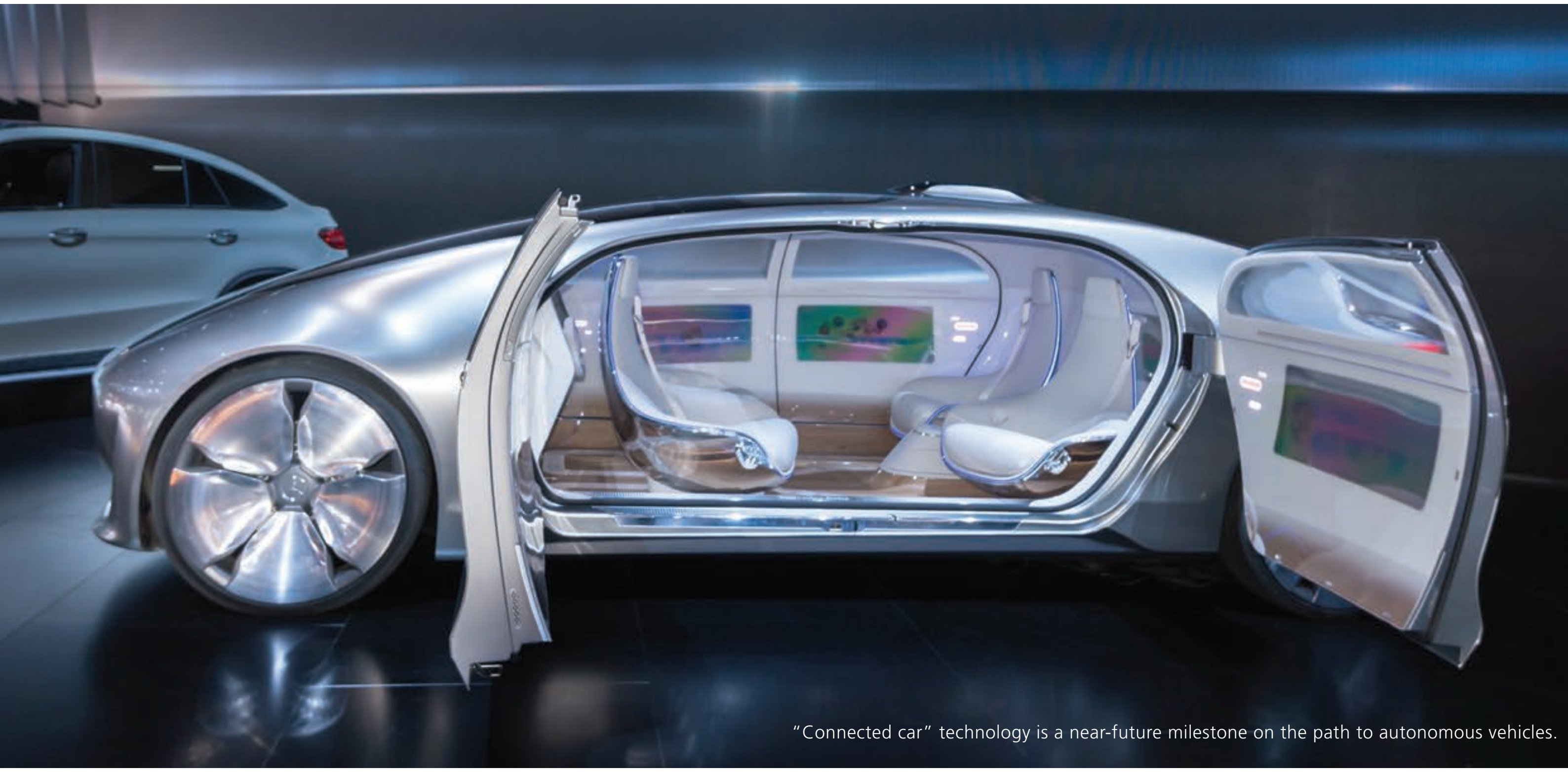
white paper

Wanted: Reliable PNT for Intelligent Transportation Systems

spectracom



"Connected car" technology is a near-future milestone on the path to autonomous vehicles.

