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Vorlesung Kommunikationsnetze

Research Topics: QoS in VANETs

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Institut für Organisation und Management von Informationssystemen

Content - QoS in Vehicular Ad Hoc Networks

- Basics (Mobile Wireless) Ad Hoc Networks
  - Terminology: Ad Hoc, MANET, VANET, Mesh, WSN
  - Mobile Wireless Ad Hoc Network characteristics
  - Hidden Terminal Problem

- Research motivation: Background Applications

- VANETs are „Broadcast“-Networks (VANET characteristics)

- QoS medium access mechanism

- QoS Resource Allocation

Basics - Terminology - Ad Hoc

– ***Ad Hoc*** is a latin phrase which means „for this purpose“

- A general solution designed for a specific task
  – non-generalizable
  – non-adaptable for other purposes

– ***Ad Hoc Network***

- Communication between network nodes can be set up using direct links between the nodes
  ⟶ There are no other active components to set up the communication
  ⟶ Nodes have to take care of the functionality of these components

- Nodes can setup, join or leave the network at any time
  ⟶ Protocols and mechanisms have to be designed to allow this

Basics - Terminology II

- ***MANET*** - Mobile Ad Hoc Network
- ***VANET*** - Vehicular Ad Hoc Network
- ***WSN*** - Wireless Sensor Network
- **MESH** - (Fully) meshed network

Basics - Mobile Wireless Ad Hoc Networks

- Direct communication between mobile nodes using a wireless link
  - Data is exchanged between the nodes directly
  - In opposite „infrastructure network“: Nodes communicate via their base-station only

- Mobility of nodes - dynamic topology
  - Links between the nodes appear and disappear at any time
  - Involved protocols have to adapt

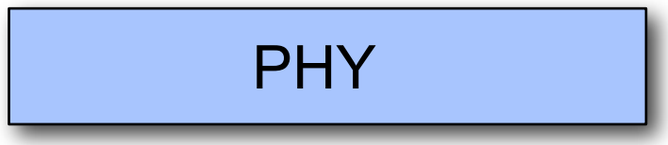
Basics - Mobile Wireless Ad Hoc Networks

What functionality is needed ? What has to be provided by the nodes ?

Basics - Mobile Wireless Ad Hoc Networks

What functionality is needed ? What has to be provided by the nodes ?

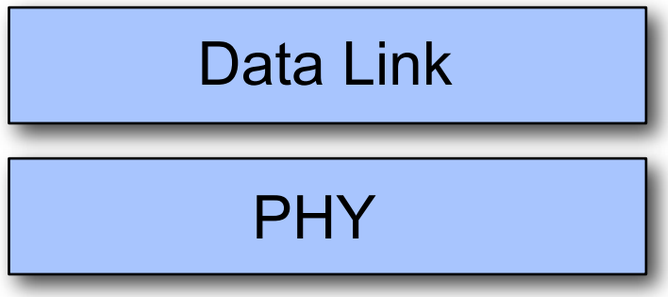
– Layer 1 - Wireless communication for stream of Bits
no Ad Hoc properties needed



Basics - Mobile Wireless Ad Hoc Networks

What functionality is needed ? What has to be provided by the nodes ?

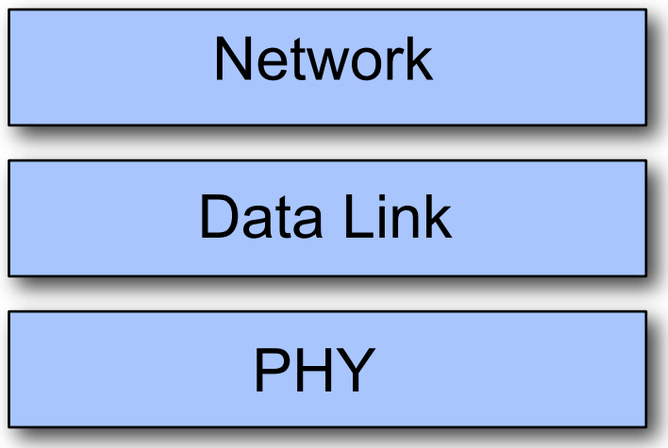
- Layer 2 - Ad Hoc MAC protocol
- Layer 1 - Wireless communication for stream of Bits
  no Ad Hoc properties needed



Basics - Mobile Wireless Ad Hoc Networks

What functionality is needed ? What has to be provided by the nodes ?

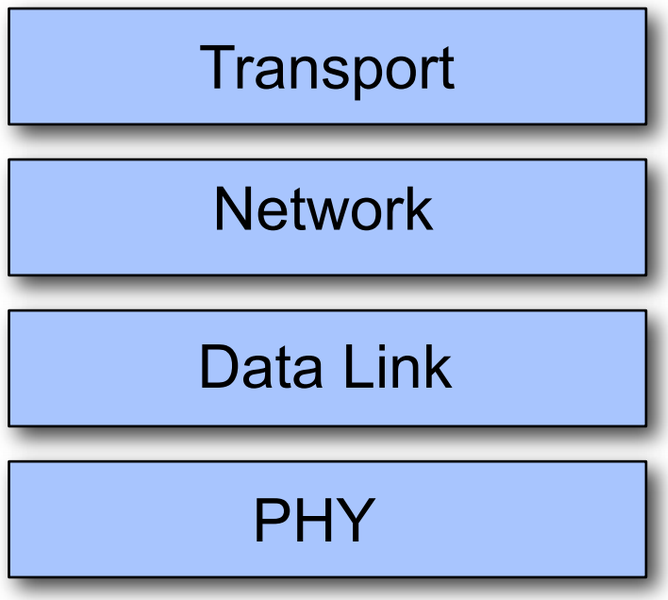
- Layer 3 - Ad Hoc Routing protocol
- Layer 2 - Ad Hoc MAC protocol
- Layer 1 - Wireless communication for stream of Bits
  no Ad Hoc properties needed



Basics - Mobile Wireless Ad Hoc Networks

What functionality is needed ? What has to be provided by the nodes ?

- Layer 4 - End to End communication
  Ad Hoc only for certain circumstances
- Layer 3 - Ad Hoc Routing protocol
- Layer 2 - Ad Hoc MAC protocol
- Layer 1 - Wireless communication for stream of Bits
  no Ad Hoc properties needed



Basics - Mobile Wireless Ad Hoc Networks

What functionality is needed ? What has to be provided by the nodes ?

- Layer 5 - Sessions overcome changes in underlying layers
- Layer 4 - End to End communication
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- Layer 3 - Ad Hoc Routing protocol
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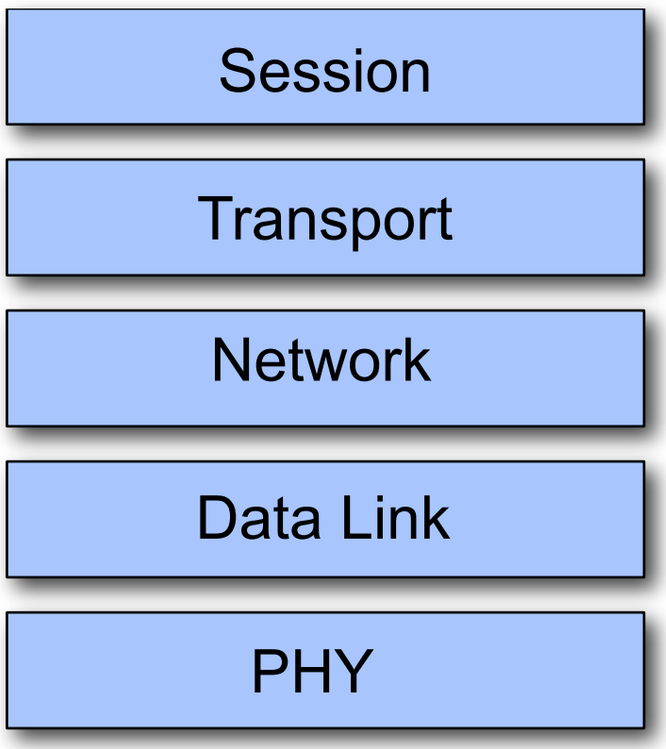

Basics - Mobile Wireless Ad Hoc Networks

What functionality is needed ? What has to be provided by the nodes ?

- Layer 6 & 7 - Application/Host specific
- Layer 5 - Sessions overcome changes in underlying layers
- Layer 4 - End to End communication
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- Layer 3 - Ad Hoc Routing protocol
- Layer 2 - Ad Hoc MAC protocol
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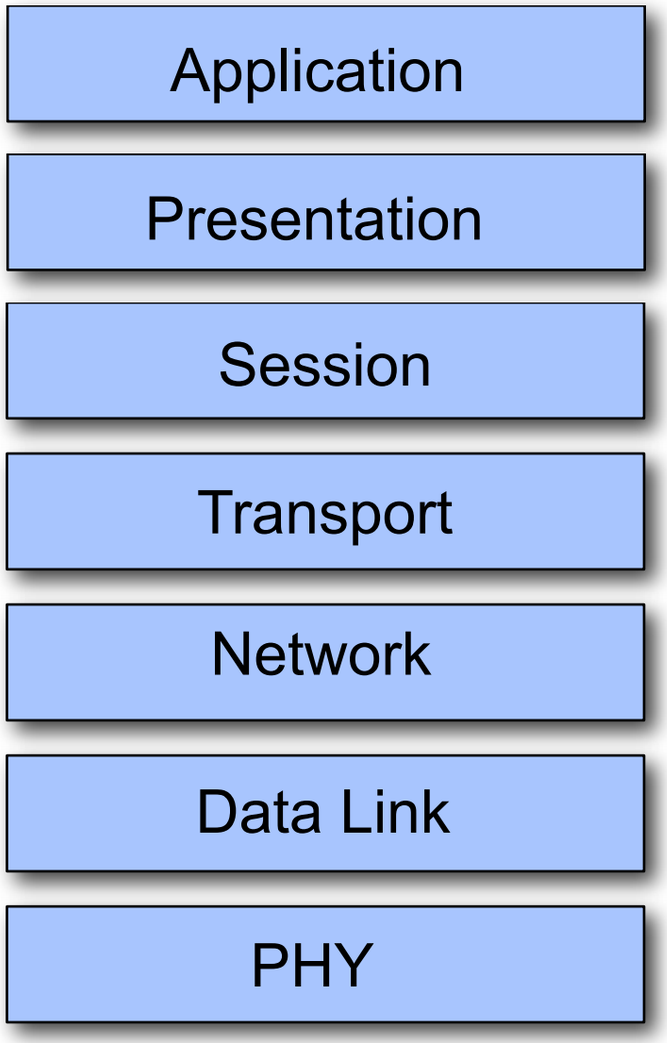
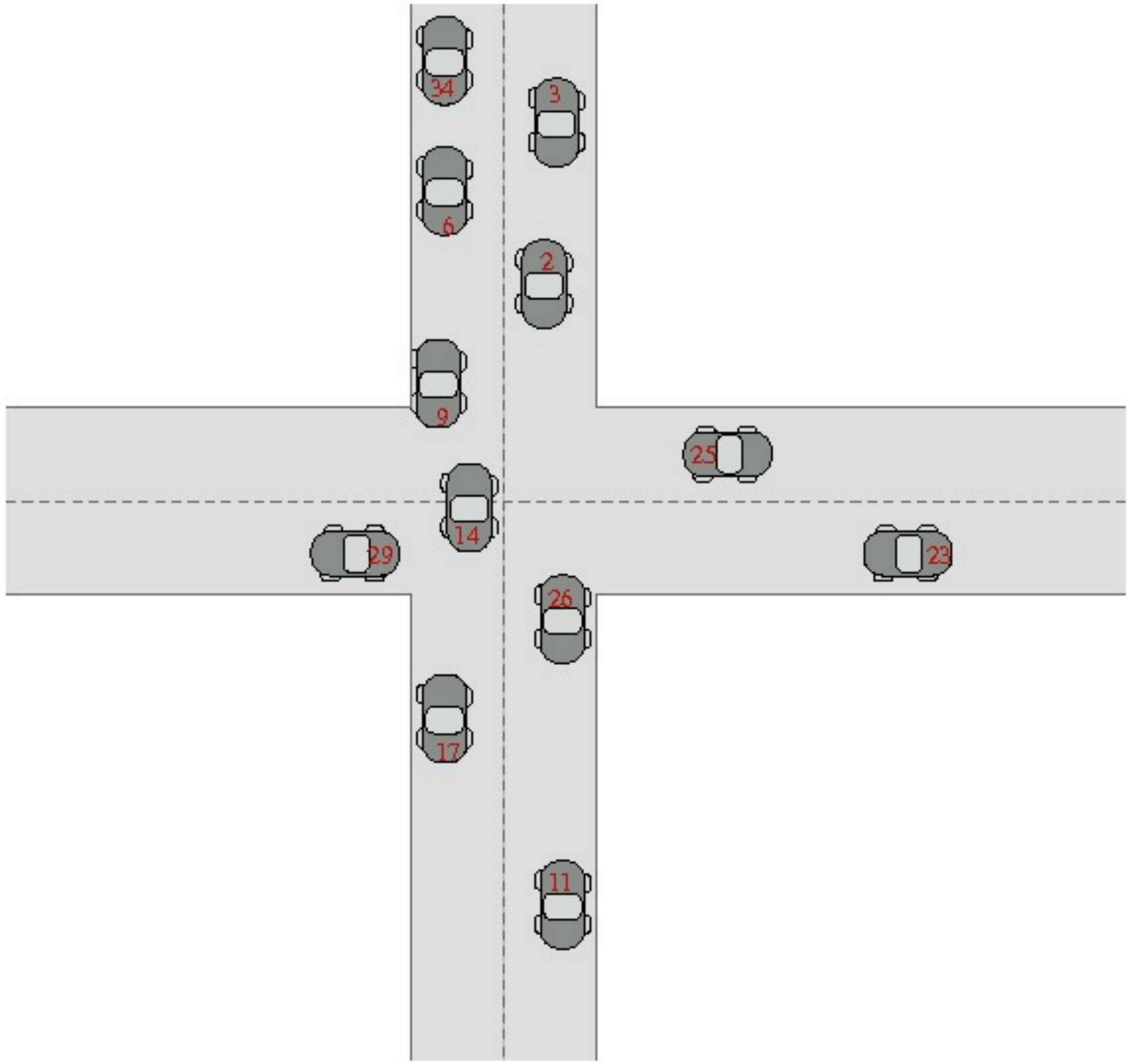


Basics - Hidden Terminal Problem



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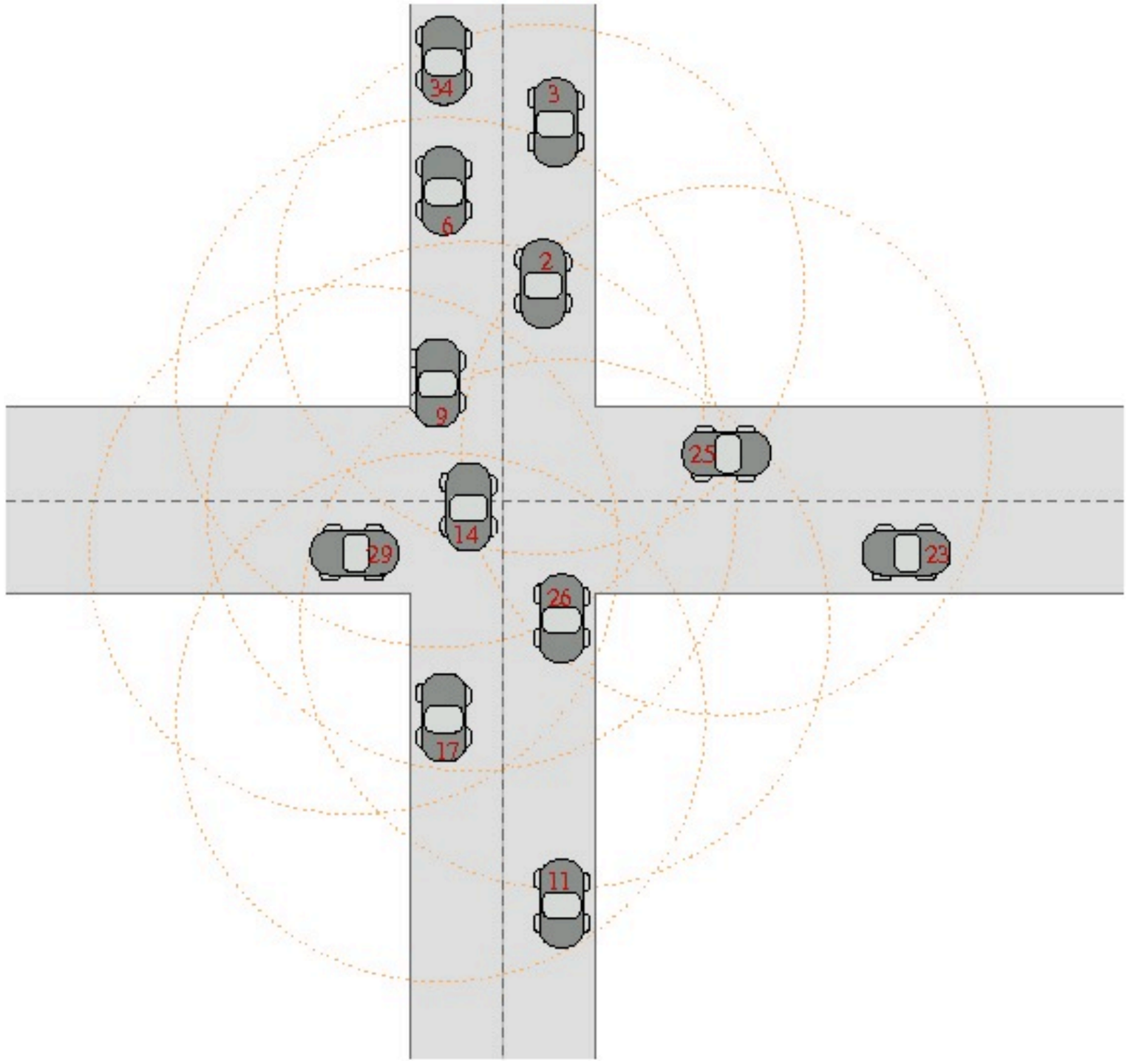

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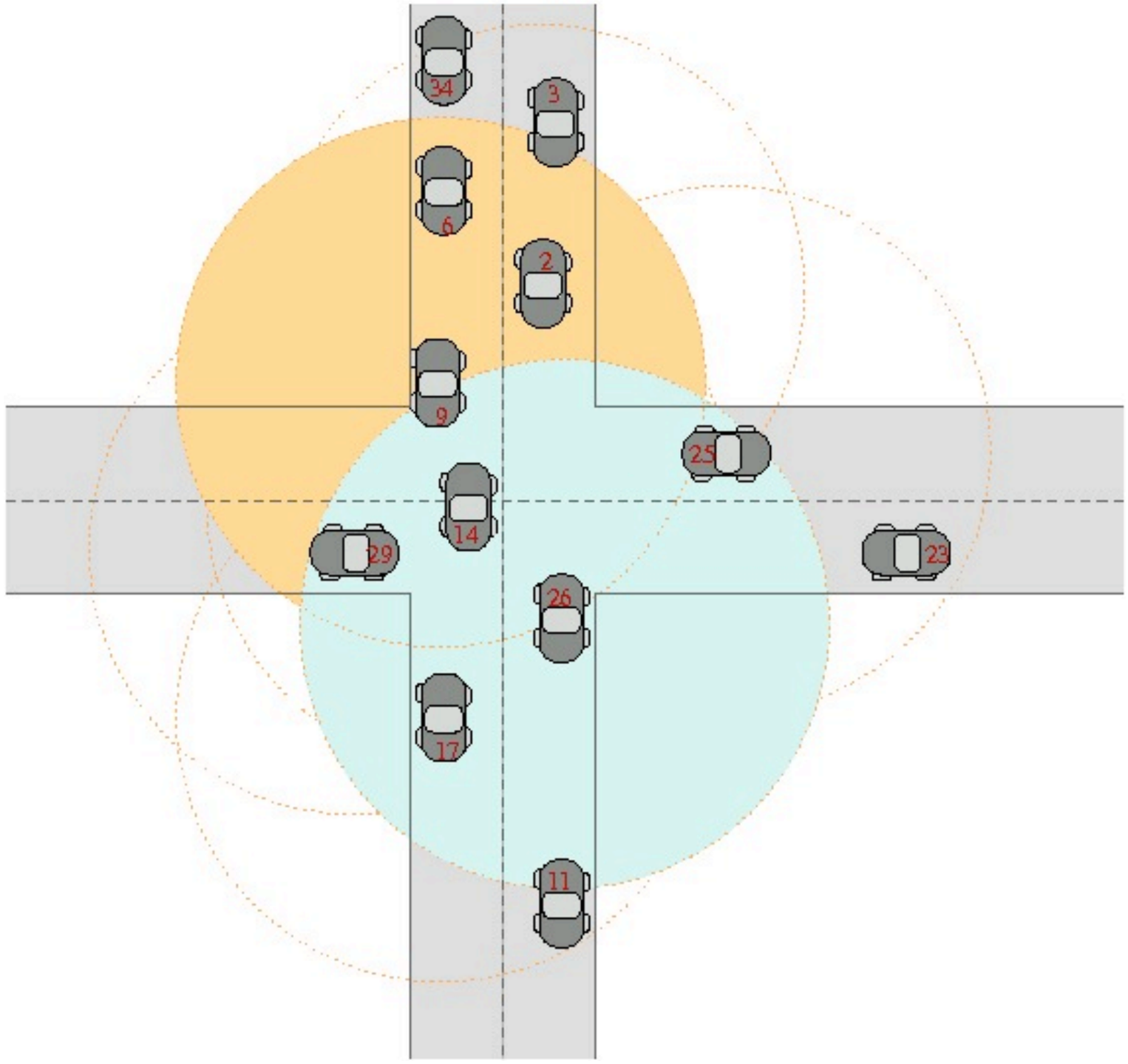

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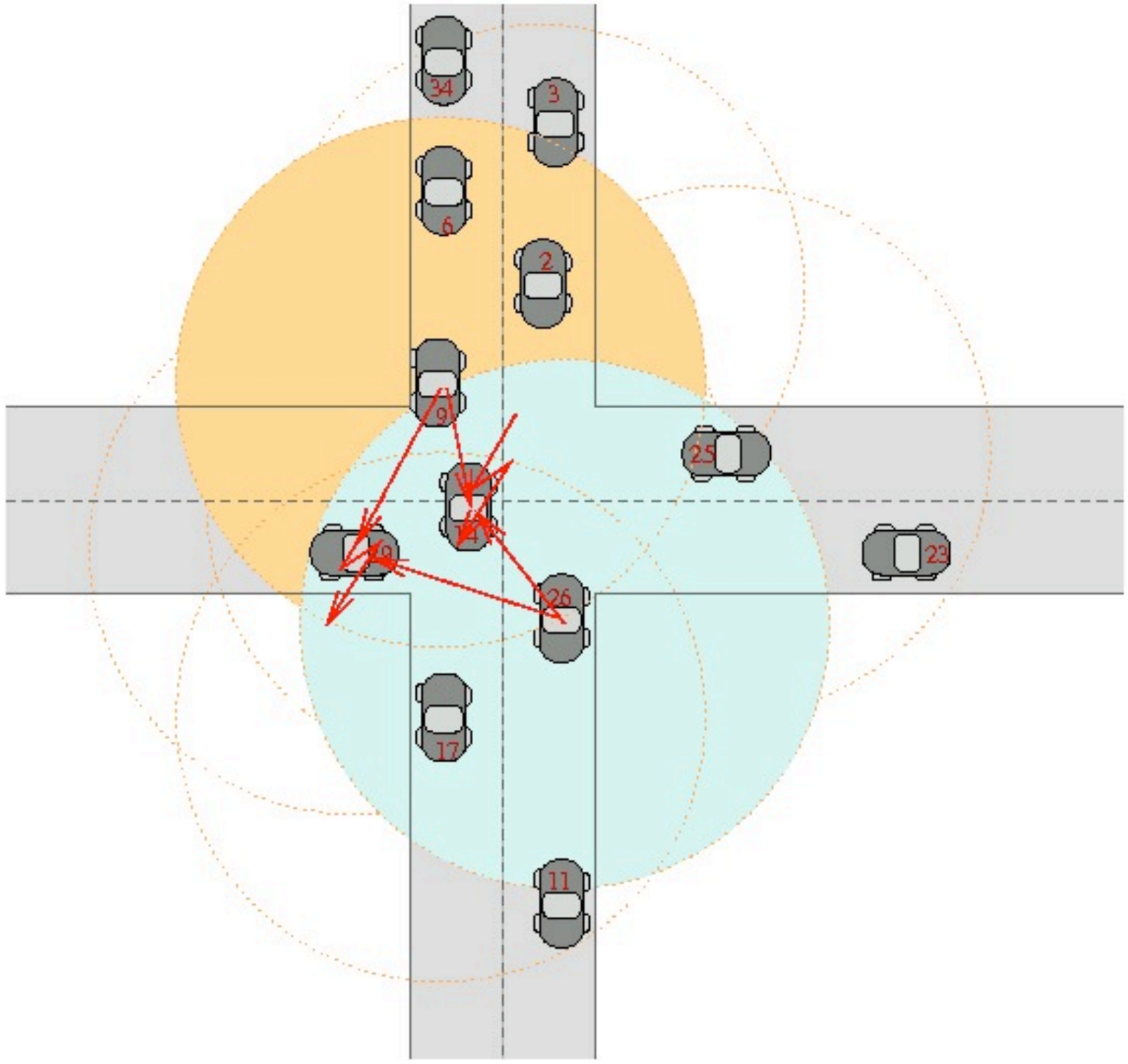
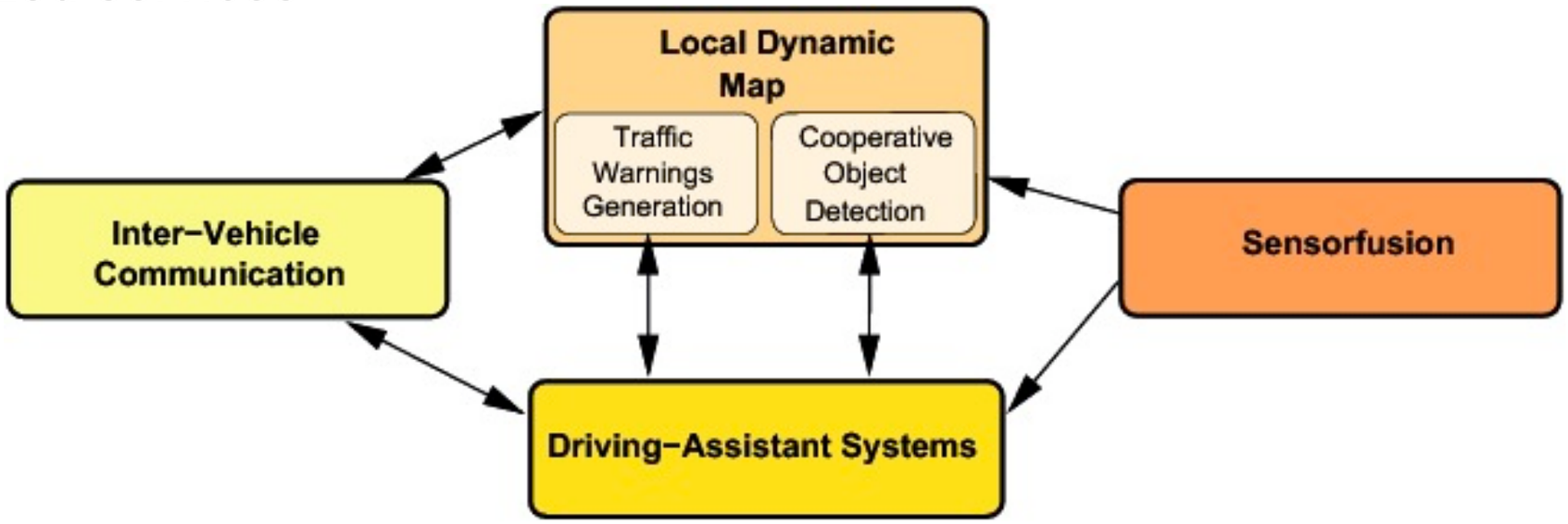


