S1 EP37 - The History of Automotive Connectivity

Thursday, July 06, 2023 · 17:56

On this week's episode, Amir Bar-Niv, VP of Marketing, Automotive Business Unit, and Mark Davis, Senior Director of Solutions Marketing, describe the history of automotive connectivity and future trends in Automotive Ethernet. Take a deep dive into their conversation detailing the technology and protocols developed to advance automotive connectivity. In case you missed it, read the blog to learn more: https://bit.ly/3PBmpnA

Speakers

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Christopher Banuelos 00:04
Welcome to the Marvell essential technology podcast. I'm your host, Chris Banuelos. On today's episode, jump into a conversation with Amir Bar-Niv, VP of Marketing in the automotive business unit. And Mark Davis, Senior Director of Solutions Marketing discussing a past and future history of automotive connectivity. Take a deep dive into their conversation as they discuss some historical milestones and the technology used in vehicles, as well as how technology continues to evolve in tomorrow's next generation of automotive.

Mark Davis 00:41
This is Mark Davis, I'm the Senior Director of Solutions Marketing with responsibility for automotive and enterprise networking are two of our data infrastructure markets. And I'm here with my good friend Amir Bar-Niv.

Amir Bar-Niv 00:54
Hi everyone. My name is Amir Bar-Niv. I'm the Vice President of Marketing for the automotive B.U. in Marvell and happy to be here again on this very important podcast on the topic of the past and future history of automotive connectivity.

Mark Davis 01:10
Amir, let's set the stage here for our listeners. Why should anyone care about the history of automotive connectivity? I mean, we want to move forward, not backwards, right?

Amir Bar-Niv 01:23
Well, you're right, yeah. But the short answer is that the history of automotive connectivity is in many ways still, today's automotive connectivity. There are two reasons for that. First is that the end to end Ethernet network that are so critical to enabling the software defined vehicle have not made it into mass production yet, so it is set to change beginning in the middle of the decade. So for the most part, the cars on the road today use a variety of connectivity standards and protocols. Second, even if in the case of end to end Ethernet networks, the Ethernet does not make it all the way to the edge. It makes it to the hands, you might say, but not to the fingers. A perfect example is the cameras that are now commonplace in most vehicles. Those cameras connect to processors over point to point protocols links using proprietary networks protocols, such as low voltage differential signaling, also called LVDS, that have been introduced by companies like Maxim, their technology called GMSL or TI's FPD Link. And of course, the natural question is why? To understand why, it helps to understand how and why different protocols developed in the first place. So Mark, you know, something about this. How did it all start?

Mark Davis 02:36
Yeah, so until the mid 80s, there was really no network to speak of in the car. So all the electronic components of a car were hardwired to each other as required. But over time, there were new design requirements, new features in the vehicles that made that old approach untenable. So with the help of clever engineers at Robert Bosch, they designed what's known as a serial bus system. And that serial bus system would enable electronic control units, also known as ECUs and subsystems all to communicate with one another. And that was the big advance that allowed for the introduction of new features via software and overtime, then this became the Controller Area Network, or CAN, our listeners have probably heard of that. And the CAN protocol initially operated at a one megabit per second. It was first deployed in the 1991, Mercedes Benz W140 S-class, and it became one of the five protocols that are used in onboard diagnostics, or OBD, II vehicle diagnostic standard. And that's been mandatory for all cars, all light trucks sold in the US since '96.

Amir Bar-Niv 03:52
So you said five protocols. What's wrong with CAN, such as all these other were required?

Mark Davis 03:58
Well, I guess you could say, like so many things in life, it comes down to cost. So CAN is super capable, super robust. But frankly, that level of performance wasn't really required for all the minor electronics in the vehicle. So think about power windows, electric sunroofs, wipers, turn signals in the Link.

Amir Bar-Niv 04:19
So let me guess manufacturers started doing their own thing?

Mark Davis 04:23
Yeah, that's exactly right. And naturally, that got a bit chaotic. So a new serial protocol was born LIN or a local interconnect network. And that was under the auspices of the manufacturer led LIN Consortium. So the LIN bus became the alternative to the CAN bus whenever the application required low cost or had very few requirements and for which bandwidth really wasn't important. So as you can imagine, LIN is typically used for subsystems that aren't important to vehicle performance, not important to safety and it remains in common use today, like you were saying at the outset for what are known as mechatronics. Like that's things like seat motors, mirrors, door locks. So the introduction of LIN, you have the beginning of the so called hierarchical in-car network now, including CAN and LIN.

Amir Bar-Niv 05:19
Okay, I see where this is going. It's not much of a hierarchy with only two protocols, a larger hierarchy is obviously needed.

