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Authorities' roles in implementation and operational use of C-ITS services in Finland Preliminary results (2023)

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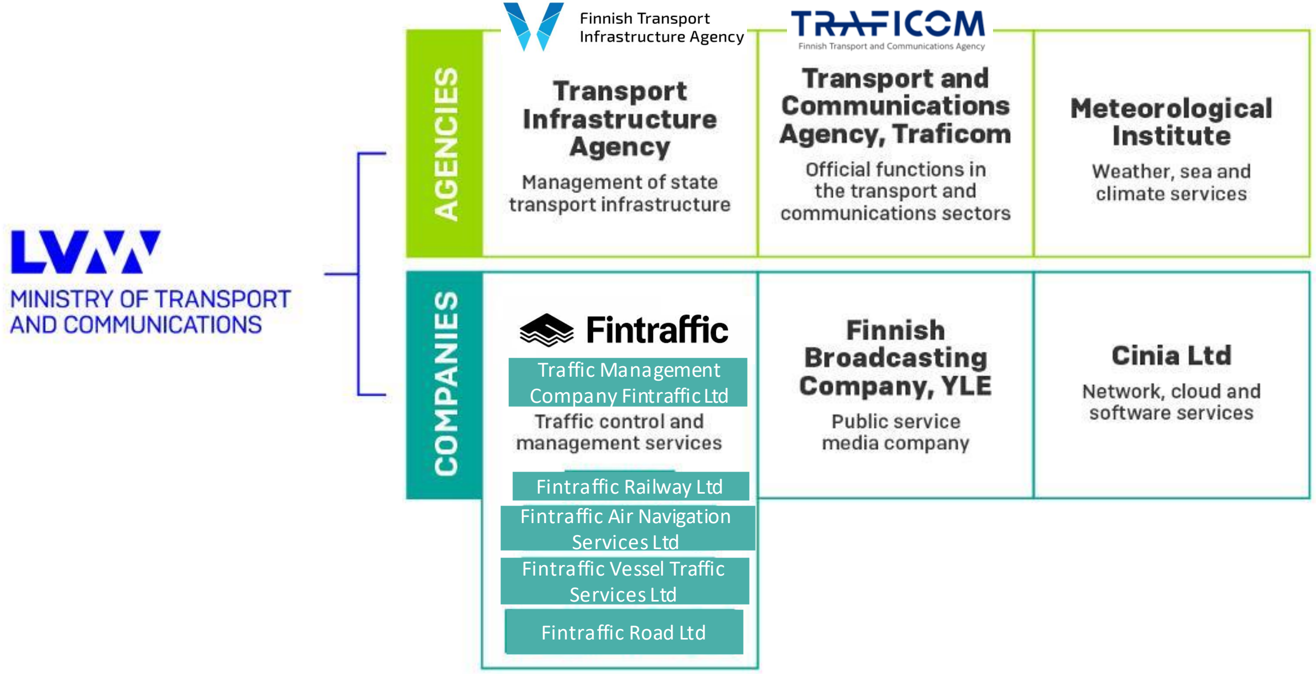
Composition of the administrative sector



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Ministry of Transport and Communications (2018). Press release.
Ministry of Transport and Communications. Administrative sector.
Fintraffic. Subsidiares.

Content

Authorities' roles in implementation and operational use of C-ITS services in Finland

1. Project background, objectives and methods
2. Summary of results
    1. A proposal for organizing the roles of public authorities in Finland
    2. A proposal for organizing the roles of services in Finland
    3. Exchanging C-ITS messages with automated vehicles: implications for roles
3. Discussion and recommendations

Note: Results of requirements and roles in European Union C-ITS Security Credential Management System (EU CCMS) in separate presentation

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1. Project background, objectives and methods

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Project Partners (Management Group)

- Finnish Transport and communications Agency (Traficom)
- Finnish Transport Infrastructure Agency (Väylävirasto)
- Ministry of Transport and Communications
- Fintraffic Ltd
- City of Tampere
- Consultants: Traficon Ltd and VTT Technical Research Centre of Finland Ltd

TRAFICOM Finnish Transport and Communications Agency

Finnish Transport Infrastructure Agency

LVM MINISTRY OF TRANSPORT AND COMMUNICATIONS

Fintraffic

TAMPERE

TRAFICON

VTT

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Aim of the project

1. How should C-ITS services be implemented in Finland?
2. What are the different actors and especially their roles in the implementation of the services and the infrastructure required by them, as well as in monitoring C-ITS services and C-ITS units?
3. Does transmitting C-ITS messages to automated vehicles and receiving messages from automated vehicles create any new responsibilities and roles, possible distribution of roles to different actors?

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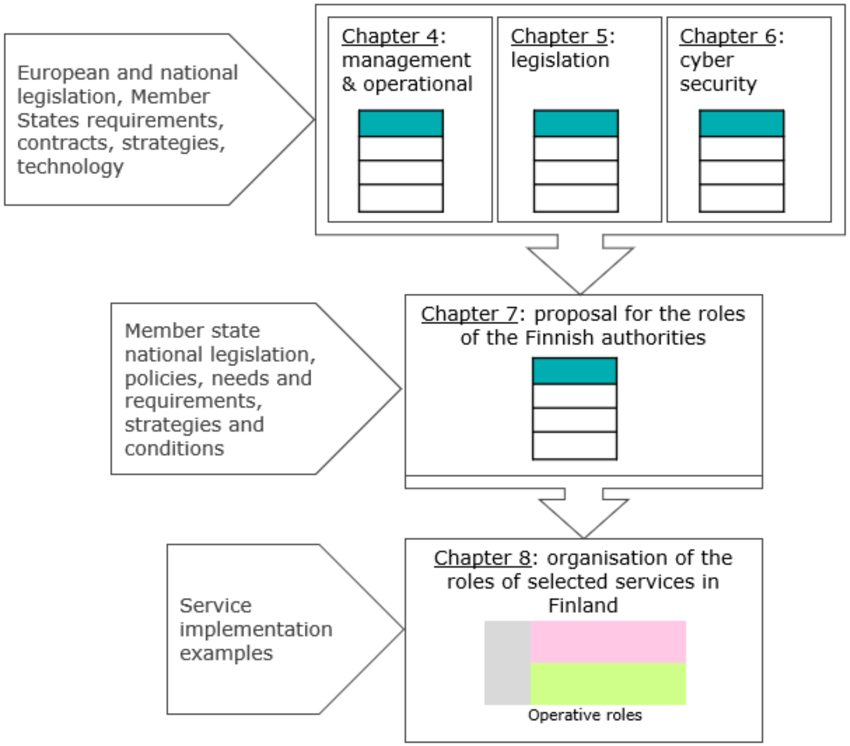
Methods

- **Literature review**: standards, research reports, surveys and European and national legislation
- **Cooperation** in the management group
- **Interviews**: management group organizations
- **Two workshops**:
  - Evaluation of European and national legislation related to C-ITS services, with experts from project organizations as participants.
  - Workshop of the co-Nordic EU CEF funded NordicWay 3 project on the ecosystem of Interchange Nodes.
- **Expert knowledge** of the management group members.

C-ITS actors and roles



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Summary of the European and national legislation related to C-ITS services discussed in the work

- **Legislation for intelligent transport systems in road transport**: ITS directive and delegated acts, C-ITS draft delegated act (2019, not in effect), Finnish national law on transport services
- **Radio equipment legislation**: EU radio equipment directive and delegated act as well as national legislation
- **Legislation for market surveillance and information security and protection**: Laws: accreditation and market surveillance, data protection and electronic communication, type approval and motor vehicles, road safety, traffic system and highways, information security assessment and obligations
- **Cyber security legislation**: NIS Directive to ensure a common high level of cyber security throughout the Union
- **Other national legislation**: Road and street network information systems, Road Traffic Act, Land Use and Building Act, laws and regulations from agencies and ministries
- **Legislation under preparation**: EU Data Act proposal, Access to vehicle data, Cyber Resilience Act

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2. Summary of results

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Proposal for organising authorities' roles in Finnish C-ITS services

- The proposal presented here is based on the C-ITS delegated act proposal published by the European Commission in 2019 (not in effect), current European and national legislation, and C-Roads Platform specifications and reports.
- The proposed architecture description of the roles is based on the ISO TS 17427 high-level description of C-ITS actors, their roles and tasks as presented in the C-Roads Platform WG1 report:
  - Policy Framework
  - System Management
  - System Operation
  - Service Recipient

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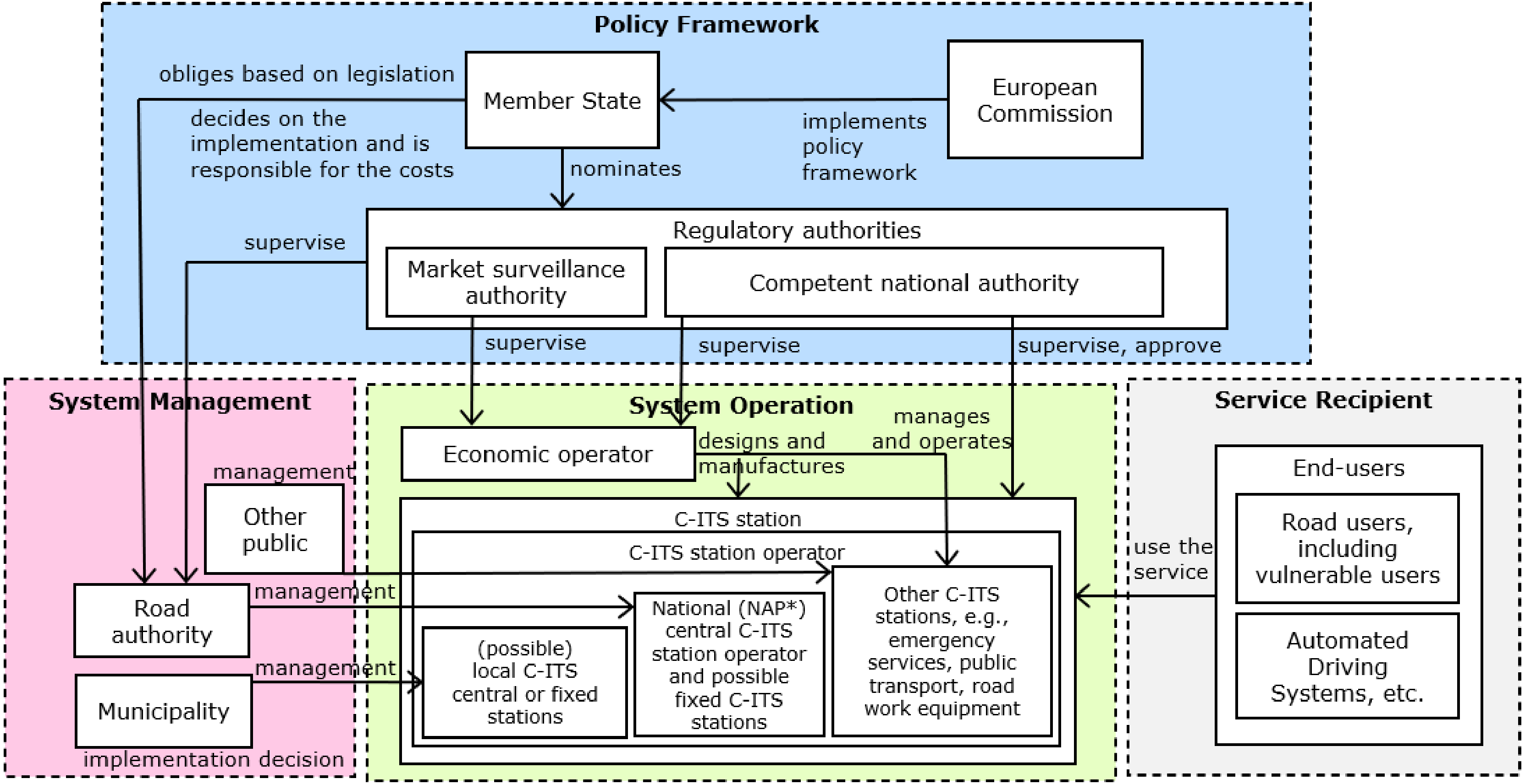
Proposal for organising authorities' roles in Finnish C-ITS services



*NAP = National Access Point

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Proposal for organising authorities' roles in Finnish C-ITS services

- **Policy framework**: tasks of the competent national authority, the market surveillance authority and the radio equipment supervisory authority for the *Finnish Transport and Communications Agency (Traficom)*
- **System management**: role and tasks for the *Finnish Transport Infrastructure Agency and the municipalities*
- **System operation**: role and tasks for the *Fintraffic Ltd and the municipalities*
- *Economic actors* can also lead, manage and operate C-ITS services

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Proposal for organising authorities' roles in Finnish C-ITS services (1/2)

Actor name	Proposal for the role in Finland
PROPOSAL FOR A NEW ROLE: Competent national authority of C-ITS	Finnish Transport and Communications Agency (Traficom)
Market surveillance authority: motor vehicles	Finnish Transport and Communications Agency (Traficom)
Controller of radio frequencies	Finnish Transport and Communications Agency (Traficom)
Authority responsible for notification, radio equipment	Finnish Transport and Communications Agency (Traficom)
Supervisory authority, radio equipment and use of radio frequencies	Finnish Transport and Communications Agency (Traficom)
Market surveillance authority, radio equipment	Finnish Transport and Communications Agency (Traficom)
PROPOSAL FOR A NEW ROLE: Market surveillance authority: C-ITS stations	Finnish Transport and Communications Agency (Traficom)

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Proposal for organising authorities' roles in Finnish C-ITS services (2/2)

Actor name	Proposal for the role in Finland
PROPOSAL FOR A NEW ROLE: Responsible for the authorities' C-ITS implementation	Finnish Transport Infrastructure Agency (national road network) and municipalities (road and street network)
PROPOSAL FOR A NEW ROLE: C-ITS National Access Point	Fintraffic Ltd
PROPOSAL FOR A NEW ROLE: C-ITS central station operator	Fintraffic Ltd or Fintraffic Road Ltd (national road network) and municipalities (road and street network)

Note: Results of requirements and roles in European Union C-ITS Security Credential Management System (EU CCMS) in separate presentation

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Organisation of proposed C-ITS services roles

- Based on the selection criteria created in the work, authorities' roles in C-ITS were examined for two C-ITS services:
  - road work warning and
  - traffic light service

