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AUTONOMOUS VEHICLES ARE DRIVING INVESTMENT IN FIBER, EDGE, AND 5G

WHAT'S COVERED?

- The Needed Infrastructure
- How It All Works
- Data Production, Collection, and Storage
- Who's Leading the Charge?
- The Challenges Ahead
- Living on the Edge
- Before you Customize

The world is about to experience a dramatic shift—one that will have rippling effects on world economies, personal lives, the environment, societies, and geopolitics. Every industry from oil and gas to groceries will be impacted. Lives will be saved, companies will be destroyed, and the world as we know it will cease to exist.

The transportation industry—specifically, the adoption of autonomous vehicles—is poised to disrupt the world on a massive scale.

Or not.

The truth is, none of us knows what tomorrow will bring, let alone are we able to predict the entire "future." But, one thing is clear: the convergence of vehicles with machine learning, artificial intelligence, a 5G network, fiber, and edge computing are about to have a big moment.

The question we're left with is: "how big?"

Waymo reported in 2018 that its fleet drove 1.2 million miles in California, with an industry-leading rate of one report of human intervention per 11,017 miles driven. The Washington Post

TERMINOLOGY: Self-Driving, Driverless, Autonomous, or Automated?

Essentially, these all refer to the same thing: cars that don't require humans to operate. But there are some quibbles among purists. Autonomy implies decision-making and existing technology isn't that advanced. Driverless and automated are more accurate terms, but are less used.

Just know that when you hear any of these words, they mean roughly the same thing.

Self-driving and autonomous vehicles are already here. Apple is now testing more cars than rivals Uber, Waymo, or Tesla. TuSimple, a San Diego-based startup focused on driverless long-haul trucking was valued at more than $1.1 billion in May of 2019. In short, it's not a matter of if autonomous vehicles are widely accepted, but when.

But there are key challenges facing this potential disruption.

The infrastructure needed to support massive numbers of self-driving and autonomous vehicles just doesn't exist. Yet. And when you drill down into the infrastructure needs, a bigger gap develops between what's needed for local driving versus highway driving.

Both scenarios will require a vast network of sensors, fiber connections, 5G connectivity, hardware, software, data collection and storage solutions, and edge computing.

THE NEEDED INFRASTRUCTURE

The success of all of this boils down to infrastructure. Latency is a hindrance to progress, so data needs to be transferred as quickly as possible. Any delay could be catastrophic.

That means we'll need to build a fast, reliable, and secure infrastructure capable of processing data in real-time. There are three core components to this success.

Fiber

Fiber is the supporting structure for 5G networks and edge computing. In fact, 5G can't exist without it. All of the bandwidth 5G will make available will be handled by the fiber's backhaul network—the connection from the tower to the service provider's network.

Edge Computing

Edge computing is a mesh network of data centers that process and analyze data at the data's source. By decentralizing the data center, edge computing can deal with high volumes of data at faster speeds.

5G

Short for fifth-generation network, 5G will eventually replace the existing 4G LTE network and promises to give end-to-end connectivity across the country. With speeds up to 100 times

faster than 4G, it will connect sensors to edge computing devices, enabling smart cities, connected homes, and most importantly, a network of mobile data centers (i.e. automated vehicles).

These pieces are dependent upon each other. Edge computing is critical to 5G's success, and, likewise, 5G is an integral part of the success of autonomous vehicles.

We have to get the edge right to make the rest of it work.

HOW IT ALL WORKS

Fiber, 5G, and edge computing will be essential support structures for many types of transportation communications. As vehicles, roads, and cities become more interconnected, information will become vital to the success of driverless vehicles. While systems can be complicated, the three most common ways vehicles and networks will interact are:

- **Vehicle-to-Infrastructure (V2I):** Vehicles communicate with sensors throughout a city including, but not limited to, bridges, roads, and traffic signals
- **Vehicle-to-Vehicle (V2V):** Vehicles communicate directly with other vehicles, sharing information about road conditions, speed, and weather.
- **Vehicle-to-Everything (V2X):** Traffic lights "speak" to vehicles, which in turn, communicate with weather services or municipalities.

