Guaranteeing Pro-Active and Reactive Safety in intersections through resource management at the Edge

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DIVERSE — 5th Workshop on Advanced Technologies in Industrial Vehicular Systems
10. September 2024, Padua, Italy.

Challenges for Urban Autonomous Driving

- A majority of AV crashes occur at intersections.
- The most considered influence on accidents in urban intersections is occlusion.
  - Parked vehicles
  - Stopped vehicles
  - Buildings
  - Construction
- Perception of AV alone is not sufficient in urban intersections, or decreases speed/performance

Hornsgatan, Stockholm (Source: Google Maps)

Overview of the Talk

Background

Towards increased safety at smart intersections

- Augmented AV perception
- Pro-active safety through traffic orchestration
- Reactive safety through contingency path planning

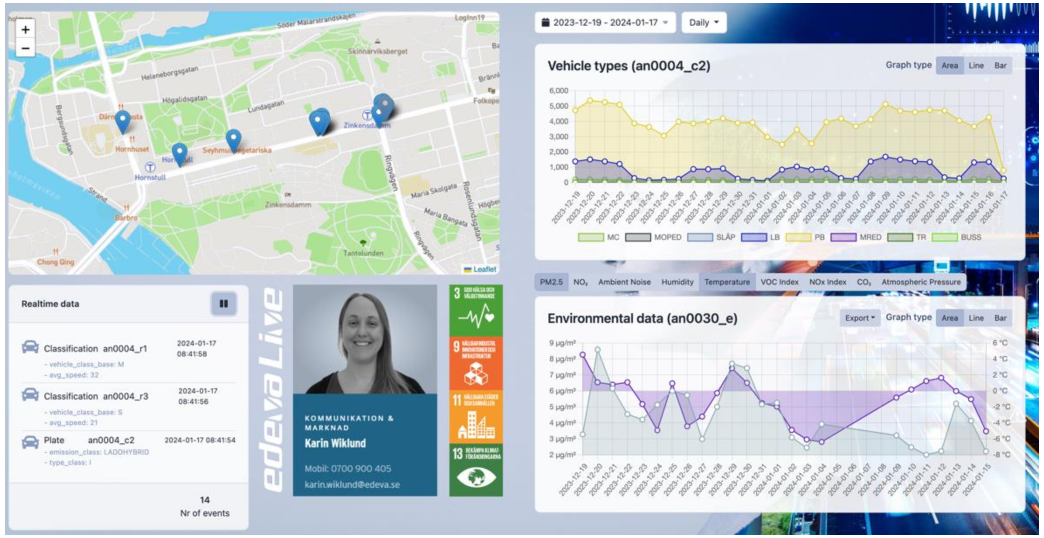
Platform support to meet workload demands

- Scheduling reservations to isolate applications
- Request arbitration under different types of timing constraints

Conclusions and future work

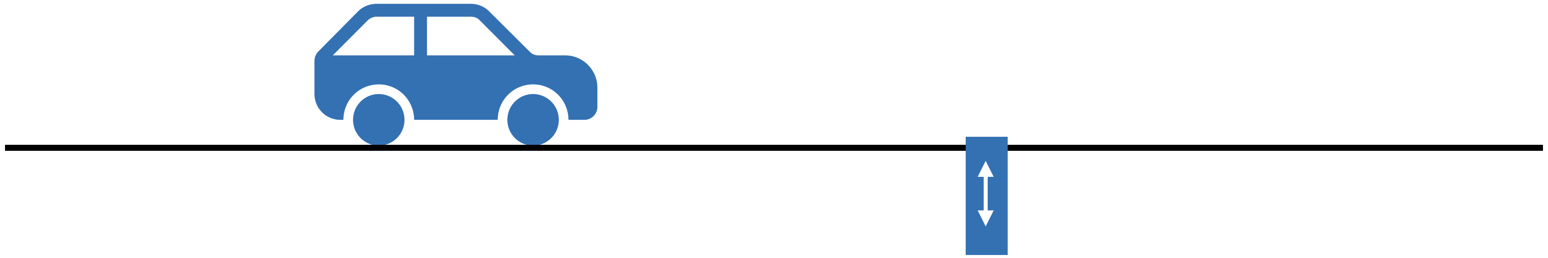
Holistic Information at Intersections

- In addition to cameras for perception, various data can be available at intersections
  - Vehicle Class
  - Emission Class
  - Speed
  - Weight
  - etc.



