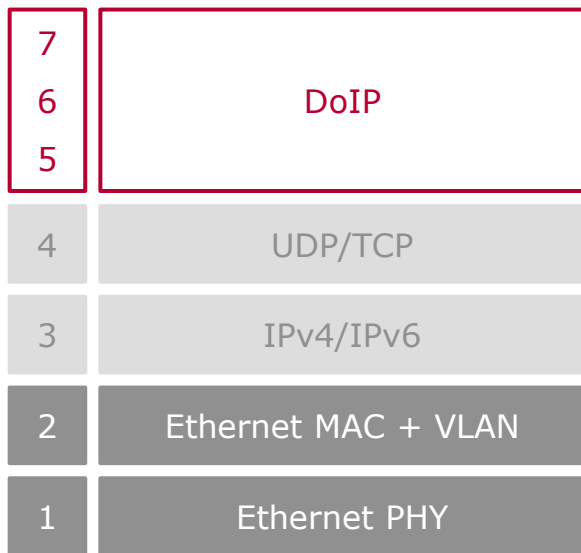# ▶▶ Fast Vehicle Diagnostics with DoIP

Also for In-Vehicle Ethernet ECUs?

Protocol Introduction

ISO 13400 – Diagnostic communication over Internet Protocol (DoIP)

▶ Diagnostics and ECU re-programming

▶ Vehicle access protocol

7 6 5	DoIP
4	UDP/TCP
3	IPv4/IPv6
2	Ethernet MAC + VLAN
1	Ethernet PHY

ISO/OSI Model

Advantages

▶ High-speed vehicle access

▶ Ethernet and TCP/IP as well-known technologies

▶ Parallel ECU re-programming via gateway

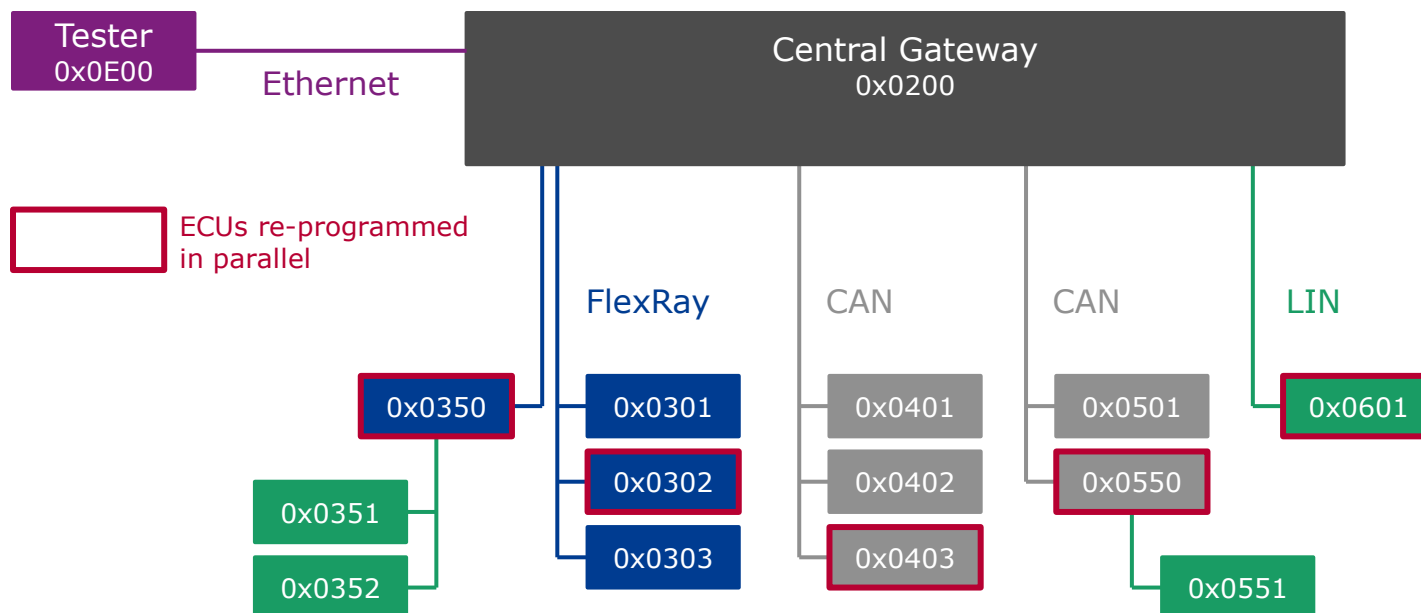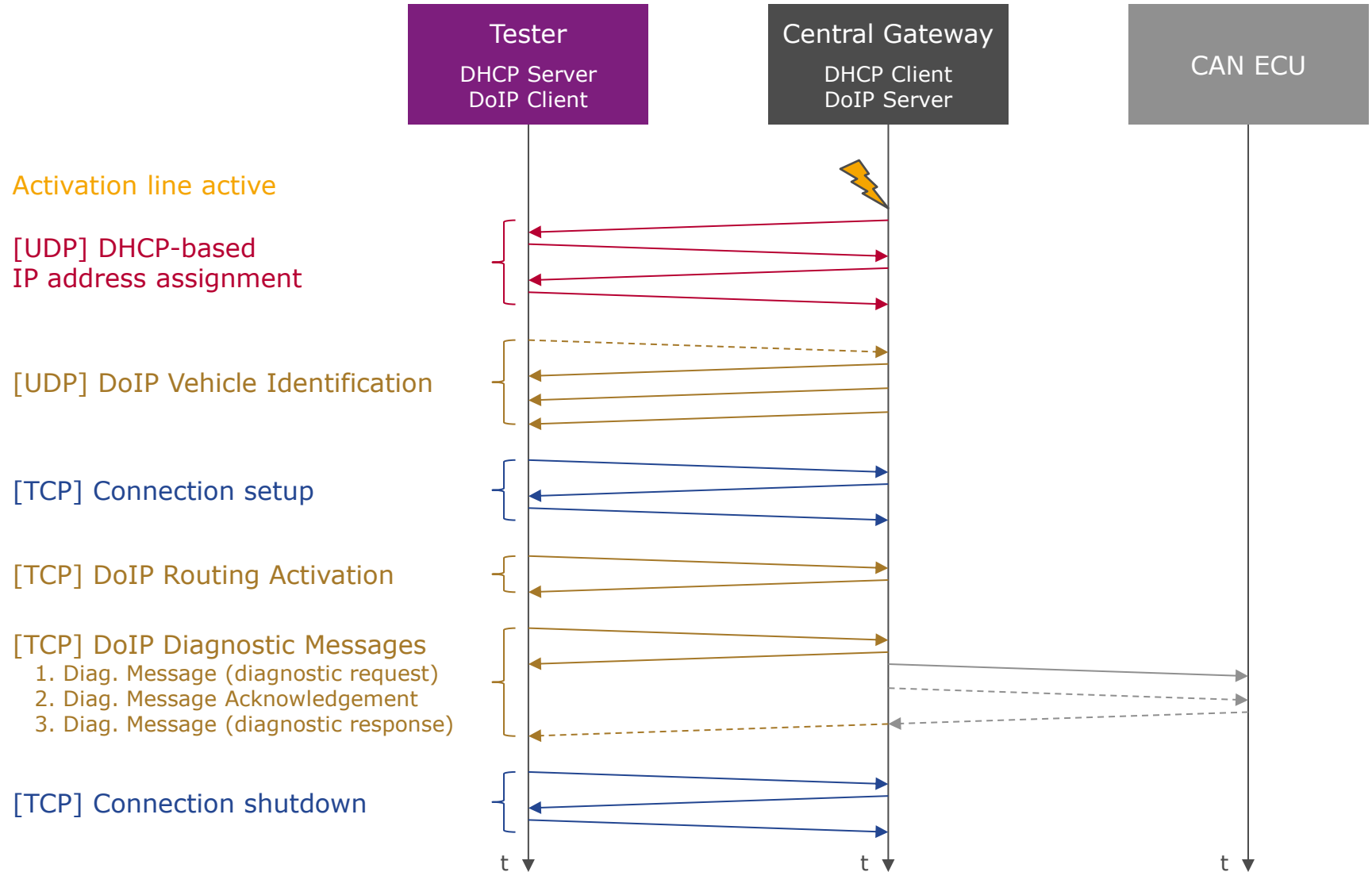| PRB	Ethernet Hdr	IP Hdr	UDP/TCP Hdr	DoIP Hdr	Payload e.g. UDS data	CRC

Ethernet Frame

DoIP Gateway to Classical Bus Systems

Tester is connected via Ethernet to the gateway and uses DoIP for diagnostics and ECU re-programming

▶ Addressing of ECUs is based on logical DoIP addresses
  ▶ Gateway maintains address mapping table and forwards UDS messages
▶ Due to high bandwidth of Ethernet, parallel ECU re-programming is possible

| Tester 0x0E00 | — Ethernet — | Central Gateway 0x0200 |

ECUs re-programmed in parallel

FlexRay: 0x0350, 0x0301, 0x0302, 0x0303, 0x0351, 0x0352
CAN: 0x0401, 0x0402, 0x0403
CAN: 0x0501, 0x0550, 0x0551
LIN: 0x0601

DoIP Gateway to CAN

Tester	Central Gateway	CAN ECU
DHCP Server DoIP Client	DHCP Client DoIP Server	

Activation line active

[UDP] DHCP-based
IP address assignment

[UDP] DoIP Vehicle Identification

[TCP] Connection setup

[TCP] DoIP Routing Activation

[TCP] DoIP Diagnostic Messages
   1. Diag. Message (diagnostic request)
   2. Diag. Message Acknowledgement
   3. Diag. Message (diagnostic response)