FIGURE 1

Many vehicles are already connected in these ways. Public transportation, emergency vehicles, airplanes, and new models of cars are constantly communicating valuable information to the networks they're connected to. This is achieved with a variety of technology that supports, enhances, and validates the other.

RADAR Sensors

Radar isn't exactly new technology—it's been used by the military for decades—but it is finding new life in the world of autonomous vehicles. Capable of detecting the velocity of objects, distance, and horizontal/vertical positions, radar uses radio waves to detect a vehicle's physical place in the world.

LiDAR Sensors

Lidar works similarly to radar, but it uses infrared light instead of radio waves to identify objects around it. It then uses that information to create what is essentially a 3-dimensional map to predict how those objects will behave.

SONAR Sensors

Like radar, sonar has been used by the military for decades. Short for "sound navigation and ranging," SONAR uses sound waves to detect objects around it. Because SONAR has a limited range, it's mostly used for things like parking assist.

Cameras

Capturing everything from road markings to signs to colors and pedestrians, cameras are the "eyes" of autonomous and driverless vehicles. By placing cameras at all angles on a vehicle, they're capable of giving a 360-degree view of a vehicle's surroundings. Of course, image quality and weather conditions play a major role in their usefulness.

GPS

GPS—or, global positioning system—uses satellites to calculate longitude and latitude positions anywhere on earth. By locking a signal onto a handful of satellites at a time, GPS also helps calculate speed, direction, and distance. It's extremely accurate and is not affected by weather conditions.

DATA PRODUCTION, COLLECTION, AND STORAGE

Because autonomous and self-driving vehicles

Name	Size in Bytes
Byte	1
Kilobyte	1,024
Megabyte	1,048,576
Gibabyte	1,073,741,824
Terrabyte	1,099,511,627,776
Petabyte	1,125,899,906,842,624
Exabyte	1,152,921,504,606,846,976
Zettabyte	1,180,591,620,717,411,303,424
Yottabyte	1,208,925,819,614,629,174,706,176

