

Probabilistic Aggregation for Data Dissemination in VANETs

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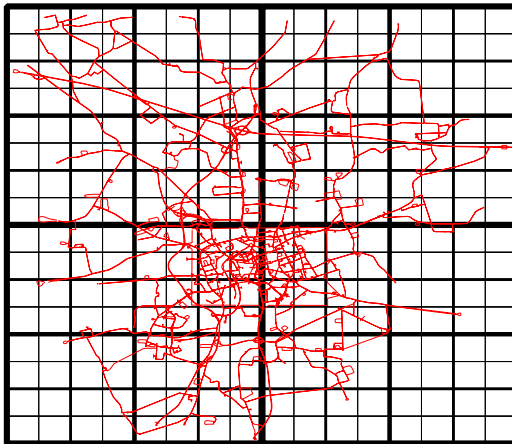


Duplicate Sensitive Aggregation





Duplicate Sensitive Aggregation



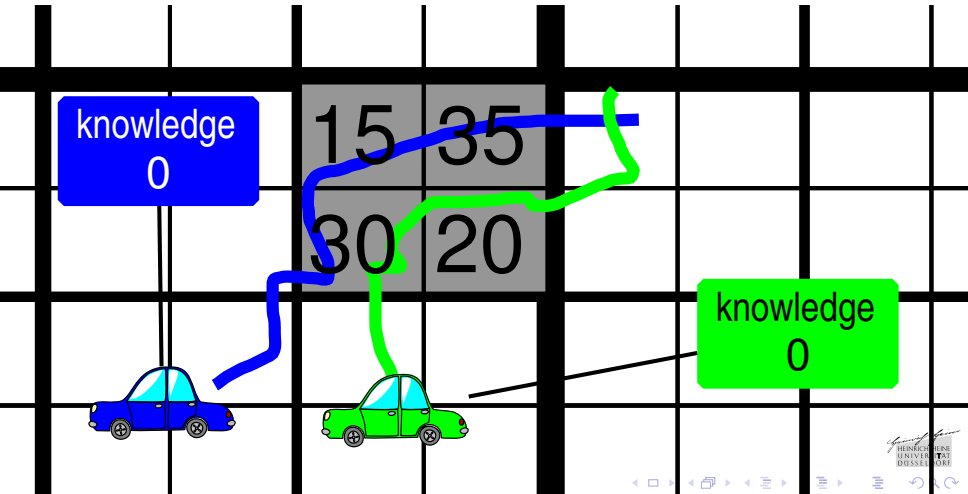
Duplicate Sensitive Aggregation

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36	18	26	18	5	15	35	10	12	26	3	25	36	18	20	26
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15	15	30	20	10	26	3	25	36	18	10	15	30	20	8	16
26	3	18	5	15	35	10	12	18	5	15	35	10	12	36	18
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10	3	25	26	3	25	36	18	35	26	3	25	36	18	18	5
3	35	10	12	5	15	35	10	15	30	20	8	16	18	5	15
5	20	8	16	15	30	20	8	26	3	25	36	18	10	15	30



