So if you bring to that level of discussion, which is simpler from an

investment perspective and from a return to investment perspective, out of those three, basically only T-Mobile has been able to beat S&P500 in the US market. So that tells a lot.

Max Yeah, perfect. I'm glad you brought up that kind of market comparison for this next question. Are there things that the industry has learned around other participants potentially benefiting from more connectivity, and such that the benefits accrued to parties other than the operators? For example, hyperscalers, application providers, the Netflix's of the world where people are watching on their phone now seamlessly, whereas maybe that wasn't possible in a 4G world because the latency wasn't good enough. Are there things that emerged that were interesting learnings around other participants than the operators having benefited from the 5G build out?

Herkole Absolutely, and I think those two constituencies particularly the application I think have gained a lot. Because remember, we wouldn't have Uber if we didn't have LTE. We wouldn't have been watching so much Netflix and other content provider on our smartphones if there was LTE or 5G. So over the top industry I think has benefited substantially from the wireless for the wireless industry. And the cloud industry and the hyperscalers, I think obviously they have benefited because of the certain expenditure. There's been certain movement in industry to move part of the wireless infrastructure into the cloud, in terms of you'll hear like cloud run or cloud core or virtualization, etc.

Those things are in their infancy. There isn't too much there, but they have gained from the fact that they bring the data center close to the data centers and core networks or the wireless network so that the content is closed and the latency is low. So in that respect, both the cloud providers, the cloud content providers and over the top application providers, I think that benefited a lot. And directly and indirectly obviously the end consumer has benefited as well, because that goes to the satisfaction and better lifestyle for the consumer.

So undoubtedly, and I think it's fair to make the point, that the wireless industry and the mobile industry has made a significant contribution to the overall development of society, overall development of the economy. And those things should be applauded and those things should be muchly appreciated. To what degree the telecom industry on its own has reaped the benefits of those achievements, I think that's a million-dollar question.

6G and AI Outlook

Max Yeah, perfect. Oh, that's helpful. Okay, Herkole Sava, moving on to 6G now you said it was kind of in its infancy stage where we talked about how it's the waveform improvements that will continue relying on tower infrastructure largely for the last mile and then an IP backbone. What's going to be different between 5G and 6G? Are we headed for the same type of situation? Or is 6G going to be able to deliver on use cases for the enterprise that 5G was never able to deliver on?

Herkole Yeah, I think it's fair to say that we're at the very early stages of the 5G. So if you look from a development perspective within the three GBP, the three GBP has decided that by release 20, which is supposed to be finished if I'm not mistaken, by 2027, they'll complete the development on the 5G. And then release 21, which is scheduled for 2028, that will be the first release of 6G with the fundamental features of 6G as well. If you look in terms of vision of the 6G and those things that are usually debated and

discussed on international mobile telecommunication organizations, so there's an IMT 2030 framework as it's known. There's a lot of enhancements on top of the 5G.

So they're talking about smart industries and robotics, which is tackled in 5G as well. They're talking about fixed wireless. They're talking about next gen IOT. Or connectivity on transportation, critical communication. So the three leg stool of the 5G with the 6G is intended to be improved even further. There are some other development there that are new and particularly the domain of AI and the communication, it's something new that has been seriously considered for 5G, and we can elaborate on that further. There are other direction and other discussion in terms of the integrated sensing as part of the 6G in larger scale and the benefit that integrated sensing could be to the communication, and then it's ubiquitous communication.

So it's built on the fundamentals of the 5G and enhancing those things. And probably there's a couple of things that are considered as a newest thing, or this discussion in terms of having energy efficient systems as well in more... Those things have been on 5G as well, but taken to another level. But I think the intersection between AI and telecom and mobile telecommunication, I think that that may be the most noticeable new thing on 6G, compared to the 5G, I would say.

Max Can you elaborate on that?

Herkole Yes, so if I would look at the potential implication of AI or the benefits of AI and telecommunication system, I would characterize it as follows, and I will put a caveat here. The more engineering complex systems we deal the challenges the AI class become. So when you're trying to deal with very complex engineering systems like the mobile telecom network, people shouldn't expect that AI will address the issues and provide results overnight. It's going to take much longer than in some other industries like finance or health or HR or consumers, et cetera. Those things are much easier for generative AI or other AI technologies. So I would like to make that point. So I would like to emphasize that.

