

# Automotive Ethernet Testing



**WHITE PAPER**

*Verifying the quality, functionality and performance of Automotive Ethernet*

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## OVERVIEW

Cars today are evolving rapidly. The purely mechanical systems of yesteryear have now largely been replaced by advanced digital systems, transforming vehicles into mobile data centers featuring sophisticated bandwidth-hungry applications that improve safety, fuel consumption, while delivering a great experience for both drivers and passengers.

The new digital systems are critical for success in a fiercely competitive market. This places huge demands on manufacturers to ensure the best possible Quality of Service (QoS) and reliability from these in-car networks.

Rigorous testing of the in-car Ethernet networks and components—from the R&D drawing board to when the vehicle leaves the auto-plant production site—is therefore essential.

In this White Paper, we'll explore current and upcoming in-car applications, look at the past, present and future of automotive Ethernet technologies, and examine how [Xena's Ethernet traffic generation and analysis solutions](#) can be used to ensure end-to-end quality and reliability for the new wave of automobiles being driven on roads around the world.

## Cars today ...

Modern vehicles rely on advanced features to improve driver safety and passenger enjoyment. Advanced Driver Assistance Systems (ADAS) have seen huge advances in the last decade, bringing in new systems such as:

- Adaptive cruise control (ACC)
- Automatic parking
- Blind spot monitoring
- Collision avoidance systems
- Driver drowsiness detection
- Hill descent control
- Lane departure warning systems
- Lane change assistance
- Parking sensors
- Pedestrian protection systems
- Rain sensors
- Surround view systems
- Traffic sign recognition
- Wrong-way driving warnings

Many of these features rely on data from a fusion of cameras and sensors, and only a robust, high-bandwidth network can ensure reliability and QoS across all these components.

While ADAS enhances driver safety, infotainment systems increase driver comfort. Though less critical to safety and wellbeing, they're no less demanding in their network bandwidth requirements. Native GPS

navigation, heads-up displays, and passenger entertainment systems place a significant burden on the network as data passes between processors, speakers and screens.

## The evolution of Automotive Ethernet

Various networking technologies have been used in cars for many years. Some examples are:

- CAN (Controller Area Network)
- FlexRay
- LIN (Local Interconnect Network)
- MOST (Media Oriented Systems Transport)
- 100 Mbit/s Ethernet (100BASE-TX)

While these legacy networking systems played an important part in the development of cars, they're no longer sufficient to meet the needs of our data-hungry, always-on world. Low bandwidth, potential EMC interference issues, plus the weight and cost of all that cabling makes them unsuitable for modern ADAS and infotainment applications.

## Advanced features demand an advanced network

As more networking functions are added to in-car systems, legacy networks are being replaced by backbone configurations. Whereas 100Mbps connections used to be sufficient, today's vehicles need multi-gig connections to power their advanced features. And when the autonomous car of tomorrow launches, it is likely that 25Gbps or even 100Gbps networks may become the norm.

## Why is Automotive Ethernet testing important?

These new waves of automotive innovation create significant testing demands. While the temptation is to funnel all testing efforts toward the newer, customer-facing application side, it's critical that this doesn't happen at the expense of Ethernet testing. Just as all the modern appliances we take for granted—TVs, washing machines, fridges—are useless if the power goes off, even the best-tested in-car application can't function without Ethernet.

While Ethernet device providers will have conducted their own testing to deliver a quality device, it's important to test that the Ethernet functionality works properly in concert with other systems. After all, any Ethernet switch will behave differently once it needs to share resources with other systems. The only way to know how that effects QoS and application performance is through extensive testing.

## Automotive Ethernet Standards

In November 2011, the OPEN (One-Pair Ethernet) Alliance Special Interest Group (SIG) (OPEN Alliance SIG) was formed. One month later, it released the BroadR-Reach (OABR) automotive Ethernet specification.

The OABR specification was the first major push for a standardized approach to automotive Ethernet. Designed to use a single, full duplex twisted pair 100Mbps interface, OABR aimed to use fewer cables to reduce the cost and weight of in-car networks.

