

Information-Centric Mobile Edge Computing for Connected Vehicle Environments: Challenges and Research Directions

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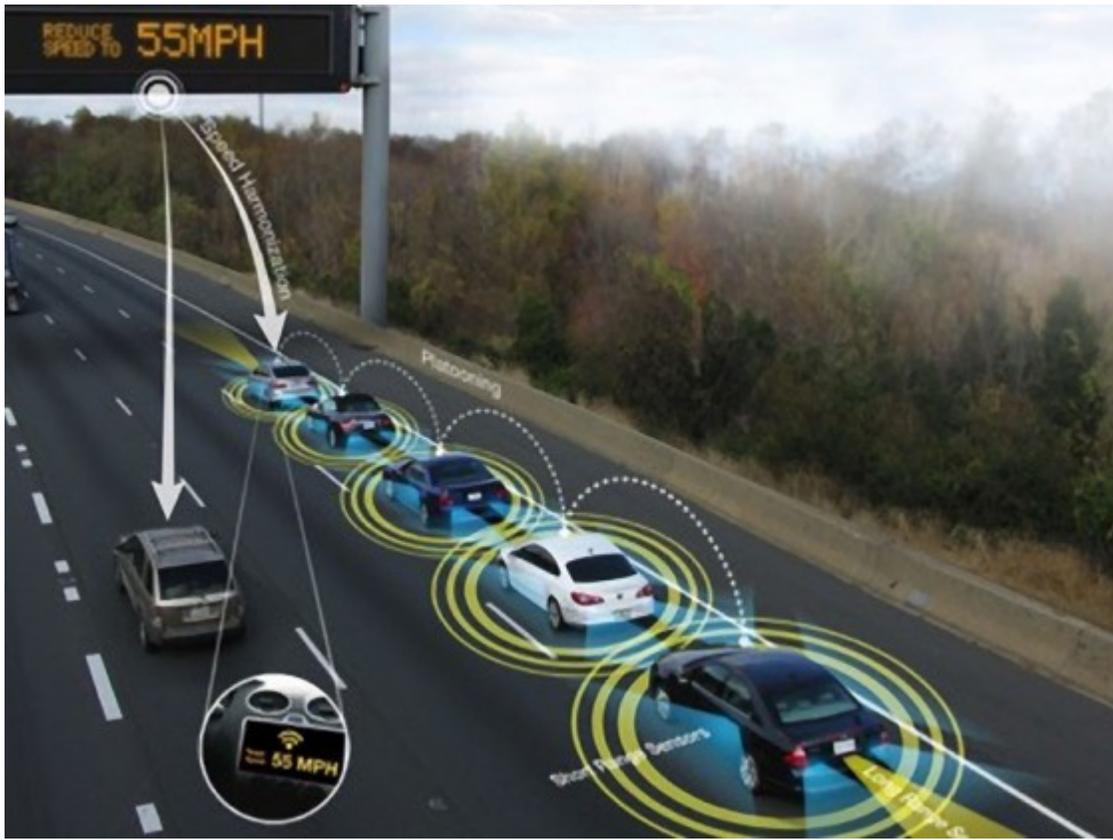


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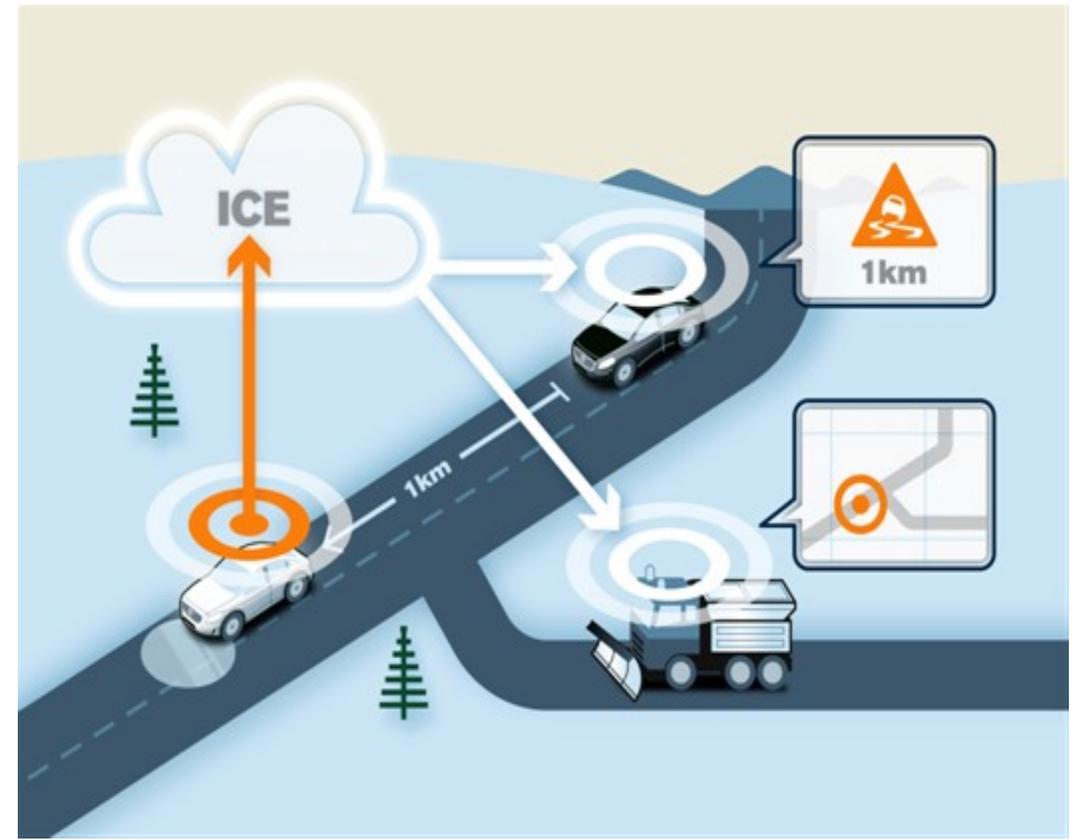


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<http://www.montana.edu/news/16120/msu-researchers-to-collaborate-on-automated-and-connected-vehicle-research-opportunities>



<http://www.autoconnectedcar.com/2014/03/volvo-new-connected-car-features-magnets-real-time-cloud-road-data-driver-sensing/>

