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**Intelligent Transport Systems (ITS);**
**Pre-standardization study of ITS test mode**
**for operational devices in the field**

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***ETSI***

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# Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Intelligent Transport Systems (ITS).

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# Introduction

ITS station communication devices require testing to verify their conformance regarding the ITS protocol stack implementation as well as the transmission and reception parameters. Therefore, an additional implementation of a test mode and a corresponding message set is proposed. The present document shows the ability of testing the communication of the devices under test in non-shielded environments. This includes but is not limited to over the air tests that do not interfere with operational devices. Furthermore, it enables the identification of non-working and damaged components crucial to the ITS communication using the test mode message set. This allows pro-active failure detection as well as prevention of devices in the field. In context with Vision Zero efforts of the European Union [i.3], it contributes largely to a reliable communications network upon which road safety is enhanced.

# 1 Scope

The present document describes a test mode for the ITS protocol stack. The test mode provides the ability of testing RF and functional requirements regarding the communication of devices. This includes but is not limited to over the air tests in non-shielded environments without affecting operational ITS stations not targeted by the message.

# 2 References

## 2.1 Normative references

Normative references are not applicable in the present document.

## 2.2 Informative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

NOTE: While any hyperlinks included in this clause were valid at the time of publication ETSI cannot guarantee their long term validity.

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] ETSI TS 102 941: "Intelligent Transport Systems (ITS); Security; Trust and Privacy Management".

[i.2] ETSI TS 103 097: "Intelligent Transport Systems (ITS); Security; Security header and certificate formats".

[i.3] VISION ZERO White Paper: "Roadmap to a Single European Transport Area".

NOTE: Available at https://ec.europa.eu/transport/sites/transport/files/themes/strategies/doc/2011_white_paper/white-paper-illustrated-brochure_en.pdf.

[i.4] ETSI TS 102 940: "Intelligent Transport Systems (ITS); Security; ITS communications security architecture and security management".

# 3 Definition of terms, symbols and abbreviations

## 3.1 Terms

For the purposes of the present document, the following terms apply:

**Test ITS-AID:** ITS-AID that is used for sending ITS facility layer message for test purposes

**Test Mode (TM):** state that enables specific tests of the ITS-S on functional and radio-frequency level

**Test Mode ITS-AID:** ITS-AID that is solely used for TMM

**Test Mode Message (TMM):** dedicated message type carrying test mode payload data

**Test Mode Service (TMS):** facility at the ITS-S facilities layer to generate, receive and process TMM

## 3.2 Symbols

Void.

## 3.3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

| | |
|---|---|
| AA | Authorization Authority |
| AID | Application Identifier |
| AT | Authorization Tickets |
| BTP | Basic Transport Protocol |
| CA | Cooperative Awareness |
| CAM | Cooperative Awareness Message |
| CRL | Certificate Revocation List |
| CTL | Certificate Trusted List |
| DENM | Decentralized Environmental Notification Message |
| DTS | Dedicated Test System |
| EOL | End Of Line |
| GN | GeoNetworking |
| GNSS | Global Navigation Satellite System |
| IFI | In-Field Inspection |
| ITS | Intelligent Transport Systems |
| ITS-S | Intelligent Transport Systems Station |
| MAC | Medium Access Control |
| OBD | On Board Diagnostics |
| OBU | On Board Unit |
| PDU | Protocol Data Unit |
| PTI | Periodic Technical Inspection |
| RF | Radio Frequency |
| SSP | Service Specific Permission |
| SUT | System Under Test |
| TMS | Test Mode Service |
| V2X | Vehicle to Everything |

# 4 Test mode specification

## 4.1 Test mode overview

The test mode is a means to verify RF and functional requirements of the ITS protocol communications. This requires access to functionality located in the facility layer of the ITS protocol stack as well as new functionality to conduct these tests. Therefore, a Test Mode Service (TMS) with specific permissions to access this functionality is needed. The test mode should be usable in non-shielded environments without affecting operational ITS stations. Hence, a separation of traffic, provided by usage of a dedicated certificate chain, is required.

