6th UCAAT User Conference on Advanced Automated Testing

ETSI

Paris, 16-18 October 2018

Organizer: TESTING SOLUTIONS &SERVICES

Diagnosis of V2X communication via evaluation modules and textual rule sets

Presented by Tim Ruß

ifak

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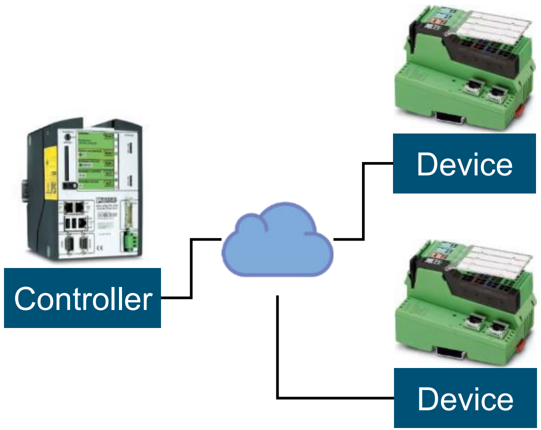
Motivation

ifak: Institute for Automation and Communication

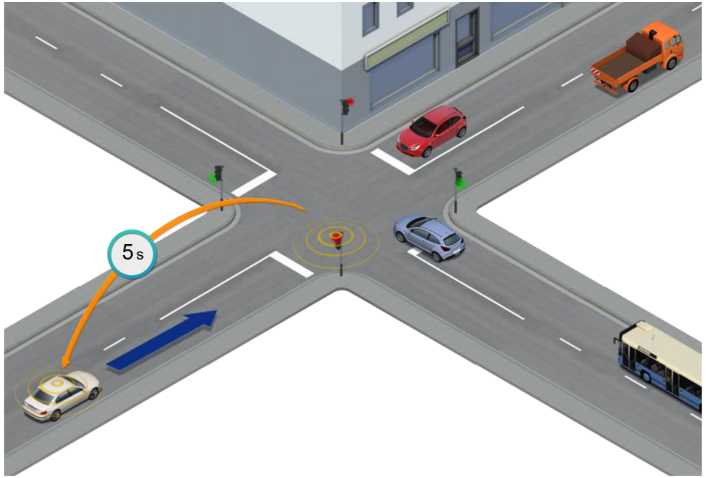
- Applied research
- Test laboratories

Examples for our communication domains

Factory Automation



Vehicle-to-X (also: Car2X)



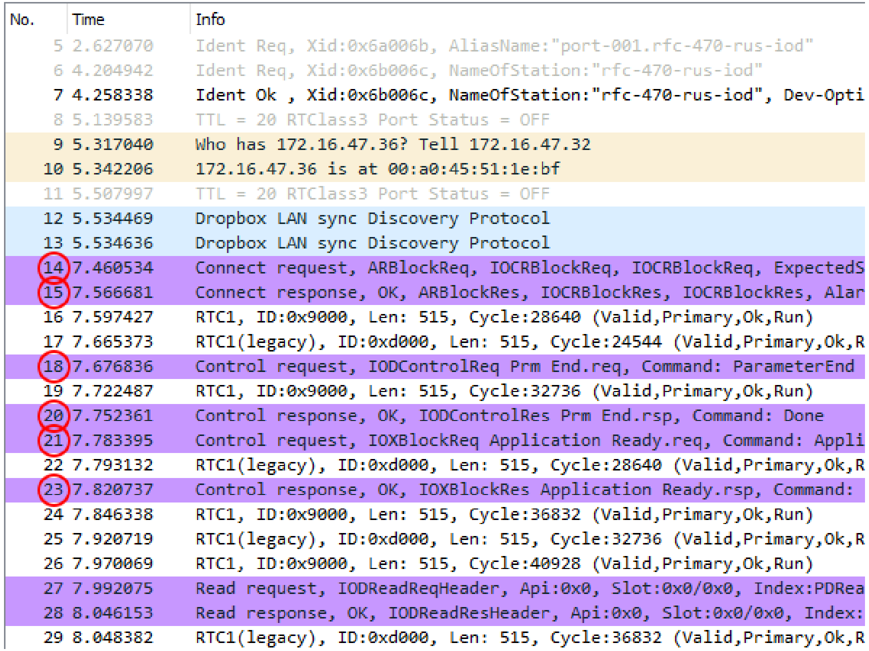
Left images © Phoenix Contact

Right image © CAR 2 CAR Communication Consortium

Manual process: Checking Wireshark records

- Search for connection / startup sequence
- Search for errors (alarms, connection releases…)