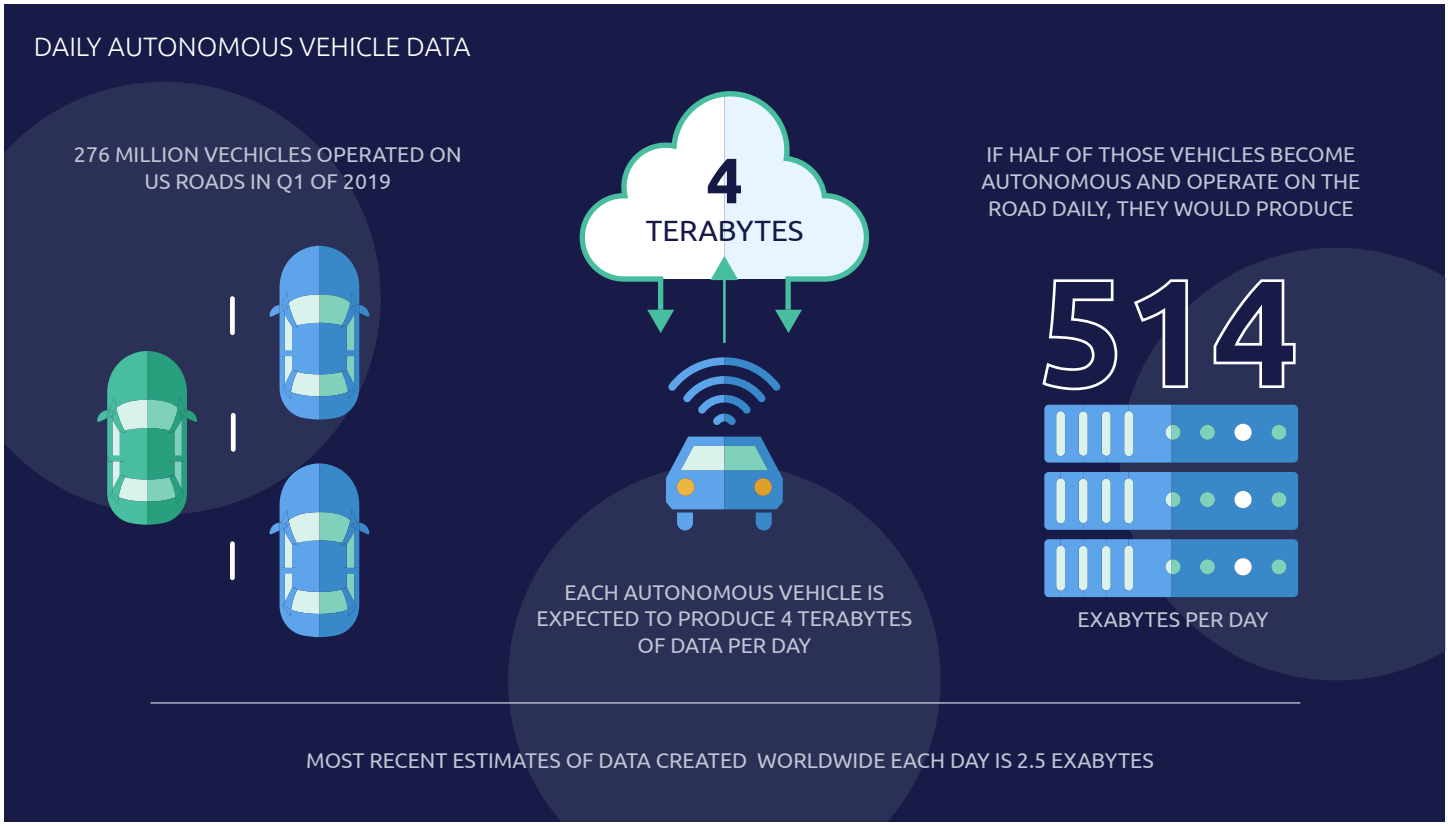

FIGURE 2 (SOURCE: INTEL, STATISTA, DOMO)

rely on a combination of cameras, radar, sonar, GPS, LIDAR and a host of other software and hardware solutions, one thing is certain: they produce a ton of data.

Some estimates put autonomous vehicle data numbers at 4,000 GB of data/day—as much data as 3,000 people using video, Internet, and chat. Others put the number at 300TB/ year per vehicle.

And those numbers are based on just one hour of driving per day. Right now, data numbers are all over the place because there's no way to know how many of these vehicles will be on the roads in the coming years. Or what the infrastructure to support them will look like.

These massive amounts of data will be distributed to edge computing devices in order to produce real-time information. Some of it will be transferred to, processed, and stored in the cloud. As with all data—especially in this day and age—some big questions come up. Who keeps all of this data safe, how do they keep it safe, and in the end, who owns it?

Privacy & Security

For manufacturers, data privacy concerns boil down to safety; they want to add as many safety monitoring systems as it takes to keep vehicles safe. This includes facial recognition software (to detect drowsiness), microphones, sensors that can tell when you enter and exit the vehicle, and heart rate monitoring. Some technologies are even working toward capabilities to judge a driver's emotional state.

Consumers, on the other hand, are skeptical of these safety claims and worry their data will be collected and sold or, potentially, used against them when accidents occur or insurance rates are adjusted. GM caught the brunt of consumer backlash in 2011 when they tried to change their OnStar user agreement to allow sharing of data with third parties. Other concerns involve data hacks and breaches, or full takeovers of a vehicle's control.

Some propose tighter privacy controls for individual owners versus public-use vehicles, for instance, family cars versus public, autonomous taxis.

Ownership

The question of data ownership is particularly thorny. Manufacturers, software companies, hardware companies, municipalities, and citizens all have valid claims. And personal interests. Obviously, whoever controls the data stands to gain the most from it. So while security and privacy will be the main talking points in the future, ownership should be the bigger concern.

On the surface, it appears that consumers will bear the majority of the costs and risks, while corporations and governments gain all of the advantages. Consumers may be more reluctant to hand over personal data via their modes of transportation as they become more aware of the threats and concerns facing them. Then again, maybe not.

WHO'S LEADING THE CHARGE?

