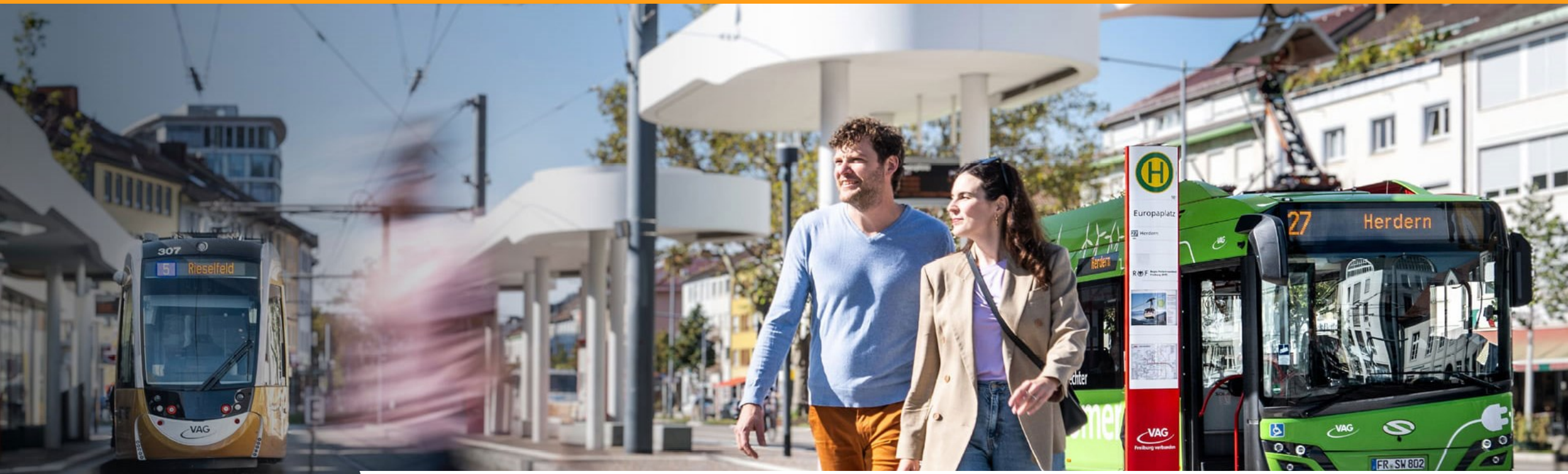


Proposal for VDV Specification 435.X

PTX Interface
Integration of ITCS IBIS with V2X OBU

Ivo Herman (Herman) – Dominique Müller (Trapeze) – Fabian Riether (Yunex)

15.08.2024

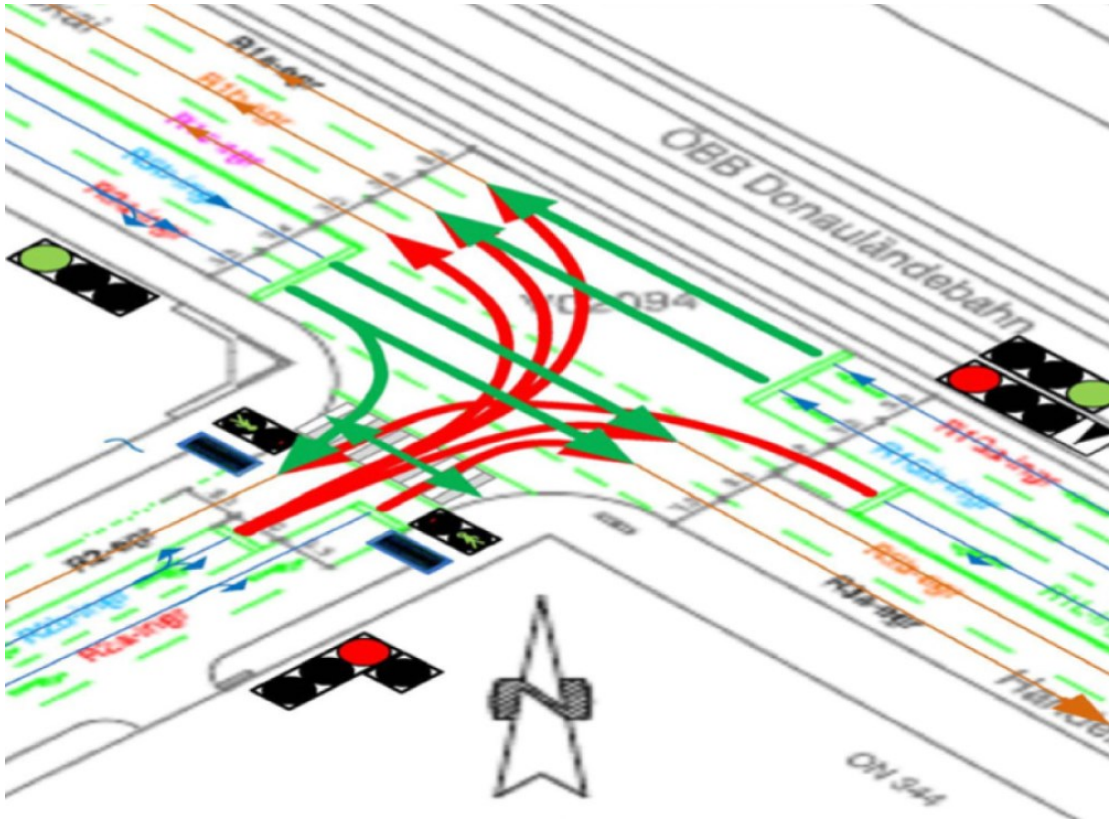
Trapeze™

YUNEX TRAFFIC

HERMAN

What is «V2X»? What is «C-ITS»?

Interconnecting vehicles with each other and with infrastructure

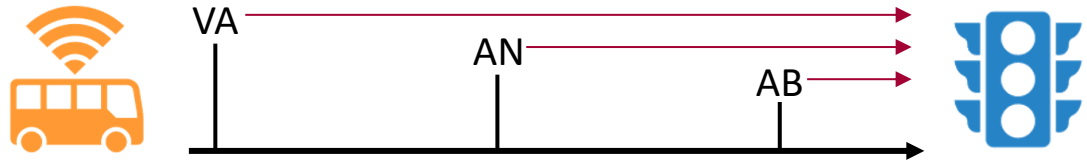


Layout of the junction with phase information for each lane

Why Now?