Connected automated driving

- is one of the major technological drivers in the automotive domain today

Exemplary use case: Electronic Horizon



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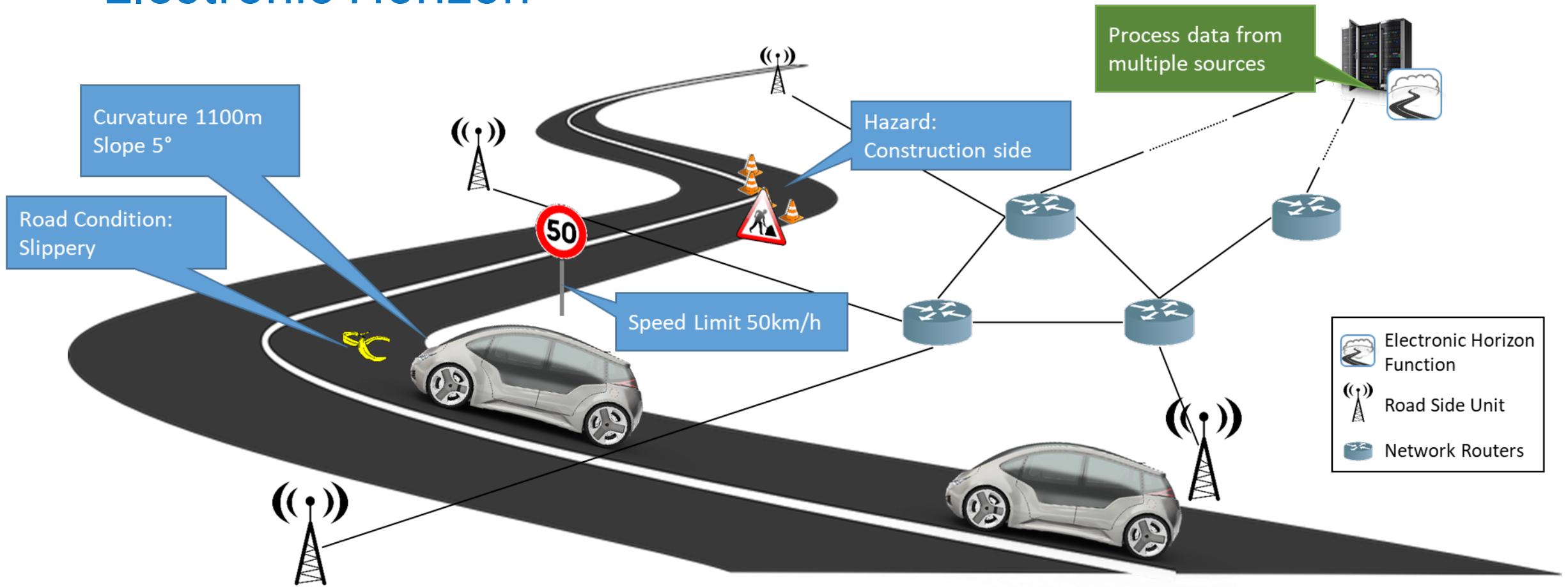


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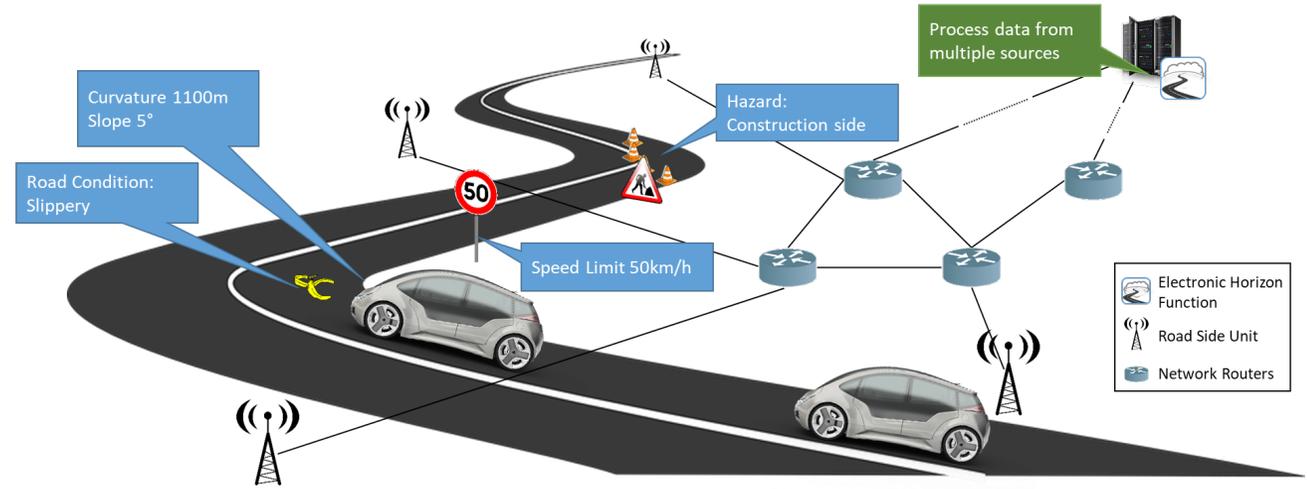


Use Case

Electronic Horizon



Use Case Electronic Horizon



Use Case

Electronic Horizon

- Environment model
 - provide a detailed preview of the road ahead



Picture: Bosch http://www.bosch-presse.de/pressportal/de/media/dam_images/pi9512/header-connectedstudy_img_w386.jpg