## 4.2 Test mode service

The test mode service should be located within the facility layer. It should have the ability to send proprietary message types (test mode messages) and have specific permissions to access ITS stations protocol functions. TMS should only receive messages over a dedicated BTP port. It should be able to trigger CAMs, DENMs or other messages at their respective facility layer services for testing purposes when in test mode state and only then. To protect operational ITS station traffic from interference as well as the test mode service from abuse, a dedicated certificate chain is used once test mode is activated. These certificates have strong restrictions and apply separate SSPs to the service. Only DTS should have permission to trigger events through test mode messages, while SUTs should only receive certificates with permissions to send test mode message response messages. TMS should only be able to trigger events within the ITS protocol stack if a corresponding test mode AT certificate is active.

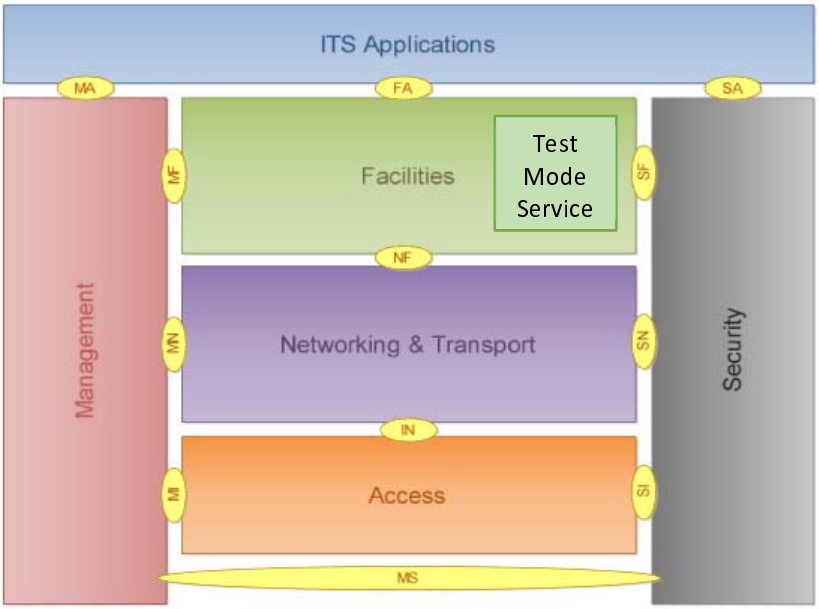


**Figure 1: Test mode service in V2X architecture**
**(Original image source: ETSI TS 102 940 [i.4])**

## 4.3 Test mode message format

Test mode test messages refer to messages being sent and processed by the test mode service. These messages should be routed over a dedicated BTP port and are optionally encrypted.

Data fields contained in test mode message transmitted by DTS:

- Signed by test certificate (public key attached to message)
- Requested message type to be returned (Test mode message, CAM, DENM, etc.)
- Requested data fields to be transmitted
- Requested mode of transmission for reply (either wirelessly or via OBD)
- Requested transmission power to be used
- Requested frequency/channel to be used
- Requested antenna to be used by OBU for reception of test mode messages
- Requested antenna to be used by OBU for transmission of test mode messages
- Target temporary MAC
- Time
- Message counter

Data fields contained in test message transmitted by SUT:

- Signed by test certificate (public key attached to message)
- Selected transmission power
- Selected antenna
- Selected frequency/channel

- Software/V2X protocol stack version
- Hash of software/stack version
- Hardware version
- GNSS position
- Time
- Message counter

## 4.4 Test mode activation

Test mode of the SUT should only be activated by authorized ITS-S DTS. Therefore, test mode messages should be signed with AT certificates carrying a test mode dedicated ITS-AID. AT certificates should be signed by a dedicated AA certificate. A dedicated test mode AA is an AA that operates according to the accepted Certificate Policy and is additionally allowed by the Policy Authority to issue test mode ATs. Depending on the criteria of the Policy Authority this may be a dedicated test AA or an AA that also issues regular ATs. The DTS should choose a SUT and send a message to activate the test mode. As this message should be signed by a test mode AT, the SUT will request a corresponding AA to validate the certificate chain, in case it is unknown. This should be done in accordance to the general certificate exchange approach for message types like DENM or CAM.

