EPIC: an Epidemic based dissemination algorithm for VANETs

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SAPIENZA
UNIVERSITÀ DI ROMA

Technologies, mOdels, and Protocols for Cooperative Connected Cars (TOP-Cars)

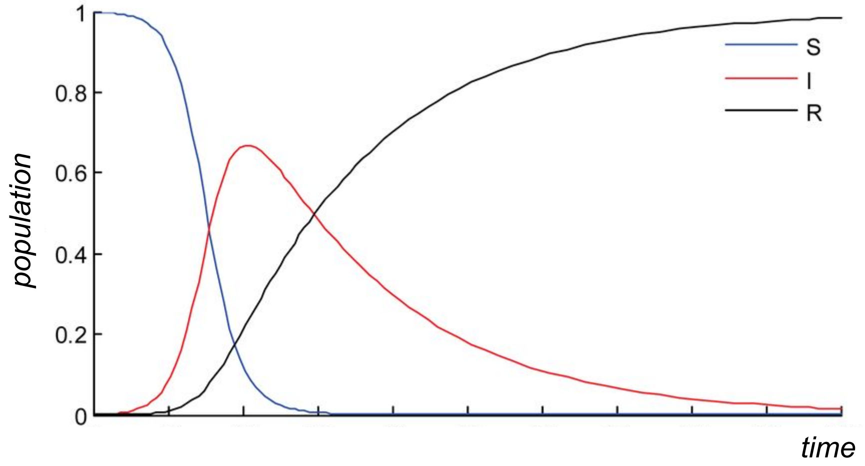
Outline

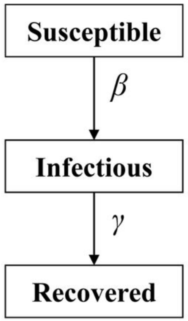
1. Motivation
2. Related work
3. Epidemic-style dissemination
4. EPIC
5. Performance evaluation
6. Results

Motivation and Goals

- Data dissemination in VANETs deals with complex network topology and can lead to inefficiencies and broadcast storm
- We can express efficiency of a dissemination process in terms of:
  - Ratio of vehicles which act as relay of vehicles in the target dissemination area
  - Data overhead carried by the network
- The main goal of our proposed dissemination algorithm is to maximize efficiency using only local information at nodes, plus any information that is collected by nodes through the background beaconing process carried out in VANETs.

Susceptible-Infected-Recovered Model





$$\frac{dS}{dt} = -\beta SI$$

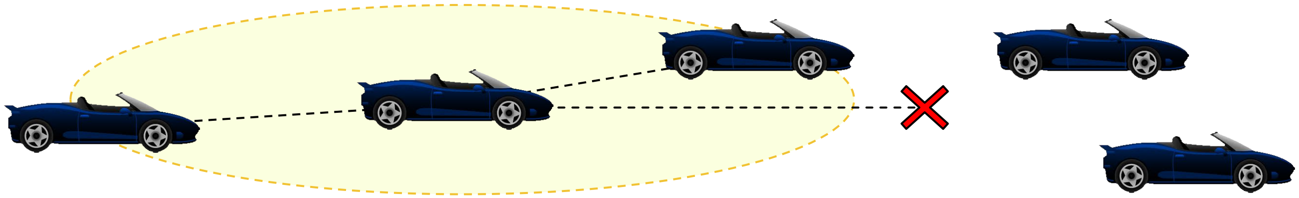
$$\frac{dI}{dt} = \beta SI - \gamma I$$

$$\frac{dR}{dt} = \gamma I$$

Related work

- Data dissemination in vehicular networks: Challenges, solutions, and future perspectives, L. Aparecido
- Epidemic Algorithms for Reliable and Efficient Information Dissemination in Vehicular ad-hoc Networks, M. Nekovee
- Broadcast storm mitigation techniques in vehicular ad hoc networks, N. Wisitpongphan and et al.
- An Empirical Study of Epidemic Algorithms in Large Scale Multihop Wireless Networks, Deepak Ganesan et al.

Epidemic-style dissemination



- Vehicles in the network adopt the Susceptible-Infected-Recovered model for each disseminated message
- By epidemic algorithms, we refer to network protocols that allow rapid dissemination of information from a source through local interactions
- One key advantage that epidemic algorithms offer is that they do not need any information on the *complete* network topology

Dissemination Algorithm

Procedure to be executed by vehicle *A* on message received by *B*

For simplicity we consider the dissemination of a *single* message

---

procedure OnMessageReceipt
    if state = *RECOVERED* **then**
        return
    else if state = *SUSCEPTIBLE* **then**
        rcv_messages ← *empty list*
        state ← *INFECTED*
        timer ← $\max\left\{T_{min},\ T_{max}\left(1 - \frac{d_{AB}}{R_{max}}\right)\right\}$
        rcv_messages.*append*(msg)
    else if state = *INFECTED* **then**
        rcv_messages.*append*(msg)

    on timer *expiry*:
    do_relay ← *EvaluatePositions*(rcv_messages)
    if do_relay **then**
        msg ← *updateMsg*(msg)
        relayMessage(msg)
    state ← *RECOVERED*

Waiting phase rule: Set timer and keep buffering incoming messages until timer expiry

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        state $\leftarrow$ *INFECTED*
        timer $\leftarrow \max \left\{ T_{min},\ T_{max} \left(1 - \frac{d_{AB}}{R_{max}} \right) \right\}$
        rcv_messages.$append$(msg)
    else if state = *INFECTED* **then**
        rcv_messages.$append$(msg)

    on timer *expiry*:
    do_relay $\leftarrow$ $EvaluatePositions$(rcv_messages)
    if do_relay **then**
        msg $\leftarrow$ $updateMsg$(msg)
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    state $\leftarrow$ *RECOVERED*

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        rcv_messages ← empty list
        state ← INFECTED
        timer ← max{T_min, T_max(1 − d_AB / R_max)}
        rcv_messages.append(msg)
    else if state = INFECTED then
        rcv_messages.append(msg)

    on timer expiry:
    do_relay ← EvaluatePositions(rcv_messages)
    if do_relay then
        msg ← updateMsg(msg)
        relayMessage(msg)
    state ← RECOVERED
```

Waiting phase rule: Set timer and keep buffering incoming messages until timer expiry

Packet header

ID	TTL	Emitters
4 Bytes	1 Byte	$(14 \cdot n)$ Bytes

- We call *emitter* a vehicle which has already broadcast a message M
- If, during the waiting phase of vehicle v, the message was sent to v by a set S of vehicles, then geographical coordinates (8 Bytes) and MAC (6 Bytes) addresses of vehicles in S are appended to *emitters* field before the message relay by v
- M's header contains information about a subset vehicles which relayed it previously

Dissemination Algorithm

Procedure to be executed after the waiting phase

```
procedure EvaluatePositions
    input:
    rcv_messages ← list of msgs received during wait

    initialization:
    emitters ← list of GPS coordinates of each emitter in rcv_messages