Use Case

Electronic Horizon

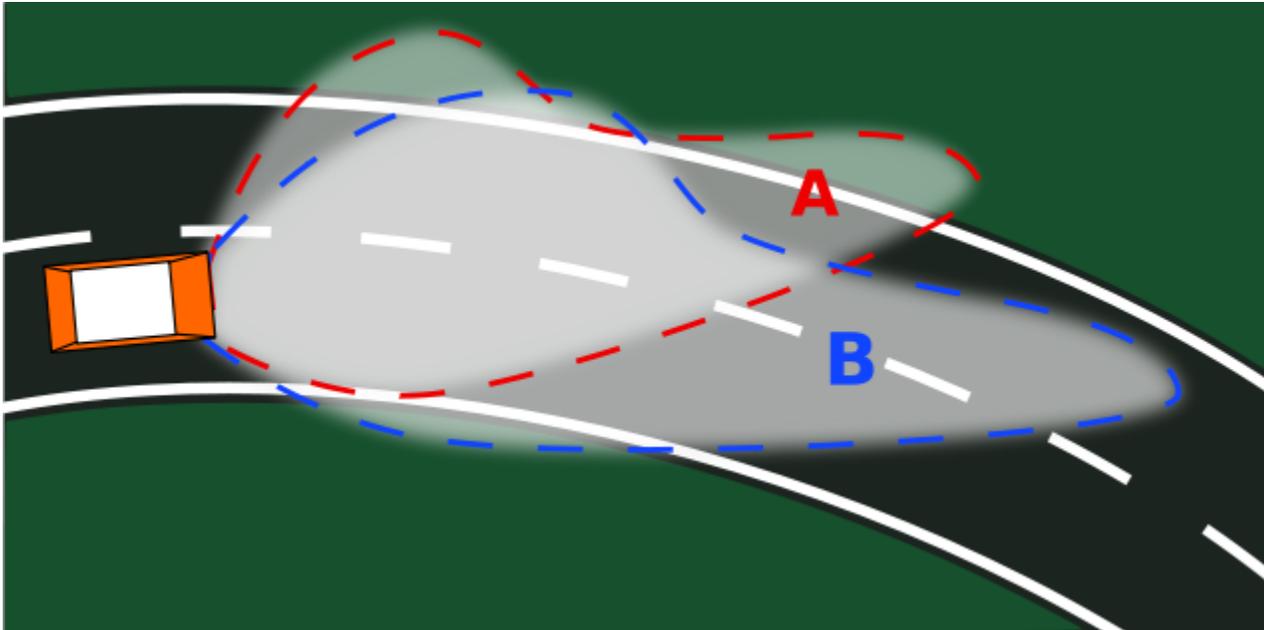
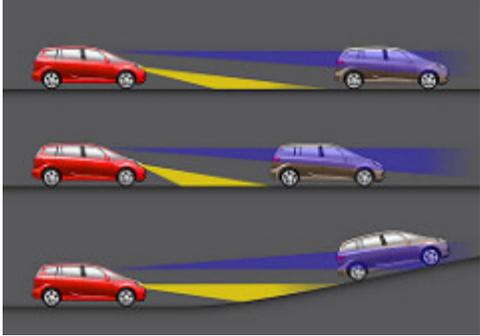


Picture: Bosch http://www.bosch-presse.de/pressportal/de/media/migrated_media/pi8704/1-cc-20576_img_h720-2.jpg

- Environment model
 - It allows for new features and functions such as
 - adaptive cruise
 - e.g. reduce velocity to catch next green light
 - predictive power-train control
 - e.g. gear up and down to reduce fuel or battery consumption
 - adaptive navigation
 - e.g. based on the traffic ahead

Use Case

Electronic Horizon



- Environment model
 - It allows for new features and functions such as
 - adaptive headlight adjustment
 - e.g. to spot hazard

Use Case

Electronic Horizon



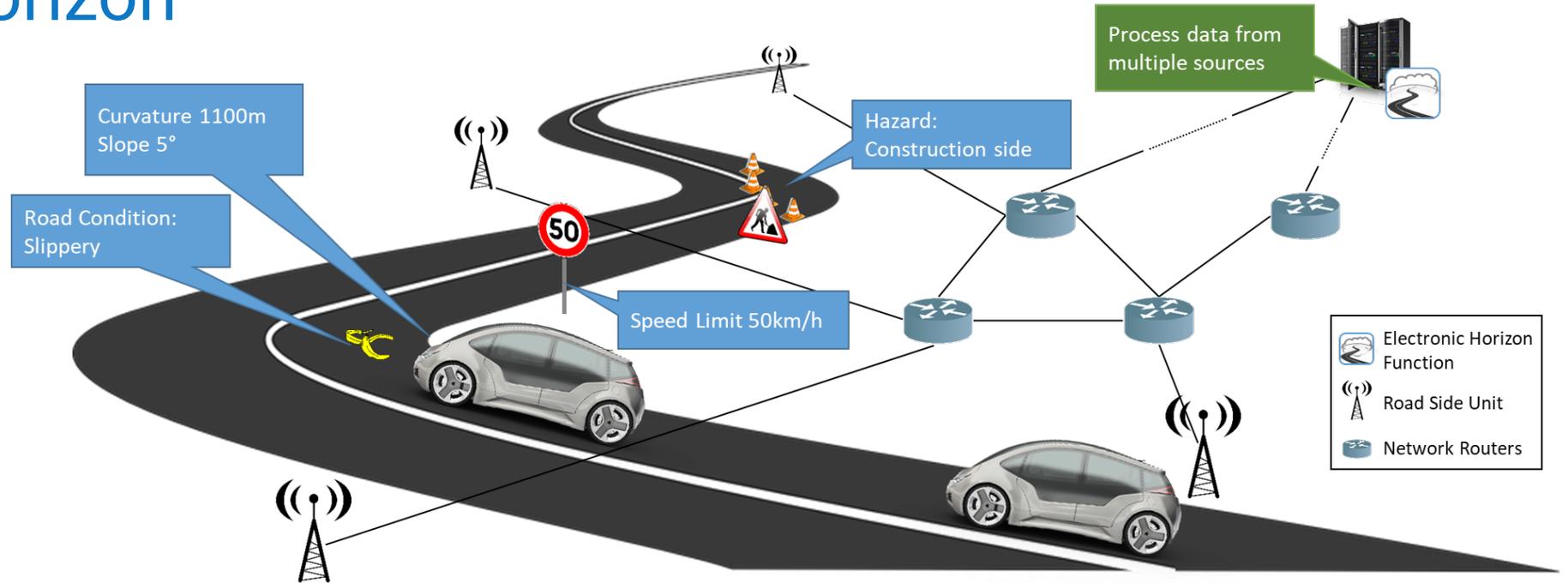
- Environment model
 - Mix of personalized and common information

Under the personalized production paradigm, consumers can personalize their cars with accessories to fit their lifestyles.

