Rashmi Mohan: This is ACM Bytecast, a podcast series from the Association for Computing Machinery, the world's largest education and scientific computing society. We talk to researchers, practitioners, and innovators who are at the intersection of computing research and practice. They share their experiences, the lessons they've learned, and their visions for the future of computing. I am your host Rashmi Mohan.

For most of us, spending a day without our mobile phones is a recipe for disaster. From running our businesses to ordering our food, to navigating our world around our cities, these devices power our world. Have you given much thought to what powers these devices?

Our next guest knows a thing or two about wireless computing and energy. Shyam Gollakota leads the Networks and Mobile Systems Lab at the University of Washington's, Paul G. Allen School of Computer Science and Engineering. His research involves work in wireless computing, battery free computing, mobile health, and human computer interaction.

He's the co-founder of multiple startups in the field of life sciences and mobile computing. His work has been recognized across the world by way of numerous Best Paper Awards and a National Science Foundation Career Award. He was featured in the Forbes 30 Under 30 All Star Alumni list for making waves in the world of energy. And the MIT Tech Review's, 35 Innovators Under 35 list. He's also the winner of the 2020 ACM Grace Murray Hopper Award. Shyam, welcome to ACM Bytecast.

Shyam Gollakota: Thank you, Rashmi. It's my pleasure to be here.

Rashmi Mohan: It's wonderful. Shyam, I'd like to lead with a question that I ask all of my guests. If you could please introduce yourself and talk about what you currently do. As well as talk to us about what drew you into this field of work.

Shyam Gollakota: Yeah, definitely. So, as Rashmi said, I'm a professor at the Paul G. Allen School of Computer Science and Engineering at the University Of Washington. And my group works on mobile systems broadly and ubiquitous computing.

So when I grew up in India until the age of 16, I did not really know even how to type on a keyboard. I used to use a single finger to keep typing. I did not know why people got a PhD, or even the name of the major universities in the US. If you think about it, the internet and more recently, mobile phones have kind of transformed and democratized access to information and knowledge. So a kid growing up in a village in India or in a country in Africa has as much access to information as they could growing up in the United States.

So it's not just the internet and mobile phones. We are also thinking about things like wearables, internet of things, and brain mission interfaces. What's really exciting about the research in this broad field of mobile systems and ubiquitous computing, is that it's now geared towards addressing some of the most important societal problems, including healthcare, understanding biology, climate change, and even things like low power wireless robotics.

It's a truly exciting field to be in because you can not only build systems, almost like an artist, but you can have enormous impact on millions of lives. And also can envision what these futuristic devices and networks are going to look like five to 10 years down the line.

Rashmi Mohan: That's amazing. I have never heard anybody describe the field of computer science and art sort of in that same breath. What made you choose CS in the first place, Shyam? I mean, obviously across the world, technology is something that is extremely attractive from the perspective of being able to solve problems, as well as in terms of just career prospects. What was it for you?

Shyam Gollakota: When I was choosing between majors, I did not want to do computer science because the primary thing people think of the computer science as is programming. You're just programming, sitting in a cubicle and programming. That's great. People are doing phenomenally exciting things with just programming, but I was drawn towards more impactful things, which are where you could interact with people.

So I was drawn towards health. I was drawn towards actually making things, building things where you can build things with your own bare hands. But one of the things which I learned at that point from my family members and other people, is that computer science is actually pretty broad. It's not just about learning Java or C++, but it's almost like a toolkit to have impact on multiple disciplines on the world.

And I'm really glad that I learned that a long time ago, because if you see it what's happening right now, computer science is in every aspect of society, be it healthcare, be it finance, be it almost every aspect of society has computing embedded in it. So that's great that we are all in the field, which is impacting millions and billions of people in positive, and sometimes negative ways as well.

Rashmi Mohan: I think that's an incredibly valuable point that you make, right? The application of computer science itself in across the world. I think it's almost become as simple math or basic language. It's one of those things, analyzing data to being able to look at it and possibly make use of it, using technology to sort of further your area of expertise that you're in, has become, I guess, second nature to most people.

It's also one of those very welcoming fields, I feel. It doesn't matter what you've studied. To be able to sort of get into computing, to be able, even if even to do some basic programming or to build systems, is something that welcomes people. In some ways I find that to be very encouraging.