Mark Davis 05:26

Yeah, that's right. But there is a good reason for a larger hierarchy. And the reason, believe it or not, you could say came down to music. So in the late 90s, CDs, of course, were everywhere and on top of that, you had interest in navigation. That was a hot item after Garmin first introduced their first automotive product in '97. But at the time, there was no multimedia networking standard and that really put a damper on the tunes you might say. Not for long, though, because a group called the MOST Coperation developed a new protocol known as MOST, which stands for media oriented systems transport, and initially, that supported 15 uncompressed stereo audio channels, and then later over time, was able to transmit all forms of infotainment throughout the car.

Amir Bar-Niv 06:18

Okay, that's interesting. So now we have a three tier hierarchy, right, CAN, LIN, and MOST. Sounds like a lot of cabling in cars, very big cable harness, do any of those protocols address what we know as drive-by-wire?

Mark Davis 06:32

Yeah, that's a good point. So I guess we need another protocol here. And it turns out, we have one that was also developed for exactly that purpose, called FlexRay. So FlexRay grew out of this growing interest in the early 2000s in X-by-wire, as it's called applications in which functions would be purely electrical, no mechanical fallback mechanism at all. Kind of sounds scary to say that out loud, but it works. In any case, FlexRay was first used in the BMW E70 X5. It carved out a space at the top of the cost hierarchy, you could say, for high performance powertrain and safety applications, like drive by wire active suspension, adaptive cruise control, that sort of thing.

Amir Bar-Niv 07:24

Okay, so I guess we are done, right? We've got four different protocols, each optimized for a different set of applications, different features and bandwidth requirements. Obviously, I'm kidding, because we know where this is going. This is all led us to how we wound up with automotive Ethernet.

Mark Davis 07:43

Yeah, exactly. So in 2004, BMW decided that they would introduce for the 2008 model year, a central gateway ECU, again, electronic control unit, and that would serve as the single diagnostic and programming interface to the outside world. So the way it was gonna work as an external test device was to flash via the OBD connector, each and every one of dozens of ECUs with the latest software, right. A lot easier than flashing them one by one. So each update meant flashing a one gigabyte file. Childsplay, right? Not so much. Using, at the time, the preferred high speed CAN protocol that process would take, get this, 16 hours. So you can imagine the wait time at the dealership much less on the factory floor. It just wasn't going to work. A new approach was needed and they were considering everything. You know, most FlexRay, USB, Firewire, you name it, whatever it would take to get that 16 hours down to something manageable. None of those as it turned out, could do the job. And the answer surprisingly, at the time turned out to be 100BASE-TX Ethernet. And the great news there was that off the shelf Ethernet was ready for use to handle that single ECU upgrade problem I just described. The issue of course, is that it wasn't ready for use when the vehicles running. So it needed modifications to accommodate electromagnetic emissions while still making use of the unshielded cables which of course are used throughout the vehicles in the past and today. So the open alliance is the organization that was formed to address this challenge. The result of all that was the first automotive Ethernet standard known as 100BASE-T1 and then it became I-EEE standard 802.3bw. So BMW then went on to introduce the first 100 megabit per second automotive Ethernet in 2014. So you mentioned the original date was 2008. But in 2014, 100 mbps automotive Ethernet became part of the surround view system In the BMW 7-series, and then quickly, it moved into the entertainment domain, where it displaced the MOST protocol that we talked about a second ago. Now at this point, Amir, as you know, I'm pretty much just describing your professional life story. So let me take it back to the beginning when you said Ethernet makes it to the hands, but not the fingers of the vehicle. So let's talk a little more about what's happened with cameras, which I think are the fingers in your analogy, right?

Amir Bar-Niv 10:27

Correct. Yeah, so as we look back on camera technology, it was a slow evolution that started accelerating only recently. Even though the first rear view camera was introduced in 1991 by Toyota that was in a single car. It took 11 years for the second one, which was in 2002. That was the Infiniti Q45. In both cases, these were CCD low-resolution cameras that could use low bandwidth connections. It was after that another decade before high def cameras made it into the rearview mirrors for blind spot monitoring. In this case, the data speed started at 700 megabits per second and quickly exceeded one gigabit per second and this was all based on uncompressed video transmission from the cameras. At that time, we are talking here on the mid 2010s, automotive Ethernet couldn't support the requisition data rate. Automotive was at that time, only 100 megabit per second. So as you might expect, yet another protocol was required one that I mentioned earlier, and there are several of them that are still used today in the car, what we call LVDS connectivity. We mentioned that typical examples by Maxim GLSL, and TI's FPD link that can support these multi gig speeds that are needed for the camera and display links. However, there are two major disadvantages for these protocols. One, they are proprietary, and two camera must be connected with rigid point to point connections.

Mark Davis 11:53

So Amir, given that 10 gigabit per second automotive Ethernet PHY products have already sampled in the market. Is it correct to say we're about, I don't know, two years away from being able to support uncompressed camera video with Ethernet?