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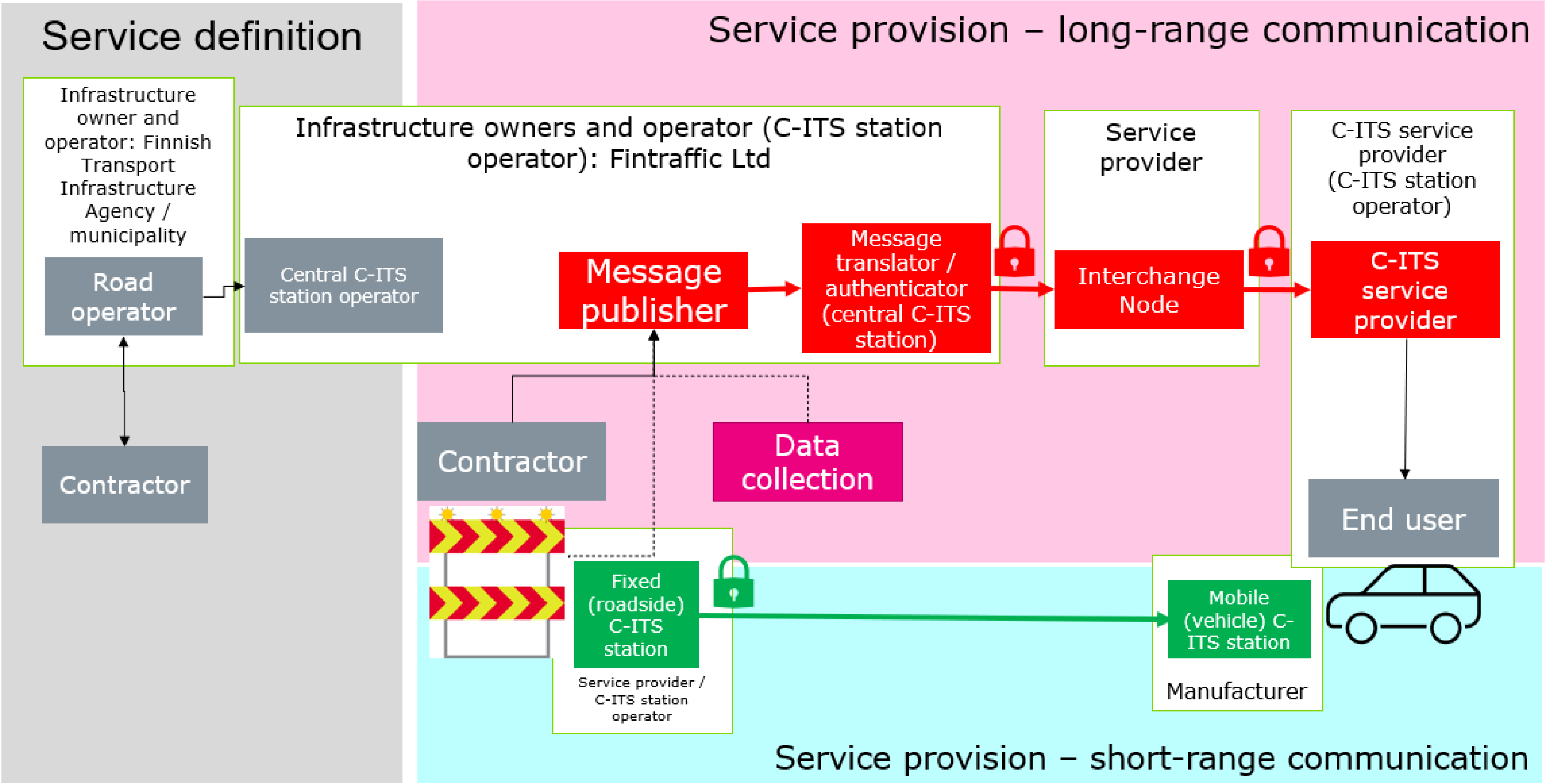
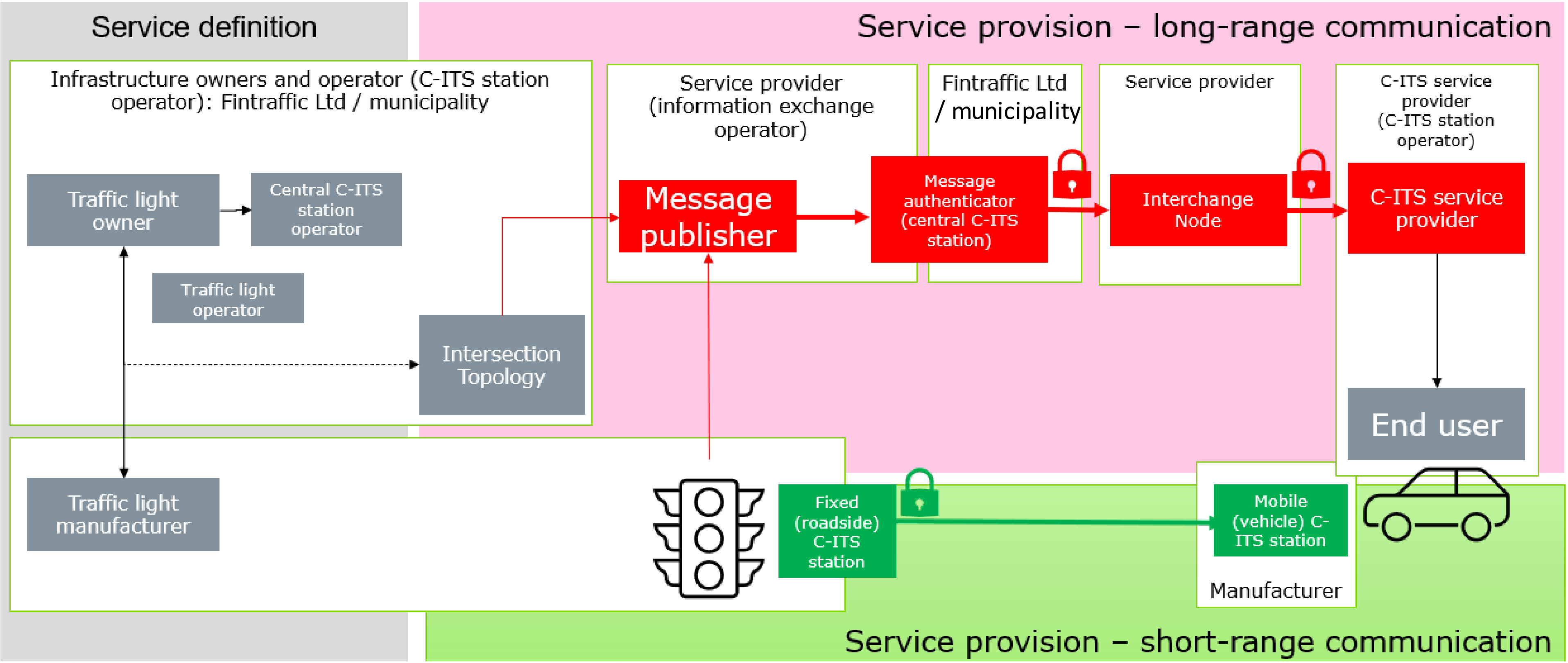
Proposal for organising the roles of the C-ITS Road Works Warning service in Finland



Proposal for organising the roles of the C-ITS traffic light services in Finland



Possible effects of road traffic automation on actors and roles

- There is not yet a clear understanding of the use of C-ITS in the exchange of information between self-driving vehicles and different operators.
- However, it can be assumed that the role of C-ITS services works the same regardless of whether the end user is a human or an automated driving system.
- The new role in automated traffic that is certainly known is the joint operator of automated driving systems, i.e., the operator of automated vehicle fleet.
  - Exchanges information with the automated driving systems it operates as C-ITS messages, or the role of the end user when transmitting information to the automated driving systems it operates through its own channels.
  - Such a joint operator of the vehicle fleet can act as for example OEM representative, robot taxi company, logistic company or transport operator.
- Automatic driving systems may also need remote control centers (role: end user) that guide or control the operation of the automatic driving system in exceptional situations.

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Discussion and recommendations

- **Existing legislation** should be applied to all C-ITS services or other similar types of services, regardless of technology or communication protocol. It would be consistent to use the roles of the authorities presented in this report based on the legislation in all cases.
- Under certain conditions, **municipalities and cities** have the right to place technical equipment, and telecommunications companies have the right to place cables, base stations and radio masts on property owned or controlled by another. This construction capability improves the coverage areas and capacity of potential C-ITS stations in an urban environment, should the need arise.
- For the services to be implemented in a nationally consistent manner, it is recommended to set up **national working groups** or similar bodies that coordinate individual C-ITS services or service categories, whose tasks include the definition of these services, e.g., in terms of service levels, information exchange profiles and detailed role divisions.
- **The development of road traffic automation** can set requirements related to the timeliness and reliability of the information needed by automated driving systems. C-ITS services according to C-Roads can provide one such selection of means by which up-to-date and reliable information can be transmitted to connected and cooperative automated driving systems. The role of the authorities in the ecosystem has been discussed for example in the ecosystem work of the NordicWay 3 project.
- Results of requirements and roles in European Union C-ITS Security Credential Management System in separate NW3 final webinar presentation

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Thank you

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Jari Myllärinen, Finnish Transport Infrastructure Agency, jari.myllarinen@vayla.fi

Ilkka Kotilainen, Traficon Ltd, ilkka.kotilainen@traficon.fi

Source

Study of Authorities' roles in implementation and operational use of C-ITS services in Finland. Unpublished report (2023). Report in Finnish language, original name: Viranomaisten roolit vuorovaikutteisten älykkäiden liikennejärjestelmien (C-ITS) palveluiden käyttöönotossa ja operatiivisessa käytössä.

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Cellular C-ITS from studies to deployments

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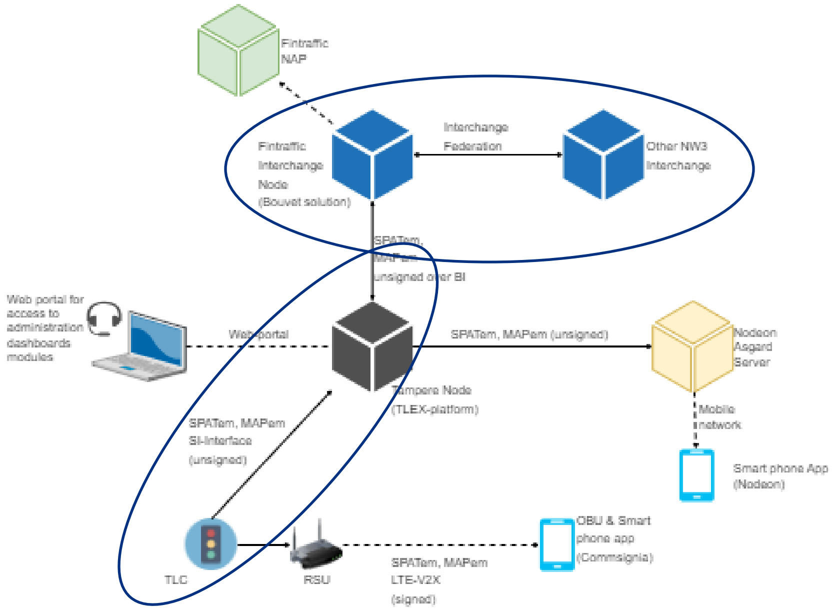
Nordic WAY

Gathering and sharing traffic light C-ITS data

Insights from the C-ITS pilot in city of Tampere.

Overview of the Finnish C-ITS pilot eco-system in NordicWay 3

Finnish Interchange implementation



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Tampere pilot scope

- To increase understanding of the technical requirements when collecting and produce C-ITS data from traffic lights
  - Is the data interoperable?
  - Is the predicted data consistent?
  - technical requirements for traffic light C-ITS data?
- **Use case:**
  - Collecting data from multiple devices of different suppliers and different traffic light control principles into a centralized system.

Schedule:

- Study: 2020 -2021
- Technical part: 2022
- Validation part: 2023

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Participants

- Fintraffic Road
- Mattersoft Ltd
- City of Tampere
- Nodeon Finland
  - Monotch
- Swarco Finland
- Normivalaistus
  - La Semaforica

Fintraffic TAMPERE

Mattersoft Ltd. init

NODEON monotch

swarco dynniq

NORMIVALAISTUS

LA SEMAFORICA traffic solutions for a better life

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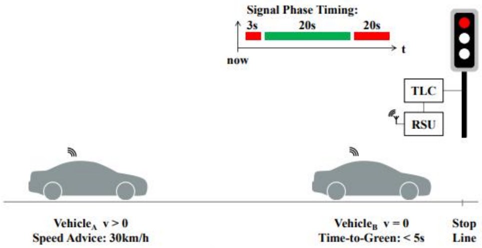
C-ITS use cases related to traffic lights

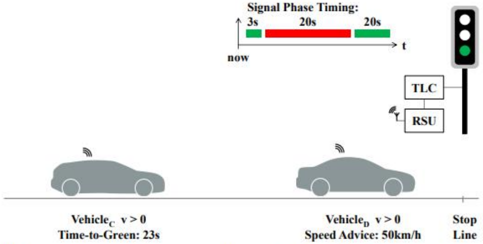
- Green Light Optimal Speed Advisory (GLOSA)
- Signal Phase and Timing Information
  - SPATem
  - MAPem

Not in the pilot scope

- Imminent Signal Violation Warning;
- Traffic Light Prioritisation;
- Emergency Vehicle Priority.



(a) Scenario 1: Current phase of traffic light program is red



(b) Scenario 2: Current phase of traffic light program is green

Figure 2: Intersection approach scenarios

Source: Exploring GLOSA Systems in the Field: Technical Evaluation and Results
Stahlmanna, Möllera, Brauerb, Germanc, Eckhoffb
https://www.david-eckhoff.net/pdf/stahlmann2017exploring.pdf

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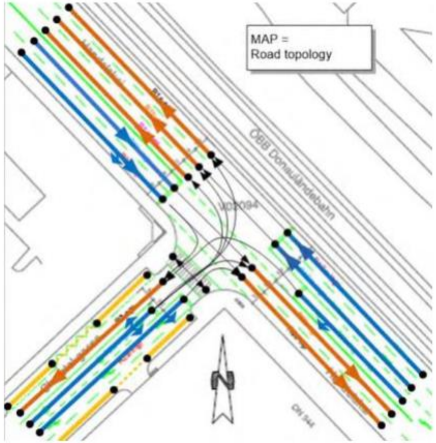
GLOSA - Green Light Optimal Speed Advisory - messages

- SPATem (Signal Phase And Timing Extended Message)
  - Real-time status information of signal timing and operation of traffic lights, including upcoming events (predictions) in the timing
- MAPem (Map Extended Message, road and lane topology and traffic maneuver message)
  - Topology/geometry of intersections (lanes and allowed driving directions, stop line locations, pedestrian crossings, bicycle lanes, etc.).



Kuva 7I-5.1. Esimerkki liittymän topologian koodauksesta MAPEM-viestimuodolla (EU EIP A4.2 Workshop in Madrid, September 2016 / Andreas Schmid).