There is a concerted effort in terms of improve the, or to explore the capabilities of AI from a technology implementation on the wireless networks. Meaning the telecom networks have been developed with software on the physical layer, on IP layer, et cetera. Now there's a concerted effort to see how the AI will perform on the space and it can bring benefits to the telecom networks in terms of efficiencies and performance, number one. Number two, these efforts in terms of improving the operation of the wireless networks through the AI and machine learning. And machine learning is critical here as well. I know the people sometimes intermingled use AI and machine learning, but those things are different. But machine learning is important here. And the subject of the self-organized network that's almost 10 years old now, it started with LTE. But with the advance of the AI, I think that's an area that can give benefits and efficiencies in the network.

The third area of interest is if the mobile networks particularly would be able to venture and migrate the data centers and core networks into the data centers that are capable to deploy and process workloads for the AI outside the telecom space. So to some degree, becoming a competitor of hyperscalers. Because not everything in the future AI is going to be a very large language model. You have small models, you have mid-size models, inferences can run on mobile edge core, you can run on devices. So that dynamic of architecture going outside the pure connectivity is another area of interest.

And the fourth or another area that I'm particularly keen to see how things are going is

how the AI can improve the application, and particularly video compression that is transported on wireless network. So there is a stream of work that is currently happening with the media called NVIDIA Maxine and they claim that they can compress the H264 videos up to 10%. Knowing that the 70% of the traffic on mobile networks is around video, if you're able to reduce that traffic to 10% of it, and again, I don't want people to get hyper excited about these numbers, these are early days. People evaluate the new technologies on best use cases. But even let's say you reduce it by half, that's a significant gain in terms of capacity.

So another area of AI implication is what AI could do on the application that they're running and the traffic that is running on mobile networks. And most importantly as well, how a smartphone or a personal compute device is going to evolve in an AI area. Those are directions I think will be quite interesting for the future of mobile networks.

Max Got it. That's super helpful. Yeah, because just to frame the last thing you said in terms of how more capacity is helpful is because if an IP backbone or tower infrastructure reaches capacity, then in theory you need to build more. But if you can compress better, then you can just have more traffic on the same infrastructure.

Herkole Exactly, exactly. And one of the reasons that 6G, the three GBP took a decision not to upgrade, at least at this stage, the waveform and remain with OFDM for 6G, was exactly this. I think was the pressure from a mobile operators that they have spent so much capex on 5G and they don't want necessarily to go and upgrade their networks for another standard that may or may not bring substantial gain on the specular efficiency. So there was a lot of pushback from the mobile network operators to remain with the same waveform on the 6G and 5G. Obviously there's going to be announcements as we said, there's people talking about full duplex improvements on massive MIMO, be informing control planes, et cetera.

All of those are incremental change, but fundamentally the decision was to stay with the same physical layer, or very similar to what you have in 5G for exactly that reason that there's very little appetite in the industry today to go and do a forklift on the towers to replace the radios or to deploy something completely different now. So the 5G industry would like to reap the benefits of the huge capex that they have invested today before I think embarking to new Gs.

So I'm not absolutely sure if we will have any significant 6G deployment by 2030. So if you follow with a 10-year-old cadence, you would say that 6G is going to be 2030. I think the jury is still out if 2030 is going to be as vigorous in terms of 6G deployment as it was with 5G in 2020 or 4G in 2010, I would say. We have to wait and see how things develop with advanced 5G before a solid footing and deployment on 6G will have a reasonable timeframe.

Max That's super helpful. And if we kind of reuse the simple simplified framework we articulated earlier. There's this concept of spectrum and then there's this concept of annual spend to outfit the towers with radios. So for 6G in its current contemplated three GBP specs, can the operators use the same spectrum? And then can the operators use the same radios that they put on all the towers for 5G? Or is there going to have to be more spending?

Herkole I think that's the goal. Yeah, that's the goal and I think that's where the decision a couple of weeks ago from the three GBP run. Obviously it'll be more spectrum like here in the United States as part of the One Beautiful Bill, it was a mandate from the congress to the FCC to find an additional 800 megahertz of spectrum because the

wireless traffic, mobile traffic grows at average 20% a year. So there's going to be more demand. Assuming that again, think technologies like AI, if they have a major capacity reduction on video traffic that we discussed as an example, that's going to be a major, major benefit. But the desire is not to at least the first wave of 6G to have new radios there.