VANET - Background / Target application

Distribution of environmental data via a vehicular ad hoc network (VANET)

- Driving assistant systems
- Safety systems
- Decentralized services



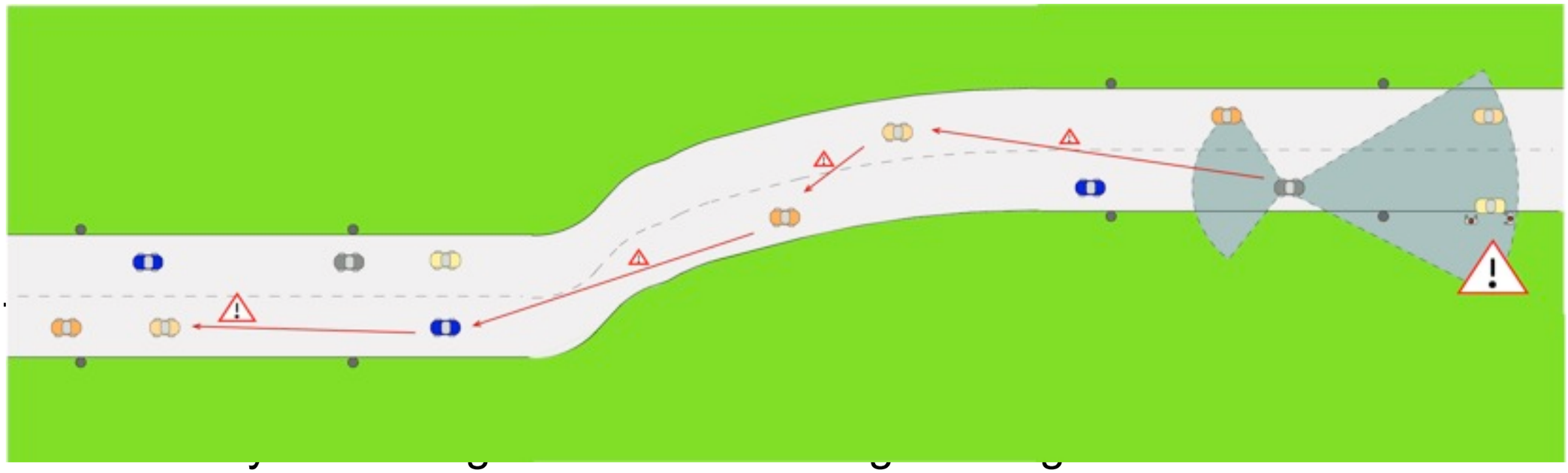
Focus application: Driving assistant systems

- Data collected by sensors
- Distribution of objects/events in the surrounding of a vehicle

Distribution of special event messages

Warning messages

- Generated by critical events on the road
- Transported along the road over a longer distance
- Need a high reliability and low latency



Distribution of sensor data / object information

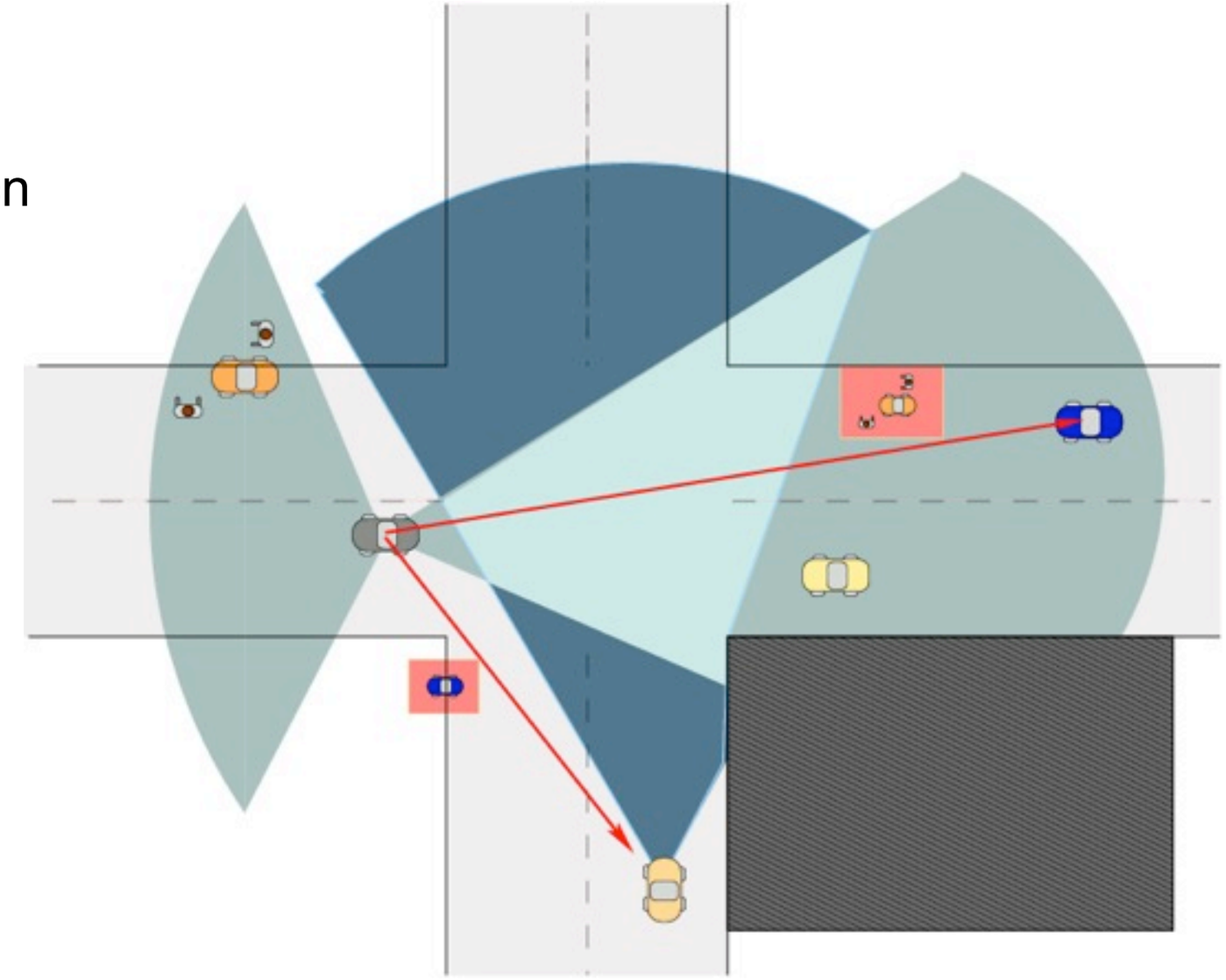
Object messages

- Containing object information of the surrounding
- Distribution range is 1 or 2 hops

- Helps to increase the knowledge of the traffic situation

- Broadcasting the sensor information will flood the network

- Information is redundant between vehicles



VANET - Quality of Service issues

QoS parameters

- Bandwidth requirements
- Reliable communication – packet loss, bottlenecks, unconnected sections
- Prioritization of certain types of messages
- Packet delay requirements
- Reliable transport for object information

Target application

- Vehicle going along a road with a maximum speed of 250 km/h (70m/s)
- Maximum sensor range approximately 150m
- Distribution range up to 3000m
- Packet delay for high priority objects is chosen to 0,5s

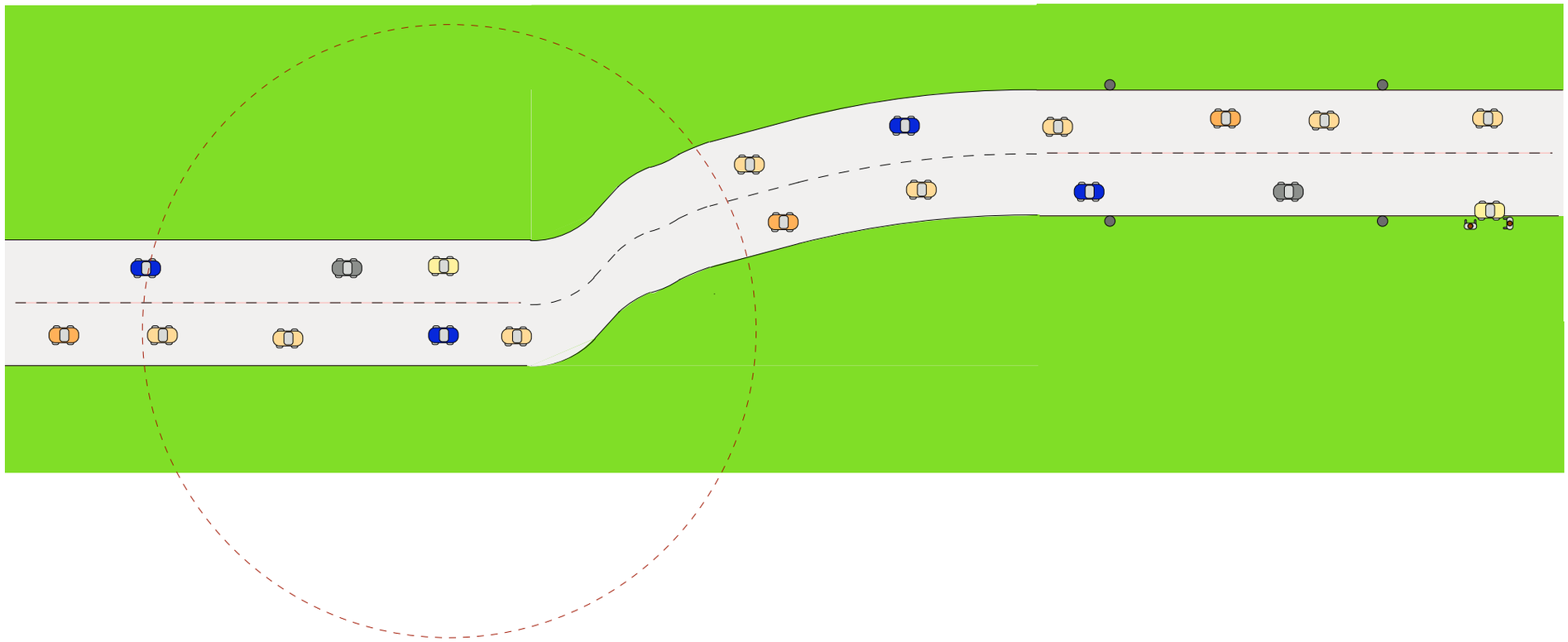
VANET characteristics

- Short Range Communication
  - Communication Range with Line of Sight up to 500m
  - Multi-path propagation
  - Channel properties changes due to the surrounding of the vehicles (huge difference for inner-city-scenario and highway-scenario)

- Network nodes are fast moving vehicles
  - Topology changes very fast (Lifetime of a link between two nodes can be very short)

VANET characteristics - a Broadcast Network

– If one node sends data - all of its neighbors receive it (broadcast)



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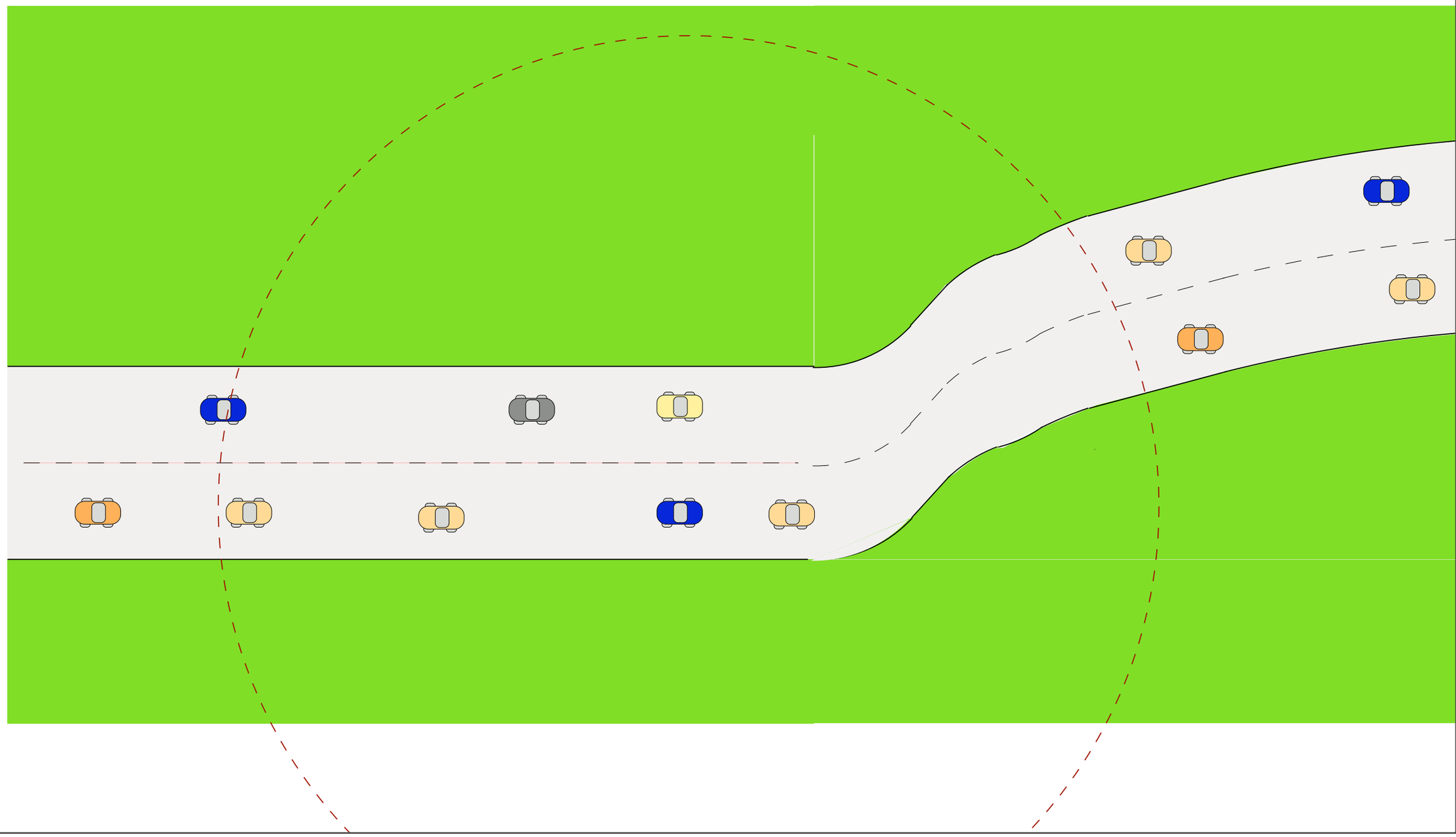

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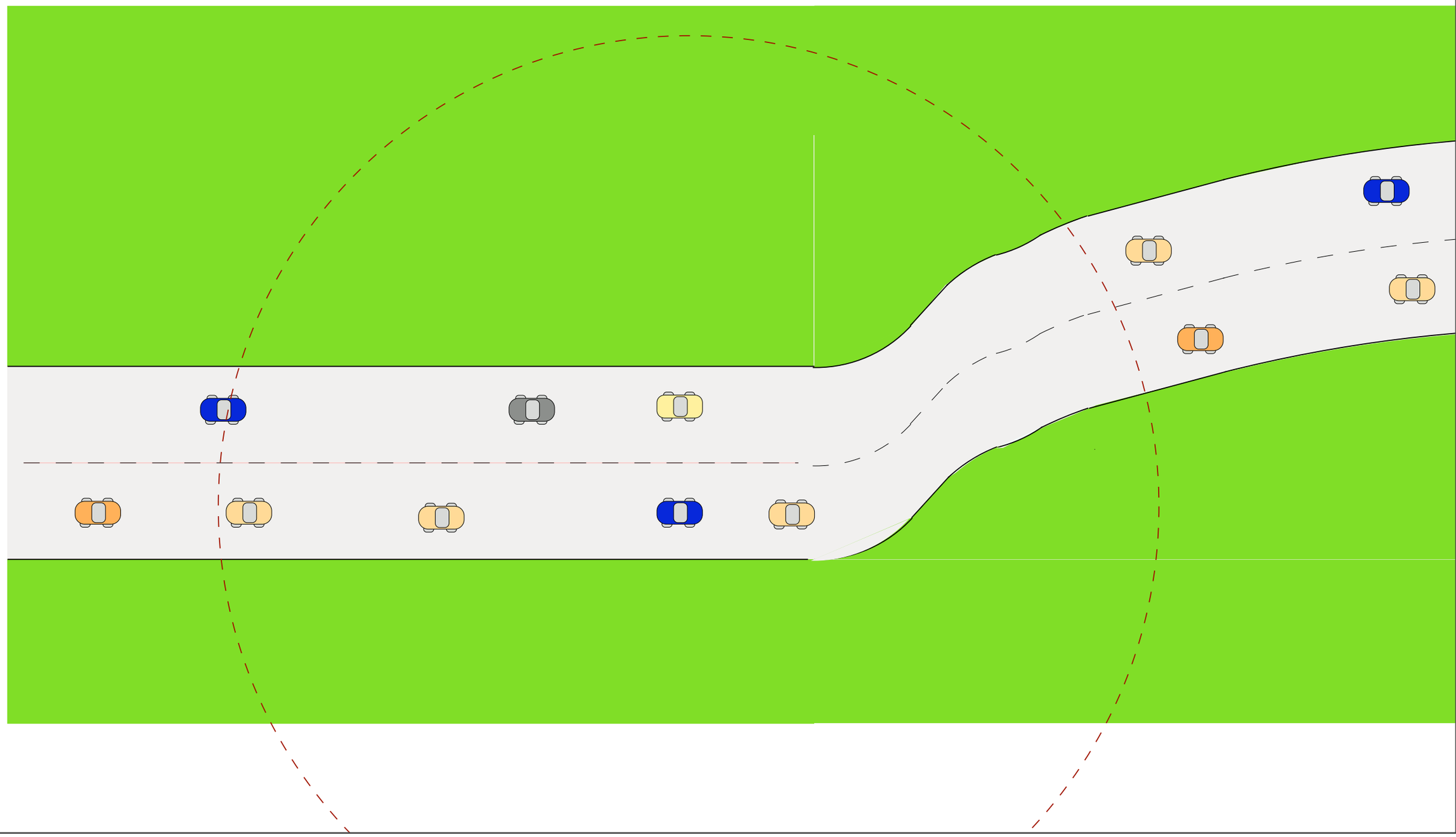

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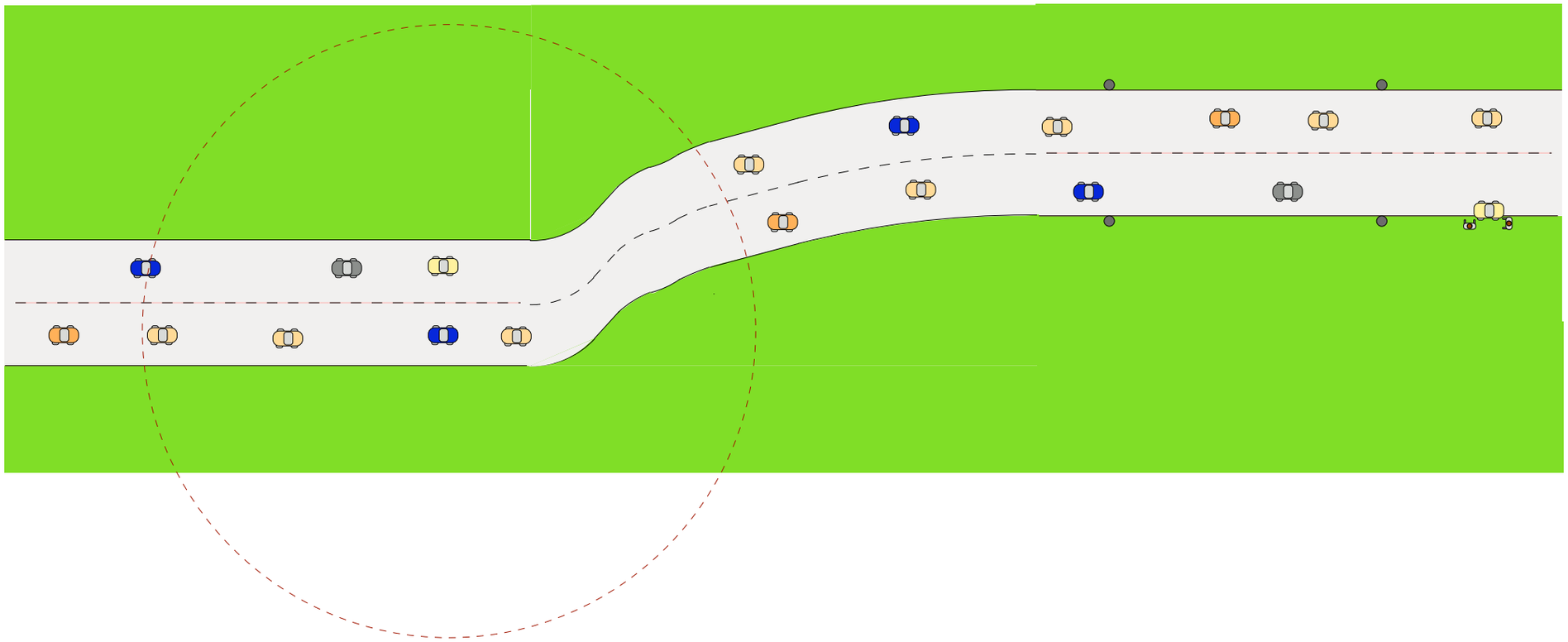