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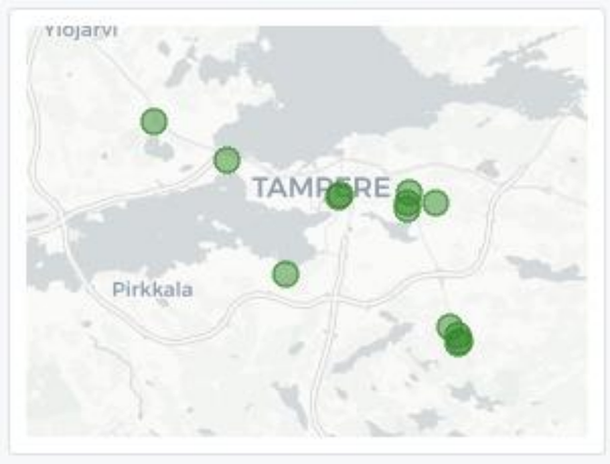
Traffic light intersections

- TL Controllers (12 pcs) in Tampere region
  - Swarco Finland: EC-2, ITC-2
  - Normivalaistus: La Semaforica, Cartesio
- Control Method
  - Adaptive (Imflow)
  - Coordinated (Syvari)
  - Tarffic Actuated (Syvari)



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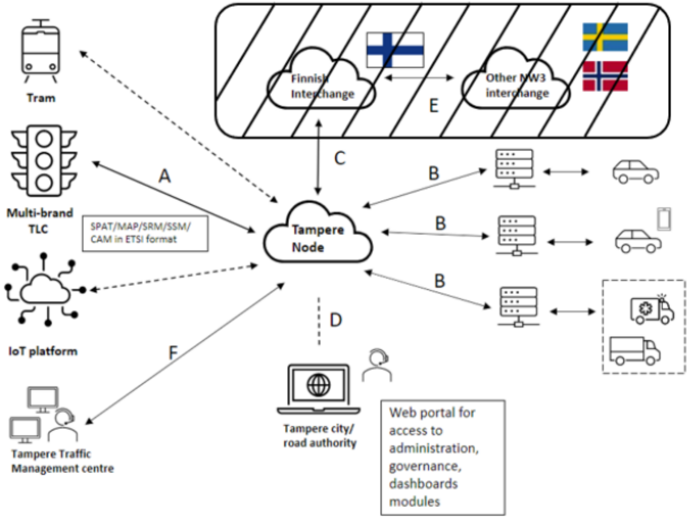
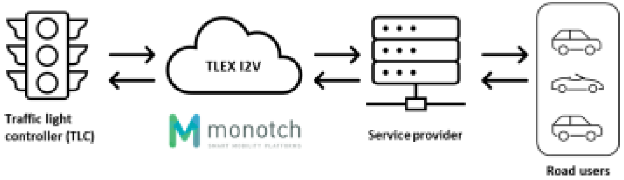
How to transfer messages?

- The transmission of MAPEM and SPATEM message sets is specified in the document "European handbook for MAPEM and SPATEM creation" (version 1.0 / May 21, 2021) published by C-ROADS.
- The transmission of traffic light messages to the TLEX cloud service was implemented using the TLEX-FI interface (known as UDAP-FI in the Netherlands).





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Lessons learned

- You need to increase the amount of hardware/computing power in the field.
- Configuration (at least in the early stages) is labor-intensive.
- The devices (and compatibility) were not as ready as initially anticipated.
  - There were challenges with the stability of the controllers' basic operations.
- Now we have a better understanding of what needs to be considered when writing C-ITS requirements.
  - Suppliers understand better the demands of the customers.
- The overall picture is still unclear (regulation and roles are incomplete, revision of the ITS directive).

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Lessons learned

- Processes are needed to maintain MAPem and SPATem data in a changing world.
- As the number of users grows, there is a need for dialogue between stakeholders (more stakeholders than traditional traffic lights operations).
- To ensure data reliability and availability, the following are needed:
  - **Monitoring**: Continuous monitoring of data to ensure its accuracy, integrity, and proper functioning.
  - **Control:** Implementation of control mechanisms to regulate data access, storage, and usage, ensuring security and adherence to established protocols.
  - **Oversight:** Regular oversight and audits to assess the overall data management practices, compliance with regulations, and identification of any potential issues or risks.
- Funding of the Interchange Node is unclear, should it be like NAP or every city

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Next steps

- Validation and comparison of C-ITS message data
  - Especially from a traffic engineering perspective
- More potential pilots on end devices/applications, enabling data for other pilots
- Possible system extensions
- Testing interoperability with other systems and the national access point
- Initiate a technical dialogue among stakeholders regarding Traffic light C-ITS
- Develop a technical requirements specification for traffic lights regarding C-ITS services.
  - Designing a technical architecture for traffic lights

(b) Operation mode 2: Time-to-Green (TTG)

Figure 3: Instrument cluster display of GLOSA

Source: Exploring GLOSA Systems in the Field: Technical Evaluation and Results
Stahlmanna, Möllera, Brauerb, Germanc, Eckhoffb
https://www.david-eckhoff.net/pdf/stahlmann2017exploring.pdf

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In future.. The NordicWay3 is ending..

We need to make a decission how we will manage and share C-ITS data in the future

At a strategic level, we have a couple options:

A. Do it ourselves, manage and distribute the data and the service internally.

B. Partner with a third-party who will handle it on our behalf.

- In this option, we require transparency and the need to know and understand how the data is shared and managed, along with the underlying principles.

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Thank You!

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Interoperability and C-V2X technology on C-ITS environment

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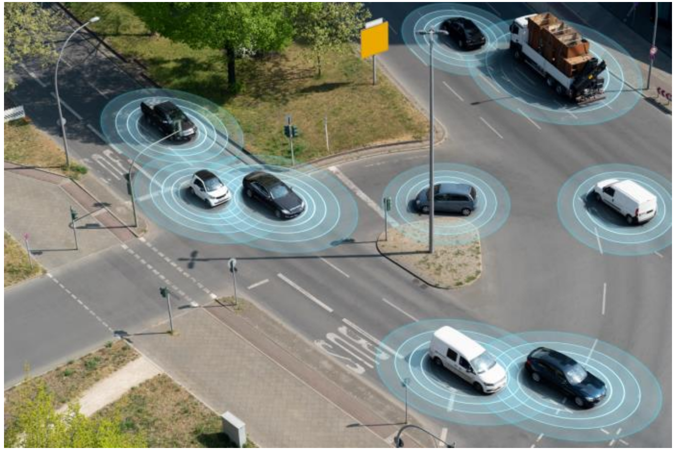
Background

- The main goals of the project:
  - Demonstrate the functionality of the EU C-ITS Credential Management System (EU CCMS).
  - Test C-V2X 5.9 GHz short-range (PC5) and long-range technologies and demonstrate the compatibility of the EU CCMS with these technologies.
  - Demonstrate the interoperability of C-V2X technologies with C-ITS services defined in C-Roads.
  - Test and demonstrate the use of simultaneous dual communication in a single intersection (long-range/short-range).



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C-ITS services

- Technical scope of the project validated with following C-ITS services:
  - Infrastructure to Vehicle communication
  - C-Roads service: Signalized Intersection
  - Use case: Signal Phase and Timing Information
  - SPATEM and MAPEM C-ITS messages

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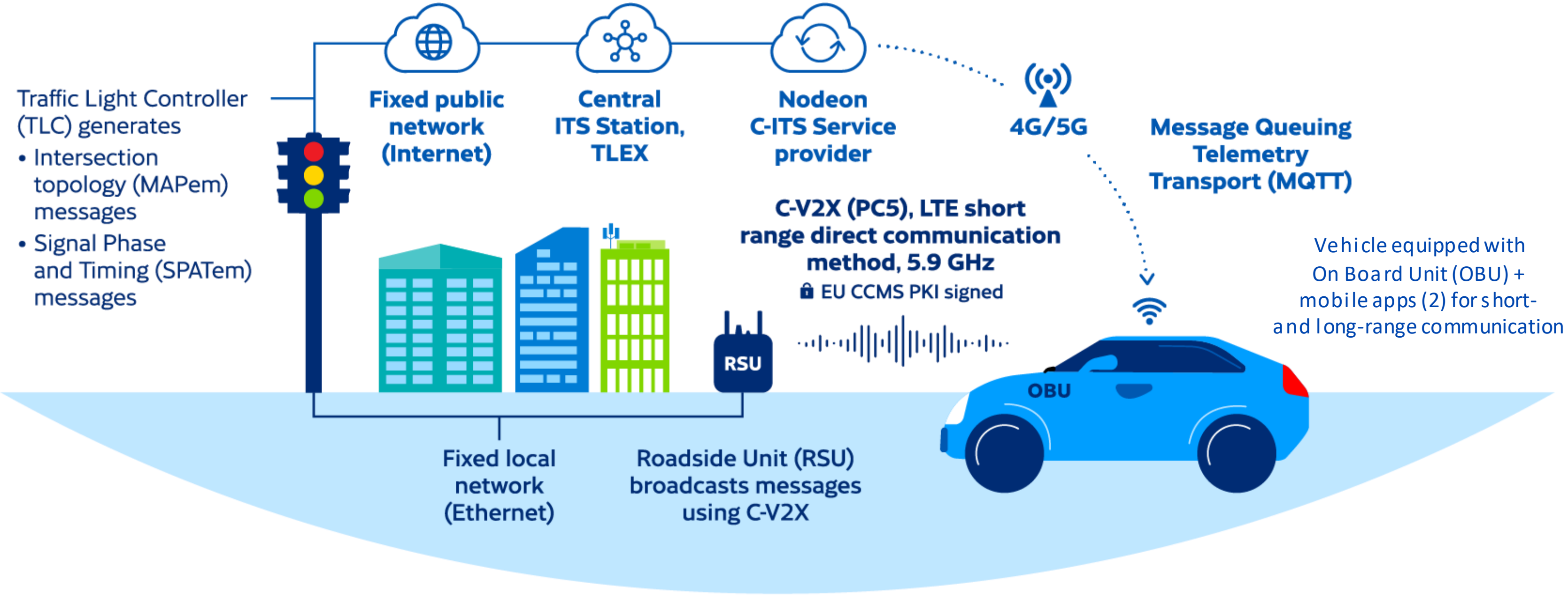
Pilot system technical architecture



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Pilot system

- Long-range and short-range communications
  - RSU ↔ OBU (Commsignia C-V2X, PC-5)
  - IP-based long range (TLEX, Nodeon Asgard)
- Traffic light controller generating SPATEM and MAPEM messages
  - Long-range communication: TLEX (SI)
  - Short-range communication: RSU (Commsignia proprietary protocol)
- RSU and OBU enrolled to the European C-ITS Credential Management System

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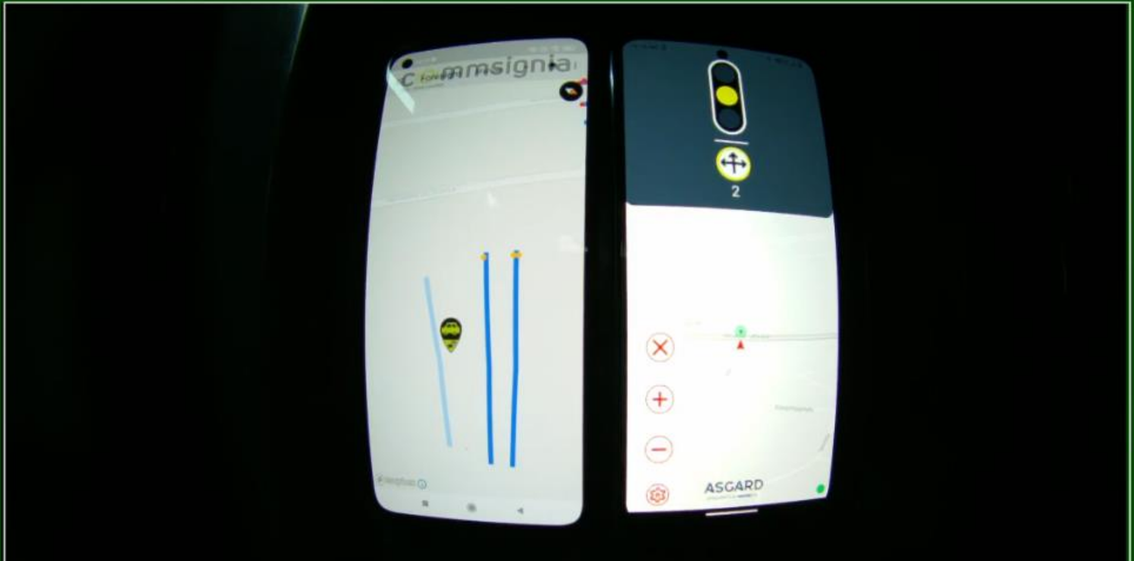
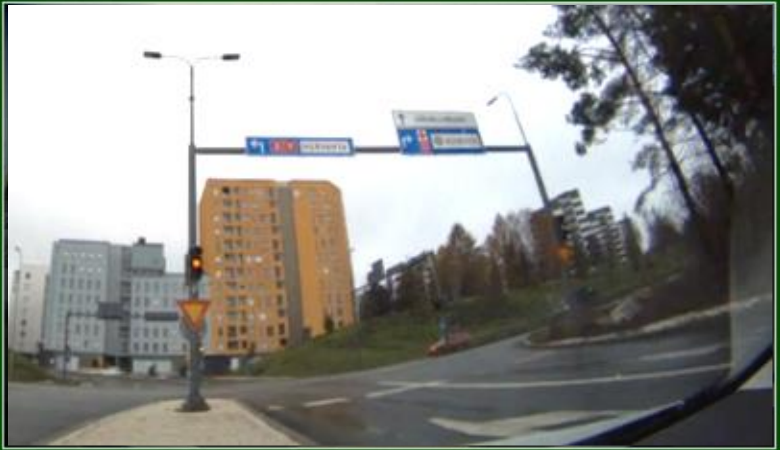


VIDEO RECORDING SCENARIO FOR COMPARING LIVE SITUATION AND BOTH MOBILE APPLICATION STATUS



SHORT RANGE LONG RANGE

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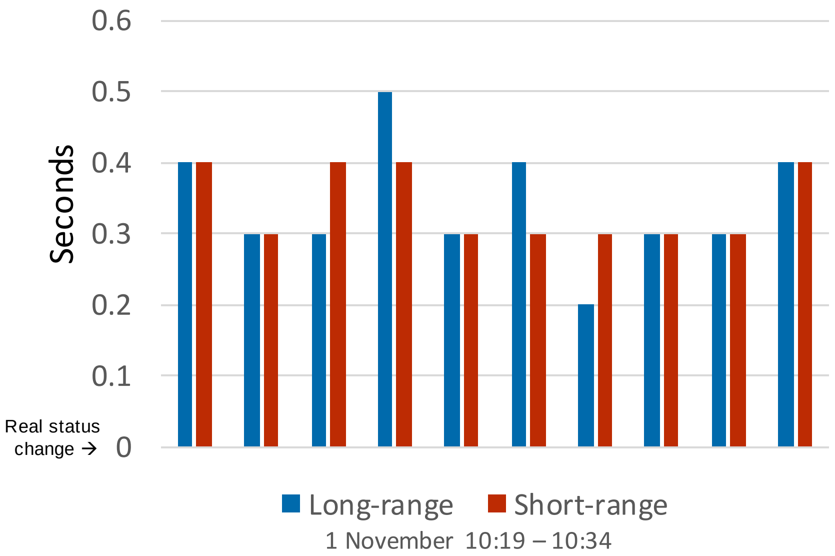
Initial results 1/3

End-to-end latency in status change (10 cycles)



- Latency of both communication methods calculated with previous slide test scenario.
  - Represents delay between real traffic light status change and status change in both mobile applications.
  - Delay rounded to the closest tenths of a second.
- Human eye interpretation of an overall delay: "blink of an eye".
- Not significant difference between communication methods.