→ Demand to automate such processes



```
No.  Time      Info
  5 2.627070   Ident Req, Xid:0x6a006b, AliasName:"port-001.rfc-470-rus-iod"
  6 4.204942   Ident Req, Xid:0x6b006c, NameOfStation:"rfc-470-rus-iod"
  7 4.258338   Ident Ok , Xid:0x6b006c, NameOfStation:"rfc-470-rus-iod", Dev-Opti
  8 5.139583   TTL = 20 RTClass3 Port Status = OFF
  9 5.317040   Who has 172.16.47.36? Tell 172.16.47.32
 10 5.342206   172.16.47.36 is at 00:a0:45:51:1e:bf
 11 5.507997   TTL = 20 RTClass3 Port Status = OFF
 12 5.534469   Dropbox LAN sync Discovery Protocol
 13 5.534636   Dropbox LAN sync Discovery Protocol
 14 7.460534   Connect request, ARBlockReq, IOCRBlockReq, IOCRBlockReq, ExpectedS
 15 7.566681   Connect response, OK, ARBlockRes, IOCRBlockRes, IOCRBlockRes, Alar
 16 7.597427   RTC1, ID:0x9000, Len: 515, Cycle:28640 (Valid,Primary,Ok,Run)
 17 7.665373   RTC1(legacy), ID:0xd000, Len: 515, Cycle:24544 (Valid,Primary,Ok,R
 18 7.676836   Control request, IODControlReq Prm End.req, Command: ParameterEnd
 19 7.722487   RTC1, ID:0x9000, Len: 515, Cycle:32736 (Valid,Primary,Ok,Run)
 20 7.752361   Control response, OK, IODControlRes Prm End.rsp, Command: Done
 21 7.783395   Control request, IOXBlockReq Application Ready.req, Command: Appli
 22 7.793132   RTC1(legacy), ID:0xd000, Len: 515, Cycle:28640 (Valid,Primary,Ok,R
 23 7.820737   Control response, OK, IOXBlockRes Application Ready.rsp, Command:
 24 7.846338   RTC1, ID:0x9000, Len: 515, Cycle:36832 (Valid,Primary,Ok,Run)
 25 7.920719   RTC1(legacy), ID:0xd000, Len: 515, Cycle:32736 (Valid,Primary,Ok,R
 26 7.970069   RTC1, ID:0x9000, Len: 515, Cycle:40928 (Valid,Primary,Ok,Run)
 27 7.992075   Read request, IODReadReqHeader, Api:0x0, Slot:0x0/0x0, Index:PDRea
 28 8.046153   Read response, OK, IODReadResHeader, Api:0x0, Slot:0x0/0x0, Index:
 29 8.048382   RTC1(legacy), ID:0xd000, Len: 515, Cycle:36832 (Valid,Primary,Ok,R
```

Agenda

- Scope and methods
- Approach
- Use case
- Summary

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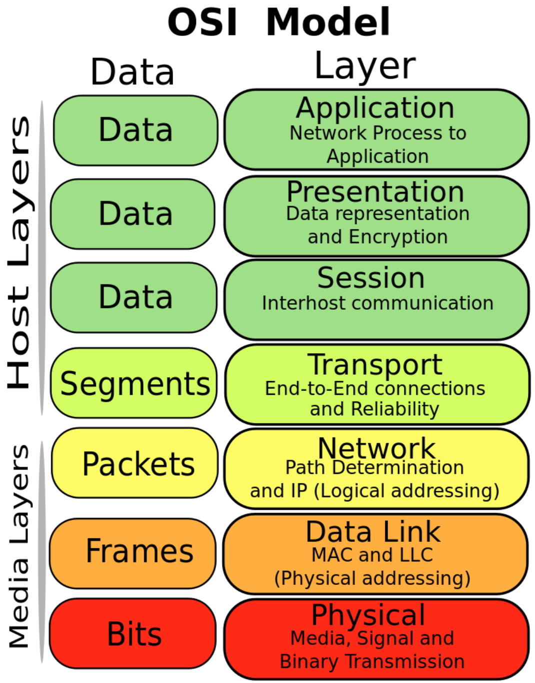
Scope and methods

Scope and terminology

- Network communication of distributed (computer) systems:
  - OSI reference model
  - Protocol Data Units of higher levels: “messages”
- “Checking” those messages:
  - **Verification**: If a specification is correct according to the design. Prior to the implementation.
  - **Validation**: Check if customer expectations fulfilled
  - **Conformance check**: Check if an implementation matches the underlying specification



OSI Model

	Data	Layer
Host Layers	Data	Application Network Process to Application
	Data	Presentation Data representation and Encryption
	Data	Session Interhost communication
	Segments	Transport End-to-End connections and Reliability
Media Layers	Packets	Network Path Determination and IP (Logical addressing)
	Frames	Data Link MAC and LLC (Physical addressing)
	Bits	Physical Media, Signal and Binary Transmission