When car manufacturers wanted to optimize the cost and weight of in-car copper cabling, Ethernet was an obvious choice. Legacy 100Mbps Ethernet on copper wires (100BASE-TX) wasn't an option due to EMC issues. And as 100BASE-TX uses two twisted pairs, this wouldn't have helped deliver in-car networking via a single cable.

### 100BASE-T1 and 1000BASE-T1

100BASE-T1, the IEEE equivalent to the BroadR-Reach specification, was introduced in October 2015. IEEE also developed a higher-speed automotive Ethernet specification. Called 1000BASE-T1, this specification can transport 1Gbps speeds over Reduced Twisted Pair Gigabit Ethernet (RTPGE) and a single twisted pair copper cable.

While BroadR-Reach and the IEEE specifications were important developments in automotive Ethernet, increasingly complex in-car systems demand higher speeds. How much higher? McKinsey & Company estimates the car of today transmits 25GB of data every hour<sup>1</sup>. Once vehicles become truly autonomous, this number could go up to 500GB an hour.

### The Multi-Gig Future

To evolve automotive Ethernet beyond BroadR-Reach and 1000BASE-T1, the auto industry needed a standard that could support much higher speeds. The IEEE answered this call by creating a Multi-Gig Automotive Ethernet PHY Task Force.

By March 2018, the task force had fully developed a Multi-Gig automotive Ethernet standard that supported speeds of 2.5, 5, and 10Gbps.

But this is just the beginning of the automotive industry's data speed requirements. Speeds beyond 10Gbps will likely become the norm as drivers demand more data. This is another reason why Ethernet has replaced the likes of dedicated CAN, LIN, and MOST networks: unlike discrete automotive networking technologies, automotive Ethernet has a clear specification roadmap that's ready to support speeds of up to 100Gbps.

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<sup>1</sup> McKinsey & Company. <https://www.statista.com/chart/8018/connected-car-data-generation/>

## The Protocol Stack

The Ethernet protocol stack is based on the seven-layer OSI model of computer networking. Automotive Ethernet specifications address Layer 1 of the OSI model, including these sublayers:

SUBLAYERS	FUNCTIONS
PCS (Physical Coding Sublayer)	<ul style="list-style-type: none"> <li>- Determining a functional link has been established</li> <li>- Scrambling/descrambling</li> <li>- Coding</li> </ul>
PMA (Physical Medium Attachment Sublayer)	- Framing - octet synchronization/detection
PMD (Physical Medium Dependent Sublayer)	- The transceiver for the physical medium

Auto-negotiation isn't used in Layer 1, as it introduces additional latency. Even this increase could exceed the start-up time requirements of automotive networks. Instead, you should force devices into a higher-speed mode to meet the needs for low latency in automotive networks.

Each standard has different bandwidth requirements and modulation. Those with lower bandwidth requirements can be run on cheaper cabling to reduce costs. And those supporting PAM-3 modulation see less electromagnetic interference—allowing for more aggressive EMC filtering.

SUBLAYERS	10Base-T1S	100/1000Base-T1	2.5/5/10Gbit
<b>Duplex mode</b>	Half Duplex	Full Duplex	Full Duplex
<b>Wires</b>	Single twisted pair	Single twisted pair	Four twisted pairs
<b>Modulation</b>	PAM-2	PAM-3	PAM-16
<b>Signaling levels</b>	3	3	3
<b>Symbol rate</b>	12.5 - 25 Msps	75/750 Msps	200/400/800 Msps
<b>Bandwidth</b>	6.25 – 12.5 MHz	37.5/375 MHz	100/200/400 MHz
<b>Additional features</b>	Decision feedback equalization  PLCA to avoid contentions	Decision feedback equalization	Decision feedback Equalization

		Echo and crosstalk cancellation	
		Partial response transmit filter	

## TSN – Timing Matters

Timing is another important driver of automotive Ethernet innovation. ADAS and autonomous vehicle functions typically need to function in real time, using a complex combination of sensors. This creates a growing need for [time-sensitive networking \(TSN\)](#) in automotive Ethernet.