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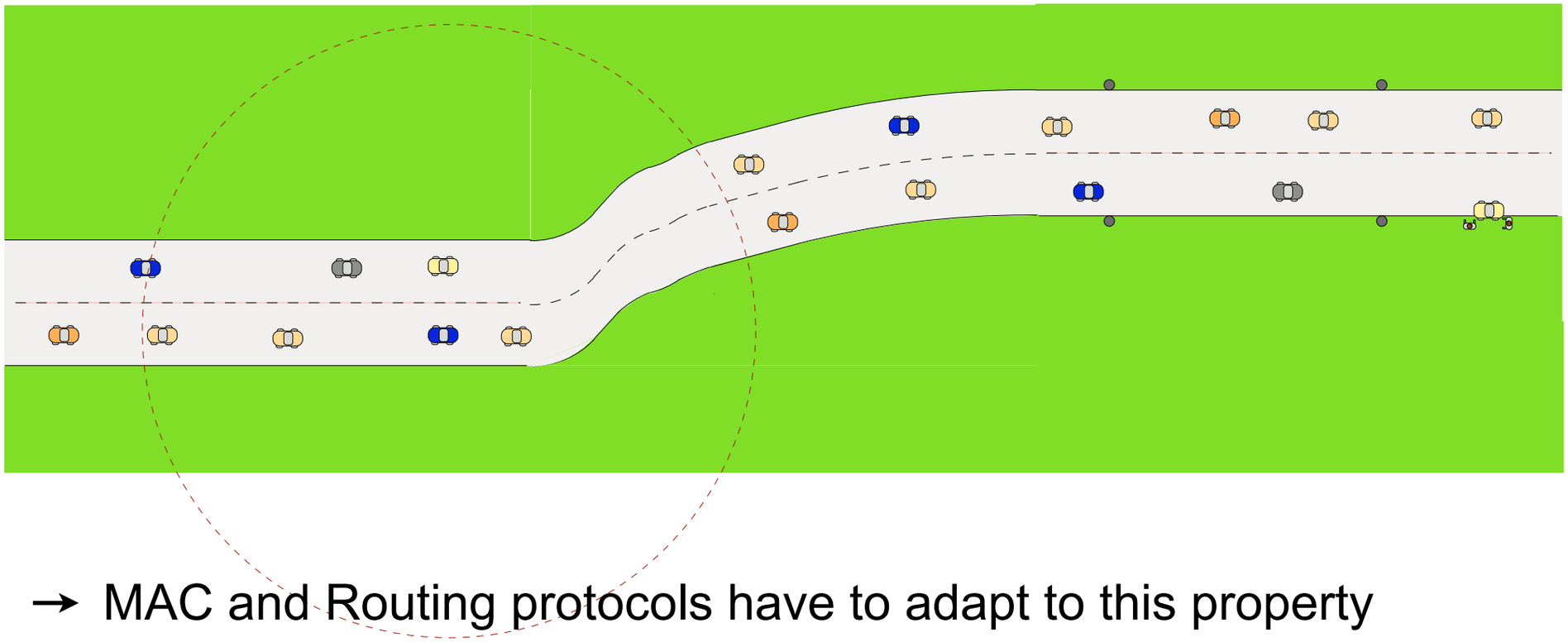
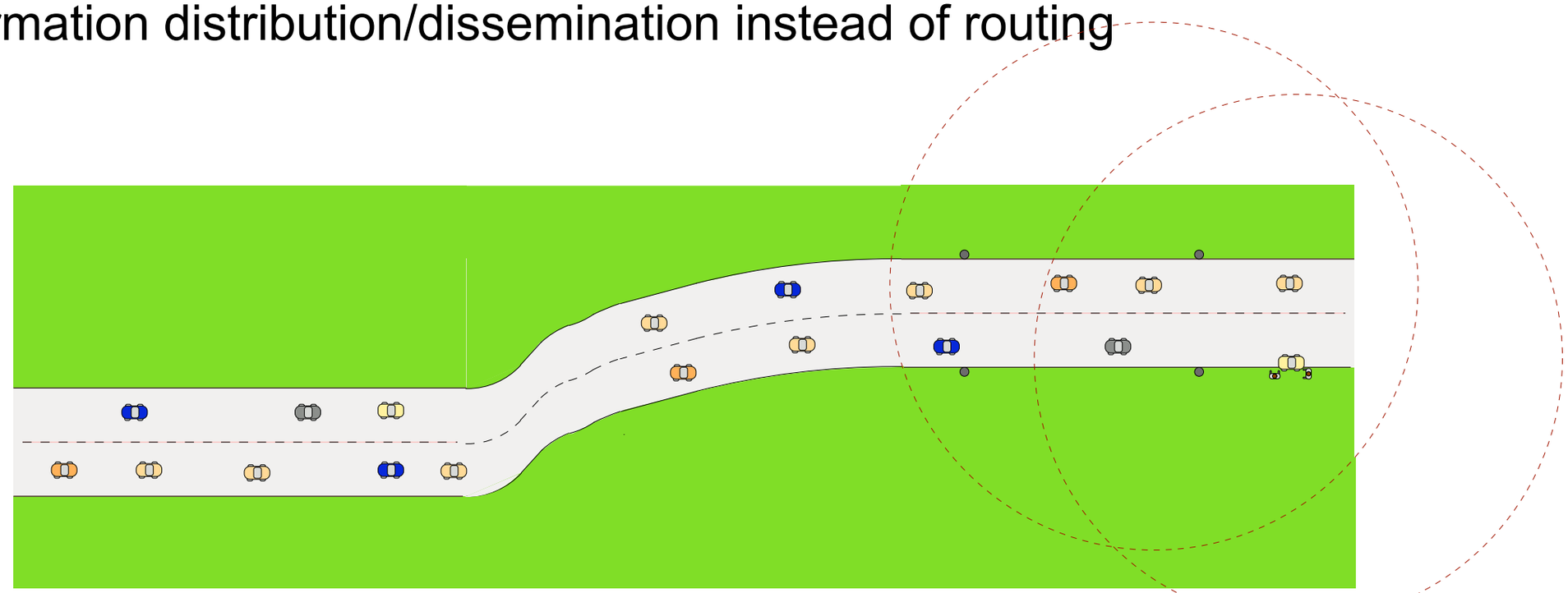


→ MAC and Routing protocols have to adapt to this property

VANET characteristics - a Broadcast Network

– Information distribution/dissemination instead of routing



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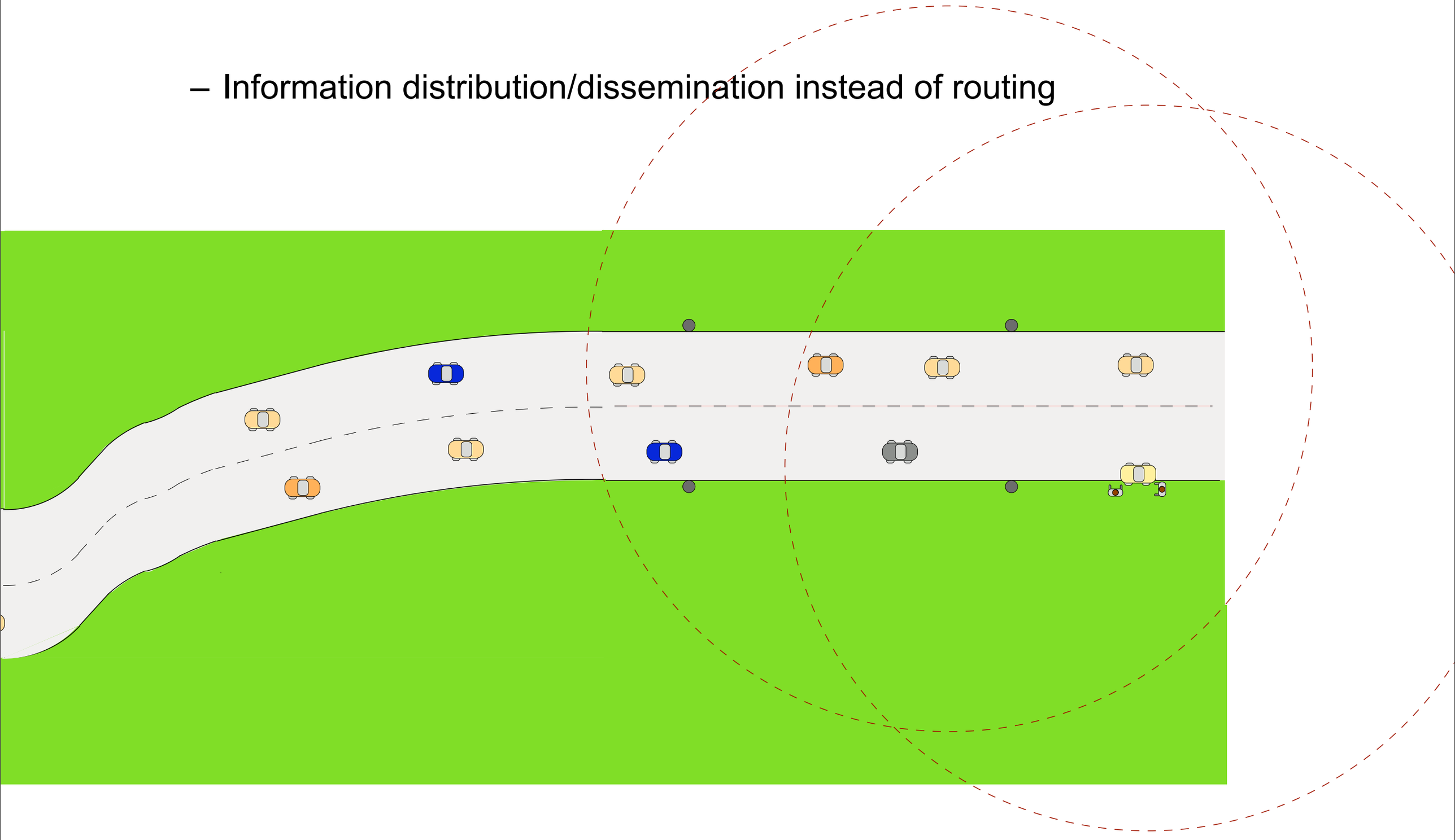

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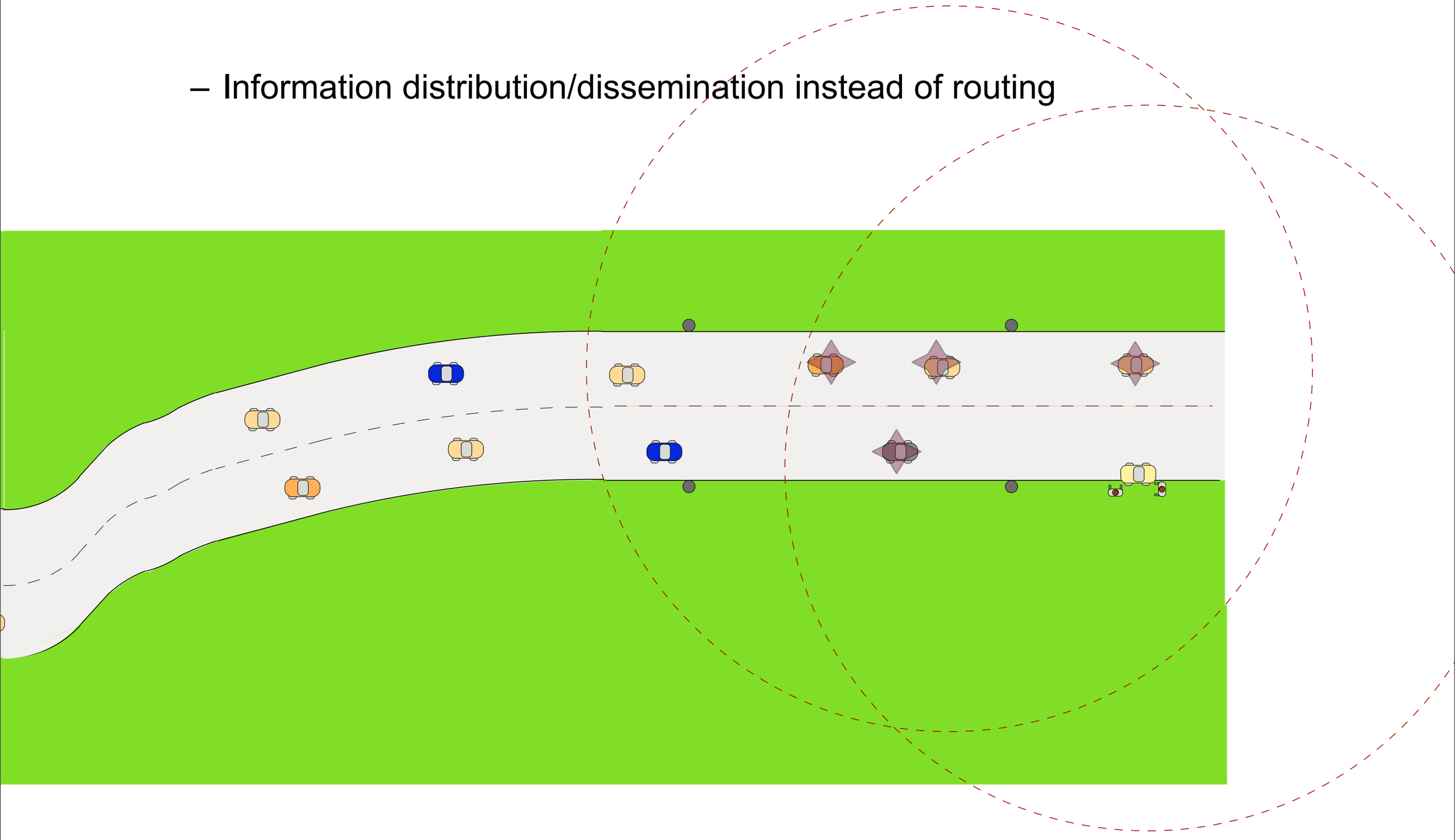

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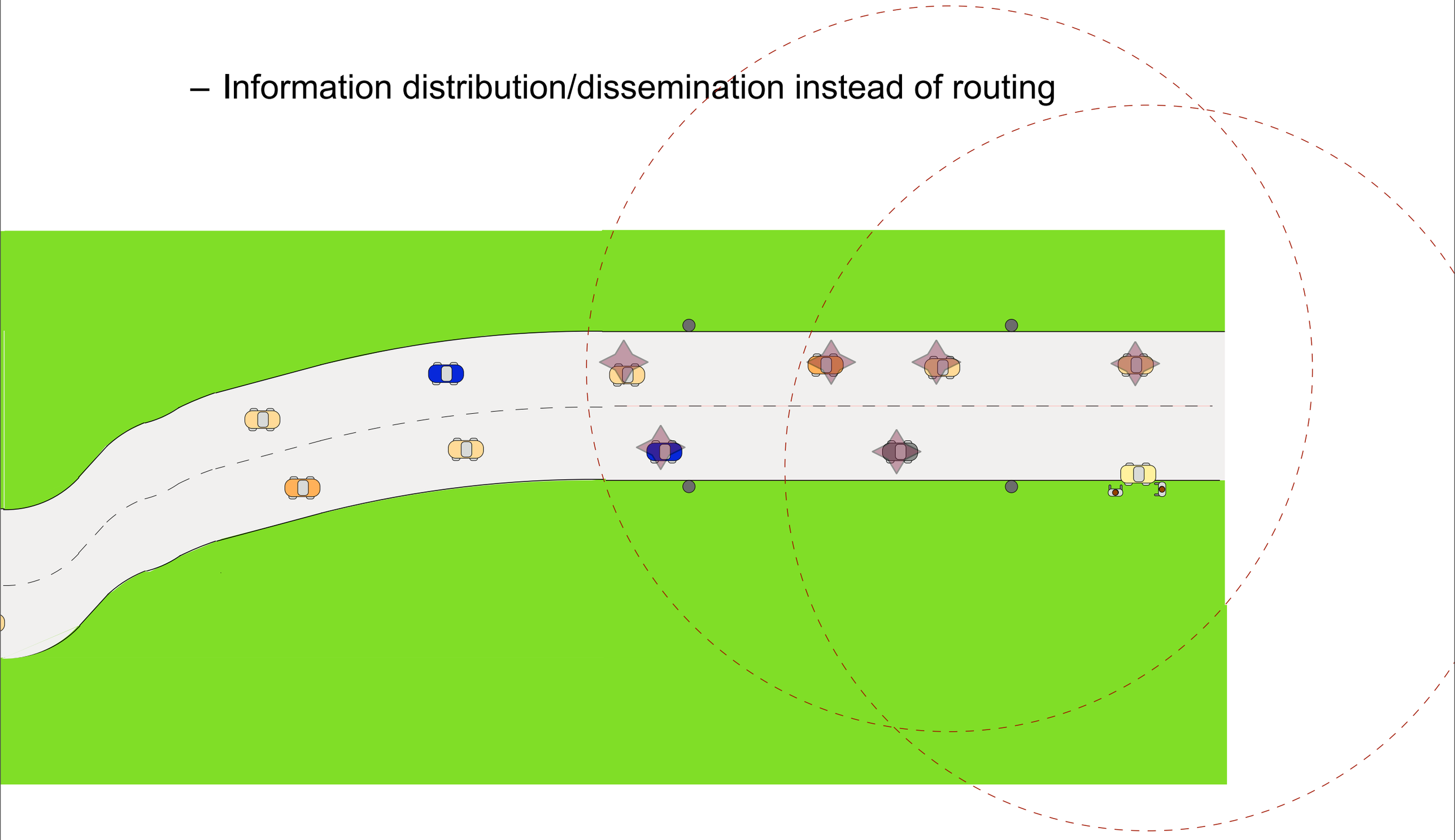

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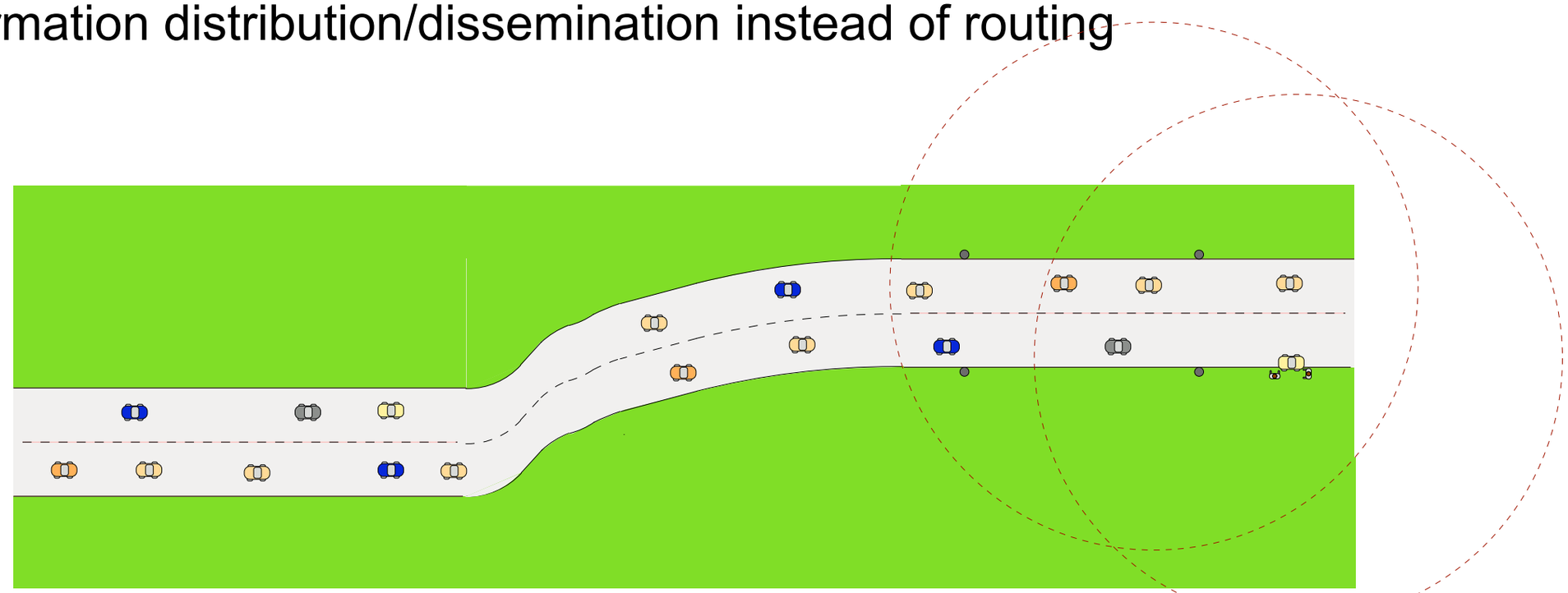
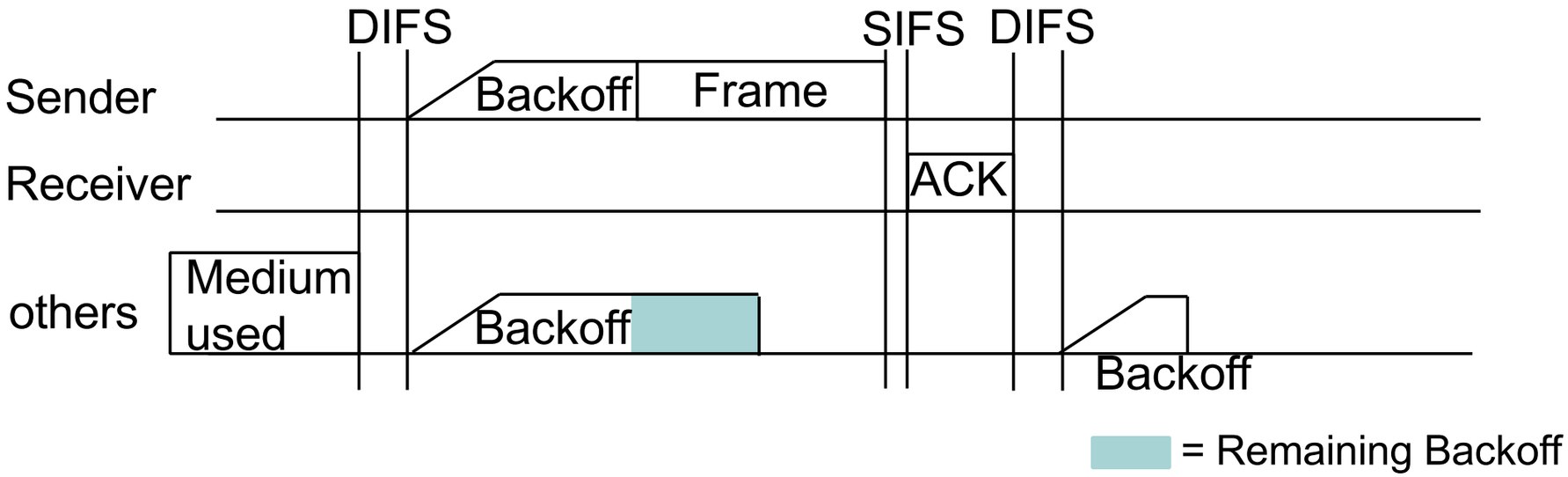


– Challenges
  - prevent flooding of the network
  - progress on the road

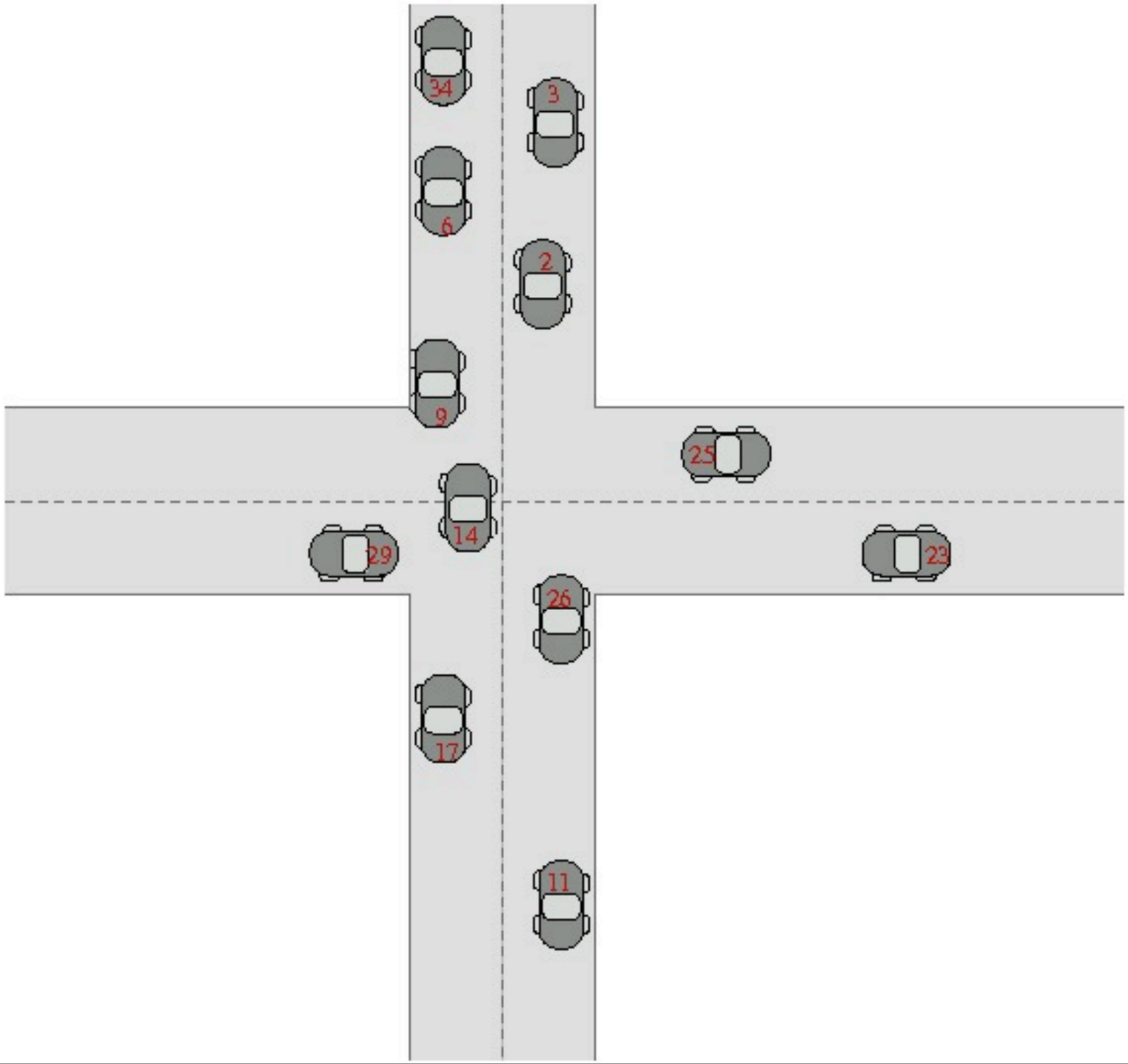
MAC IEEE 802.11

- Access mechanism: Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA)
- Fair access due to back-off mechanism
- Prioritization of messages with inter-frame spaces
- Acknowledgement of unicast messages