Shyam Gollakota: Yeah. I completely agree with you. I think when I started in my undergrad, I did not know how to type. The bar is low in terms of learning languages and learning the tools of logic and computing. The bar is lower than other disciplines, which I think is really a part of computing.

Rashmi Mohan: Got it. Yeah. I agree. What was your journey like from the broad sort of computer science education that one gets in college to sort of narrowing it down to the areas that you actually worked on in your PhD? And beyond in the areas that you're continuing to work on now?

Shyam Gollakota: In my PhD, I worked on wireless networks, improving the performance and security of wireless networks. It was a pretty interdisciplinary domain because we had to work across computer science, electrical engineering. Learn about, I did not know what an antenna was at that point. So we had to learn a lot about all those things because my undergrad was in computer science.

But when I moved to UDub, which where I'm a faculty at, I was actually more interested in the space of mobile systems and ubiquitous computing. There was a whole center here at that point, which is led by the late Professor [inaudible 00:06:42], which was across UDub and Intel. It was a ubiquitous center, a ubiquitous computing center. The future vision of embedding tiny, cheap devices into everyday billions of everyday objects, was incredibly exciting and it was very futuristic and I wanted to be part of that future.

Rashmi Mohan: Oh, that's great. I mean, sounds like a great opportunity. And for you to sort of be able to take that leap and move into that space. One question I did have though, is one of your most prolific contributions is your work around the ambient back scatter and the ability to use ambient energy into power devices. I was wondering if you could maybe dive into that a little bit and talk about that work.

Shyam Gollakota: This is actually a pretty longstanding vision in the field of ubiquitous computing, which is embedding cheap connectivity into lots and lots of everyday objects. And we're in fact, seeing the first steps of it today in today's internet of thing devices, or IOD which we all call it in the tech community.

The challenge is that as these IOD devices become smaller and more numerous, powering them is going to be pretty challenging. Batteries add weight, they add cost, and they require recharging and replacement, which can be pretty impractical if you're going to be deploying 100s of these devices at a large scale. This is a pretty big problem, which is designing and powering these devices using batteries or recharging them manually. Becomes a pretty big problem if you were talking about a large scale deployment.

Another problem from a networking perspective, is that the act of generating a radio signal, which is required for communication, is a very power expensive operation. In fact, the biggest power consuming component in these IOD devices is typically a radio. What back scatter sees is instead of generating your own radio signals to communicate, we can have devices, in fact, battery free devices, talk to each other by just reflecting signals in the environment. Like TV signals, radio signals, wifi signals.

Or even you can put your own custom signals into the environment and all these battery free devices can communicate with each other by leveraging these ambient signals in the environment. And because these signals are kind of ubiquitous on most of these signals, we can reflect them off and enable battery free devices at a very low power.

And the intuition is kind of similar to using mirrors to communicate by reflecting sunlight. Back in the day, people used to have mirrors. They used to move them slightly. And depending on how the sunlight used to change, you could communicate at long distances. We're doing a very similar thing using radio signals. And because we're not generating signals of our own, we can communicate at audios of magnitude two to three times, 100 to 1000 times better, lower power than your typical radios.

And that's kind of exciting because when the communication cost comes down, the networking cost comes down to being completely negligible. You can start designing battery free devices that you can harvest from solar power, from radio signals, from all kinds of different sources. And in fact, over the last decade, what we have seen is that when we introduce this concept of back scatter and ambient back scatter, we demonstrated communication ranges of around, or foot are pretty short ranges.

But since then we and other people across the world, in fact, you need lots of people to work on this domain. What we have shown is that we can get ranges of up to 100 meters. And we can also achieve 10s of megabit per second speeds when you're close by. And this has been one of the big shifts in how we think about low power back scatter, where we can now think of it as a general purpose communication mechanism that is not just limited to RFID. But you can use it now for sending all kinds of data from temperature, sensors, cameras, microphones, and I think even ARVR headsets, where power is a pretty big issue.

It's also found very niche applications in implanted devices, like for example, brain mission interfaces. So it's a pretty exciting field because the vision of creating battery free computing, where you can get rid of batteries and enable connectivity, I think is going to be pretty transformative for the field of computing.