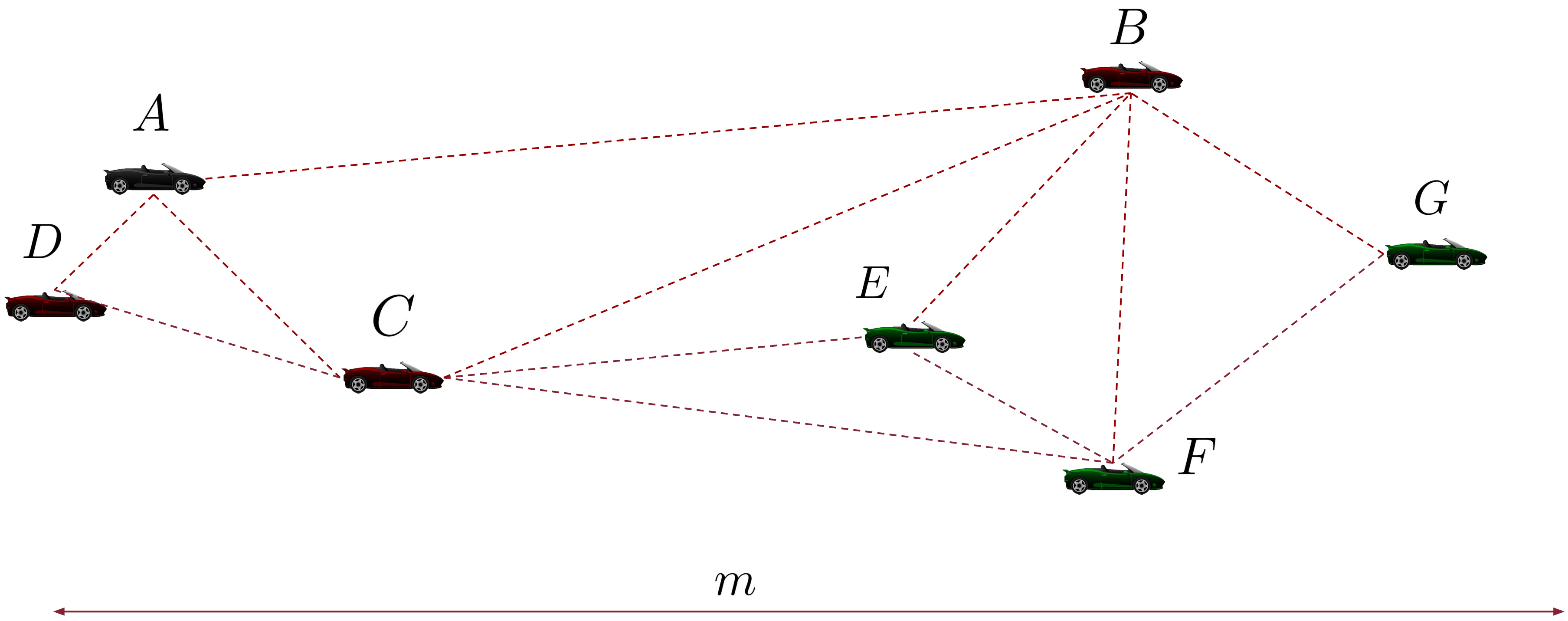
    main:
    for emitter in emitters do
        for coord in neighbors_coord do
            if dist(emitter, coord) < R_min then
                neighbors_coord.remove(coord)
    if neighbors_coord.length > α·neighbors_num then
        return True
    return False
```

We say that a neighbor n is covered by an emitter $e \in emitters$ if

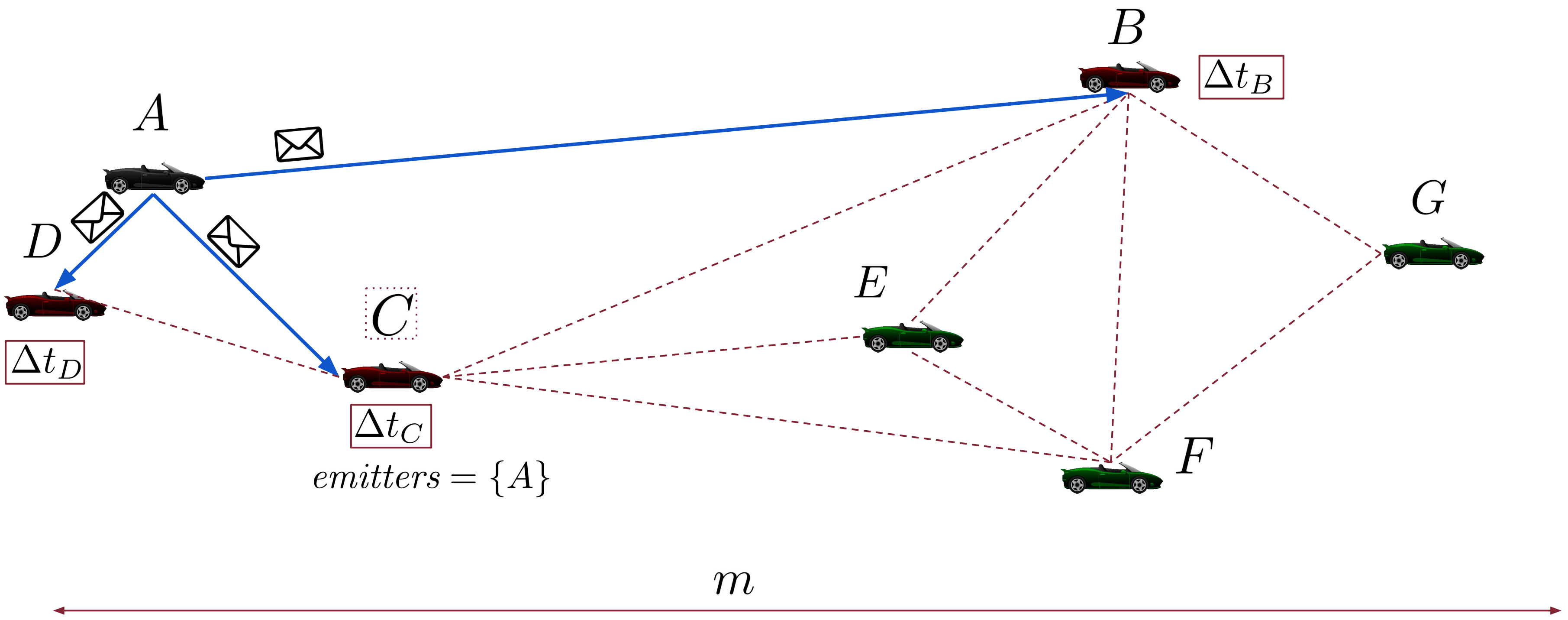
$$\min_{e} dist(n, e) \leq R_{min}$$

Broadcast phase rule: Let N be the number of neighbors and N_r the ones not covered by any emitter. If $\frac{N_r}{N} > \alpha$ relay the message.