Aggregation for Car-2-Car Applications

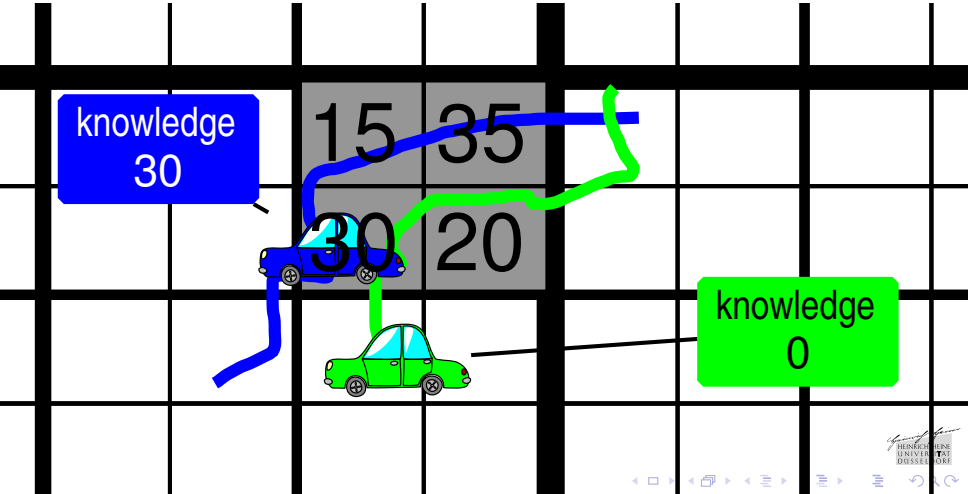
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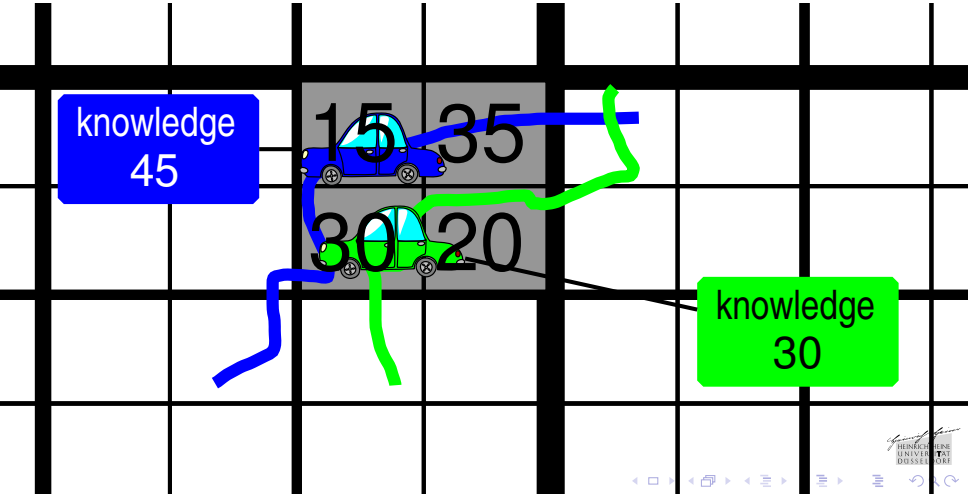
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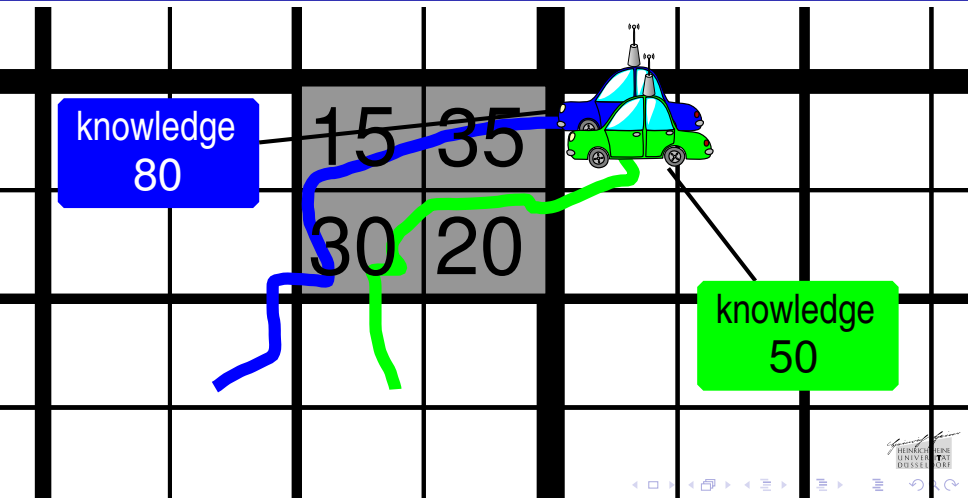
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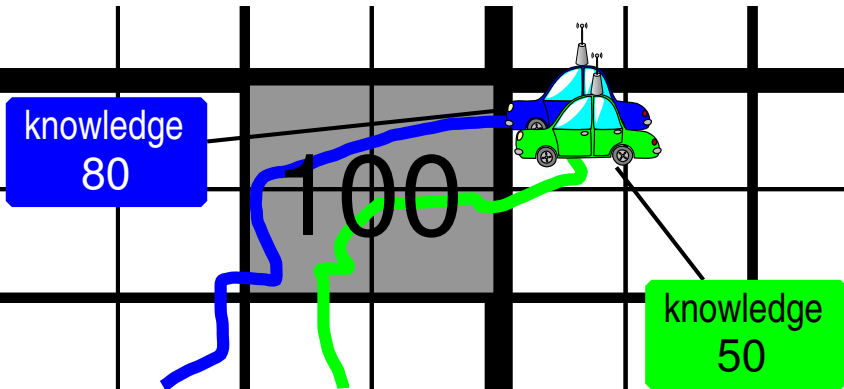