Source: https://live.edeva.se/open-dashboard

- Active measures exist to influence traffic dynamically



Infrastructure Guided Decision Making Support

Roadside Unit (RSU) provides resources to AVs:

- Augmented AV perception
- Traffic orchestration to avoid congestion at intersection
- Contingency path planning during likely collisions and establish safety zones

Proactive

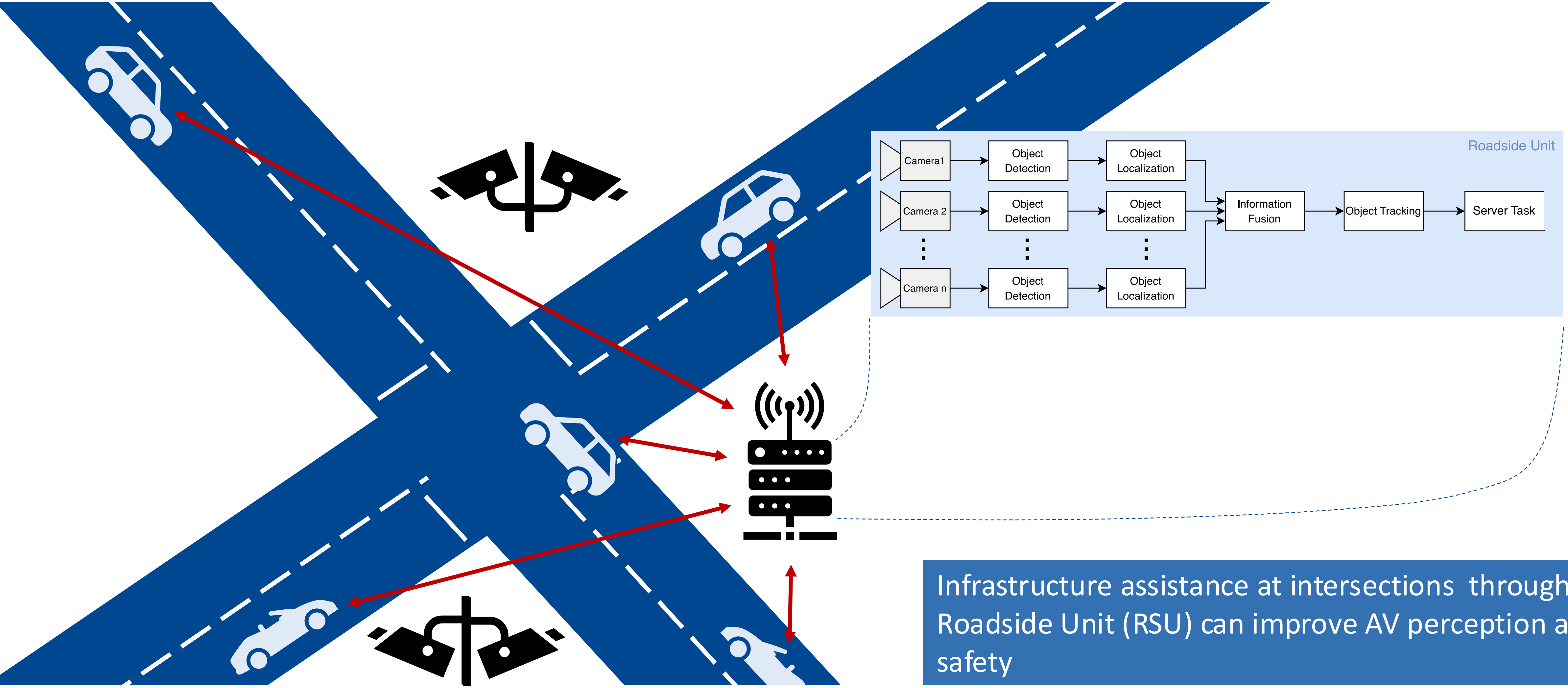
Reactive

- Path Planning
- Establish Safety Zones
- Scene Perception

Safe Infrastructure Guided Decision Making Support

- Computational resources for different workloads
- Handle AV requests with timing constraints

Improve AV Perception through Infrastructure Support



Infrastructure assistance at intersections through Roadside Unit (RSU) can improve AV perception and safety

Traffic Orchestration

Time-to-Collision (TTC)

“The time that remains until a crash between two vehicles would have occurred if the crash course and speed difference are maintained.” Hayward, 1972.

Quantify the severity of a conflict as well as its probability.

→ Take evasive action if a threshold is exceeded.