Rashmi Mohan: For sure. I mean, just the way you're describing it. It's certainly, I would say even for regularly people, I think the idea of actually being able to achieve battery free computing is mind blowing. And then the applications that you speak of, it might be a necessity, not just a convenience or a nice to have. So what kind of experiments have you run, Shyam, in order to be able to sort of evaluate the efficacy of this concept?

Shyam Gollakota: We have deployed multiple of these devices over the years. For example, we showed that we can use the TV tower signals from Seattle here to enable communication and harvest power from them. We have also demonstrated a battery free walkie talkie kind of a device, where you can talk into the device and someone else can actually, you can, the signal can go to a Skype call and you can make a Skype call to the other end of the world, for example, using this battery free phone.

We have shown that we can use this back scatter mechanism to transmit video data or camera data over pretty good distances. Basically we have demonstrated a variety of different applications over the years. One of the challenges with harvesting power is that the amount of power you can harvest is pretty small, right? You can't harvest huge amounts of power if you have a very tiny solar cell. Or if you're trying to harvest power from your radio signals or from your wifi signals and so on and so forth.

So the really exciting things from a computing perspective, is how do we design energy efficient computation and optimizations to be able to do these computations and sensing in an energy efficient manner? In a way in which even if you lose power, for example, if let's say that a cloud comes over and the amount of power you're harvesting is actually much lower, you should be able to continue the computation and be able to checkpoint and do all kinds of interesting things.

So it's really pushing computing to an extreme, where we used to talk about doing computing on the cloud and then smartphones and smart watches, where things are constrained computationally. Now we are talking about doing computing and communication on a completely battery free device where the amount of energy you can harvest is not reliable. So you need the amount, the kind of mechanisms you need to design are completely different. And that opens up a lot of opportunities to do very exciting things.

Rashmi Mohan: For sure. Yeah. And also, I mean, I'm wondering, you were just talking about Seattle, but geographically also, I mean, I'm guessing solar energy is one of the primary sources. You might have a very different sort of outcome based on where you run these experiments.

Shyam Gollakota: Exactly. So we had to deploy a variety of different sensors in a variety of different environments. In fact, Seattle is a great place to run because it's cloudy most of the time over here. So if we can get it to work here in the winter, it's probably going to be a little bit more reliable in other parts of the world.

Rashmi Mohan: For sure. Yeah. I also read your latest research, Shyam, around wireless sensing by battery free devices, but you were talking about wind dispersal. I was wondering, could you talk to us a little bit more about that?

Shyam Gollakota: I'm really excited about this work, which just came out last month in March. The problem we are considering is how do we deploy? Let's say we created these battery free sensors, and we want to deploy 100s of them in different environments. Let's say for farming. Or for example, during a forest fire, how do you actually go deploy them? If you have a human go there and deploy them, it's going be pretty expensive.

So wanted to ask the question, which is how do we deploy 1000s of these sensors across a large area in a completely automated fashion? So the goal we had was to design wireless sensors that can be dispersed and carried around with the wind. So if you have such kind of a passively dispersed systems, you can enable and disperse large scale sensor networks across a variety of different applications. From digital farms, forest, glaciers, and hard to reach radios.

And if you can actually look at nature, nature has done this in a phenomenal manner because of evolution. Plants have evolved mechanisms to disperse their seeds using wind. A very complete example is the very simple dandelion seed, which you can just see around in the spring. They can travel as far as a kilometer in dry, windy, and warm conditions.

So the question we ask in this work is can we create and design computers and sensors that can be dispersed in the wind, similar to dandelion seeds? This would be incredible, but achieving this is also challenging for multiple reasons. First, many of these seeds, like the dandelion seeds, are pretty small and lightweight.

And if you want to do something like this, your sensors would require significant miniaturization of all the components, including the sensor itself, the interfaces, the power, the computing platform, communication power source. You can't really use a battery because that adds a lot of weight. And finally, the dandelion seeds themselves have a very interesting structure, which allows them to stay in the wind for a long time.

And more importantly, as they fall down, they always fall down in upright position with the seed facing down. So inspired by what's happening in nature in particular dandelion seeds, we designed a millimeter scale, battery free computing devices that use completely programmable microcontrollers, which you or I, or any computer engineer can program and actually create these devices now.

