White Paper

Performance Testing BroadR-Reach Automotive Ethernet

Key Elements for an Automotive-Specific Ethernet Test Regime

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Introduction

Ethernet has long been the standard for data communication across local area networks (LANs), with the result that today's IT and telecommunications professionals are well versed in the unique challenges of testing Ethernet/IP performance.

But Ethernet is a relatively new proposition for automotive OEMs. Offering significant cost and performance benefits over legacy in-vehicle networking technologies, it is set to play a growing role in future in-vehicle networks—and it now has a viable physical layer standard for the automotive industry, in the form of Open Alliance BroadR-Reach® (OABR).

As vehicle manufacturers begin explore the opportunities offered by OABR, they will face new performance testing challenges that present a step-change away from existing performance testing regimes for legacy technologies such as CAN Bus, LIN, MOST and FlexRay.

This white paper—one of a series on different aspects of BroadR-Reach testing is intended to give automotive developers a rapid introduction to Ethernet/IP performance testing, with specific focus on aspects which are unusual or particular to in-vehicle networks and OABR.

As a member of the OPEN Alliance Special Interest Group, Spirent is playing a key role in establishing best practice test standards for new in-vehicle networks based on BroadR-Reach. Drawing on our 25+-year heritage in network testing, our engineers have been working closely with automotive manufacturers to develop tailored, industry-specific answers, ensuring tomorrow's vehicles can take full advantage of the benefits of 2-wire Ethernet.

Likewise, Spirent is an active member of the Institute of Electrical and Electronics Engineers (IEEE) and the European Telecommunications Standards Institute (ETSI), defining protocol test standards in the data link, network and transport layers, including TCP/IP.

We trust you will find this document useful. However, if you have particular questions, or would like more detailed technical information on testing methodologies, we would be delighted to help.

Ethernet/IP Performance Testing in IT and Telecommunications

In the wider world, Ethernet is a well-established technology.

A great variety of standards and methodologies already exist around Ethernet/IP performance testing, and in many instances, teams engaged in the R&D of automotive systems stand to save a great deal of time, money and effort by applying and adapting these existing best practices.

In this section, we will review some of the key Ethernet/IP performance tests regularly conducted in the context of IT and telecommunications.

Throughput, Delay, Jitter, Packet-Loss, Packet Out of Order

Common metrics for testing Ethernet/IP performance include:

- **Throughput**—The maximum volume of data that can be successfully delivered between two points, usually measured in bits or packets per second
- **Latency**—The time taken for data packets to travel between two points
- **Jitter**—he variation in latency (e.g. due to network congestion)
- **Packet loss**—The failure of data packets to reach their destination
- **Packet out of order**—The delivery of data packets in a different order from that in which they were sent

While these performance metrics are often tested separately, there is another option. Since its creation in 1999, the Internet Engineering Task Force (IETF) RFC-2544[1] benchmarking methodology has supplied network engineers with a shared set of performance tests. These tests can be automated for increased testing speed.

Commonly used in the design, deployment and maintenance of Ethernet telecommunications networks, RFC-2544 includes Throughput, Latency and Frame Loss Tests, and is set to prove a valuable tool for automotive engineers working on Ethernet/IP applications.

Switch Benchmarking

Sitting on Layer 2 of the Open Systems Interconnection (OSI) model, Ethernet switches play a central role in network operation, effectively managing the flow of data.

In August 2000 IETF RFC-2889[2] was created, extending RFC-2544's benchmarking methodology to Local Area Network (LAN) switching devices. The current standard for initial performance testing of OSI Layer 2 switches, it covers common performance and Quality of Service (QoS) tests, as well as tests that deal with switch-specific functionality.

1 *http://www.ieft.org/rfc/rfc2544.txt*
2 *http://www,ieft,org/rfc/rfc2889.txt*

Quality of Service

Ensuring (QoS) is key concern for organisations whose businesses depend on the timely and accurate transmission of data across local and wide area networks. In automotive applications, where lives could depend on the timely delivery of critical data, the ability to effectively classify and prioritise will be absolutely vital.

Key QoS architectures and standards include:

- **DiffServ**—A networking architecture that uses the Differentiated Services CodePoint IP header field (a replacement for the original Type of Service field) to classify and prioritise packets.
- **IEEE 802.1Q**—A networking standard that supports the use of virtual LANs, or VLANS. Through the addition of a 12-bit 802.1Q VLAN ID and 3-bit 802.1p p-tag, VLANs enable the partitioning of a single LAN into multiple, virtual LANs, as well as the prioritisation of particular Ethernet frames.

Synchronisation

During the rapid adoption of Ethernet by telecom and wireless providers, ensuring synchronisation between nodesand reliability of service has been a common challenge. To meet this need, a number of protocols have already been developed. These include:

- **IEEE1588v2**—(or Precision Time Protocol) both a protocol and a testing standard
- **802.1AS**—A sub-protocol and a standard, for especially time-sensitive applications

Like QoS tests, synchronisation performance test will have an important role to play in the development of automotive Ethernet.

Application Playback

By recording the traffic from videos, Electronic Control Units (ECUs) and proprietary systems and playing it back to a device under test, network engineers can gain a more complete picture of network performance.