Obviously FCC allocates new spectrum, and as you have capacity constraints in the network, then depending on the value of the spectrum and depending on the frequency of the spectrum, and the technologies, then you have to decide if you require the spectrums on macro sites, if the small sales. Indoor, in-building, outbuilding. So that's work in progress, but the FCC was mandated to look at those. Currently they're looking at the frequencies between four gigahertz and five gigahertz. For the 6G. There's discussion around the globe for other frequencies. There's discussion even for frequencies above millimeter wavelengths for sensing and some niche use cases. But for broadband mobile network as we know it, I think there's an interest around 47, 67 gigahertz, 10 to 15 because those frequencies may be more suitable for EMBB than dedicated high frequencies that are necessarily only for specific use cases and not large market deployments.

Max Got it. Got it. That's super helpful. And so if we just sum up your perspective on 6G as of today, acknowledging that it's very early days, it's going to be, sounds like more of the same, sounds like enterprise use case is still a bit of a question mark.

Herkole Again, more of the same from fundamental telecom technologies. I think that the big unknown here is the impact of AI. The impact of AI could be a revolutionary step. So that is a little bit unknown. There's been promising signs and there's a variety of organizations like AIRun, RunAI or other companies here. So NVIDIA is playing a significant role. They seem to be investing a lot in the telecom space. So there's a global concerted effort to see the benefits of AI in telecom space and if those materialize in terms of efficiency performance and other use cases that we discussed here, then 6G has the potential to become a revolutionary technology.

And what the NVIDIA R&D, through the Maxim program, is claiming is that for an H.264 encoder, they're capable of getting compression gains up to 90%. Therefore, only 10% of current throughput required for H.264 would be possible by using these AI techniques - that instead of sending raw data, you start with the frame, and then you send the AI parameters and the link, and the images and the video are generated locally. Obviously, this is the early days, and those numbers could be the optimal numbers in ideal cases.

But even if someone assumes a 50% gain in terms of capacity, knowing that 70% of the traffic in mobile networks is video, that's a significant capacity gain if and when materialized with video products and video technology in the market on wireless technology. So, the capacity gains are not coming only by adding spectrum or improving spectral efficiency, but they could come very well by the efficiency of transmitting a certain application - and particularly video - on the wireless network that would give free capacity for wireless networks. That would be an ideal scenario for mobile network operators, because they wouldn't have to spend too much on acquiring spectrum, or building new sites, or incrementing their deployments on the current site.

So, that's another area of interest that AI could have a positive impact on the wireless networks.

But from a fundamental technology, wireless technology, I think there's a lot of similarities to what is being discussed today between 5G and 6G, I may say.

Max Is there any reason why the participants that capture value in a world with AI is going to be different than it was in 5G pre AI? Is there any reason to think that the 6G future is going to be different in terms of the operators just being hyper-competitive and having to build out to maintain pace and the application layer effectively capturing a lot, or most of the value? I don't know if that's saying too much.

Herkole Yeah, I understand your point. That will go into if the mobile network operators and the mobile ecosystem itself would be able to show values outside the consumer space. Would they be able to bring additional revenues with some of the things that we discussed earlier. Be it in enterprise or providing additional services with their networks that go outside their core connectivity aspect of the network. So they're able to do those things. Obviously I think that the things can change. If it's all the same, then obviously we'll have implication of AI on the device side. Is a device going to be a compute platform that you're going to do a lot of inference on the device? Or is the device going to be, for lack of a better word, a dummy device with very little processing and you do everything on a mobile edge core?

So you provide a slew of devices that are very low cost and all the processing for those devices is done on mobile edge core of a mobile network operator. So the AI can allow that to be offered. And there has been certain initiatives in the last two, three years I think to explore that path as well. In addition to the adding more processing power on the device to do 10 billion or 20 billion AI models running on the device.

There's another line of thinking saying, well, what if my device basically becomes just a user interface and all the processing is done on a mobile edge core, and you have an AI interface with the sensing and other activities that brings that information to the device without having much more processing there. But again, a visual interface and other sensing interfaces on those devices. So there's other things that would happen on that space as well that may have an implication on mobile networks.