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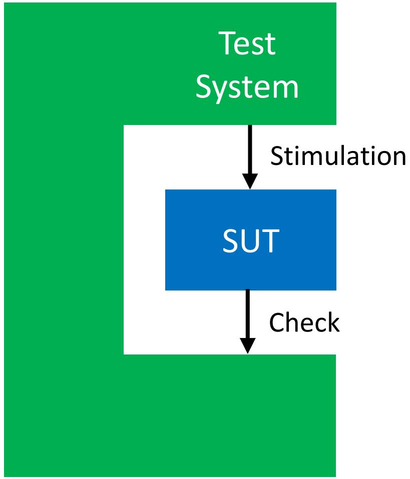
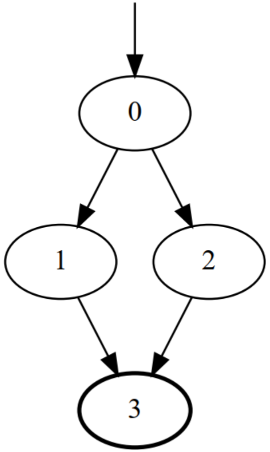
Testing methods for software (e.g. source code)

- Architecture: Test system around System Under Test (SUT)
  - Stimulation via input parameters
  - Check of states or return values
  - E.g. Unit Tests
- Coverage criteria
  - E.g. check program execution paths





Testing network protocols

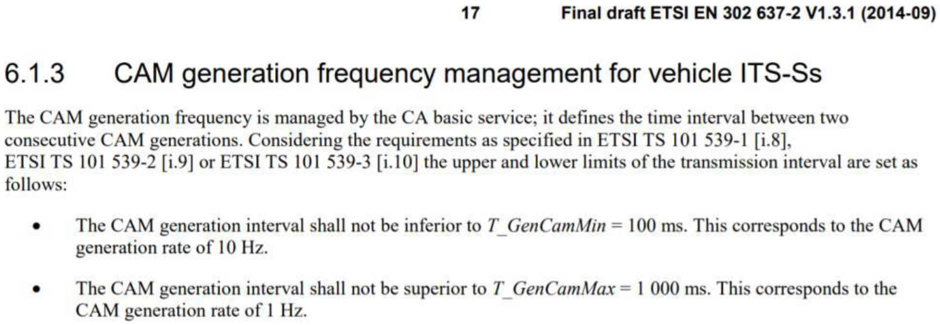
- Fuzzing: Generate random input/network data
- Conformance check
  - Replace other protocol layers with test system (upper tester, lower tester)
  - Run <u>subsequent</u> test cases…

→Difficult for already running systems without test interfaces

→Demand for diagnosis after commissioning

Protocol specifications given in different formats

Example: Generation frequency of V2X status messages (CAMs) as plain text:



17 Final draft ETSI EN 302 637-2 V1.3.1 (2014-09)

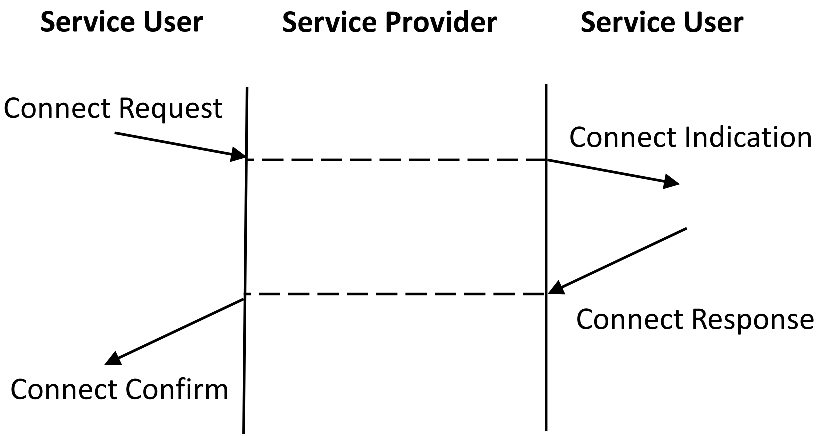
6.1.3 CAM generation frequency management for vehicle ITS-Ss

The CAM generation frequency is managed by the CA basic service; it defines the time interval between two consecutive CAM generations. Considering the requirements as specified in ETSI TS 101 539-1 [i.8], ETSI TS 101 539-2 [i.9] or ETSI TS 101 539-3 [i.10] the upper and lower limits of the transmission interval are set as follows:

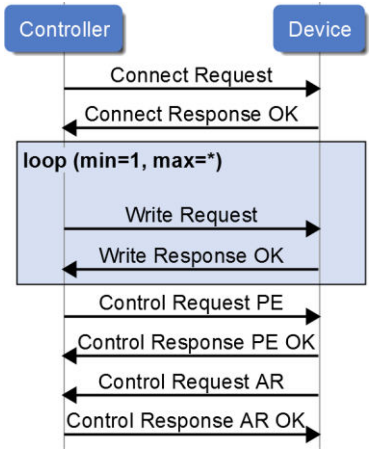
- The CAM generation interval shall not be inferior to *T_GenCamMin* = 100 ms. This corresponds to the CAM generation rate of 10 Hz.
- The CAM generation interval shall not be superior to *T_GenCamMax* = 1 000 ms. This corresponds to the CAM generation rate of 1 Hz.