V2X technology has achieved a breakthrough

- Successful field testing in C-ROADS projects
- V2X already available as standard equipment in cars
- Deutsche Autobahn GmbH will equip approx. 1200 mobile barrier panels with V2X by the end of 2024
- German cities are now starting to equip their intersections with RSUs



Traffic signal control according to VDV 420 or 426 is outdated

- specification dates from 1984 (last revised in 1992)
- communication cannot be secured; hacker attacks on tram switches have led to personal injury and property damage
- analogue radio frequencies will be restructured by the end of 2028 (channel spacing reduced from 20 kHz to 12.5 kHz, some shifted to other frequency bands) and will no longer be available by the end of 2036
- technological advances of the last 50 years cannot be utilised and implemented into new functions
- statically defined reporting point chains are inflexible and therefore not suitable for dynamic operation control

Agenda

1. Use Cases
2. Architecture
3. Principles
4. Messages

Use Cases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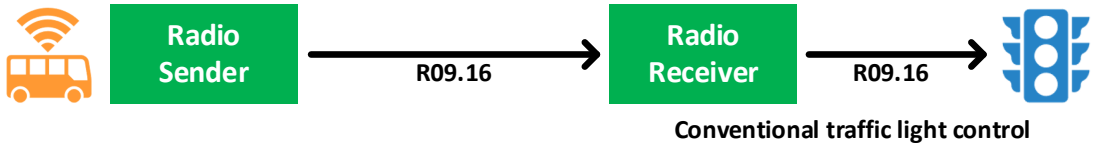
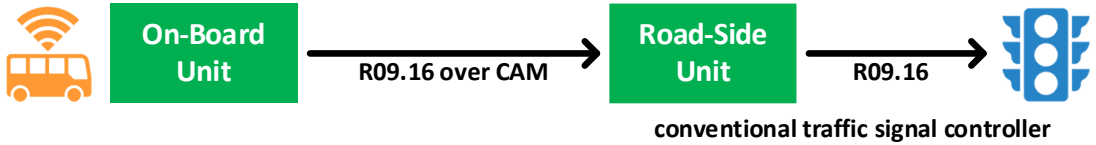
Traffic Light Priority Migration from VDV 420/426 (R09.16) to V2X

Switch from analogue or digital radio to V2X – coordinated between municipality and public transport company

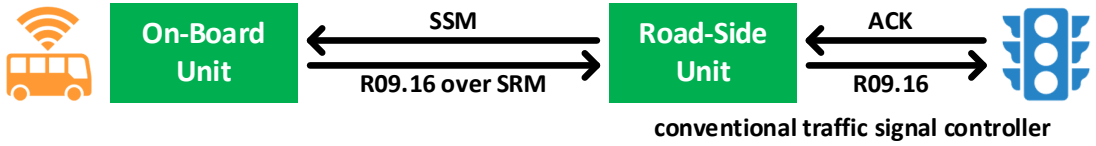
Current Situation: VDV 420 (analog) or 426 (digital)



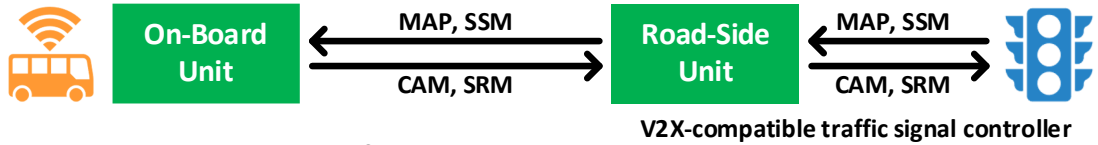
Stage 1A: Conversion of radio link (uni-directional)



Stage 1B: Conversion of radio link (bi-directional, hopping)

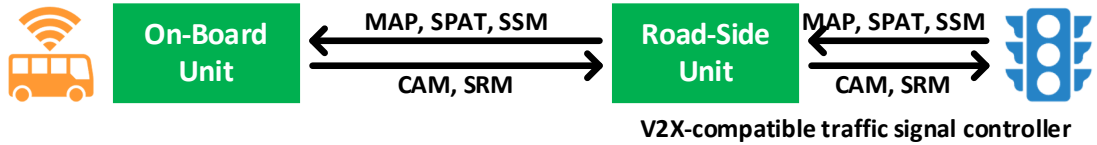


Stage 2A: Traffic Signal Priority with V2X



Advantage: No need for reporting point chains
→ less effort for data preparation
→ flexible dispatching (e.g. path dispatch) becomes possible
→ reduced waste of «green» thanks to continuous ETA updates