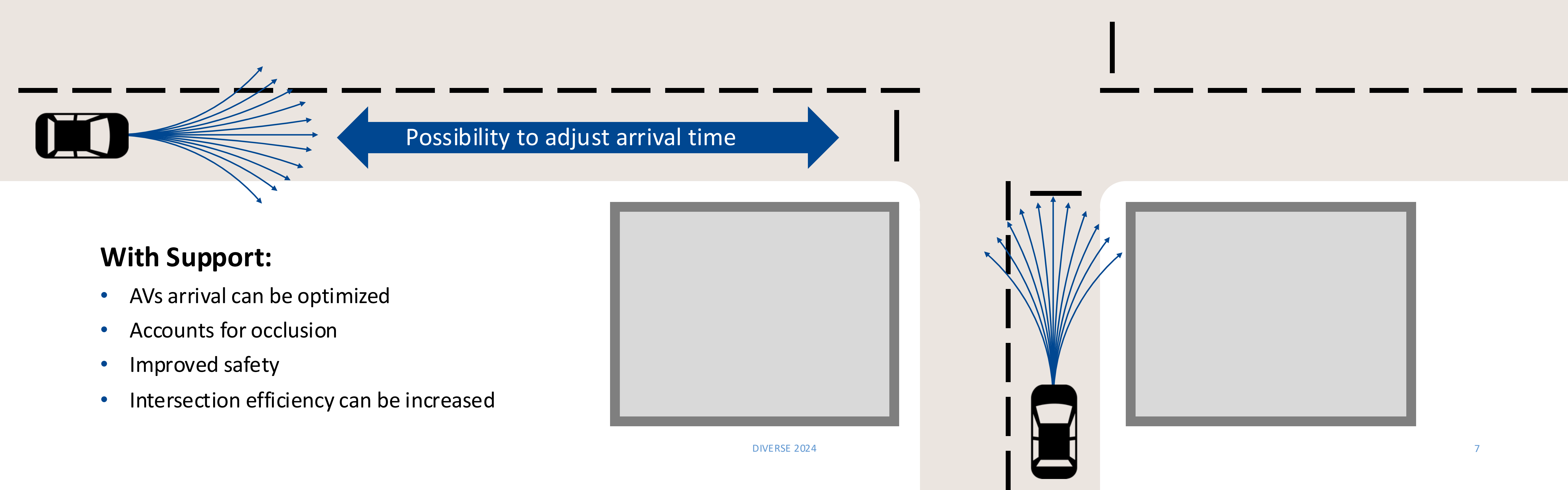
Utilise SSM for Traffic Orchestration

Orchestrate / support AV planning to arrive at intersection when likelihood of collision is minimal.

→ Reduce the likelihood of encounters that lead to difficult-to-control situations.

Traffic Orchestration

- Provide advancing AVs with decision-making support to reduce the likelihood of conflicts at the intersection.
- Consider possible trajectories and their likelihood
- Recommend actions to AV that reduce likelihood of conflict



With Support:

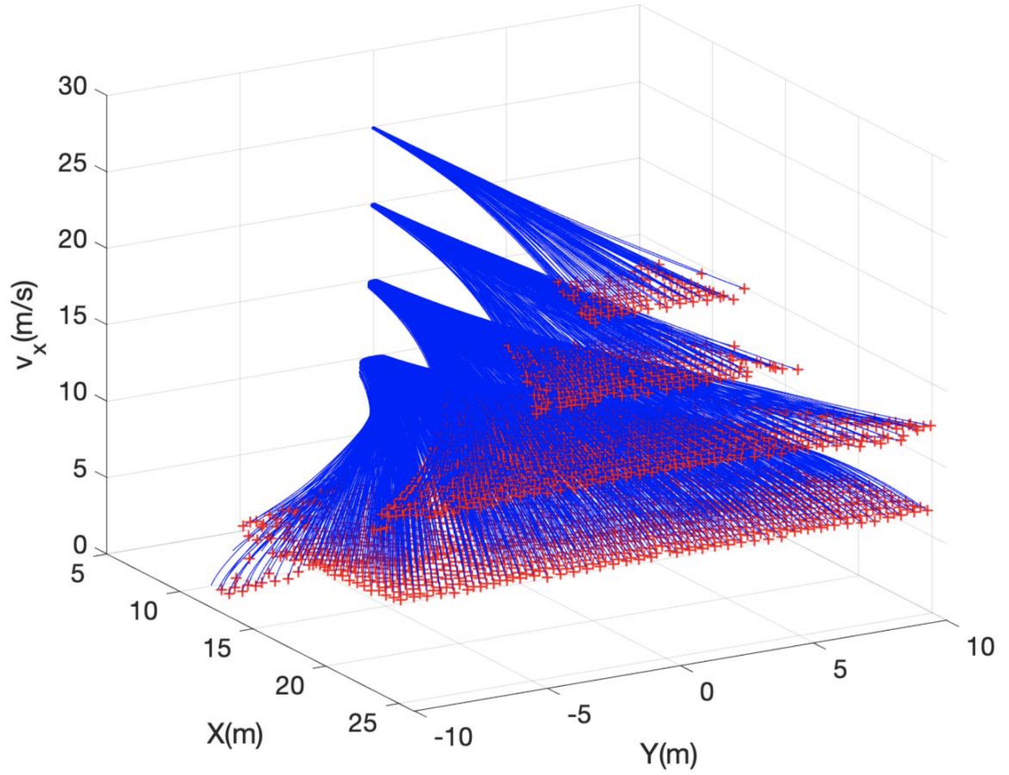
- AVs arrival can be optimized
- Accounts for occlusion
- Improved safety
- Intersection efficiency can be increased

Support Decision Making in Unavoidable Collisions

- Trajectory library is used to present possible evasive actions of the ego vehicle.
- Parameterized:
  - Initial velocity
  - Weight
  - Size
  - etc.