Formal graphical descriptions for network protocols (1)

Time Flow Charts

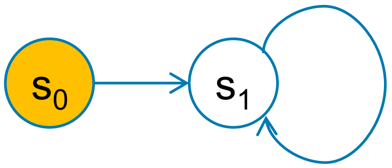


Sequence Charts

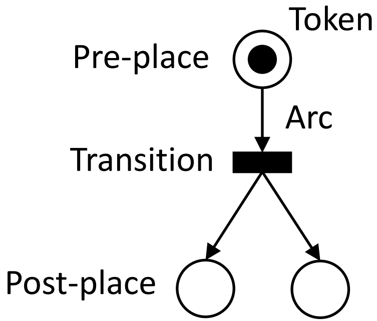


Formal graphical descriptions for network protocols (2)

Finite State Machines



Petri nets



Aim: Check requirements and errors at the same time (like parallel test cases, but not all have to be executed) → diagnosis

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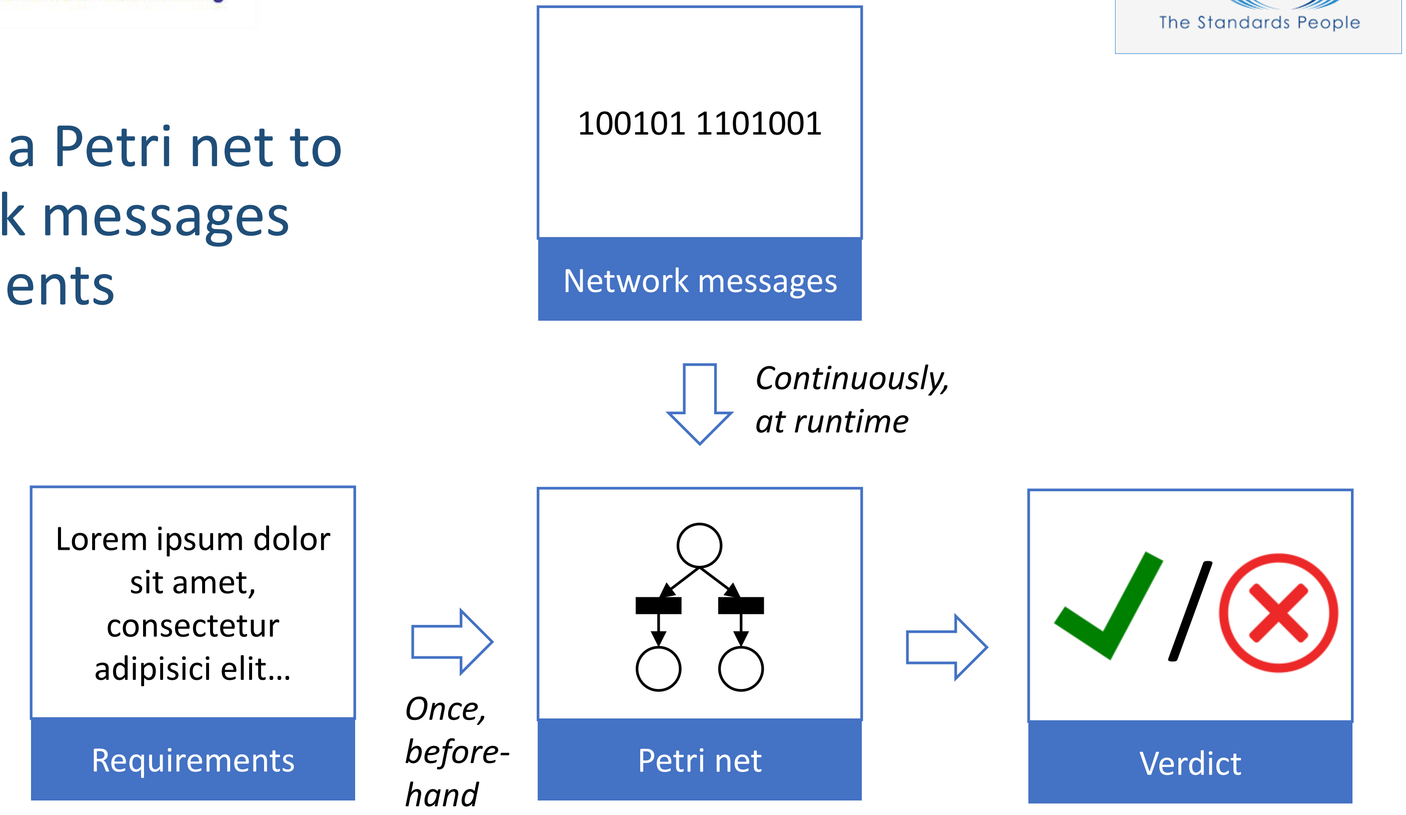
Approach