Stage 2B: Traffic Signal Priority incl. Signal Phase Assistance

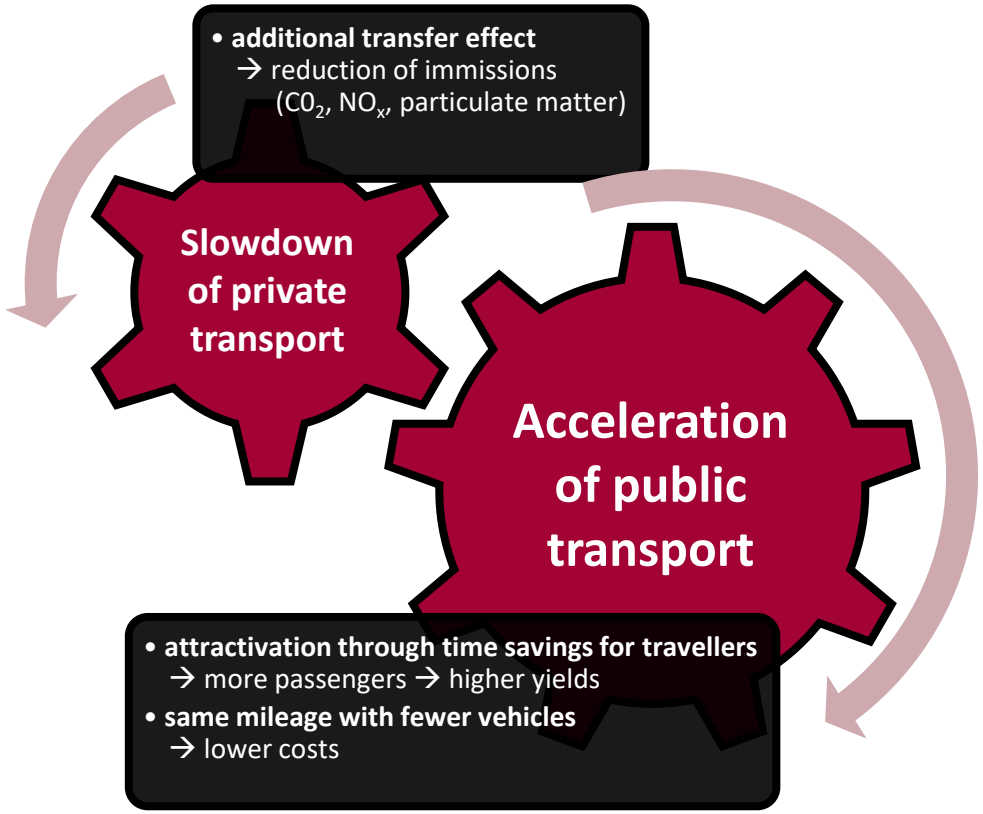


Advantage: Driving Assistance
→ traffic becomes smoother, safety increases
→ energy savings and increased passenger satisfaction

BASt-Handlungsempfehlung: «Nutzung der C2X-basierten ÖV-Priorisierung an signalisierten Knotenpunkten» (Kap. 3.3)

What Does V2X Promise for Public Transport?

Conventional public transport priority at traffic lights



Additional benefits thanks to V2X

Continuous Communication

no reporting points
→ less effort for data supply
→ allows flexible dispatching

continuous ETA update
→ reduction of «wasted green»

Driving Assistance

Energy-optimised approach to junction
→ energy savings up to 30% (*)

Time-optimised departure from stop
→ increased customer satisfaction

Timely lane change
→ smoother traffic

Global Standard

→ interaction with private vehicles

→ not limited to traffic light priority

Warnings

→ increased safety

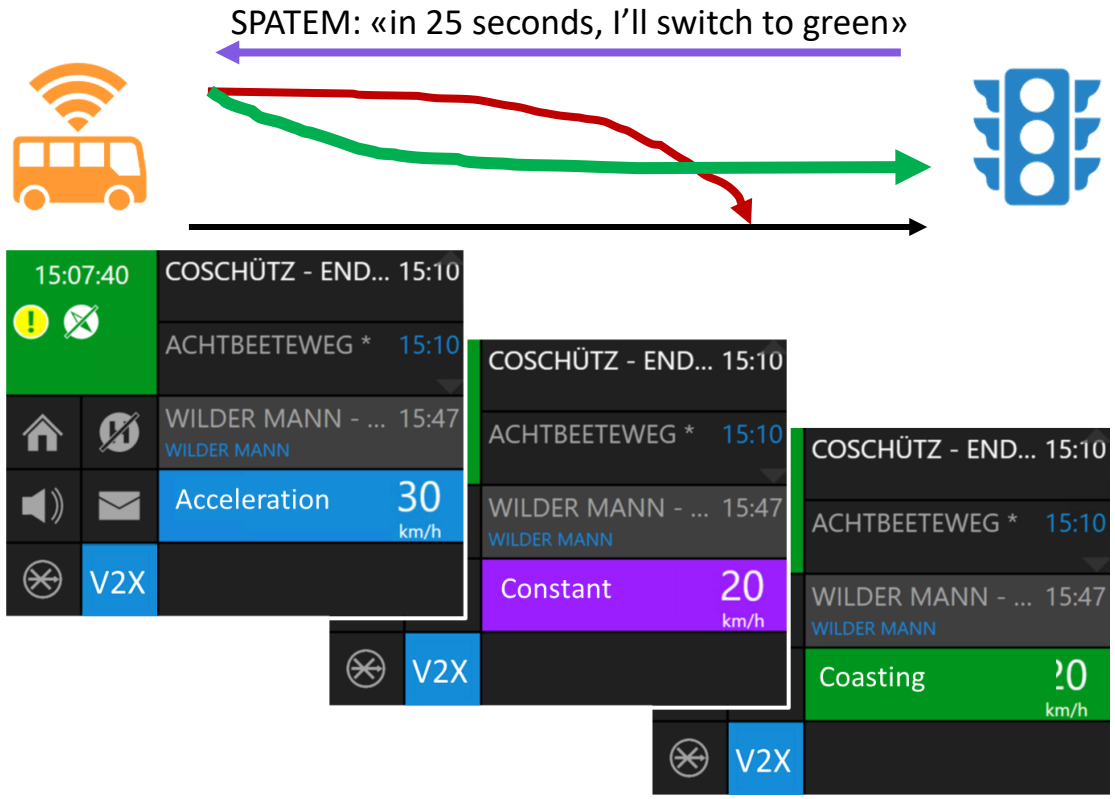
- approaching emergency vehicles
- oncoming traffic in bottlenecks
- dangerous road conditions, construction sites
- vulnerable road users in the blind spot
- etc.