Risks

Max No, that's super helpful. That's super helpful. Well Herkole Sava, moving on to the last segment of our discussion here. I want to talk about risks and pitfalls. And maybe just before moving on to kind of broader macro risks and pitfalls for investment in the space, can you elaborate on the fixed wireless for people's homes? That seems to be one use case that has taken off. You mentioned I think Verizon or T-Mobile having seven or eight million of these kinds of-

Herkole T-Mobile.

Max T-Mobile, yeah. So can you elaborate on what worked there and what use case seems to be resonating for those customers?

Herkole So basically what you have, you have a router at home which is known as a 5G router and you install it at home. Usually you install it in a good location, close to the window to get a better signal. And through that connectivity so that router now is connected to the same tower that your smartphone is connected when you're outside. And inside the house, that router obviously offer the WiFi connectivity. So by the virtue of having a

device that has got a larger number of antennas and bigger size antenna compared to smartphone, you get a better spectral efficiency on fixed wireless and you get a higher throughput. And it's a fixed deployment, so that router doesn't move, that stays in your house.

So basically that's a substitute for the fiber connection that comes to your house or cable connection that comes to your house. Obviously you may not have the same performance, but not everybody requires one Gigabit connection at home. I may have a fiber connection one Gigabit at home, but I barely use it. So if the fixed wireless has been able to provide very competitive prices in certain geographies in the United States that were a monopoly before.

And that has been quite attractive, particularly with age groups between 80 and 35 and 40. So the younger generation that is not necessarily all the time at time, that requires certain price constructs. It's more attracted to the competitive markets and new technologies. In early days I think from the data that I've seen as part of my studies, et cetera, those were very attractive to this kind of offering. It started with very competitive prices in $50 a month, and that had a positive impact I think even on the other competitive because the cable and fiber reduced the price. These current offers, I think go to $30. So T-Mobile today, I think they offer the fixed wires for $30 a month. So it has proven to be a good source of revenue, at least for T-Mobile as I said, and to some degree for Verizon as well. So that's how the-

Max In areas where there's one fiber provider and the fiber provider has a monopoly and therefore tries to exert pricing power, then all of a sudden fixed mobile comes up as an alternative where the mobile operator can actually provide service in your house for a more competitive price than the fiber.

Herkole Yeah, and then you can bundle that service with a wireless service with your smartphone and you can get better benefits. Not to mention that sometimes you don't have fiber at home. So you can send the router and you can have service tomorrow. Fiber, you require certain time to install it. There's certain movements that you can take the router with you. So I have the router at home today and I give you an announced plan and you can take the router into a second property that you own. If you go to camping or somewhere else, you can take that router with you. You can have 5G connectivity there. So there are certain differences between puer wired connectivity 5G and fixed wireless that have certain benefits in terms of costs, speed of deployment and how you can take that service with you that have been explored and discuss in the past few years.

Max That's super, super, super interesting, Herkole Sava, PhD. So risks and pitfalls. What do you think are the biggest strategic risks and dangers for the industry as we continue to move through this mobile technology improvement and capex build?

Herkole The biggest risk, I think there's an inner risk and there's an outside risk as well. I think the outside risk is that the hyperscalers and the cloud companies and over the top, and OEMs, the smartphone OEMs, would require to have an upper leg on revenue generation through the wireless technologies, and the mobile network operators won't get the dessert part of the pie. That's a risk.

And the second risk, I think the inner risk is that if the mobile network operators won't be able to innovate and to expand beyond the pure connectivity that they have historically offered. So if they remain only with that part of the offering, I think that in the long term that could be a stagnation. Could be turning the telecom mobile network

operation at telecom to a utility, similar to utility industry. So those are the two major risks that I see going forward.

Positive Signals to Watch

Max And if you had to give advice to investors, what do you think are the biggest flags to look out for? And the flip-side, the biggest potentially opportunities for out-sized return on investment in this space?

Herkole So yeah, we touched on certain things. Obviously the intersection of AI and mobile networks. I think that's a very interesting area to keep an eye on. The caution aspect, as I said, would be the fact that would the telecom industry remain the same as we have known historically? Or would they diversify and go into the other areas in order to generate better revenues and more returns for their investors?