Approach: Using a Petri net to compare network messages against requirements



100101 1101001

Network messages

Continuously, at runtime

Lorem ipsum dolor sit amet, consectetur adipisici elit…

Requirements

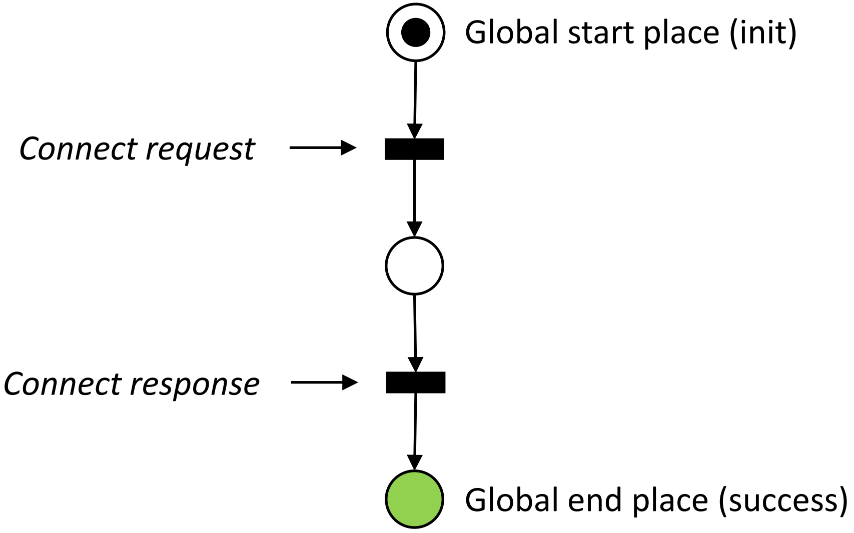
Once, before-hand

Petri net

Verdict

Case 1: Check a sequence of messages

Example: *“A connect request is followed by a connect response.”*



Global start place (init)