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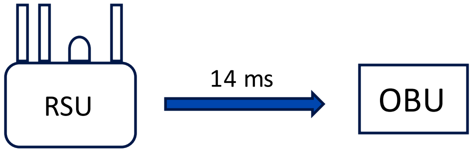
Initial results 2/3



- Short-range communication
  - RSU → OBU latency 14 ms
  - Majority of the end-to-end latency generated by devices/applications
- Average size of the messages
  - SPATEM 526 bytes
  - MAPEM 994 bytes
- 100% of messages received by OBU signed

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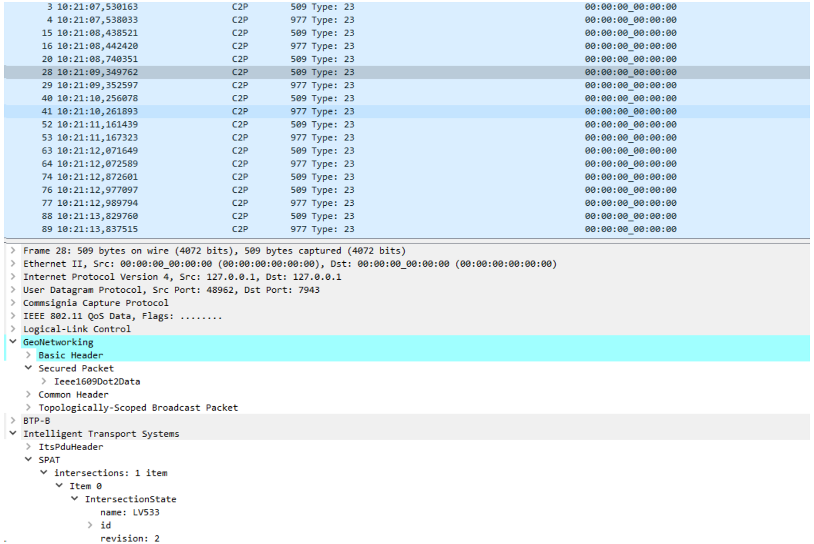
Initial results 3/3

- Used certificate authority: Microsec, registered to ECTL
- C-V2X short-range devices were interoperable with EU CCMS.
- Some device manufacturers might have tools to automatically enroll devices to the EU CCMS.
- Long-range solution were not interoperable with EU CCMS.



Findings

- No standard (or even de-facto standard) in place for communication between TLC and RSU.
- Latency differences between short- and long-range communication was surprisingly small even though long-range communication chain includes much more backend/software components and best-effort networks (public fixed Internet and public mobile network).
- Measuring the latency between different hops in the entire communication chain is challenging, as there are many actors in the chain.
- Mobile applications may also affect the latency (also in this project some unexpected delays in mobile app level were pinpointed during longer tests).
- Public fixed Internet and public mobile network provided stable and well-working platform for long-range communication in this project.
- Project underlined that public “best-effort” communication platform doesn`t give any guarantees (no SLA). Occasional increased demand in mobile network, network coverage problems, national and international level problems in the fixed teleoperator core networks, problems in cloud services, and cyber threats may lead to significant problems in critical C-ITS applications (creating backbone for infra support to automated driving in the future).

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Summary

- C-V2X tests were successful.
- The use of EU CCMS were successfully tested in short-range communication scenario (long-range method didn't provide support in this test).
- No standard for communication between TLC's and RSU's.
- No significant difference between delays in long- and short-range communication in this test (does not give guarantees for other tests where other vendors/components are used).
- Both methods provided well-working platform for at least informative C-ITS applications.
- Evaluation of mobile networks (/best-effort networks) capabilities to support critical C-ITS applications to be done in larger scope.

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Questions

- Contact

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Utilisation of commercial mobile networks in the implementation of C-ITS services

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Agenda

- Aim
- Research questions
- Presentation of the study
- Key take aways
- Way forward

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Aim

Aim of the research is to study performance needs of C-ITS services in mobile network as well as a to define common service level framework criterion to cover various scenarios of use of services.

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Research questions

How are current commercial mobile networks suited to serve C-ITS services

↓

What are the key deficiencies/bottlenecks, if any

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Research questions

What is the capacity estimate of the C-ITS-services

What is the capacity estimate of the mobile network performance

What kind of methods should be utilized to measure C-ITS related needs on mobile networks

How are current commercial mobile networks suited to serve C-ITS services

What are the key deficiencies/bottlenecks, if any

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Research questions

Work phase 1

What is the capacity estimate of the C-ITS-services

What is the capacity estimate of the mobile network performance

What kind of methods should be utilized to measure C-ITS related needs on mobile networks

Work phase 2

How are current commercial mobile networks suited to serve C-ITS services

What are the key deficiencies/bottlenecks, if any

Work phase 3

How can the development needs be addressed?

What are the technical, regulatory and economic impacts of different operating models

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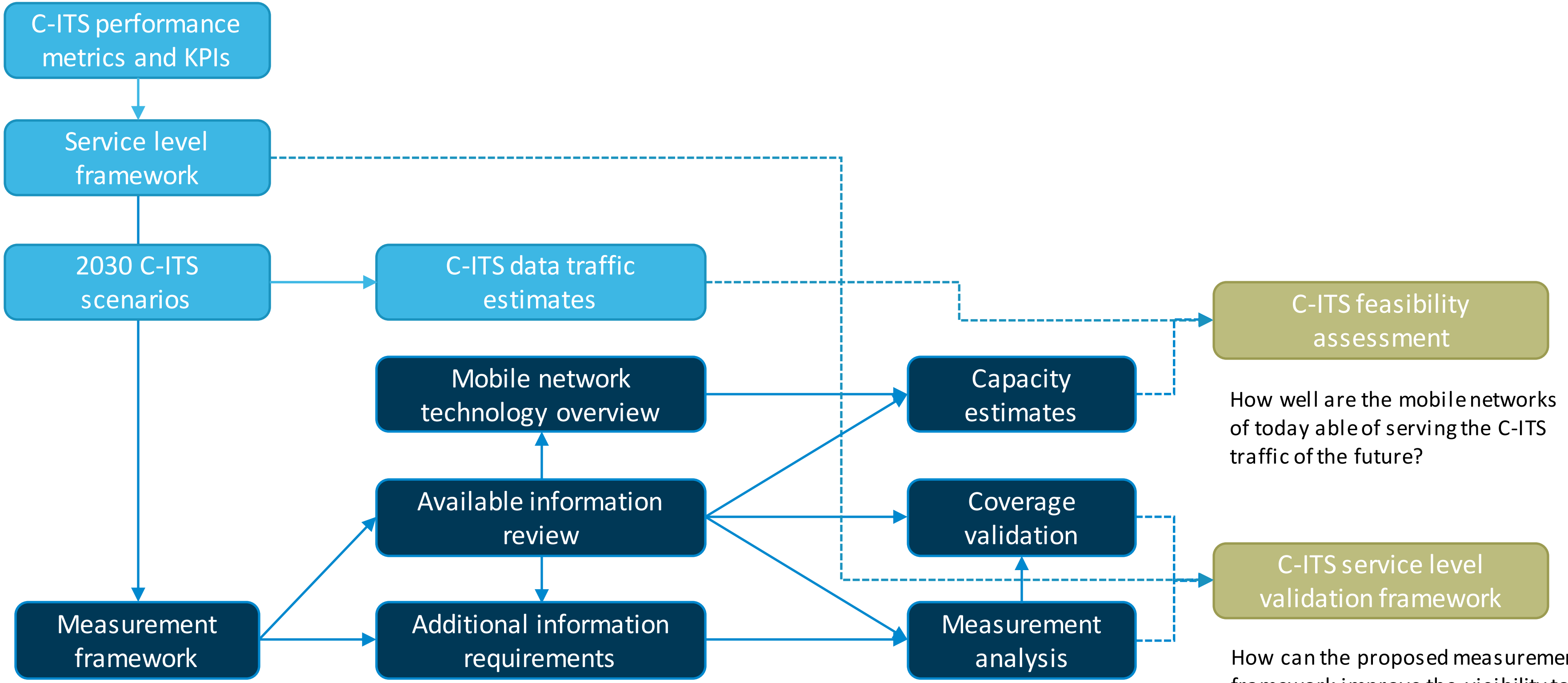
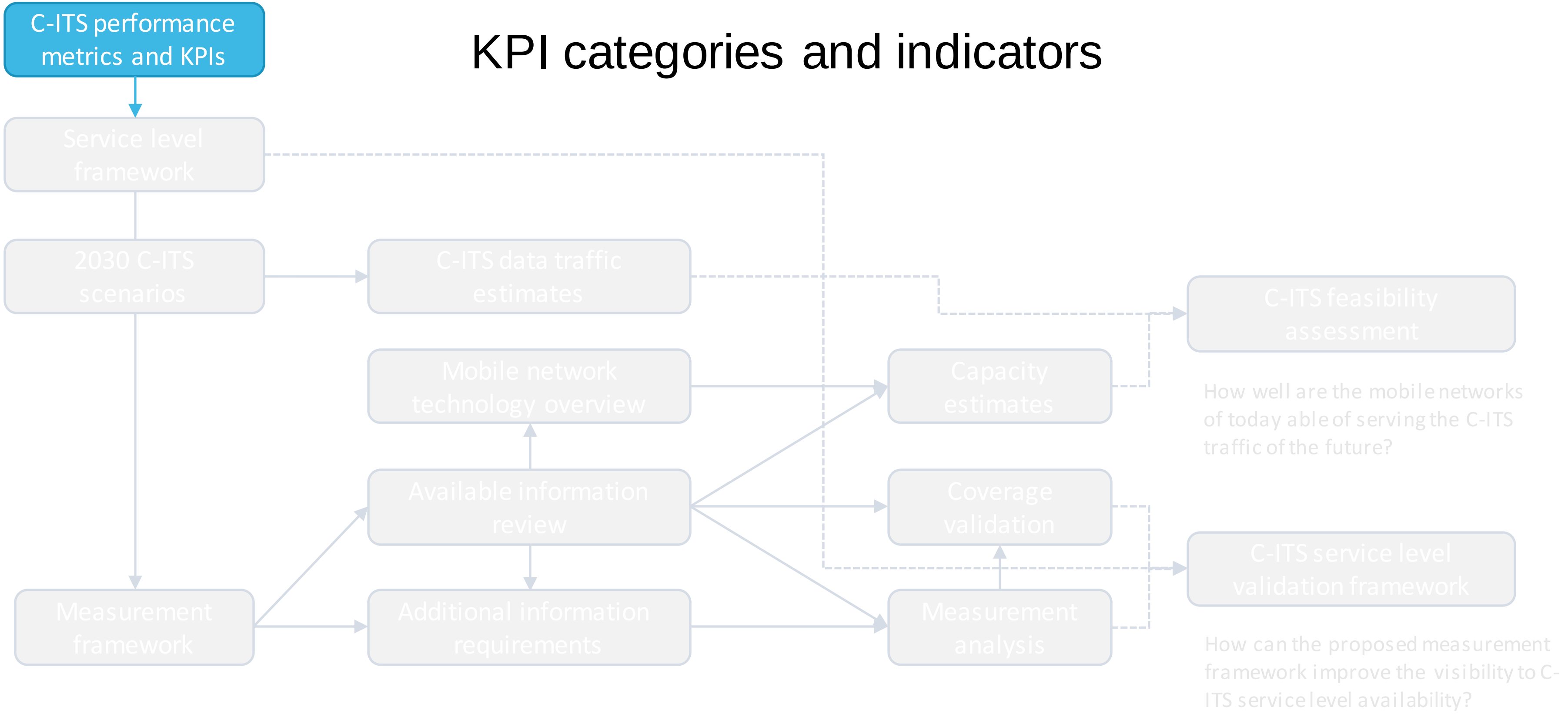


How well are the mobile networks of today able of serving the C-ITS traffic of the future?

How can the proposed measurement framework improve the visibility to C-ITS service level availability?