(*) Christian Gassel, DVB, C-ITS Forum 2024

Use Cases for V2X in Public Transportation

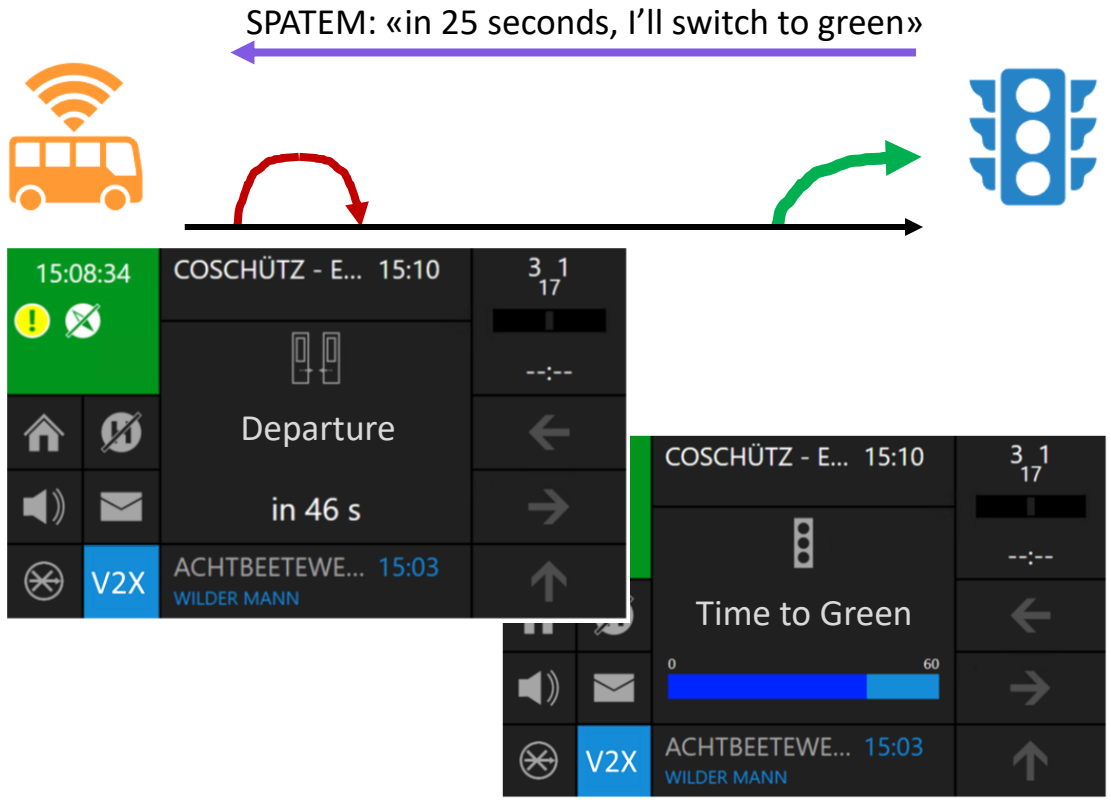
Energy-optimsed Approach to Junction

→ carry momentum



Time-optimised Departure from Stop

→ carry passengers



Currently not in scope – ideas for further evolution

Enable additional use cases…

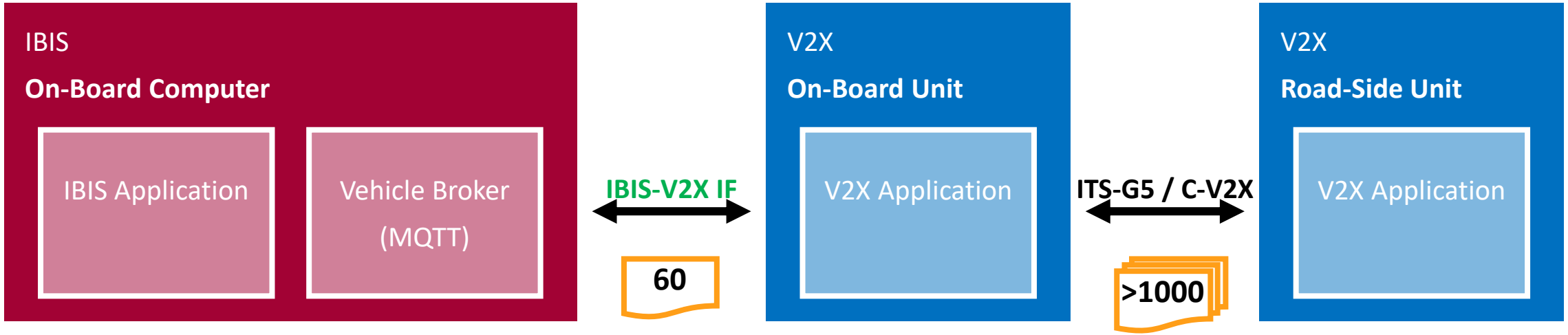
- Speed Assistant
  (dynamic speed limits)
- Safety Assistant
  (warnings about road works or accidents)
  (warnings about emergency vehicles)
  (warnings about vulnerable road users)
- Bottleneck Assistant
  (who drives first through a constriction zone?)
- Lane Change Assistant
  (timely manoeuvres)
- …