[TCP] Connection shutdown

t   t   t
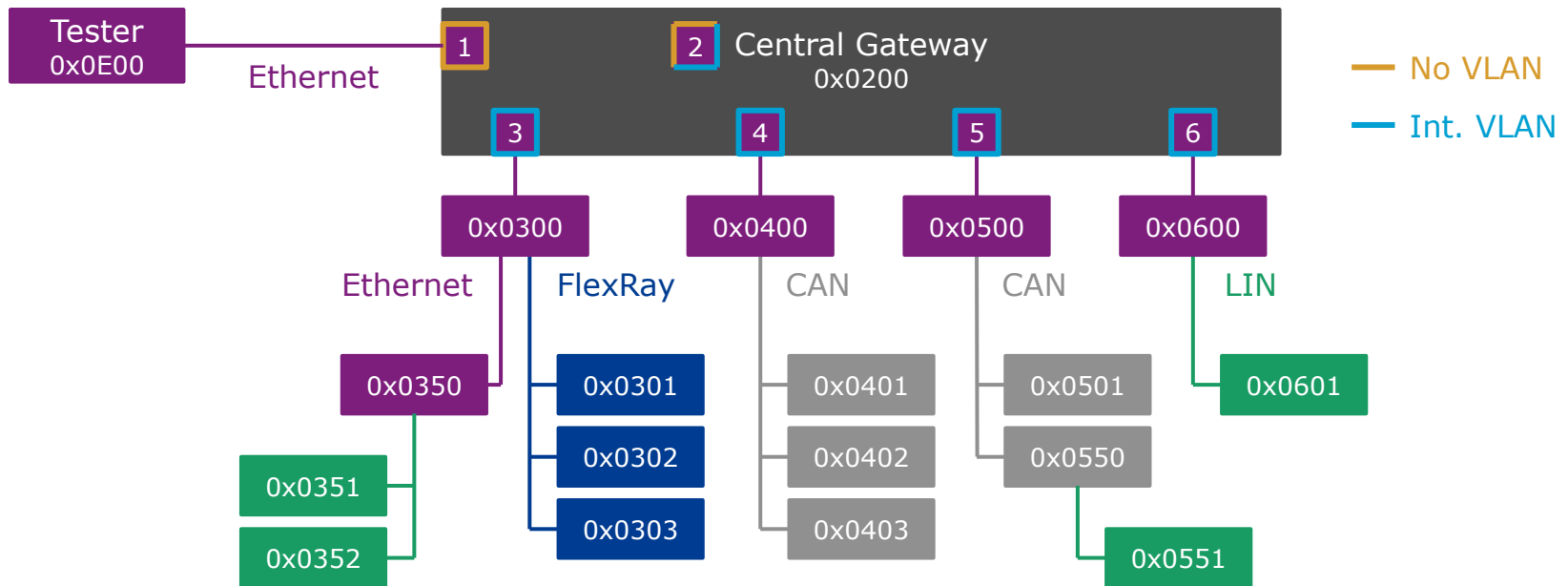
Diagnostics of In-Vehicle Ethernet ECUs