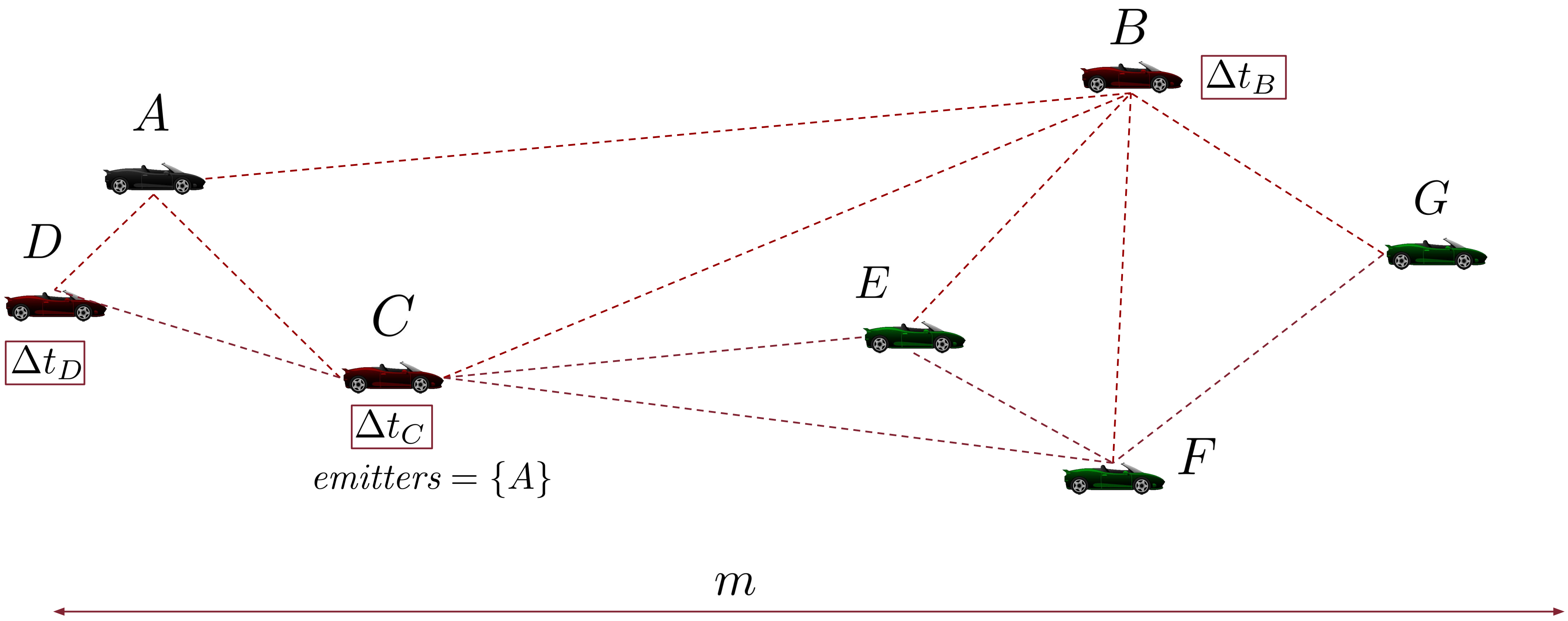
Execution example - 1



Execution example - 1



Execution example - 1



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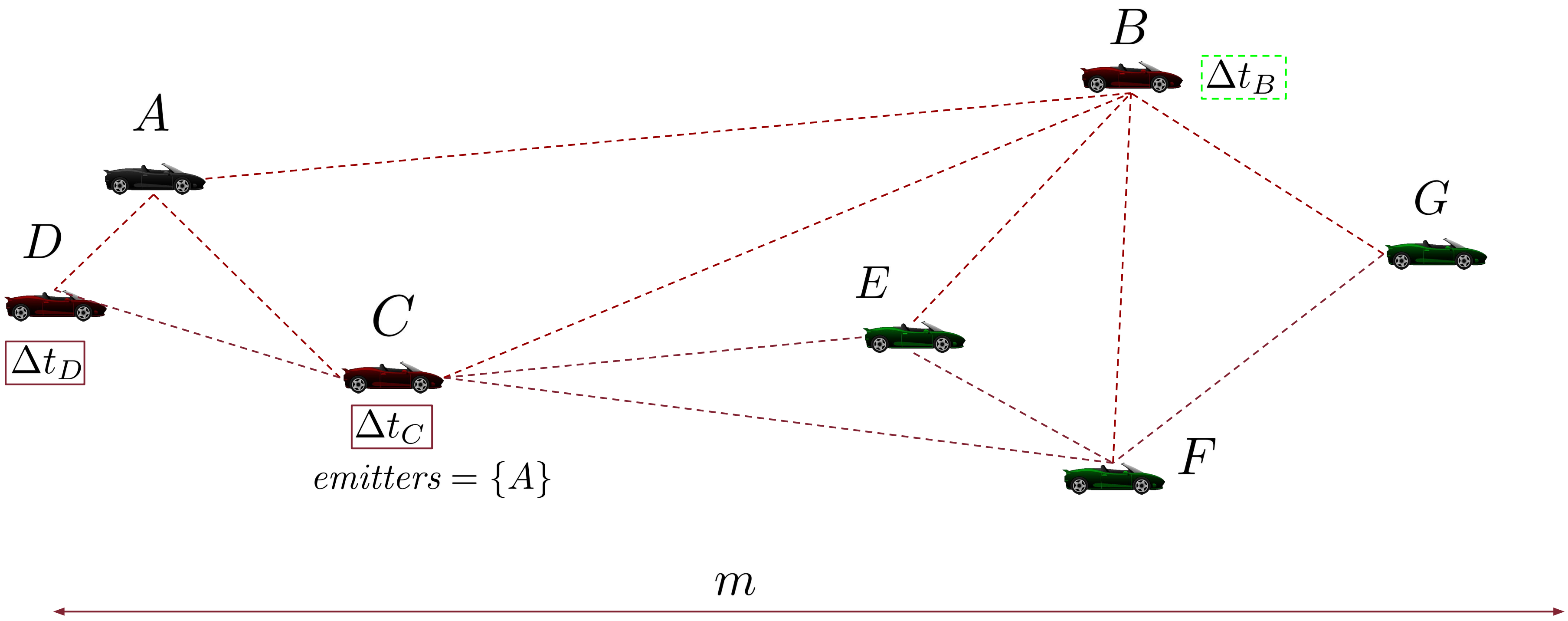

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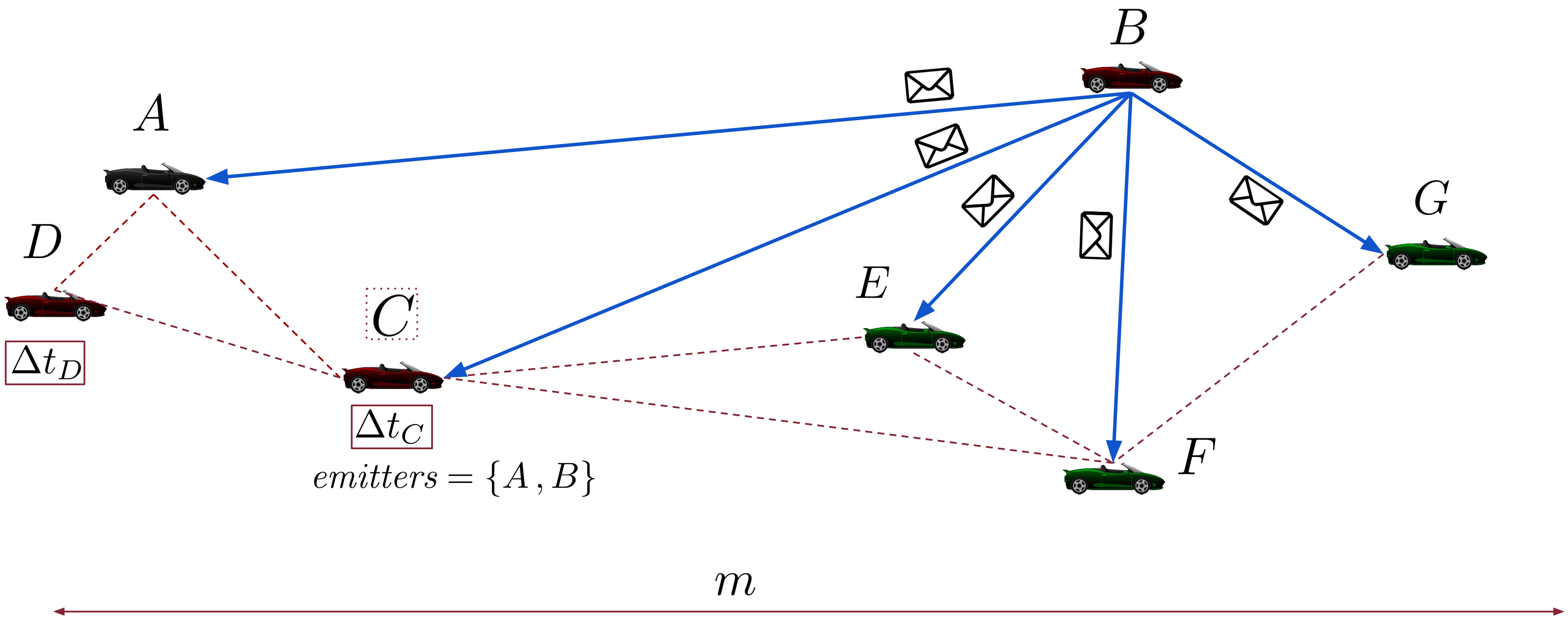

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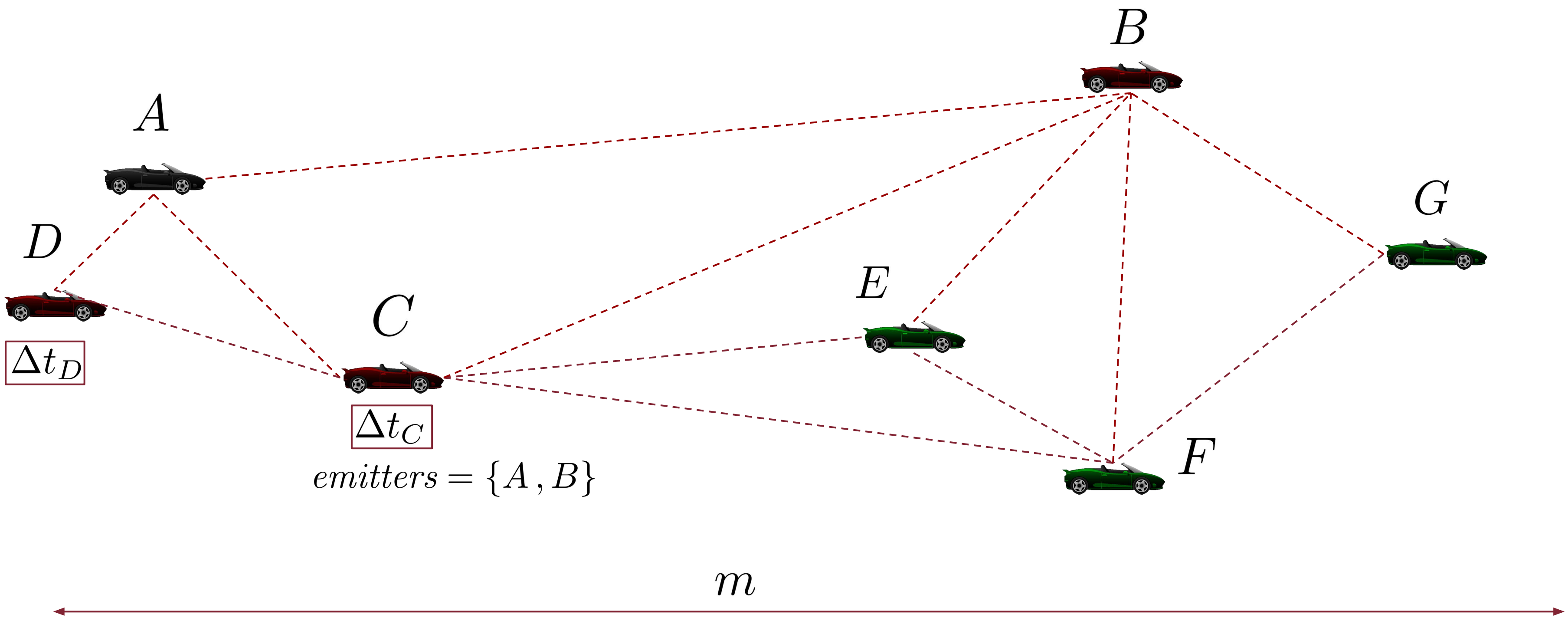

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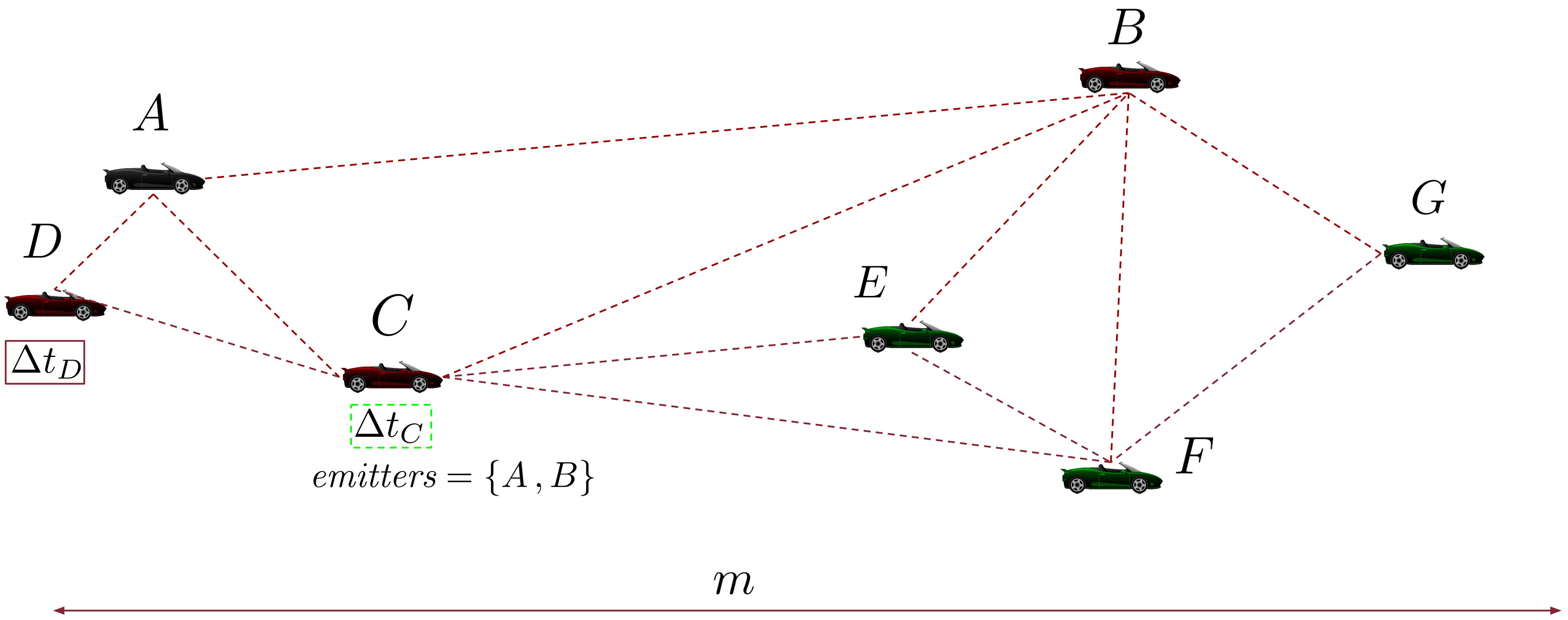