…by processing additional V2X messages

- DENM
- IVIM
- CPM
- …

Architecture

De-Central Traffic Light Priority



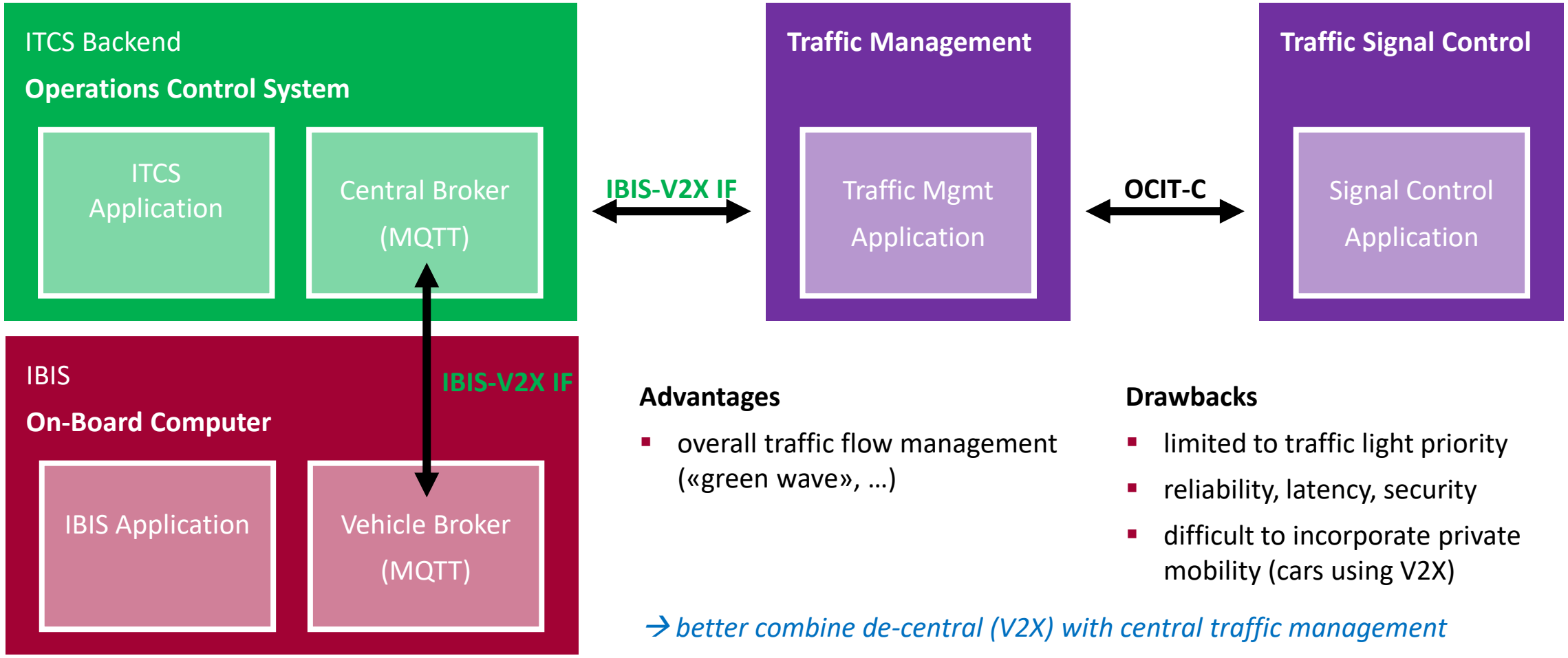
Tasks of IBIS on-board computer

- location tracking (linear and geographical)
- communication with control system
- driving support (timetable deviation, sat nav)
- passenger information in and on the vehicle
- integration of peripheral devices (passenger counters, validators, …)

Tasks of the V2X on-board unit

- communication with V2X road-side unit via air interface (ITS-G5 or C-V2X)
- communication with IBIS via Ethernet
- mediation between IBIS and V2X «worlds» (significant complexity reduction for IBIS)

Central Traffic Light Priority



Advantages

- overall traffic flow management («green wave», …)

Drawbacks

- limited to traffic light priority
- reliability, latency, security
- difficult to incorporate private mobility (cars using V2X)

→ *better combine de-central (V2X) with central traffic management*

Principles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VDV300 –> VDV301 –> VDV435

Scope of PTX Interface

- V2X OBUs shall be «pure VDV 435 devices»
  - need to implement only IoM (MQTT)
  - i.e. not a combination of IBIS-IP and IoM
- therefore, PTX includes
  - messages for device management
  - messages for operational info
- DNS-SD could be used to discover the broker

Why? V2X devices shall be cost-efficient, without the complexity that would result from multiple partial protocol stacks (e.g. IBIS-IP and IoM)

Protocol

- Transport: MQTT v5 («expiry» feature)
- Security: can use MQTTS (MQTT over TLS)
- Encoding: JSON (Protobuf would be possible)
- Topics: separate per direction
- QoS, Retention, Expiry: defined per message
- Message Header: timestamp, version

Why? Even if the messages are «point-to-point», publishing text messages to a broker aids development and testing (good observability)


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Messages

Device Management and Logging

IBIS-to-Device

- **Power State** – information about the current power level and about foreseeable «power off»
- **Log Level Configuration** – instruction to the device to publish log messages to the broker
- **Command Trigger** – instruction to the device to «do something» (e.g. reboot)

Device-to-IBIS

- **Power Request** – request to keep «power on» for some time (including need for comms)
- **Log Messages** – publishing of log messages
- **Device Version Info** – version info about the device and its components (intended for fleet repository)
- **Device Health Info** – health info about the device (intended for fleet monitoring)

Why? Device management and logging allows any device (including a V2X OBU) to become part of a well-managed on-board network

Operational Information

IBIS-to-Device

- **Vehicle Info** – static information about the vehicle
- **Operational Logon** – logon information with IDs traceable back to VDV452 (changes once per journey)
- **Operational Journey** – full details about the current journey (changes once per journey)
- **Operational Status** – geographic and «logical» location, door status, on-/off-route, … (changes frequently along the journey)

Device-to-IBIS

(none)

Why? Operational information may directly apply to certain outgoing V2X messages (e.g. CAM), or it might be useful for the OBU to provide certain value-added features

V2X-Specific Messages

IBIS-to-OBU

- **Configuration** – enabling and disabling of features including air interface mirroring on a per-message basis
- **Path Definition** – the geometric path (next few kilometers) the vehicle will travel
- **Path Location** – the location of the vehicle on the path (some kind of «logical location»)
- **R09 Request** – 1:1 copy of the city-specific R09 telegram which is sent over analog or digital radio (reporting point or other criteria)
  --> can be sent over CAM or SRM

OBU-to-IBIS

- **Capabilities** – advertisement of the services and messages supported by the OBU (= basis for configuration message)
- **R09 Response** – [only if SRM is used] the responses (SSM) from the junction controller
- **Intersection Map** – static information about junction, lanes, layout, interconnections
- **Intersection Phase** – real-time information about signal phases
- **Intersection Status** – lane assignment and signal status for assigned lane

Why? R09 Request/Response enable migration scenarios; Intersection Map/Phase/Status and Path Definition/Location enable the «reporting point free» traffic light priority and assistance for energy- and time-optimised driving

Air Interface Mirroring

OBU-to-IBIS

- **Sent Messages** – as subscribed by IBIS
- **Received Messages** – as subscribed by IBIS

OBU Storage (not on broker)