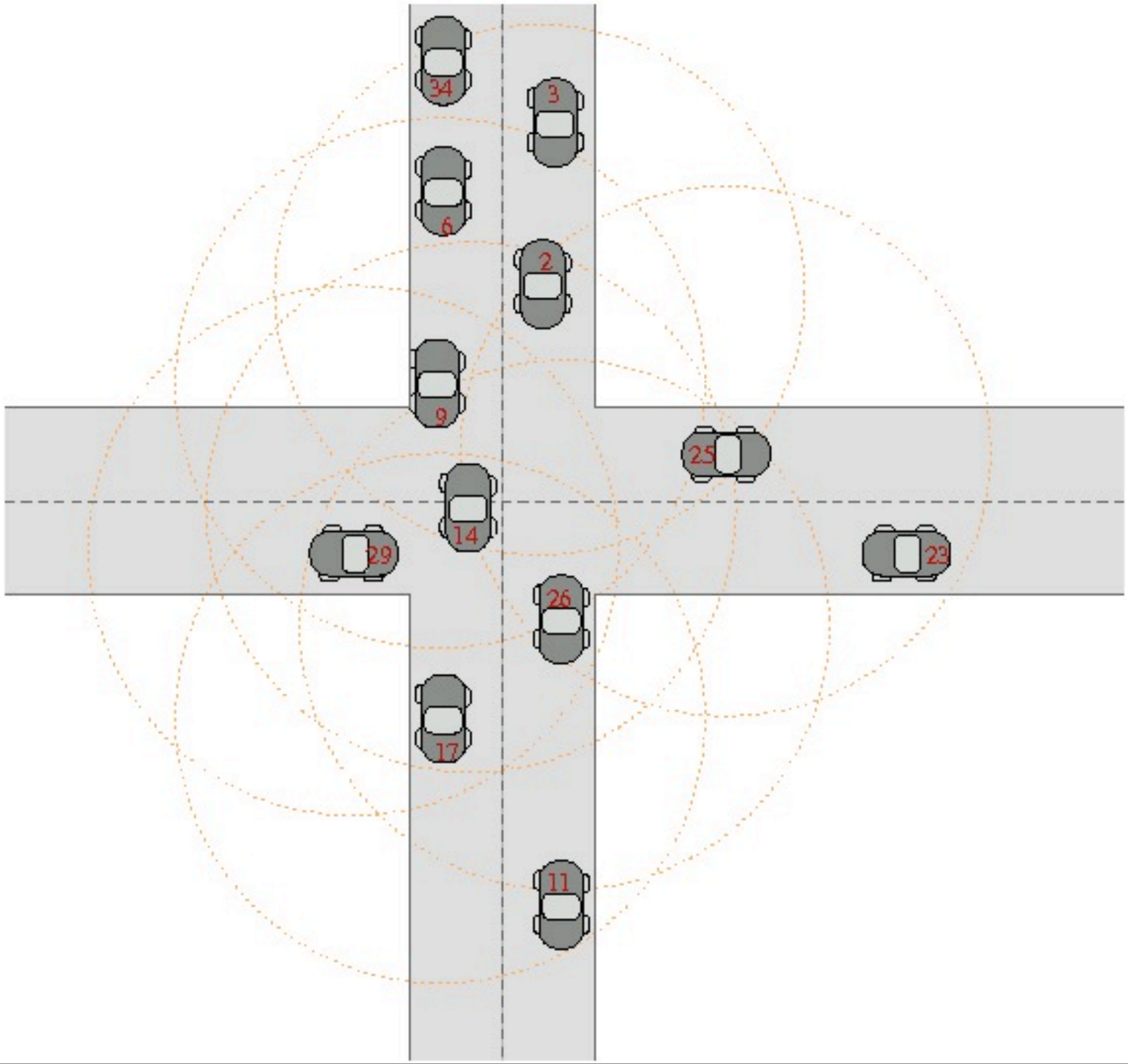


- For VANETs
  - Broadcast: No RTS/CTS and ACK
  - Contention Window CW = CWmin

CSMA and Hidden-Stations in a Broadcast network



CSMA and Hidden-Stations in a Broadcast network



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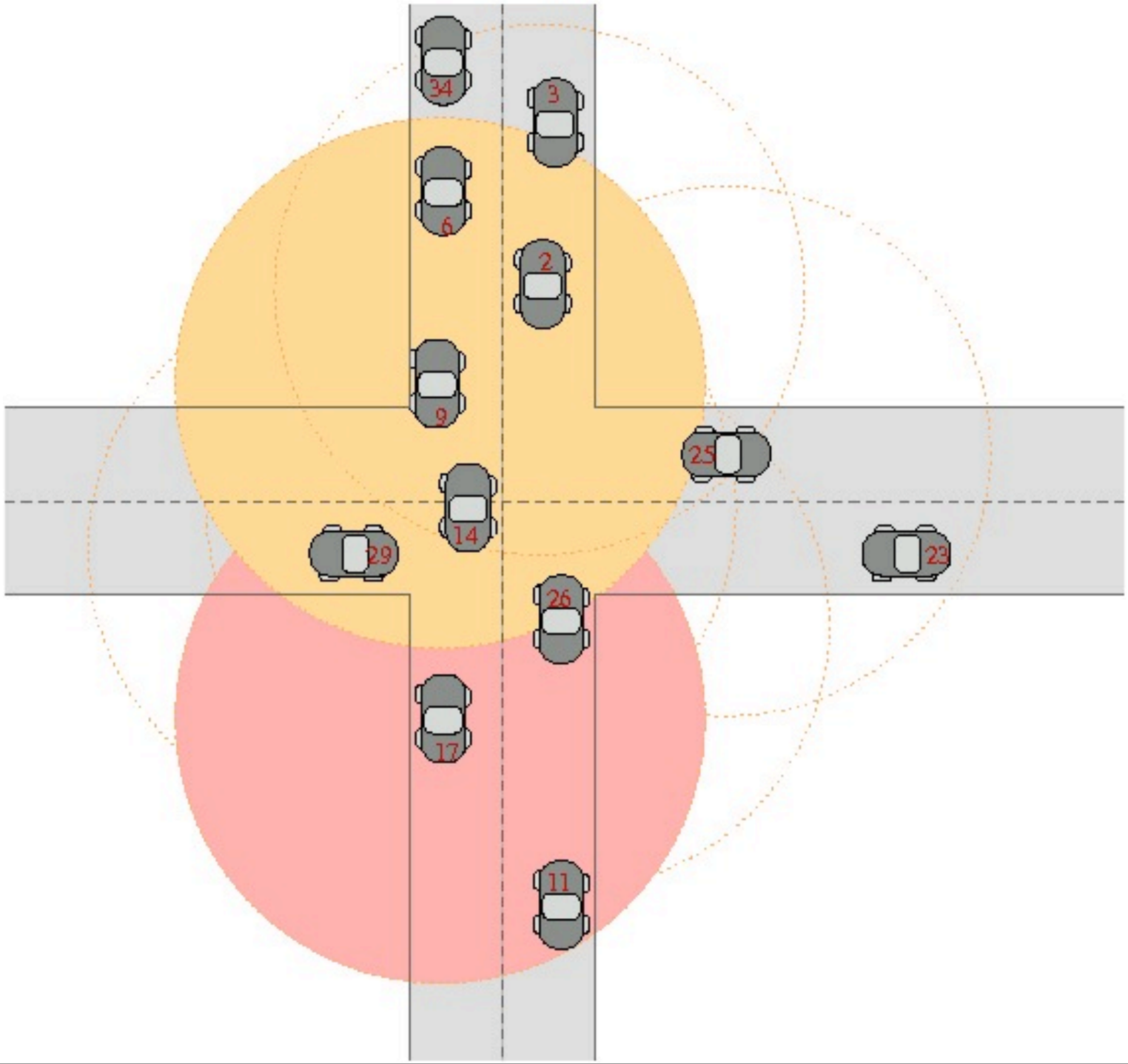
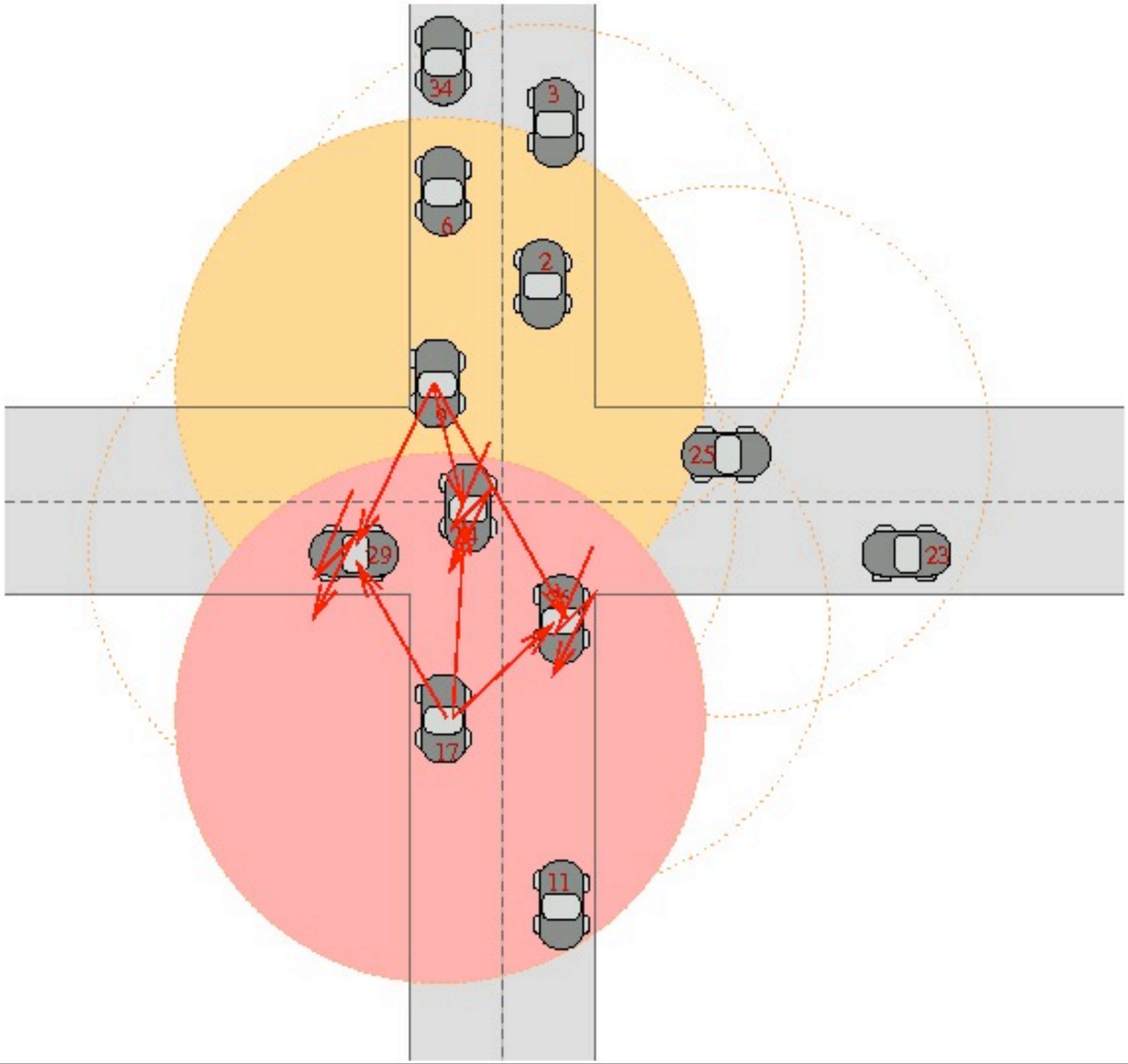


CSMA and Hidden-Stations in a Broadcast network



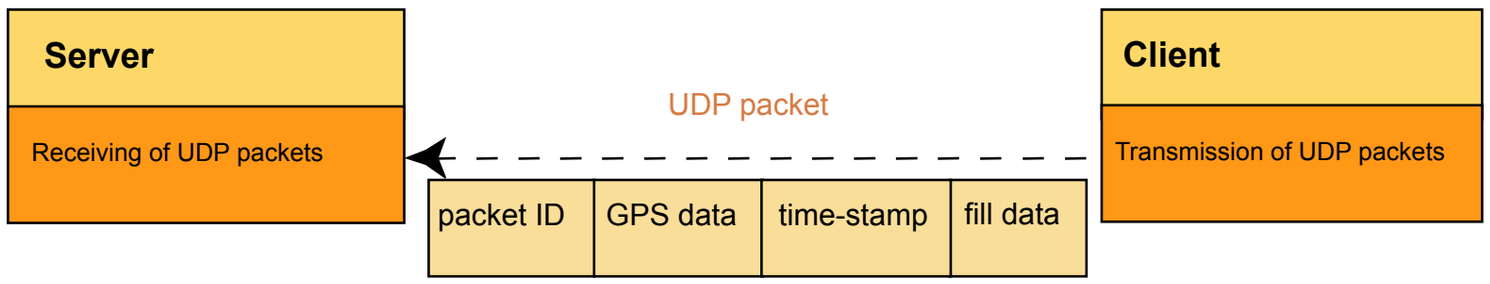
WLAN in a Vehicular Environment

Measurement set-up

- 3 cars equipped with:
  - Linux-PC
  - PC-Card Orinoco Gold IEEE 802.11B with external antenna
  - GPS-receiver for position detection
  - Synchronization using NTP (Network Time Protocol)

Method

- Using WLAN unicast mode/broadcast mode
- Transmission of UDP packets from the client to the server



Parameters

- Throughput, Delay, Distance

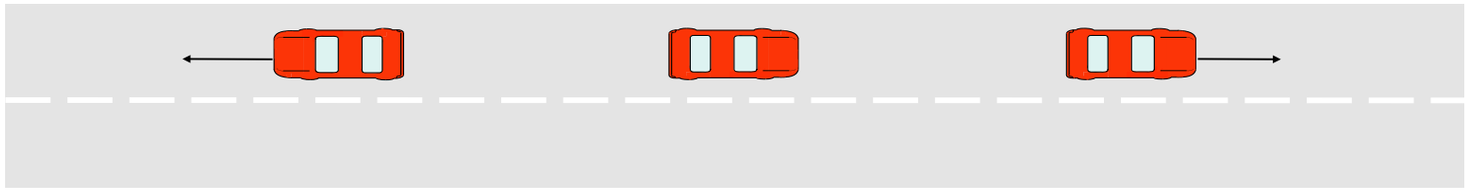
Scenarios

Measurements with 2 cars

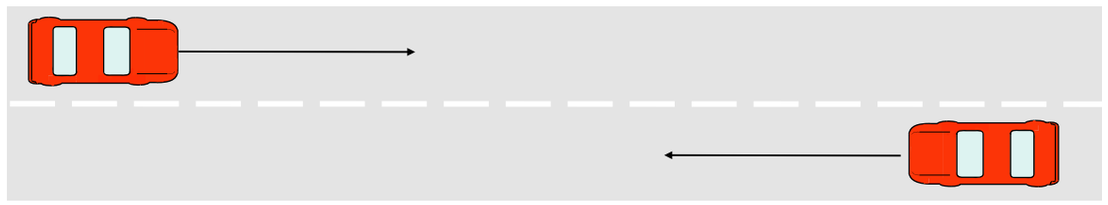
- Influence of the cars relative velocity
- Influence of the multi-path fading
- Driving in a city scenario

Measurements with 3 stations

- Influence of the medium access mechanism
- Using broadcast mode



Line of Sight Communication



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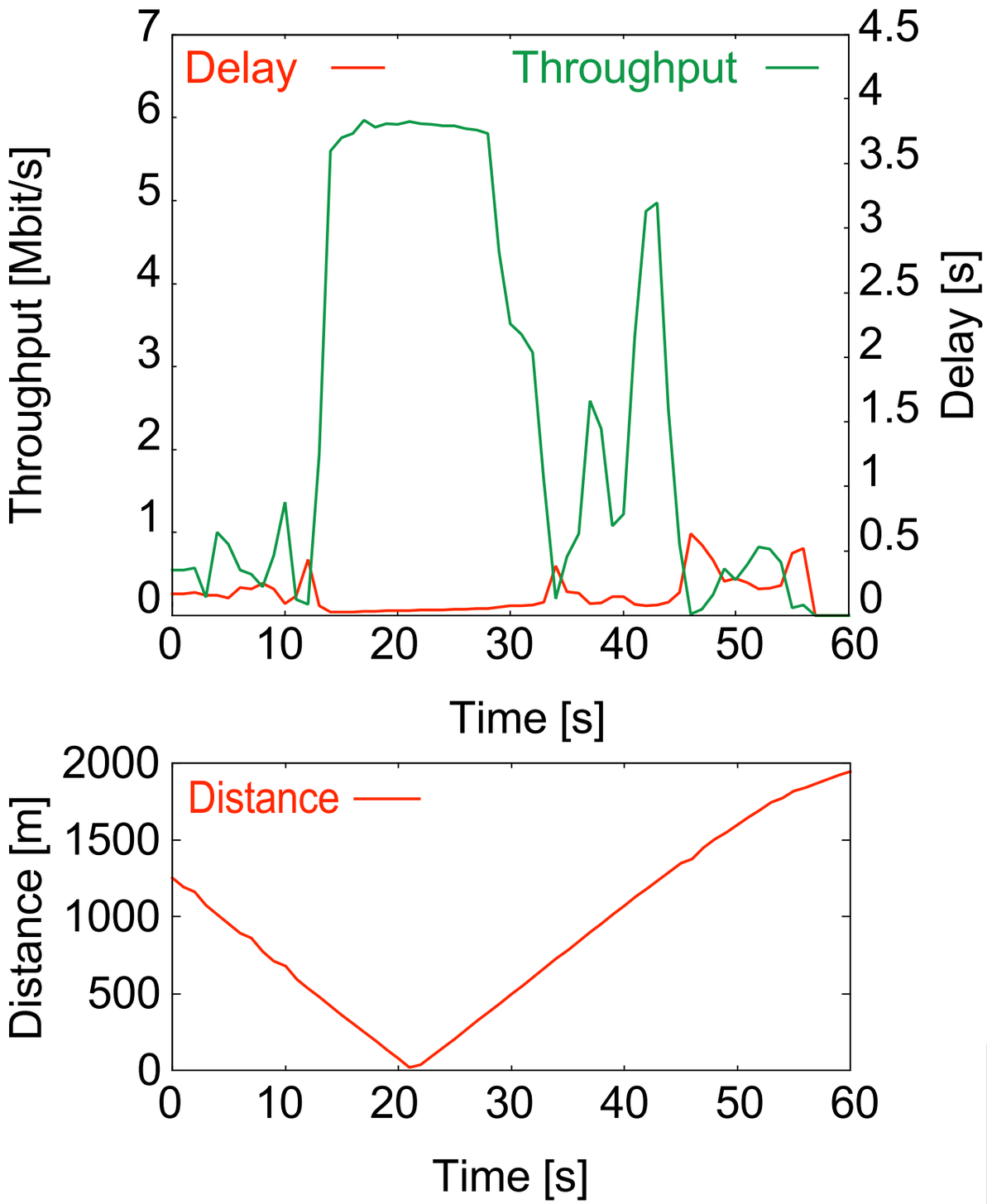

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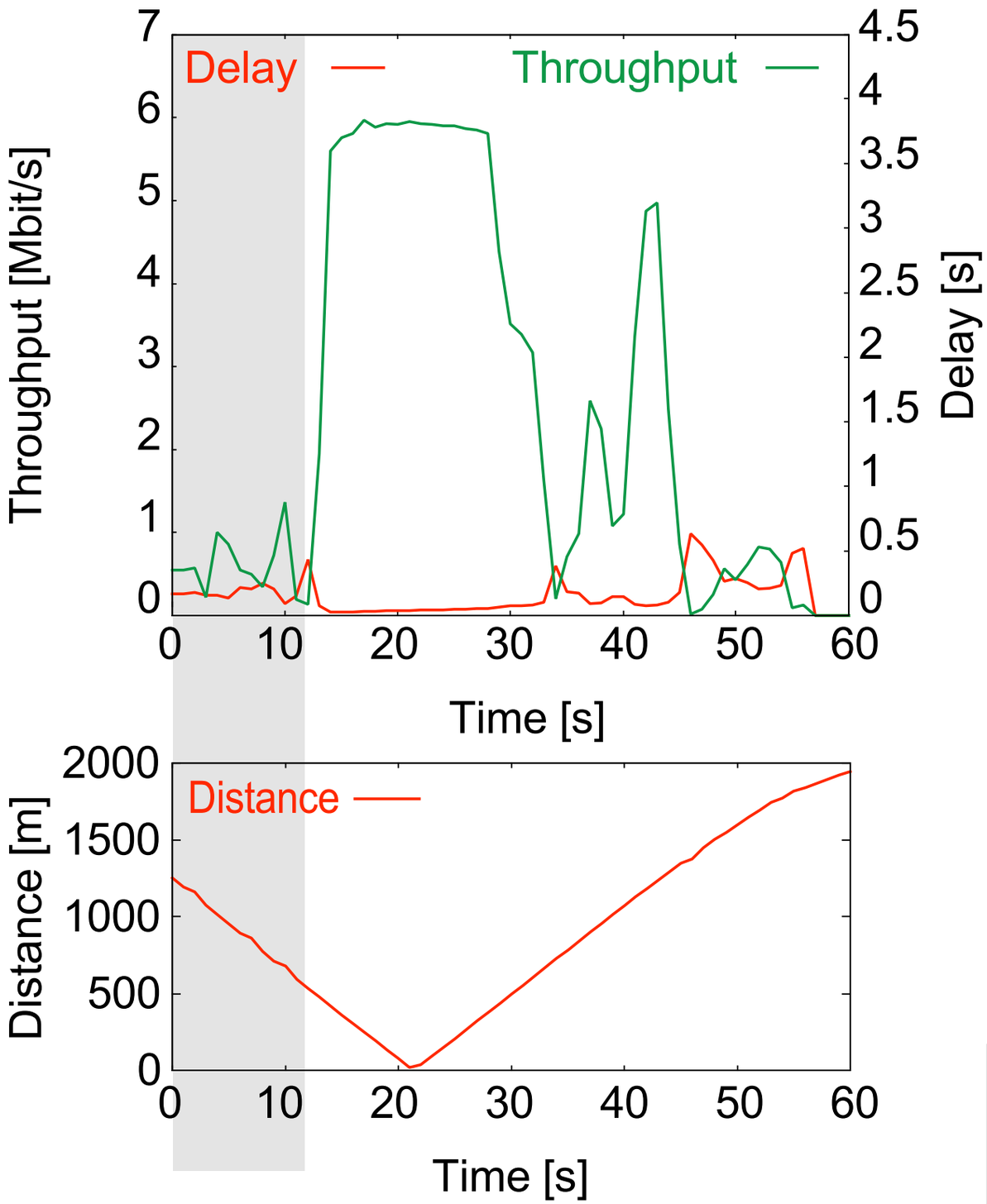
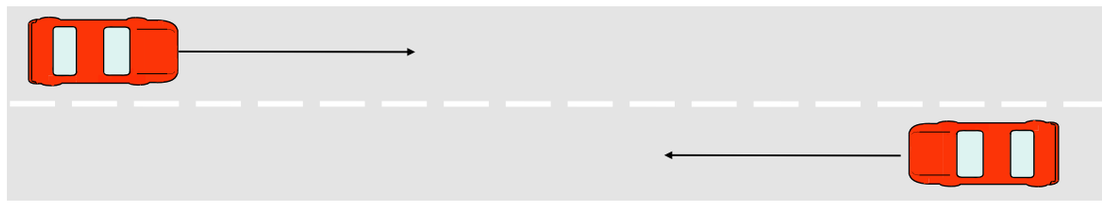