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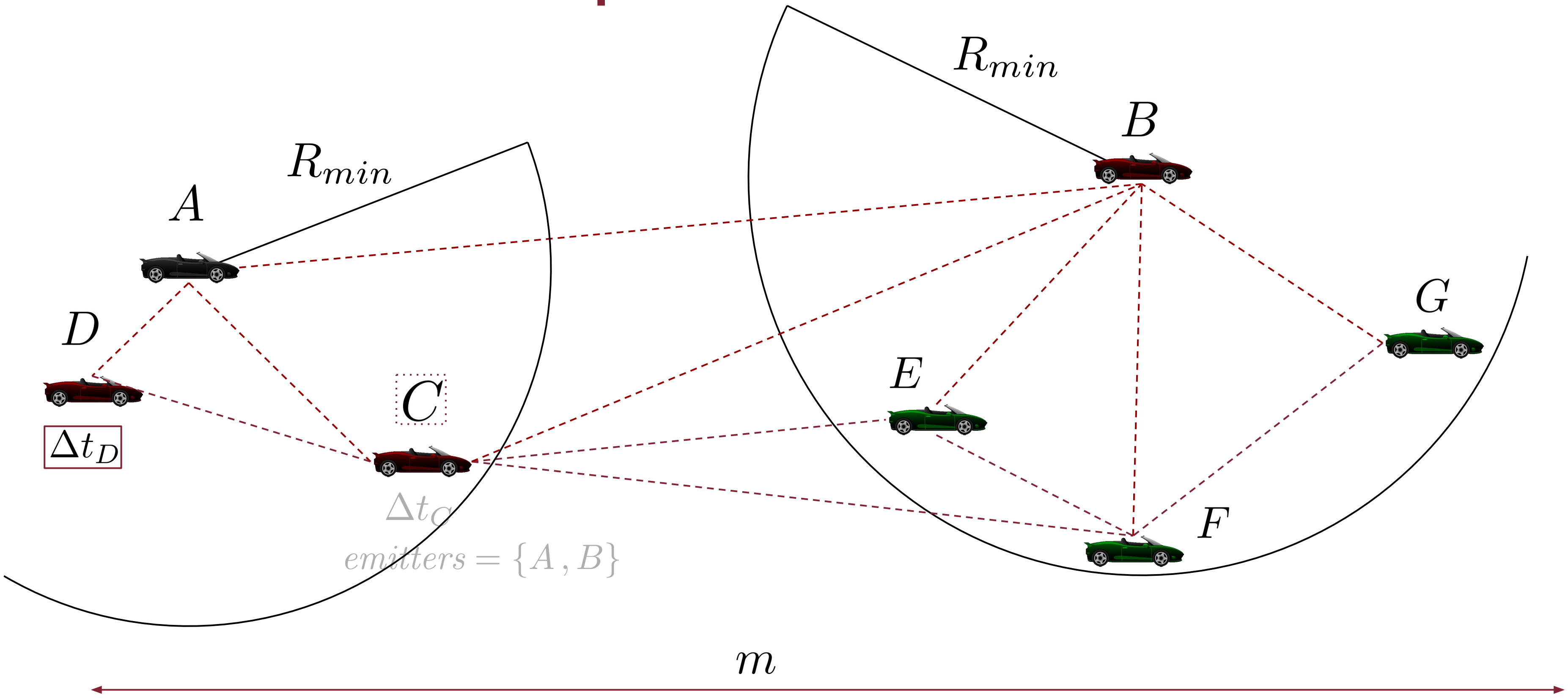

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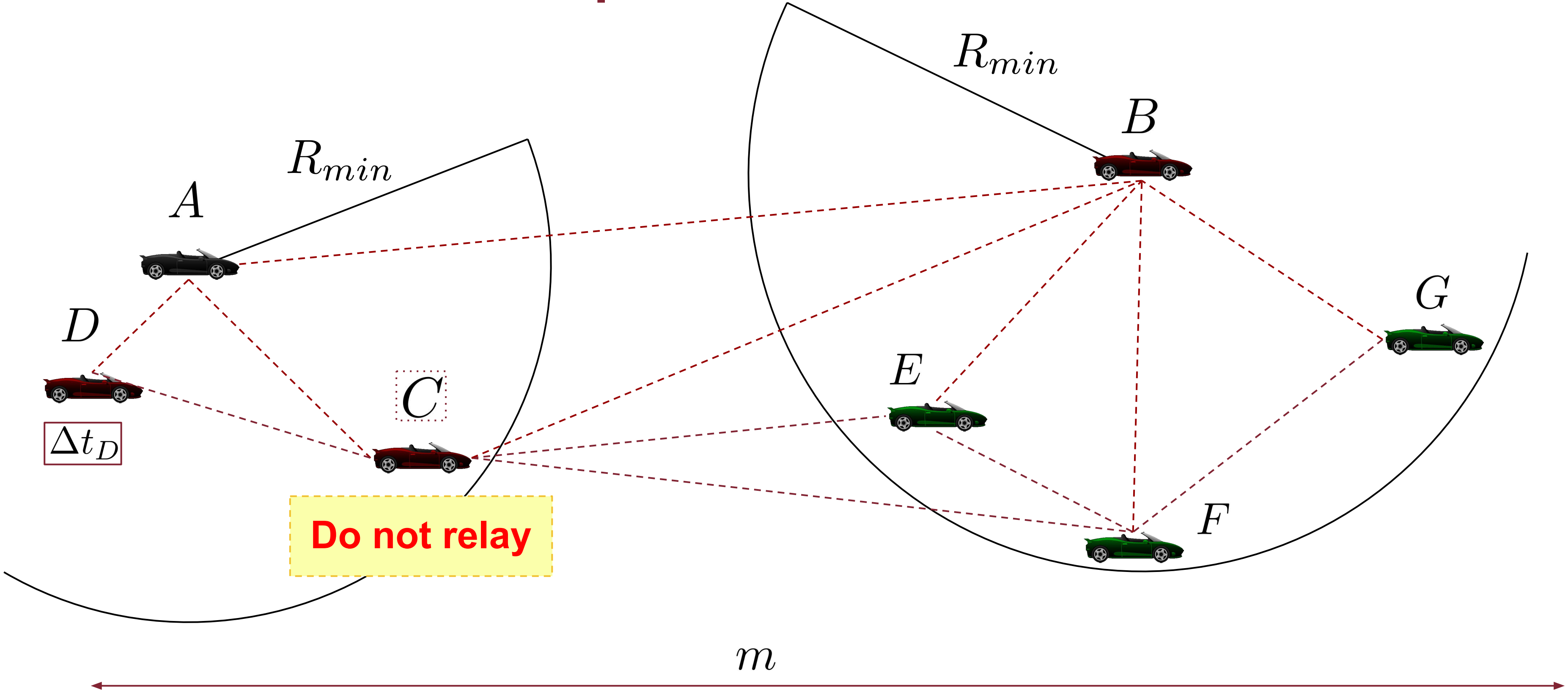
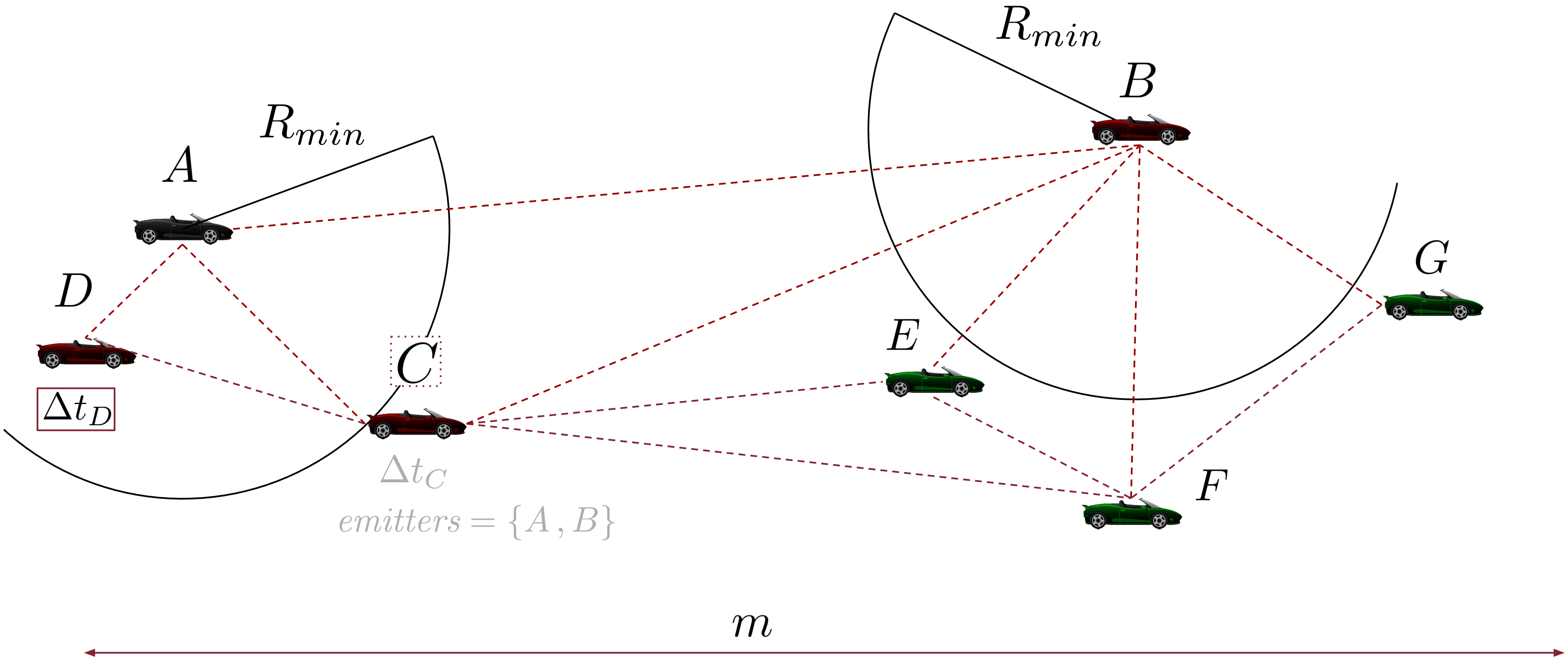
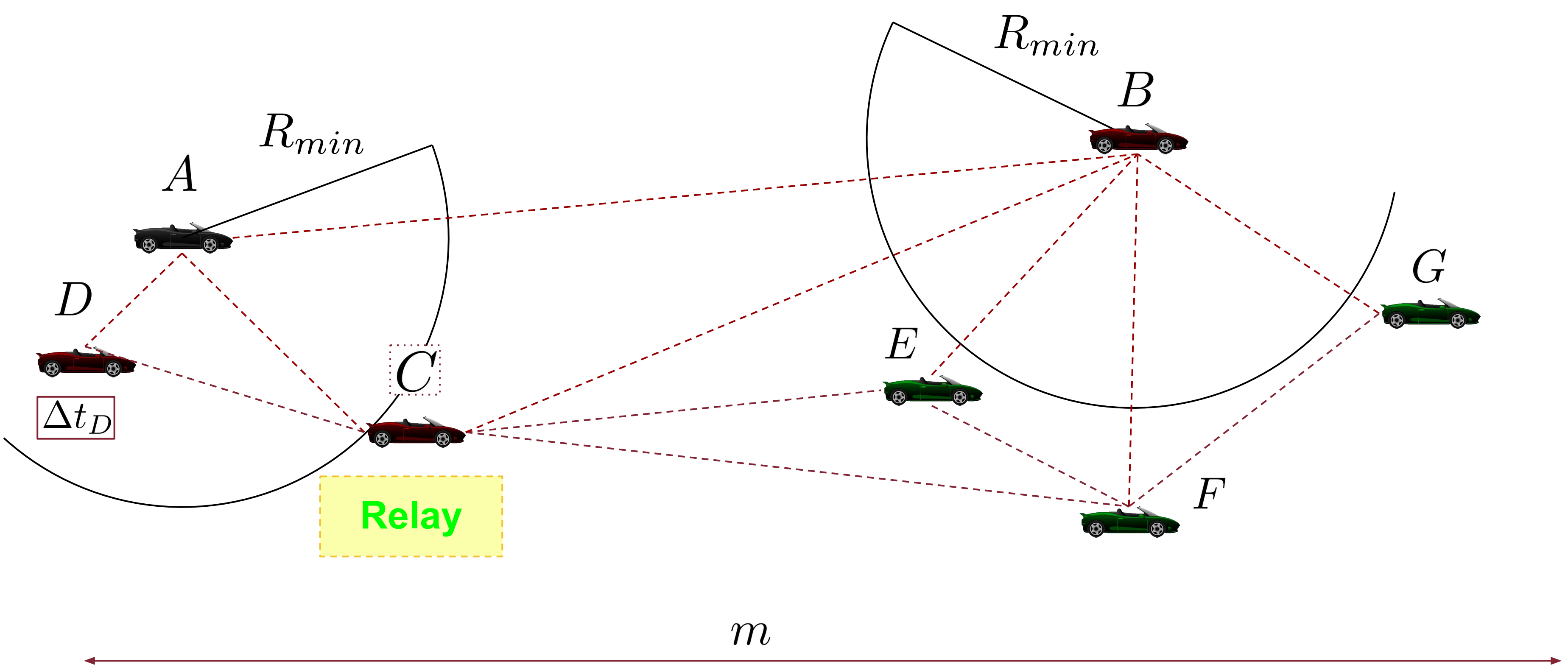


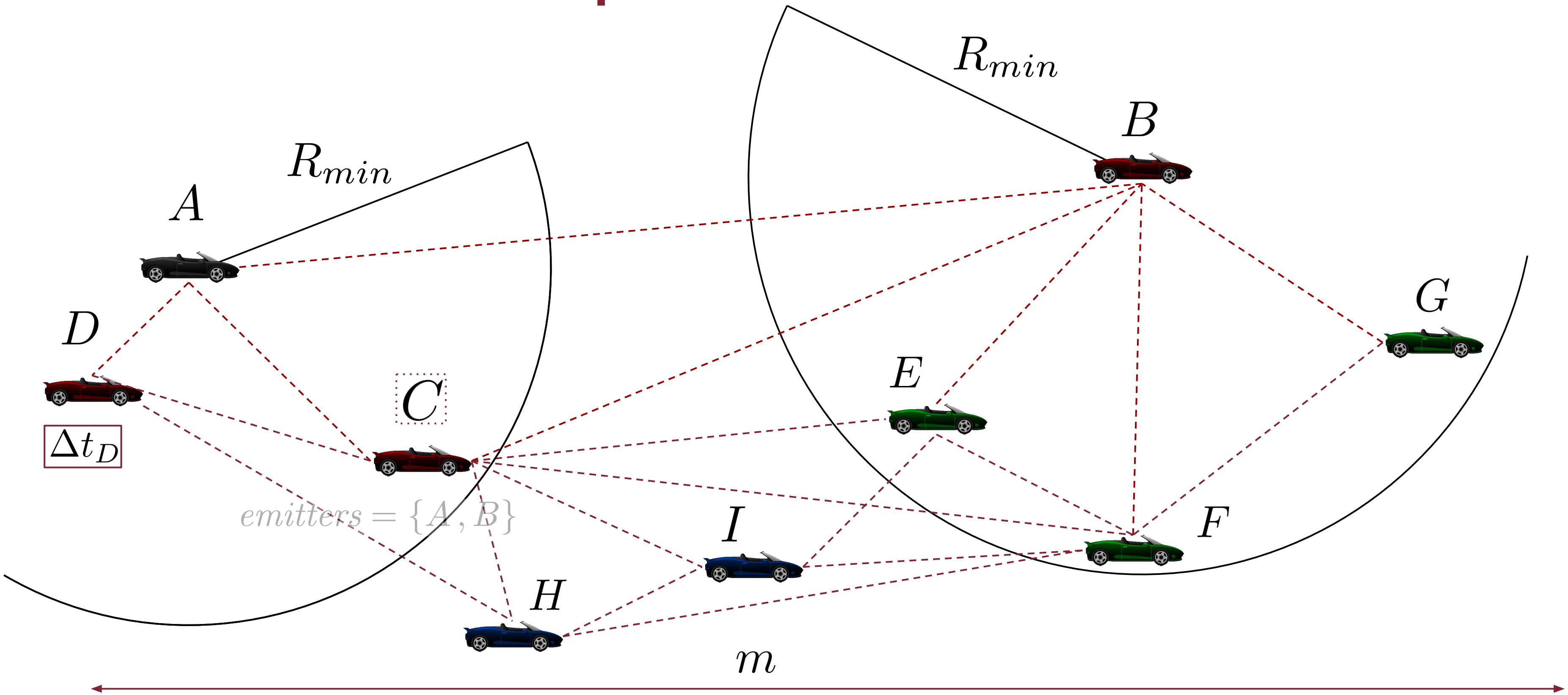
Execution example - 2



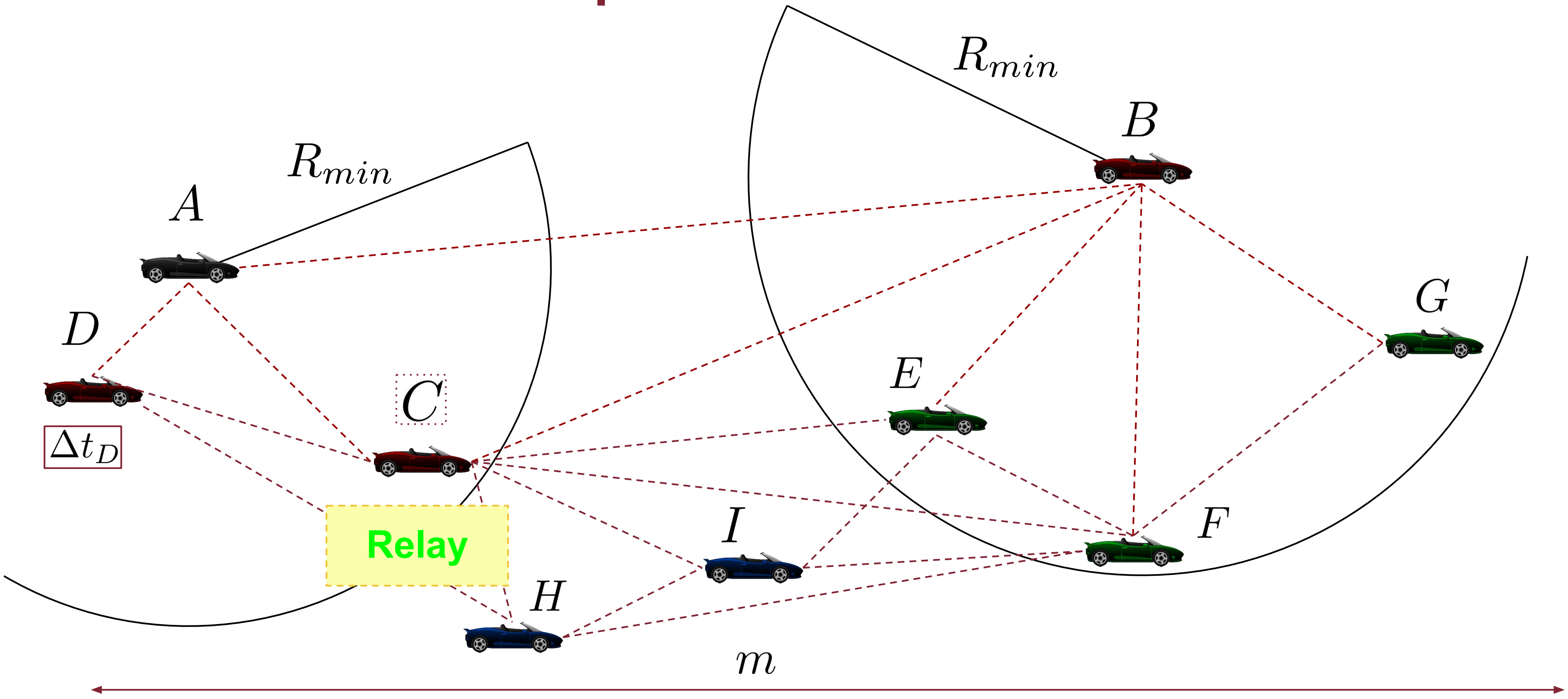
Execution example - 2



Execution example - 3



Execution example - 3



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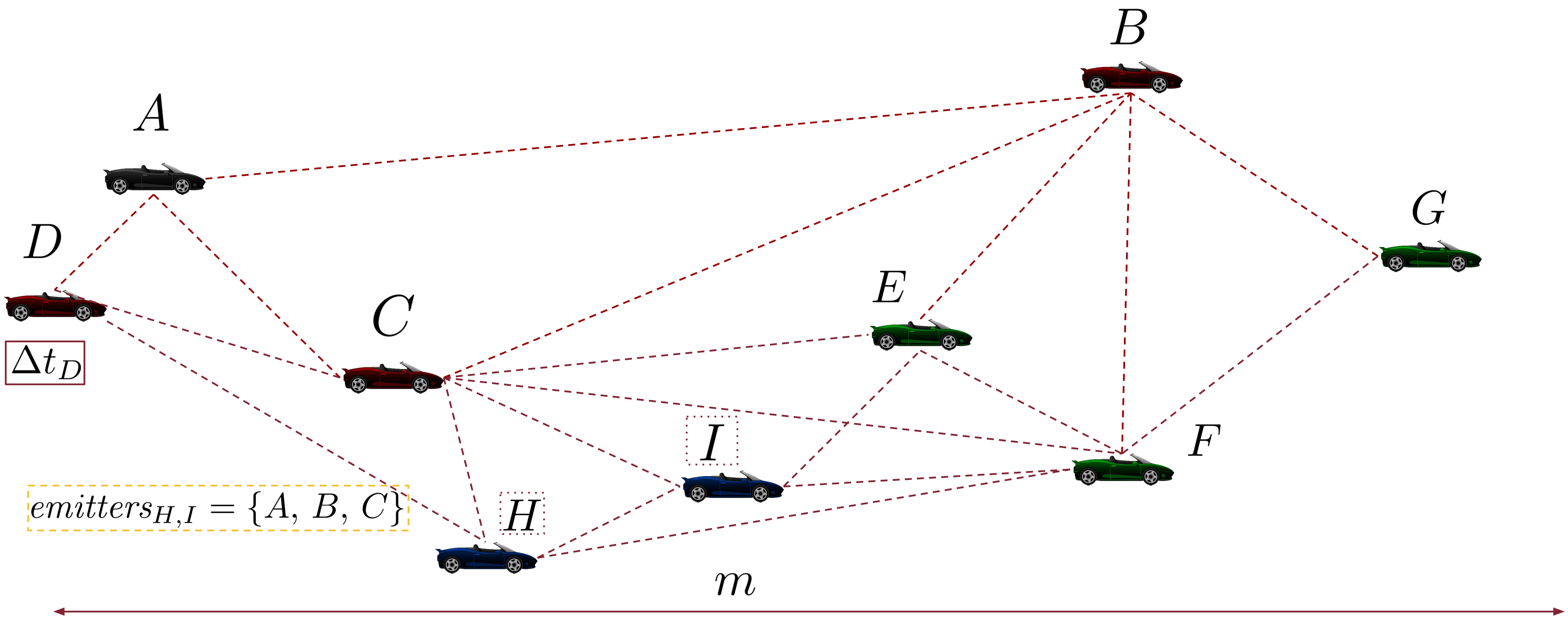