They only weight about 15 milligrams, 1-5 milligrams. They come completely integrated with communication and get ranges of up to 50 to 100 meters. And they're harvesting power using solar, even in pretty cloudy conditions. So we also, by taking inspiration from the dandelion seeds, we created a thin frame drag efficient, drag enhancing 3D porous structure, which you can computationally add to the shape of it, to change how far away these sensors can actually travel.

So when we deploy these outside and we try to release them from a drone, what we could see is that these sensors can travel for up to 100 meters of distance, even in slight breeze. And you can get even larger dispersal if you are using much windier conditions.

This is actually pretty exciting because this is part of what I think is a new direction, which we are calling the internet of biological and bio-inspired things. And I think it's going to be a major part of research in computing, which is basically designing bio-inspired and bio integrated approaches to design programmable and millimeter scale wireless systems and sensor networks.

If you look at biology, biology has a lot to teach us because many of the natural functions, including intelligence today, are orders of magnitude more energy efficient than what electronics can do. So over the next decade, I think this research domain and sensor systems in wireless has the potential for breakthroughs. As well as impact on understanding what's happening in the natural world itself.

Rashmi Mohan: That's amazingly, I mean, it's groundbreaking work and at least in my mind, as I'm summarizing. So two main problems that you're trying to solve. One is how do you harness the right amount of energy needed in order to keep these devices battery free? And two is how do you actually find a way to disperse these sensors in the areas that you need to, in the hard to get to areas, so that you can collect that data?

But that actually leads me to the question of collecting this data, Shyam. So if you actually are sending these devices out into the world. When you're talking about fires, et cetera, what do you need to do in order to collect the information that these sensors are picking up? I mean, do you actually have to go back and collect these devices at some point?

Shyam Gollakota: So these are completely, they have wireless connectivity to them, which means that they can, using the previous thing I talked about, which is back scatter, they can transmit information up to a distance of 50 to 100 meters. Which means that a drone, which is flying by can just collect the information from the forest. You can just be above the canopy of the trees and you can collect the information for example. So that's one aspect.

As in the second aspect you're probably hinting at is about sustainability, which is are you just creating lots of trash in the environment by deploying these sensors? Which we don't want, right?

Rashmi Mohan: Sure.

Shyam Gollakota: And that actually brings to an exciting direction of research, which I think is going to be a part of mobile and sensor systems. Which is creating biodegradable computing platforms, where the platform itself can be pretty much biodegradable. I think the fact that we don't have batteries helps, because when you are just using solar cells, which is mostly Silicon, it can integrate better than using a battery, which has chemicals.

And the structure itself, the dandelion seed structure itself, which I mentioned, can be made of biodegradable materials itself. The only thing which would be left at that point is a computing platform, which is a micro controller. There is ongoing work people are doing. And I think that's going be an exciting part of research on creating computing platforms which are biodegradable. So that we don't have a huge amount of environmental waste.

It's not just for sensor systems. You can see that e-waste is a pretty big problem. Even if you're thinking about something like block chains. The sorts of storage cards which are getting thrown away because of the kind of computation they're running. So I think not just in sensor system, but more broadly, there is going to be a huge amount of work in computing on addressing e-waste, I think.

Rashmi Mohan: Got it. Yeah. No, thank you for addressing that. It's definitely something that crossed my mind. I was like, okay, how do we actually deal with these devices that are out there in nature? That definitely sounds like an area of research that would be very, very exciting for anyone new who wants to get into it.

I know that you've done work with also studying how insects move about, right? Is that also related to the same goal, Shyam, which is in really figuring out how do you disperse these sensors?

Shyam Gollakota: The whole field, at least in my group, started with what we call the living IOD system, which we built back in 2018. Where the idea was we were looking around at drones. We were like, okay, so if you're trying to get mobility to these sensors, how do you get them? The most obvious thing is to use a drone.

The problem is if you look at a drone, the drones are not energy efficient. They're mechanical components. They're not really electronic components. They don't really follow the most. And what that means, if you're using an actual drone, it typically dies off in 20 to 30 minutes, if you're really good. And if you're going to really small drones, they actually end up having a lifetime of only maybe five to 10 minutes. So it's very challenging to get mobility in an energy efficient manner.

So the question we were asking is what can biology do really well? If you look at something like a bee, or an insect, they move pretty energy efficiently. And in fact they can feed themselves. You don't need to recharge their batteries. They can move really, really well.