For those of us who earn our livings advancing the state of technology, one incredibly bright and exciting spot is in the area of connected cars. While the autonomous "self-driving car" is the "marquee application" in automotive technology, a lot of the technologies required to commercially get to that point are already in place and others will find their markets soon. Long before we're all comfortable with our robotic chauffeurs, we'll be depending on our cars to give us incident and traffic alerts, pay for gas, diagnose their own electronic and mechanical issues, stream entertainment media, and above all, keep our families safe.

"Connected car" technology is actually the convergence of a broad spectrum of technical advancements in the fields of computing, wireless communications, deterministic networking and position, navigation and timing (PNT) technology. Each of these technologies have already undergone revolutionary advances in their own fields and continue to do so.

In each case, much of the change has been motivated not by what technologists foresaw, but on what public users demanded. Developers of early computers never thought they'd evolve into communications devices; later pundits saw their future as database handlers ("you can store all your recipes on it!"). Peer-to-peer networks designed for work-groups turned networks inside out when young people started using the technology to share music and video. In much the same way, the connected car will drive (and be driven by) advances in related technologies and new use cases discovered and demanded by the public. Any business that hopes to grow in this area must stay relevant. That will require collaborating with experts in the essential underlying technologies to fully realize the value of these user-centric applications.

Intelligent Transportation Systems

Many of us remember the first technology explosion in automotive electronics. In a relatively short period of time, we drivers who had been happy listening to music suddenly wanted to know where we were, how to get where we wanted to be and how to access thousands of different sources of information and entertainment. We wanted to know if the car was in good shape, if the tires needed air and whether it was time to schedule an oil change. Then we wanted help parking… first it was better visibility of the rear view, then sensors that knew where the obstructions were. Next we found out we could buy cars that parked themselves, so we demanded that too.

SAE Level	Name	Execution of Steering and Acceleration/ Deceleration	*Monitoring* of Driving Environment	Fallback Performance of *Dynamic Driving* Task	System Capability (*Driving* Modes)
Human *Driver* Monitors the Driving Environment					
0	No Automation	Human Driver	Human Driver	Human Driver	N/A
1	Driver Assistance	Human Driver & System	Human Driver	Human Driver	Some Driving Modes
2	Partial Automation	**System**	Human Driver	Human Driver	Some Driving Modes
Automated *Driving System* ("System") Monitors the Driving Environment					
3	Conditional Automation	System	**System**	Human Driver	Some Driving Modes
4	High Automation	System	System	**System**	Some Driving Modes
5	Full Automation	System	System	System	**All Driving Modes**

Table 1: SAE Levels of Vehicle Automation

These features, unthinkable until recently, are part of the technology standardization called Intelligent Transportation Systems (ITS). While ITS is a key part of the eventual goal of autonomous cars, it has already begun to impact the design of next-generation applications… it has even begun to affect our perception of what an automotive application is. In a nutshell, ITS is a standardization of the multiple communication and location technologies required to deliver the planned future of transportation. While self-driving cars are the "headliners" of this story, these technologies are being developed and even deployed today, and will soon be commercial realities in areas like security, fleet management, bike-share systems, in-dash infotainment, traffic control and automotive safety.

The SAE International (formerly the Society of Automotive Engineers) includes in its charter the role of blazing the trail for any technological automotive roadmaps. It has defined six levels of automation that can be used to describe autonomous vehicles (Table 1). These levels do not just define the order of increasing automation; the SAE put thought into ensuring that the levels align with the order in which they will be made available to the public.

We are already further down this path than some might think. For example, collision warning systems, lane departure warnings and parking distance control (Level 0 automation) have been commercially available for years. Level 1 systems (e.g. adaptive cruise control, "autonomous valet" parking) are common and are familiarly known as Advanced Driver Assisted Systems (ADAS). "Level 2" systems are developed and on deck for the very near future.

Part of this path evolution is the deployment of Vehicle-to-Infrastructure and Vehicle-to-Car communications (V2I and V2V, collectively known as V2X communications). V2X has been codified in several localized versions around the world, and uses the Wi-Fi-like Dedicated Short Range Communications (DSRC) technology to communicate from infrastructure to cars and among the cars themselves.