Once the request has been verified, the SUT should retrieve own test mode AA and AT certificates with its enrolment credentials from the test mode AA. If the retrieval has been successful, the SUT awaits a test mode trigger message for test mode activation addressed only at the SUT. Once the SUT has retrieved the test mode AT, it should change its currently used AT to the time and area limited test mode AT and acknowledge successful test mode activation to the DTS. All further messages will be signed with the test mode AT until it expires, the SUT leaves the validity area defined in the certificate, test mode is terminated via message set, a new AT is loaded or the SUT is restarted.

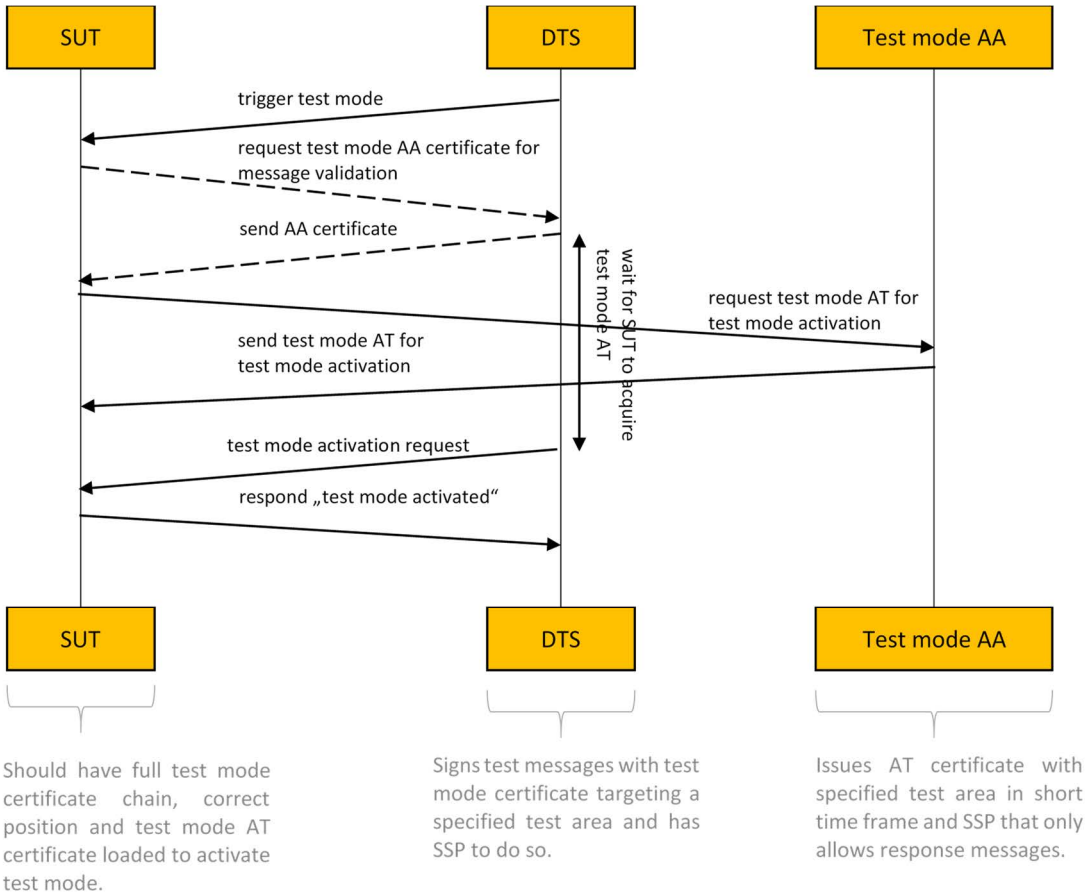


**Figure 2: Test mode activation sequence**

## 4.5 Separation of traffic

### 4.5.1 General approach

The separation of traffic is based upon 3 factors:

1) Test mode trigger messages should be routed over a separate BTP port. Hence, they should not interfere internally with basic services, even if the provided test mode is not supported.

