LINK QUALITY DOES NOT MATTER IF YOU'RE TOO LATE...

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SECURE CONNECTIONS
FOR A SMARTER WORLD

PUBLIC

DAF ECOTWIN TRUCK PLATOONING VIDEO

- EcoTwin video from DAF (2:58): https://youtu.be/R08mg0XmbS0?t=80 1:20 – 1:50

- Kees Moerman, Sr. Principal at NXP Semiconductors
  - Working at Automotive on Intelligent Transportation Systems (ITS)
    - In subset V2X communication: Vehicle to vehicle/infrastructure wireless communication
  - Smart Mobility: ITS one of the pillars, covering e.g. traffic monitoring and control
- Link quality does not matter if you're too late...
  - Wireless technology is not only about link budget, signal to noise, Shannon limits etc.
- Observations from our participation in several projects on Smart Mobility/ITS
  - EcoTwin: DAF truck platooning, real-time close distance (0.3 - 0.5 second) automated driving
  - Ensemble: Multi-brand truck platooning, 7 different truck brands
  - Concorda: evaluation V2X using different media (IEEE 802.11p, LTE-V2X, 4G LTE)

SECURE CONNECTIONS FOR A SMARTER WORLD

OUR DIGITALLY ENHANCED WORLD IS EVOLVING TO ANTICIPATE AND AUTOMATE

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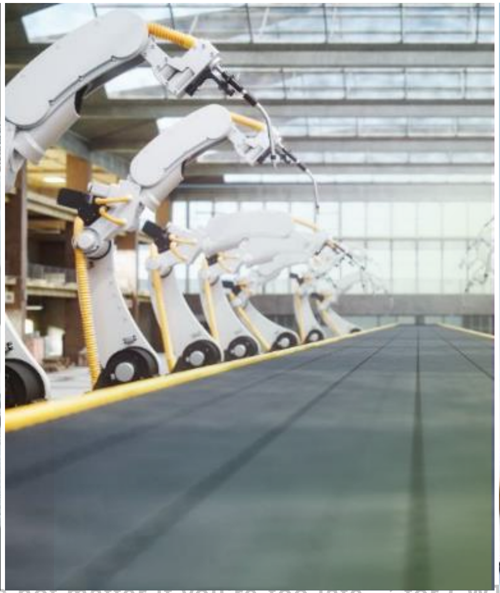



NXP AUTOMOTIVE SYSTEM SOLUTION HIGHLIGHTS

SENSE	THINK	CONNECT	ACT
Radar	S32 Platform	UWB	Electrification
V2X	ADAS Processing	Infotainment	
	i.MX	Vehicle Networking	

Introduction

Truck Platooning: system-internal latencies

Concorda: network latencies

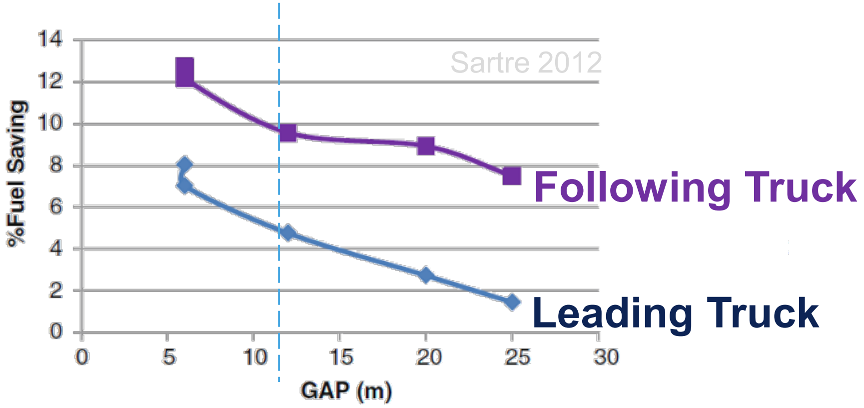
Conclusions

EcoTwin TRUCK PLATOONING

Radar
See-through Camera
G5/WiFi-p (4 antennas in cabin mirror)

Radar
Camera
G5/WiFi-p 4 antennas

Rationale (a.o.):
Fuel costs are up to 33% of transportation
Rise of fuel costs expected



Following-Vehicle functionality:

- Longitudinal automation: braking, throttle: (C-)ACC and S&G
- Short distance: **0.5** seconds
  → 11m @ 80 km/h
- Lateral control: lane keep assist
- HMI and Transition-of-Control for platooning hook-up/detach
- Safety system
  - Audio, Video (see-through), redundant WiFi-p, Diagnostics
  - Radar for Cut-in Detection
- RDW exemption for public road (for a specific period and trajectory) based on extensive safety analysis

HIGH PERFORMANCE V2V COMMUNICATION

- Platoon driving at 11 meter distance @ 80 km/h (0.5s):
  - String stable platooning requires ≤80 ms system latency
  - Collision avoidance requires ≤50 ms latency*
- Detection with physical sensors only:
  - Decision → action 1st car→ detection 2nd car→ Decision

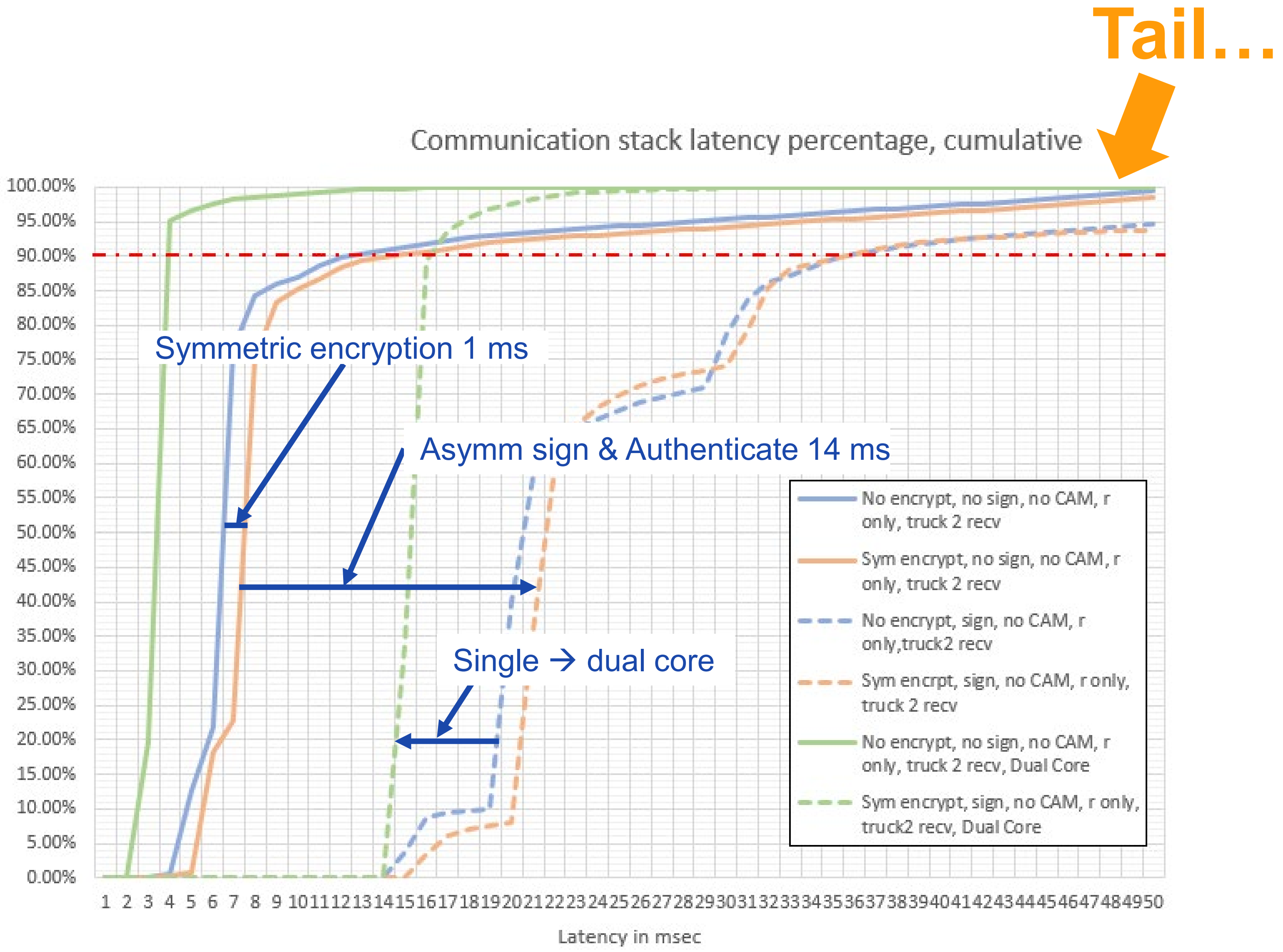
    200 ms | ~ 200 ms
- Using Car-to-Car communication and reasoning
  - Decision → send+receive* → Decision