DSRC's use case is literally life-saving and requires a high degree of time-sensitivity. V2X systems share messaging related to vehicle location (latitude, longitude, altitude) and motion (velocity, heading and acceleration) along with messages used to control the vehicle (lights, steering and braking). Given the ability to control itself, the connected car now has non-line-of-site "visibility" into braking vehicles up the road, traffic signals that are about to change and any sudden changes in traffic speeds or patterns.

At first the challenges of precision timing and synchronization in ITS systems don't seem apparent, but consider the impact of timing in the vehicle's decision-making . Fractions of meters can make all the difference between safe driving and potential tragedy. A vehicle at 60 mph (100 km/hr) moves 3 cm every millisecond. While that is a small amount of motion, it is this level of control that is required and indeed, current standards are considering 1 millisecond accuracy as a minimum performance requirement for V2X[1].

It's important to note that deterministic networking now becomes especially critical since latency will be just as important as time accuracy in real-time decision making. If the system needs to respond within 1 millisecond (1 kHz update rate) then subsystems need to respond at least an order of magnitude better (to tens of microseconds). The basic principles for such Time Sensitive Networking (TSN) have roots in Audio-Video Bridging (AVB) technology designed as part of IEEE 802.1. These approaches will continue to evolve to form the basis for much of the foundational technology underlying the connected car. In connected cars, jitter, precision in scheduling, IP convergence and switching become safety issues[2]. One solution is time-triggered Ethernet (TTEthernet) that hopes to provide Quality-of-service (QoS)-style message prioritization[3].

It's clear that even linear growth in the number of connected cars becomes exponential growth of the number of endpoint connections. This drives the need for "fog" computing[4]. Conceptually similar to cloud storage, fog computing distributes both storage and intelligence among "endpoint" entities, in this case vehicles and transportation infrastructure elements. Since storage is now not only distributed, but distributed among mobile endpoints, the number of possible paths is an order of magnitude larger than in centralized communications and computing. When network edges become servers, planning and design became more difficult, especially now that 1) the "edges" of the network are in motion and 2) the consequences of failure are much greater. Timing is now both more difficult and more crucial.

Position and Navigation Technologies

At Level 3 of the SAE hierarchy, we see an increased reliance on the vehicle's position, heading and velocity data for accuracy and reliability. Successful ITS requires accurate location and navigation technologies. When objects move with little or no human control, the accurate location of the object becomes a literally vital concern.

The connected car requires Global Navigation Satellite System (GNSS) subsystems that work within the confines of multi-sensor, multi-technology integrated systems. GNSS currently fulfills a role as a standalone system, but it will need to work alongside ultrasound, lidar and radar transceivers; it also has to not only work with, but interact with, gyroscopes, odometers, accelerometers, tachometers and altimeters. Finally, it goes without saying that the system needs to provide accurate location information quickly and under every conceivable scenario.

This means that requirements for tomorrow's position and navigation technology do not represent an incremental step over the technologies available today. While DSRC standards operate at 10 Hz and can update position information every 100 ms, as shown, that's is a very long time to a vehicle traveling at highway speeds. Current automotive navigation systems are successful when they can report location within 3 meters of accuracy 95% of the time[5]. Newer additions reduce that to 1.5 m (in "lane-level" applications)[6], but any driver who has ever hit the brakes in the nick of time knows that +/- 1 m can make a very critical difference, so new technologies like relative positioning, aka Differential GNSS or DGNSS, can reduce that to centimeters[7] (relative to other vehicles and infrastructure entities) in V2V applications.