2) Outgoing messages from the SUT should not interfere with other ITS-S as they are signed with certificates carrying a test mode ITS-AID. In succession this should force all ITS-S that are not in test mode, to drop these messages.

3) The alternative AA that is exclusively responsible for test mode certificates guarantees the possibility of strong regulation for issuing of test mode certificates.

### 4.5.2 Certificate chain

The certificate chain and its management follow the general model and processes of certificate chains for ITS station as stated in ETSI TS 102 941 [i.1]. It applies the general ruleset and introduces the necessary AA and AT certificates on an alternative branch. This branch is a result of the introduction of dedicated test ITS-AIDs which are derived from regular ITS-AIDs. This means that every ITS-AID has a mirror Test ITS-AID.

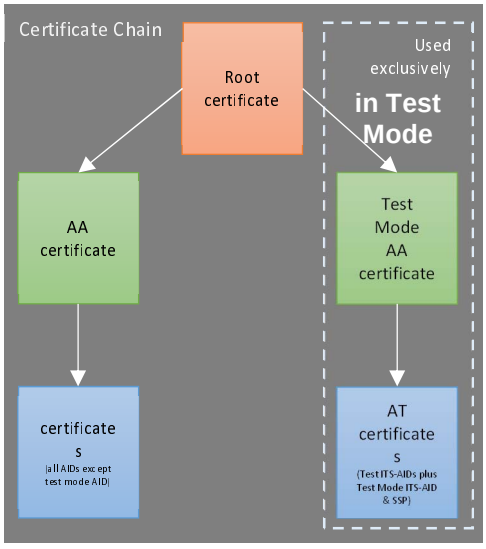


**Figure 3: Illustration of separate certificate chains for operational usage and test mode usage**

### 4.5.3 AA certificate properties

AA certificates should be conformant to certificate profiles for subordinate certification authority certificates as stated in ETSI TS 103 097 [i.2]. In addition, the following restrictions should apply:

- The `toBeSigned` component `CertificateId` should be set to the choice `name` contain a unique name associated to the certification authority and should not be set to the choice `none`.
- The certificate should be the only one to contain the ITS-AID correspondent to test mode in its `certIssuePermissions` in addition to mirrored Test ITS-AIDs (all that are needed for testing; e.g. CAM, DENM).

### 4.5.4 AT certificate properties

Certificates issued for test mode should have the following properties:

- Dedicated ITS-AID on top of ITS-AID permissions for services that should be usable (CAM, DENM)
- Validity restricted to single SUT test area
- Restricted to single test sequence time frame
- Signed by dedicated AA certificate
- SSP distinction between AT certificates for DTS (trigger message capabilities) and AT certificates for SUTs (response message capabilities)

## 4.6 Test procedure

### 4.6.1 Test item execution

Tests should only be triggered by a DTS based on its legitimated SSPs. The test that is triggered in a SUT will result in a response being either a message of a certain type (CAM/DENM) or a test mode message carrying test results or both.

