TOWARDS IN-NETWORK COMPUTING INFRASTRUCTURES FOR CONNECTED VEHICLES

2ND KUVS FACHGESPRÄCH ”NETWORK SOFTWARIZATION”

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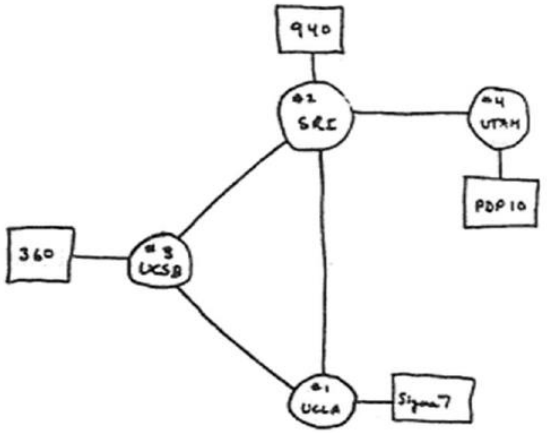
Towards In-Network Computing Infrastructures For Vehicles
Contribution

- An Information-Centric Networking (ICN) implementation for Edge Computing
- Novel resolution strategies for Named Function Networking (NFN) at the Edge in mobile/automotive scenarios
- Functional demonstration as part of a real world Proof-of-Concept prototype

Resolution strategy for NFN to handle mobile scenarios; demonstrated as part of a real world PoC

Networking at Internet Scale
The Status Quo

- The Internet was initially designed for host-centric communications
  - Remote login, file transfer…
- The classic Internet architecture is well suited for communications between two stationary hosts (TCP/IP,….)
- **However, the communication pattern has changed significantly over the past decades.**



Source: Scientific American - Early sketch of ARPANET's first four nodes
http://www.scientificamerican.com/gallery/early-sketch-of-arpanets-first-four-nodes/

Consumers are interested in data, independent of **where** it resides in the network.

Networking at Internet Scale
Information-Centric Networking: Primer

- Information-Centric Networking (e.g., [1], [2]) empowers the data plane by
  - **addressing data directly** instead of addressing the host providing it
  - providing **naming schemes**, flexible to address content and its representation
  - achieving a **loosely coupled communication model** directly on the network layer
  - providing **flexible hop-by-hop routing and forwarding** decisions
  - defining **in-network caching capabilities** at all nodes to increase the availability of data

[1] V. Jacobson, D. K. Smetters, J. D. Thornton, M. F. Plass, N. H. Briggs, and R. L. Braynard, “Networking named content,” in Proc. Int. Conf. on Emerging Networking Experiments and Technologies (CoNEXT), New York, NY, USA: ACM, 2009, pp. 112.

[2] Lixia Zhang, Alexander Afanasyev, Jeffrey Burke, Van Jacobson, K.C. Claffy, Patrick Crowley, Christos Papadopoulos, Lan Wang, and Beichuan Zhang, “Named Data Networking,” SIGCOMM Comput. Commun. Rev. 44, 3, 2014, 66–73.

Information-Centric Networking provides access to data directly instead of the host.