Duplicate Sensitive Aggregation



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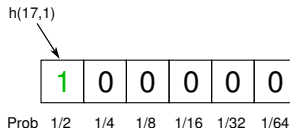


Probabilistic Counting

Definition (FM-Sketch)

- Data structure for
- Probabilistic counting of
- Distinct elements

ID: 17
Value: 4



21	20	19
18	4	17
15	14	13

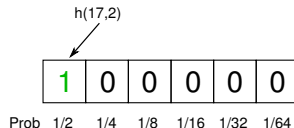
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 $P(h(x) = i) = 2^{-i}$

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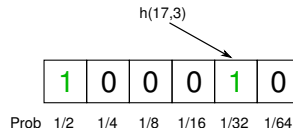
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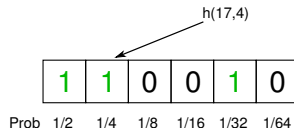
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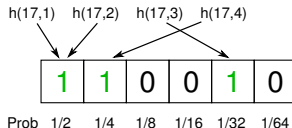
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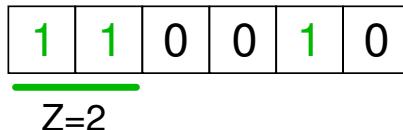
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Computation of Elements



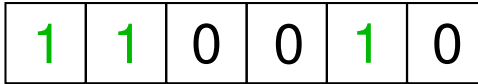
$$Z(S) := \min(\{i \in \mathbb{N}_0 \mid i < w \wedge s_{i+1} = 0\} \cup \{w\}) = 2$$

$$C(S) := \frac{2^{Z(S)}}{\rho} = \frac{2^2}{0.775351} = 5.15773$$

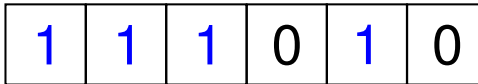
Accuracy can be improved by using multiple sketches