A number of players are working on autonomous and self-driving vehicles in varying degrees, each with their own strengths. Some are pursuing level 3 autonomy, while others are skipping humans completely to offer fully automized level 4 and 5 vehicles. Some are focusing solely on software, while others want to build and maintain their own infrastructure and manufacturing facilities.
The most obvious companies in the game at this

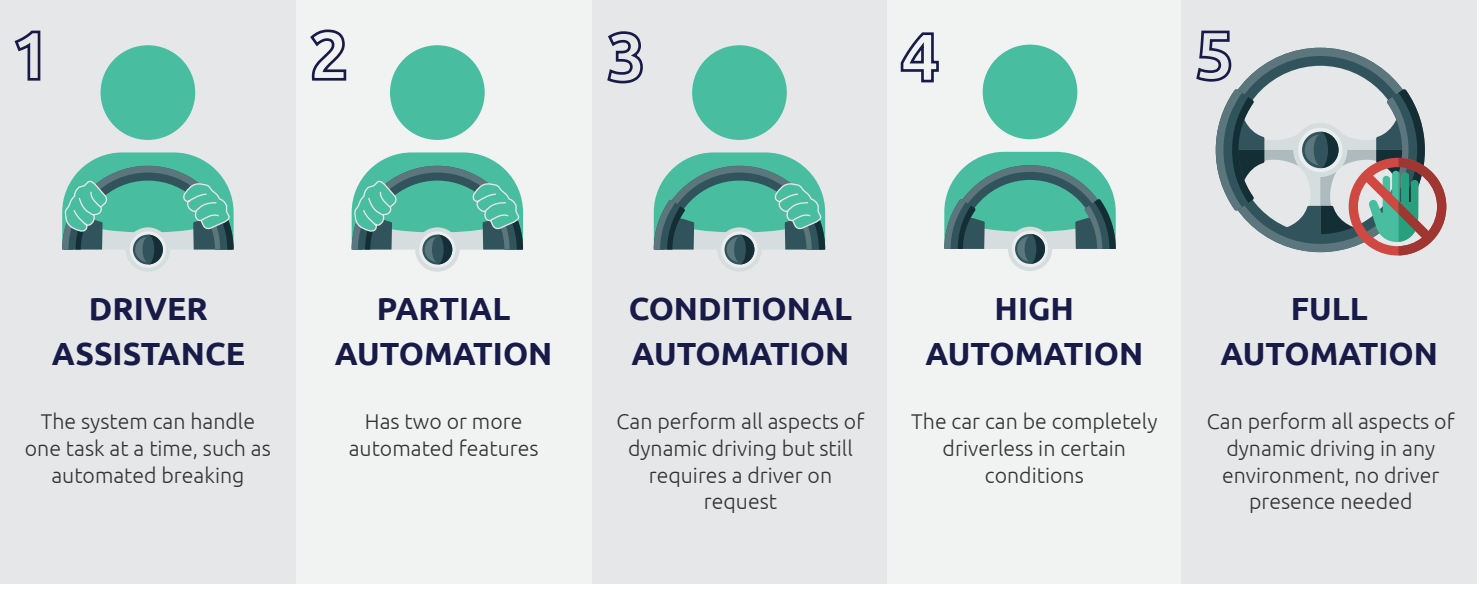

FIGURE 3 (SOURCE: TUXERA - AUTOMOMOUS CARS WILL GENERATE MORE THAN 300TB OF DATA PER YEAR)

point are Tesla, Apple, Alphabet (Waymo), and Uber. Major car companies are also in the mix, including GM, Volvo, Cadillac, and BMW, among some others.

When it comes to true autonomy, a Bloomberg article puts Waymo in the lead—at least a year ahead of others. That same article points out that Daimler is leading the car manufacturing charge in European car markets.

Where all of this ends up is hard to say. From a competitive standpoint, these companies are in a race to get safe, autonomous and self-driving vehicles to market. But the complexity of the technologies required to create these vehicles also needs high-levels of collaboration and standardization—all of which may be bigger challenges than the technology itself.