KPI categories and indicators



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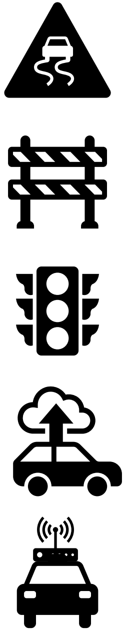
Selection of C-ITS-services for the study

Selection criteria

1. Strategy and legislation
2. Needs in Finland
3. C-ITS message type
4. Logic of transmission
5. Technical challenge
6. Automated driving

Selected C-ITS services

1. Hazardous Location Notification service, Temporarily slippery road use case (HLN-TSR)
2. Road Works Warning service, Lane closure use case (and other restrictions) (RWW-LC)
3. Signalised Intersection service, Signal Phase and Timing Information use case (SI-SPTI)
4. Probe Vehicle Data service, Vehicle Data Collection use case (PVD-VDC)
5. Collective Perception Service (CPS)



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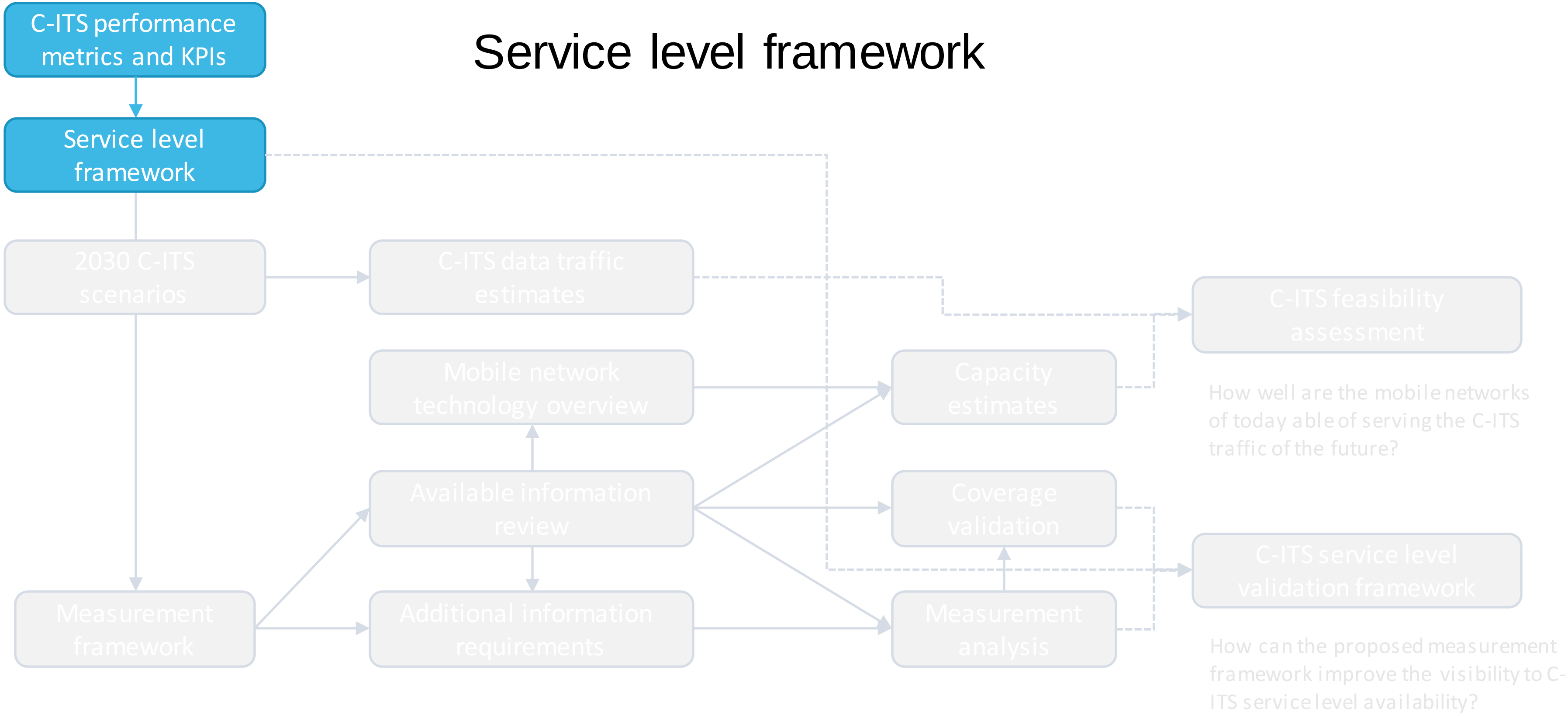
KPI categories and indicators

- Relevant indicators have been chosen by combining telecommunication system performance indicators with C-ITS communication performance indicators and excluding non-relevant metrics.

Key Performance Indicator (KPI)	Description	Unit	Quality of service definition notes
Availability			
Network coverage	Also, geographic coverage. Percentage of the road network and/or selection of road classes (to be case by defined) where cellular mobile network is available. (Adapted from EU EIP 2022)	%	Availability of cellular mobile network considered binary: available or not.
Reliability			
Packet loss rate	Packets not received by the destination application within the maximum tolerable end-to-end latency for that application.	%	-
Integrity			
Latency: End to end latency	Time since a message is transmitted until it is received, at application layer	ms	End-to-end latency recommendation is defined as the value under which latency is 99 % of cases.
Throughput (network, capacity), communication	Instantaneous data rate/throughput as perceived at the network layer	bps	Includes download and upload rates

Service level framework



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Service level framework

- Service level framework was defined and based on the C-ITS quality-of-service requirements.
- The quality-of-service requirements were analysed using the five selected C-ITS services.
- The threshold values follow the findings of the quality-of-service literature review, Key Performance Indicators (KPI) selected and expert opinion estimations.

Key Performance Indicator (KPI)	Level 0: Unreliable operability	Level 1: Basic operability	Level 2: Medium operability	Level 3: High operability
Availability	No or unreliable network coverage	Verified network coverage	Verified network coverage	Verified network coverage
Reliability	Reliability < 90 %, Packet loss rate > 10 %	Reliability > 90 %, Packet loss rate < 10 %	Reliability > 95 %, Packet loss rate < 5 %	Reliability > 99 %, Packet loss rate < 1 %
Integrity	End-to-end Latency > 1 s Throughput < 5 Mbps (download and upload)	End-to-end Latency < 1 s Throughput > 5 Mbps (download and upload)	End-to-end Latency < 500ms Throughput > 20 Mbps (download and upload)	End-to-end Latency < 100ms Throughput > 100 Mbps download, > 25 Mbit/s upload

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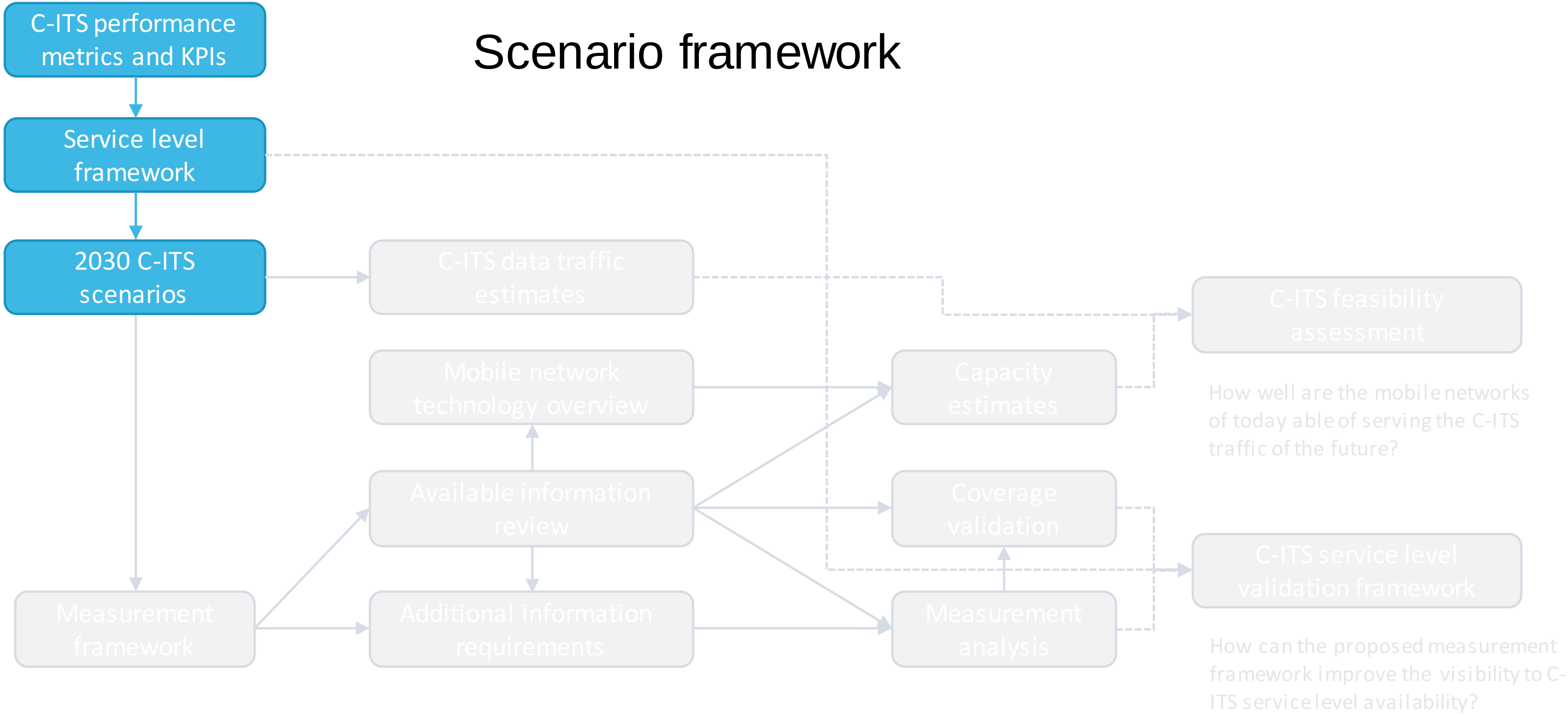
Scenario framework



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Scenario framework

- Scenario analysis parameters are:
  - Environment, vehicle density and mobile sector coverage
  - Information (or message) density parameters
  - Connectivity architecture models
  - C-ITS-message model parameters

Use Case / Information density factors	RWW: Lane closure (and other restrictions)	HLN: Temporarily slippery road	SI: Signal Phase and Timing Information	PVD: Vehicle Data Collection	Collective perception
Participating vehicles per road km	High traffic road: 73 vehicles x 5 = 365	High traffic road: 73 vehicles x 5 = 365	Main streets: 26 vehicles x 5 = 130	High traffic road: 73 vehicles x 5 = 365	Main streets: 26 vehicles x 5 = 130
Update rate (or sensor update rate) (Hz)	2 Hz (ETSI short range), 0.1 Hz (LHTI 5GAA)	1 Hz (ETSI short range), 0.1 Hz (LHTI 5GAA)	2 Hz (ETSI short range), 1 Hz (GLOSA 5GAA), 0.5 - 4 Hz (field experience)	1 Hz (ETSI short range), 1 Hz (GLOSA 5GAA)	10 Hz (mitigation, event triggered) (Garcia et al.)
Density Parameters values included in the length of relevance area (10 km or 1 km2) - Number of hazards or traffic control messages - traffic signals (n) in the area (km2) - vehicles participation percentage (%)	1 (estimated per 10 km length of relevance)	10 (estimated per 10 km length of relevance)	19 (estimated per km^2) (5GAA urban)	100%, 50%, 10% (recom. in literature), but already included in forecast of participating vehicles	–
Length of relevance (km) or area of relevance (km^2)	Length: 10 km	Length: 10 km	1 km^2	Length: 10 km (10 x 1 km)	1 km^2
ETSI C-ITS message type	DENM	DENM	SPAT (4 signals)	CAM	CPM
Size of message (bytes)	400	400	1600	100	1000 (5GAA), 1600 (Garcia et al.)
Number of new detections per vehicle (CPM)	–	–	–	–	43, 25, 10 (recom.) (5GAA)

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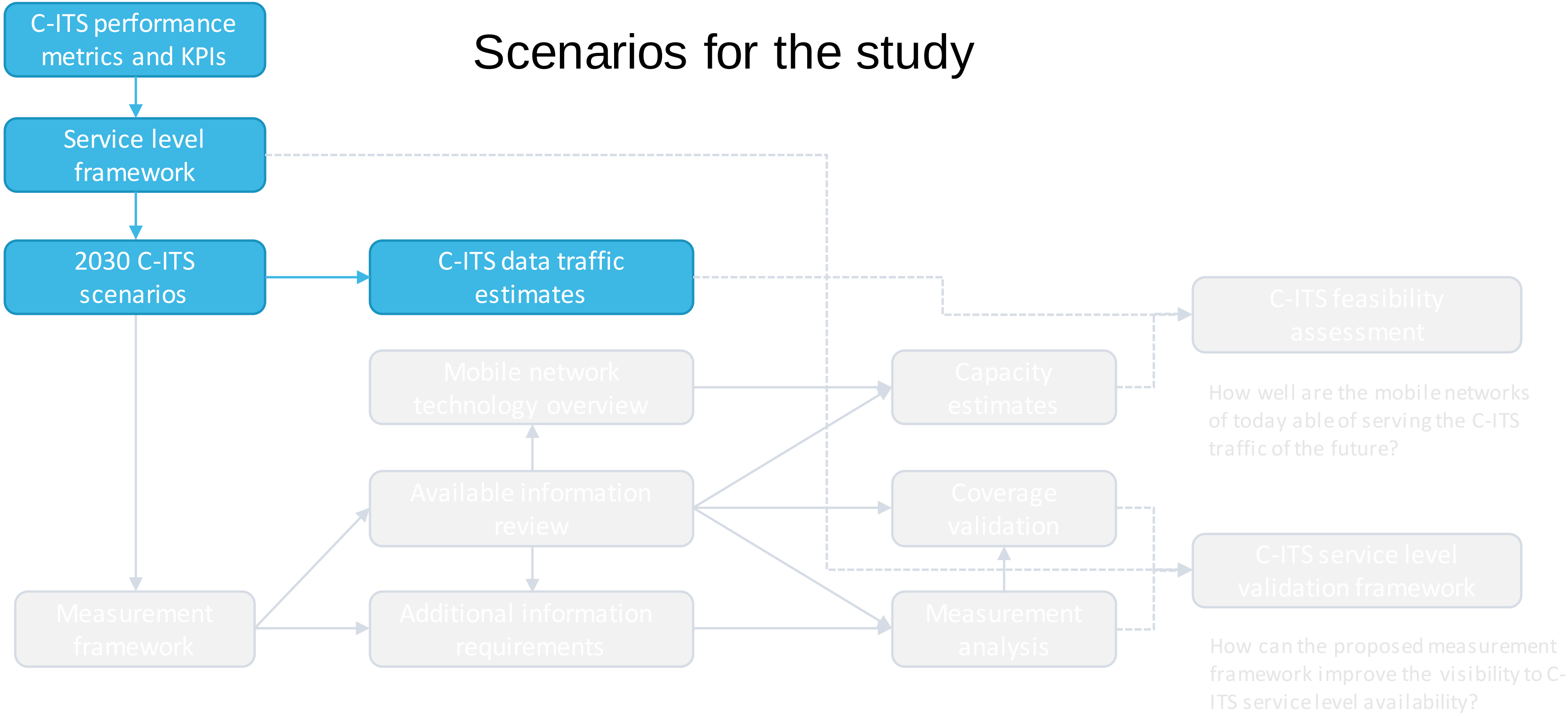
Scenarios for the study



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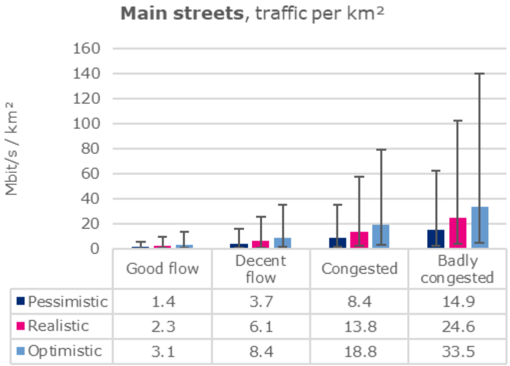
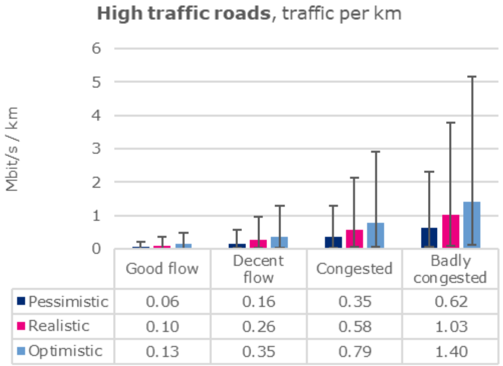
Scenarios for the study

- Traffic flow estimated in 4+1 scenarios (good flow, decent flow, congested, badly congested & extreme)
- Percentage of C-ITS-communication capable vehicles varied
- Information density parameters varied
  - Update rate
  - Density factors (such as number of hazards, traffic signals, etc.)