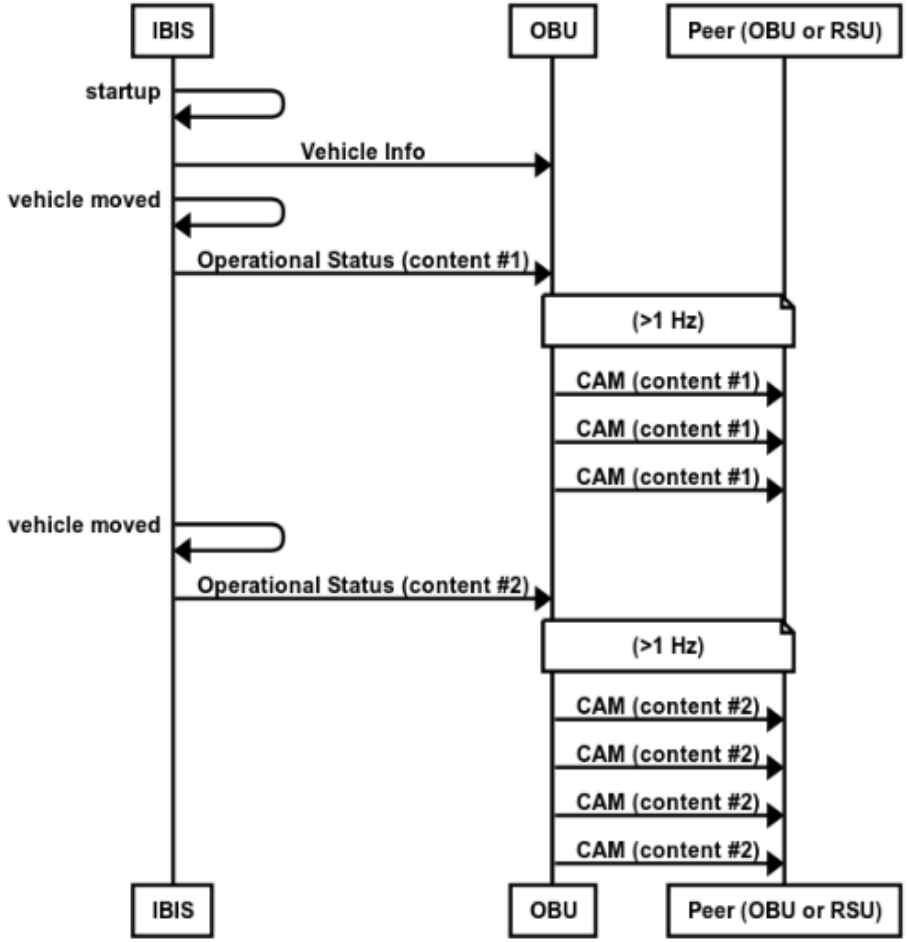
- **PCAP Dumps**
  - to be retrieved via HTTP or other means
  - can be directly analysed with WireShark (no plug-in required)

Why? Air interface mirroring allows

- *lower-level functional testing*
- *verification of RSU messages (e.g. MAP, SPAT)*
- *general discovery of «what is in the air» (increased understanding --> further innovation)*

Use Cases and Interactions

Sending CAM



Sending out the CAM is a basic function of any vehicle in the C-ITS context. The CAM consists of of a low-frequency and a high-frequency component:

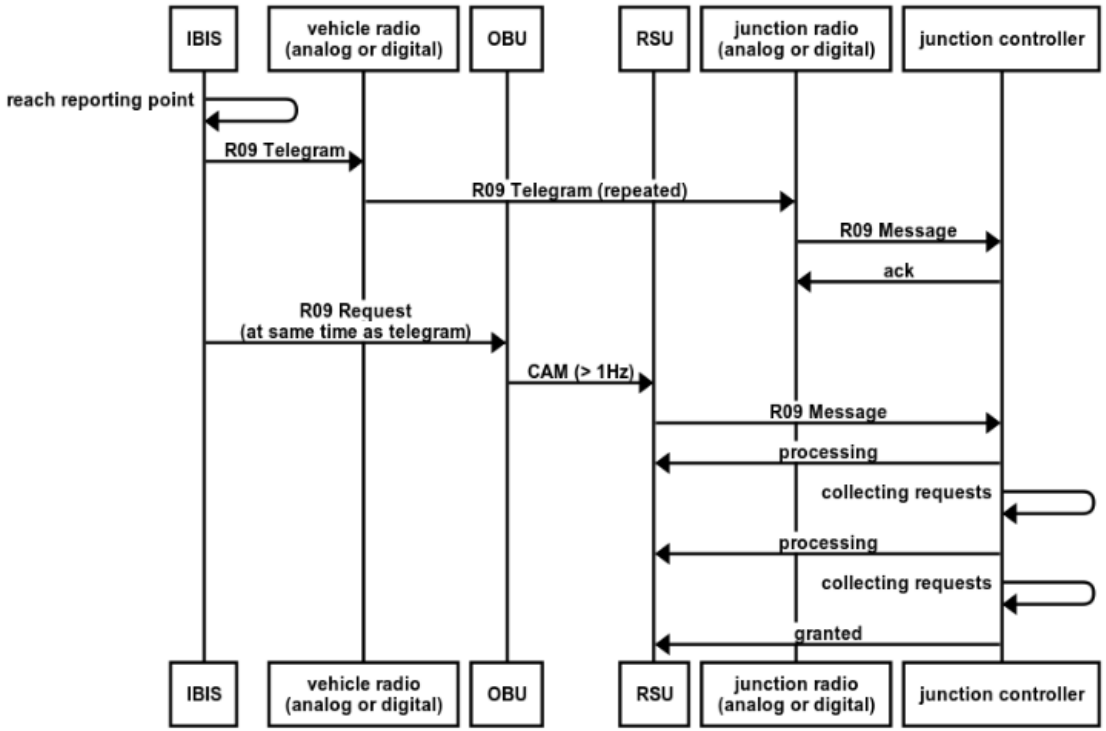
- The low-frequency contains static information about the vehicle (e.g. vehicle type, dimensions, …)
- The high-frequency component changes as the vehicle moves through space (e.g. geo location, heading, speed, …)

The following PTX messages convey the information that the OBU requires to send out CAM:

- Vehicle Info (→ low-frequency information)
- Operational Status (→ high-frequency information)

OBU may complement Operational Status with own sensor data (e.g. IMU, …)