THE CHALLENGES AHEAD

While some are predicting a complete disruption of the transportation industry by 2030, there are signs that things could be a bit more challenging than originally thought. There are a number of technical challenges to overcome at this point, but the most perplexing challenges will be changing human behaviors and expectations.

Challenging, however, does not mean impossible. Technology changes human behavior all the time, especially when it's beneficial to our lives and the well-being of those in our communities. Autonomous vehicles and their accompanying technological advancements have the potential to reshape our societies in unimaginable and positive ways. There are a few specific areas that will need particular attention:

Complexity & Functionality

Open roads are a complex system made up of a variety of vehicle types, hazards, signals, signs, rules, and obstacles. A human driver makes millions of micro-decisions, especially as they navigate congested city streets. One might have to unexpectedly change lanes, brake for a child on a bike, or avoid a pothole. Until compute power has the ability to make such decisions, full transport autonomy will remain a fantasy.

Obsolescence

Car owners maintain ownership of their vehicles for an average of 11 and a half years. That's a lifetime when it comes to technology and software. With such high stakes, vehicle manufacturers, software engineers, and hardware manufacturers will need new ways to keep systems up to date. Tesla has ventured into these waters by creating a system fully reliant upon software and firmware updates, but even their approach has been criticized.

Management & Maintenance

Data management was mentioned earlier, but it's not the only management and maintenance concern. As vehicles move away from combustion engines and toward electric batteries, new types of service stations and mechanics will be required. While some programs have already begun to address this issue, convincing consumers that upkeep won't be a challenge could be, well, a challenge.

Integration & Cooperation

A number of companies and government

organizations are going to be required to get on the same page if there's any hope of autonomous and self-driving vehicles becoming mainstream. While competition is fierce, none will succeed without the support of another. Fortunately, auto manufacturers and technology companies recognize this challenge and have been reportedly working hand in hand.

Timing

Industry regulations, government support, politics: all play a hand in the success of not just autonomous and driverless vehicle manufacturing, but the infrastructure needed to run them.

Municipalities will need to upgrade traffic systems. Sensors will need to be installed and maintained along major roads and bridges. More robust data collection, storage, and analysis will be required. 5G will need to be implemented.

With some patience, forward-thinking, and collaboration, coordinating and syncing the numerous systems, processes, and networks required to make this entire endeavor a success may be challenging, but will not impossible. Plenty of smart and talented people are already putting the pieces in motion.

LIVING ON THE EDGE

Mainstream adoption of autonomous vehicles, along with other data heavy applications that will come along with the IoT, will drive growth in edge compute and storage at an unimaginable scale. As reported in NetworkWorld, IDC predicts edge infrastructure will be a main player in the growth of the server and storage markets. A lot of this expected growth is because the edge is still in its infancy -development and deployment will be the focus over the next decade with product lifecycles of 12-36 months.

Edge infrastructure will be located next to wireless towers, connected to buildings, and in less controlled environments compared to traditional data centers for real-time data processing. Standard size and performance attributes for the edge will vary greatly and look different from standard data center environments. To ensure optimal performance, custom mechanical solutions will be required to adapt system requirements based on location, application, and environmental factors - think, extreme temperatures.

BEFORE YOU CUSTOMIZE

At Tenere, we have the tools to help autonomous transportation industry leaders design for manufacturability, flexibility, reliability, scalability, and cost.

For years now, we've collaboratively engineered, manufactured, and assembled hundreds of thousands of custom data center racks, enclosures, chassis, disk drives, routers, switches, drive sleds, and data center HVAC units. We have the experience and technical expertise to help build out custom edge computing infrastructure and communication boxes for the autonomous transportation industry. Let us know when you're ready to get started.

ABOUT TENERE

Tenere has been providing single-source custom server rack solutions—from prototype to production—to technology companies for more than 15 years. They are a leading North American contract manufacturer of custom mechanical solutions for Cloud Infrastructure, Network Architecture, Fiber Optics, Self-Serve Kiosk, Autonomous Transportation, and Alternative Energy companies.

They have industry-leading expertise in prototyping, design for manufacturability, tooling, sheet metal fabrication and stamping, injection molding, assembly, integration, testing, and supply chain.

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