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Dynamic Link Selection Method for Suitable Communication Cost Allocation in Internet of Vehicles

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DEPLOYING TODAY, **EMPOWERING TOMORROW**

Background: Spreading of Connected Services

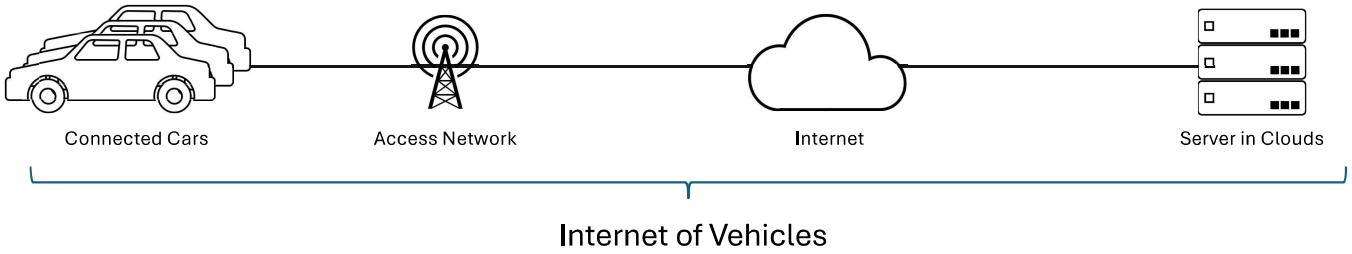
Connected Cars and Services depending on the communication function

Connected Services[1]

Safety Connect®[2, 3]	Service Connect[4]	Remote Connect[3, 5]	Wi-Fi Connect[6]	Drive Connect[7]

excerpt from https://toyota.com/connected-services

Internet of Vehicles: improving mobility experience through End-to-End components



Current and Future Situation

- Current Situation
  - Vehicle manufactureres ship vehicles with built-in communication devices and SIM contracts, bearing primary costs
  - Aiming for communication cost reduction, and compliance for eCall (automatic emergency call system)

- Future: 5G proliferation, expectations for advanced connected services
  - Use-cases leveraging high-capacity, low-latency
  - High-capacity: Passengers viewing video content via in-vehicle entertainment services
  - Low-latency: Traffic digital-twin assists drivers from cloud

- Dirrerent beneficiaries communicate on IoV platform
  - Passengers, owners, vehicle OEMs, service providers (3rd vendors)
- Need for stable connectivity
  - Evolution of communication technology + **concurrent use of multiple connectivity**

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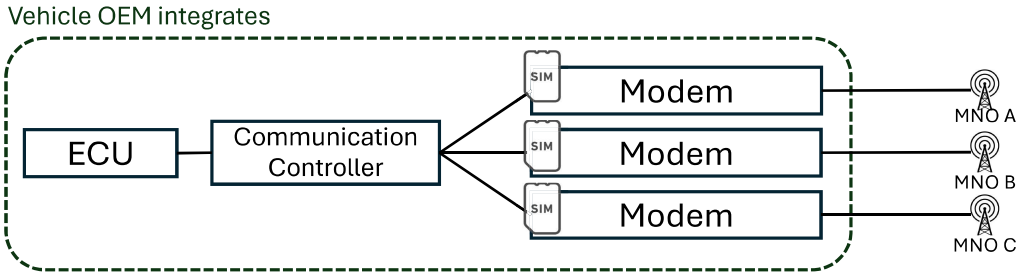
Combine multiple connectivity
- Continuous communication across coverage
- Bandwidth aggregation for high-capacity
- Detour during failures and disasters

Forms of Multiple Connectivity Usage in Vehicle

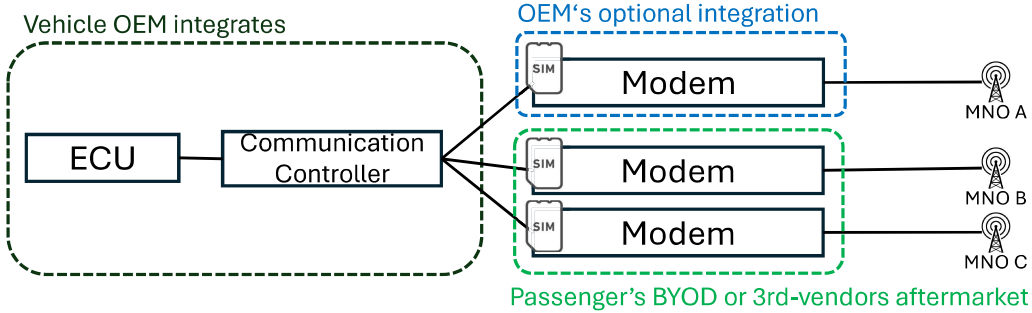
- Traditional approach: Vehicle OEMs equip communication devices and SIM