Problem – Vehicle parameters are typically not known!

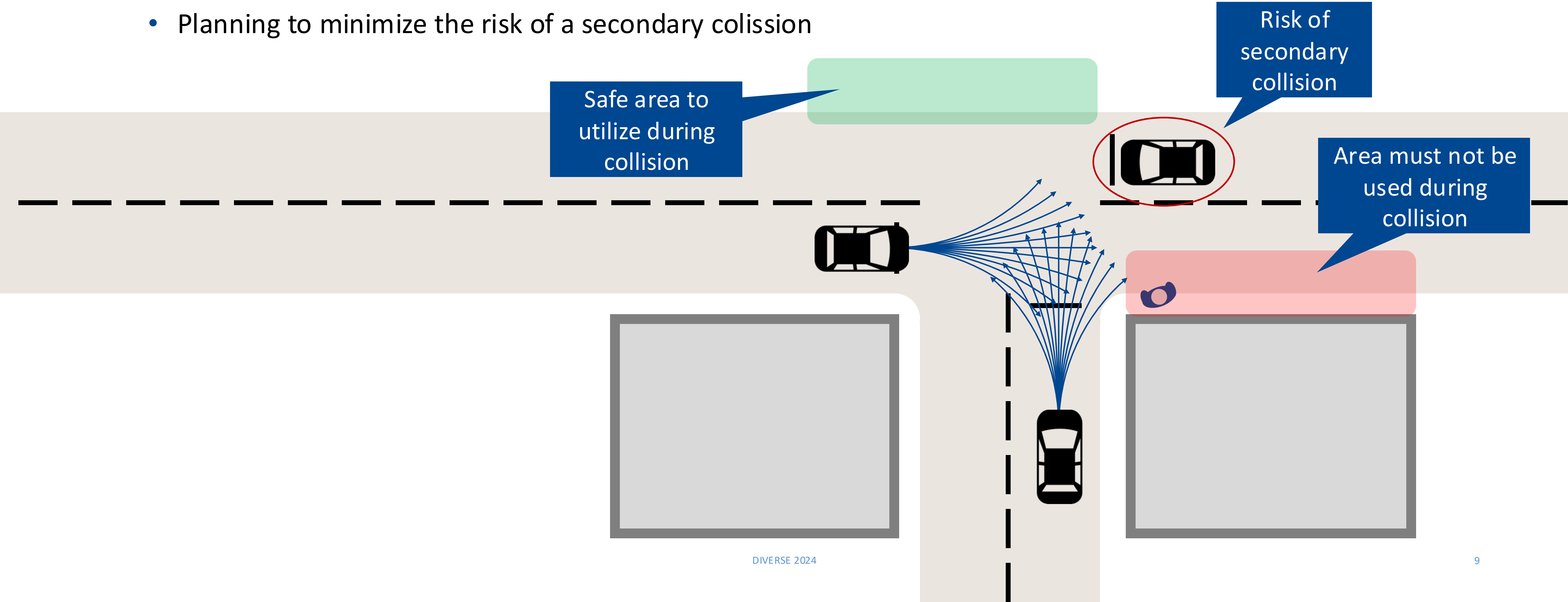
- → RSU at the intersection has more accurate data on vehicle parameter, involved actors, etc. than individual AV.