Main streets Mbit/s/km^2	Good flow	Decent flow	Congested	Badly congested
Pessimistic (low adoption)	1.4 Mbit/s/km^2 (0.2 - 5.8)	3.7 Mbit/s/km^2 (0.6 - 15.6)	8.4 Mbit/s/km^2 (1.3 - 35.0)	14.9 Mbit/s/km^2 (2.3 - 62.2)
Realistic	2.3 Mbit/s/km^2 (0.3 - 9.6)	6.1 Mbit/s/km^2 (0.9 - 25.7)	13.8 Mbit/s/km^2 (2.1 - 57.8)	24.6 Mbit/s/km^2 (3.7 - 102.7)
Optimistic (high adoption)	3.1 Mbit/s/km^2 (0.5 - 13.1)	8.4 Mbit/s/km^2 (1.3 - 35.0)	18.8 Mbit/s/km^2 (2.9 - 78.8)	33.5 Mbit/s/km^2 (5.1 - 140.0)
Extreme				288 Mbit/s/km^2

High traffic Mbit/s/km	Good flow	Decent flow	Congested	Badly congested
Pessimistic	0.06 Mbit/s/km (0.00 - 0.22)	0.16 Mbit/s/km (0.01 - 0.57)	0.35 Mbit/s/km (0.03 - 1.29)	0.62 Mbit/s/km (0.05 - 2.29)
Realistic	0.10 Mbit/s/km (0.01 - 0.35)	0.26 Mbit/s/km (0.02 - 0.95)	0.58 Mbit/s/km (0.04 - 2.13)	1.03 Mbit/s/km (0.08 - 3.78)
Optimistic	0.13 Mbit/s/km (0.01 - 0.48)	0.35 Mbit/s/km (0.03 - 1.29)	0.79 Mbit/s/km (0.06 - 2.90)	1.40 Mbit/s/km (0.11 - 5.16)
Extreme				12.6 Mbit/s/km

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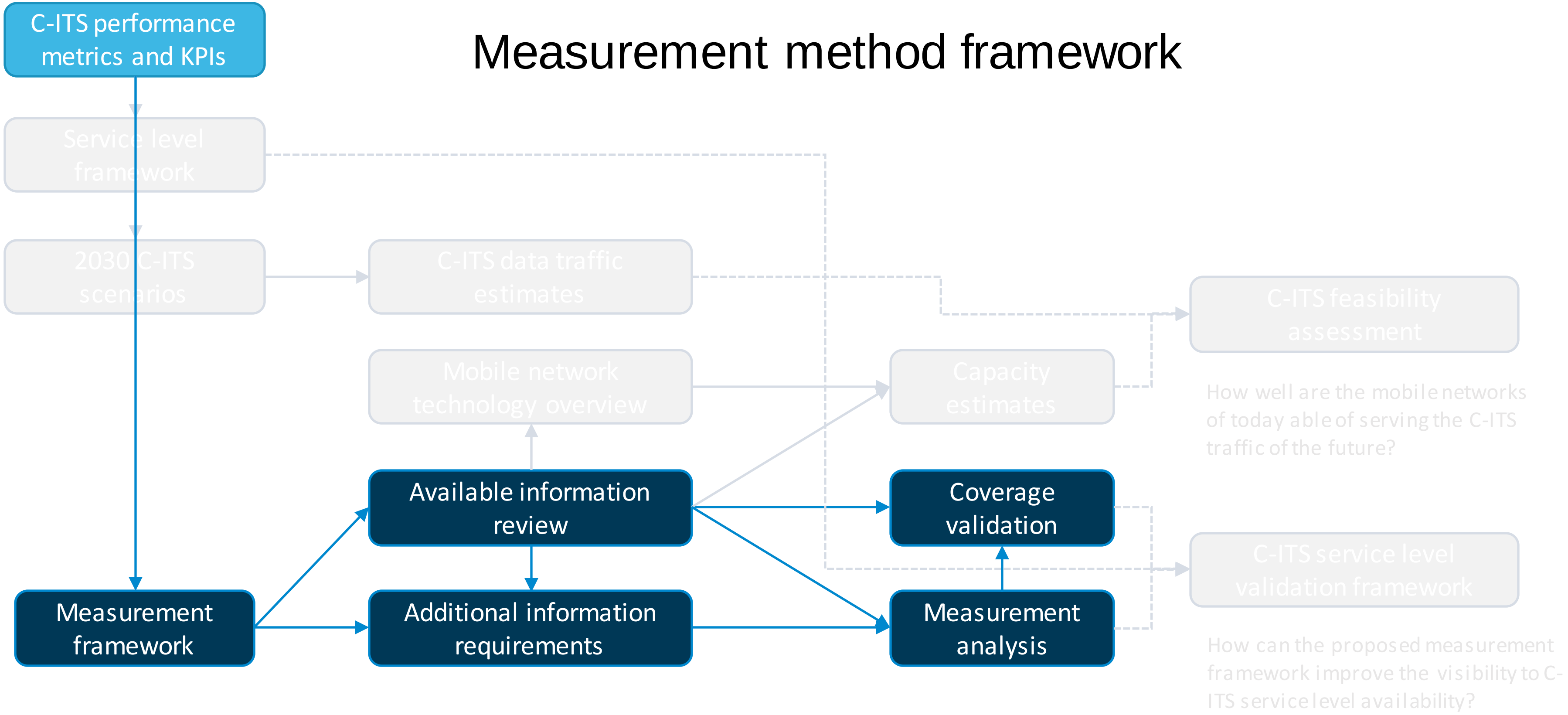
Measurement method framework



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Nordic WAY

Measurement method framework

Measurement framework

Field measurements

Coverage predictions
Identify potential problem areas for further study

Drive tests
- Scanner
- Latency test
- Stress test
  - DL throughput
  - UL throughput

Fixed point tests
Tests over longer time period to verify service availability during different times

Available information review

Traficom:
☑ collects coverage predictions from operators

Coverage	Basic	30 Mbit/s	100 Mbit/s	300 Mbit/s	1 000 Mbit/s
4G	☑	☑	☑	☑	
5G	☑	☑	☑	☑	☑

☑ conducts measurements to validate service availability

Additional information requirements

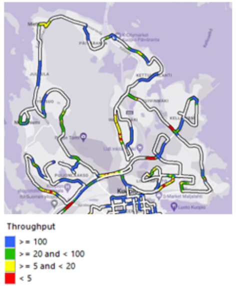
Additions:
☑ collected information sufficient
☑ analyse per operator to identify the potential problem areas

☑ include throughput measurement to assess service level availability

Test case	Current method	Proposed method
Scanner	☑ Measure frequencies of all operators	☑ Measure frequencies of all operators
Voice service	☑ Voice call success	☒ not relevant for C-ITS
Data service	☑ Ping tests ☒ no throughput measurements	☑ Ping tests ☑ Throughput measurement (stress test)
Application simulation (option)	☒ none	☐ service-level tests ☐ service-specific tests

Coverage validation

Measurement analysis



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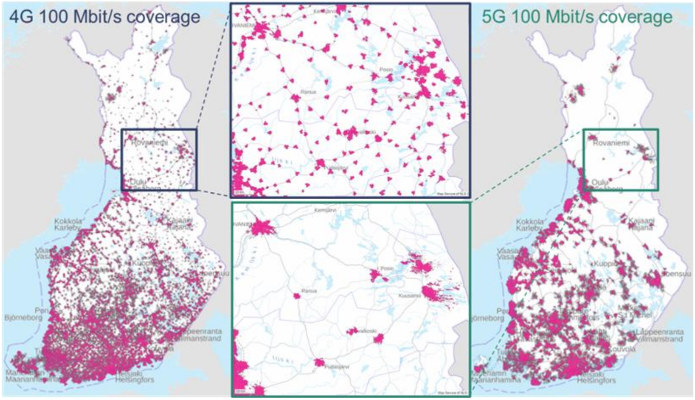
Nordic WAY

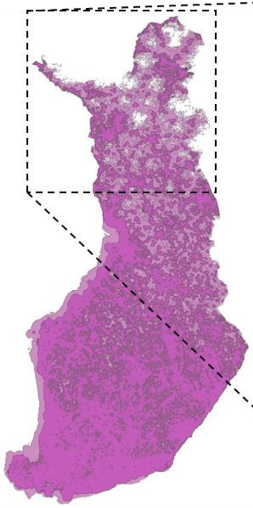
Measurement method framework

Available information review
Combined operator coverage analysed

Traficom:
- ☑ collects coverage predictions from operators
- ☑ conducts measurements to validate service availability

Coverage	4G	5G
1 Gbit/s		☑
300 Mbit/s	☑	☑
100 Mbit/s	☑	☑
30 Mbit/s	☑	☑
Basic	☑	☑





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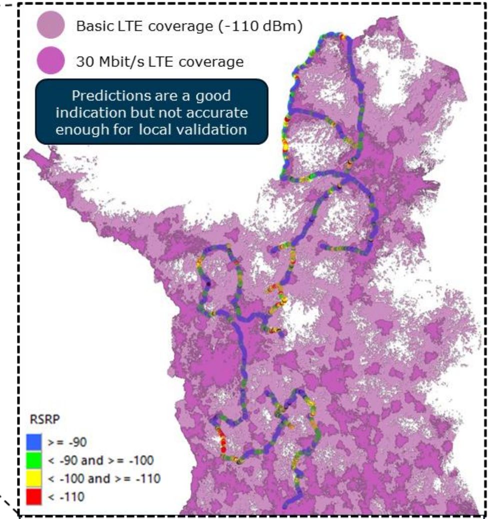
Frequency scanner measurements from northern Finland

Coverage validation
Combined operator measurements analysed



Predictions and measurement results are compared in detail in the report

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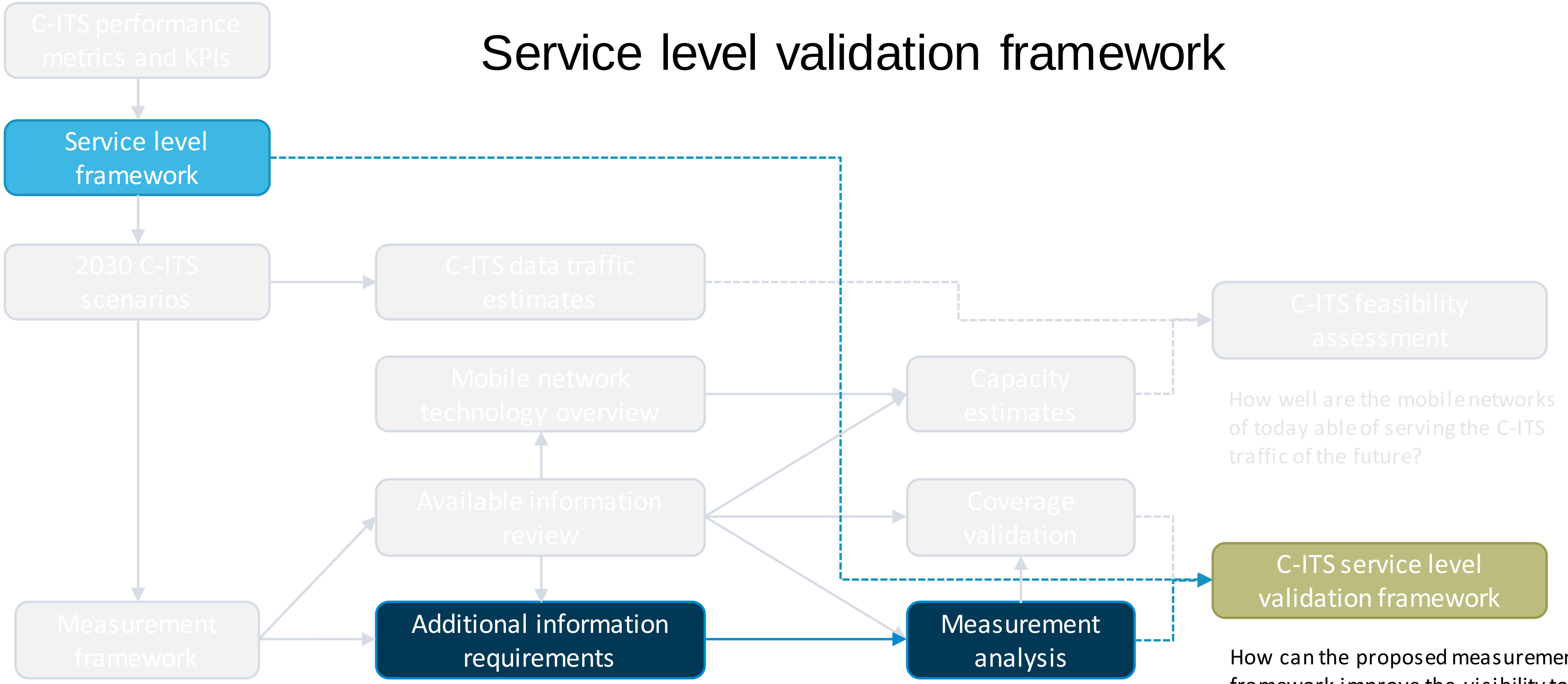
Service level validation framework



How can the proposed measurement framework improve the visibility to C-ITS service level availability?