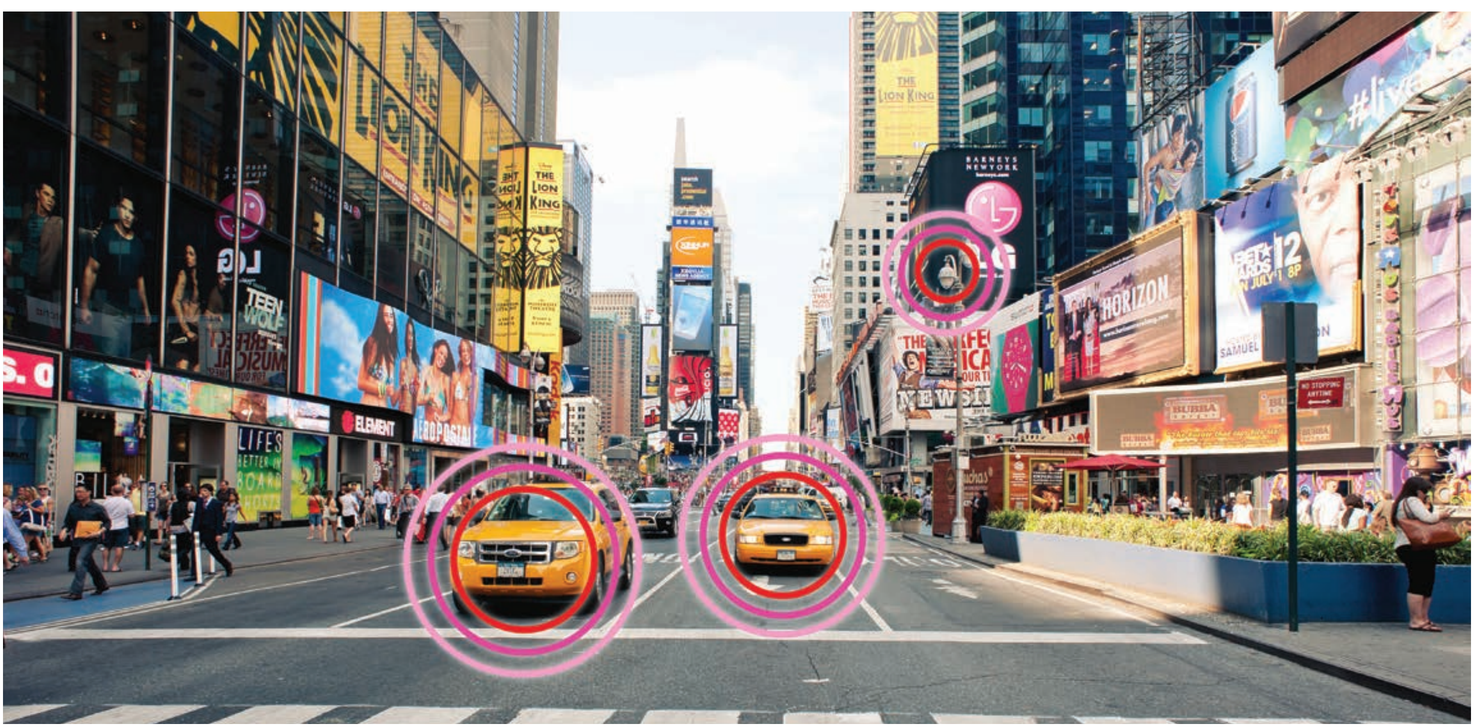
This creates a number of challenges for the technology developer or implementer, as there is an exponentially increasing number of scenarios that must be set up and validated when developing these systems and subsystems. They also must be developed cost-efficiently. According to the Boston Research Group, one thing that has to eventually happen for autonomous system realization is that, "...some of the most vital enabling components—specifically lidar sensors and GPS—must be further developed, and their costs scaled down, before OEMs will adopt them[8]." This drives a requirement for exploring highest-value options to assist in the development and deployment of new technologies.

SUMMARY

Motor vehicles of the near future require vastly improved reliability and accuracy in communications and time and location awareness. Driverless cars have been prototyped and hyped as successful proofs of the concept, and pre-ordained routes have been successfully and safely navigated under controlled conditions.

While these technologies may seem futuristic, those who compete in these commercial areas are currently researching and developing initial applications. A key feature of the successful connected car is accurate PNT technology. These must be more reliable and accurate than ever before, and they must co-exist with a multitude of other types of sensors and the computational loads associated with them.

All of this makes for an exciting new market, but it creates a daunting task for those of us who need to deliver solutions that will enable the possibilities with a high degree of safety. At Spectracom, we approach these problems collaboratively. Our knowledge spans a spectrum of technologies including synchronization for time sensitive networks, GNSS signal management and sensor fusion, and simulation and test. To learn more about how Spectracom can help, visit out web site http://spectracom.com.



V2X connects cars to each other and to transportation infrastructure.

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