    < 50 ms

© TNO Mobility and Transport

*: example, also depends on factors like brake capacity difference (ref: Concorda final event presentation)
**: actual RF communication latency via IEEE 802.11p is 2..3 ms typ. at link layer (box-to-box)

THE REALITY…



- Average fulfills requirements
  - Note: latency at low-level link, not application
- However, long out-of-the-box tail
  - Eats into time for other functionality
- Example options to improve
  - Process priorities
  - Real-time kernel patch (Linux)
  - Multi-core: use core affinity
    - Including IRQ handling!
    - Ethernet versus 11p(USB) split
  - Once platooning, use symmetrical encryption only (change standard)
  - (Different (hard real-time) OS)
  - Minimize logging…

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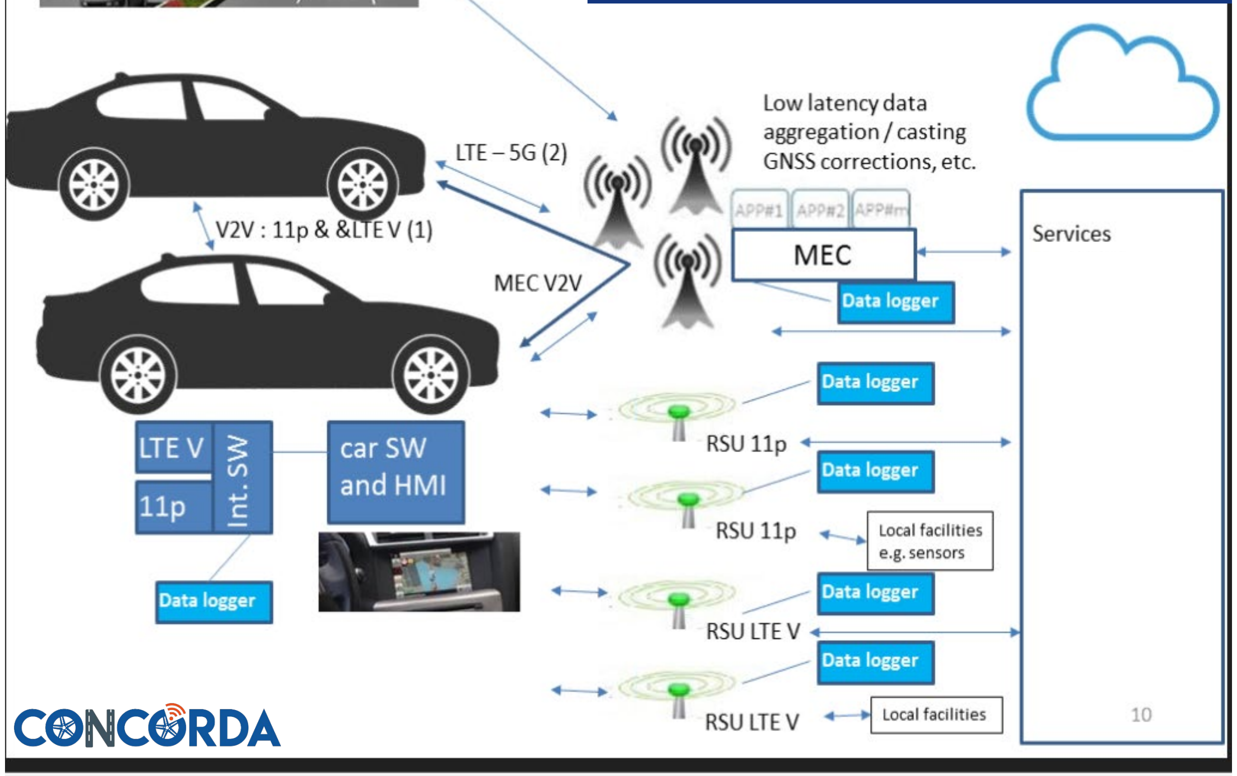
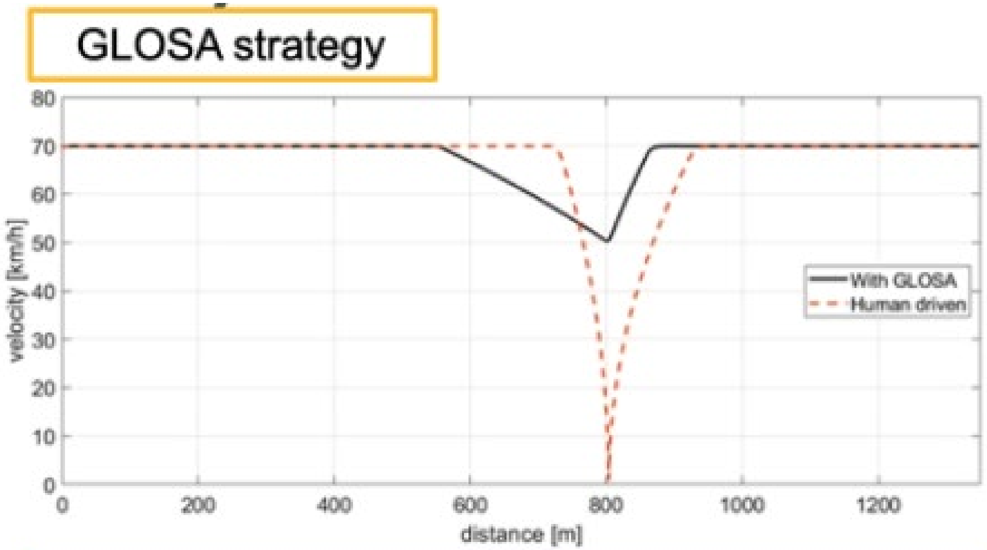
CONCORDA (CONNECTED CORRIDOR FOR DRIVING AUTOMATION) EU PROJECT