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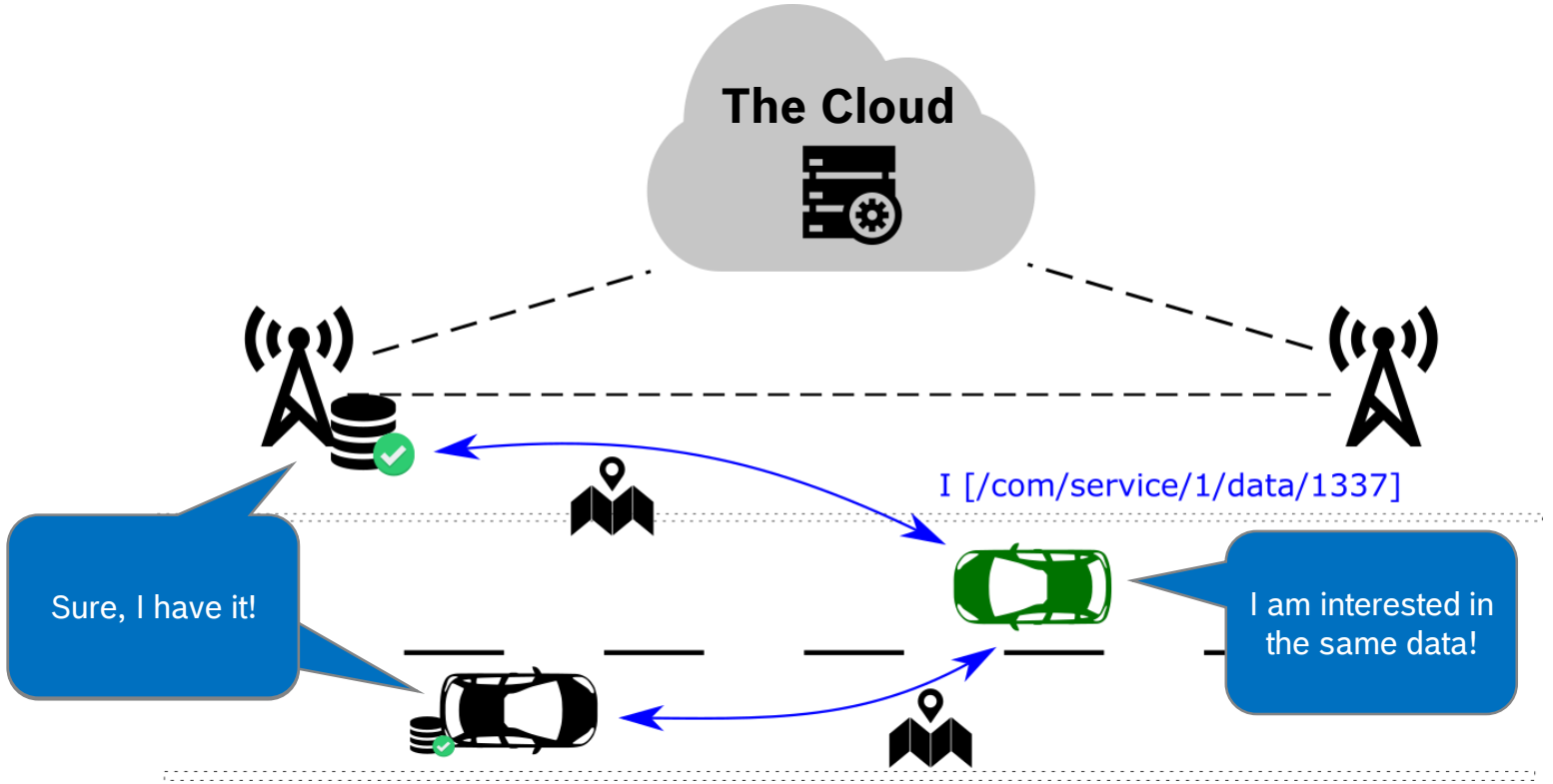
Networking at Internet Scale
Information-Centric Networking for Connected Vehicles



Mobility support, intrinsic multi-cast and multi-homing capabilities by nature.

Networking at Internet Scale
Named-Function Networking (NFN): Primer

- Named-Function Networking [3]
  - enhances ICN to **provide access to computation results** instead of static content
  - uses ICN principles for transporting and delivering data
  - define **workflows** using naming schemes in an ICN
  - uses **resolution strategies** to determine the “best” location for a computation
  - has its origin in data centers, focus: **transport function code to data**

[3] M. Sifalakis, B. Kohler, C. Scherb, and C. Tschudin, „An Information-Centric Network for Computing the Distribution of Computations,” in Proc. ACM Conf. on Information Centric Networking, Paris, France, 2014

Named Function Networking is an extension to ICNs to provide access to computation results.