Not explicitly specified by ISO 13400 but there are two paradigms

1. Transparent switch
   ▶ Tester has direct access to in-vehicle Ethernet ECUs
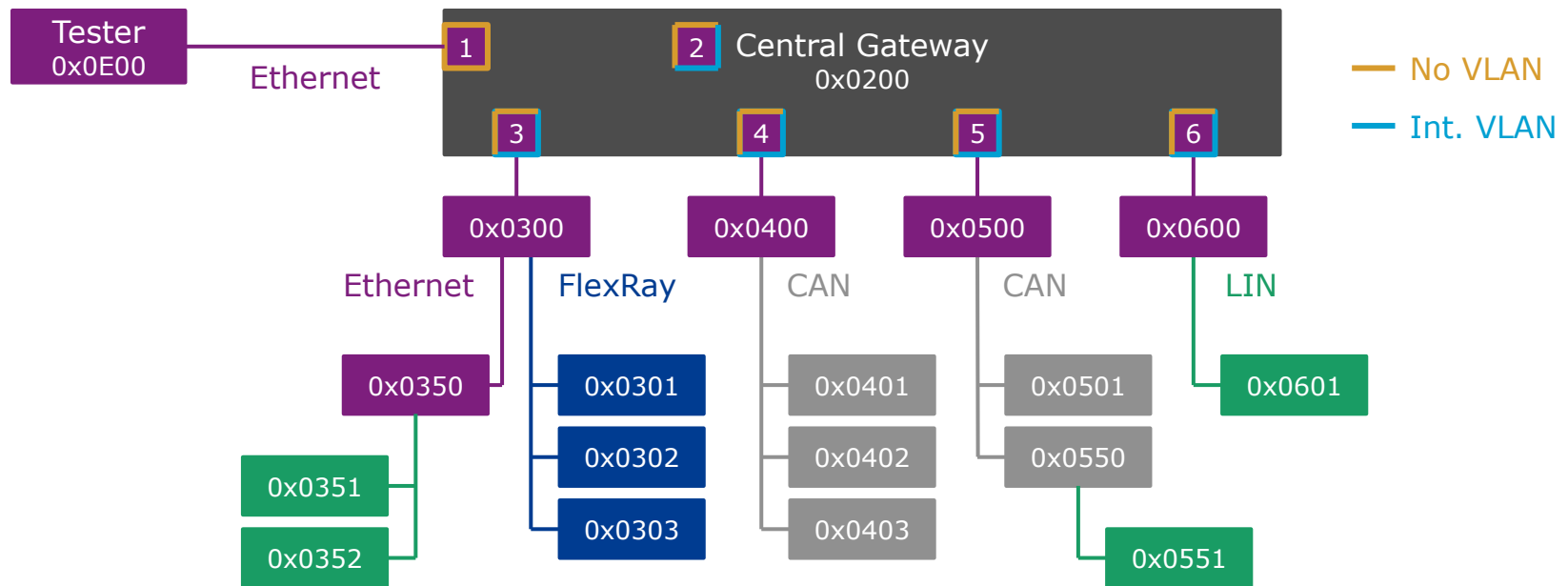
2. Locked switch (e.g. via VLAN encapsulation)
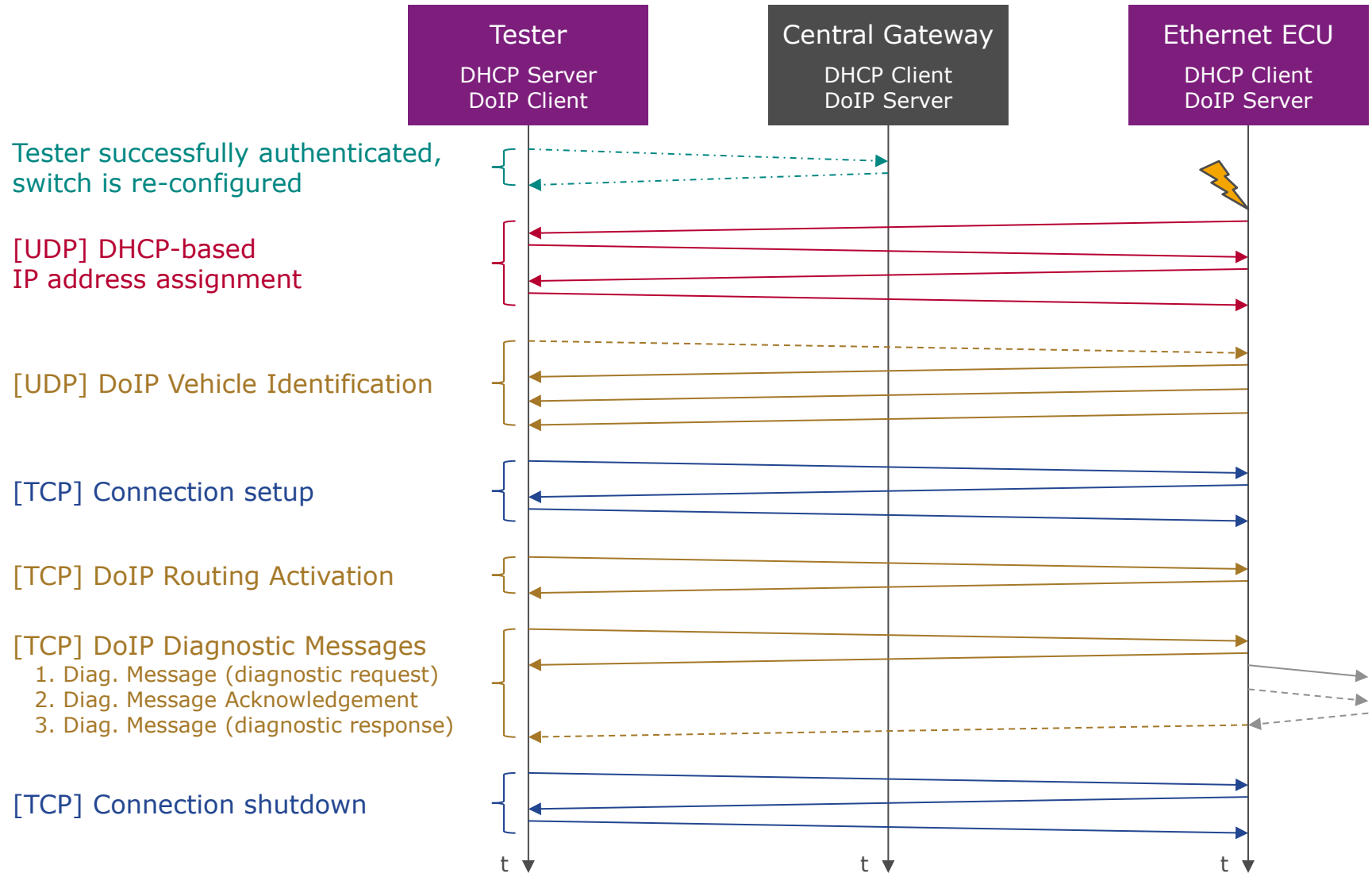   ▶ Tester has no direct access to in-vehicle Ethernet ECUs