Source: <https://me.engin.umich.edu/news-events/news/koren-appointed-distinguished-university-professorship>

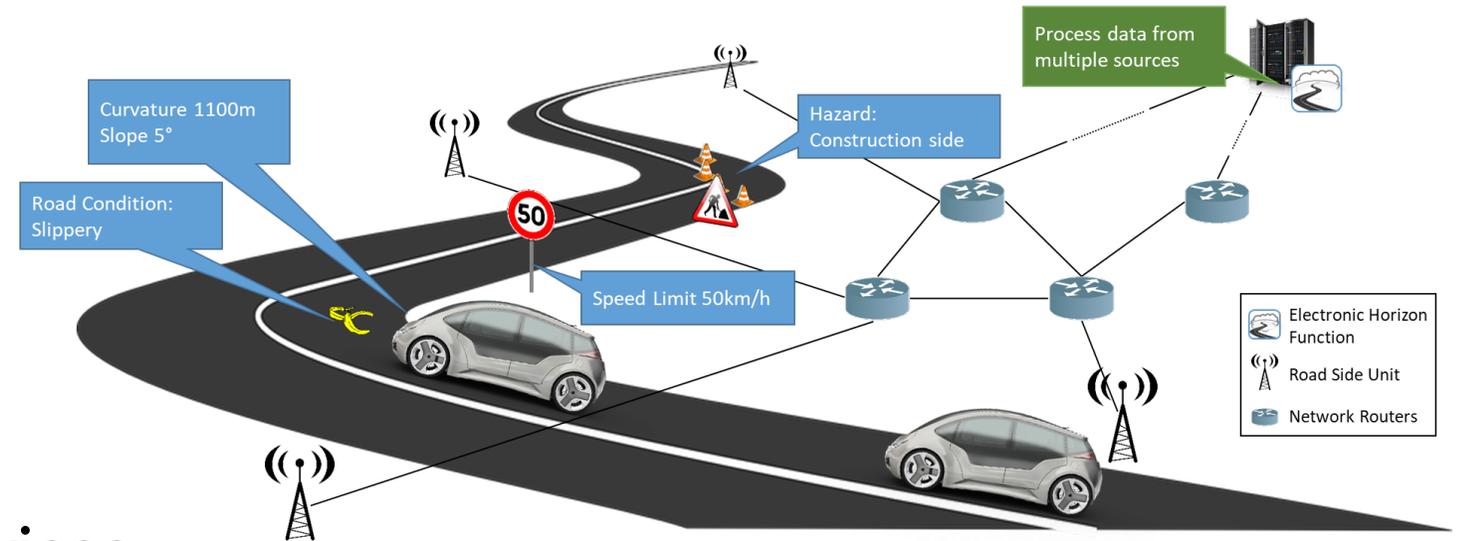
Use Case

Electronic Horizon



Nowadays, services are running in the cloud

Motivation for Edge Computing



- Accessing cloud based services
 - total latency in the range of 30-100ms [1]
- Unacceptable for many latency-critical mobile applications
 - autonomous driving, realtime online gaming, virtual sports
 - may require tactile speed with latency approaching 1ms [2]

[1] M. Satyanarayanan, P. Bahl, R. Caceres, and N. Davies, "The case for VM-based cloudlets in mobile computing," IEEE Pervasive Comput., vol. 8, no. 4, pp. 14-23, 2009.

[2] G. Intelligence, "Understanding 5G: Perspectives on future technological advancements in mobile," London, UK, 2014.

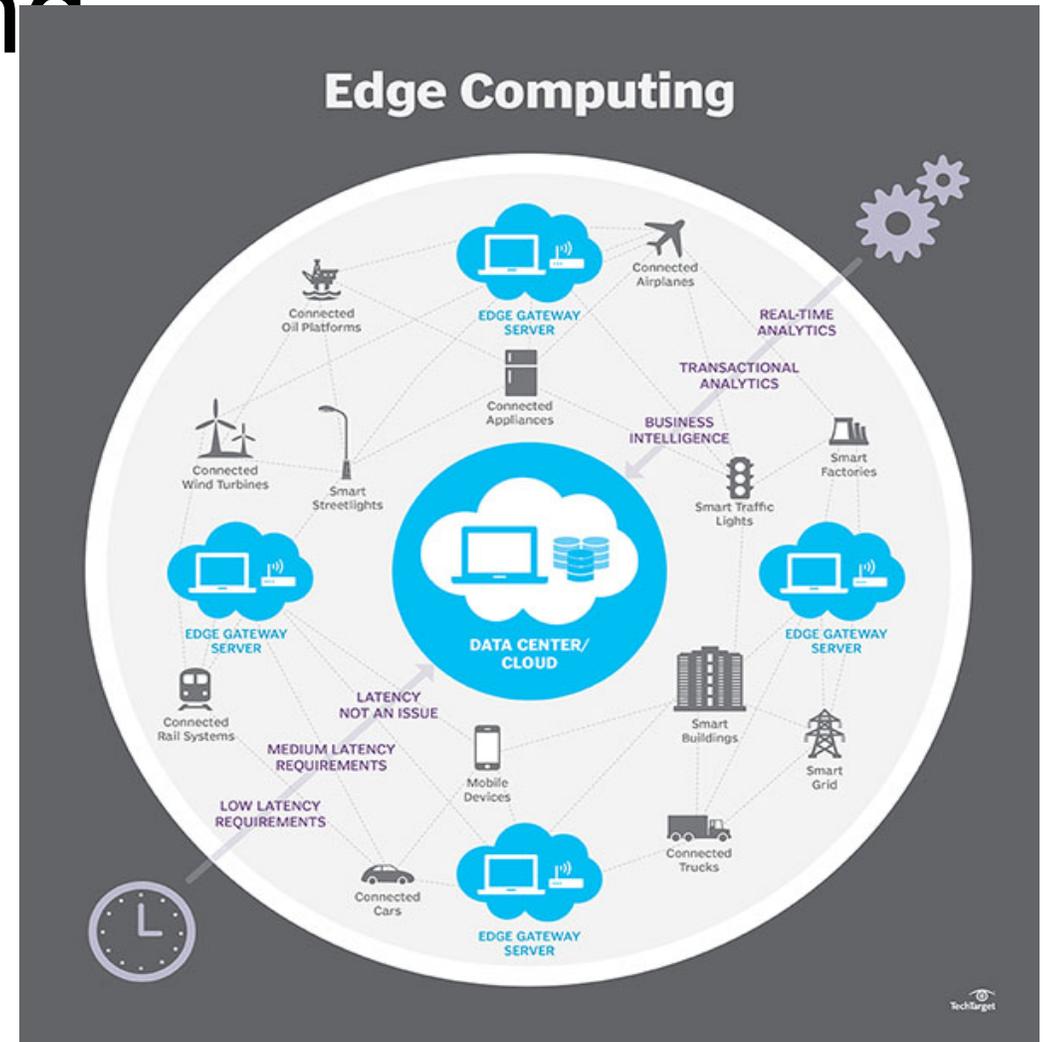
(Mobile)Edge Computing

Bring computational resources, storage and services closer to the consumers

Edge computing helps ensure that the right processing takes place at the right time

- Benefits

- Latency & bandwidth reduction
- Computation offloading
 - IoTs, cameras, cars might not have sufficient computing power
 - need to collect data from other sources
- Context awareness due to proximity



Source: <http://searchdatacenter.techtarget.com/definition/edge-computing>

Source: cisco 2014.