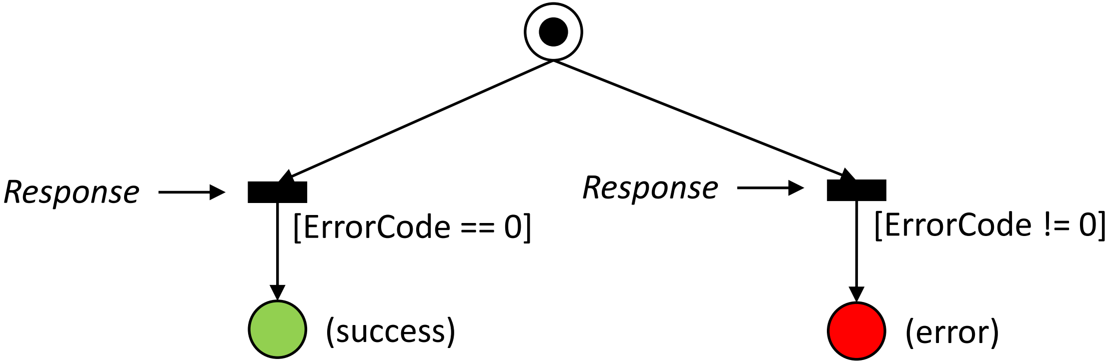
Connect request

Connect response

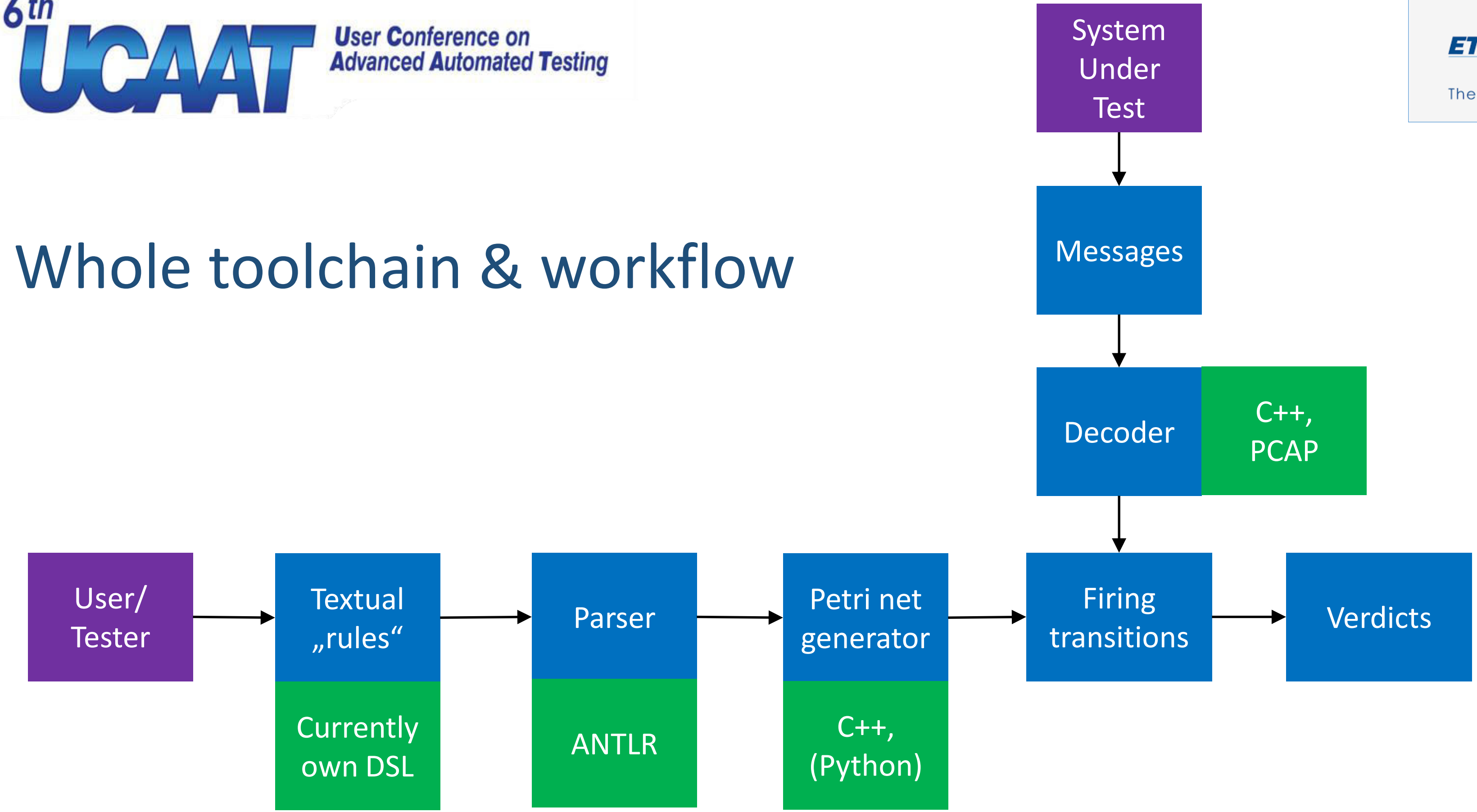
Global end place (success)

Case 2: Check parameter values within messages

Example: *“The ErrorCode of the response must be 0.”*



Whole toolchain & workflow



Creation of structures via subnets

- Structures for control flow, e.g. from UML Sequence Diagrams
- Considered most important:
  - Alternatives (“alt”)
  - Parallels (“par”)
  - Loops (“loop”)
  - Errors (“not”)
- Start and end places as interfaces between structures

Description of net creation with Python

Text

„A net N consists of places P, transitions T and flow relations F.“

Mathematical

$N = (P; T; F)$

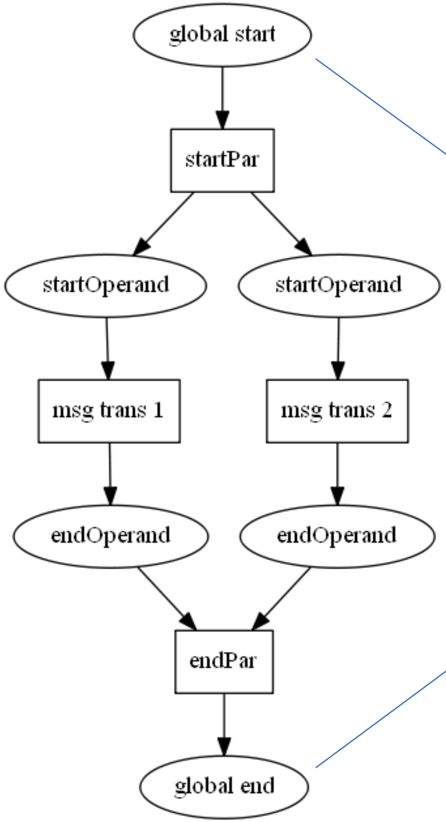
Python

```
class Petrinet :
  def __init__ (self):
    self.places = []
    self.transitions = []
    self.arcs = []
```

```
def createPar(self, interfaces, operandCount):
  startTrans = self.petrinet.addTransition()
  self.petrinet.addArc(interfaces.getStartPlace(), startTrans)
  endTrans = self.petrinet.addTransition()
  self.petrinet.addArc(endTrans, interfaces.getEndPlace())
  operands = []

  for i in range(0, operandCount):
    operandStartPlace = self.petrinet.addPlace()
    self.petrinet.addArc(startTrans, operandStartPlace)
    operandEndPlace = self.petrinet.addPlace()
    self.petrinet.addArc(operandEndPlace, endTrans)
    operandInterfaces = NetInterfaces(operandStartPlace, operandEndPlace)
    operands.append(operandInterfaces)

  return operands
```



possible interfaces to other structures

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Use Case

Use Case: Vehicle-to-X communication (V2X)