Tester 0x0E00		Central Gateway 0x0200

```
Tester          1        2   Central Gateway
0x0E00                        0x0200
       Ethernet
                3        4       5        6

              0x0300   0x0400  0x0500   0x0600

      Ethernet    FlexRay   CAN      CAN      LIN

     0x0350    0x0301   0x0401   0x0501   0x0601

0x0351         0x0302   0x0402   0x0550

0x0352         0x0303   0x0403            0x0551
```

— No VLAN
— Int. VLAN

Transparent Switch

Dynamic switch re-configuration

▶ At the beginning, the tester can only communicate with the gateway
  ▶ Locked switch because of security reasons

▶ After tester authentication, the gateway re-configures the switch
  ▶ Tester has direct access and gateway is no bottleneck anymore

Communication between Tester and Ethernet ECUs

	Tester	Central Gateway	Ethernet ECU
	DHCP Server	DHCP Client	DHCP Client
	DoIP Client	DoIP Server	DoIP Server

Tester successfully authenticated, switch is re-configured

[UDP] DHCP-based
IP address assignment

[UDP] DoIP Vehicle Identification

[TCP] Connection setup

[TCP] DoIP Routing Activation

[TCP] DoIP Diagnostic Messages
  1. Diag. Message (diagnostic request)
  2. Diag. Message Acknowledgement
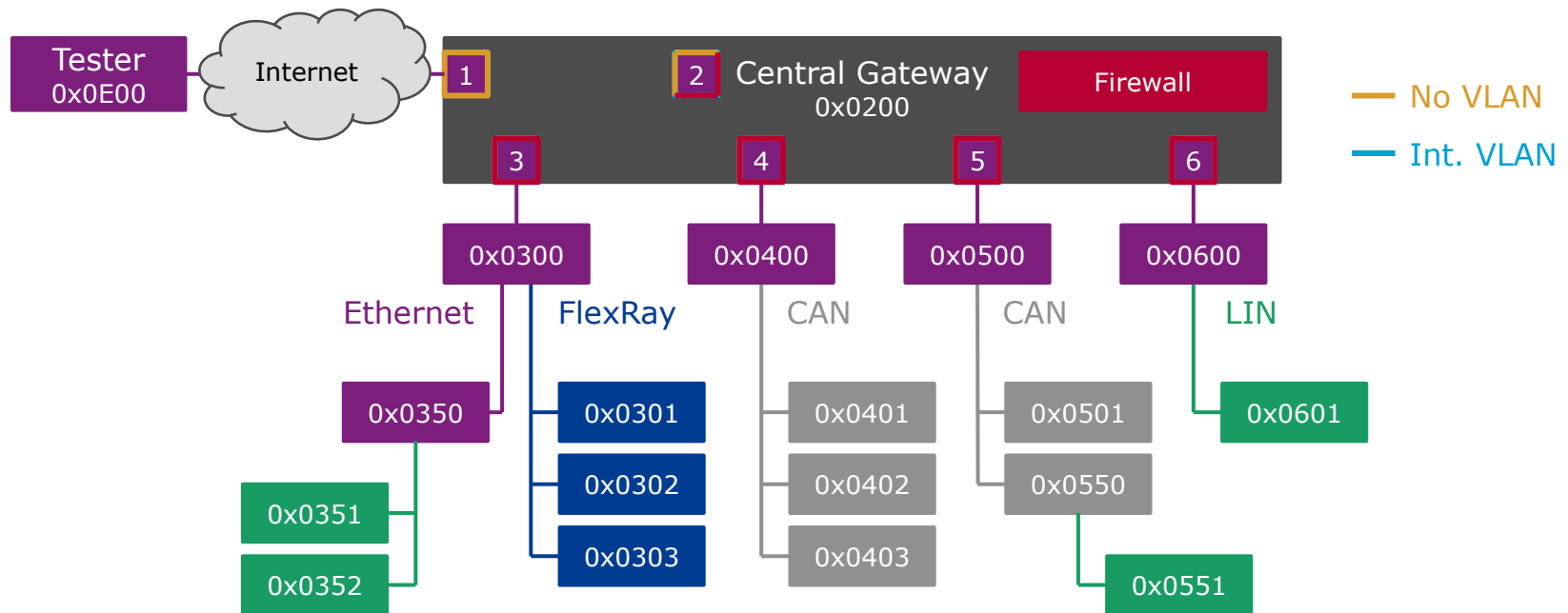 3. Diag. Message (diagnostic response)
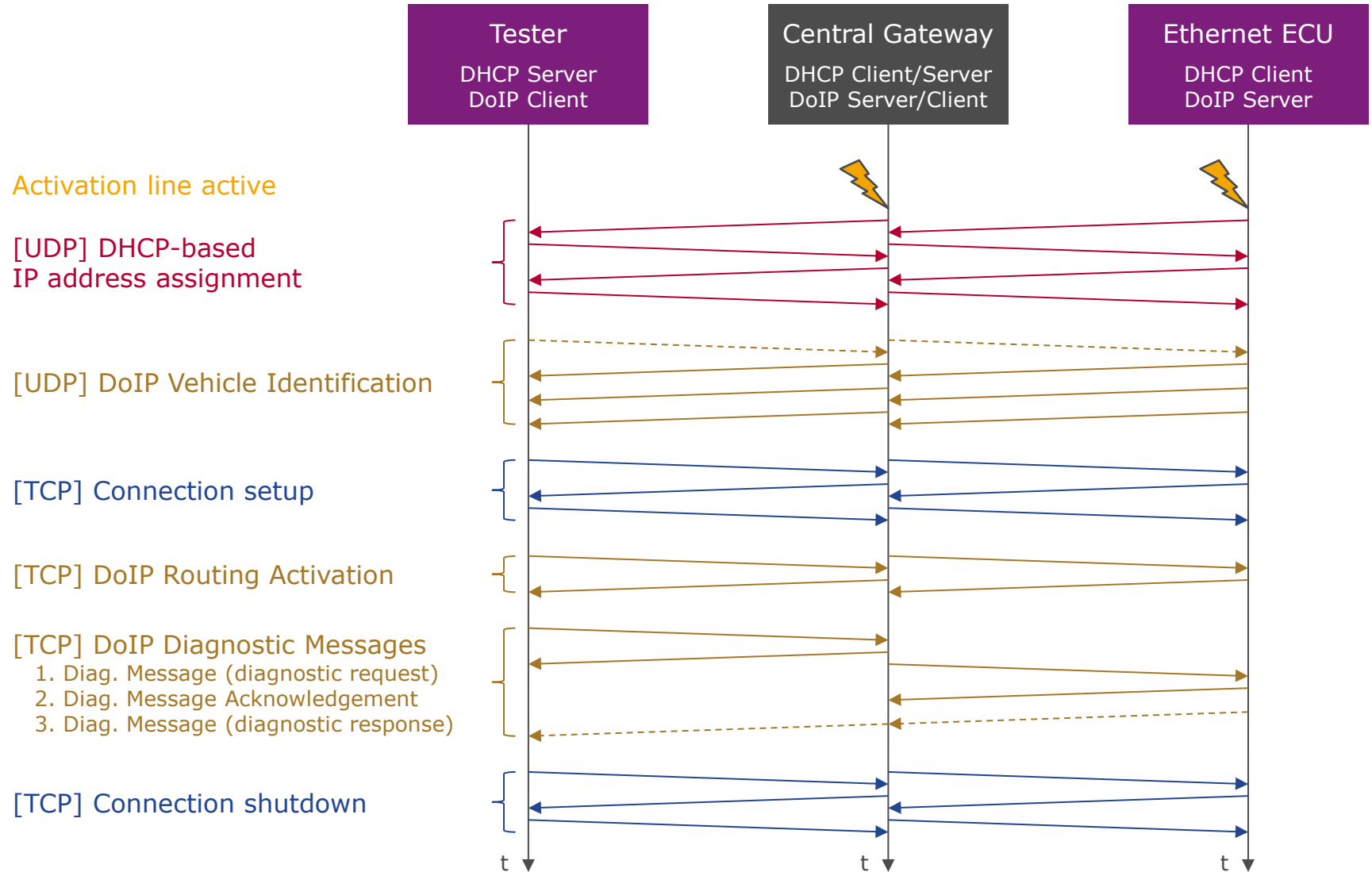
[TCP] Connection shutdown

Locked Switch

A transparent switch is a potential security risk

▶ Once the switch is transparent, other external devices are able to directly communicate with in-vehicle Ethernet ECUs