The relationship between the clouds and the hyperscalers and the telco world I think is a very interesting one. Would there be possibilities, therefore merger and acquisition? Probably not in the next few years, but in mid to long term. And how that would evolve particularly in the world of AI where mobile networks and mobility gives you a lot of data to be collected from the sensing and environment, and that data becomes so fundamentally valued to you that you would like to own it. And as part of that, you acquire and merge with a mobile network operator. That's an interesting scenario, an interesting question.

So far the hyperscalers haven't explored that too much and haven't been too much interested because there's complexities to operate the mobile networks, but there are things that could open up in the future I think that may be beneficial and maybe interesting as well.

Investor Checklist

Max Cool, that's super helpful. Herkole Sava, PhD, is there anything on this topic that we haven't touched on today that you think is particularly important or impactful that investors should know about?

Herkole I think we have touched on most of the things. I think obviously we have to keep an eye on how things develop with the 6G, and particularly the lane of AI. The telecom industry has gone through a consolidation process in the last 10, 15 years, and that consolidation has happened on the operator space. That consolidation has happened on the network equipment vendors. That consolidation has happened on the chipsets that go in the smartphones, and that consolidation has gone into the smartphone as well.

So 10, 15 years ago you had like 10 chipset vendors on the smartphones, today you have only four. You have, again, you have Qualcomm, MediaTek, Apple and Huawei, HiSilicon. You have Huawei, Ericsson, Nokia, ZTE, a little bit of Samsung on the run. And in most of the geographies, if not all of them, you have three major players as a mobile network operator. So there has been a move of consolidation that has brought

certain efficiencies, but there are certain risks with that consolidation as well. Geopolitics is playing a factor now as well, at least in the health of certain equipment providers out of Europe because they're being pushed out of China, so they have to compensate for revenues out of Europe or the United States.

So there's strategically, there is geopolitical forces and technological forces that have shaped this industry and may have an impact in the years to come that the markets I think need to keep an eye on those forces as well.

I believe that we covered everything on this call - the most important topic, both from a direction, strategy, and measure development on the technology side. One area that it's worth mentioning, that we probably didn't pay too much attention to, is what is known as non-terrestrial communication and non-terrestrial networks. This has been an area that both 5G and 6G are paying a lot of attention to, and the operators have spent on this area.

It's worth mentioning, for instance, the partnership between SpaceX and T-Mobile. So, T-Mobile today offers direct-to-device connectivity from SpaceX satellites to their devices, and in the near future, they will provide a two-way video call with WhatsApp and weather tools as well.
Most importantly, and most recently, StarX entered an agreement with Star with Equistar, to acquire 50 MHz of their spectrum. And that has drawn a lot of attention from the analysts.

There's been some kind of mixed feeling as people try to understand if that would be a direct competition to the M&Os, or why SpaceX acquired the spectrum. I think we have to be realistic, and a non-terrestrial network will never match the performance and quality of terrestrial networks, because the laws of physics basically cannot be beaten.

But there are certain ways that spectrum could be used directly for Starlink - either for direct connectivity to smartphones, or, more interestingly, they could establish an efficient network to have their cars - Tesla cars - talk directly to the satellites. In this way, they can overcome certain limitations in terms of transmit power or antenna size on the smartphones, and could give them a quite interesting architecture and connectivity, either for the consumers in the car or for telemetry of the car to go to their satellite network and not depend on the other parts.

Verizon and AT&T are working with AST in this space, and so they're lending their spectrum to those who have this connectivity. AT&T has been working with Global Star - I'm sorry, Apple has been working with Global Star - has invested, if I'm not mistaken, around $1 billion in them, and is using their spectrum for the purpose of direct-to-Apple-smartphone connectivity.

So, the area of NT&T, or non-terrestrial networks, is another area of interest both in 5G and 6G. But I do see it as a complementary connectivity and complementary activity, rather than a direct competitor to the terrestrial networks.

I thought this would be worth mentioning as an addition to what we have discussed as part of this call.

Max Cool. Well, thank you so much for your time, Herkole. This was exactly the kind of conversation we were looking to have. You're clearly an industry expert and we're very thankful for having gotten a bit of your time today.

Herkole Thank you. It was very nice talking to you and wish you every success with your programs.