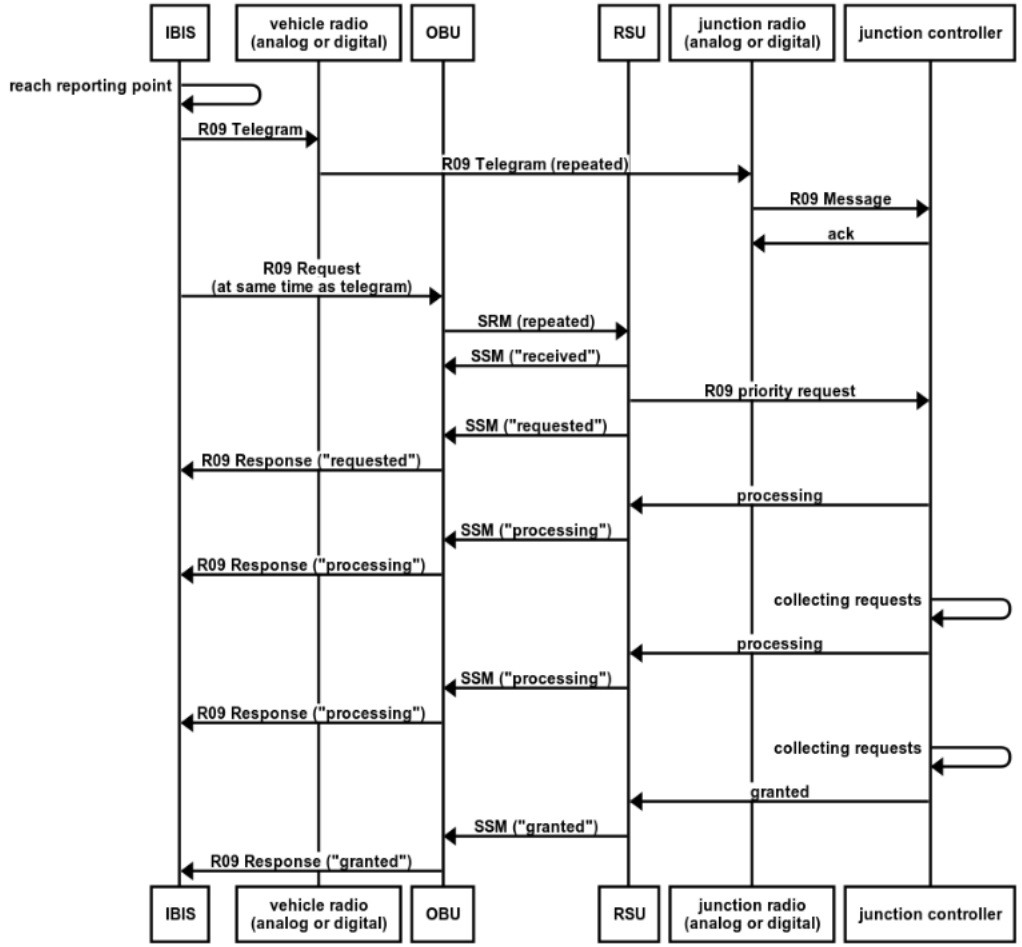
Sending R09 over CAM [stage 1A]



R09 exists in many city-specific variants. Whenever the sending condition is met (e.g. passing a reporting point), the IBIS creates the message and sends it out over the conventional narrow-band radio. In parallel, it hands it to the OBU for sending embedded in CAM. The OBU does not (need to) know the content of the R09 message.

- timing (when to send out) is up the the IBIS
- OBU repeats the CAM with R09 payload a few times to increase the probability of reception
- migration is enabled
  - in the vehicle, both the vehicle radio and OBU send out R09
  - at the junction, either junction radio or RSU receive the message and forward it to the junction controller
- as in VDV420 or VDV426, the channel is uni-directional (i.e. there is no reply from the junction controller)
- the range is limited by a single “hop” from OBU to RSU (→ some far away reporting points might have to be shifted)

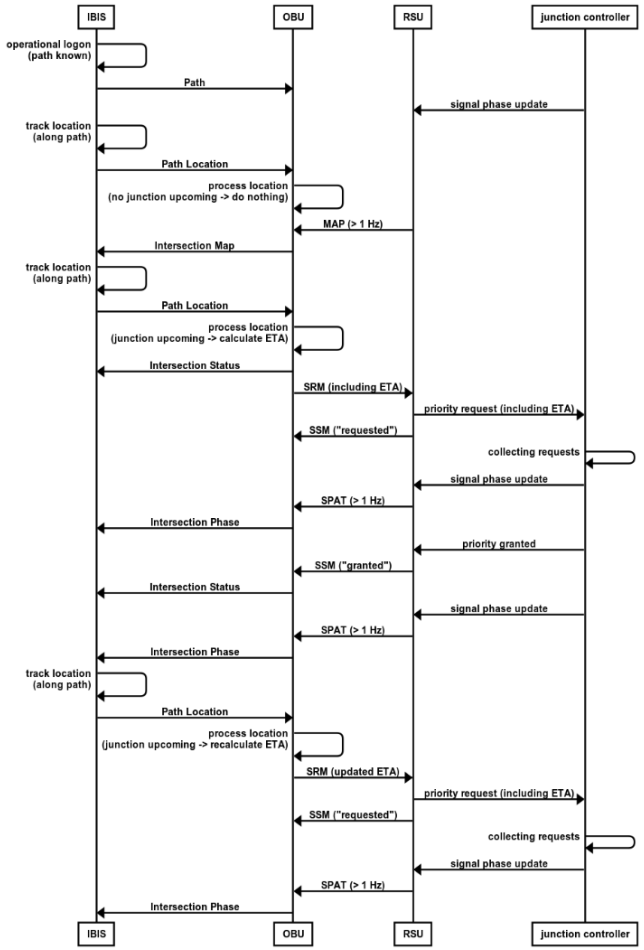
Sending R09 over SRM [stage 1B]



From an IBIS perspective, it does not matter whether the R09 message is embedded in CAM or SRM. If SRM is used, there may be a response over SSM conveying the status of the request at the junction controller.