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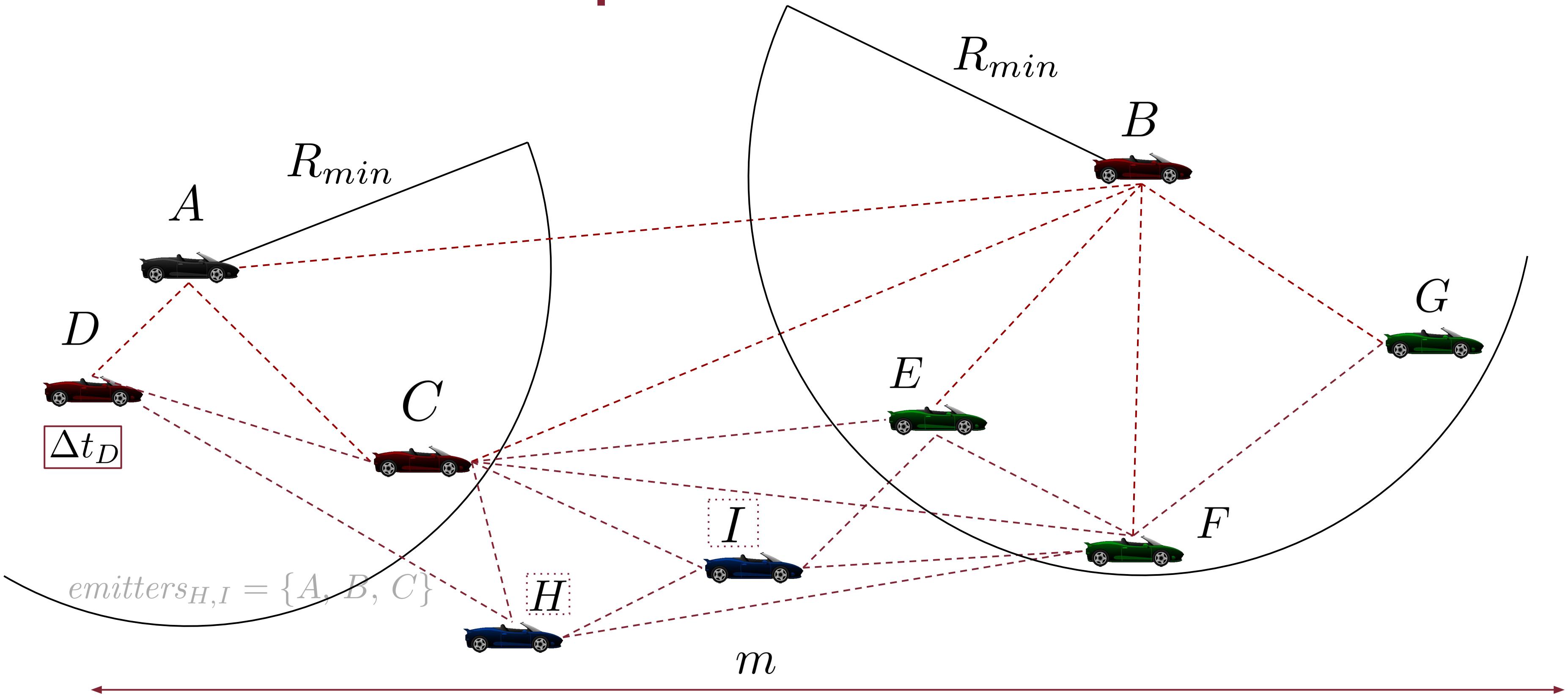

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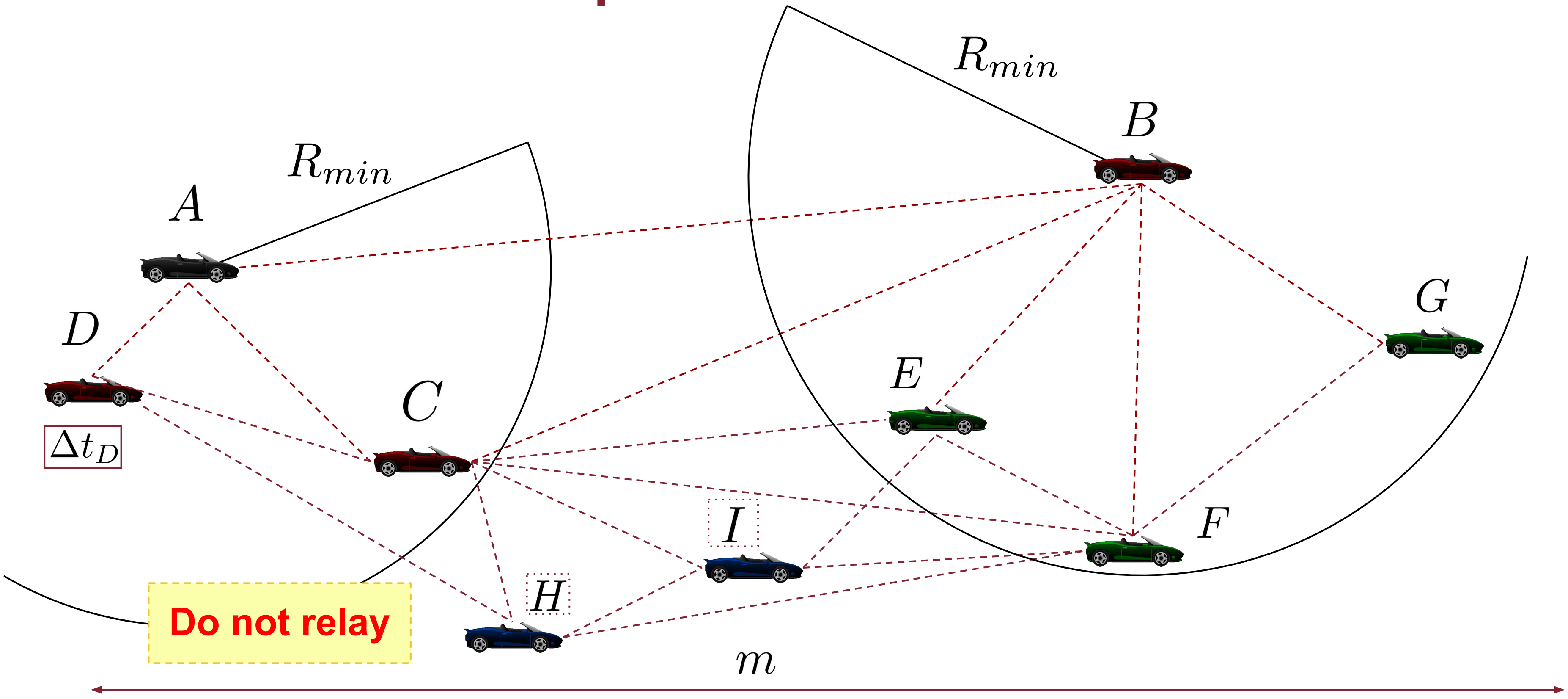
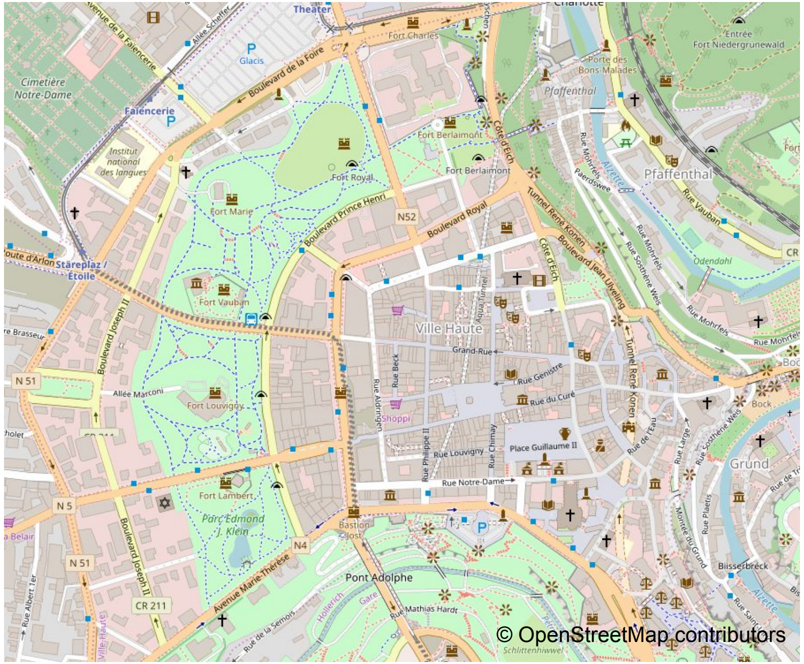


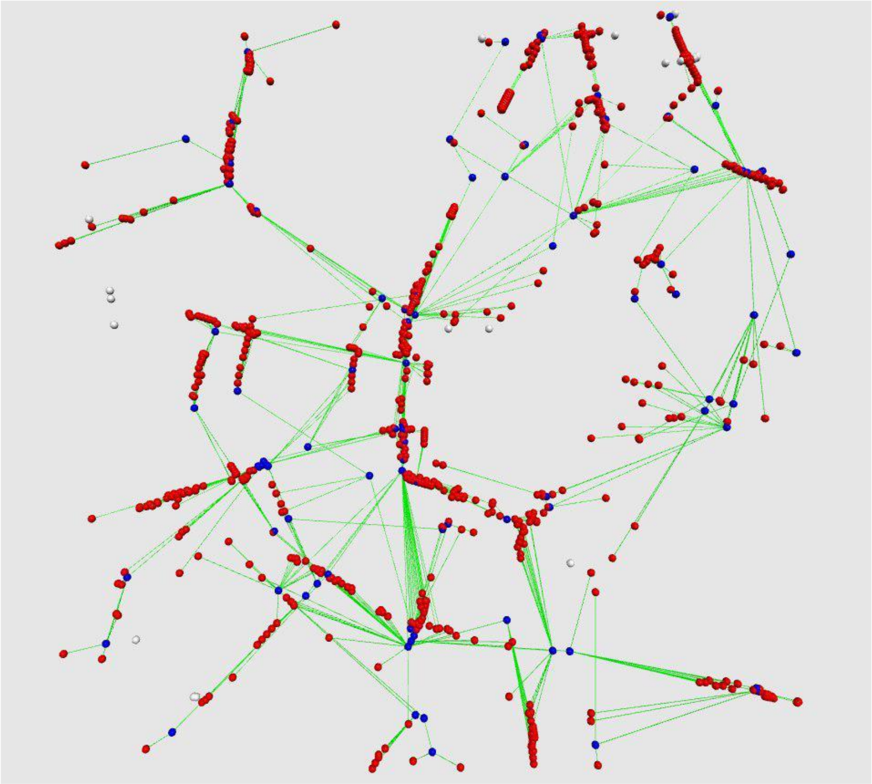
Simulation scenario

Parameter	**Value**
Number of vehicles	790
Road length (km)	28.19
Dissemination area (km^2)	3.9
Avg. vehicle density (veh/km)	28.02
Avg. c δ nectivity degree (veh)	11.6 - 43.8
R_{min} (m)	85 - 170
R_{max} (m)	500
T_{max} (ms)	200
α	0.05
Packet loss	0.01

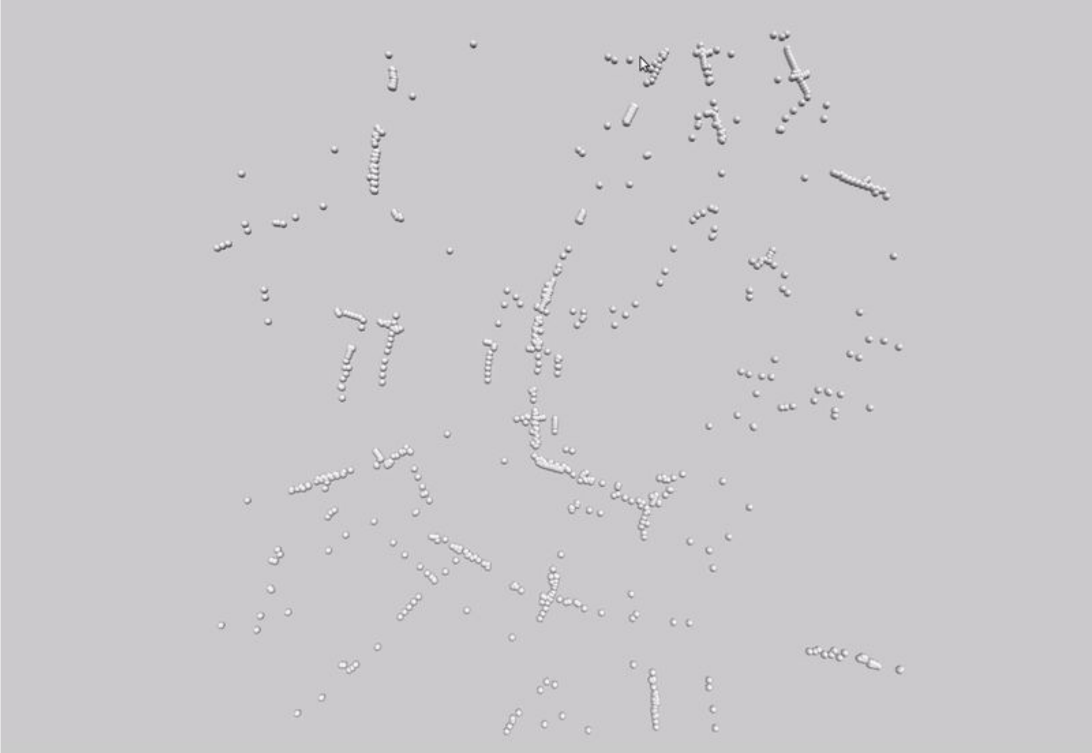


