Automotive Ethernet Conformance Testing

Key Elements for an Automotive-Specific Ethernet Test Regime

Introduction

This white paper—one of a series on different aspects of Automotive Ethernet testing—is intended to give automotive developers a rapid introduction to protocol conformance testing for Ethernet, with specific focus on aspects which are unusual or particular to in-vehicle networks.

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 100BASE-T1/1000BASE-T1 standards. Drawing on our 25+ year heritage in network testing, our engineers have been working closely with auto 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.

In the IT sector, where Ethernet is well established, OEMs are able to confidently purchase proven protocols, tested by vendors and debugged through years of extensive use. As a result, conformance testing at the development phase is often minimal. The same cannot be said for automotive networks. OPEN Alliance standards is still in its infancy and it would be unwise to rely too heavily upon new protocols without thorough testing.

What's more, vehicle manufacturers are required to stand behind their entire product—its safety, reliability and performance—in a way that is rare in IT. With hard-won brand reputation, multi-billion dollar recalls and, ultimately, customers' lives at stake, automotive companies understandably place great importance upon testing every critical aspect in house.

Protocol Conformance Testing

In general, protocol conformance testing involves taking each requirement in a relevant international standards document—aid down by a body such as the Institute of Electrical and Electronics Engineers[1] or European Telecommunications Standards Institute[2]—and testing to see if the device under test (DUT) operates according to that requirement.

This is done by running a series—usually thousands—of single function tests, covering each requirement in turn. Usually these tests are automated, due to the sheer volume involved, and to ensure a methodical, standardised approach.

Within the IT industry, pure conformance testing has waned in importance as the main protocols have become well established. Moreover, the inflexibility of the standard tests can be a problem. Conformance is therefore included within a suite of test approaches:

- **Conformance testing**—Confirms the application of protocols within the DUT comply with the relevant international standards
- **Negative testing**—Checks the robustness of the protocols when the system encounters problems and unexpected outcomes
- **Stress testing**—Establishes performance characteristics such as the maximum load a network can handle, and what happens when this is exceeded

In the automotive sector, the protocols to be tested will often be embedded within hardware, such as the engine control unit. However, software protocols, such as in the infotainment system, should not be overlooked.

[1] *http://standards.ieee.org/*
[2] *http://www.etsi.org/standards*

Conformance Testing for Automotive Networks

It is clear, judging by Spirent's conversations with vehicle manufacturers as part of the OPEN Alliance SIG, that the automotive sector wishes to retain far closer control over its conformance testing than in IT, where suppliers are often trusted to meet the relevant standards as a matter of course.

There are several reasons for this, including:

- Automotive Ethernet is a new technology growing at a rapid rate. This is fundamentally changing the nature of in-vehicle networks, and there may be unexpected bugs that have yet to be ironed out by extensive use.
- As Ethernet increasingly becomes the backbone of a vehicle's network systems[3], so the new protocols will influence its safety-critical functions. They must therefore be tested thoroughly.
- Unlike in the IT sector, automotive manufacturers bear the brunt of costs and reputational damage from any potential recalls if unexpected protocol errors arise.
- Vehicle manufacturers understand the importance of brand image and reputation, and must therefore have complete confidence in every finished vehicle. Regardless of where a fault lies, from the customer's point of view the buck stops with the OEM.
- By developing their own understanding of conformance testing, automotive manufacturers will be well positioned to create their own protocol test standards for Tier 1 suppliers in turn.

Today, automotive OEMs are primarily concerned with testing network conformance as part of research and development, and ensuring vendors are required to test to the most relevant standards. However, in time, sample-based protocol conformance testing will become an important part of production line validation.

[3] BMW "Ethernet–The Standard for In-Car Communication"

What to cover?

Importantly, automotive conformance tests should be focused upon protocols on the Open Systems Interconnection (OSI) Layer 3 (Network), and higher.

For the next generation of connected cars, the following protocols will be of particular importance:

- **IPv6**–The revised version of the Internet Protocol, providing a system of unique identification for networked devices, designed to counteract IPv4 address exhaustion.
- **IPv4**–Also on the Internet layer, this connectionless protocol for packet-switched networks will eventually be superseded by IPv6, but still carries the vast majority of internet traffic.
- **TCP**–On the transport layer, the Transmission Control Protocol is one of the key components of the Internet Protocol (and Industrial Protocol) suite.
  - **Relevant Internet Engineering Task Force (IETF) standards documents include**:
    RFC 675; RFC 793; RFC 1122; RFC 2581; RFC 5681
- **UDP**–Another transport layer protocol. User Datagram Protocol enables applications to send messages to other hosts on a network without prior communications to set up special transmission channels or data paths.
  - **Relevant Internet Engineering Task Force (IETF) standards documents include:**
    RFC 768; RFC 2460; RFC 2675; RFC 4113; RFC 5405
- **DHCPv6**–The Dynamic Host Configuration Protocol is an application layer protocol used for configuring IPv6 hosts with IP addresses, IP prefixes and other configuration needed to operate on an IPv6 network.
  - **Relevant Internet Engineering Task Force (IETF) standards documents include**:
    RFC 3315; RFC 3319; RFC 3633; RFC 3646; RFC 3736; RFC 5007; RFC 6221
- **DHCPv4**–The preceding Dynamic Host Configuration Protocol version.
  - **Relevant Internet Engineering Task Force (IETF) standards documents include:**
    RFC2131; RFC 2132; RFC 3046; RFC 3942; RFC 4242; RFC 4361; RFC 4436

Technical Challenges of Automotive-Specific Testing

Although many network testing techniques are easily adaptable from IT to automotive, most automated protocol conformance test apparatus is not. Conformance testing requires a full, step-by-step assessment of each individual requirement set out in the respective standard document, so conventional test systems are configured to methodically work through pre-determined batteries of tests, from start to finish, and issue a pass/fail.