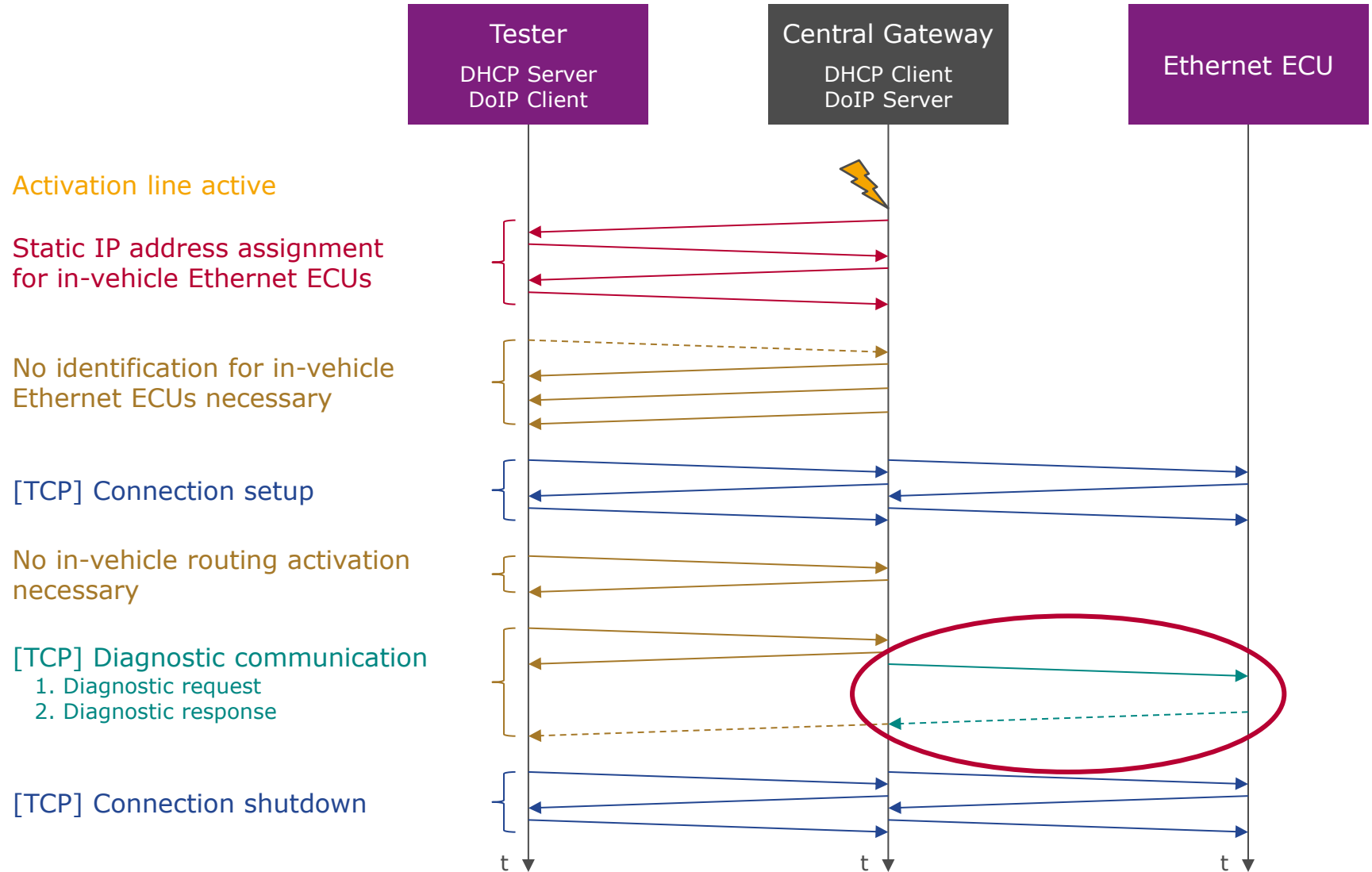   ▶ E.g. if the tester connects to the vehicle over the Internet

When using a locked switch, the gateway can implement security mechanisms

DoIP Gateway to Ethernet – Emulated DoIP Tester

Tester	Central Gateway	Ethernet ECU
DHCP Server	DHCP Client/Server	DHCP Client
DoIP Client	DoIP Server/Client	DoIP Server

Activation line active

[UDP] DHCP-based
IP address assignment

[UDP] DoIP Vehicle Identification

[TCP] Connection setup

[TCP] DoIP Routing Activation

[TCP] DoIP Diagnostic Messages
   1. Diag. Message (diagnostic request)
   2. Diag. Message Acknowledgement
   3. Diag. Message (diagnostic response)

[TCP] Connection shutdown

DoIP Gateway to Ethernet – Simplified Routing

Tester	Central Gateway	Ethernet ECU
DHCP Server DoIP Client	DHCP Client DoIP Server	

Activation line active

Static IP address assignment
for in-vehicle Ethernet ECUs

No identification for in-vehicle
Ethernet ECUs necessary

[TCP] Connection setup

No in-vehicle routing activation
necessary

[TCP] Diagnostic communication
  1. Diagnostic request
  2. Diagnostic response

[TCP] Connection shutdown

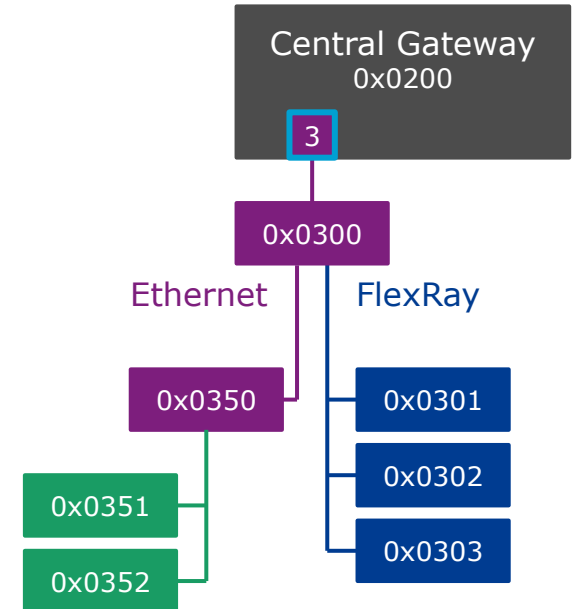# Simplified Routing to In-Vehicle Ethernet ECUs