So what we designed is what we call the internet of living things. What we did is we created these sensors, which are so small that they can piggy back off insects like bees. And as the bee is flying around, let's say you put like 100s of these sensors on these bees. As the bee is flying around, or these insects are flying around, they're going to collect information as well as the location of whatever they're sensing.

At the end of the day, they're going to come back and you can collect all the information. And then you have a map, a temporal map of what the sensor information is. And how the insects themselves are moving in space, which would be providing a mobile platform for internet of thing devices.

The other aspect of this, which we are also explored, and we had quite a bit of impact in the space, is using that to understand insect behavior. Clearly if you put sensors on piggyback behind the insect, you can use that to basically understand where the insect is going.

So if you remember back in 2020, in the middle of everything else we were going on, we also had what people were sensationalizing as those killer hornets, murder hornets. And they were actually here in Washington State. So we worked closely with Washington Department of Agriculture to design wireless sensors, which can piggy back on these murder hornets, which were captured.

And the biggest challenge, which people did not know is where's the nest of these murder hornets? Because once they establish a nest, it's really hard to, and if you don't destroy the nest, it's going to be hard to eliminate them from the environment. So back in September of 2020, one of my students from Iowa worked really closely with the Washington Department of Agriculture. And lots of tries and retries, uses kind of the wireless technology to track the location of the nest. And they could destroy the location, which is great because now they have tools to do this repeatedly.

Rashmi Mohan: ACM Bytecast is available on Apple podcasts, Google podcast, Podbean, Spotify, Stitcher, and TuneIn. If you're enjoying this episode, please subscribe and leave us a review on your favorite platform.

That's amazing and I'm now starting to see also what you were talking about. It is not just wanting to do computing for the sake of computing, but really trying to solve problems that the world is facing today. And then the things that really matter to us in a day to day sort of way.

So I have to pivot to the other area of interest that you have, Shyam, which is around healthcare. You have a very strong interest in healthcare and you seem to be working on many solutions in that space. So what drove that?

Shyam Gollakota: Yeah. So at the beginning, when I was talking about how mobile systems can be used in some of the biggest societal challenges like healthcare, I think one of the big problems in healthcare is the cost of some of the medical device hardware. I can give you an example of a project, which is ongoing.

Every newborn baby in the United States gets what's called an auto acoustic emission testing, which is effectively a hearing screening. So if you're a newborn baby born in the United States, or much of Europe, for example, you have to get a hearing test, for example, it's auto acoustic emission testing.

And this is actually pretty useful because if you can detect hearing loss early in a baby's life, it can transform their neurological development because you can intervene. This is great, but the actual device itself costs as much as 5000 to $10,000.

So this might work in the rich parts of the United States, but when you're working in, for example, in Kenya, we were shocked to learn that the whole country of Kenya has a handful of auto acoustic emission testing devices. This is pretty shocking and sad because we're talking about babies here. And if we can intervene and know that there's a hearing loss, do this test, it can really help millions of kids.

So the good news, however, is that almost everyone across the world has a smartphone. Or even earphones, earphones are still super cheap. And the sensors in these devices are kind of state of the art compared to what medical devices have. So if you can repurpose the sensors on this devices using the software, then we can transform these devices into medical diagnostic tools. And I think that can be transformative to lots of lives.

Rashmi Mohan: For sure. I mean, that does sound almost like a miracle. So I'm wondering if you could talk a little bit more about some of the applications that you've actually been able to use these day to day devices that we use in our world.

Shyam Gollakota: So one of the first projects which actually got me interested in using mobile devices, is on using them for sleep apnea and sleep tracking. When I started at UDub, the question which you're asking is can we use wireless signals like wifi, which is ubiquitous, or acoustics to track someone's breathing or heart rate in a completely contactless manner?

And that's exactly what we showed here, which is that you can use your smartphone and we can transform these smartphones, and now smart speakers, into completely contactless, active sonar systems. So at a high level, we transmit inaudible sound from the speaker on your smartphone. And these sound signals will get reflected off the human body. And the reflections are going to arrive back at the microphone themselves.

When the person is breathing, the minute motion is going to change the reflections and you can design algorithms to extract the breathing motion from these specific devices. And what's exciting about using these kind of microphones and speakers, is that almost all the devices today, including smartphones, laptops, smart speakers, Alexa, for example, or earbuds, have these sensors.