Merging Two Aggregates

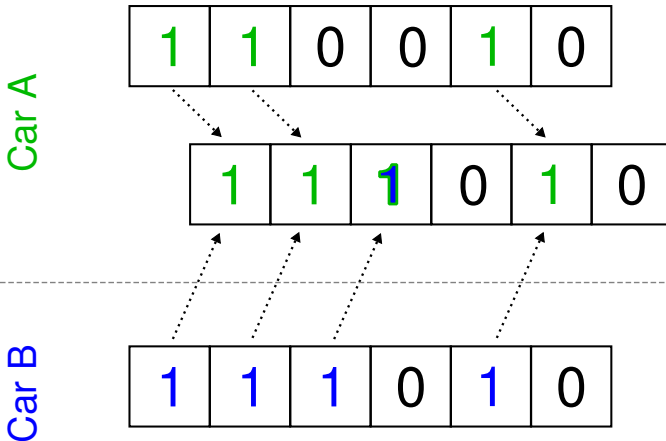
Car A



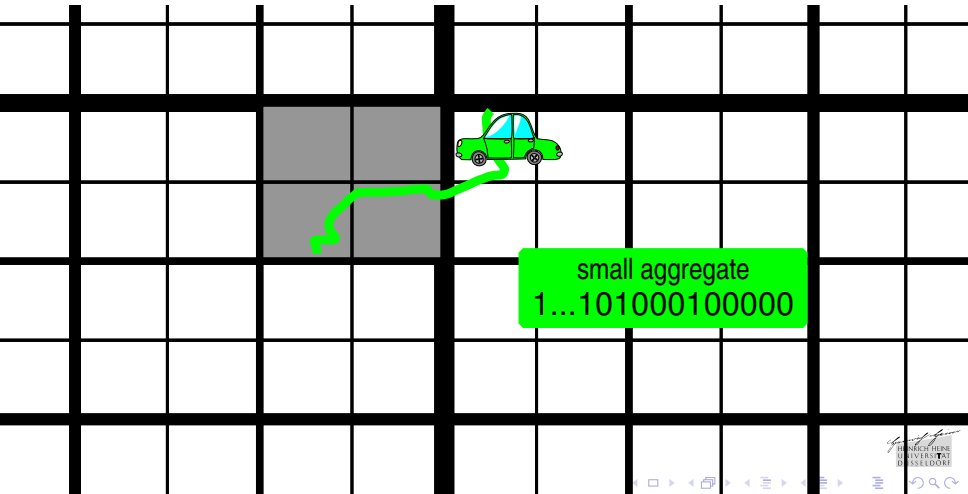
Car B



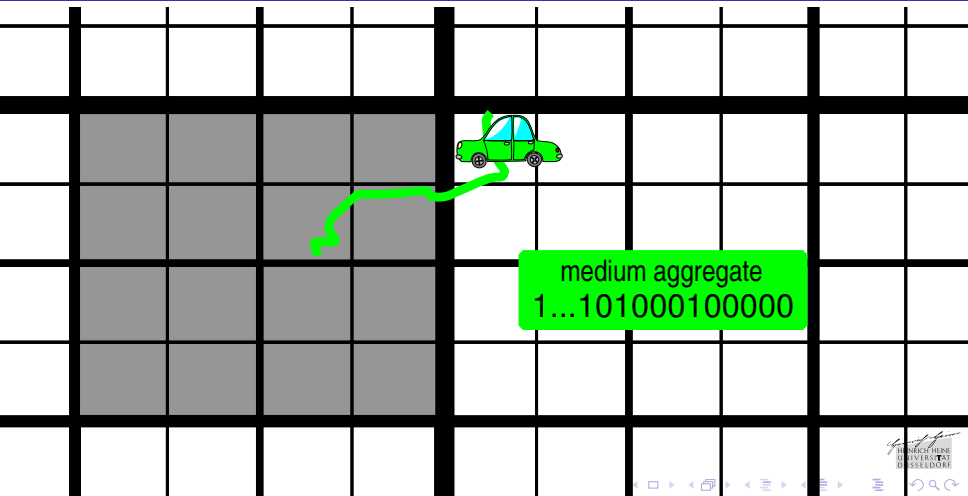
Merging Two Aggregates



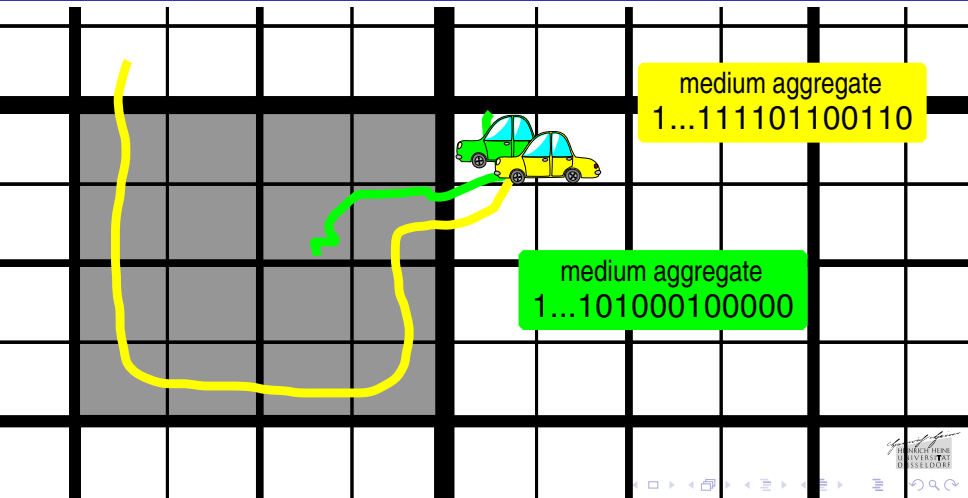
Aggregation of Larger Regions



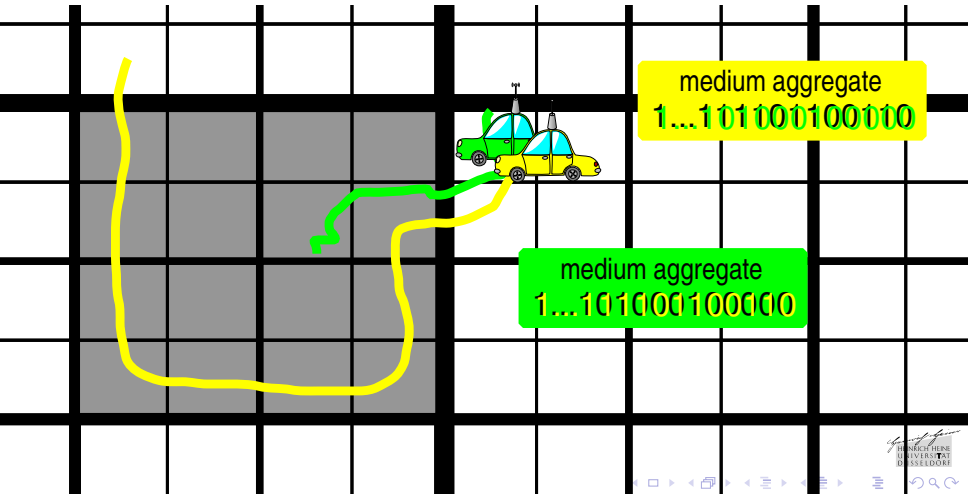
Aggregation of Larger Regions



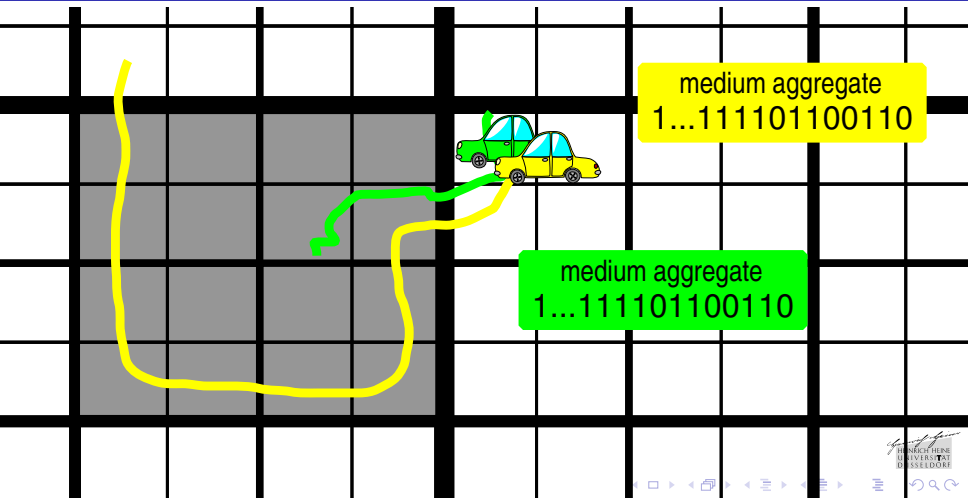
Aggregation of Larger Regions



Aggregation of Larger Regions



Aggregation of Larger Regions



Adaptions to VANETs

- Values can change often
- Aggregates have to represent this procedure

⇒ **How can elements be erased out of a sketch?**

Soft-State Sketches

Deletion of a specific measurement is not possible, but ...

Measurements can die out after some time

- Extending static bit-field to more flexible (TTL-) counters