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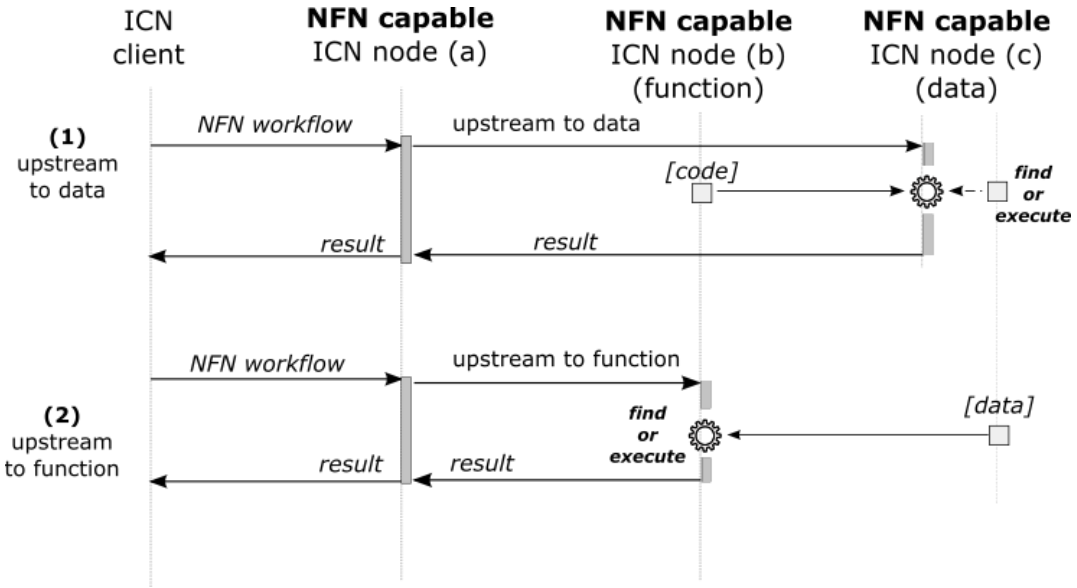
Limitations of today´s Resolution Strategies in NFN

- Default resolution strategy in NFN:

  Find or eXecute (FoX)

  - forward comp. requests upstream into core network



- Timing requirement

  Eq 1: $Deadline_{Application} > Time_{Computation} + Time_{Transmission}$

Due to high degree of mobility in vehicular scenarios no timing guarantees can be given.

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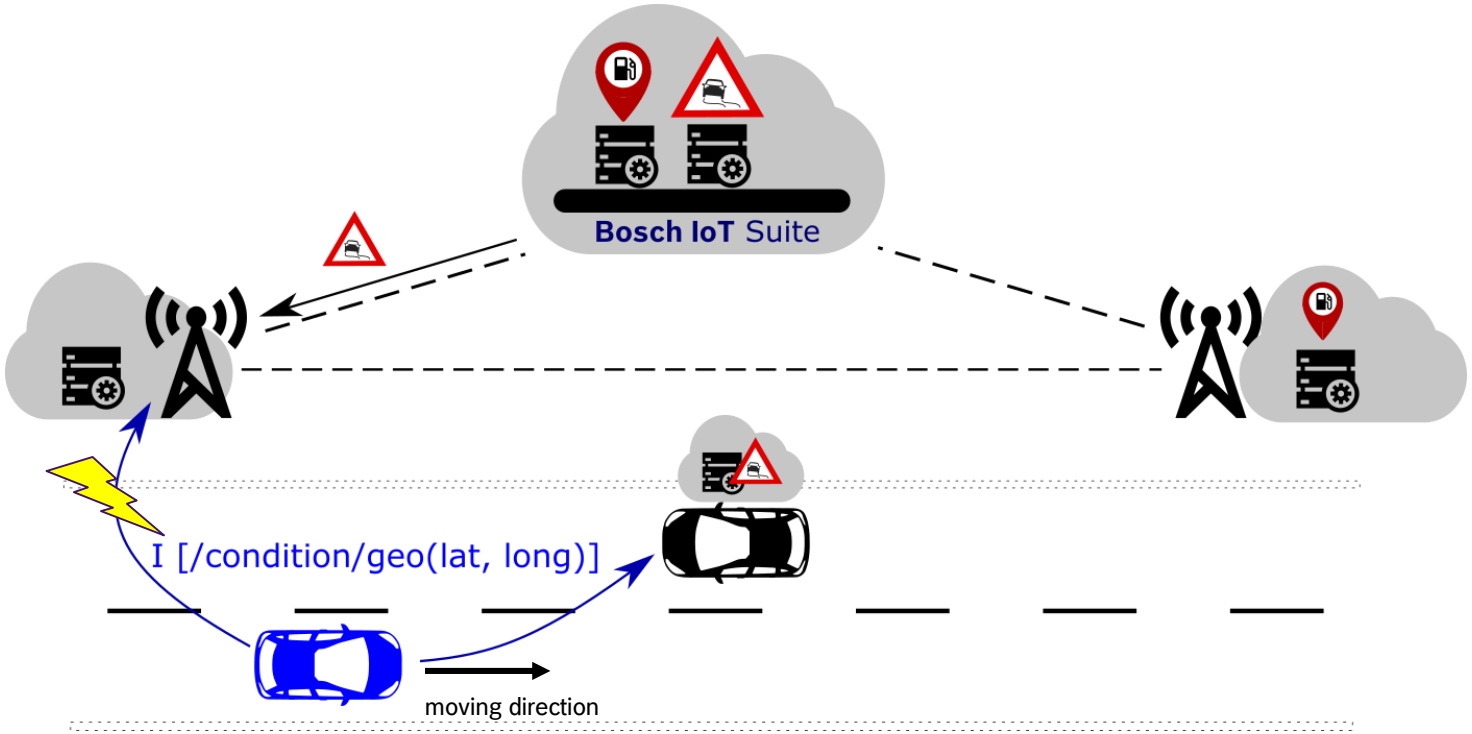
Limitations of today´s Resolution Strategies in NFN