(Mobile)Edge Computing

- However, current deployment
 - is based on coarse-grained virtual machines (VM)
 - heavily relies on the underlying host-centric networking model
- Data dissemination is still challenging
 - between the highly mobile participants
 - nodes constantly joining and leaving the network.
- How to find the closest instance of an edge cloud in dynamic networks.

In this work, we argue that Information Centric Networking (ICN) could enhance the capability of (M)EC

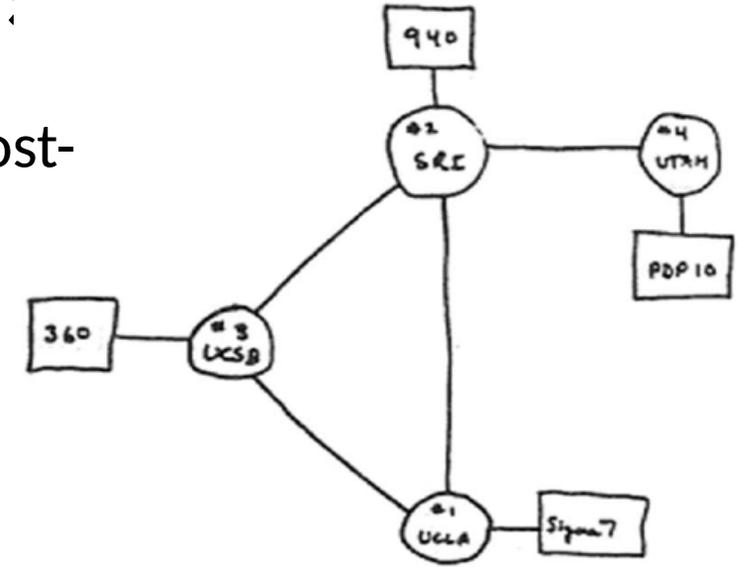
Information Centric Networking (ICN)

TCP/IP

- The Internet was initially designed for host-centric communications
 - Remote login, file transfer
 - Conversations



- TCP/IP is well suited for communications between two stationary hosts



THE ARPA NETWORK

DEC 1969

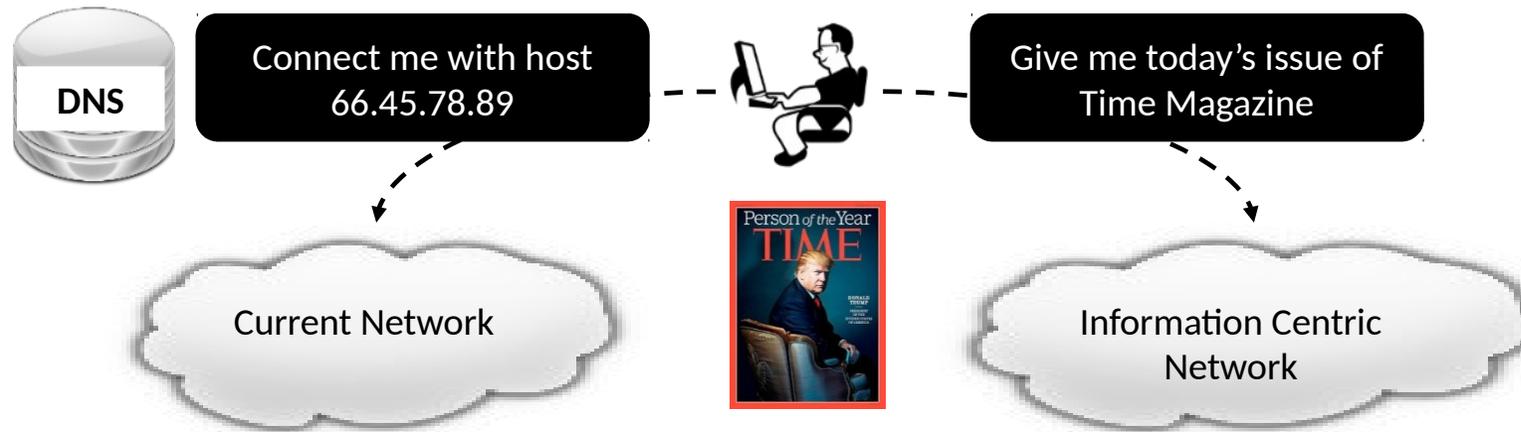
4 NODES

Source: Scientific American - Early sketch of ARPANET's first four nodes

<http://www.scientificamerican.com/gallery/early-sketch-of-arpanets-first-four-nodes/>

Information Centric Networking (ICN)