✓ OEM bears communication cost initially
X Lifecycle difference: Vehicle >> Communication Technology
X Countermeasure for Cellular generation transition needed
X Limited freedom in contracts and cost optimization

Our reserch focuses on this form

- Freely attachable connectivity: Passengers' smartphone tetheruing, e.t.c



✓ Freedom in connectivity contract
✓ Easy adaptation to new communication technology
✓ Effective use of existing communication contracts
X Mixed cost burden and beneficiaries

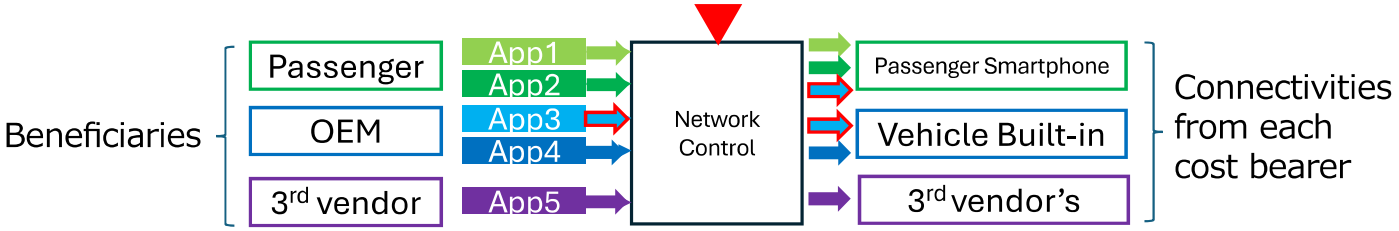
Multiple cost bearers' connectivity carries multiple beneficiaries' communications

Need for multiple connectivity usage that avoids disorderly use and enables appropriate cost distribution

Proposal: Multiple Connectivity Communication Enabling Appropriate Cost Distribution

- Connectivity selection based on cost bearers and app beneficiaries

App3 communication permitted via passenger smartphone by cost bearer



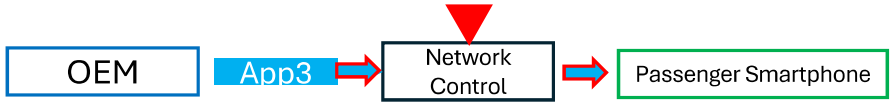
Only communication from apps permitted by cost bearer can flow

▼

Based on consent, can provide arbitrary connectivity to others

- Monitor usage and billing

App3 communicated 543MB via passenger's smartphone



Monitor permitted communication volume

▼

Later settlement and billing

- Usage limits per beneficiary

usage stopped due to OEM consumed passenger's connectivity up to 600MB limit

Upper limit restrictions on link per beneficiary

▼

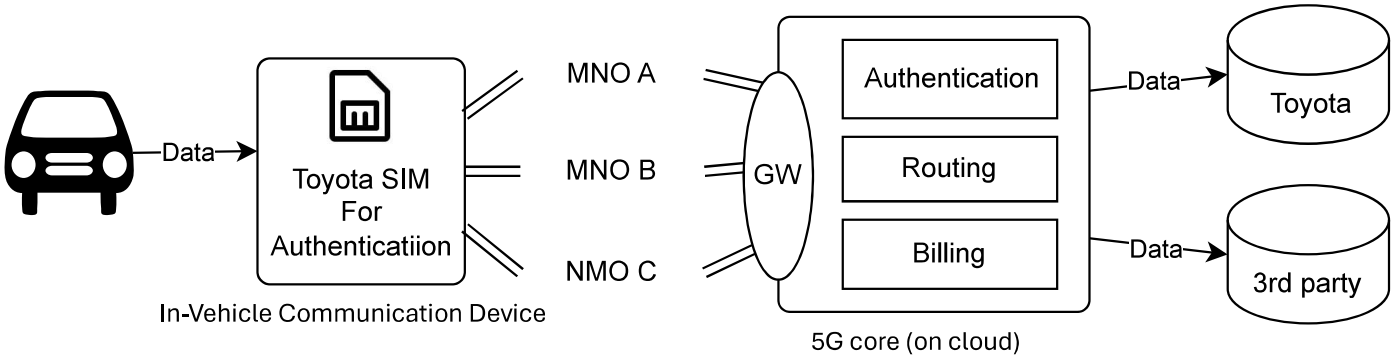
Effective use of remaining manthly communication capacity