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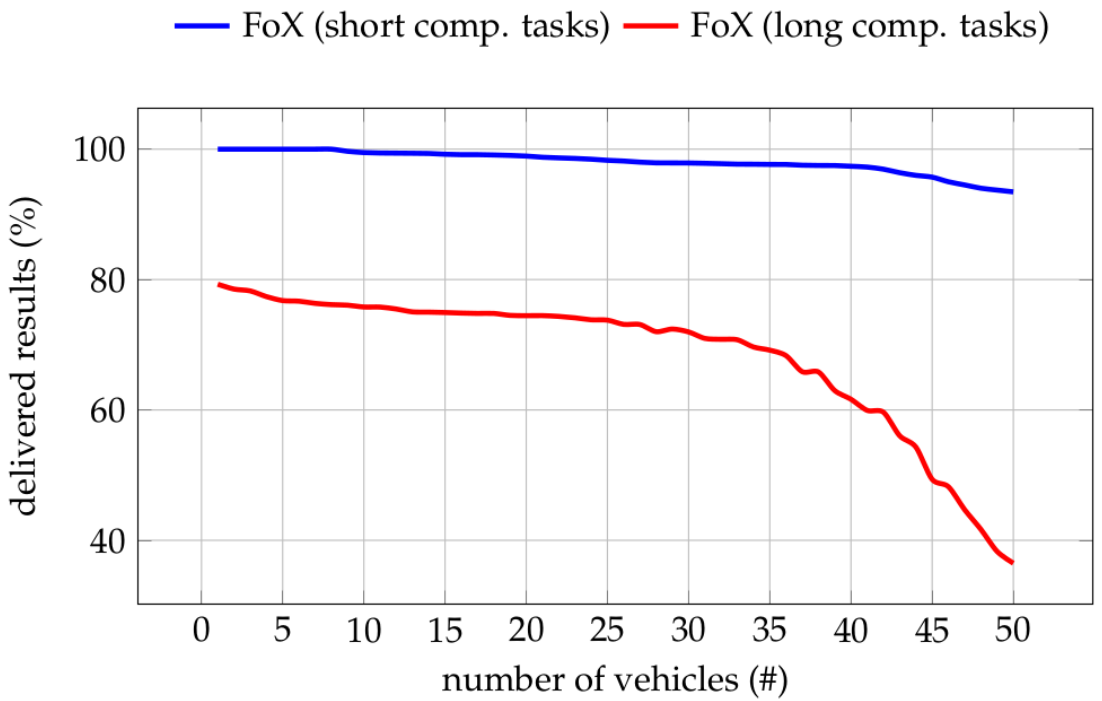
Simulation of Mobile Scenarios using NFN



Simulation based on PiCN [9]

- FoX performs well for short computations
- Limitations of FoX are experienced for long running tasks as querying the network takes time before starting the computation locally

Increasing no. of vehicles as well as computation complexity results in reduced data delivery using FoX