- peer-to-peer forwarding (“geo routing”)
  - SRM propagated by OBUs and RSUs
  - range problems less likely
- one SRM typically leads to multiple SSM (status changes)
  - immediate acknowledgement of reception by RSU (to stop OBU from repeating more)
  - wait period for considering requests from other vehicles
  - final decision “granted” or “rejected” (or some other states) … which can still be reversed at any time
- OBU sends “R09 Response” to IBIS upon receiving SSM

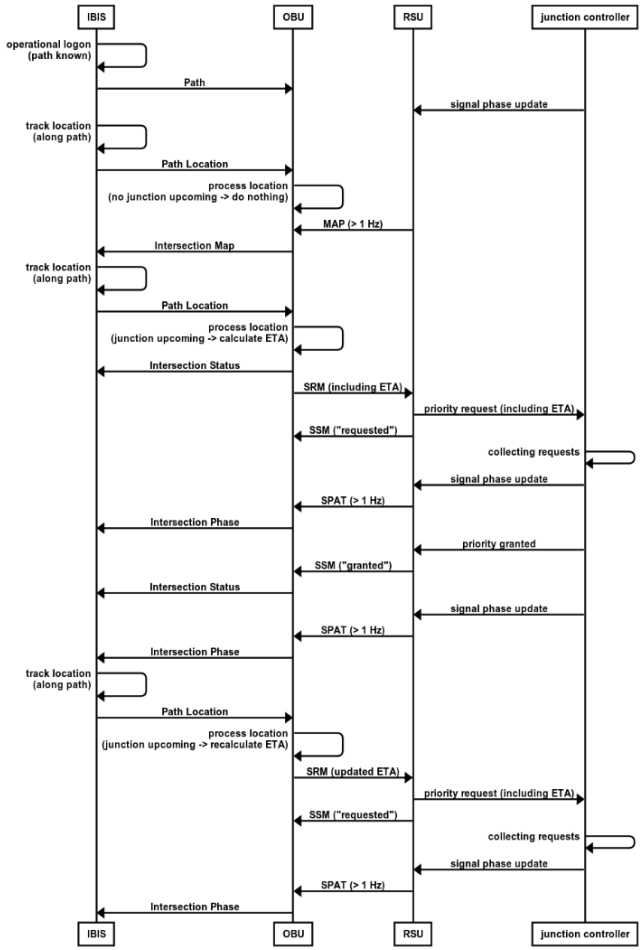
Sending SRM with ETA [stage 2A]



ETA calculated by OBU (not junction controller)
→ Reporting points no longer needed

- IBIS sends “Path” (string of geo points) and “Path Location” (location on path) to OBU
- OBU obtains MAP messages from various junctions
  - decides which ones are relevant (i.e. on the path)
  - for relevant junctions: decides the “movement” (ingress and egress lanes) and calculates the ETA
- for relevant junctions only, OBU sends to IBIS
  - “Intersection Map”: layout for visualization (from MAP)
  - “Intersection Phase”: phase info for visualization (from SPAT)
  - “Intersection Status”: lanes to use, status of priority request (fusion of info from “Path”, “Path Location”, MAP, SPAT, SSM)
- for relevant junctions only, OBU sends to RSU
  - SRM (with ETA): priority request (based on “Path”, “Path Location”, “Vehicle Info”, “Operational Status”, MAP)

Signal Phase Assistance [stage 2B]



Use Cases

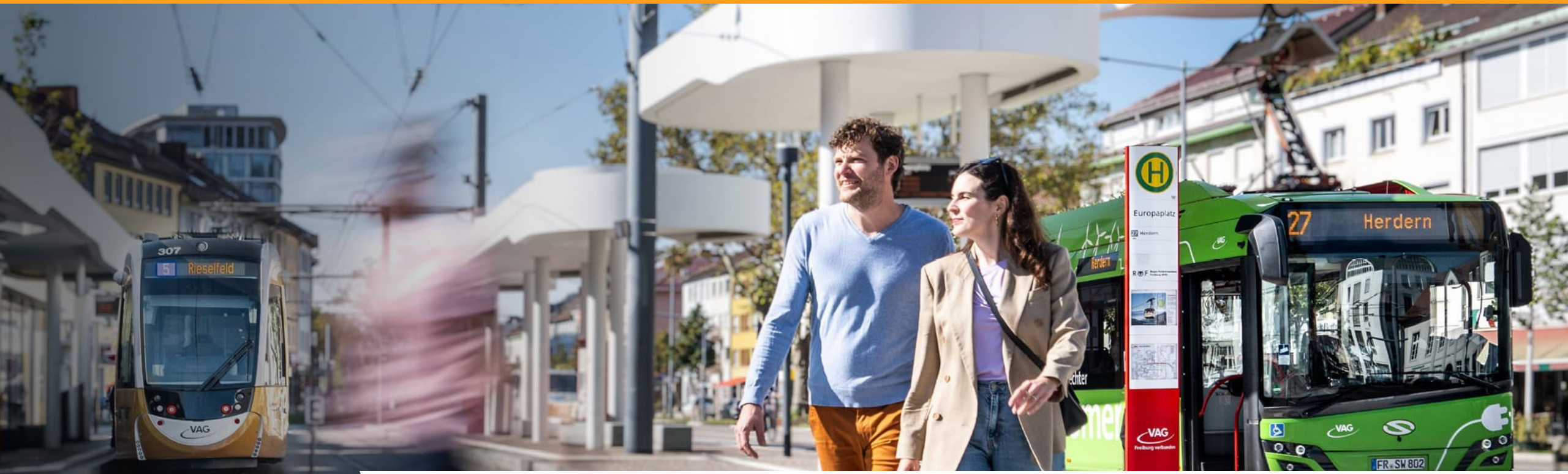
- energy-optimized approach to intersection
- time-optimized departure from stop

Signal phase assistance

- builds on the interactions of stage 2A
- does not depend on
  - whether or not a priority request was made
  - whether or not it was granted or rejected

Driving recommendations

- calculated by IBIS or OBU or both
- visualized on driver terminal



Thank you for your attention.
Do you have any questions?

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