So we can transform just in software, all these devices into contactless, physiological sensors, kind of similar to a Star Trek tricorder. And in fact, build a whole system where we can contactless track breathing. And this is actually a pretty interesting field because you can't just independently work by yourself. You have to go and work with physicians, understand what the real problems are.

And you need students who are willing to put that into disciplinary effort to understand the problems. So we went and deployed this at Harborview Medical Center with patients who were sleeping. We did more than 300 hours of tracking over here when we were deploying it. And we showed that we can detect sleep apnea and also do sleep tracking in a contactless manner.

This technology is actually already being used today to track more than 30 million hours of sleep in the world as of 2021. And we also recently adopted this technology to detect things like opioid overdoses. We've also generalized this technology to smart speakers, such as Amazon Alexa device, to track the breathing of infants, or track, detect cardiac arrest, or monitor heart arrhythmias.

And this really requires the best of what computing can offer, because you need to design machine learning algorithms that can detect and track minute motions on the human body caused by heartbeats, so that we can figure out if someone has irregular heart rhythm. And the exciting thing is that we're already seeing this thing, after we started this out almost 10 years back, now we are starting to see smart speaker companies publicly. They have products now where they're slowly adopting these wireless sensing solutions for health and motion tracking as well.

Rashmi Mohan: Wow. That sounds incredible. I have to ask, Shyam, though, is it something that is better suited at this point for people who have an active issue and are willing to engage with this sort of monitoring?

And so to explain my question a little deeper, if I have a sleep apnea problem. I go to a doctor, they diagnose it and then say, "Hey, you know what? We have this app that you can use. It'll give us a stronger sense of data. We'll be able to really detect if this is a challenge for you. Or we'll be able to detect more information that'll help us treat you better."

That's one way of adopting this, right? Or would this just be as something that a regularly healthy person would then say, "Hey, you know what, I'm just going to have this monitoring me on a regular basis. So that if there is something that is sort of latent, it'll come to the fore."

Shyam Gollakota: I think that in the medical domain, that is, I feel if you talk to physicians, there is a bit of a hesitation when people make ... There's people who work on general health and wellbeing, and people who work on medical conditions, right?

So for example, if you take a wearable device, activity monitoring device, and you take it to your physician, they'd be like, "What do I do with this?" So people have to be a little bit careful, I think in terms of the future of health and medicine on these smart devices.

In terms of sleep apnea, one of the big challenges, actually, you just can't go to the doctor and the doctor just says, "You have sleep apnea." The way sleep apnea is diagnosed today, is you basically sleep in a sleep lab, for example. Or you're wearing a bunch of different sensors on your body. Can range from 10 to 30 sensors on your body over the whole night.

And you're being monitored for, monitoring all kinds of things like you're breathing, your motion and so on and so forth. And then they basically figure out if you have sleep apnea. It's a pretty expensive process, and it's not really convenient because you're wearing all kinds of sensors and wires and so on, on your body.

So I think of these solutions, which you're talking about as alternatives, which are basically bringing and democratizing the ability to understand if you have a condition like sleep apnea, to lots of people without having to spend 1000s of dollars in your insurance money. Or if you don't have insurance, that's even more challenging to understand if you have sleep apnea.

But to the broader question of health, you can also imagine that people can use this for sleep tracking. Because if you're sleeping, people always want to know. Sleep is a very important thing and you want to know how well you're sleeping. So a lot of these solutions, if properly validated, can help understand how you're sleeping.

Rashmi Mohan: Got it. Although I have to ask then, is any of these devices that's actually tracking? I know you mentioned that the devices themselves will send out inaudible sounds that will then get reflected. The question really is there anything else that's being listened to? There's always a question of data privacy, right?

And can have a very different meaning to every party in this equation. As a patient, I have a certain view of data privacy. As a healthcare provider, there may be a certain view. As a researcher, you might have a different one. So I'm wondering what is your take on all of this? How should we be interpreting this?

Shyam Gollakota: I think privacy is a pretty big deal. And in particular when you're talking about healthcare. And there are very specific guidelines, HIPAA guidelines, in terms of how you are managing the data. So anything that you're making a healthcare claim, which is allowed by FDA, you have to maintain all the data privacy compliance.