- Vehicles send out status messages periodically (Cooperative Awareness Messages, CAM)
- Monitoring modules shall capture and check messages according to user defined rules

First prototype

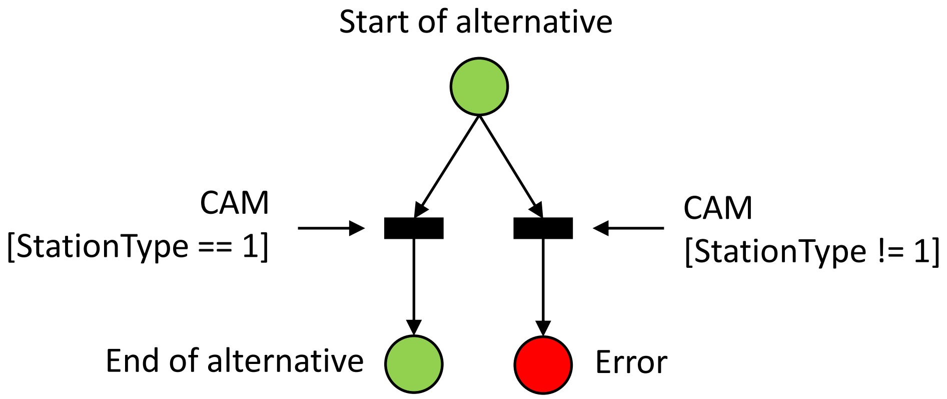
New version

User-selected requirements for CAM payload

- User defined: StationType == 11 (Tram)
- From CAM protocol specification: 1 Hz ≤ f ≤ 10 Hz

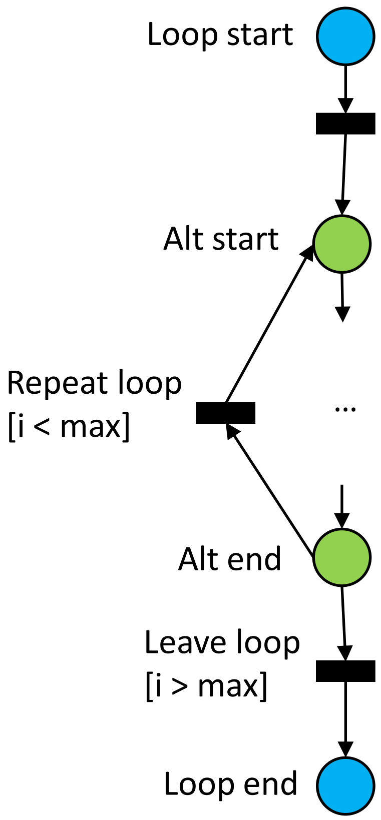
Check the vehicle role (1)

“Every CAM shall have a *<u>station type of 1.</u>”*



Check the vehicle role (2)

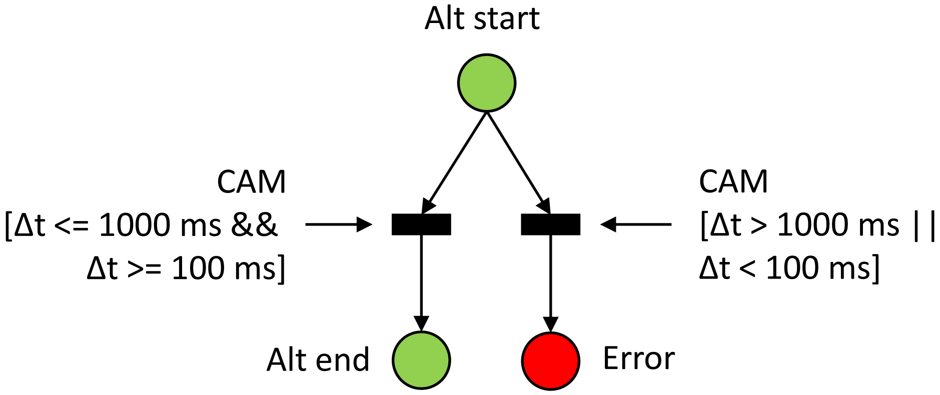
"<u>Every</u> CAM shall have a station type of 1."



Check the message interval (1)

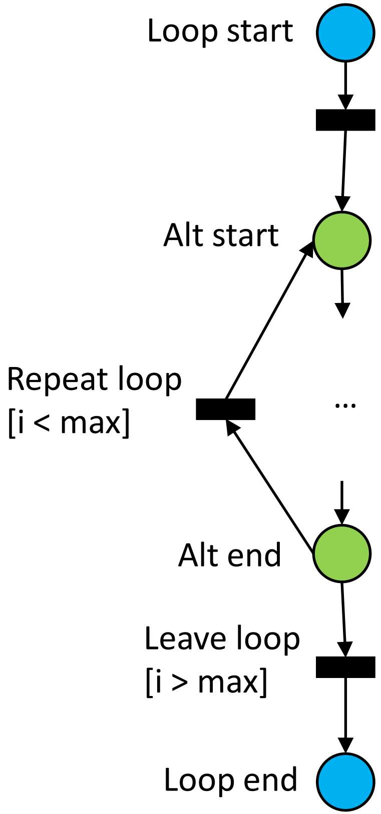
“The transmit frequency shall always be <u>between 1 Hz and 10 Hz</u>.”