- Counters are set to maximal value
- Decrementation of counters emulates die out process
- If counter = 0 then the 'bit' is not set

Merging Aggregates

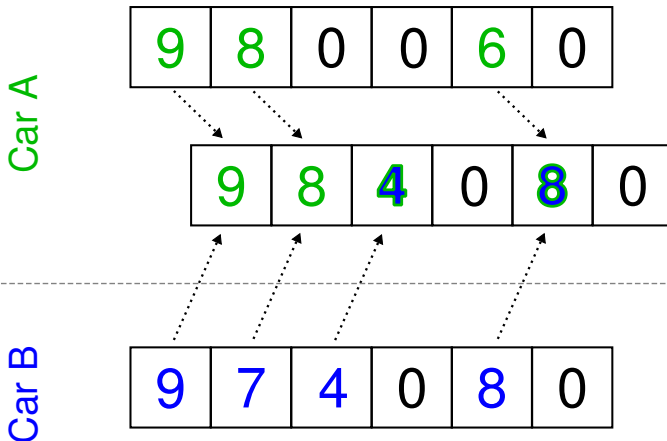
Car A

9	8	0	0	6	0
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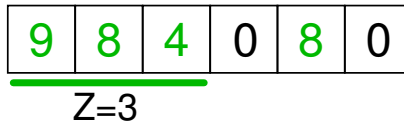
Car B

9	7	4	0	8	0
---	---	---	---	---	---

Merging Aggregates



Computation of Elements

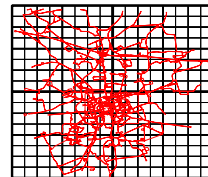


$$Z(S) := \min(\{i \in \mathbb{N}_0 \mid i < w \wedge s_{i+1} = 0\} \cup \{w\}) = 3$$

$$C(S) := \frac{2^{Z(S)}}{\rho} = \frac{2^3}{0.775351} = 10.3179$$

Example VANET Application

- City scenario
- Cars count
 - Free parking places
 - Total number of parking places
- Aggregation of measured data
- Periodical dissemination of
 - Local (aggregated) information
 - Aggregates of adjacent cells