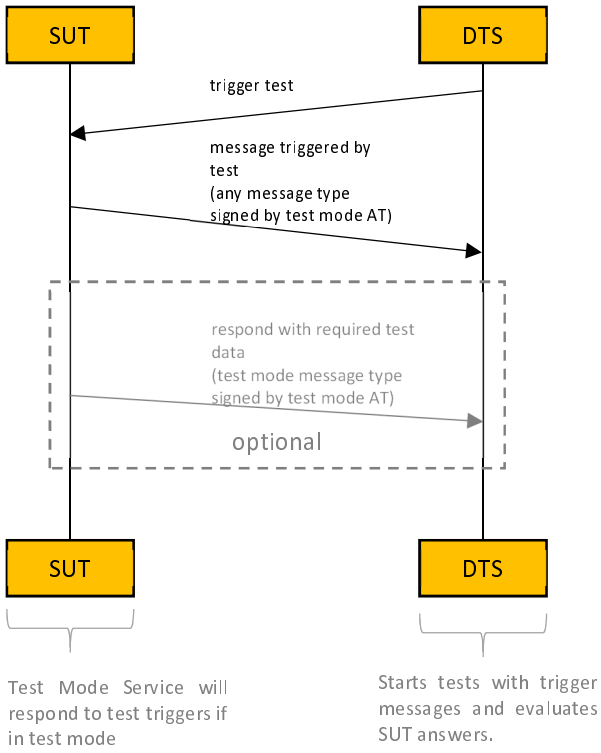


**Figure 4: Test mode test sequence**

### 4.6.2 Test items

The test mode should provide information about certain parameters located in several layers of the protocol stack. The following parameters are of interest and should be verified:

- **Reception ability:** To determine whether the SUT is able to receive a generic ITS message. This is checked in both GN and Facility Layer. The verification of signed messages is not within the scope of this test.
- **Transmission ability:** To determine whether the SUT transmits ITS messages, and if these messages are received correctly at a receiver compliant to the current ITS standards.

- **Reception quality:** To determine if the SUT is able to receive ITS messages from transceivers in a minimum distance. The distance is determined through the free space loss of the RF signal.
- **Transmission power:** To determine compliance with maximum possible transmission power and with the minimum required transmission power. Determine the ability to adapt the transmission power according to regulations (lower transmission power in the vicinity of tolling stations). This is due to possible manipulations at the device when already operational.
- **Protocol conformance after software-update:** The Protocol conformance is of importance during the device lifetime. This should be checked after every SW-update.
- **Functionality of accepting certificates:** Accepting valid certificates is a crucial function within the ITS communication system. It is therefore imperative to test if the SUT is able to verify messages signed with valid certificates.
- **Functionality of rejecting certificates:** Rejecting invalid certificates is a crucial function within the ITS communication system. It is therefore imperative to test if the SUT is able the detect messages signed with invalid certificates. The certificates may be out of date or issued by the wrong CA.
- **Functionality of Certificate Revocation List (CRL) and Certificate Trusted List (CTL):** Verifying if a certificate is either on the CRL or CTL is a crucial function within the ITS communication system. It is therefore imperative to test if the SUT can determine the allocation of certificates to revocation or trusted lists.
- **Maximum performance test/stress test:** Ability to process defined number of messages in a defined time.
- **Functionality of message content verification:** Verifying the authenticity of messages and message content is a crucial function within the ITS communication system. It is therefore imperative to test if the SUT is able to correctly use hash functions to verify unaltered message content.

## 4.7 Use cases

### 4.7.1 General purpose

The test mode provides means to verify and maintain the quality of ITS stations both initially and over time, without affecting regular operation of the communication network. This should ensure the overall reliability and quality of ITS network over time. Use cases are exemplary for device lifetime cycle applications of the test mode.

Table 1 provides an overview of test items required by each use case. A detailed description and an exemplary workflow of each use case is given in the following clauses.

**Table 1: Use cases and required test items**

| Test Item/Use Case | Use Case 1 (Repair/Maintenance) | Use Case 2 (PTI) | Use Case 3 (EOL/initial test) | Use Case 4 In the Field Inspection |
|---|---|---|---|---|
| Reception ability | x | x | x | x |
| Transmission ability | x | x | x | x |
| Reception quality | x | x | x | |
| Transmission quality | x | x | x | |
| Transmission power | x | x | x | |
| Protocol conformance after software-update | | | x | x |
| Functionality of accepting certificates | | x | x | x |
| Functionality of rejecting certificates | | x | x | x |
| Functionality of certificate revocation list (CRL) and certificate trusted list (CTL) | | x | x | x |
| Maximum performance test/stress test | | | x | |

| Test Item/Use Case | Use Case 1 (Repair/Maintenance) | Use Case 2 (PTI) | Use Case 3 (EOL/initial test) | Use Case 4 In the Field Inspection |
|---|---|---|---|---|
| Functionality of message content verification | | | x | x |

### 4.7.2 Repair and maintenance in authorized workshops

The goal is to verify the RF-compliance of the device under test using a standardized interface and message set.