1

- Low throughput due to high distance
- Delay approx. 250 ms



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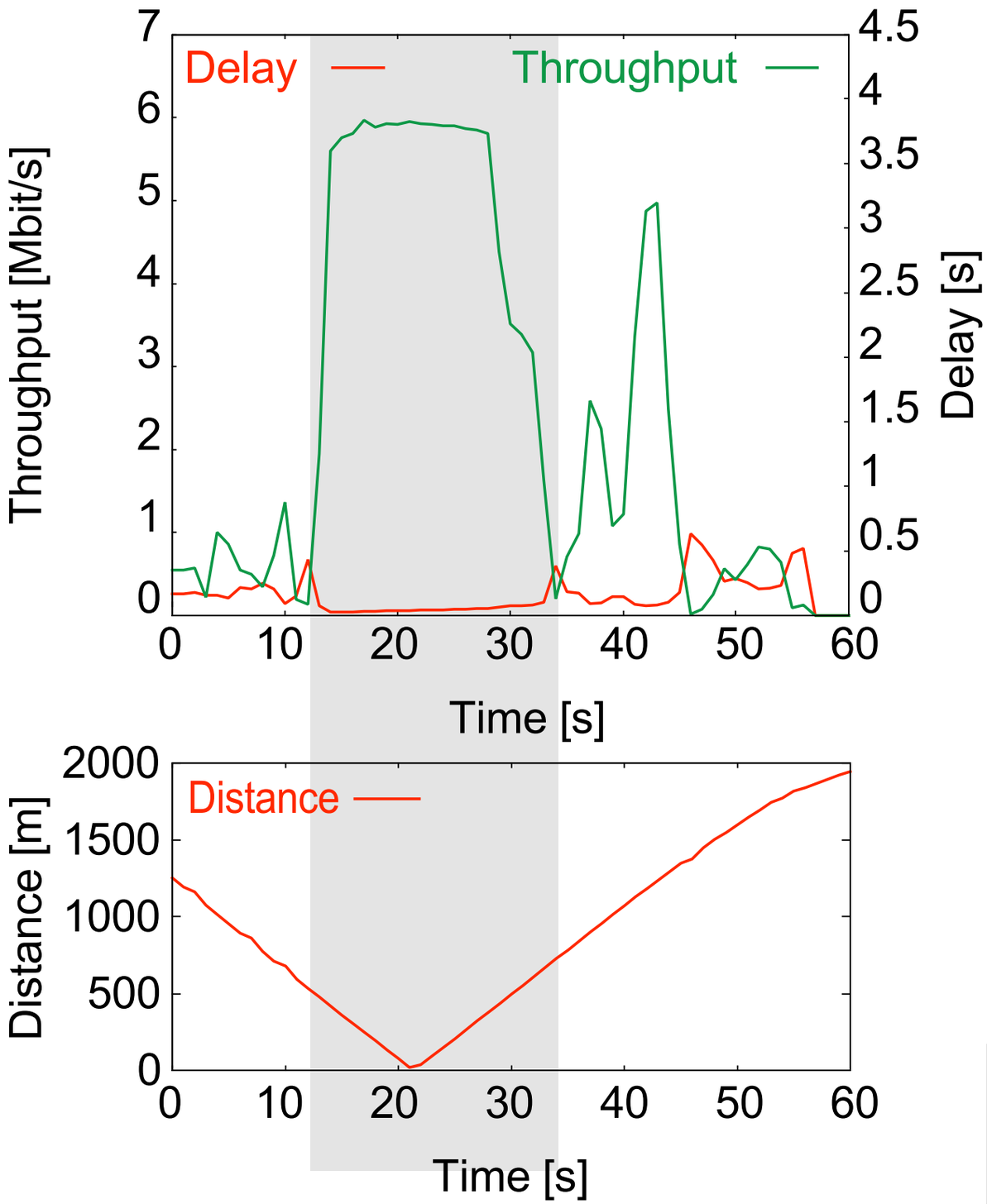


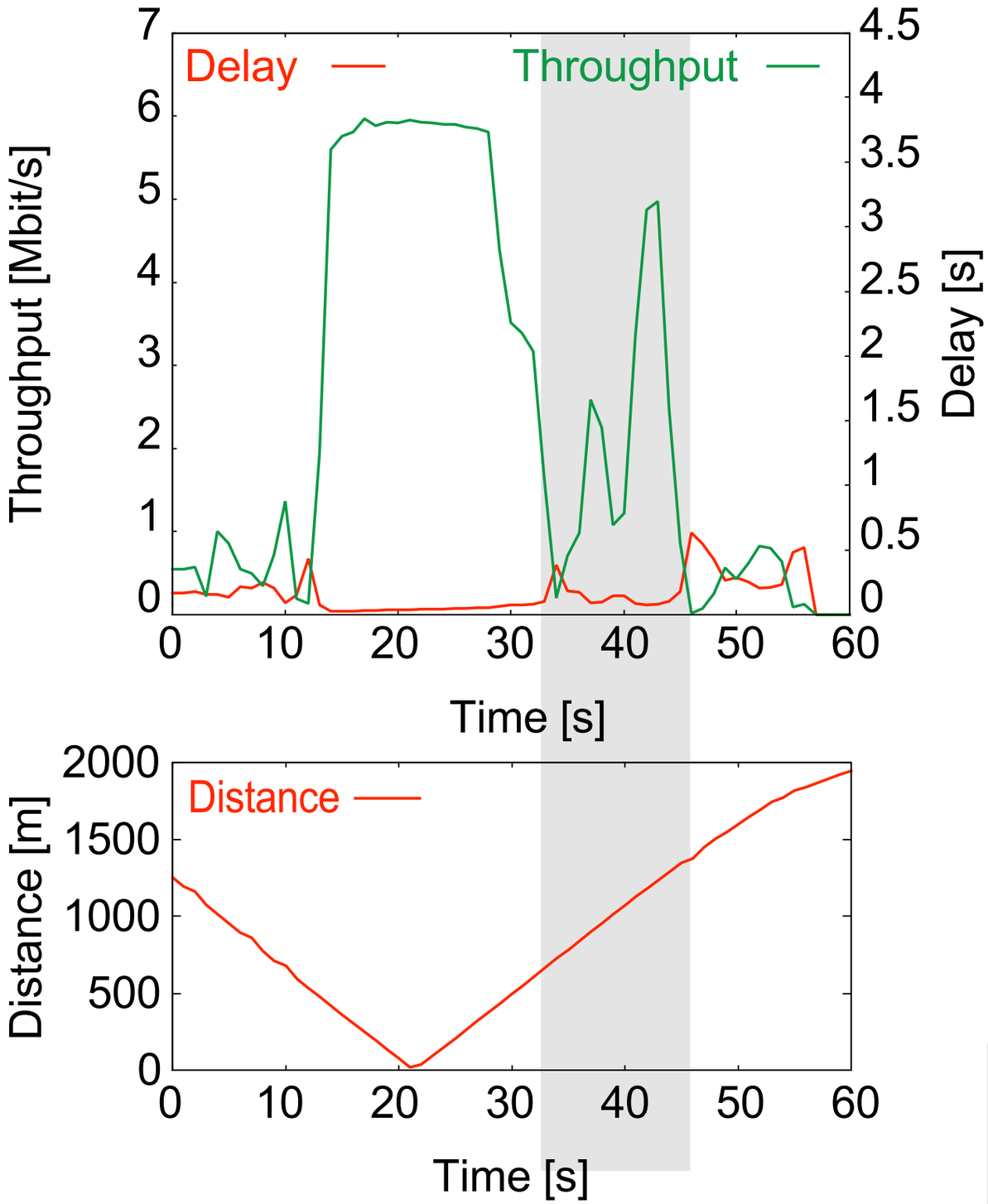
1

- Low throughput due to high distance
- Delay approx. 250 ms

2

- Maximum possible throughput
- Delay approx. 100 ms

Line of Sight Communication



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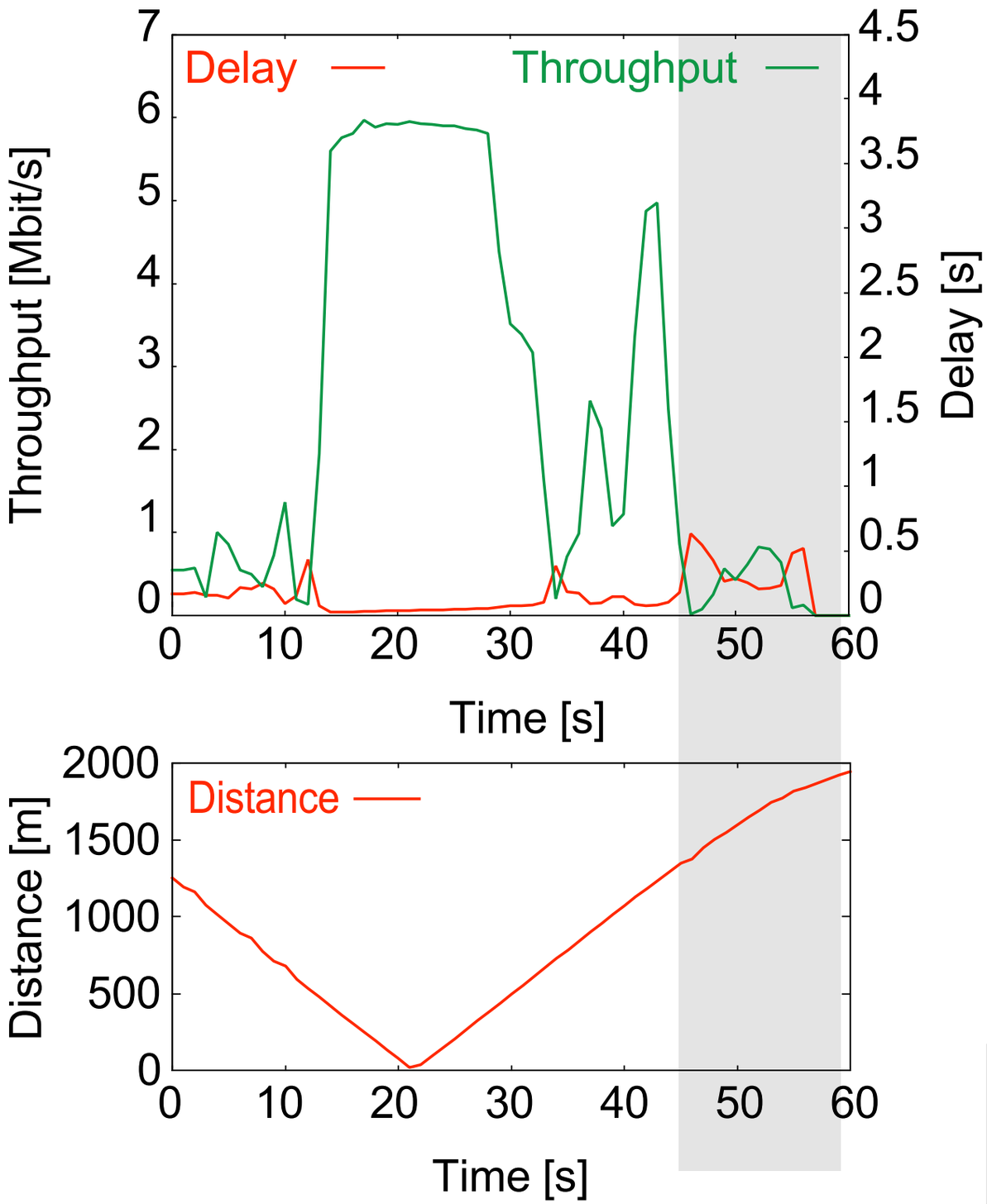
- Drops in the throughput with increasing distance
- Growing latency

Line of Sight Communication



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- Low throughput due to high distance
- Delay approx. 250 ms

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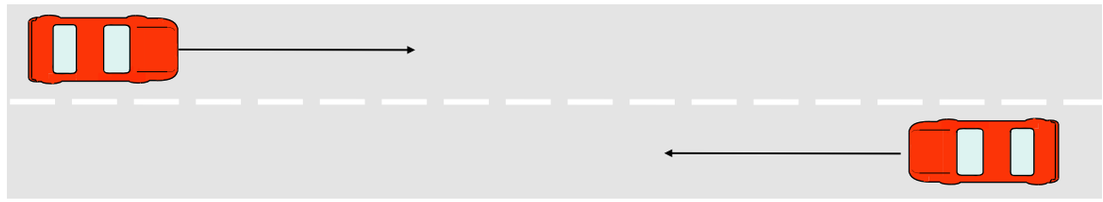
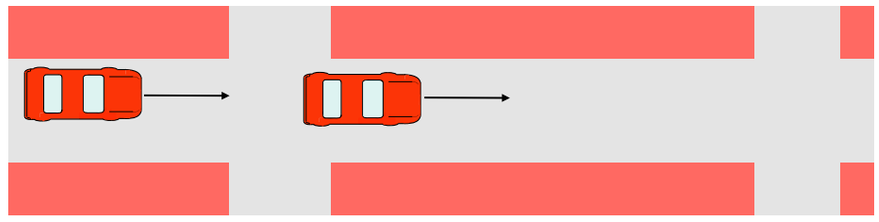
- Maximum possible throughput
- Delay approx. 100 ms

3
- Drops in the throughput with increasing distance
- Growing latency

4
- Low throughput
- Accordingly high latency



Multi-path propagation



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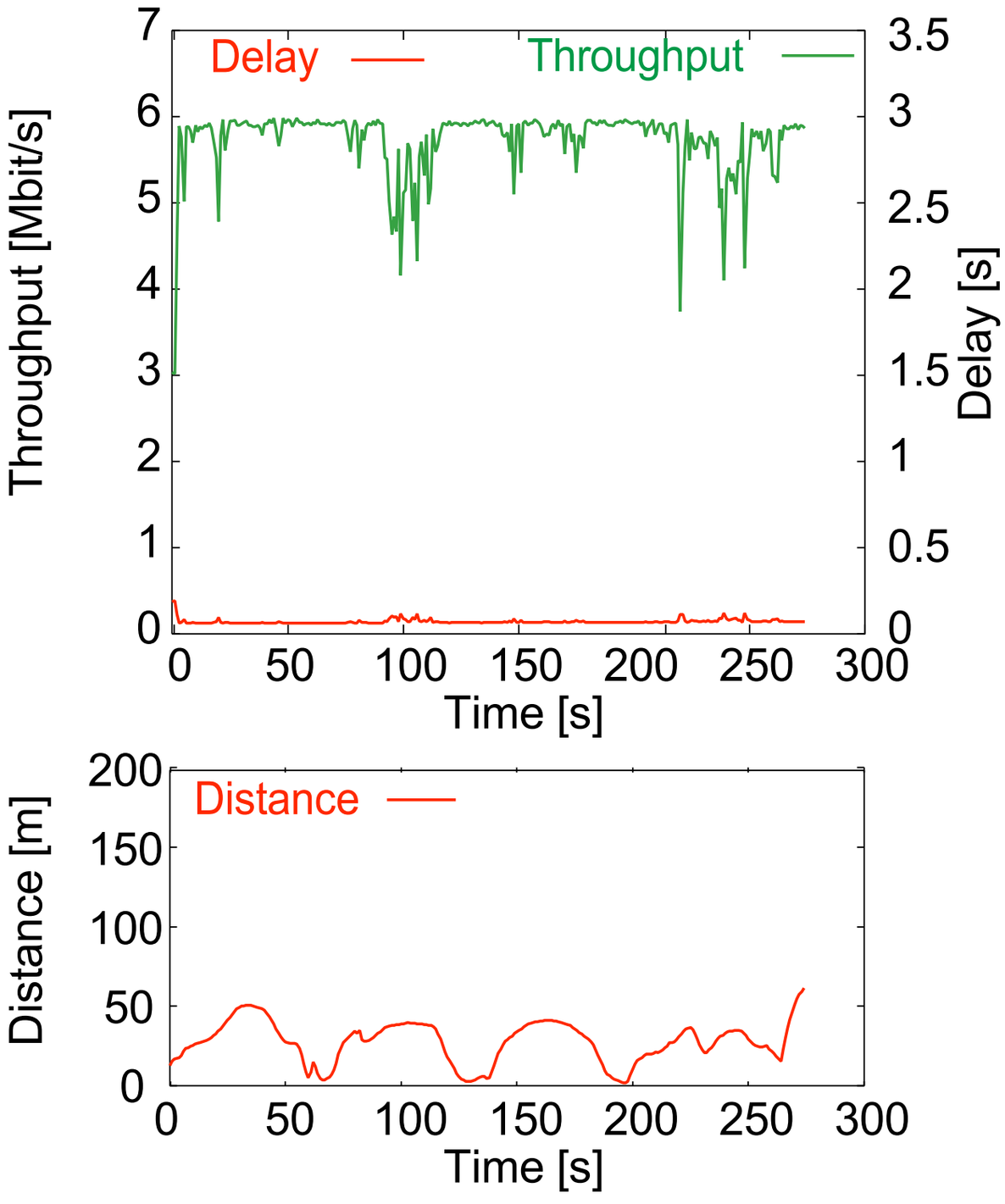

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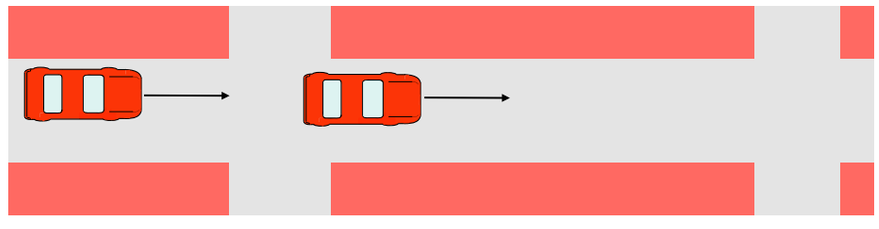
- Mostly 5 to 6 Mbit/s
- But frequent drops in the throughput



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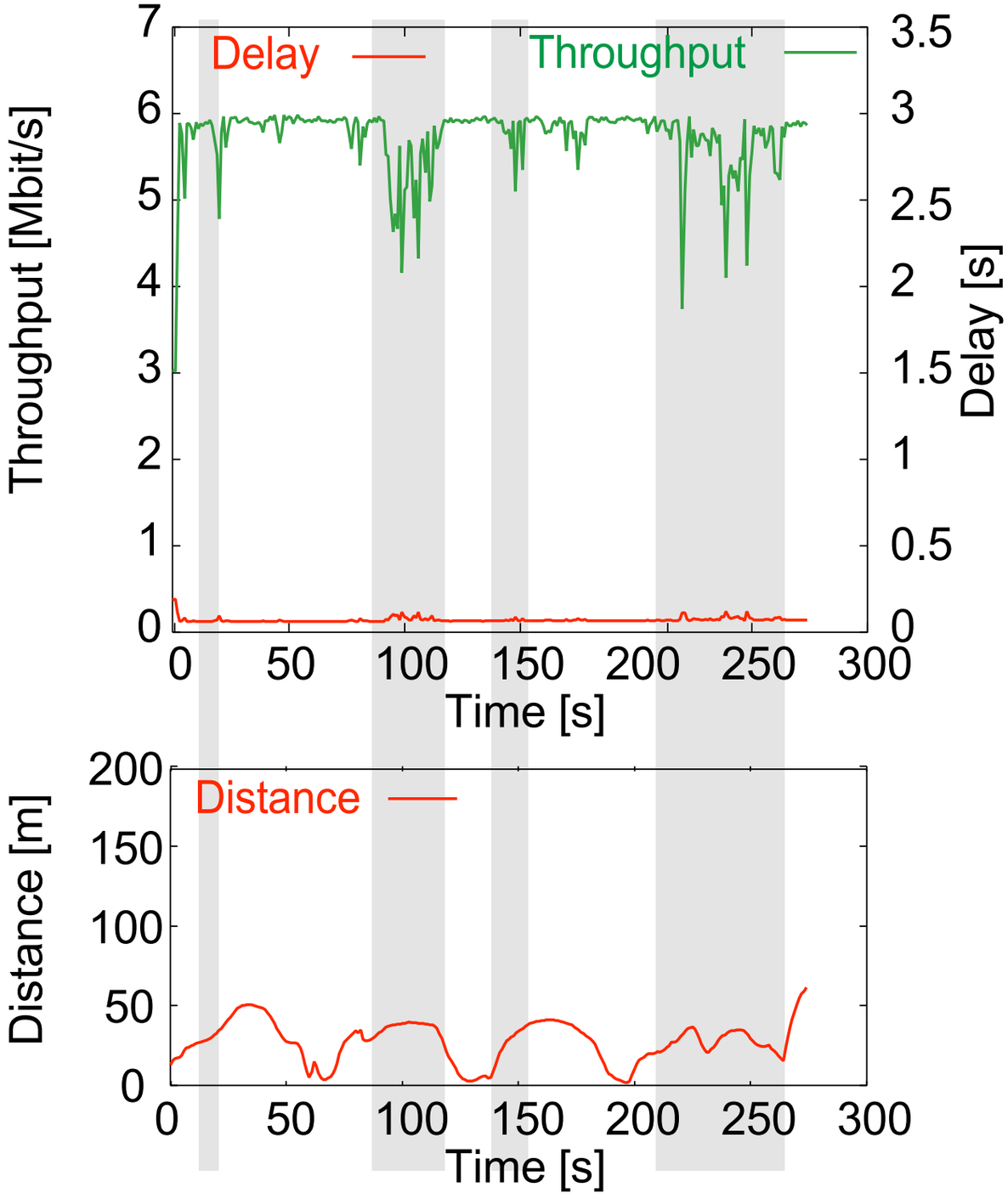
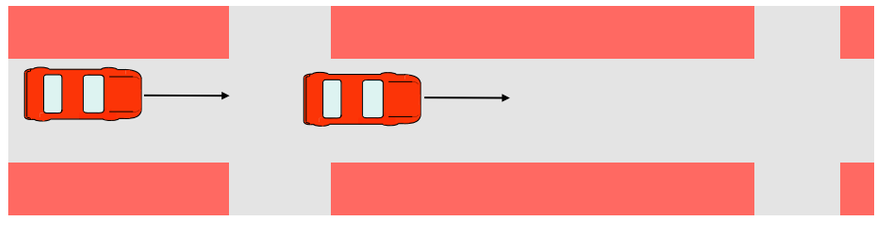
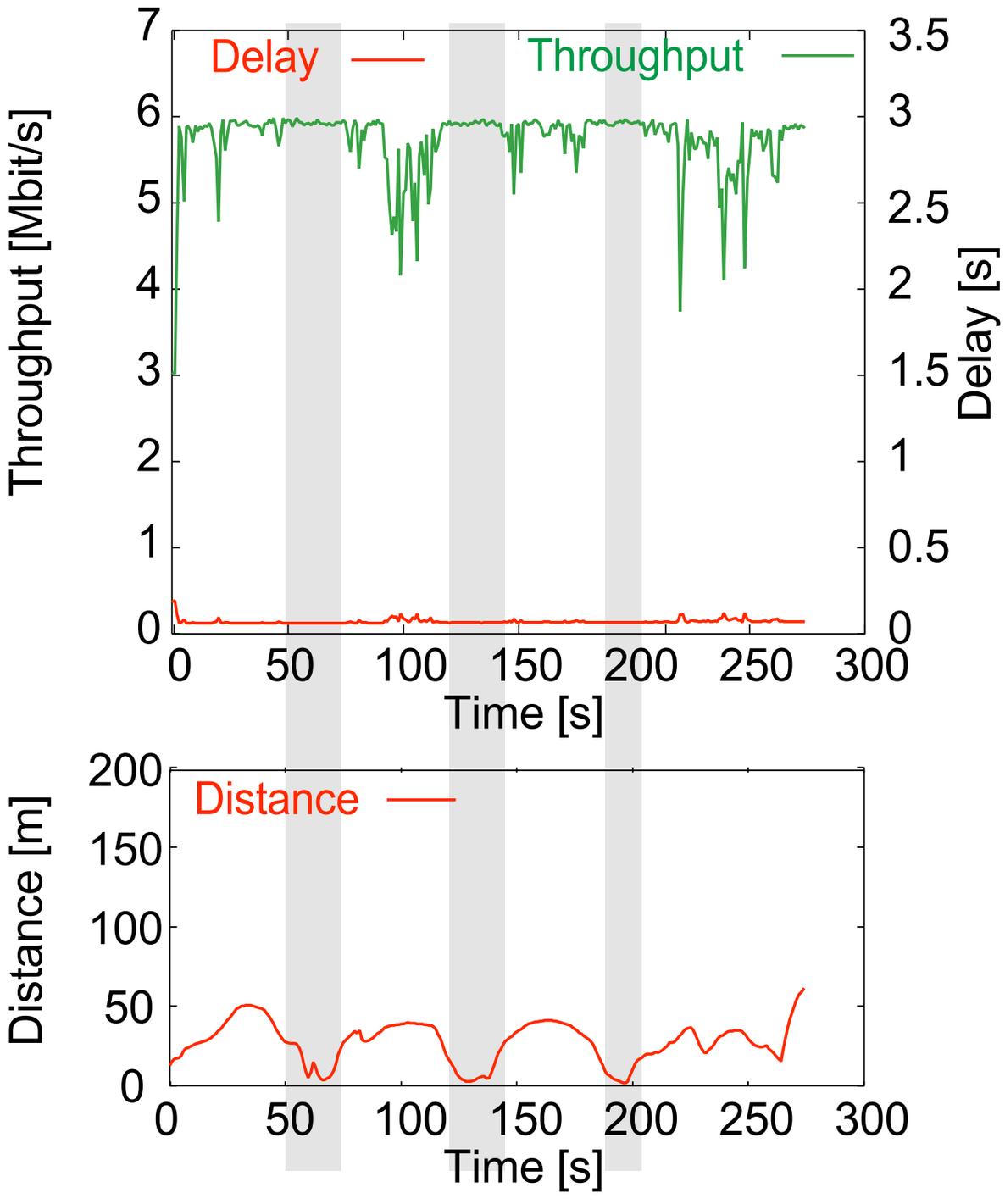