Apply cost distribution through multipath communication with these requirements

Prior Research: IRIGATE – Communication Management via Cloud 5G Core

- Introducing multiple network link control to IRIGATE method we are verifying
  - researching to decouple vehicles from communication links/contracts using cloud 5G core

IRIGATE Environment Overview:



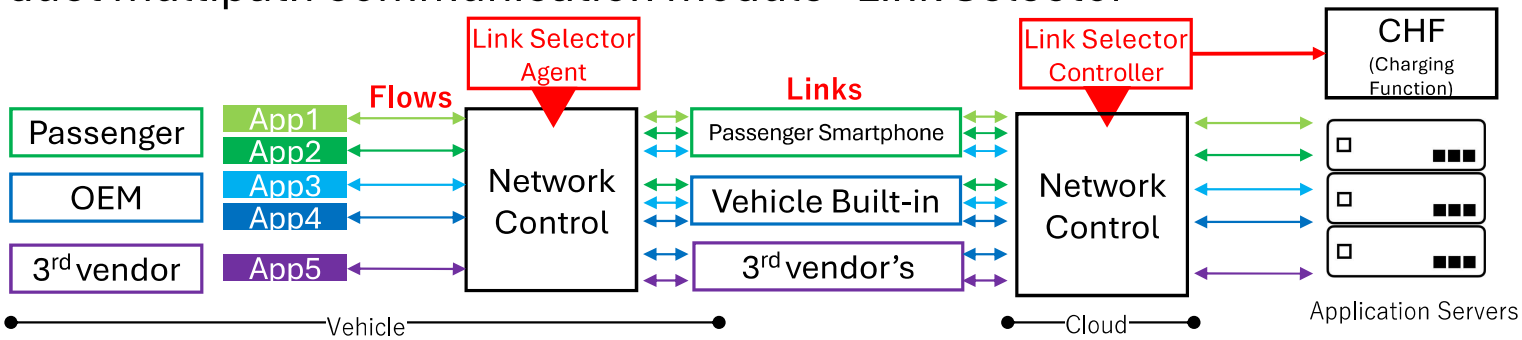
- Communication method without OEM's built-in connectivity:
  - Decoupling vehicle and communication device/contract: Mechanism to freely add connectivity after chipping
  - Cloud 5G core and vehicle connect via authentication SIM through N3IWF
  - Cloud 5G core secures and centrally manages vehicle communication through N3IWF IPsec