Multiple options

1. Routing of pure UDS messages (CAN like)
   - ► Addressing based on port numbers
     - › Multiple sockets required, if ECUs on sub-networks shall be diagnosed
   - ► Not possible to handle multiple diagnostic requests in one frame

2. 1:1 routing of DoIP Diagnostic Messages
   - ► DoIP addresses are used
   - ► Multiple diagnostic requests in one frame
   - ► Open points
     - ► "Protocol" is currently not specified
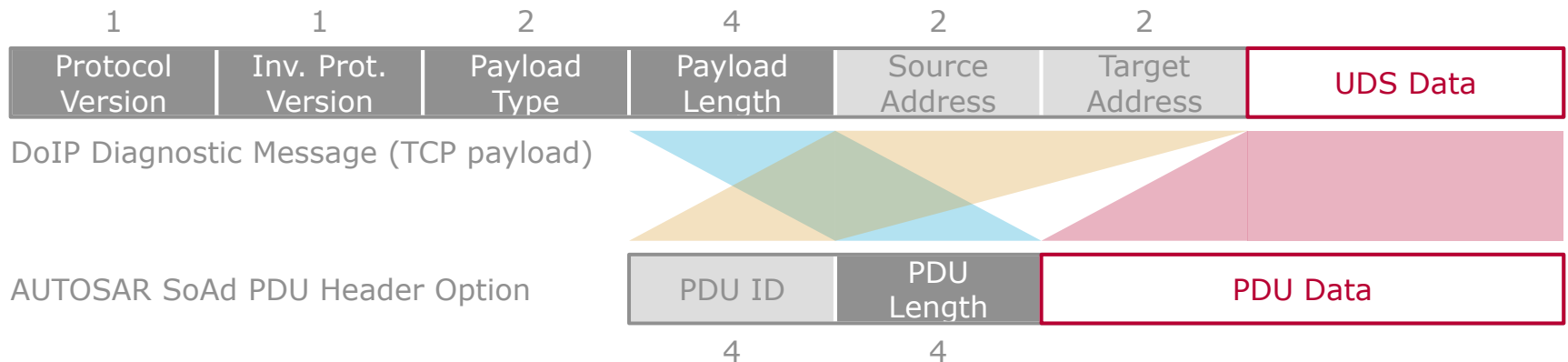   - ► DoIP Diagnostic Messages have some unnecessary overhead for this use case

1	1	2	4	2	2	
Protocol Version	Inv. Prot. Version	Payload Type	Payload Length	Source Address	Target Address	UDS Data

DoIP Diagnostic Message (TCP payload)

Simplified Routing to In-Vehicle Ethernet ECUs

3. Slim transport protocol

- ▶ Protocol Version / Inverse Protocol Version not required in-vehicle
- ▶ Payload Type not required because only diagnostic requests and responses are routed

1	1	2	4	2	2	
Protocol Version	Inv. Prot. Version	Payload Type	Payload Length	Source Address	Target Address	UDS Data

DoIP Diagnostic Message (TCP payload)

AUTOSAR SoAd PDU Header Option

PDU ID	PDU Length	PDU Data
4	4	

- ▶ AUTOSAR defines the Socket Adaptor PDU Header Option
  - > Transmission and reception of multiple PDUs within one Ethernet frame

- ➜ Socket Adaptor PDU Header Option can be used as a slim transport protocol for diagnostic communication to in-vehicle Ethernet ECUs
  - ▶ Efficient routing in AUTOSAR basic software possible

Also for In-Vehicle Ethernet ECUs? – Yes, but…

…there are different ways to diagnose in-vehicle Ethernet ECUs

1. Tester has direct access – transparent switch
   - Direct access to in-vehicle Ethernet ECUs via DoIP
     - + Very good performance because gateway is no bottleneck
     - – Security risk, dependent on use cases and infrastructure

2. Tester has no direct access – locked switch
   - AUTOSAR Socket Adaptor PDU Header Option between gateway and in-vehicle Ethernet ECUs
     - + Security mechanisms can be applied within the gateway
     - – Performance of the gateway likely to be a bottleneck

- There are more topics to be considered: Unique MAC addresses, CAN-based testers, diagnosing without gateway, complexity of ECUs and testers, …

➜ Combinations of the two presented paradigms are possible

Your questions are welcome!

Author:
Marc Weber
Vector Informatik GmbH