But it's just not about data in my opinion, actually. I think that even the choice of technology you're going to apply for a specific health condition, can have a significant impact. For example, in the first two years, when I was at UDub, we were publishing a bunch of works. One of the earlier works on using wifi for doing gesture recognition and imaging and sensing through walls, for example.

It's pretty exciting, but the problem is that if your mobile device is going to point at your neighbor's bedroom and I can figure out what their breathing is, I don't think anyone is going to be happy about it. So we shifted to working on short range solutions like sonar, which cannot really go through walls. And you have to turn it on to basically do it because it's actually actively generating signals. It's not just listening to you, you're actively generating inaudible signals to be able to get your permission, to basically track everything.

And it's also interesting that that's a way the industry is going as well. They are all looking at short range, wireless sensing technologies, which can't really go through walls and so on. So I think that when people work on these kind of applications, we need to be aware of the nexus between the choice of the technology, privacy, and application itself. And I think paying attention to it would be important in terms of what is a good fit for, in terms of technology and application.

Rashmi Mohan: Yeah, for sure. Right. And I also heard one of your older talks around this topic. When you also talk about one of the main reasons for being able to actually innovate in this area is to be able to, like you said, democratize medical attention and save time. And to areas that may not otherwise have the kind of resources that maybe the Western world does.

But in the Western world itself, how do you prevent armchair medical analysis? When all of this data is now available to me, am I going to start getting paranoid about, oh my gosh, my heart rate is off by so much. Or how do we share this data in a way that is actually useful?

Shyam Gollakota: I think that's where the next wave of mobile health is going to be. Where it's not just going to be about wellness. It's actually going to be about medical diagnosis. And when you're making a medical diagnosis, FDA comes into the picture. And they are, FDA thankfully has a variety of different procedures to follow in terms of how you display the data, who is prescribing these tests.

I think that's where the future of mobile health really is. It's not just about ... I think wellness is going to be a significant part of mobile health as well. But I think what's going to be transformational is when you are trying to do medical diagnostics using these devices, you have to go through FDA. You can't just get a medical result to someone without getting through FDA because that's not how the thing works here. And once FDA gets involved, it basically becomes similar to existing medical devices as well.

The big advantage though is that FDA has itself come out with rules for software as a medical device. And that's actually to recognizing the fact that when people can design software and existing platforms, FDA is not going to require you to basically go test every single hardware component on your smartphone. But it's going to be figuring out is your software done in a specific way? Is it properly tested?

And it's basically software testing at that point. And having a pretty high bar in terms of how your software is done and evaluated. Which is kind of a much easier bar to cross than designing custom hardware, which each and every component has to go through FDA's rigorous requirements.

Rashmi Mohan: Yeah, no, that's extremely reassuring. And great to hear about how the FDA also is transforming to meet the needs of the industry and how the research is progressing. I know you recently received FDA clearance for your sonar based respiratory device monitoring.

The other area that I definitely wanted to talk about, Shyam, is looking at your LinkedIn profile, it tells me that you're a serial entrepreneur. You have three startups already. How do you do justice to all of these roles? And what drove that interest from being deeply embedded in research and academia to want to start a company?

Shyam Gollakota: So when we are creating these kind of a futuristic technologies, that industry at that point might not be exploring, there are two paths to adoption. One path is that the industry becomes aware of it, and they start exploring it, and ends up being a variant of what you're working on. A few years down the line, it has actually happened as well.

But this requires a lot things to align. And quite honestly, a lot of luck is involved as well. To make sure that there are enough people in specific company that you're interested in and knowing they know enough about the work to basically want to invest resources into it.

The second path is what you're proposing is pretty drastic for the industry, in terms of what you're seeing, then you will have to do a startup to demonstrate the product and convince the industry to adopt your solutions. And that's much harder than writing a paper and requires a completely different skillset. Like who's the most willing customer?

Because people might show excitement, but the real thing is when people are willing to put money into the thing. And they're going to put their own money into the thing, that's when you know that they are real, willing customers. So being in both these helps actually. Really helps in terms of learning new skills.

But I also think that being a researcher is kind of liberating because it's almost like, as I was mentioning earlier, it's almost like being a painter or an artist. And you can kind of paint the future of technologies by prototyping things in the lab. So it's kind of like you can be in the lab, you can paint the future, and things will happen. Now, if you throw out five ideas, couple of them, people are going to latch onto them.