However, most IT network conformance tests are not relevant to automotive protocols. Worse, many automotive DUTs do not have the functionality or management language to perform every required interaction, and therefore cannot pass a standard test on an IT-specific workbench.

The classic conformance test for IPv6 includes some 640 test cases. Of these, at least a third are not required in automotive settings. Likewise, a vehicle electronic control unit (ECU) will typically not support the Upper Tester activities demanded as part of a conformance test. For example, one interaction required by the TCP test standard is to remotely reboot the machine from the test device; a vehicle ECU lacks the necessary management language to perform this function.

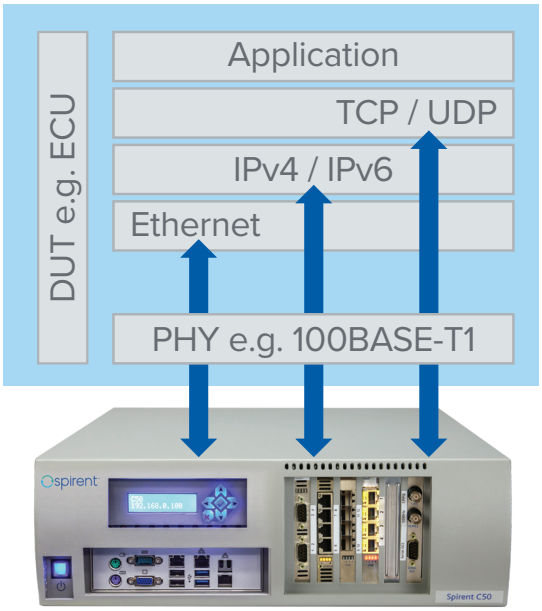
As a result, off-the-shelf IT network test equipment cannot carry out the tests demanded by existing standards. Similarly, vendors can never truly state that supplied hardware and software conform to the relevant standards. Therefore, companies using and supplying protocols within the automotive industry—whether vendors or OEMS—need a customized solution, specific to the sector, comprising all or any of the following options:

- The ability to skip steps within an automated conformance test program, or define which tests are and are not critical to the function in question
- Opportunities to build relevant management language into the test apparatus rather than the DUT
- An agreement to create new, automotive-specific protocol test standards, and reflect these within the automated procedures

Towards an Automotive-Specific Protocol Conformance Test

Through our membership of the OPEN Alliance Special Interest Group, Spirent is working closely alongside automotive manufacturers and vendors, to overcome the testing challenges presented by the burgeoning use of Automotive Ethernet. Clearly, protocol conformance testing is a key hurdle.

As a result, we have created a tailored version of our Spirent TestCenter, based on the popular test automation platform TTworkbench.
Using well known and established methodologies, Spirent TestCenter automates the full range of relevant test steps, within a single tool:



- **Conformance** with relevant standards for each protocol
- **Negative** testing to confirm robustness and stability, including "fuzzing" capabilities to rule out weaknesses
- **Performance** testing to quantify capacity and check proper functionality at high load levels

About Spirent Communications

Spirent Communications (LSE: SPT) is a global leader with deep expertise and decades of experience in testing, assurance, analytics and security, serving developers, service providers, and enterprise networks.

We help bring clarity to increasingly complex technological and business challenges.

Spirent's customers have made a promise to their customers to deliver superior performance. Spirent assures that those promises are fulfilled.

For more information, visit: www.spirent.com

Crucially, the system allows full customization of test routines, enabling OEMs and suppliers to combine official standards from the likes of IEEE and IETF with bespoke automotive tests, tailored to the specific application concerned. This includes varying the weighting of particular test steps, to emphasise areas that are most critical to safety or automotive performance. Rather than—or as well as—adopting the IT industry's tests wholesale, this approach enables automotive engineers to modify standard protocol requirements to meet the industry's unique needs, and establish new standards for vendor tests.

In time, in common with other technologies, automotive Ethernet will move beyond the current research, development and verification phases, where everything must be tested in depth, to a "two-stage" process. Here, suppliers will certify that their protocols form to the specified standards, and manufacturers will test a representative production-line sample as confirmation. However, to protect safety, profitability and brand reputation alike, each test must be rigorous, methodical and foolproof to perform.

Next Steps

Spirent's experienced network testing engineers are ready to help any manufacturer to find answers to the ongoing challenge of conformance testing. For more information, or to read detailed white papers on other aspects of testing in the next generation of connected cars, please don't hesitate to get in touch.

More information about Spirent's test solutions for automotive Ethernet may be found at www.spirent.com/Automotive.

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For more information, call your Spirent sales representative or visit us on the web at www.spirent.com/ContactSpirent.

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