1
- Mostly 5 to 6 Mbit/s
- But frequent drops in the throughput

2
- Throughput drops with larger distance



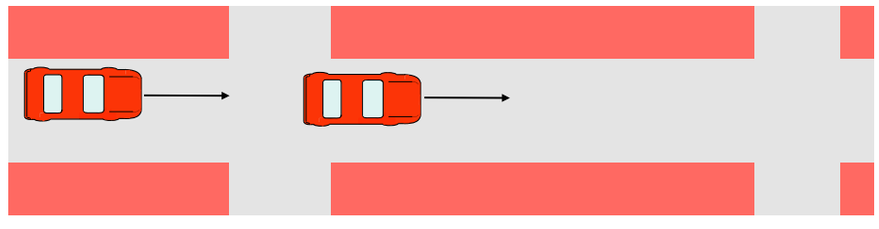
Multi-path propagation



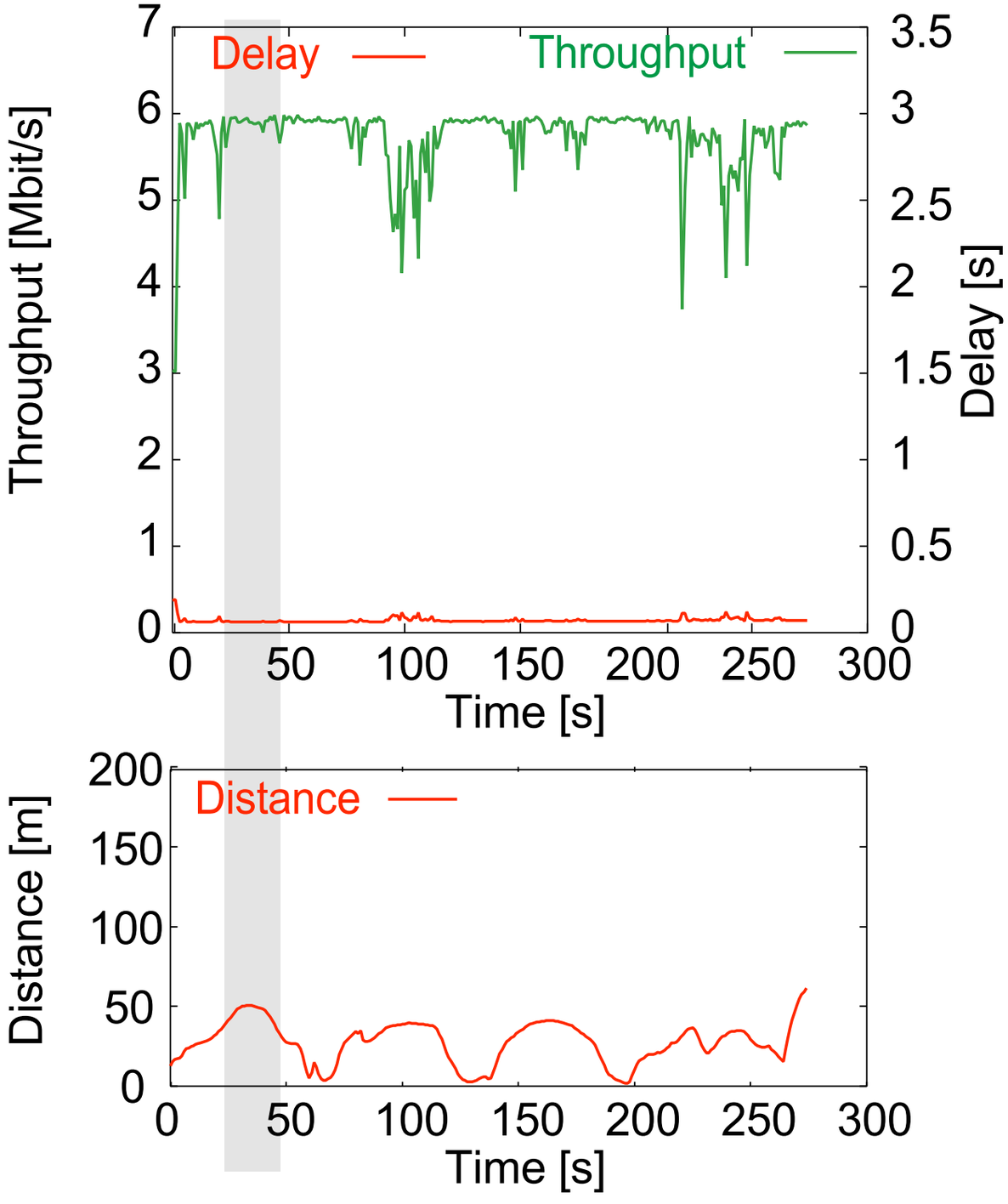
1 - Mostly 5 to 6 Mbit/s
- But frequent drops in the throughput

2 - Throughput drops with larger distance

3 - Low distance results in high throughput



Multi-path propagation

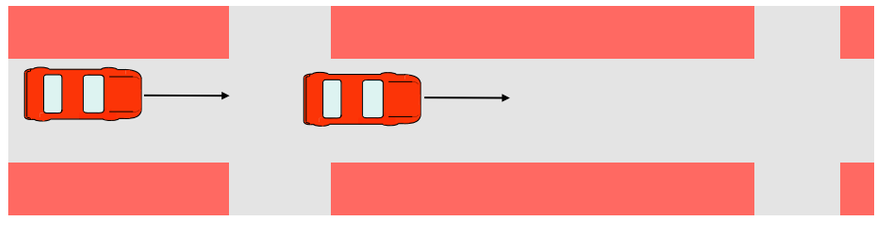


1 - Mostly 5 to 6 Mbit/s
- But frequent drops in the throughput

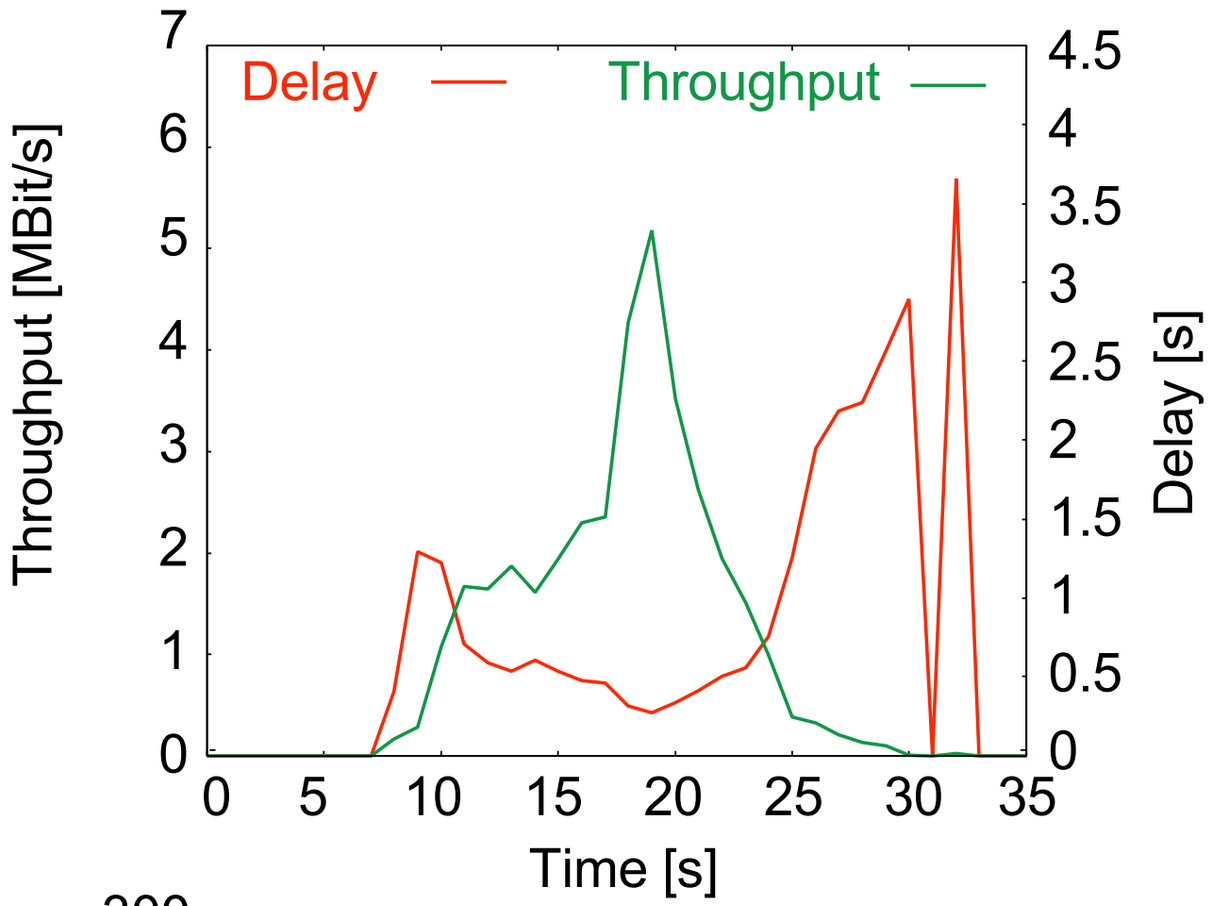
2 - Throughput drops with larger distance

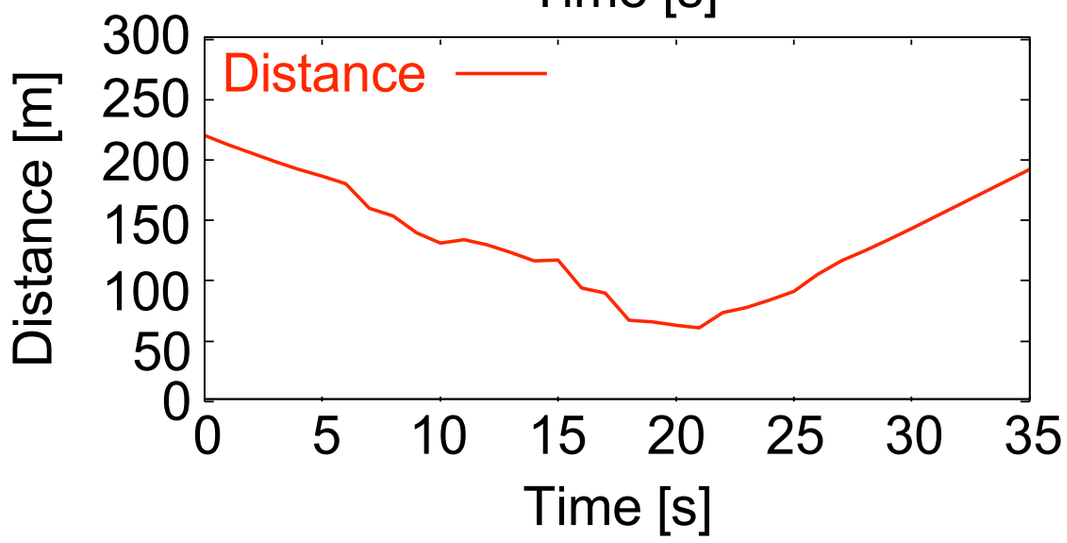
3 - Low distance results in high throughput

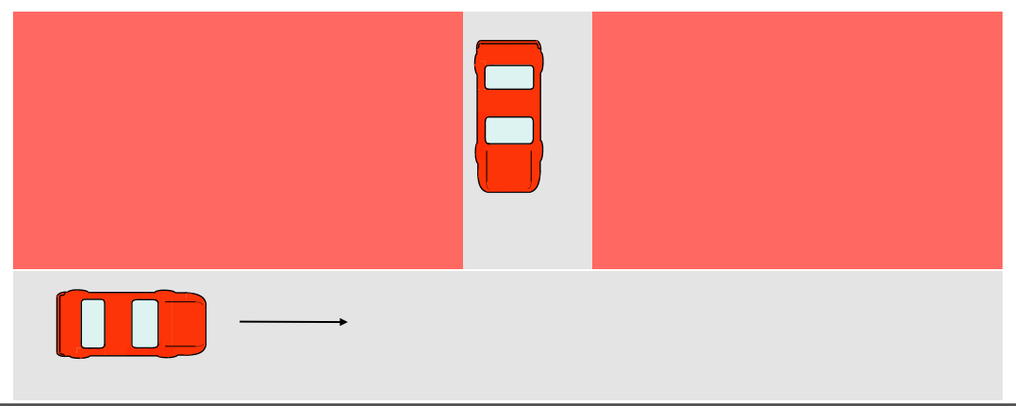
4 - But larger distance does not necessarily mean low throughput



Short connectivity







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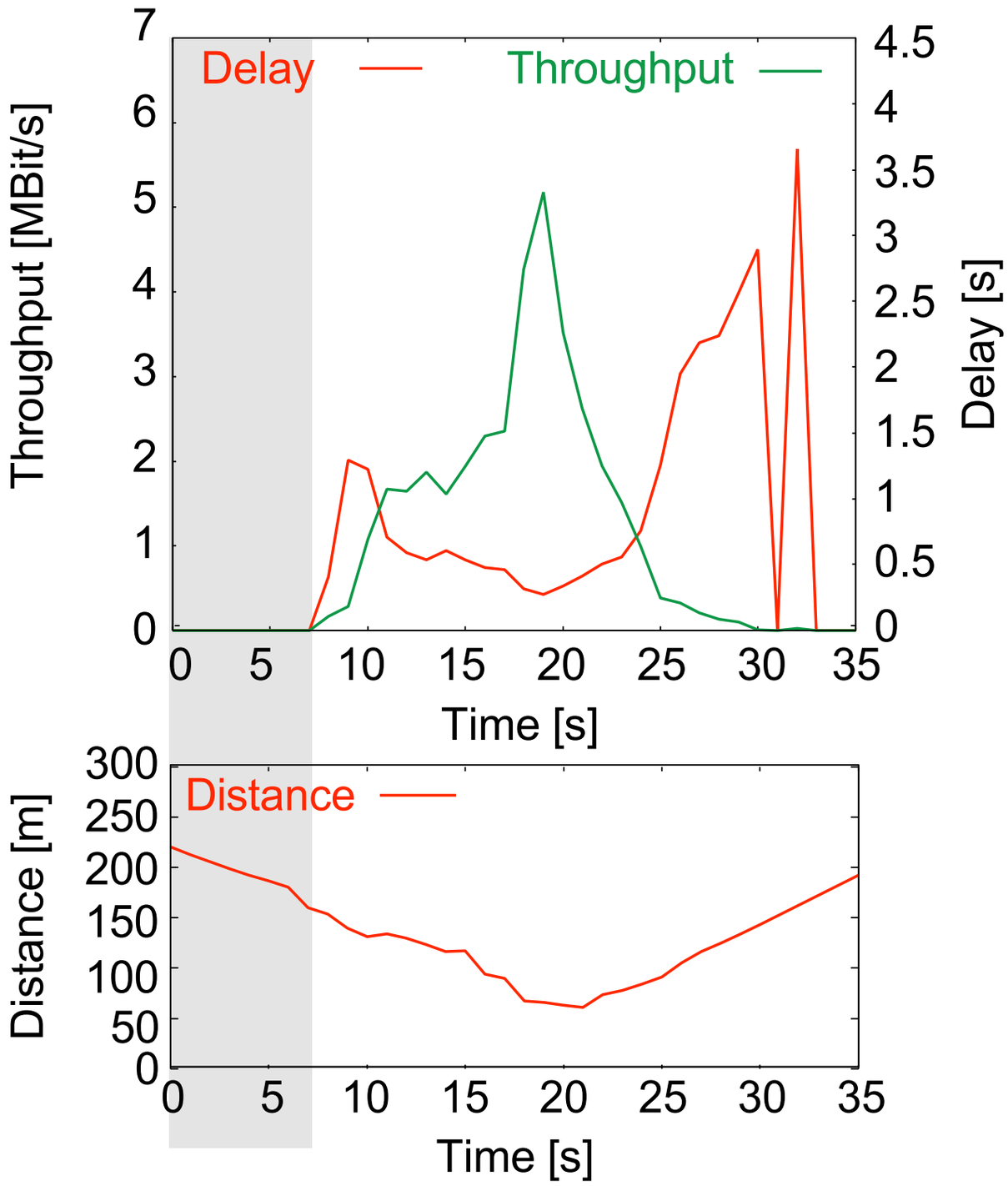
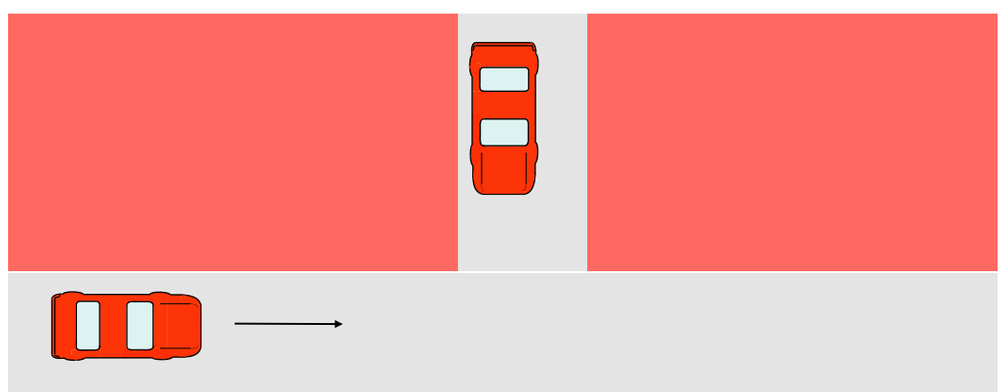


1

- Distance 150 to 200m: No contact between the vehicles



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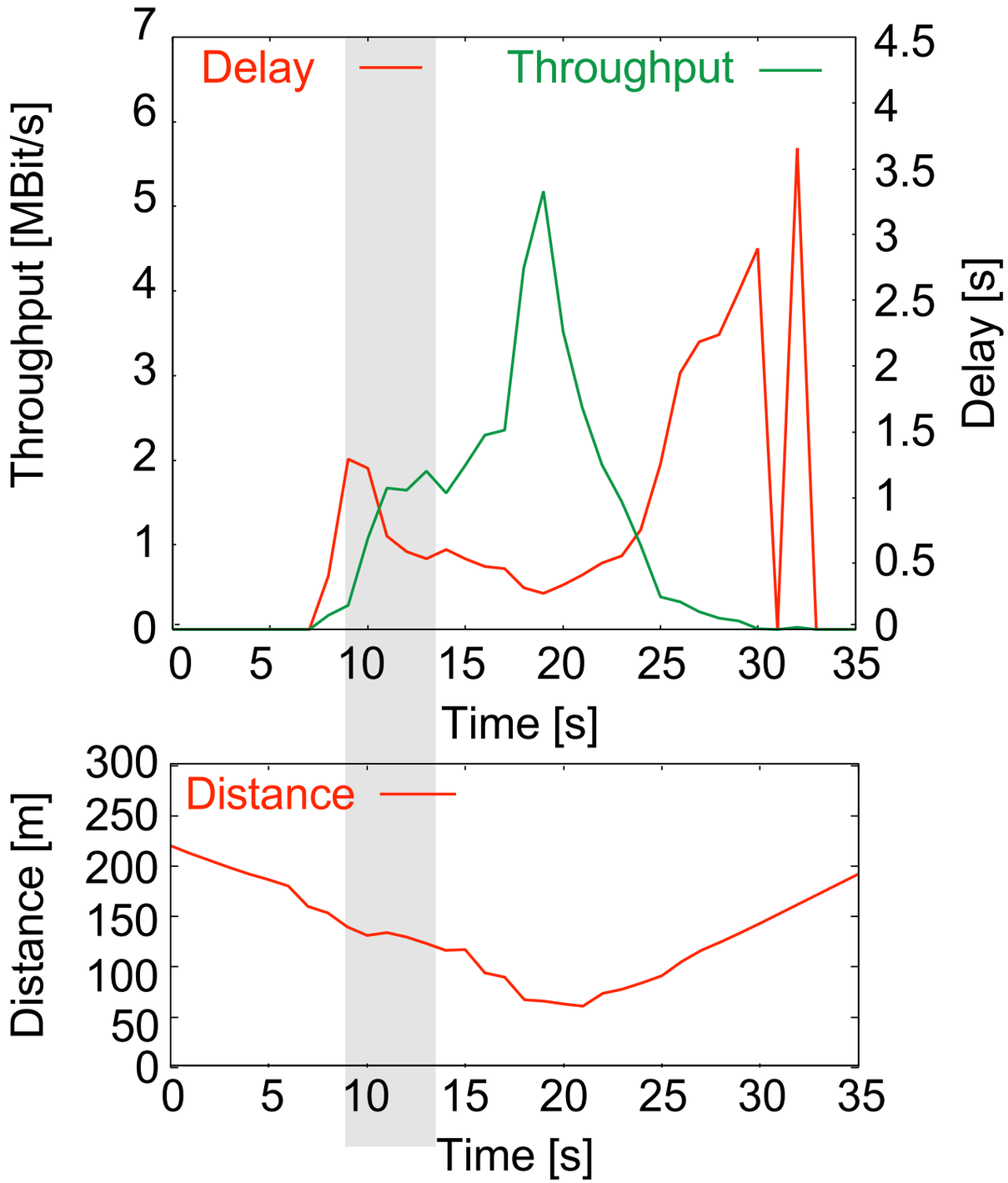
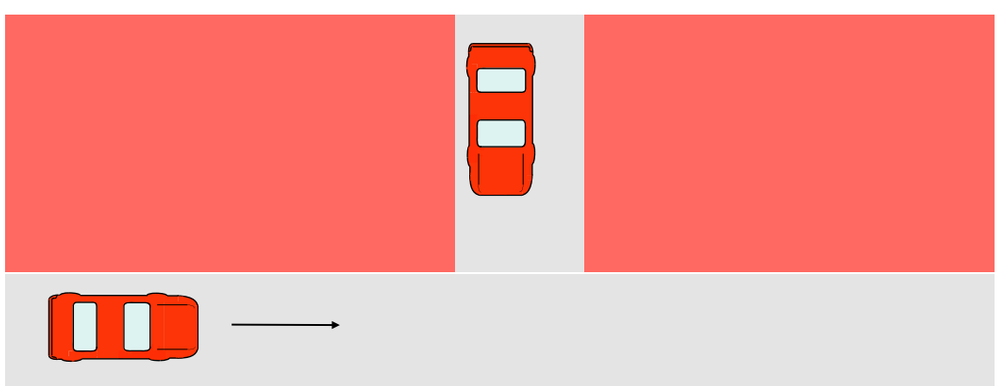


1 - Distance 150 to 200m: No contact between the vehicles

2 - Throughput increases with shorter distance

- Despite static situation a variation in the throughput can be seen



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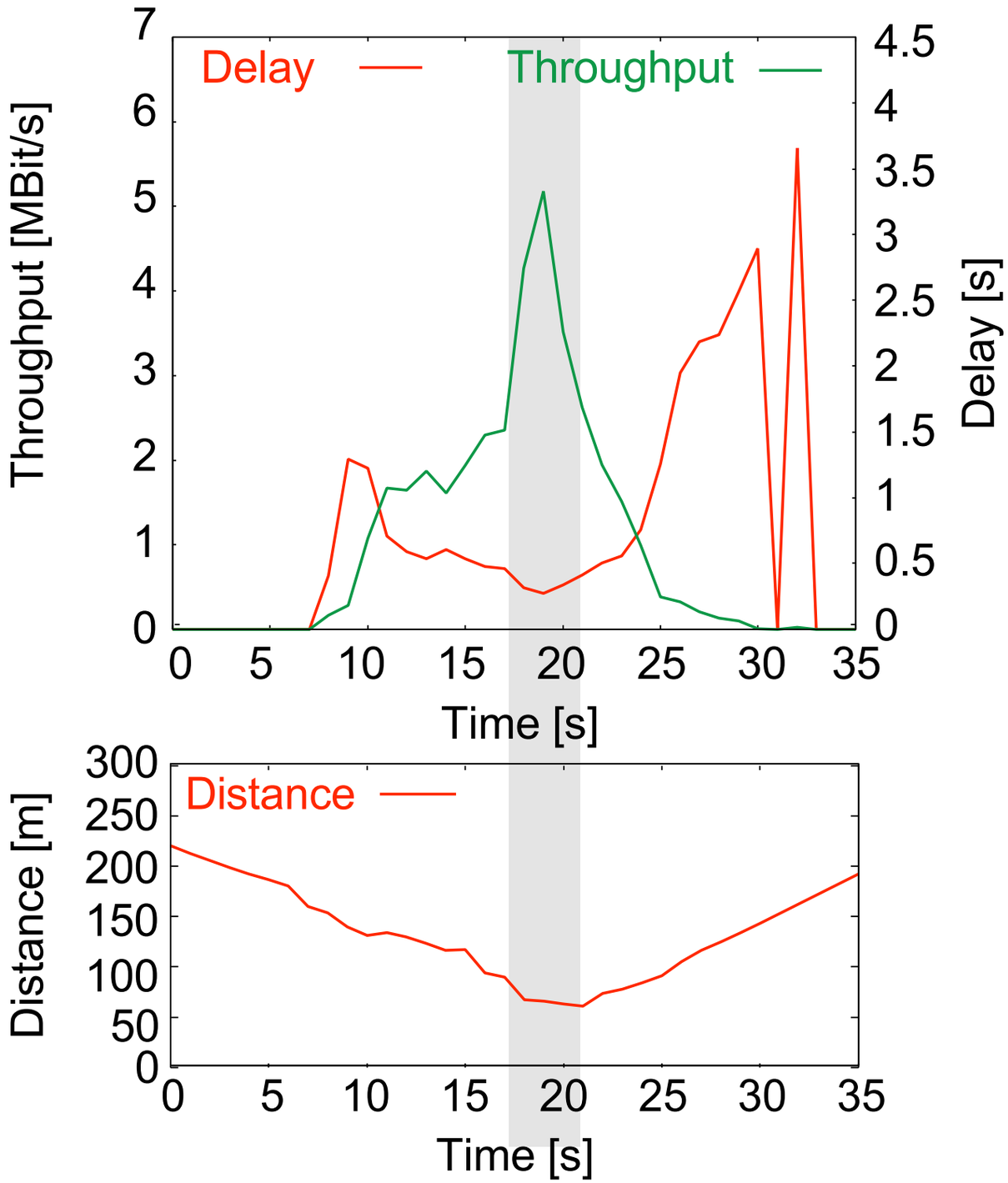
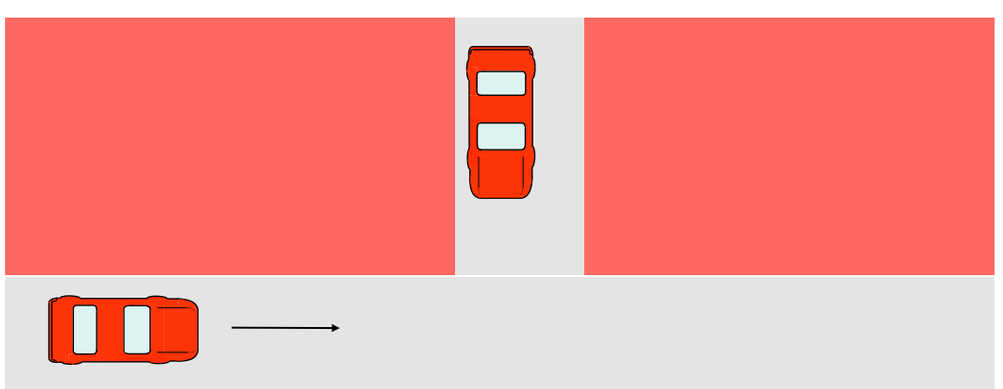