The traffic played back takes two key forms:

- **Unicast**—Traffic is sent to one destination, identified by a unique address
- **Multicast**—Traffic is sent to multiple, select destinations

Unicast is the most common form of communication within LANs and the Internet, while multicast is used for more complex applications—for example, by a video server sending out numerous channels, to numerous recipients.

Performance Challenges for Automotive Ethernet/IP Systems

While the IT and telecom industries will offer automotive OEMs proven performance testing tools and methodologies, testing Ethernet/IP for automotive applications is set to present some unique challenges.

Timing in Safety-Critical Systems

At present, Ethernet is most frequently used in-vehicle to support updates and diagnostics, and connect Rear Seat Entertainment (RSE) systems with their storage[3]. In future, however, it has the potential to be relied on in a range of safety-critical applications, from Advanced Driver Assistance Systems (ADAS), such as video cameras and radar, through to x-by-wire systems controlling braking and steering.

As these systems are developed, rigorous performance testing will naturally be essential—if OEMs are not only to protect drivers and passengers, but their own reputations.

Synchronicity

When a vehicle is activated, every device it contains needs to be ready to start functioning, together. As Ethernet is used for more in-vehicle applications, achieving effective, reliable synchronisation is set to prove a common challenge for OEMs.

Prioritization

At the same time as Ethernet finds its way into ADAS and x-by-wire systems, its cost and performance benefits are also likely to see it become the standard choice for infotainment and communication.

This means that switches must be able to effectively recognise different types of data traffic, and prioritise that belonging to the vehicle's safety-critical systems. The use of VLANs offers a potential solution to this challenge, but rigorous performance testing will be paramount if OEMs are to safeguard QoS.

3 BMW "Challenges in a future IP/Ethernet-based in-car network for real-time applications"

Key Performance Tests for Automotive Ethernet/IP Systems

Testing and optimising the performance of in-vehicle Ethernet/IP technology means testing everywhere Ethernet switches are embedded:

- Electrical Control Units
- Body Domain Gateways
- Domain Controllers
- Sub-Domains

Based on Spirent's 20 years of Ethernet/IP testing experience, we believe the following tests will be especially useful to those working on next-generation, Ethernet-enhanced vehicles:

1. RFC 2889 & RFC 2544 Tests

These two performance benchmarking methodologies define a number of performance tests for network interconnect devices and LAN switches, including crucial latency and throughput tests.

2. Jitter

The first industry standard definitions for Jitter and its measurement were set out by the Metro Ethernet Forum (MEF) in 2004. Systems capable of testing networks to such standards are currently available, and stand to offer great advantages when applied in automotive applications.

3. Bandwidth/Load

The importance of bandwidth/load tests will already be well understood by automotive network engineers. Ethernet networks, however, bring a new testing challenge—testing overload. Impossible on a traditional CAN Bus network, overload has the power to seriously compromise the performance of safety-critical devices.

Testing Ethernet overload requires a physical test system, capable of both generating the traffic and reducing the interframe gap (the time between the transmission of Ethernet packets). Such systems will give automotive engineers the ability to define and produce the high loads (e.g., 103%) needed to effectively test overload scenarios.

4. QoS

As discussed, the successful prioritisation and effective queuing of Ethernet packets will be crucial to the technology's adoption within automotive applications.

For OEMs, the IEEE 802.1Q standard defines a common, proven system for delivering QoS based on VLAN tagging, as well as providing a mechanism for Class of Service testing.

An important amendment to 802.1Q, the 802.1Qav standard describes additional rules for shaping traffic, through the forwarding and queuing of time-sensitive streams.

5. Timing

OEMs can also take advantage of existing standards as they work to meet the challenging synchronisation demands of automotive Ethernet applications. IEEE 1588v2 and, particularly, 802.1AS are ideally suited to this task.

6. Testing Performance Under 'Real World' Conditions

Testing Ethernet performance with real traffic is has two key applications in automotive network R&D.

While Ethernet is likely to become increasingly commonplace in in-vehicle networks, some established technologies will exist alongside it for many years. Ethernet is unlikely to replace CAN Bus for connecting indicators, for example, since the latter technology is both cheaper and more naturally suited to the job.

This means OEMs will need to be able to test an Ethernet network's ability to handle automotive-specific traffic such as CAN Bus messaging.

The natural solution to this challenge is record and replay—recording the traffic from automotive specific systems and replaying it over Ethernet. At the same time, record and replay of unicast and multicast traffic is also likely
to prove an increasingly important technique in determining the performance of Ethernet-connected Infotainment systems.

Spirent Solutions for Automotive Ethernet

The Spirent C1/C50 hardware platform provides automotive test engineers with a fully integrated BroadR-Reach test solution. The C1/C50 includes Spirent's TestCenter Packet Generator and Analyzer software for advanced performance and functional testing of Layer 2/3 In-Vehicle Networks and components.

Additional Spirent test packages are available separately, including:

- Protocol conformance
- Device/Network security and robustness
- Pre-defined, automated Test Suites (such as IEEE1588v2 or AVB)

For detailed information please visit our Website: www.spirent.com/go/automotive

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