- Concorda prepares the European motorways for automated driving and high-density truck platooning with adequate connected services and technologies.
- The main objective is to **assess performances** of the hybrid **communication** under real traffic situations.
- Quality of service, safety, **latency** needs to be compliant for automated driving, so that in future the connected data can contribute as an additional sensor data.

Integrate communication services in practical, real-life and complex environments
Adapted for connected automated driving services with hybrid communication architecture
Including the newest communication technologies and guarantee their coexistence



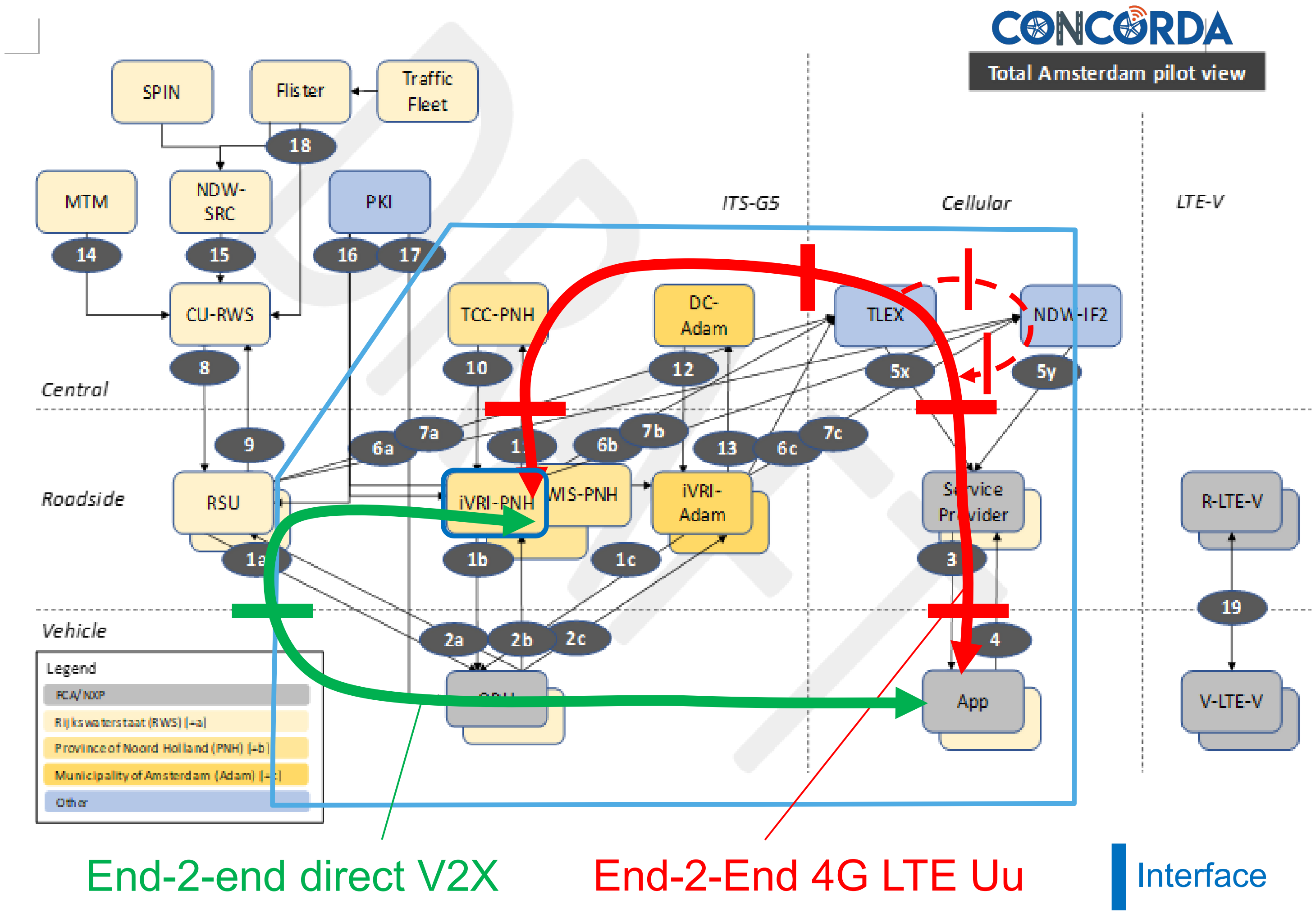
- ‘GLOSA’: **G**reen **L**ight **O**ptimal **S**peed **A**dvisory
  - Infrastructure to vehicle communication
  - Optimize driving speed based on distance to traffic light and traffic light schedule
  - Improve fuel economy, drive time, traffic flow
- Concorda: evaluation of ITS links
  - direct V2X communication
    - IEEE 802.11p (ITS-G5)
    - LTE-V2X (LTE PC5)
  - Classic LTE telecom infrastructure
    - LTE-Uu 4G (via back-end/mobile edge computing)