$\Delta t = t_{CAM(n)} - t_{CAM(n-1)}$

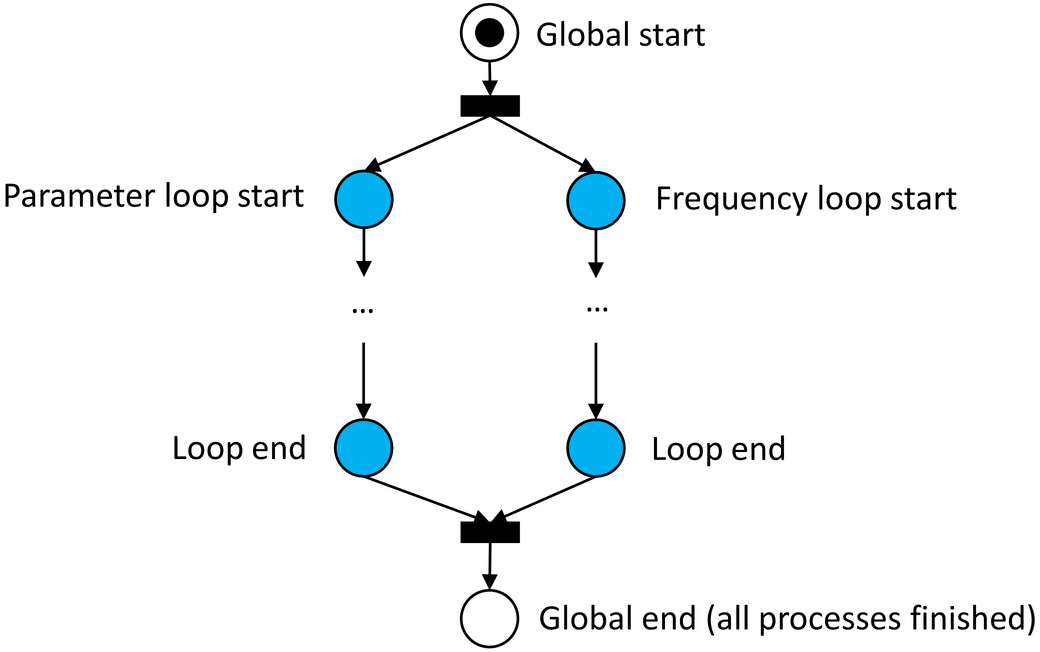


Check the message interval (2)

“The transmit frequency shall <u>always</u> be between 1 Hz and 10 Hz.”



Check parameter and frequency



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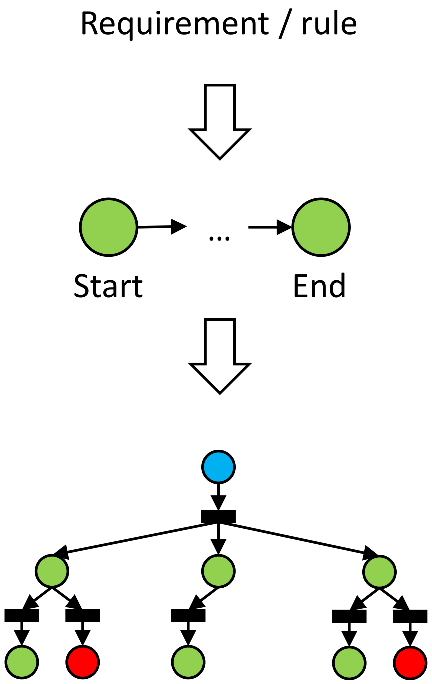
Summary

Summary

- Check several requirements and detect errors at the same time → Diagnosis
- User-selected requirements as “rules”
- Petri subnets with interface places
- Connect subnets
- React to decoded messages (move tokens), create verdicts



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Thank you for your kind attention

Tim Ruß

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ifak

(Backup)

Example for DSL

```
import <denm_cancelation.components> as stations
Rule {
    name: "DENM Cancelation";
    description: "Abkündigung einer DENM prüfen"
    Declaration {
        Signal {
            name: "V2X_DENM";
            use DENM.causeCode as cause;
        }
    }
    sequence {
        Loop [3] {
            Message CyclistWarning(from == rsu and to == car1);
            Message CyclistWarning(from == rsu and to == Any);
        }
        Message CyclistWarning(from == rsu and to == Any and canceled == true);
    }
}
```