One example is a collision-avoidance system. If data arrives too late, out of sync, or in the wrong order, the system can't alert the driver to a potential crash in time. To ensure any braking, navigation or camera-based systems operate properly, you need to ensure timing can be measured and controlled by the network—and can reserve resources for time-sensitive functions.

To create a shared time reference, a centralized time source needs to synchronize timing data across the whole network—from gateways and end devices, to every Ethernet switch between. And with timing data moving between so many devices, thorough testing is essential to ensure this data isn't lost, delayed or corrupted.

## Automotive Ethernet Test Requirements

Whatever protocols you use, any automotive Ethernet system includes a range of chips, sub-systems like ECUs, and automotive switches. All of these components need to be tested thoroughly to ensure they deliver the functionality and performance users expect. And once the system is fully assembled, the same tests need to be repeated to assess how different components work in tandem.

Functional Ethernet test requirements depend on the Device Under Test (DUT) and the application. For an automotive switch, the functional Ethernet lab-testing during development and QA verification typically includes:

- Testing with unicast, multicast and broadcast frames
- Test of MAC address learning
- VLAN capability verification:
  - Testing with untagged frames, frames with one VLAN tag and double-tagged frames
  - Testing with different VLAN priorities
- Stress testing:
  - Testing with high traffic load
  - Testing with different frame sizes (including undersized and oversized frames)

- Testing with different interframe gap settings

When testing fundamental Ethernet performance during development and QA, these parameters need to be verified:

- Throughput: the maximum data rate that can be transferred through the DUT
- Latency: the time it takes to transfer data through the DUT (also known as Frame Transfer Delay)
- Frame loss: data frames lost during the transfer of data through the DUT
- Jitter: the variation in packet delay (also known as Frame Delay Variation)

In most cases, all tests should follow the IETF (Internet Engineering Task Force) [RFC 2544](#) Benchmarking Methodology for Network Interconnect Devices. This framework specifies throughput, latency and frame loss testing. Most Ethernet testers also include jitter testing in their [RFC 2544](#) test suite.

Layer 2 switches are also a commonly used component in automotive Ethernet. Testing these involves following the IETF RFC 2889 Benchmarking Methodology for LAN Switching Devices. [RFC 2889](#) is a methodology for benchmarking switching devices, forwarding performance, congestion control, latency, and address handling and filtering. Following [RFC 2889](#) and [RFC 2544](#) in tandem provides a solid testing foundation for automotive Ethernet.

## Xena's Automotive Ethernet Solutions

Xena offers a range of solutions for testing automotive Ethernet—from switch R&D through to production line testing.

### For R&D Testing

Xena's [Valkyrie Ethernet traffic generation and analysis platform](#) includes the [Odin-1G-3S-6P](#) 6-port 1Gbps test module. This test module, equipped with BroadR-Reach 100BASE-T1 and 1000BASE-T1 transceivers (from Technica Engineering), makes it easy and cost-efficient to test and verify BroadR-Reach automotive Ethernet solutions.

Valkyrie can also do multi-gig Ethernet testing right up to [400Gbps Ethernet](#).

## Testing up to Layer 3

Valkyrie includes free test software that make it easy to test a wide range of Ethernet specifications, from 10BASE-T1S to 40GBASE-T.

[ValkyrieManager](#) configures, generates and analyzes Ethernet traffic between Valkyrie test equipment and DUTs. It can help you test:

- Traffic generation at line rate
- Flexible MAC address generation
- Generation of unicast, multicast and broadcast frames
- Generation of frames without VLAN tags, with one VLAN tag and double tagged frames
- Configurable VLAN priority
- Frame sizes from 56 bytes (undersized) to 16384 bytes (oversized)
- Adjustable interframe gap (IFG), configurable from 16 to 56 bytes

[Valkyrie2544](#) offers full support for the 4 test types specified in RFC 2544:

- Throughput
- Latency
- Frame loss
- Back-to-back frames

Valkyrie 2544 also supports jitter and frame delay variation test.