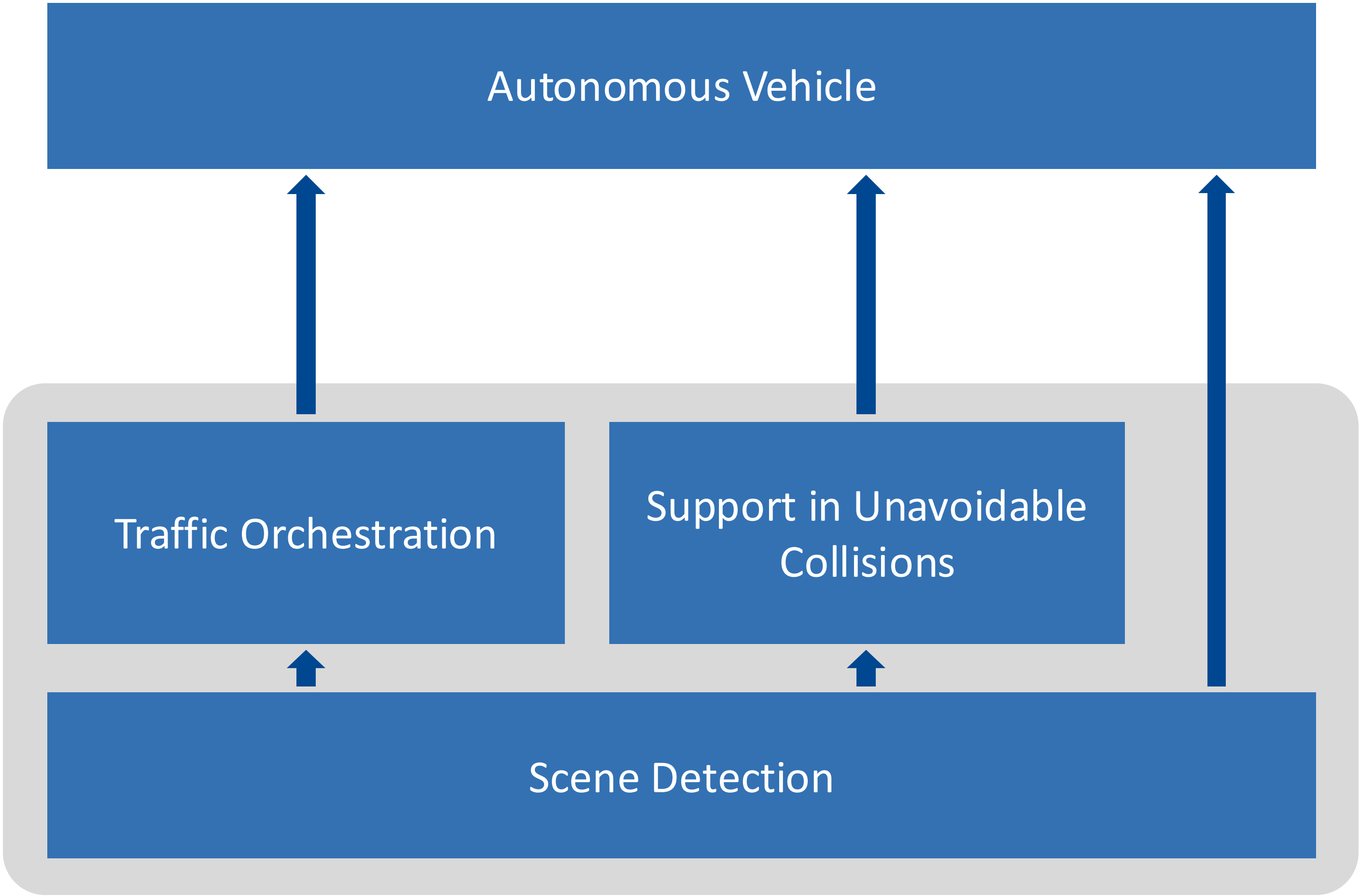
Source: Parseh et al., IEEE T-IV, 2021

Support Decision Making in Unavoidable Collisions

- SSM indicates that the likelihood of collision is above threshold
- Intersection support can include:
  - Safety Zones, areas outside the road that can temporarily be used during crash
  - Planning to minimize the risk of a secondary colission



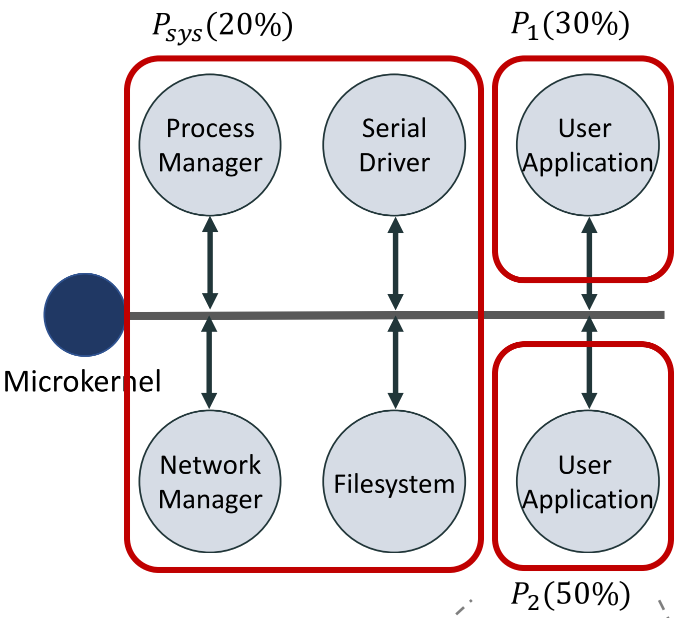
Service Types on RSU



- Different services are provided by the RSU
- Runtime interference between services must be avoided
- Computationally heavy data-driven workload
- Different AVs can have different (types of) timing requirements