- Metrics: latency, reliability



✓ GLOSA strategy-based speed profile, compared with the human-driven vehicle.
✓ GLOSA-equipped vehicles can speed up to the limited velocity faster, and thus with a shorter travelling time.

END-2-END PERFORMANCE FOR 'GLOSA' IN NL

- Architecture direct V2X versus cellular/TCC backend-based distribution
- (i)VRI: (Intelligente) Verkeers-Regel-Installatie
  - (intelligent Traffic Control Installation)
  - In this case: traffic light control
  - Generates SPAT: Signal Phase and Timing message
- OBU: On-Board Unit
  - V2X in-car module for direct comm.
  - RSU: Road-Side Unit (V2X in iVRI)
- TCC: Traffic Control Center
- TLEX: Traffic Light Exchange DB
- NDW: National Data Warehouse
- -PHN: Province Noord-Holland

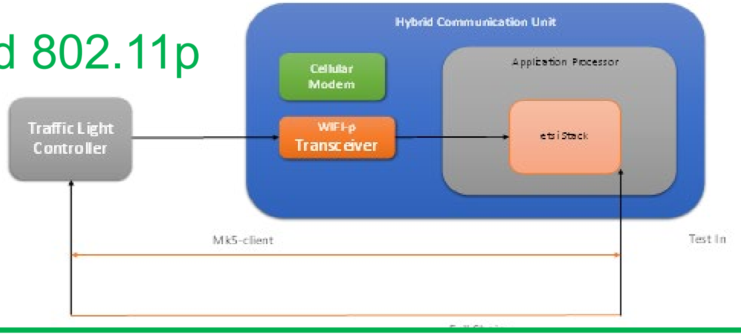


END-2-END PERFORMANCE FOR GLOSA IN NL (SPAT) AT PDR >=85%

- For ETSI “day-1” use case apps (eg GLOSA)
  - Typical requirement: max. 100 ms latency
  - V2V (802.11p/LTE-V2X) fulfils by large margin
    - LTE-V2X PC5: same + 20..40ms scheduling: OK
  - 4G/5G LTE: current back-end infrastructure determines latency
    - Format conversions, interfaces, MQTT database for geo-distribution (GeoService), …