[Valkyrie2889](#) benchmarks the performance of Layer 2 LAN switches. It supports RFC 2889 test types, including:

- All throughput and forwarding rate tests (both fully and partially meshed)
- Congestion control
- Address caching capacity
- Address learning rate
- Broadcast frame forwarding and latency
- Forward pressure and maximum forwarding rate

[Valkyrie3918](#) makes it easy to create, edit and execute all test types specified in RFC 3918. These tests include reporting the throughput, forwarding, latency and Internet Group Management Protocol (IGMP) group membership characteristics of devices that support IP multicast protocols.

[Valkyrie1564](#) provides full support for the configuration and performance test types described in Y.1564. It can validate all Ethernet Service Level Agreements (SLAs) in a single test.

## Production Line Testing

Xena [Vantage](#) is a production line test solution, based on Valkyrie. It is used for fast, automated testing of Ethernet equipment on the production line. Vantage offers auto-start features that automatically collect device data as soon as an assembly line worker connects a DUT and test jig. This streamlines testing and reduces jigging times across the production line.

[Vantage](#) also offers powerful dashboards and deep reporting features to help test managers get more insights into the production line. Vantage also includes a REST API that lets engineers build automation scripts in any language, using any tool or client environment.

[Vantage](#) is typically used for these production line test scenarios:

- Router tests
- Two-way interaction tests
- Aggregation tests
- Loopback tests
- PON aggregation tests

## **Flexible Testing from 10Mbps to 400Gbps**

[Valkyrie](#) and [Vantage](#) both offer two chassis configurations: a modular 4U version with space for up to 12 test modules, or a fixed 1U alternative that holds just one test module. Xena offers over a dozen test modules at all speeds up to 400Gbps, and with different interfaces and port densities. Click the links to learn more about Xena's [Valkyrie](#) and [Vantage](#) Ethernet test modules.

## **Test Automation**

Automated testing can help avoid repetitive, error-prone manual testing, and reduce the cost of quality assurance.

Xena's [ValkyrieCLI](#) is a powerful and easy-to-use command-line-interface (CLI) scripting API that makes test automation easier. Renowned as one of the best test automation tools in the industry, [ValkyrieCLI](#) can help test engineers:

- Control [ValkyrieBay](#) and [ValkyrieCompact](#) chassis with installed test modules
- Adopt a powerful CLI approach from any TCP/IP capable tool environment
- Onboard quickly with unified syntax for CLI- and GUI-generated test port configurations
- Test faster with Tcl, Perl, Java, Ruby, BASH and Python script examples
- Work smarter with an intelligent console tool (bundled free with [ValkyrieManager](#))

## CONCLUSION

Today, the needs of automotive Ethernet have seen the industry move from legacy BroadR-Reach 100Mbps automotive Ethernet to faster multi-gig specifications.

However, even today's 10Gbps speeds will soon be inadequate for the automotive industry. As we move beyond infotainment and ADAS systems to full autonomous driving, in-car Ethernet is likely to demand speeds of 100Gbps or more. Beyond the increase in speed, the cost of failure is also on the rise. As more drivers rely on data-powered services to keep them safe, QoS will become paramount to user safety and brand reputation.

The only way to ensure these new speeds and QoS are met effectively is to test every aspect of your automotive Ethernet solution. And the best way to do that is with robust, futureproof testing solutions designed specifically for Ethernet. Xena is one of the top three vendors in this field.

In R&D lab-based test scenarios, the Valkyrie test modules support speeds from 1Gbps to 400Gbps. With flexible configuration that can support different modules and speeds, Valkyrie offers powerful and versatile automotive Ethernet test capabilities up to Layer 3 Ethernet. In addition to [ValkyrieManager](#), the main software application, all Valkyrie test modules are supplied with a range of free software for testing [RFC2544](#), [RFC2889](#), [RFC3918](#) and [Y.1564](#). The [ValkyrieCLI](#) test automation tool is also provided free of charge.

For production line testing, Xena offers the Vantage product line which has been specifically adapted to the fast, repetitive testing needs of the factory. A simple web UI allows even unskilled workers to activate advanced test routine, and automatically make detailed test report results available to centralized databases.

Together, these world-class traffic generation and analysis solutions can satisfy all the automotive Ethernet testing needs of both developers and manufacturers at a highly competitive price point. For more information, please contact [sales@xenanetworks.com](mailto:sales@xenanetworks.com).

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