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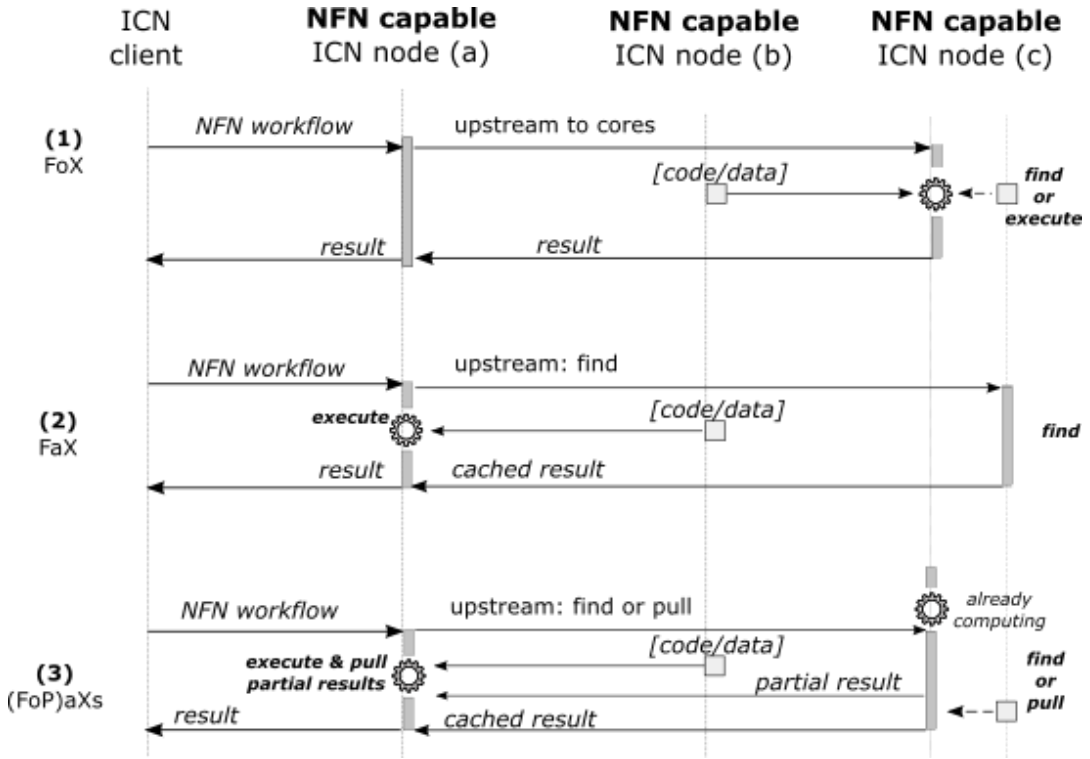
Resolution Strategies for Edge Computing Scenarios

- Two novel resolution strategies for NFN
  - **Goal**: compute closer to the consumer, and improve timely data delivery
  - **Find AND eXecute (FaX)**
    - execute comp. directly and try to find cached copy in parallel
  - **Find OR Pull AND eXecute ((FoP)aX)**
    - execute (partial) comp. directly and try to find and fetch partial comp. results from neighboring nodes



FaX and (FoP)aX improves timely delivery of data by executing computations closer to consumer.

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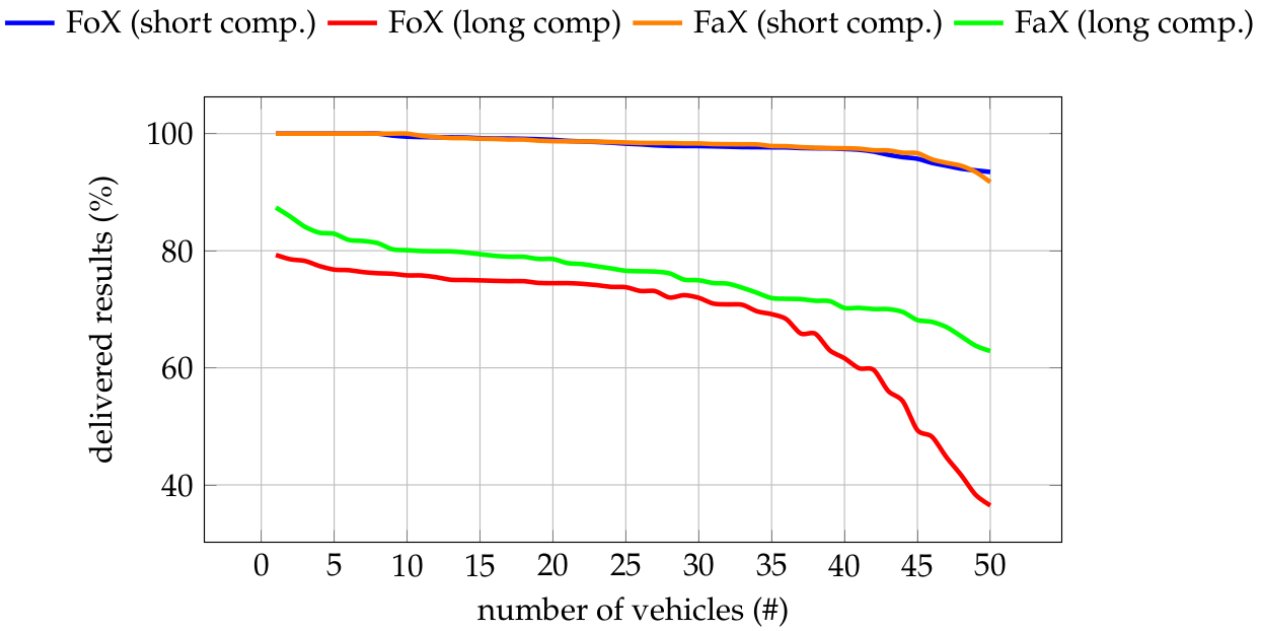
Simulation Results of Novel Resolution Strategies