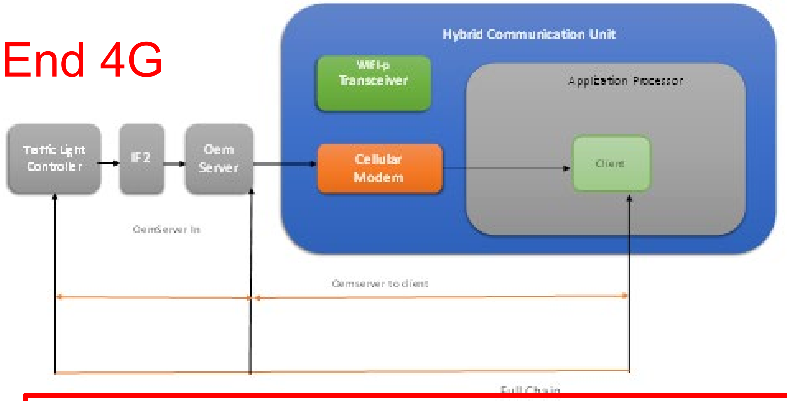
Latency Time	Mean [ms]	Max [ms]	Std. deviation [ms]	95% Reliability [ms]
ITS-G5	44	154	14	72
PC5	80	174	21	116
GS A81	99	2002	58	133
GS A9 with public APN	83	1488	29	114
GS A9 without public APN	75	698	22	105
GS NL local edge	71	2036	77	102
MQTT local edge	116	1138	85	159
MQTT central edge	122	1324	65	169

End-2-end 802.11p



90% end-2-end
- 10-20 ms w/o security (NXP: 10 ms)
  - +50 ms security (NXP: +33.5ms)
- Range 320-1080 m

End-2-End 4G



90% end-2-end w/o security:
- 120 - 320 ms
  - Of which 25 - 40 ms 4G service provider

LEARNINGS CONCORDA (SUBSET)

- Successfully demonstrated traffic control use cases as GLOSA using hybrid V2X
- However, "*Only the implementation based on ITS-G5 is currently mature enough to fully support all functional and non-functional requirements*"
- The various links have clear differences in performance, especially latency
- Quality guarantees can and should be enabled in the cellular network, and applications need to make use of these
- GeoServices should be optimized (low latency, reduce network overhead)
- Need to consider whether the current standards are really suited for this kind of architecture
  - Message content and frequency, security mechanisms optimized for ad-hoc V2X networks

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CONCLUSIONS

- In Smart Mobility, link quality does not matter if you're too late...
  - Real-time application may require bounded latencies
  - Latencies often not due to actual wireless link, but due to compute infrastructure

- Take latency requirements into account in system architecture
  - Use cases move from simple non-time-critical ones (e.g. RWW: Road Works Warning) to ‘Day-1’ applications (e.g. GLOSA) to hard real-time applications (platooning)
  - Road operators not used to look into latency aspects; more looking at data warehouses, structures, accessibility
  - On small scale: look at your real-time embedded control systems
  - On large scale ITS systems: network latency impact, keep your interfaces clean and minimal
  - Test! And again… And again…

- Test in real life situations
  - Gives real time surprises, if ‘same’ standards implemented by multiple vendors
  - Not trivial, may require lengthy safety certifications for road traffic tests as platooning

MORE INFO ON MENTIONED PROJECTS

- Ensemble multi-brand truck platooning
  - platooningensemble.eu/
  - Play list: ENSEMBLE Public Demonstration & Testing
- EcoTwin truck platooning
  - www.daf.com/nl-nl/over-daf/duurzaamheid/intelligente-logistiek/daf-ecotwin-truck-platooning
  - Video: youtu.be/R08mg0XmbS0
- Connected Corridor for Driving Automation (Concorda)
  - ertico.com/concorda/

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