1 - Distance 150 to 200m: No contact between the vehicles

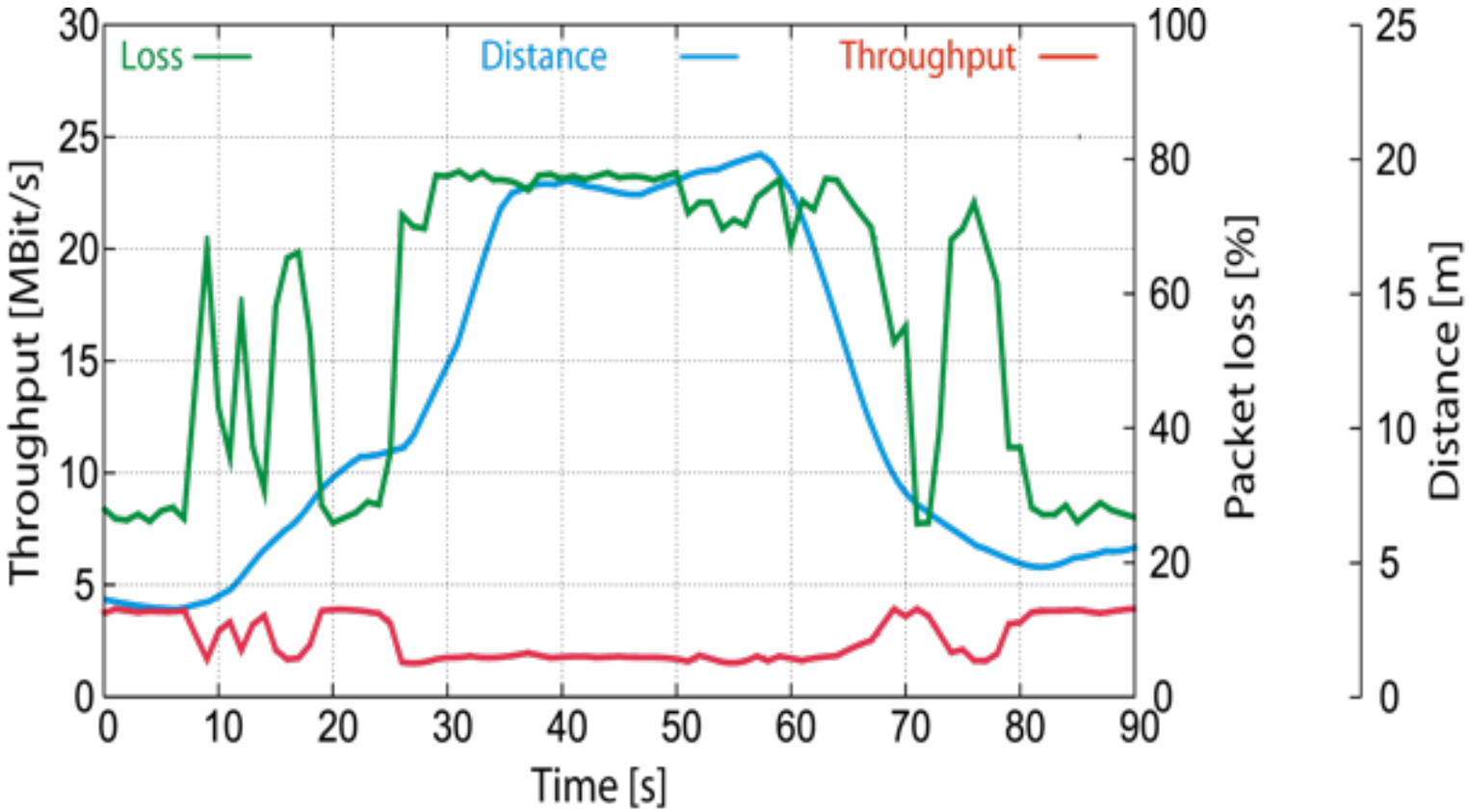
2 - Throughput increases with shorter distance

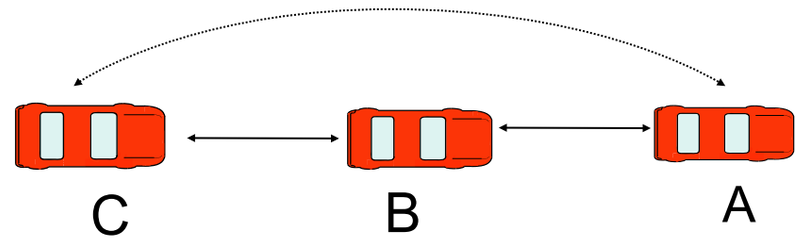
- Despite static situation a variation in the throughput can be seen

3 - During line of sight connection maximum throughput is reached



Hidden Station Problem





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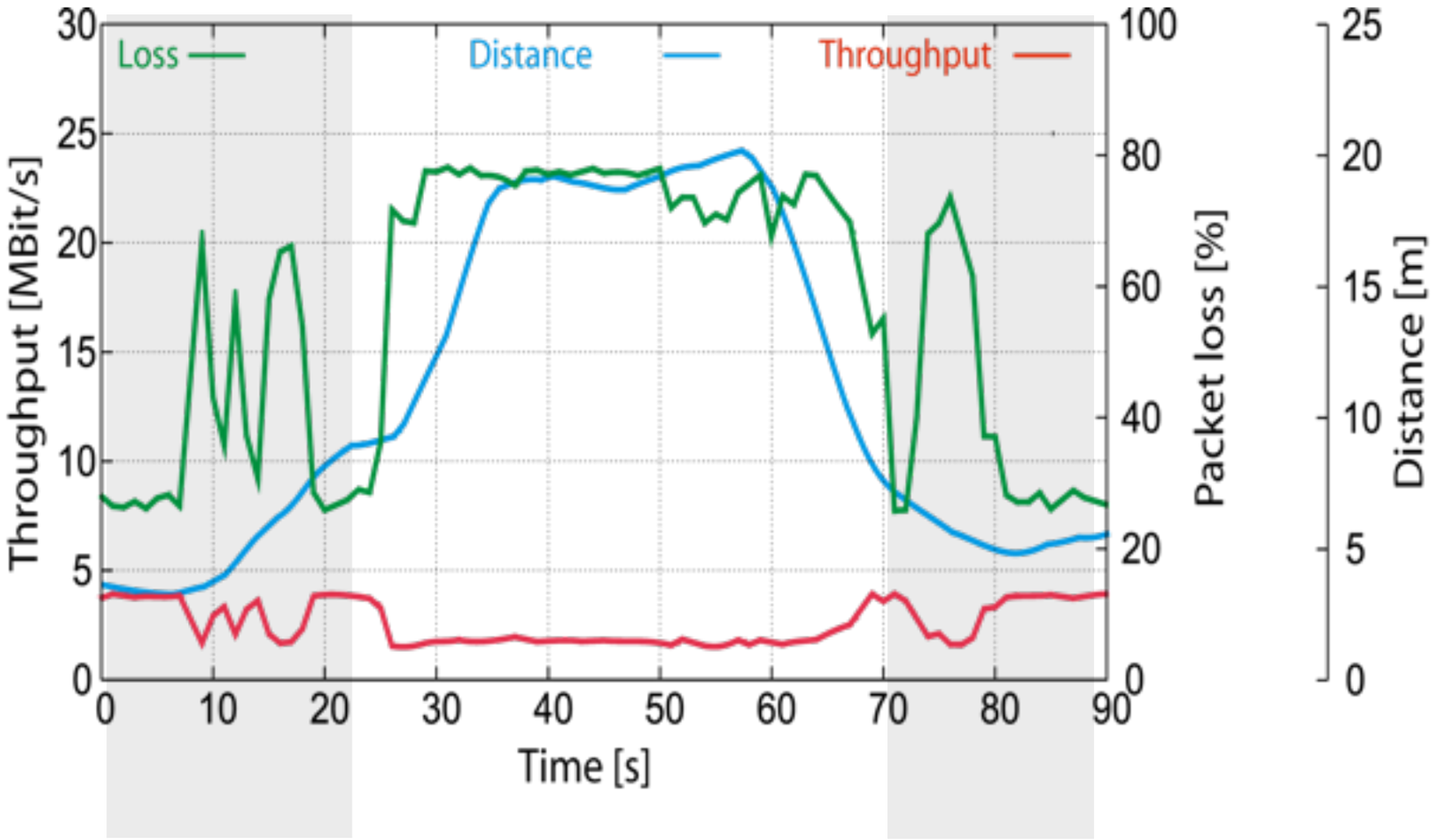
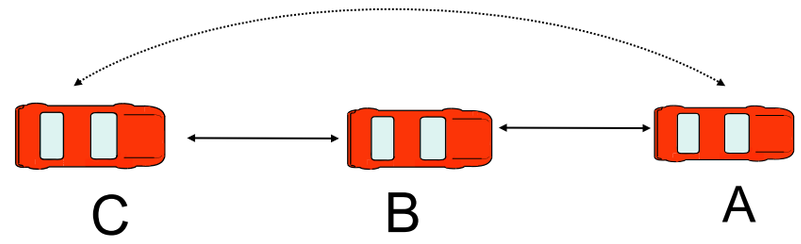
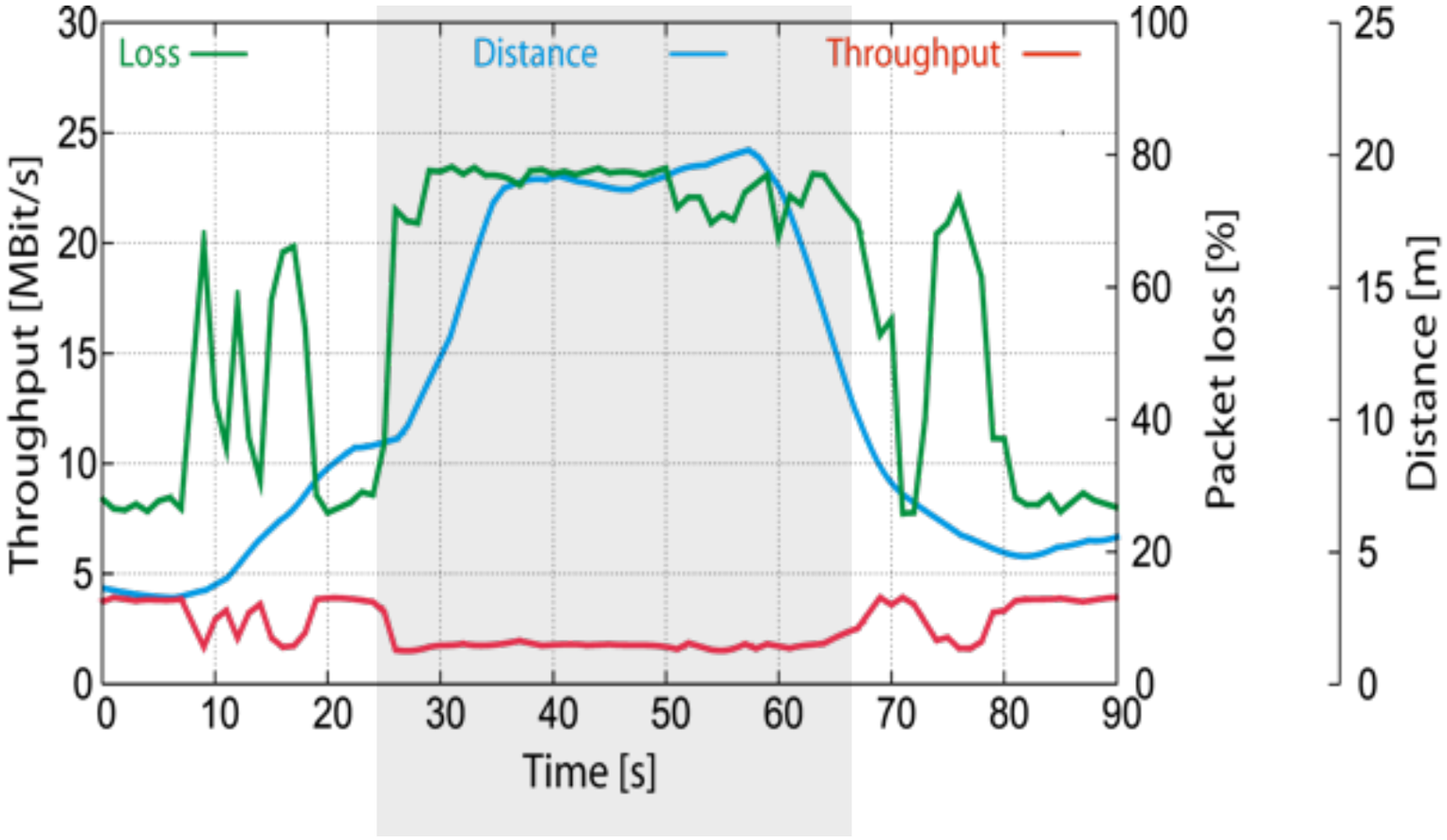


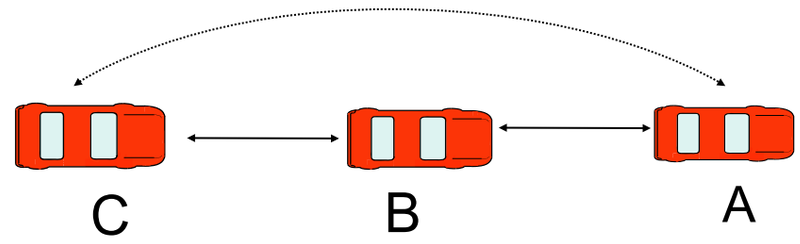


1

- No hidden station -> A and C receive each other
- Packet loss of 20% without movement

Hidden Station Problem





1

- No hidden station -> A and C receive each other
- Packet loss of 20% without movement

2

- A is a hidden station to C and the other way round
- Packet loss of 80%

WLAN for inter-vehicle communication ?

Wireless LAN (IEEE 802.11B) mainly remains unaffected by physical effects

- Relative velocity does not influence throughput
- Multi-path fading with existing line of sight connection is uncritical
- Multi-path fading without line of sight connection has impact

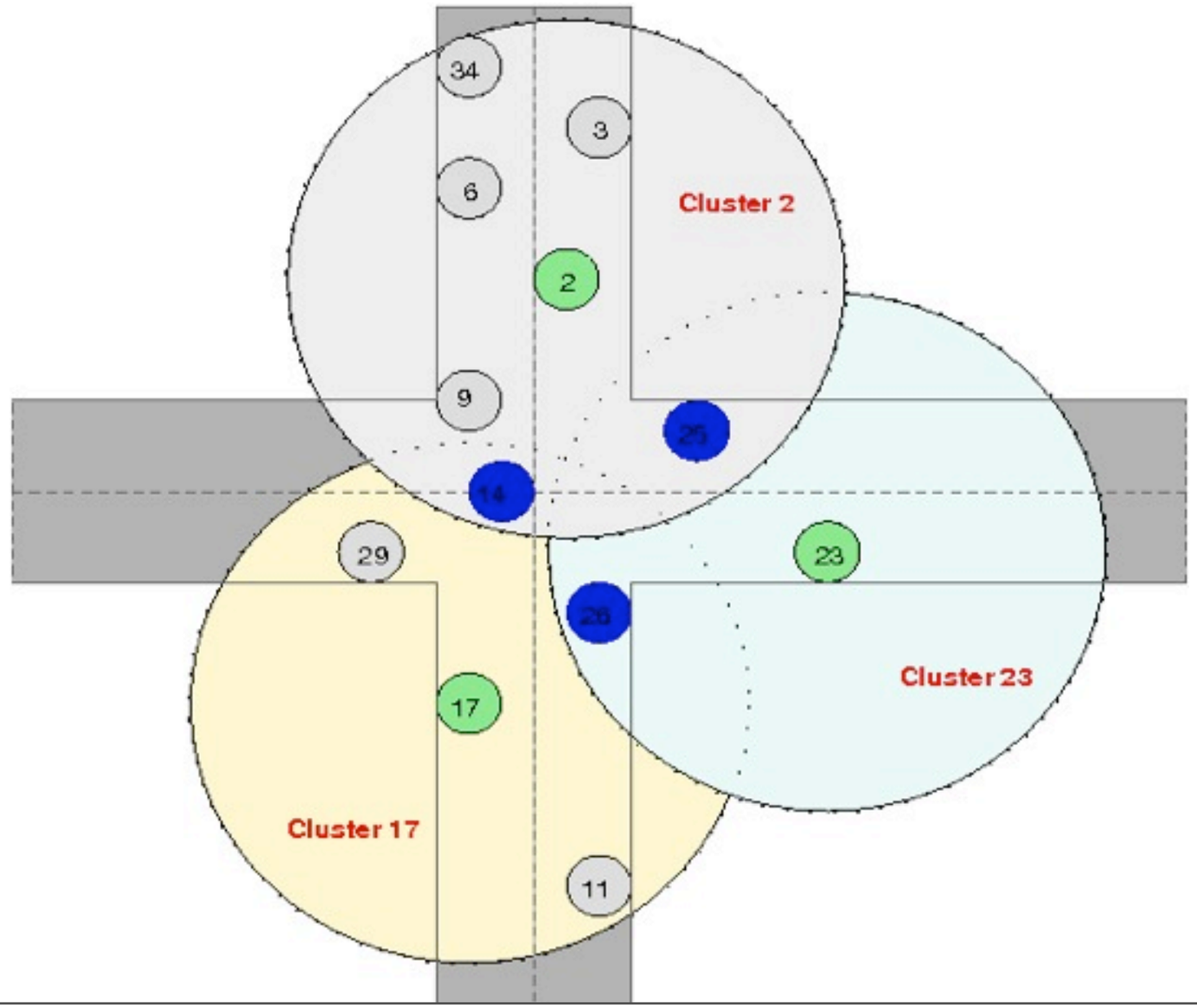
Medium Access Mechanism critical for inter-vehicle communication

- Shared channel causes smaller throughput with more nodes
- In a broadcast transmission hidden stations cause severe packet loss

Cluster-Based Medium Access

Idea

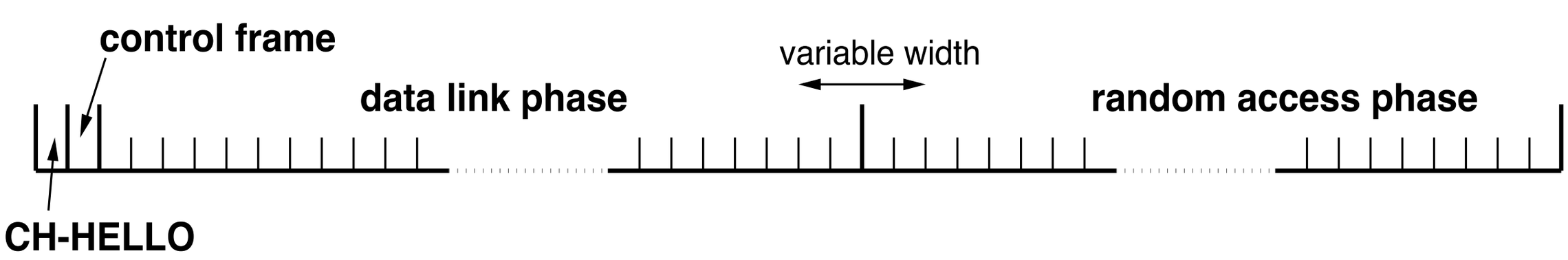
- Organization of vehicles in clusters
- Management of the medium access controlled by a cluster head
- Cluster head is chosen dynamically



Medium Access within a Cluster

TDMA-Scheme

- Channel is divided into time slots
- Slots are assigned to each station by the cluster head



Assignment Process

- Nodes send HELLO messages with required number of slots regularly
- Cluster head lists all member nodes and their slot requirements
- Cluster head assigns slots according to the list
- Undecided nodes register during the random access phase

Cluster-Based Medium Access

Advantage

- Consideration of QoS requirements possible
- Fewer collisions, thus more efficient usage of the channel possible
- Increase in reliability

Disadvantage

- Higher overhead due to centralized structure
- Frequent re-organization of clusters due the traffic dynamics

Aspects

- Algorithm for the election of cluster heads
- Space multiplexing between clusters
- Medium access within the clusters

Election of Cluster Heads

Aim

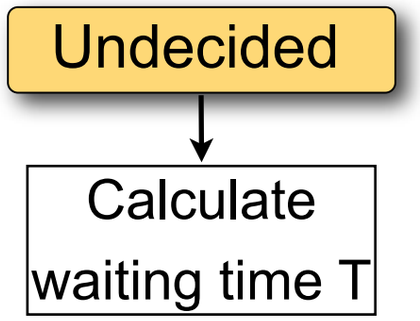
- All nodes in the network have to be assigned to a cluster
- Low frequency in changing cluster heads

Algorithm

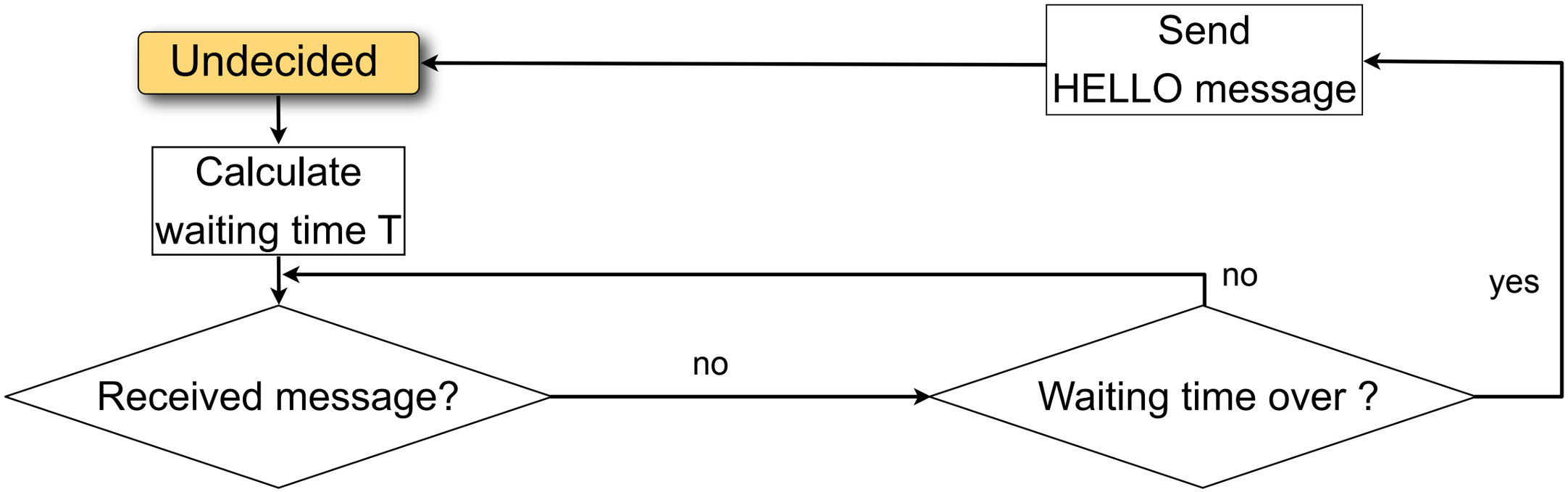
- New nodes start as “Undecided”
- If possible they join an existing cluster
- If they are too far away from the cluster head they build a new cluster
- If they are alone, they stay “Undecided”