Luxembourg

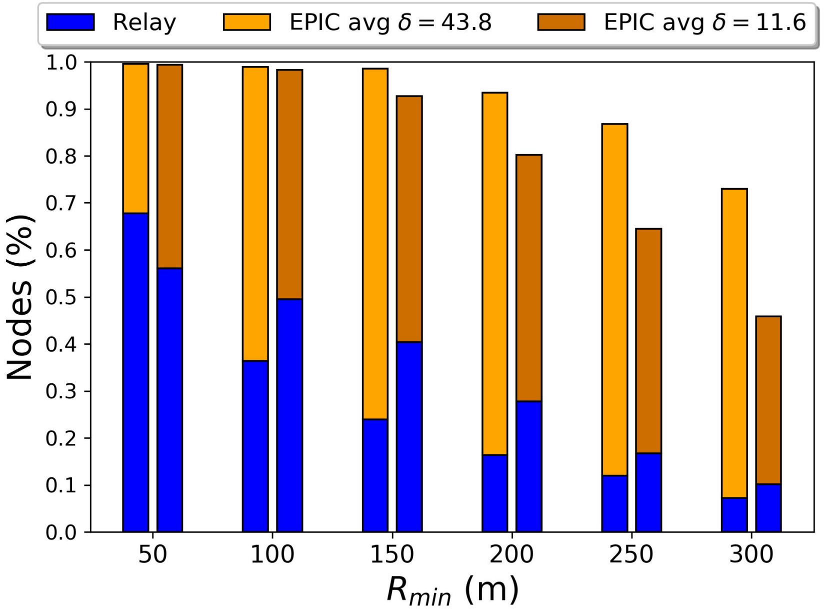
Simulation scenario

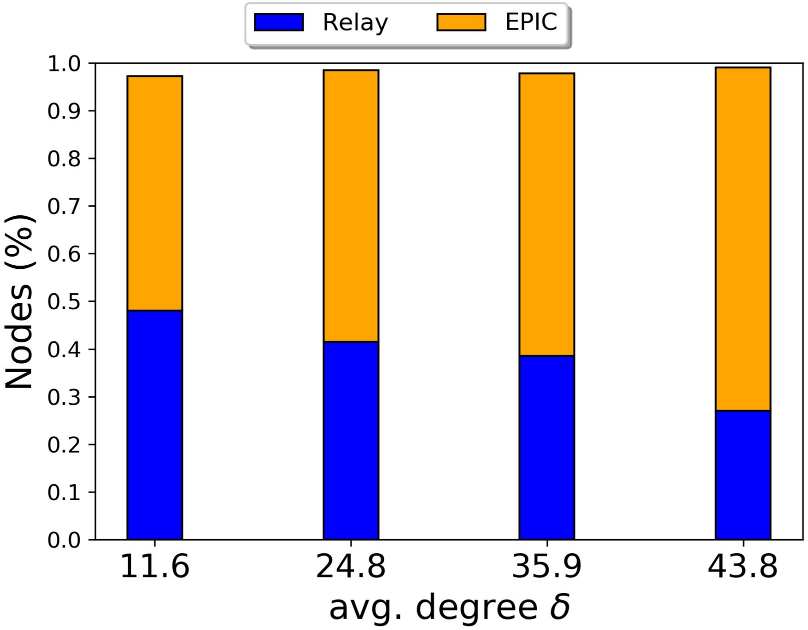


Simulation scenario

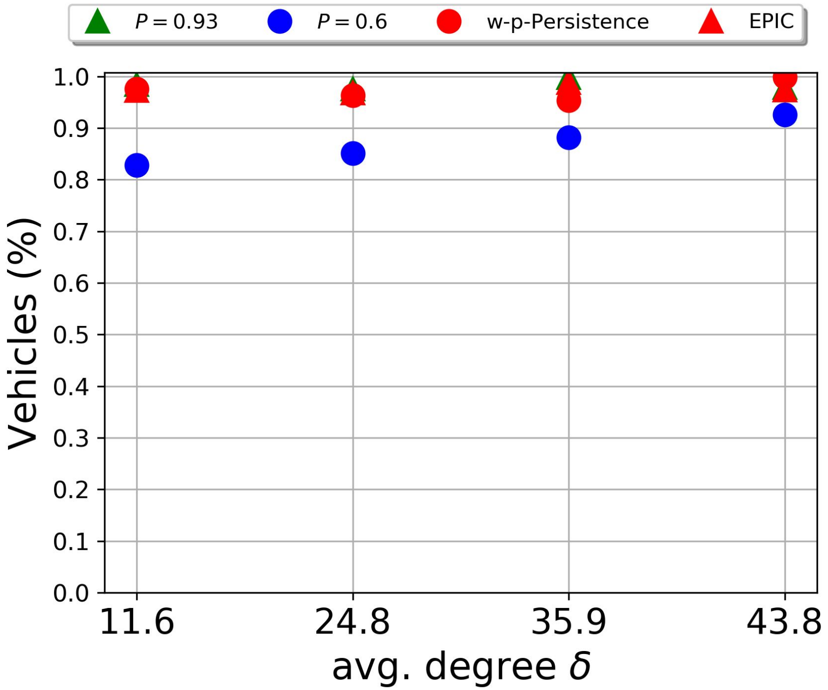


Reached and Relay Vehicles

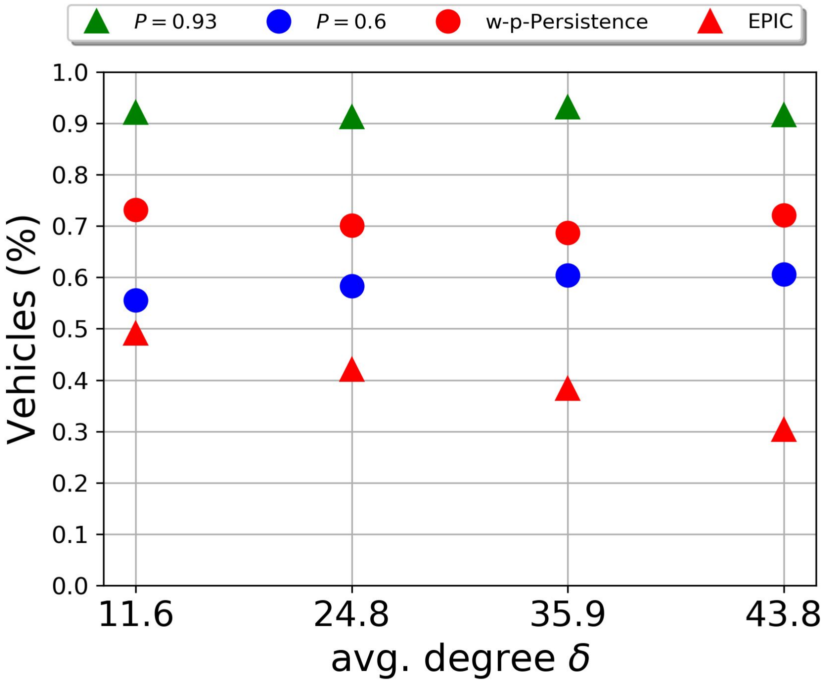




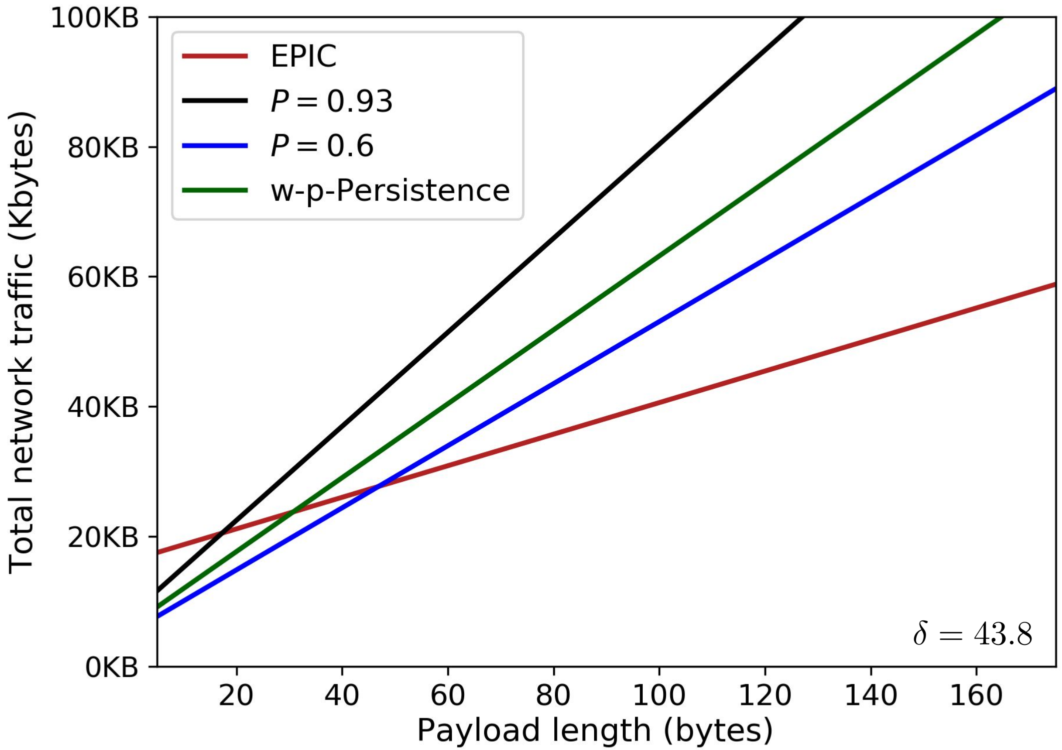
Reached Vehicles



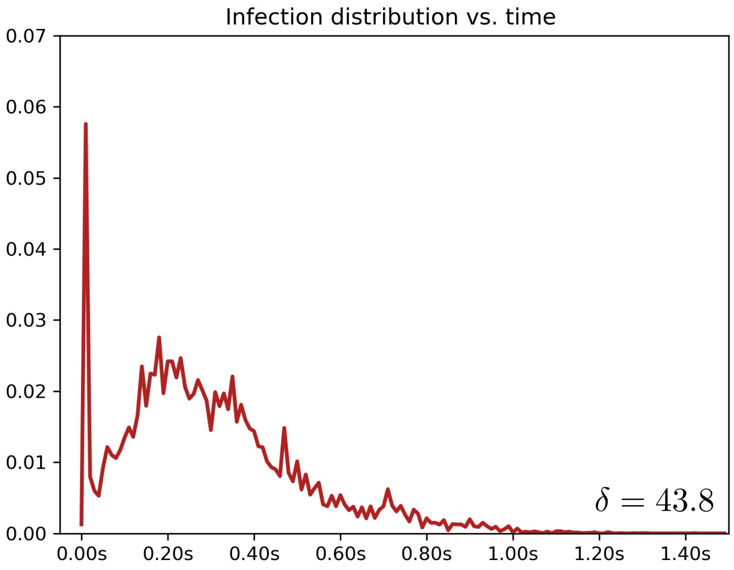
Relay Vehicles



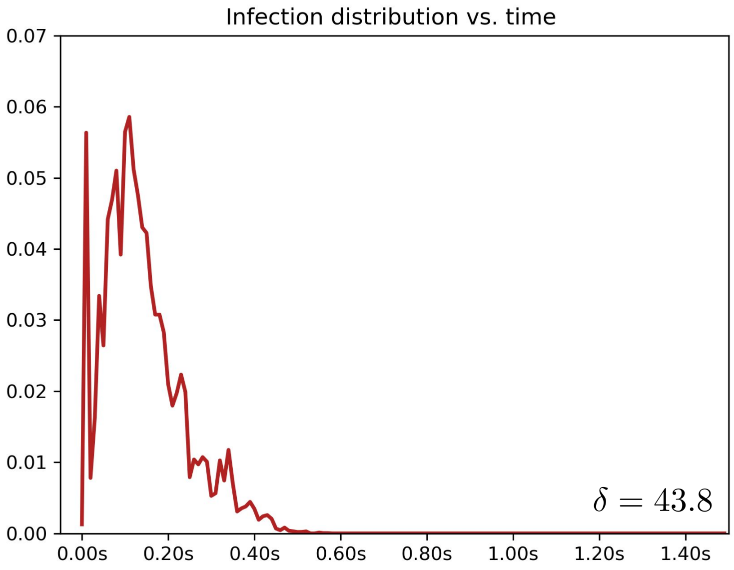
Network Traffic



Receivers distribution over time



T_{max} = 300ms



T_{max} = 150ms

Conclusions

- We designed a new protocol for VANETs, named EPIC, which disseminates messages on the basis of an epidemic approach
- We analyzed the down-stream dissemination by evaluating performance metrics like the fraction of reached vehicles, the fraction of relay nodes and the overhead needed for the correct behavior of the protocol
- We provided the simulation of the protocol execution in real urban scenarios, where obstacles are considered for the radio propagation

References

- [1] Deepak Ganesan et al. *An Empirical Study of Epidemic Algorithms in Large Scale Multihop Wireless Networks.*
- [2] M. E. J. Newman, *Networks an introduction,* chapter 17.
- [3] M. Nekovee. *Epidemic Algorithms for Reliable and Efficient Information Dissemination in Vehicular ad-hoc Networks*. Intelligent Transport Systems, IET, 3:104 – 110, 07 2009.
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- [6] N. Wisitpongphan and et al. *Broadcast storm mitigation techniques in vehicular ad hoc networks*. Wireless Communications, IEEE, 14(6), 2007.
- [8] EpicTeam, EPIC resources: simulator, data and everything else, https://github.com/Ebloin/Epidemic_VANET, 2019