N3IWF: non-3GPP Interworking Function

Introduce the multiple connectivity control to IRIGATE method

Design: Communication Control by Link Selector

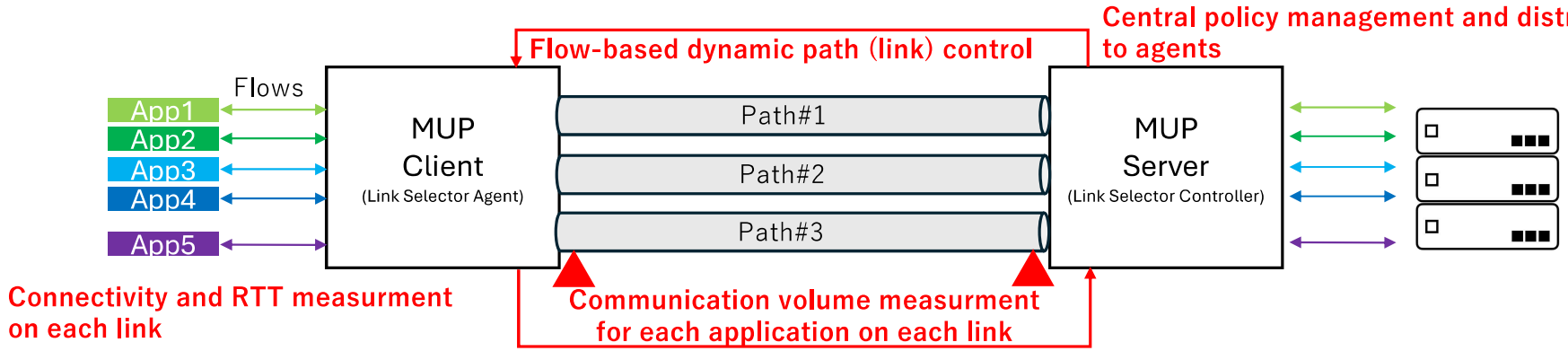
- Introduct multipath communication module “Link Selector



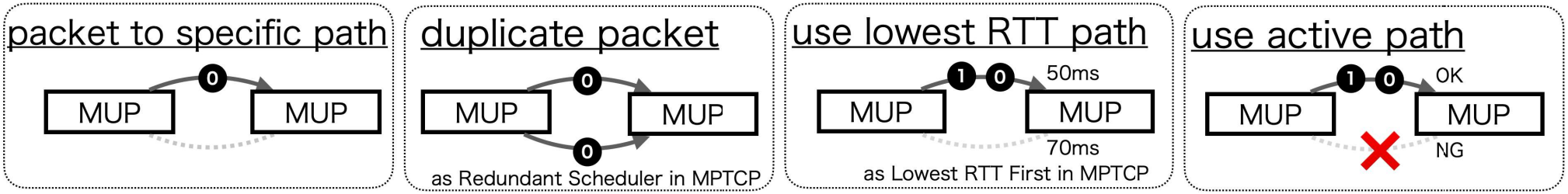
- Each application communication as **flows**: Associated with respective beneficiaries
  - Example: In-vehicle entertainment (passengers), CAN data upload (vehicle OEM)
- Each connectivity as **links**: Associated with respective cost bearers
  - Example: Vehicle built-in cellular link (vehicle OEM), BYOD tethering link (passenger)
- Flow-link relations management based on **policy**
  - Example: CAN data upload flows only through vehicle built-in link provided by vehicle OEM
  - Example With passenger consent, up to 500MB CAN data upload via passenger smartphone in emergency
- Communication volume tracking through controller and CHF cooperation

Implementation: Link Selector Using MUP [1][2]

- Implementing Link Selector by applying Multipath UDP Proxy(MUP)
  - As UDP proxy, dynamically controls communication links per application



- Examples of policy, link selection per application:

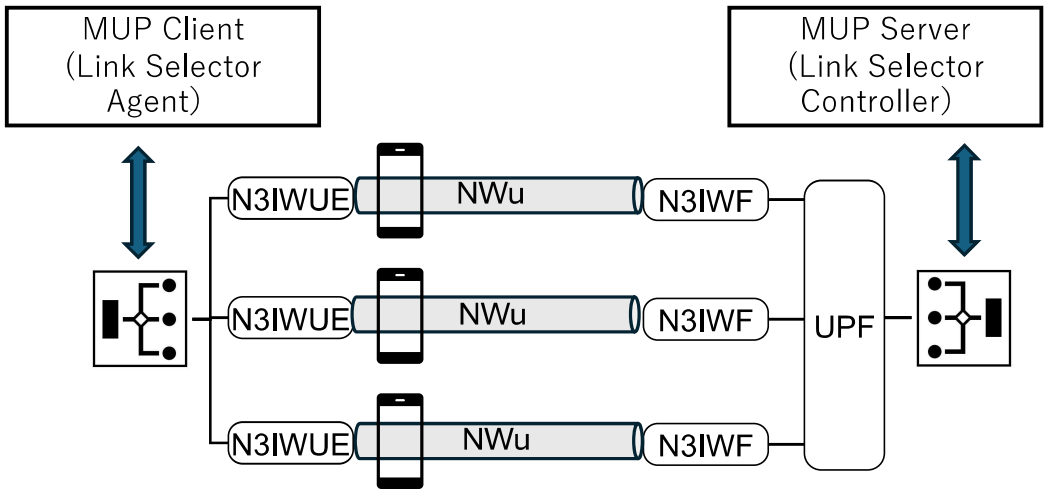


[1] N. Kaneko, T. Ito, H. Katsuta, T. Watanabe, H. Abe, R. Onishi, "Applying and Evaluating Multipath Redundant Communication Technology for WebRTC-based Video Streaming", IPSJ Transaction Digital Practice Volume Number 3, Issue Number 3, p. 21-31, Issue Date 2022-07-15

[2] N. Kaneko, T. Ito, T. Watanabe, H. Abe, R. Onishi, "Flexible Multimedia Stream Control for WebRTC on Multipath Communication Technology", IPSJ DICOMO2021, Volume Number 2021, Issue Number 1, p. 1059-1067, Issue Date 2021-06-23

Implementation: Integration into IRIGATE and Communication Control Policy

- Integration into IRIGATE method:
  Vehicle side: Set N3IWUE tunnels as links to MUP client
  Cloud side: Connect MUP server to UPF



N3IWUE: non-3GPP Interworking User Equipment
N3iWF: non-3GPP Interworking Function

- MUP policy example:

path == link

```
[[service]]
bind_addr = "0.0.0.0"
port = 10000
flow_id = 10000

[commands]
init="""
group 10 create
group 10 add path 0
group 10 add path 1
group 10 set policy active_standby
group 10 set active path 0 preempt
flow 10000 set group 10
"""
```

Traffic to/from UDP port 10000 is assigned to flow 1000

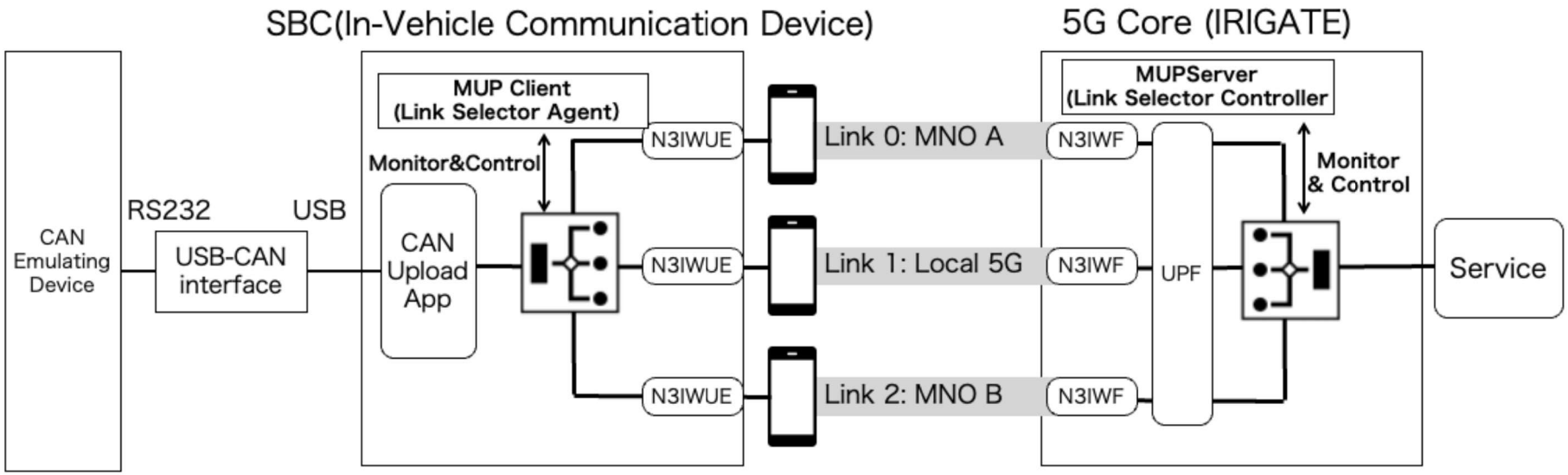
Use path 0 and path 1

Use path 1 only when path 0 is unreachable

- Communication volume measurement is implemented by MUP in this implementation

Evaluation: Experiment Perspective ans Assumptions

- Introduce Link Selector to IRIGATE testing environment, verify feasibility of link selection per application communication
- Assume situation where vehicle uploads 2ch CAN data (high/low priority)
  - Assume vehicle has 3 different network links from different cost bearers
  - CAN data upload is communication where vehicle OEM is beneficiary: normally use link 1