Currently



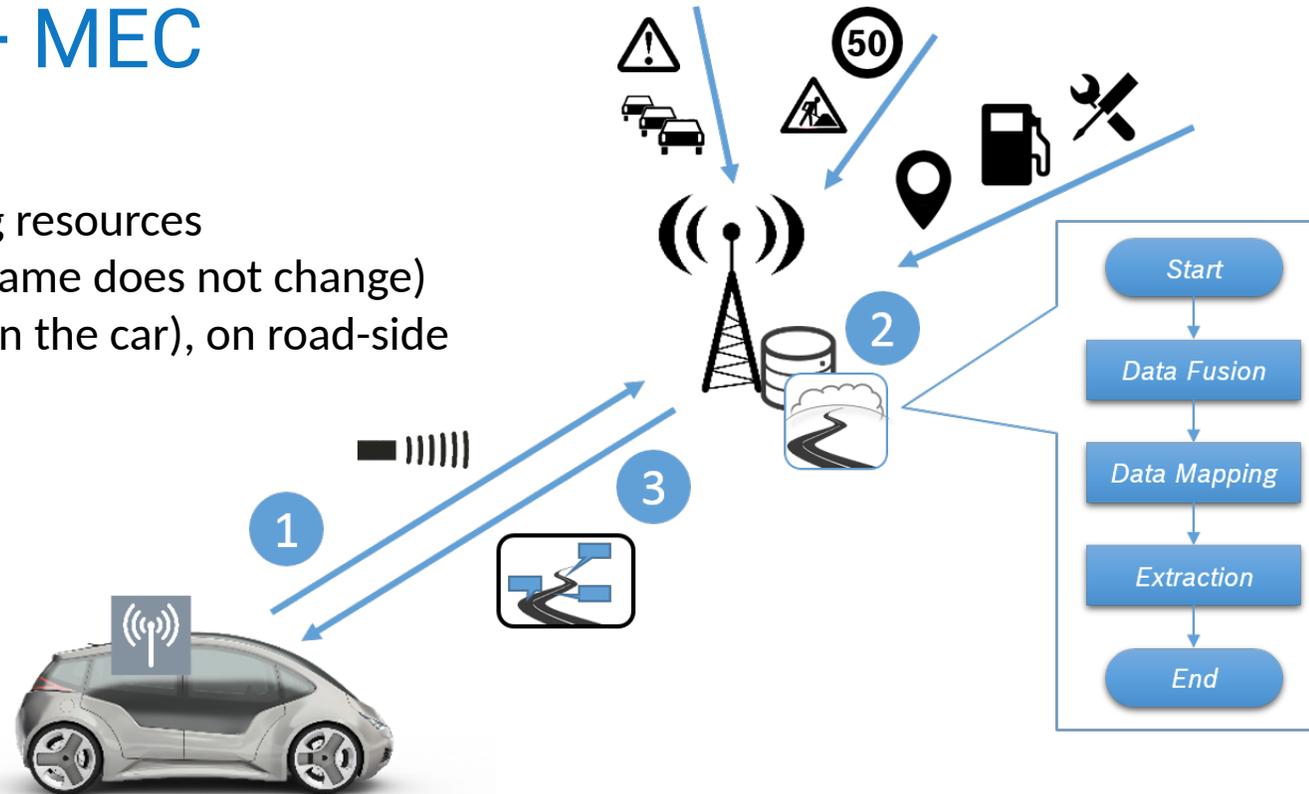
- Today, the communication pattern has changed significantly
 - Nodes are mobile and unstable in their connectivity
 - Users care about content, independent of its location
- This fits with current solutions such as CDNs, distributed cloud, load-balancing and etc.

ICN puts data as first class citizen in the network

Information-Centric Mobile Edge Computing

Electronic Horizon via ICN + MEC

- **Single abstraction** of available data and computing resources
 - They can be accessed in one universal way (name does not change)
 - The resources may be on the local machine (in the car), on road-side units or in the edge/cloud
- Consumer Mobility
- Better integrate virtualization
 - instantiation, removal, migration
- Disentangle network connectivity from access control
 - E2E security could be detrimental for MECs
 - It does not matter where data and computation results come from
 - Access control is implemented through data encryption
 - which would be “orthogonal” to accessing the bits



Research Directions



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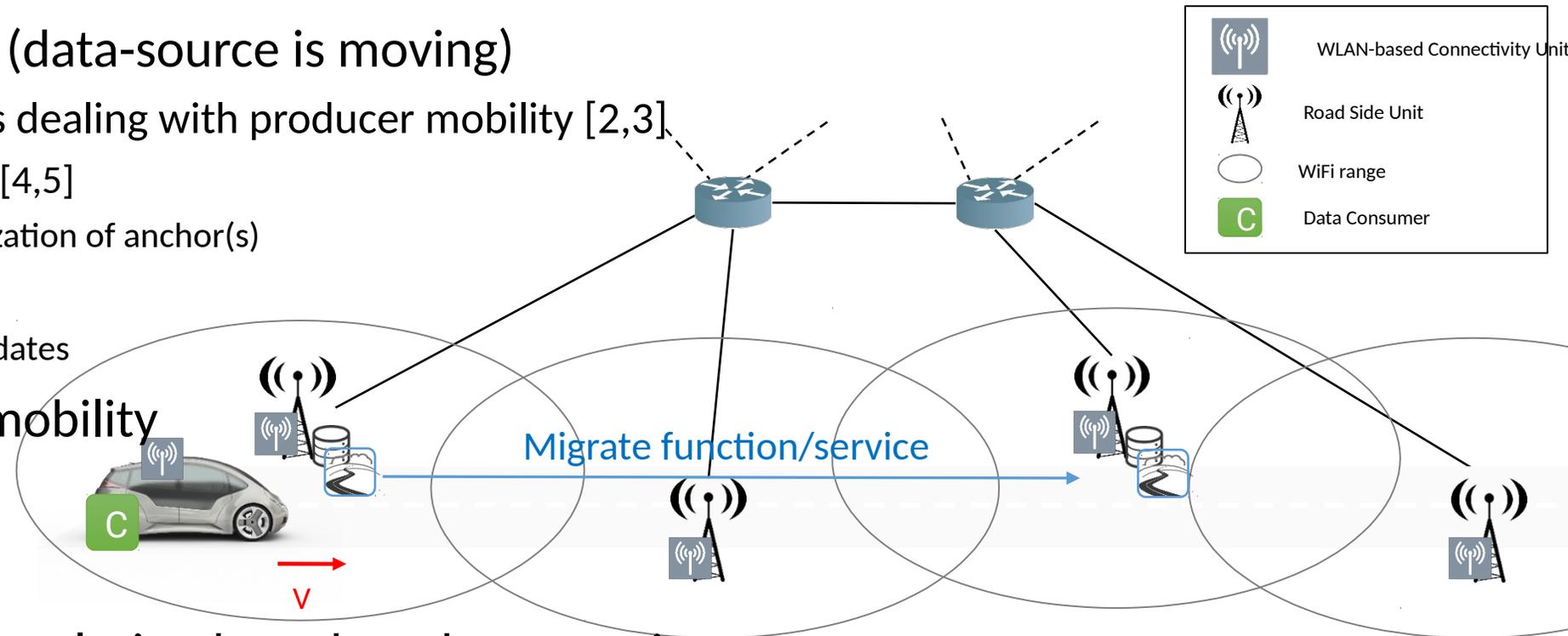


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Research Direction: Mobility

- Consumer Mobility
- Producer mobility (data-source is moving)
 - Some early works dealing with producer mobility [2,3]
 - Anchor based [4,5]
 - Synchronization of anchor(s)
 - Anchorless [1]
 - Router updates
- Function/service mobility
 - Migration



- Best not to change solution based on the scenario

[1] J. Augé, G. Caroniglo, G. Grassi, L. Muscarello, G. Pau, and X. Zeng. , MAPMe: Managing Anchor-less Producer Mobility in Information-Centric Networks, CoRR abs/1611.06785 (2016).