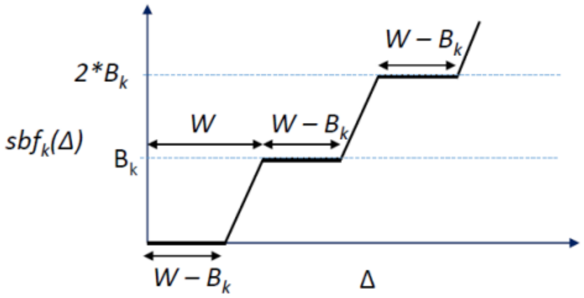
POSIX-Based RTOS

- Workload Characteristics
  - Data-driven, dynamic workloads
  - Modular updates
- QNX RTOS
  - Preferred base operating system by many automotive OEMs
  - ISO26262 pre-certified at the highest level of assurance (ASIL-D)
  - POSIX-compliant, commercially proven
  - Supports CPU reservations



Adaptive Partitioning Scheduler (APS)

- Secure partitions with guaranteed CPU time
- A partition is a container for a collection of threads
- Configured with budget as percentage of CPU time over a common sliding window (100 ms)
- The highest priority ready threads whose partition has budget is scheduled
- Budget reclamation can be enabled



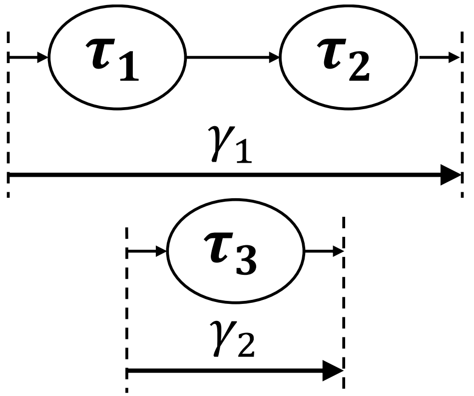
[1] Dakshina Dasari, Matthias Becker, Daniel Casini, and Tobias Blass. End-to-end analysis of event chains under the QNX adaptive partitioning scheduler. In *28th IEEE Real-Time and Embedded Technology and Applications Symposium (RTAS)*, 2022

Analysis vs. Measurements

Task	WCET	Period	Priority	Partition
τ_1	20 ms	100 ms	253	P_1
τ_2	10 ms	-	254	P_1
τ_3	x ms	10 ms	255	P_2

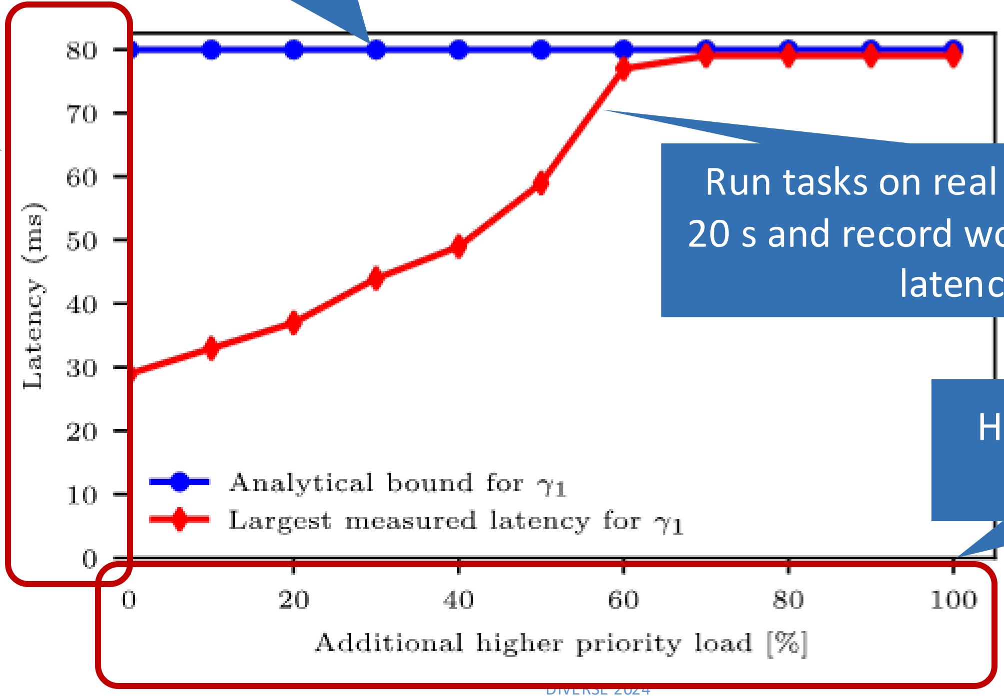
- 3 tasks, 2 event-driven chains
- All tasks on the same core
- Budget P_1 and P_2 is 50%
- budget reclaiming