Clustering Algorithm

Clustering Algorithm



Clustering Algorithm



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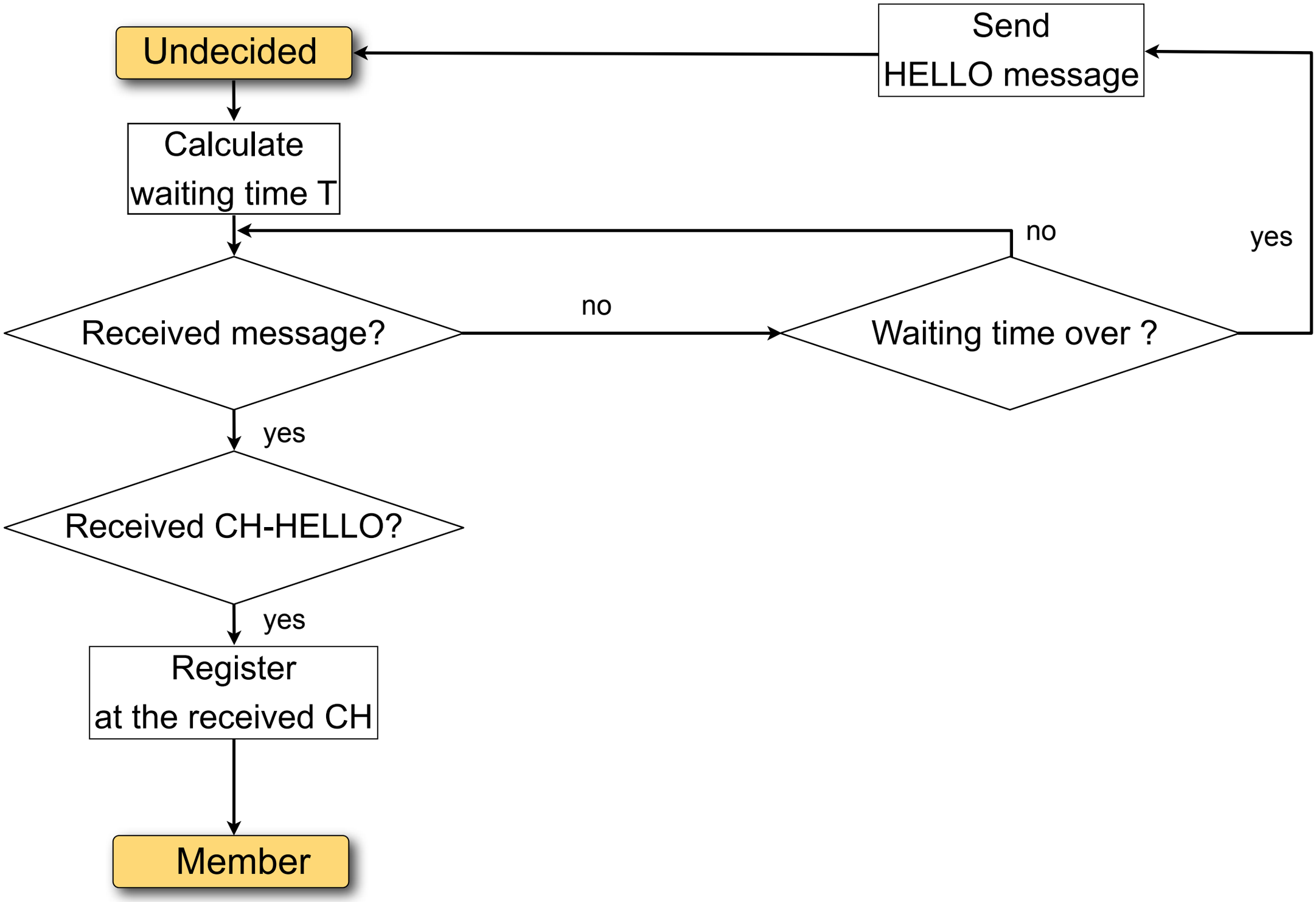
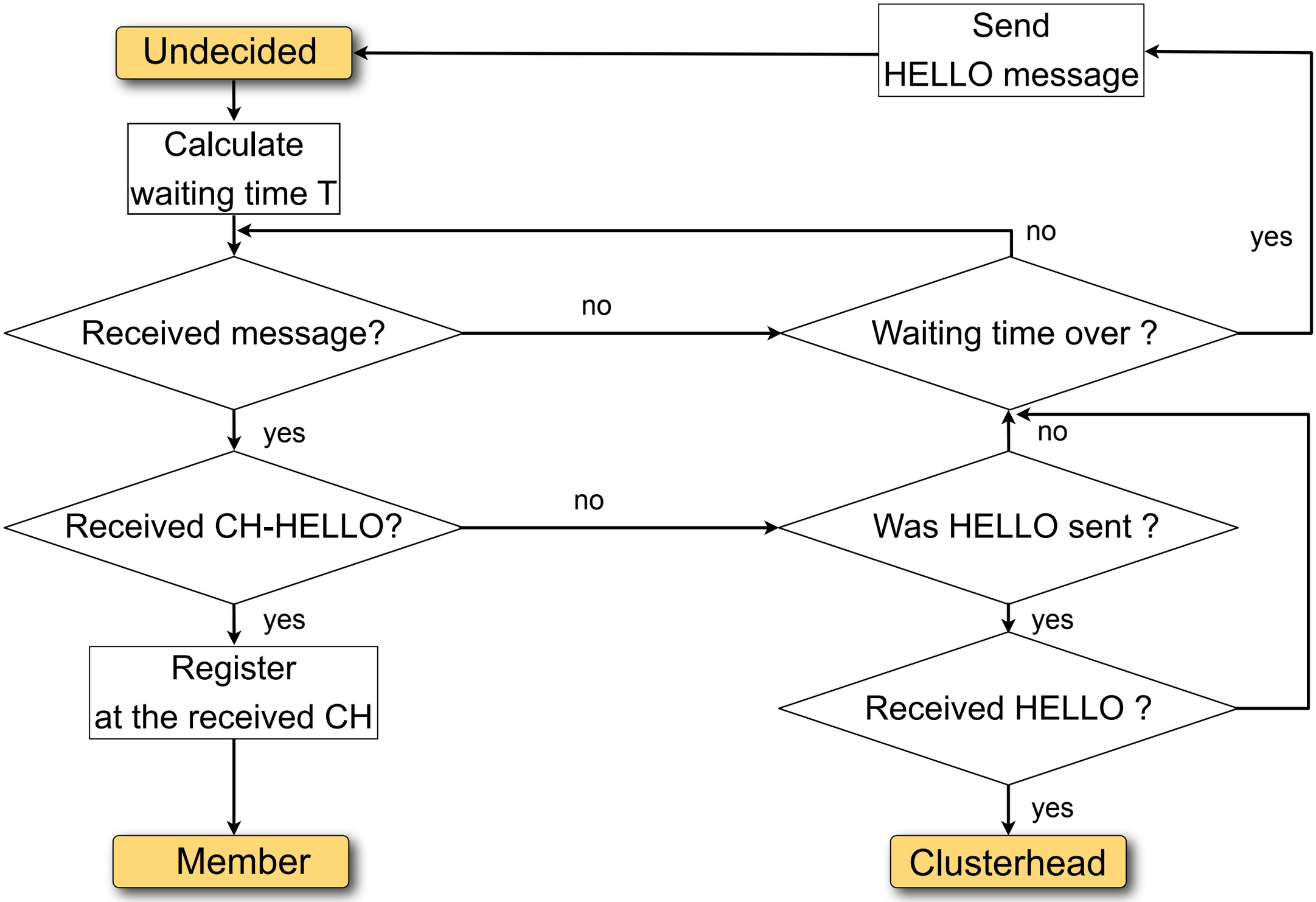


Clustering Algorithm



Clustering Algorithm

Reorganization of clusters

- Clusterhead without member nodes changes to Undecided
- Two clusterheads can exchange data directly
  - Better clusterhead is chosen according to the weighted clustering algorithm
  - Idea:
    - Clusterhead has weighted factor
    - The smaller the factor is, the better is the node suited as clusterhead
  - Parameters:
    - Mobility
    - Connectivity
    - Distance

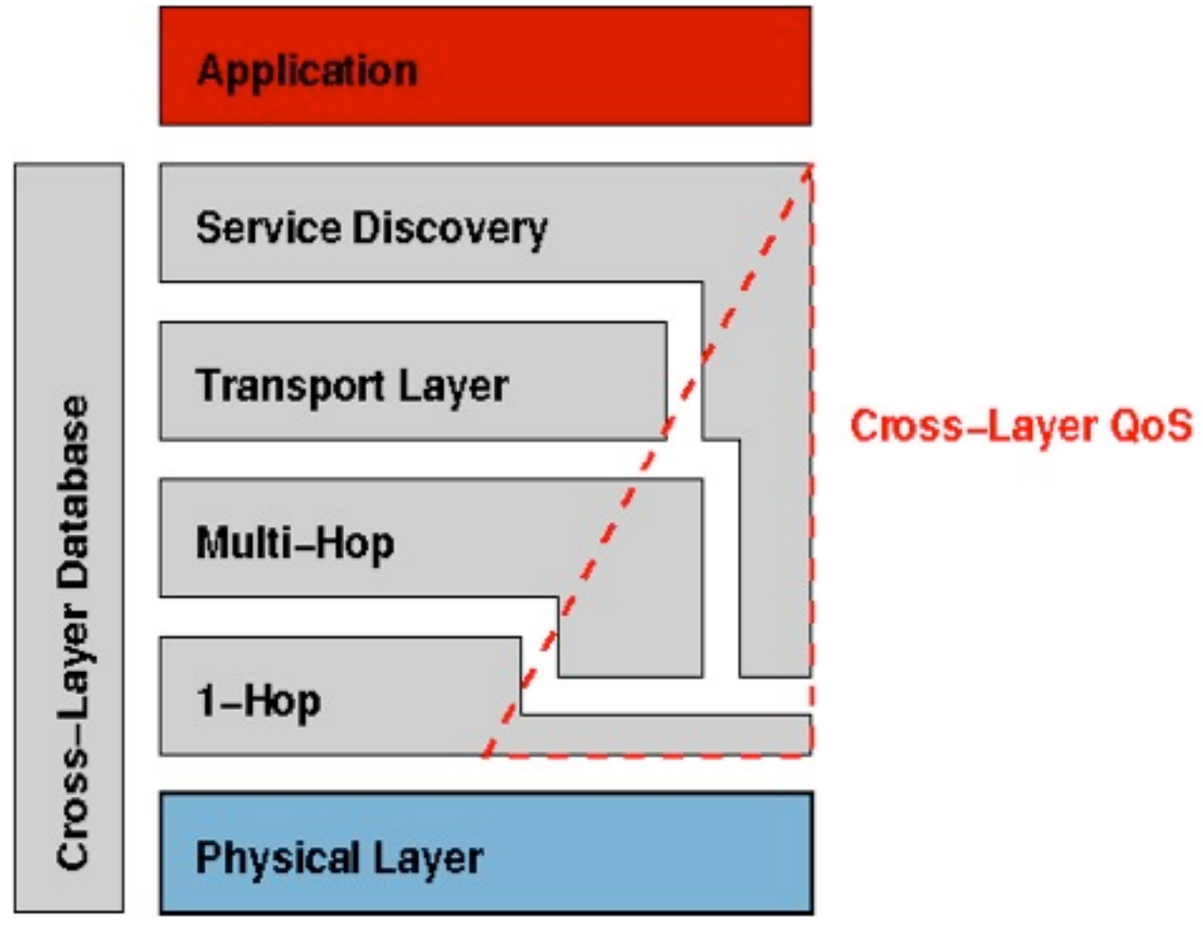
Integration of QoS in the whole communication stack

Interaction between different layers

- Interfaces not only between neighboring layers
- Management and exchange of networking information using a cross-layer database

Benefits

- Providing required QoS
- Decentralized services
- Overhead reduction by intelligent design of the stack



VANET QoS - Resource Allocation

- Guidelines
  - Limited bandwidth - prevent unnecessary messages
  - Fair/guaranteed access to the medium for each node
  - Communication range - spacial reuse of resources

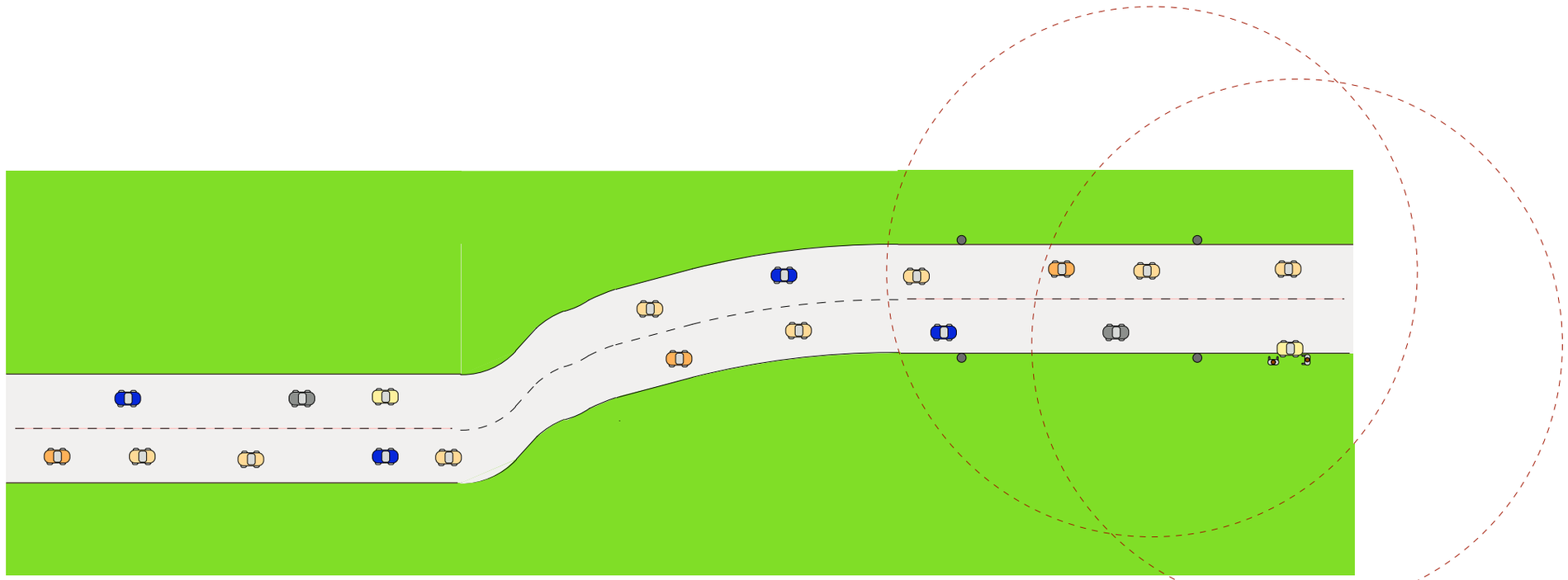
- Cross Layer QoS leads to a resource allocation mechanism

- Distributed services -> several possible information sources

- Information Dissemination vs. Distribution vs. Routing

- Spacial reuse of resources

Information sources



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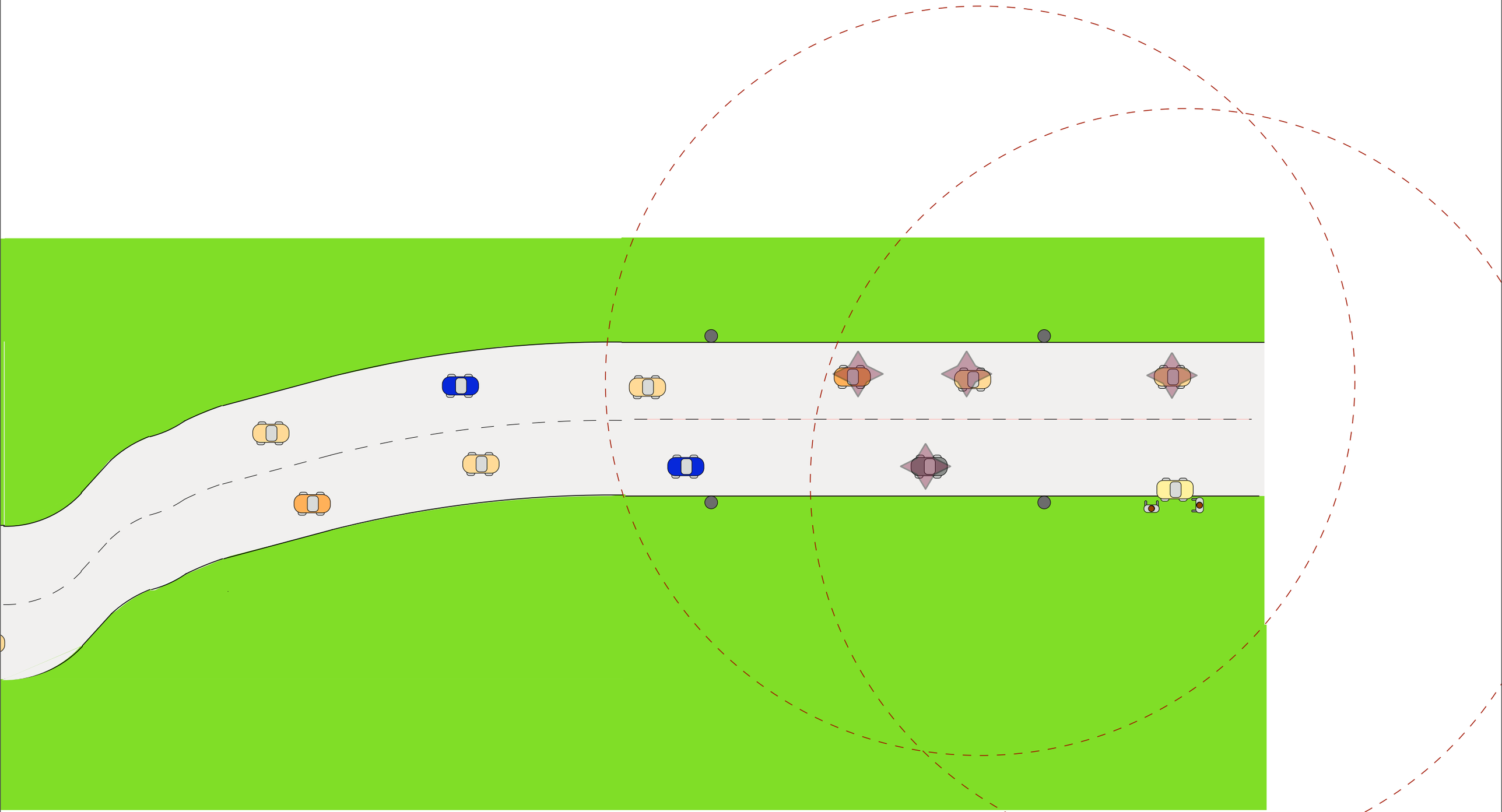

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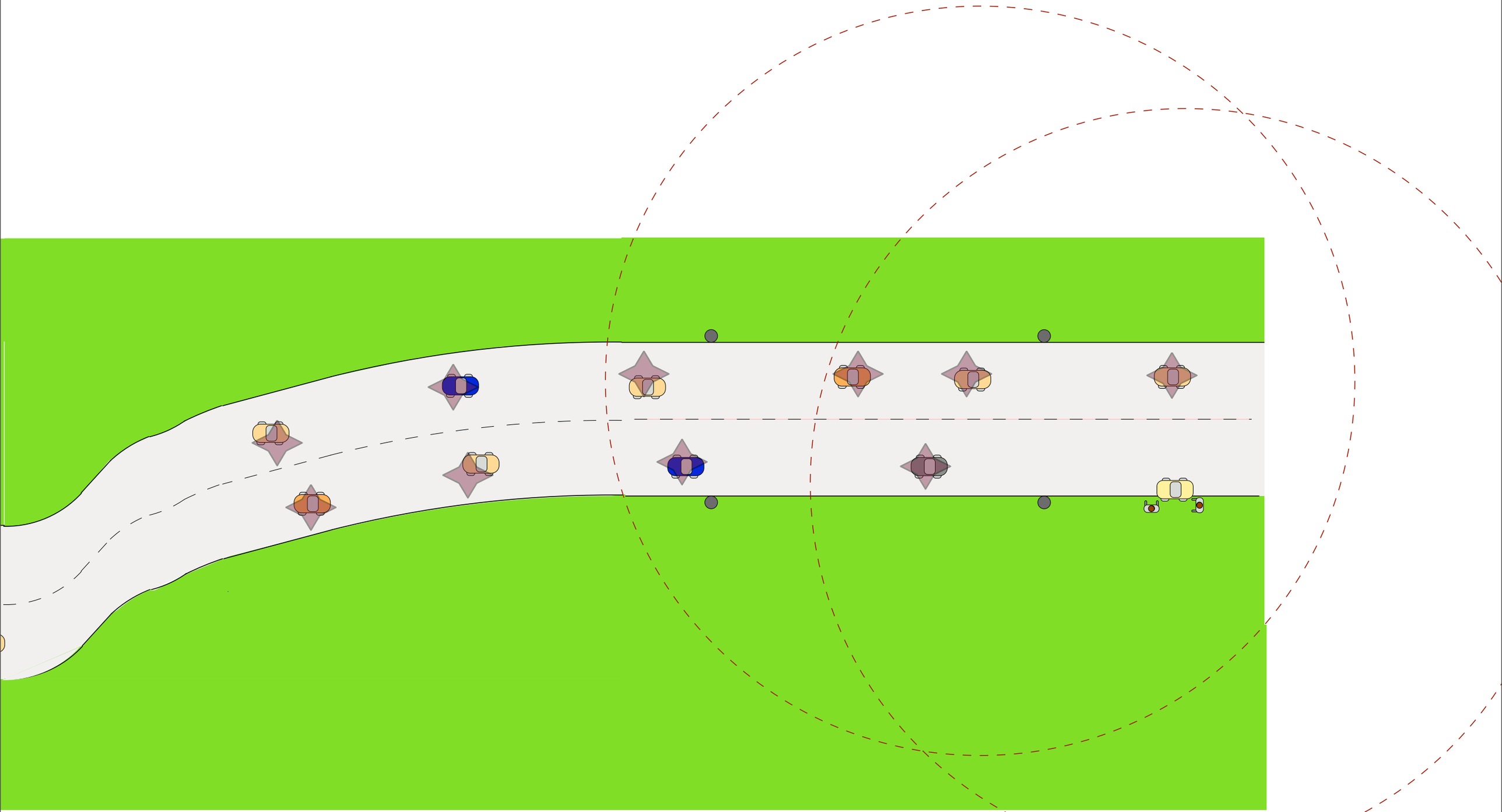

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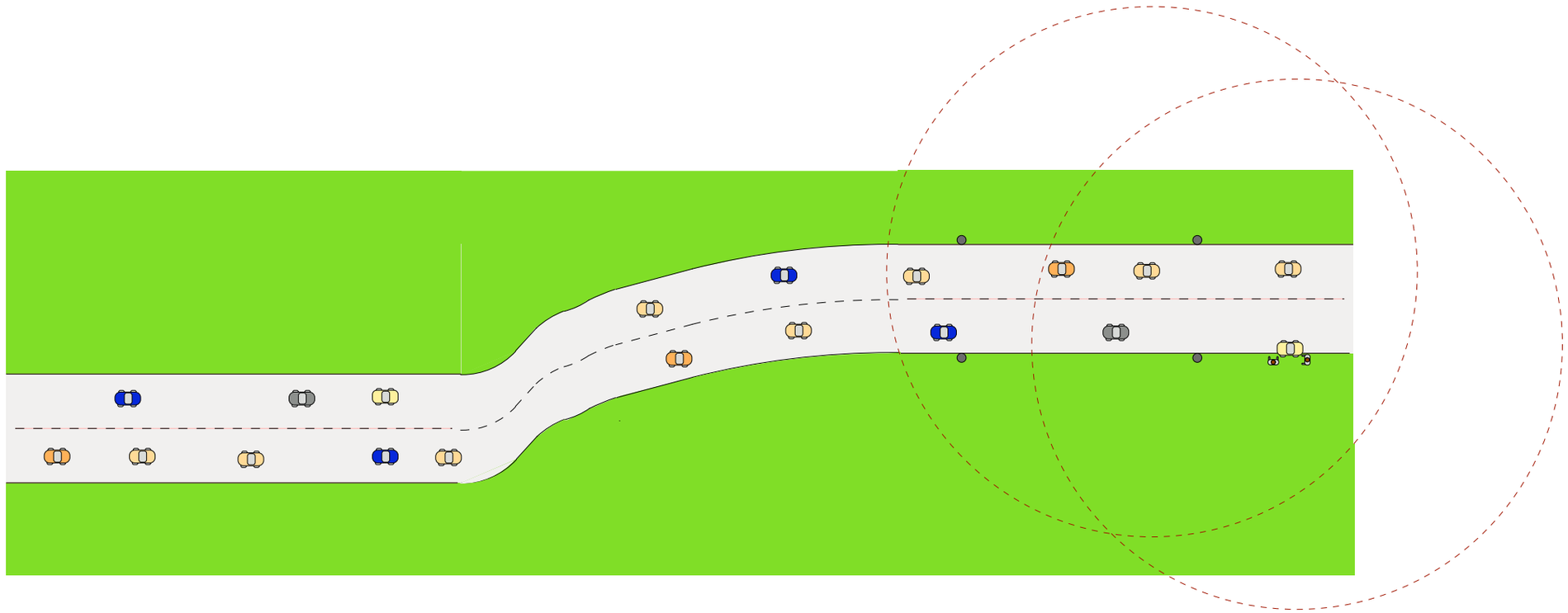

– Determine the optimum amount of bandwidth
  - with best progress of information
  - reliable information distribution
  - low latency

Excursion I: The OMI Traffic Simulator

Simulation of street traffic and communication between vehicles

- C++ based tool developed by our institute
- Visualization with a GUI based on QT4
- Traffic simulation part
  - Environment database
  - Vehicle generation
  - Vehicle routing
  - Vehicle dynamics
- Communication part
  - Model of electromagnetic wave propagation
  - Channel access resp. collision simulation
  - Upper layer protocol modules

Excursion II: Development of a demonstrator platform

Idea: *Resize the real environment*

- Combination of a self-driving model car and a Software Defined Radio (SDR) for communication
  - Car control by an embedded ARM9 based platform
  - Several sensors for movement and surrounding
- SDR development platform
  - Altera FPGA based Dev. Kit
  - In progress: Design of the physical layer of a communication system that is suitable for VANETs