[2] Y. Zhang, A. Afanasyev, J. Burke, and L. Zhang. 2016. A Survey of Mobility Support in Named Data Networking. In Proceedings of the Workshop on Name- Oriented Mobility: Architecture, Algorithms and Applications (NOM 2016).

[3] Z. Zhu, R. Wakikawa, and L. Zhang. 2011. A Survey of Mobility Support in the Internet. Request for Comments RFC 6301. IRTF.

[4] Mobilityfirst, <http://mobilityfirst.winlab.rutgers.edu/>

[5] PURSUIT, <http://www.fp7-pursuit.eu/PursuitWeb/>

Research Direction: Caching

- Prefetching popular common data and store it within ICN caches

- reduces computation time and therefore latency
- But where and when to place it?

- Predictive (proactive) caching/fetching strategies for computation results

- Cache Revocation

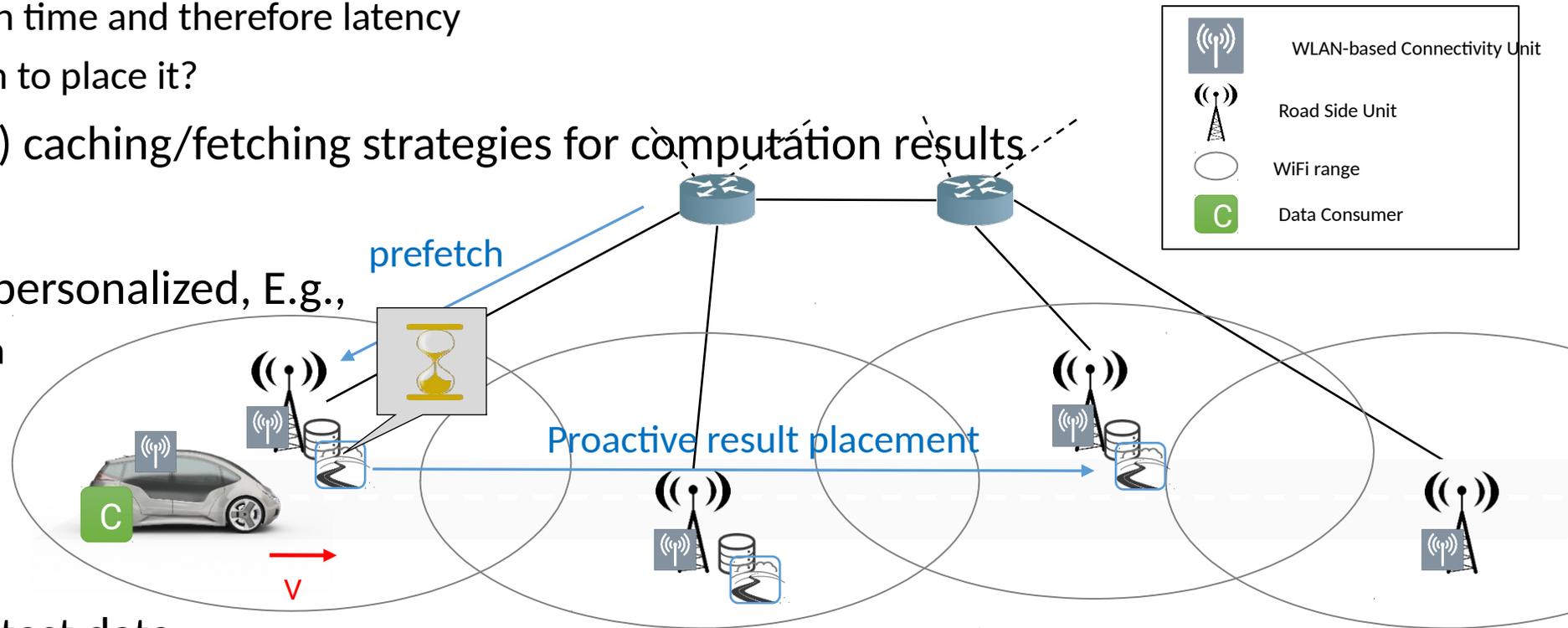
- Cache data to serve personalized, E.g.,

- Precomputed screen
- Netflix

- Monetization

- Assurance

- That this is the latest data



Research Direction: Naming

- Naming is a major/fundamental component
- More info => more visibility of what is needed
 - What do we put in the name
 - And what should go as attributes or in the pay-load
 - E.g., while accessing named functions/services, should the variables be in the name?
 - Function `add(a+b)`
 - Tradeoffs: forwarding efficiency vs ICN benefits
- Should it be hierarchical or flat or ... [1]
- schemes to access functions/services or specific instances
- schemes to query for results (e.g. personalized)
- How to provide additional context info (via name attributes)

[1] «Comparison of Naming Schemes for Local and Metropolitan Area Networks (LANMAN 2010)»