Simulation Evaluation – Technical

- Standard ns-2 simulation with obstacle modeling
- City scenario (16 km×16 km, 500 km streets)
- 10,000 nodes, ca. 2,500 equipped with car2car technology
- Realistic movement by ns-2/VISSIM coupling
- Simulation time
 - settling: 3 h
 - simulation: 15 min

Simulation Evaluation – Methodical

- Stochastic process to model occupancy of parking places
- Sketch counter: 5 Bit \Rightarrow 31 steps
- Beacon frequency: 1/5 s

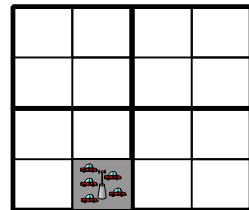
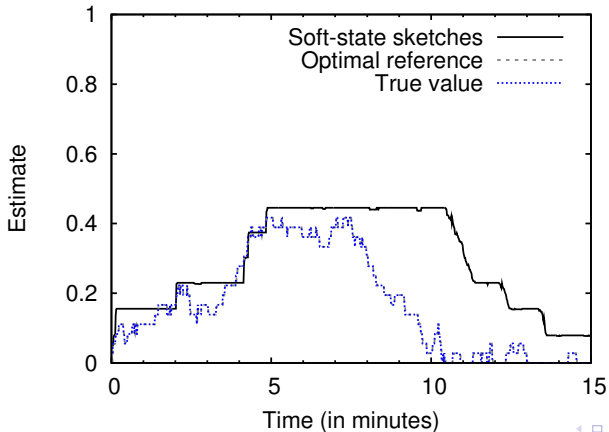
Simulation Evaluation – Methodical

Soft-State approach compared with

- True value
 - Based on global knowledge
- Optimal reference protocol
 - Cars measure value of their cell
 - No aggregation
 - Unlimited bandwidth assumed

Local Accuracy

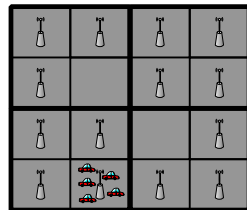
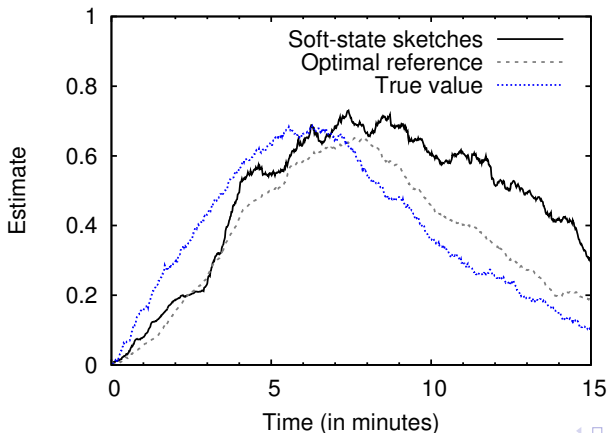
Small Aggregate






- Measurements exist
- Area of interest
- Queried cars

Forming Aggregates

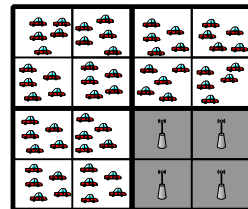
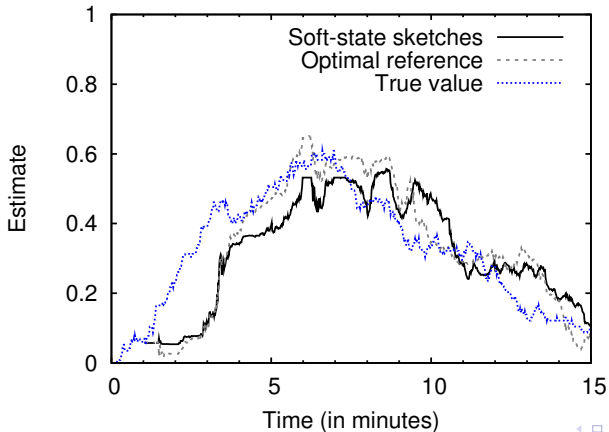
Large Aggregate



-  Measurements exist
-  Area of interest
-  Queried cars

Distributing Aggregates

Distant Medium Aggregate



Summary

- Sketches for duplicate-sensitive aggregation
- Soft-state approach for VANET applications
- Applicable for the dissemination of any kind of sums
 - Parking places
 - Current traffic situations
 - ...

Thank you for your attention!

Questions?

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