Vary WCET to affect the task utilization



Compute the latency bound using the analysis

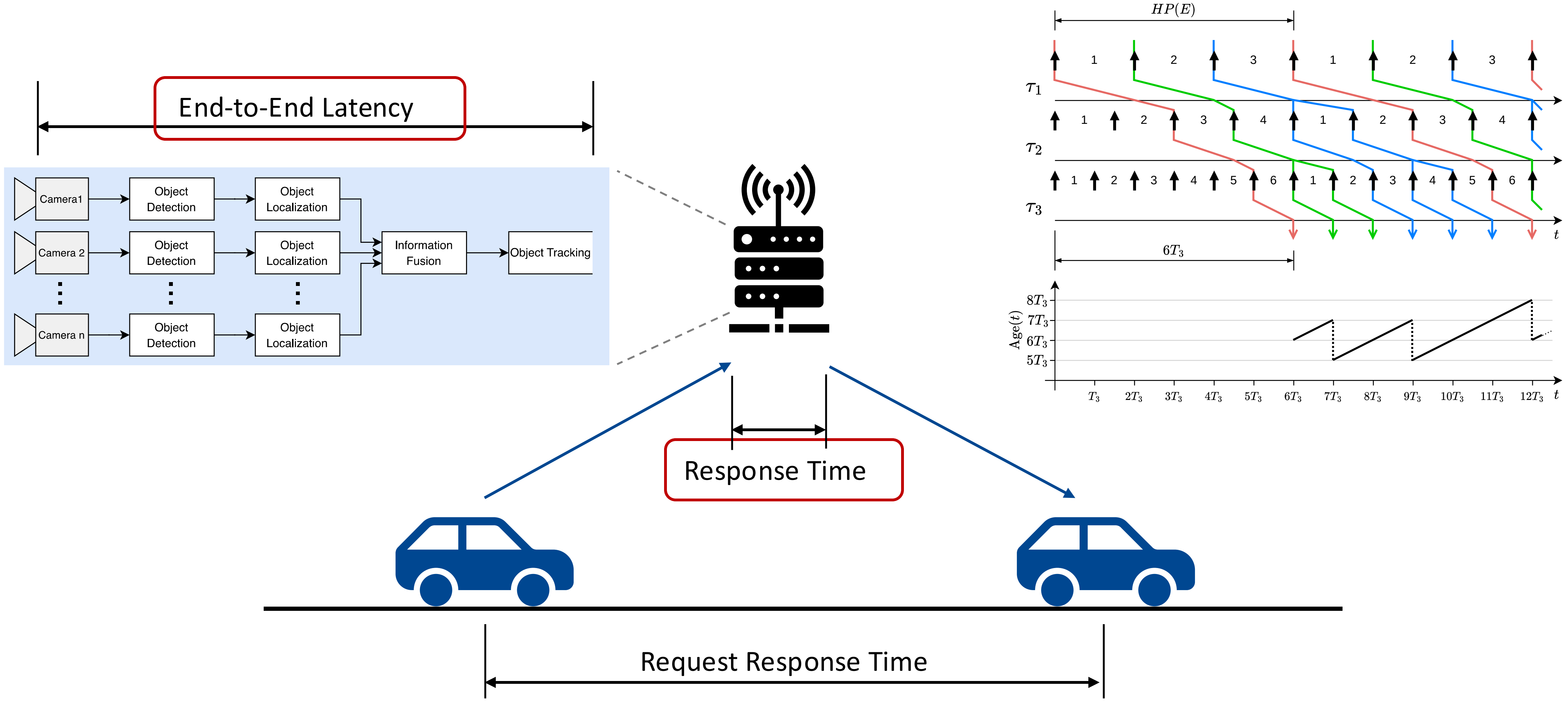
Latency of chain γ_1



Run tasks on real platform for 20 s and record worst-observed latency

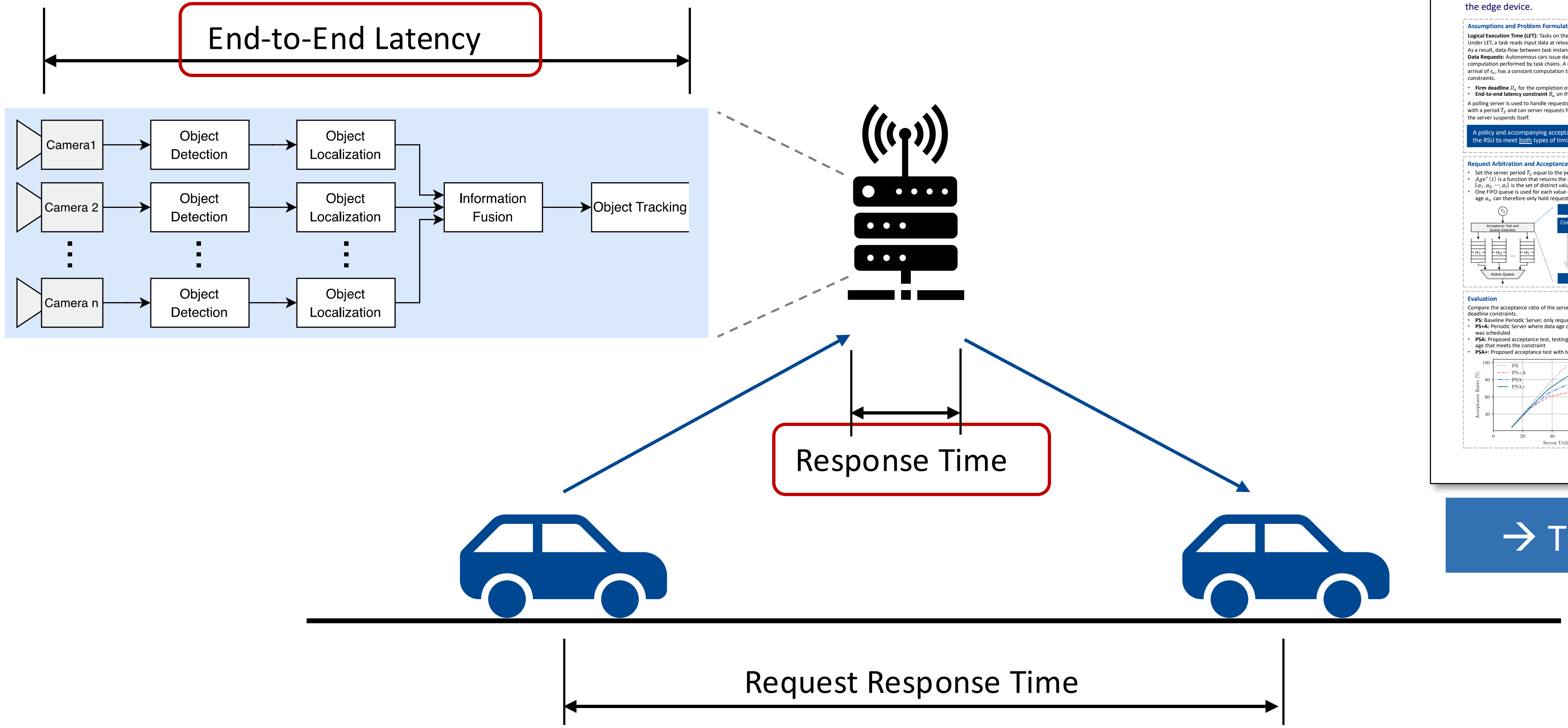
Higher priority load generated by τ_3

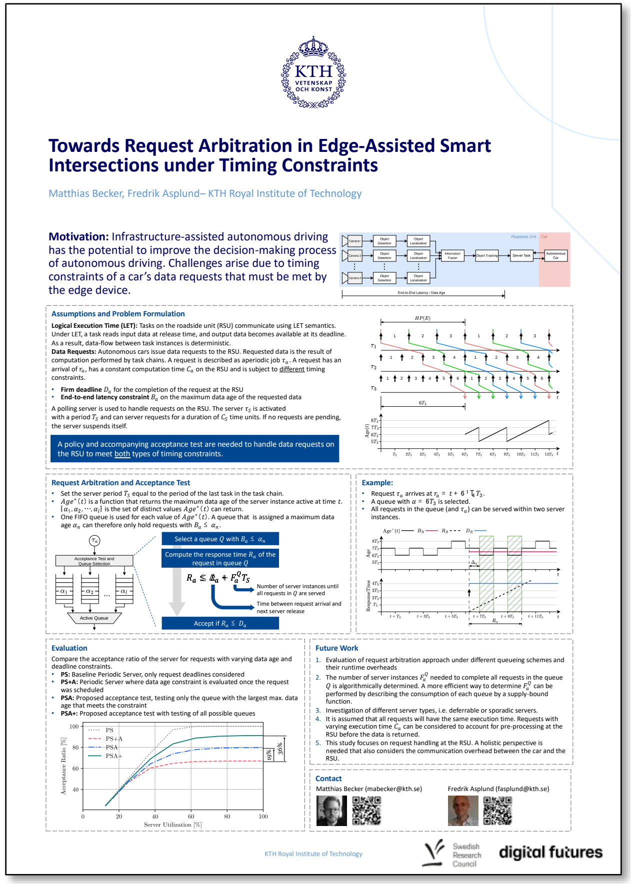
Augmented AV perception



How can both types of timing constraints be considered by the RSU?

Augmented AV perception





→ Thursday 9:00 WIP3

How can both types of timing constraints be considered by the RSU?

Conclusions and Future Work

- Infrastructure-assisted autonomous driving has the potential to reduce risks at intersections.
- Holistic view of the traffic allows for pro-active and reactive approaches for safety
- Different services for AVs emerge that are subject to timing constraints
- CPU reservations to isolate different applications/services from each other
- Server-based AV request handling considering different types of timing constraints

- Simulation study to:
  - Evaluate effectiveness of Remote-SSM
  - Identify realistic timing constraits for AV traffic at intersection

Thank You!
Questions?