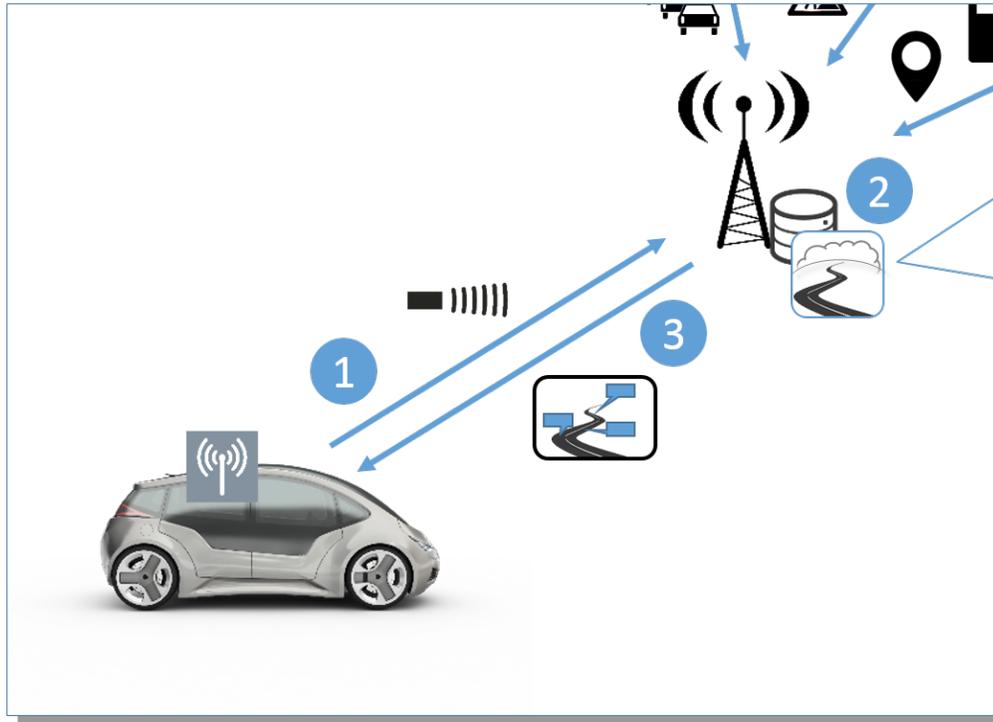
Need to perform a lot of application driven design and testing

Research Directions (Others)

Naming

Caching

Mobility



Security & Privacy, e.g.,

- MEC's will require access to data to use it for computation

Data Dissemination, e.g.,

- MEC synchronization
- Pub/sub, push from/to MEC

Routing & Forwarding,

- MEC or cloud
- Which MEC to connect to
- Switch MECs as vehicle is moving

Deployment and Orchestration, e.g.,

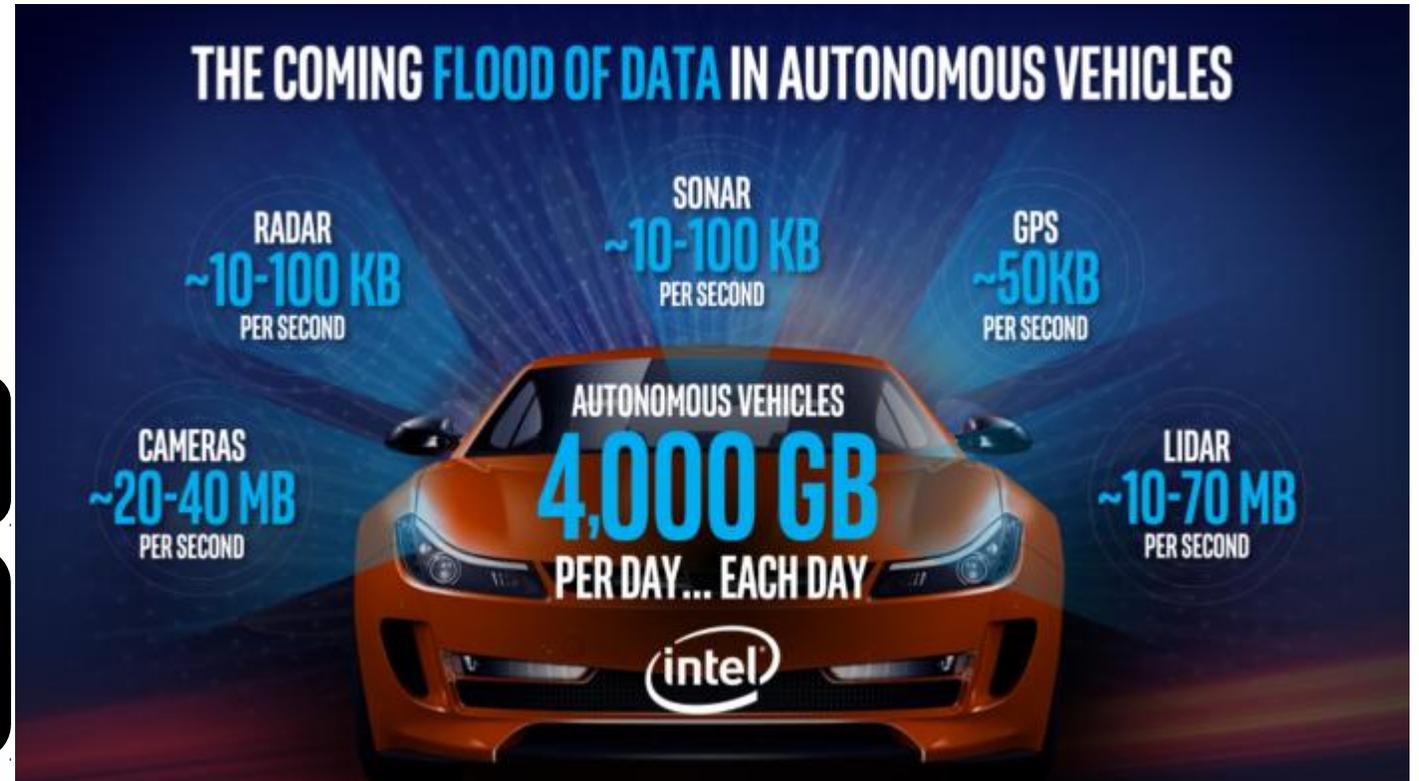
- fast deployment of function/service (e.g. unikernel) on seeing the name

Research Direction: Large scale data

- Future vehicles will be equipped with connectivity units to provide/consume data

“Just one autonomous car will use 4,000 GB of data/day”

“Each car driving on the road will generate about as much data as about 3,000 people”



<http://www.networkworld.com/article/3147892/internet/one-autonomous-car-will-use-4000-gb-of-dataday.html>

ICN can help, but naming, caching, mobility, security, needs to be further looked into

Conclusion

Information-Centric Mobile Edge Computing for Connected Vehicles

ICN has the potential to provide a lot of benefits to (Mobile) Edge Computing

However, there exists a lot of research and open issues in ICN, MEC and ICN+MEC

Acknowledgments

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Thank you & Questions



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