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Service level validation framework

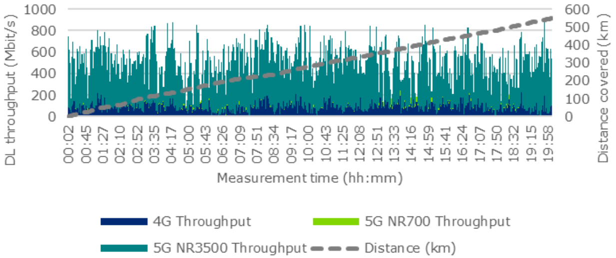
Service level framework

Key Performance Indicator (KPI)	Level 0: Unreliable operability	Level 1: Basic operability	Level 2: Medium operability	Level 3: High operability
Availability				
Network coverage	No or unreliable	Verified	Verified	Verified
Reliability				
Reliability	< 90 %	> 90 %	> 95 %	> 99 %
Packet loss rate	> 10 %	< 10 %	< 5 %	< 1 %
Integrity				
E2E latency	> 1 s	< 1 s	< 500ms	< 100ms
Throughput DL	< 5 Mbit/s	> 5 Mbit/s	> 20 Mbit/s	> 100 Mbit/s
Throughput UL	< 5 Mbit/s	> 5 Mbit/s	> 20 Mbit/s	> 25 Mbit/s

Additional information requirements → Measurement analysis

Example stress test measurements from a major Finnish city area

Example measurement results: 4G + 5G DL throughput
Average throughput: 526 Mbit/s, Distance covered: 548 km (27 km/h)



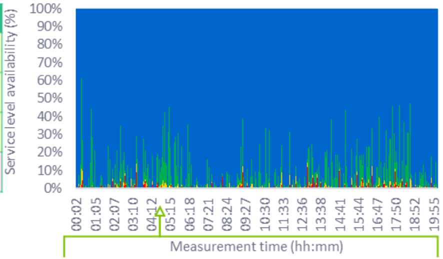
C-ITS service level validation framework

Example analysis using example measurement data

1. assess overall service level availability

Service level	Time	Distance
Level 0: <5 Mbit/s	<1 %	<1 %
Level 1 min: >5 Mbit/s	>99 %	>99 %
Level 2 min: >20 Mbit/s	>98 %	>98 %
Level 3: >100 Mbit/s	91 %	90 %

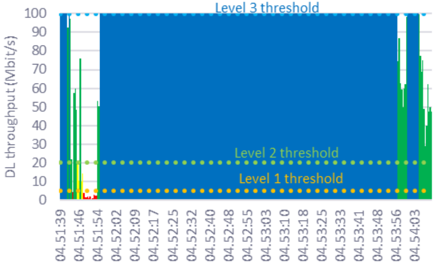
Example measurement results: 4G + 5G DL throughput
Availability different service levels, share of time (%)



2. drill down to individual areas of interest to identify issues

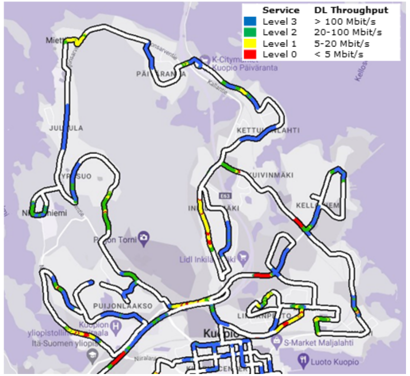
Service level	Time	Distance
Level 0: <5 Mbit/s	4 %	6 %
Level 1 min: >5 Mbit/s	96 %	94 %
Level 2 min: >20 Mbit/s	94 %	92 %
Level 3: >100 Mbit/s	85 %	75 %

Snapshot drilldown: 04:51:39-04:54:10 (2:32)
Average throughput: 506 Mbit/s, Distance covered: 1.3 km (32 km/h)



Conclusions

The proposed measurement framework allows validating service level availability and supports flexibility in the analysis.



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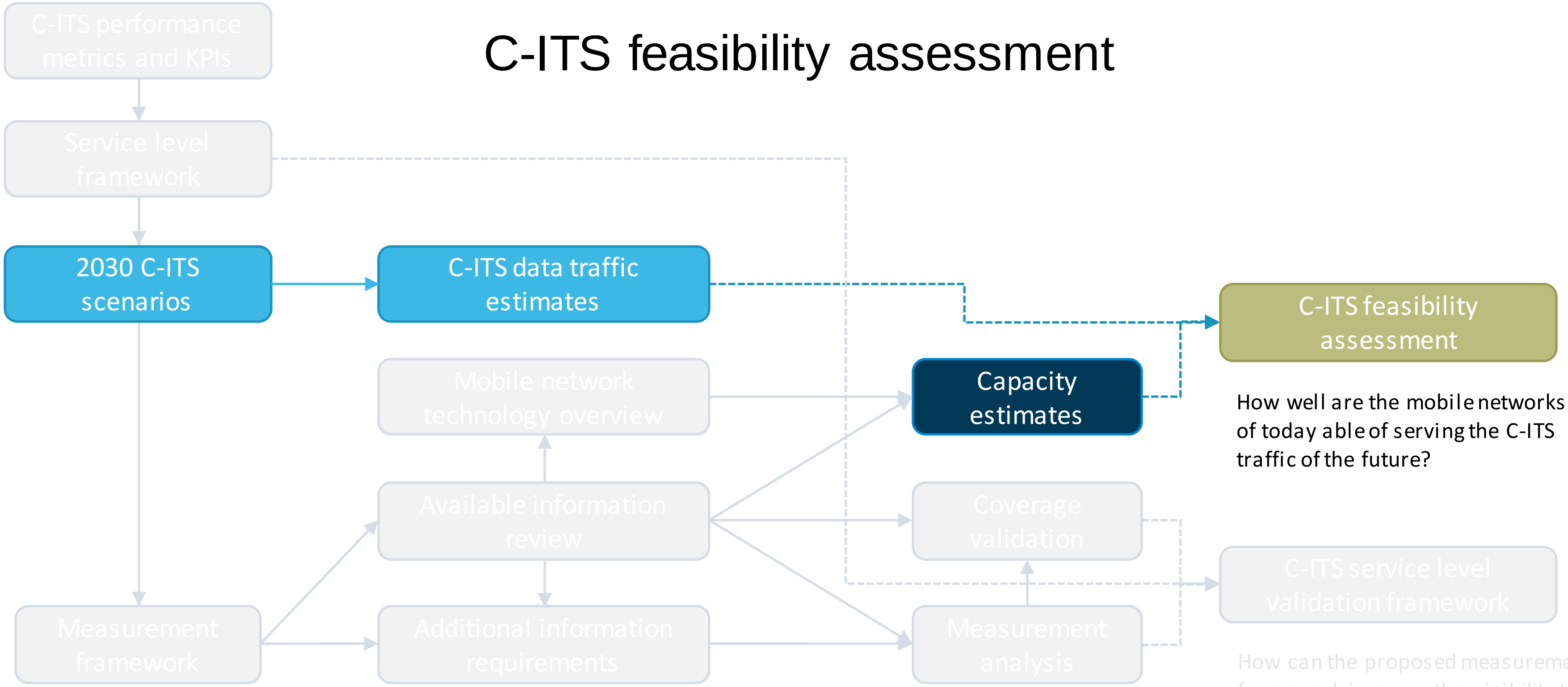
C-ITS feasibility assessment



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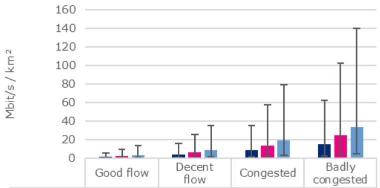
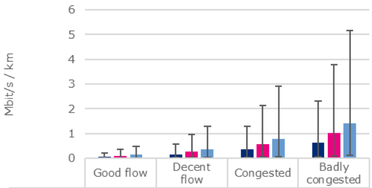
C-ITS feasibility assessment

C-ITS data traffic estimates

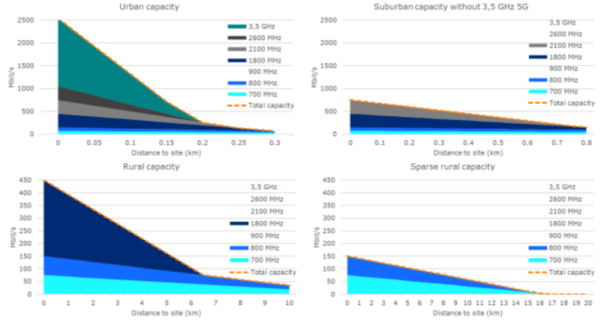


	Good flow	Decent flow	Congested	Badly congested
Pessimistic	1.4	3.7	8.4	14.9
Realistic	2.3	6.1	13.8	24.6
Optimistic	3.1	8.4	18.8	33.5



	Good flow	Decent flow	Congested	Badly congested
Pessimistic	0.06	0.16	0.35	0.62
Realistic	0.10	0.26	0.58	1.03
Optimistic	0.13	0.35	0.79	1.40

Capacity estimates



C-ITS feasibility assessment

Capacity utilization of 2030 C-ITS data in 2023

	Main streets capacity utilisation Capacity per km² (Mbits/s/km²)				High traffic roads capacity utilisation Capacity per km (Mbit/s/km)				
Area:	**Urban**	**Suburban**	**Suburban** (no 3,5 GHz)		**Urban**	**Suburban**	**Suburban** (no 3,5 GHz)	**Rural**	**Sparse rural**
Good flow									
Pessimistic	0.0 %	0.1 %	0.1 %	-	0.0 %	0.0 %	0.0 %	0.4 %	0.6 %
Realistic	0.1 %	0.1 %	0.2 %	-	0.0 %	0.0 %	0.0 %	0.6 %	0.9 %
Optimistic	0.1 %	0.1 %	0.2 %	-	0.0 %	0.0 %	0.0 %	0.9 %	1.3 %
Low: Pessimistic	0.0 %	0.0 %	0.0 %	-	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %
Low: Realistic	0.0 %	0.0 %	0.0 %	-	0.0 %	0.0 %	0.0 %	0.0 %	0.1 %
Low: Optimistic	0.0 %	0.0 %	0.0 %	-	0.0 %	0.0 %	0.0 %	0.1 %	0.1 %
High: Pessimistic	0.2 %	0.2 %	0.4 %	-	0.0 %	0.0 %	0.0 %	1.4 %	2.1 %
High: Realistic	0.3 %	0.4 %	0.7 %	-	0.0 %	0.0 %	0.1 %	2.3 %	3.4 %
High: Optimistic	0.4 %	0.5 %	0.9 %	-	0.0 %	0.1 %	0.1 %	3.2 %	4.7 %
Decent flow	-	-	-	-	-	-	-	-	-
Pessimistic	0.1 %	0.2 %	0.3 %	-	0.0 %	0.0 %	0.0 %	1.0 %	1.5 %
Realistic	0.2 %	0.3 %	0.4 %	-	0.0 %	0.0 %	0.1 %	1.7 %	2.5 %
Optimistic	0.3 %	0.3 %	0.6 %	-	0.0 %	0.0 %	0.1 %	2.3 %	3.4 %
Low: Pessimistic	0.0 %	0.0 %	0.0 %	-	0.0 %	0.0 %	0.0 %	0.1 %	0.1 %
Low: Realistic	0.0 %	0.0 %	0.1 %	-	0.0 %	0.0 %	0.0 %	0.1 %	0.2 %
Low: Optimistic	0.0 %	0.1 %	0.1 %	-	0.0 %	0.0 %	0.0 %	0.2 %	0.3 %
High: Pessimistic	0.5 %	0.6 %	1.1 %	-	0.0 %	0.1 %	0.1 %	3.8 %	5.5 %
High: Realistic	0.8 %	1.1 %	1.8 %	-	0.0 %	0.1 %	0.2 %	6.2 %	9.1 %
High: Optimistic	1.1 %	1.5 %	2.4 %	-	0.0 %	0.2 %	0.3 %	8.5 %	12.4 %
Congested	-	-	-	-	-	-	-	-	-
Pessimistic	0.3 %	0.3 %	0.6 %	-	0.0 %	0.0 %	0.1 %	2.3 %	3.4 %
Realistic	0.4 %	0.6 %	1.0 %	-	0.0 %	0.1 %	0.1 %	3.8 %	5.6 %
Optimistic	0.6 %	0.8 %	1.3 %	-	0.0 %	0.1 %	0.2 %	5.2 %	7.6 %
Low: Pessimistic	0.0 %	0.1 %	0.1 %	-	0.0 %	0.0 %	0.0 %	0.2 %	0.3 %
Low: Realistic	0.1 %	0.1 %	0.1 %	-	0.0 %	0.0 %	0.0 %	0.3 %	0.4 %
Low: Optimistic	0.1 %	0.1 %	0.2 %	-	0.0 %	0.0 %	0.0 %	0.4 %	0.6 %
High: Pessimistic	1.1 %	1.5 %	2.4 %	-	0.0 %	0.2 %	0.3 %	8.5 %	12.4 %
High: Realistic	1.8 %	2.4 %	4.0 %	-	0.1 %	0.3 %	0.5 %	14.0 %	20.5 %
High: Optimistic	2.4 %	3.3 %	5.5 %	-	0.1 %	0.4 %	0.6 %	19.2 %	28.0 %
Badly congested	-	-	-	-	-	-	-	-	-
Pessimistic	0.5 %	0.6 %	1.0 %	-	0.0 %	0.1 %	0.1 %	4.1 %	6.0 %
Realistic	0.7 %	1.0 %	1.7 %	-	0.0 %	0.1 %	0.2 %	6.8 %	9.9 %
Optimistic	1.0 %	1.4 %	2.3 %	-	0.0 %	0.2 %	0.3 %	9.3 %	13.5 %
Low: Pessimistic	0.1 %	0.1 %	0.2 %	-	0.0 %	0.0 %	0.0 %	0.3 %	0.5 %
Low: Realistic	0.1 %	0.2 %	0.3 %	-	0.0 %	0.0 %	0.0 %	0.5 %	0.8 %
Low: Optimistic	0.2 %	0.2 %	0.4 %	-	0.0 %	0.0 %	0.0 %	0.7 %	1.0 %
High: Pessimistic	1.9 %	2.6 %	4.3 %	-	0.1 %	0.3 %	0.5 %	15.1 %	22.1 %
High: Realistic	3.1 %	4.3 %	7.1 %	-	0.1 %	0.5 %	0.8 %	25.0 %	36.5 %
High: Optimistic	4.2 %	5.8 %	9.7 %	-	0.2 %	0.7 %	1.2 %	34.1 %	49.8 %
Busiest roads	-	-	-	-	-	-	-	-	-
Extreme	9 %	12 %	20 %	-	0 %	2 %	3 %	83 %	121 %

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Key take aways

- The 4G and 5G networks of 2023 are largely able to support the expected C-ITS data traffic of 2030.
- Mobile networks include by nature some level of unreliability, C-ITS-services must be able to adapt to this.
- The proposed measurement framework is suitable for monitoring and validating service level availability and supports flexibility in the analysis.
- There are still many uncertainties related to the adoption rate and implementation of the C-ITS services.