Evaluation: Experimental Scenarios

- Conduct experiments switching between 3 scenarios:
  1. When path1 disconnects, CAN 1ch traffic borrows passenger's link (path0) with passenger consent

     ↓ Switch policy
  2. When path1 disconnects, CAN 1ch traffic borrows 3rd vendor's link (path2) with their consent

     ↓ Switch policy
  3. CAN 1ch borrows passenger's link (path0), switches to path1 when exceeding certain volume

- By manipulating Local 5G base station for path1, simulate coverage inside/outside movement: power-off = movement outside, restart = inside

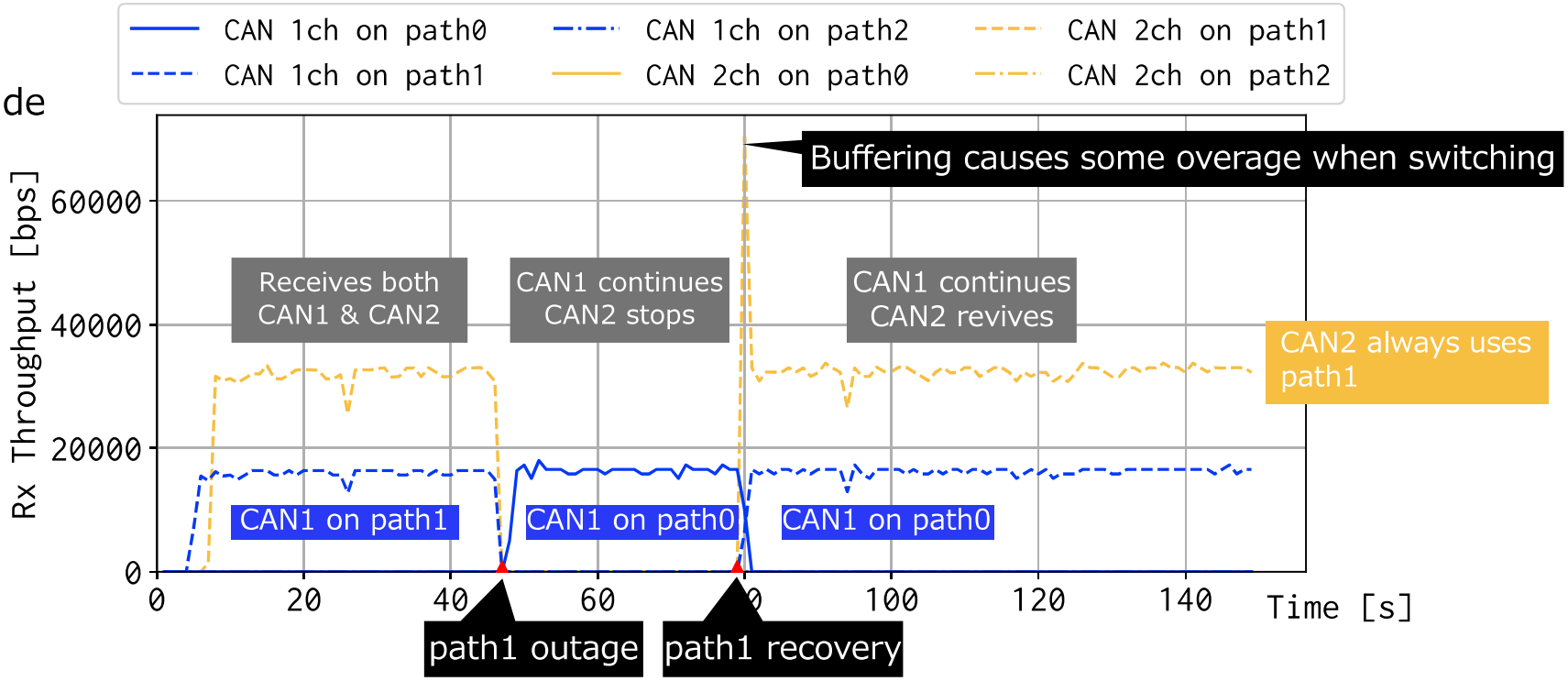
Link ID	Path ID in MUP	Link Type	Cost-Bearer
0	0	Public 4G of MNO A	Passenger
1	1	Local 5G	Vehicle OEM
2	2	Public 4G of MNO B	3rd vendor