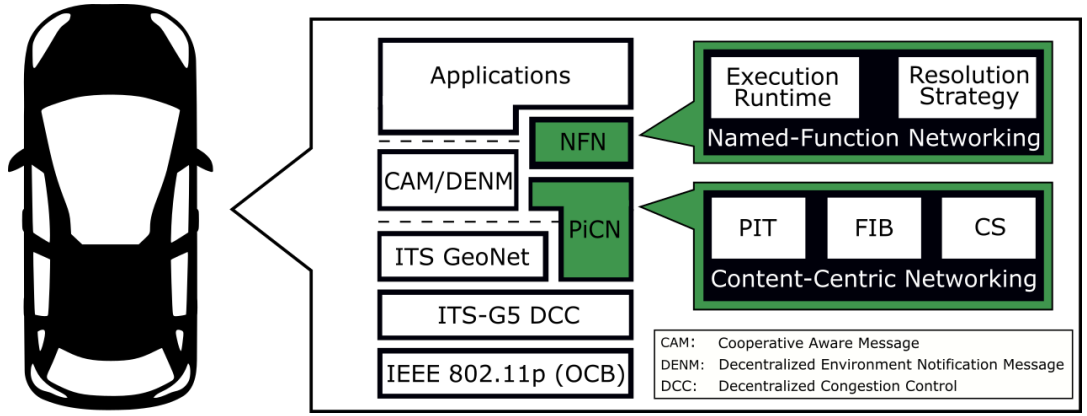
- FaX performs same as FoX for short running computations
- FaX performs better than FoX for long running computations
- Number of started executions of FaX is ~ 17 % higher compared to FoX
- FaX is suitable if resources are under/low utilized at the edge, otherwise FoX can be performed

Simulation based on PiCN [9]

Executing and querying computation/results in parallel increases data deliveries in mobile scenarios.

Towards In-Network Computing Infrastructures For Vehicles
A network stack for computation-centric vehicular networks

- Compute-Centric Vehicular PoC [5]:
  - **PiCN** [9]: ICN stack supporting network computations with NFN from University of Basel
  - **ETSI ITS-G5 DCC** [7]: Decentralized Congestion Control Layer based on OpenC2X experimental and prototype platform from the University of Paderborn
  - **IEEE 802.11p Access Layer** [6]: 5.9 GHz band based on a Linux kernel modification from Czech Technical University of Prague



First compute-centric prototype for connected vehicles: ETSI ITS G5 and NFN run in parallel.

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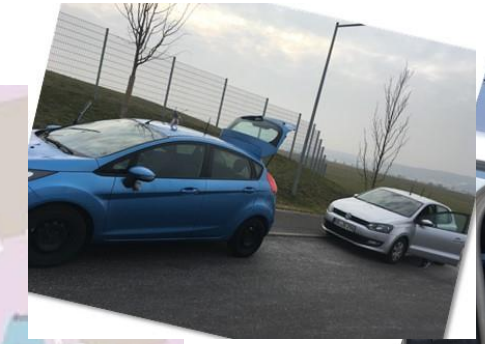
A network stack for computation-centric vehicular networks



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Towards In-Network Computing Infrastructures For Vehicles
Conclusion & Future Work

- Presentation of novel resolution strategies to support mobile scenarios in NFN
- Simulation runs have been made showing improvement of FaX compared to FoX for long running computations
- Real world prototype demonstrates the feasibility of supporting in-network computations in a connected vehicle environment

- Future work has to address directions towards a Compute-First Network [8]
  - programming abstractions, e.g., that a function can express its compute requirements to the network
  - support of further quality-of-service (QoS) guarantees, as required in automotive domain

Towards In-Network Computing Infrastructures For Vehicles
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THANK YOU

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