But there's a lot more work to be done from taking this painting and making it into a product that millions of people are willing to buy and use as well. So I think these are two different worlds. And I think many of us are trying to basically navigate both these worlds and understand and learn what's happening in both of these worlds.

Rashmi Mohan: So it's a great way to actually make progress and apply the research that you're bringing in. To see how do we actually make these real products that can scale and be valuable to many people around the world?

Interestingly enough, the teams that you build are multidisciplinary. Is that just because of the nature of the problems that you're trying to solve? Or is that a conscious effort that you make to actually bring in these diverse teams because you feel like that will actually provide a better outcome?

Shyam Gollakota: Actually, that's a great question because a lot of things are interesting at the intersection of pretty disciplines. It requires people to learn how different fields think. For example, I need to know what's important in the field of medicine.

And now after so many years of working on it, maybe I understand a little bit, but there's so much more, and there's so many disciplines. There's so many parts of your human body and each part is a completely different discipline within medicine. So we need to understand the language they speak, what they care about, and the nuances of their work.

So it's pretty challenging actually, to work in this domain. It also requires a lot of vulnerability because you've got to acknowledge that you don't know a lot of what's happening. And so you need to be able to ask questions like how does it work? And I just say, I don't know, let's figure it out. Questions which might be kind of naive for someone who is working in a specific area for years. And they have strong expertise and authority in a specific area.

It's kind of important because it's almost like you're constantly learning new things, which is why you can get out of the bed and be like, I'm actually just learning about new things every day. It also requires grad students who are kind of willing to learn along with the advisor about a new direction. And more importantly, take risks on a completely new research direction or a new topic, which is not what everyone else is working on.

So it requires really a fusion of a unique set of grad students and collaborators. Unique collaborators who are willing to actually put in the time because a lot of the physicians are pretty busy seeing patients. So a lot of things have to come together to basically make impact in these kind of interdisciplinary domains, I think.

Rashmi Mohan: That sounds like a very humbling experience and yet an invigorating one, right? Because of the kind of learning and the need to acknowledge that you don't know what you don't know. And that's kind of where I think the greatest discoveries happen.

This has been amazing, Shyam. For our final byte, I would love to understand from you, what are you most excited about in the field of say healthcare tech? Or wireless computing? Or the work that you do over the next say five years?

Shyam Gollakota: I think that just looking in the last decade, we have seen a completely different set of technologies, mobile systems, which have become quite common. Like mobile phones, smart speakers were a thing which has introduced in the last decade. Wireless earbuds were introduced in the last decade.

So you can see that it's actually pretty phenomenal in terms of the kind of devices we're talking about. We can start talking about things which can start reading your brain. And all these kind of devices will have lots of application in things like health, which can be transformed into accessible medical diagnostic tools, for example. And we can have impact on millions of people's lives.

I think that's a powerful domain to be working in. But if you couple that with futuristic looking things like tiny battery free sensors and computers that are integrated with biology and living organisms. Not just basically piggyback, but for example, let's say if we can design hybrid systems, which take the best of both. What biology has to offer and what computing has offer.

For example, if you think about something like smell, biological systems can smell some incredible things. Dogs can smell if you are having a low blood sugar. Some of these insects have much better smelling capabilities than the best human made sensors out there.

So if you can actually integrate them and create hybrid systems, we can really transform how we think about computers. Not just as electronic based systems, but something which is a hybridized system, which is basically a hybrid between biology and computing. So I think it's a great time really to be at the ground floor. And really it's kind of humbling to be there, to basically shape the direction of mobile systems, and in general, ubiquitous computing, I think.

Rashmi Mohan: This has been an eyeopening conversation, Shyam. I can't wait to see the work that you do in the future. Thank you for taking the time to speak with us at ACM Bytecast.

Shyam Gollakota: Thank you so much.

Rashmi Mohan: ACM Bytecast is a production of the Association for Computing Machineries Practitioners Board. To learn more about ACM and its activities, visit ACM.org. For more information about this and other episodes, please visit our website at learning.ACM.O-R-G/B-Y-T-E-C-A-S-T. That's learning.ACM.org/Bytecast.