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Nordic WAY

Way forward

- We will address development needs related to:
  - C-ITS services (message content, generation, transmission, etc.)
  - Mobile network (prioritizing, slicing, construction of additional base stations)
  - Measurement methods (operator-specific coverage predictions, crowdsourced measurements)

- We will propose operation models for the recognized development needs related to:
  - Regulation
  - Monitoring
  - Cooperation

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Cybersecurity in cellular C-ITS: roles of the authorities and practical example

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Nordic WAY

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Nordic WAY

1. Cybersecurity in cellular C-ITS

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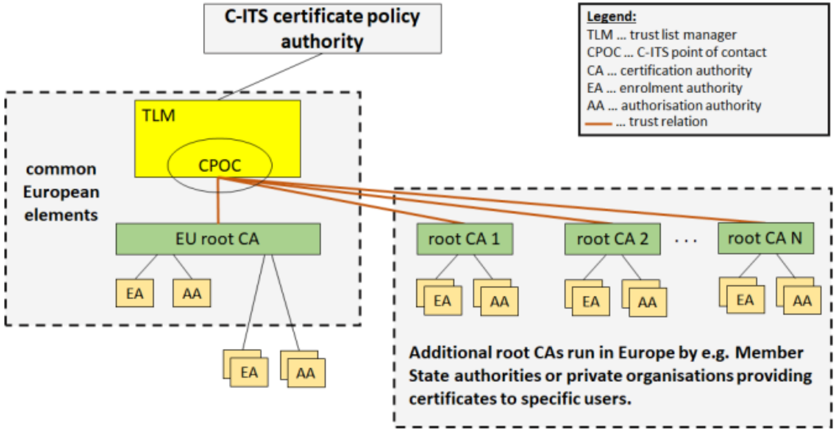
C-ITS Trust model

C-ITS: intelligent transport systems that enable ITS users to interact and cooperate by exchanging **secured and trusted messages**, without any prior knowledge of each other and in a non-discriminatory manner

EU CCMS (C-ITS Credential Management System): distributed PKI

3 security levels:

- L0: for testing
- L1: transition phase (ends in 2025)
- L2: operational phase – fully certified



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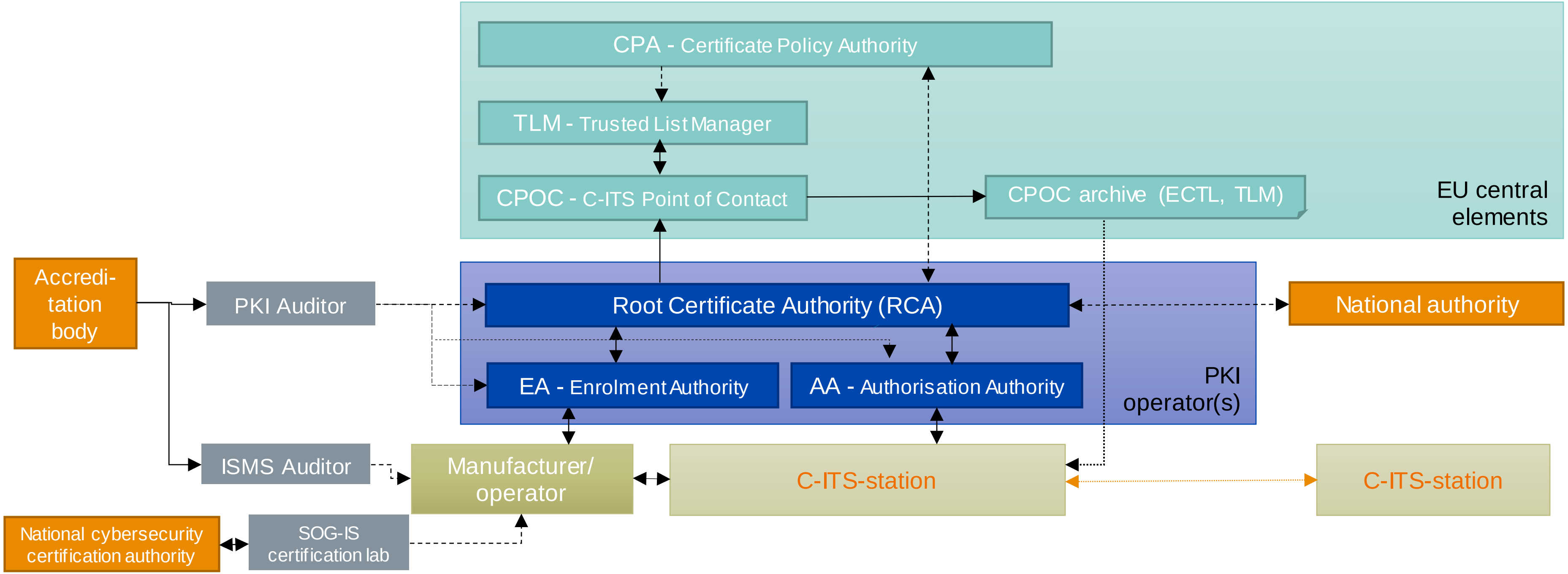
Actors in the C-ITS Trust model



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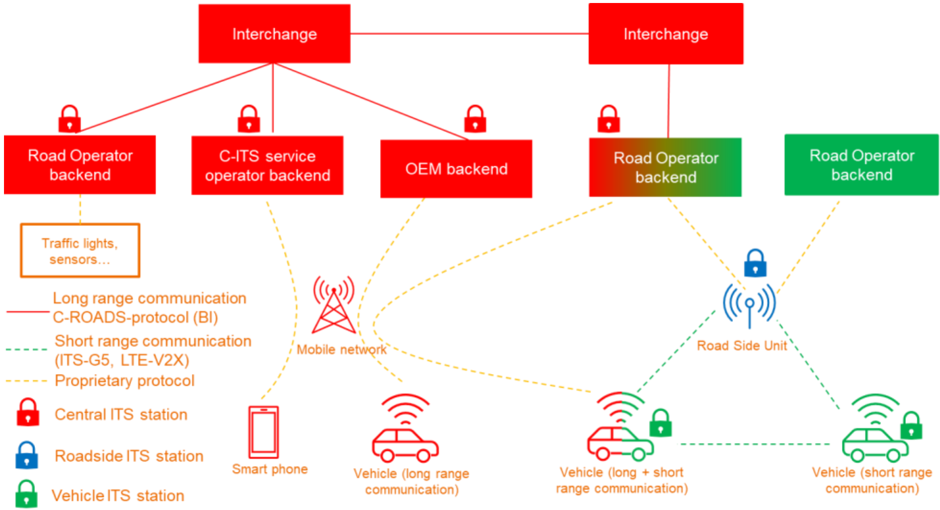
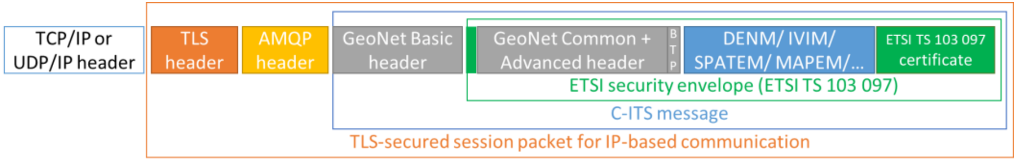
C-ITS Trust model and IP-based communications

- In IP-based communications only Central ITS-station at service provider backend
- C-Roads specifications
    - Messages secured with IEEE 1609.2 certificates
        - Geonet header required to allow forwarding by vehicles with hybrid OBU
    - IP-traffic with TLS1.3 X.509 certificates





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Proposal for organising authorities' cybersecurity roles in Finnish C-ITS services

Actor name	Proposal for the role in Finland
PROPOSAL FOR A NEW ROLE: C-ITS central station operator	Fintraffic Ltd or Fintraffic Road Ltd (national road network) / municipalities (road and street network)
PROPOSAL FOR A NEW ROLE: EU CCMS : service-specific permissions (SSP)	Finnish Transport and Communications Agency (Traficom)
PROPOSAL FOR A NEW ROLE: Root Certificate Authority (RCA), Enrolment Authority (EA), Authorisation Authority (AA)	Economic operator

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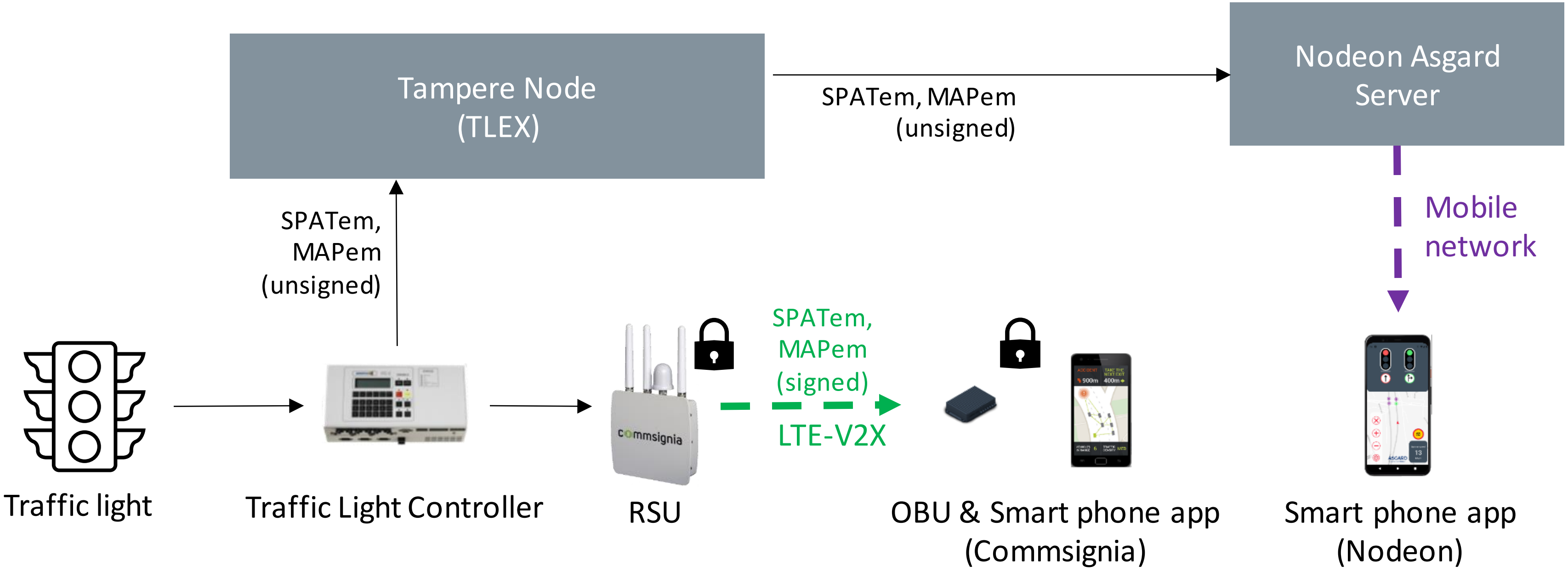
2. Cybersecurity example: LTE-V2X pilot



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Getting L0 certificate

EU RCA L0

- Application requires:
  - Registration of organisation
    - Simple mail describing needs and quantieties of OBUs and RSUs
    - Fill in and sign C-ITS EU ROOT CA & SUB CAs SAAS agreement
    - Legal registration proof of organisation
  - Station enrollment
    - Table with device identification, desired SSPs, public key

Microsec L0

- Collaboration Commsignia – Microsec
  - Tool to automatically enroll the devices in PKI
    - SSP to be entered manually

5. Registration process
Stations enrollment

IDnomic

	Name	Max EC validity period	Max AT validity period	Max AT preloading period	Validation request requires privacy	Allowed permissions
Attribute format	*ASCII*	*Integer:Unit*	*Integer:Unit*	*Integer:Unit*	*Optional, True, or False*	*PSID:SSP ; PSID:SSP ; PSID:SSP ; ...*
Default profile	Default Profile	3:Years	7:Days	30:Days	Optional	36 : 010000 ; 36 : 01E500 ; 36 : 01FFFC ; 37 : 01000000 ; 37 : 01FFFFFF ; 137 : 01E0 ; 138 : 01C0 ; 139 : 01744000FFF8 ; 140 : 01FFFFE0 ; 141 ; 623 : 01C0
Profile01						
Profile02						
Profile03						
...						

	Canonical name	Public key	Attached profile name	Station status	*Tags (optional)*
Attribute format	*ASCII (possible in HEX also)*	*RFC 5480*	*ASCII*	*Status*	*ASCII*
Example	Company_MyStation0001	3059 3013 0607 2A86 48CE 3D02 0106 082A 8648 CE3D 0301 0703 4200 0462 83FD 5D98 9904 8B76 E3E7 AABC 05C4 0A45 46C1 30C6 56F6 BDD3 97D1 1125 4114 EB01 0631 9254 9D45 67D7 1EF2 3C56 F596 2064 0867 CB88 868C 986C 227D E721 2BAA BD	Default Profile	Activated	*EmailOfOperator1 Compagny_name1 Operator1 Station_usage1*
Station01					
Station02					
Station03					
...					

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Steps towards L1 and L2

- Setup ISMS (Information Security Management System)
  - Perform risk assessment involving all C-ITS functions
    - Identify risks, steps for protecting assets, action plans, responsibilities…
  - For L1: internal assessment, confirmed by self-issued statement of compliance
  - For L2: external audit by accredited PKI auditor

- Ensure that C-ITS stations are designed, developed and assessed so that they meet the C-ROADS specifications.
  - L1: evaluation that devices are protected against basic attacks by a SOG-IS recognised test lab
  - L2: certification required according to Common Criteria

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3. Open issues and recommendations

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Open issues and recommendations (1/2)

- Governance of IP based session layer security (TLS)
  - Discussions started at C-ROADS level
- Special permissions
  - Process to request SSPs to be set up nationally
  - Which C-ITS use cases require permission of national authority
    - Certificate policy mentions services for ”governemental purposes” requiring member state permission
- Use of national Root Certificate Authority or use of EU RCA
  - The implementation of a national root certificate authority allows to influence the granting of permissions to send messages.
    - No information yet on the processes for requesting SSPs in Level 1 and 2 from EU RCA
  - As a recommendation for further work by the authorities, it is to look at various disturbances and exceptional situations related to C-ITS services and systems, the related legislation, roles and tasks.

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Open issues and recommendations (2/2)

- Message signing
  - Message signing with IEEE1609.2 certificates (for C-ROADS compliance) creates overhead but improves security
  - Future solution: Signature at facility layer to have a single trust domain
    - Use of TLS with IEEE1609.2 certificate – standards and commercial products still missing
- Amount of Central ITS stations
  - Central ITS station operator can sign on behalf of other partners (e.g. road authority on behalf of city)
    - Small actors (e.g. municipalities, roadwork contractors) may have difficulties obtaining required ISO 27001 certification
    - Signing on behalf requires trust relationship between partners
- Central ITS station certification: protection profile or security target evaluation
  - In Finland, there is no existing SOG-IS conformity assessment body for safety assessment and certification of C-ITS stations.

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For more information

Results will be reported in:

- Study of Authorities' roles in implementation and operational use of C-ITS services in Finland. Unpublished report in Finnish (2023) original name: Viranomaisten roolit vuorovaikutteisten älykkäiden liikennejärjestelmien (C-ITS) palveluiden käyttöönotossa ja operatiivisessa käytössä
- Piloting cybersecure and interoperable cellular C-ITS services. Unpublished report (2024)

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