Table 1. Communication links in our experiment

Results: Scenario 1

- When path 1 disconnects, CAN 1ch borrows passenger link (path0) with passenger consent

5G Core side readings

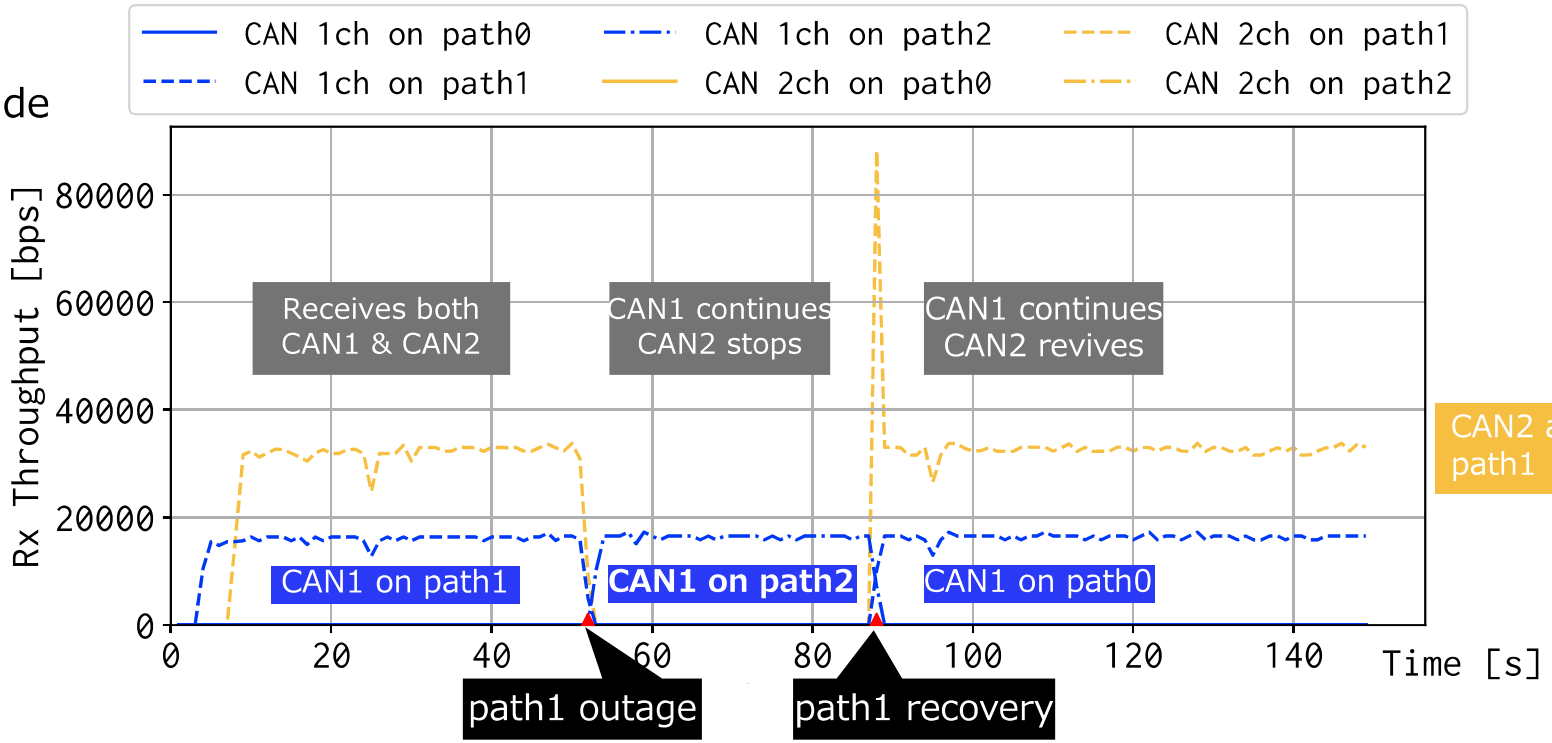


Achieving link selection per beneficiary/application

Results: Scenario 2

- When path1 disconnects, CAN 1ch borrows 3rd vendor link (path2) with 3rd vendor consent