Amir Bar-Niv 12:09

Yes, that's correct. We're looking at technology crossover point in roughly 2025, after which automotive Ethernet will be able to address any current or futures camera.

Mark Davis 12:20

But that would mean that the cameras would need to support Ethernet too, right?

Amir Bar-Niv 12:24

Oh, absolutely. And that's exactly what will happen. Since automotive Ethernet fies can now run at 2.5G, 5G, and 10G bit per second future cameras will be able to drive video, uncompressed video, from the camera module directly over Ethernet. The way to do it is using what we call Ethernet camera bridge. The camera bridge encapsulates camera video over Ethernet and instantly the camera module is part of the Ethernet based in vehicle network. Now the moment that this happened camera video can be easily shared between domains for example ADAS and infotainment in inherently scalable and flexible manner. And more than that Ethernet camera bridge the rest of the in vehicle network benefits from the mature robust nature of the Ethernet standard and can use many Ethernet based features for example, GPTP or security with MACsec and any other features that are already standard feature of the existing Ethernet network that are used worldwide in many other applications.

Mark Davis 13:25

Okay, so it sounds to me like the Ethernet camera Bridge is a no brainer, right? Maybe even a requirement if you're striving to build a software defined vehicle.

Amir Bar-Niv 13:35

That's right. Absolutely. There are many reasons you want to make cameras SDV-compliant to start with, they can easily be shared among domains. As we mentioned before, you don't need a dedicated camera for each of the domain, which is something you had to do with the point to point connectivity. In addition, the software and hardware can be easily modified independently and scaled all the way up to the camera and sensors. Specifically for the zonal architecture, with zonal switches, the camera Ethernet link is connected to a standard Ethernet port on the switch and can be routed on multiple paths for redundancy. And this all can enables basic capabilities of Ethernet like controllability, diagnostic and real time debugging of the camera links with standard Ethernet utilities used in the rest of the in vehicle network already. And this is really what the Ethernet camera bridge allows. A no brainer as you say.

Mark Davis 14:28
Okay, this all sounds great. But what about the cost of adding this Ethernet bridge capability to all the cameras in the vehicle which could, you know, could be 20 or more?

Amir Bar-Niv 14:39
Well, that's a great question. Car manufacturers are already adopting Ethernet for the backbone of the car, so this is a done deal. The transition to zonal architecture will unify the network while reducing the cost and weight of the cable harness and that's very important especially for electrical vehicles. That transition is started and is expected to accelerate. Most OEMs will be transitioning to zonal architecture by 2026. However, the cameras are still connected using point to point LVDS protocol and won't allow the cable harness cost reduction that Ethernet-based cameras will deliver. And that's why we do expect internet based cameras to quickly move into production in the late 2020s. In addition to this, what we should look at is the total cost of ownership not only the cost of the camera module, which including the saving of software modification, testing and qualification processes of the vehicle that is based on an end to end Ethernet architecture. And of course, we always need to learn from history over the 40 years history of Ethernet there were always other protocols that tried to replace it claiming to improve some network parameters and/or lowering the cost but they all failed mainly due to the Ethernet ecosystem and its collective brainpower that they could not overcome. Now automotive OEM believe that Ethernet end to end will eventually provide the lowest total cost of ownership for future vehicles.

Mark Davis 16:03
So Amir, if we look back over the history of in-vehicle connectivity, as we've been talking about, it's clear, there is a really good reason for the introduction of each of the protocols that I talked about earlier. And it's also clear to me that this approach created a hierarchy of connectivity that made it really impossible to have a truly software defined vehicle. Do you think it's fair to say that with an automotive Ethernet based in vehicle network and Ethernet camera bridge that every finger, to extend that analogy, can be part of the software defined architecture?

Amir Bar-Niv 16:41
Yes, but not only. Beyond cameras, there are displays which are also going to transition to Ethernet over time and enjoy all these benefits of Ethernet, the number of displays is going to dramatically increase in future vehicles. Some OEM are talking on anywhere between four to six displays per vehicle.

Mark Davis 17:00
All right, then, you know, I'm just gonna go ahead and unilaterally declare an end to the multiprotocol era of in vehicle networking, if everyone's okay with that. And I'd also like to tell our listeners who are interested in learning more about automotive Ethernet to pick up the seminal book on the topic, appropriately called Automotive Ethernet by Kirsten Matheus of the BMW Group. And finally, I'll simply point out that the switches, the PHYs, and the camera bridges within Marvell's Bright Lane automotive portfolio make possible the very end to end Ethernet architecture we've been talking about and that every software defined vehicle needs.

Christopher Banuelos 17:43
Thank you for listening to the Marvell Essential Technology Podcast. As always, please feel free to visit our website to learn more, and we'll see you on the next episode.