A final test to be proceeded after repair, maintenance or change of components. Corrupted components can be identified in the RF chain: (e.g. defective or detuned antenna).

EXAMPLE: Car crash with minor damage to parts containing antennas for V2X communication:

1) The vehicle enters a garage authorized to perform V2X tests and repairs.
2) Parts are replaced and car paint is renewed as necessary.
3) DTS triggers and activates the test mode in the V2X OBU of the vehicle (SUT).
4) DTS executes tests using test items transmission ability, transmission quality, reception ability, reception quality.
5) A report for test items transmission ability, transmission quality, reception ability and reception quality show correct replacement and connection of antennas.
6) Test mode is deactivated, the vehicle leaves garage.

### 4.7.3 Periodic Technical Inspection (PTI)

The goal is to verify basic functionality of V2X components during the lifetime of the SUT.

Assuming the V2X functionality is mandated and the check of its functionality is in scope of the PTI, this functionality needs to be tested to ensure the roadworthiness of vehicles and network quality by detecting faulty components during the inspection. This is explicitly due to possibility of degradation or manipulation of V2X components. As soon as communication devices are in the field, it is assumed that a potential manipulation is possible and testing is necessary.

EXAMPLE: PTI for vehicle due after statutory period:

1) The vehicle enters an authorized inspection-garage.
2) PTI inspector uses generic scan tool to perform regular tests required during PTI as well as a manual inspection on stationary vehicle.
3) DTS activates the test mode in the V2X OBU of the vehicle (SUT).
4) DTS executes tests using test items transmission ability, transmission quality, reception ability, reception quality and the functionality of accepting and rejecting certificates.
5) A report is provided to the PTI inspector.
6) Test mode is deactivated, the vehicle leaves garage.

### 4.7.4 End-of-line test/initial test

The goal is to ensure production quality and V2X compliance of new vehicles.

Although vehicle components are tested thoroughly before being considered for series production and quality standards of the automotive industry are high, an end-of-line test prevents production related flaws. Detecting flaws during production of the vehicle lowers costs in contrast to repair a vehicle that is already travelling on the road. Systematic problems can be prevented, and an individual but automatable test report can be filed.

EXAMPLE: Vehicle manufacturer conducts an EOL test after vehicle production:

1) The assembled vehicle arrives at EOL testing site.
2) DTS activates the test mode in the V2X OBU of the vehicle (SUT).
3) DTS executes tests using test items transmission ability, transmission quality, reception ability, reception quality, protocol conformance after SW-update, functionality of accepting, functionality of rejecting certificates, functionality of certificate revocation list (CRL) and certificate trusted list (CTL), maximum performance test/stress test and functionality of message content verification.
4) A report of test item performance is provided and archived.
5) Test mode is deactivated, the vehicle passes EOL test.

### 4.7.5 In-Field Inspection (IFI)

The goal is to verify ITS-ability of SUTs in the field and maintain network quality.

Basic, short test performed by RSUs or OBUs of designated entities (e.g. toll system, police cars) to ensure road safety and network quality. A short set of tests to verify SUT operability in a limited time frame (e.g. vehicle drive-by). In contrast to other damages on vehicles like broken lights, V2X module problems give no visual feedback. This test mode enables authorities to quickly check for non-visual, systematic problems of a vehicle.

EXAMPLE: Road authorities conduct spot check of vehicles on highways:

1) The vehicle enters transmission distance of stationary control.
2) DTS activates the test mode in the V2X OBU of the vehicle (SUT).
3) DTS executes tests using test items transmission ability, reception ability, protocol conformance after SW-update, functionality of accepting, functionality of rejecting certificates, functionality of certificate revocation list (CRL) and certificate trusted list (CTL) and message content verification.
4) The vehicle uses non-compliant SW-version. A report is provided to the transport authority.
5) Test mode is deactivated, the vehicle leaves transmission range.

# History

| Document history | | |
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| V1.1.1 | November 2019 | Publication |
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