5G Core side readings



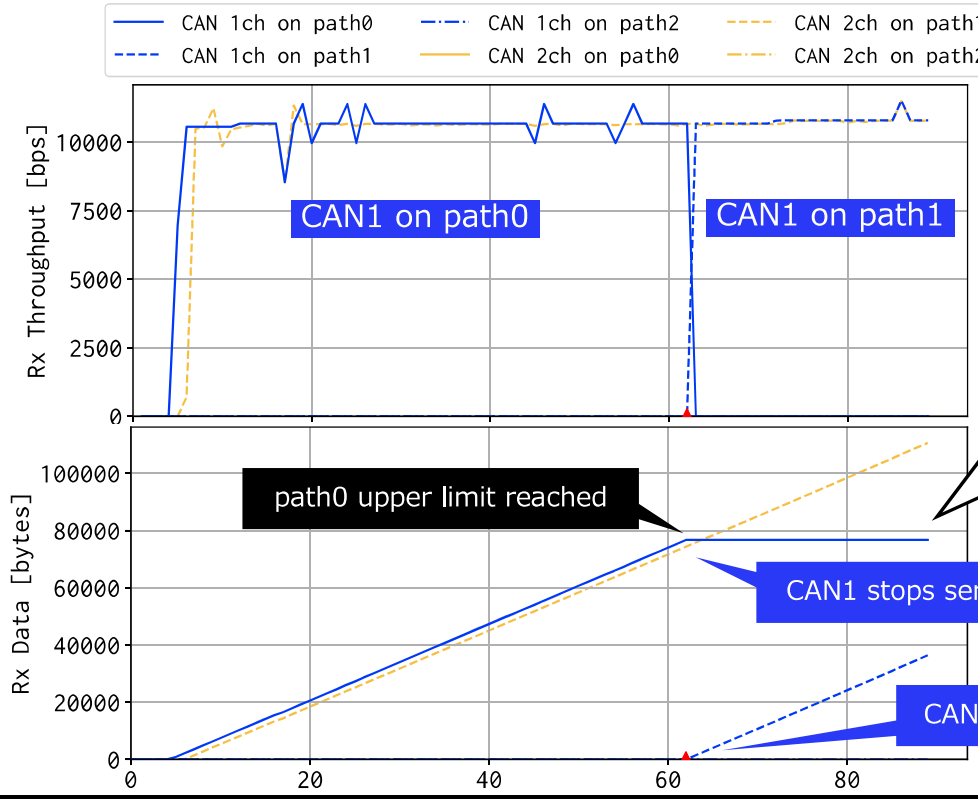
Achieving link selection per application & policy changes reflected

Results: Scenario 3

- CAN 1ch borrows passenger link (path0), switchies to path1 when exceeding certain volume

5G Core side readings

Vehicle side readings



100KB set as upper limit

CAN2 always uses path1

Switching at 80KB against 100KB limit

- Upper limit compared with UDP payload length, but figure shows MUP payload length
- Accurate measurement and control requires cooperation with CHF and MNO/MVNO

Achieving usage limitation per application & policy changes reflected

Summary

Key Takeaways

- Proposing connectivity selection method enabling appropriate cost distribution for both cost-bearers and application beneficiaries
- Veryfying feasibility: link selection per application communication flow through Link Selector experiment in IRIGATE

Future directions

- Flexible connectivity utilization with fair cost distribution is essential for realizing advanced connected services on top of IoV platform
- Need for impvoved accuracy of connectivity control through deeper cooperation with functions like CHF and collaboratikon between IoV operators and MNO
- Quantitative evaluation in scenarios including passenger and 3rd vendor app
- Applying ATSSS from 3GPP standards, refinement of overall architecture

ATSSS: Access Traffic Steering-Switching-Splitting

Questions & Answers

Thank you