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# Dynamic **Backbone** for Fast Information Delivery in **Vehicular Ad Hoc Networks**: An Evaluation Study

**Marco Di Felice**

**Luca Bedogni**  
University of Bologna, Italy

**Luciano Bononi**





# Outline

**Vehicular Ad Hoc Networks**

**Multi-hop broadcast dissemination protocol**

**DBA-MAC: Backbone Creation Process**

**DBA-MAC: Metrics for Backbone Member Selection**

**DBA-MAC: Medium Access Control Protocol**

**Performance Results**

**Conclusions**

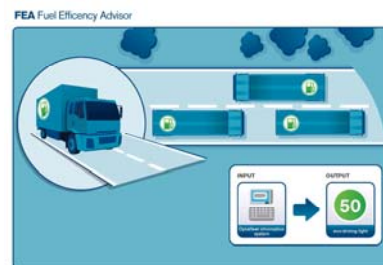


# Vehicular Ad Hoc Networks (**VANETs**)

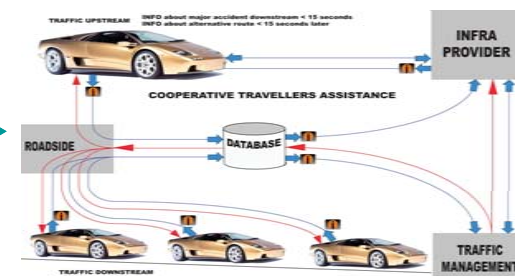
- ❖ The success and popularity of VANETs are demonstrated by the increasing number of EU research **projects** and **applications** proposed for the vehicular environment.

## EXAMPLES

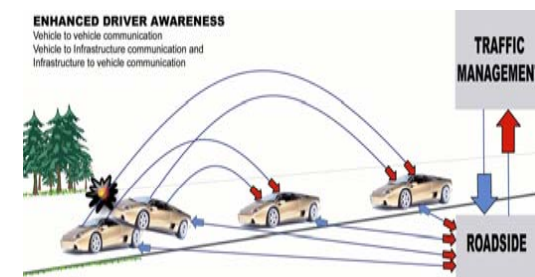
- Enhanced Driver Assistance Applications (**CVIS** Project)
- Cooperative Driver Assistance (**CVIS** Project)
- Adaptive Cruise Control (**Eurofot** Project)
- Forward Collision Warning (**Eurofot** Project)
- Fuel Efficiency Advisor
- ...



<http://www.eurofot-ip.eu/>



<http://www.cvisproject.org>



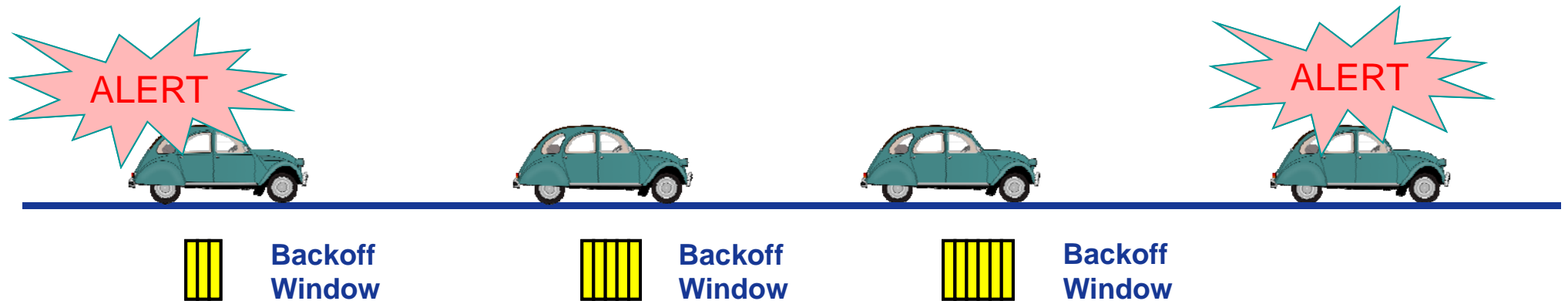
- ❖ Most of these applications require **fast and efficient information delivery** over multiple hops.



# Reactive Multi-hop Broadcast Schemes

## ❖ Reactive multi-hop broadcast schemes:

- Once an ALERT message is produced in the VANET, the next-forwarder is decided on-the-fly among the neighbours of the sender vehicle.
- Techniques** to decide the next-hop forwarder: biased contention, *black bursts*, *spatial bipartition*, etc.



**PRO:** Reduced network overhead

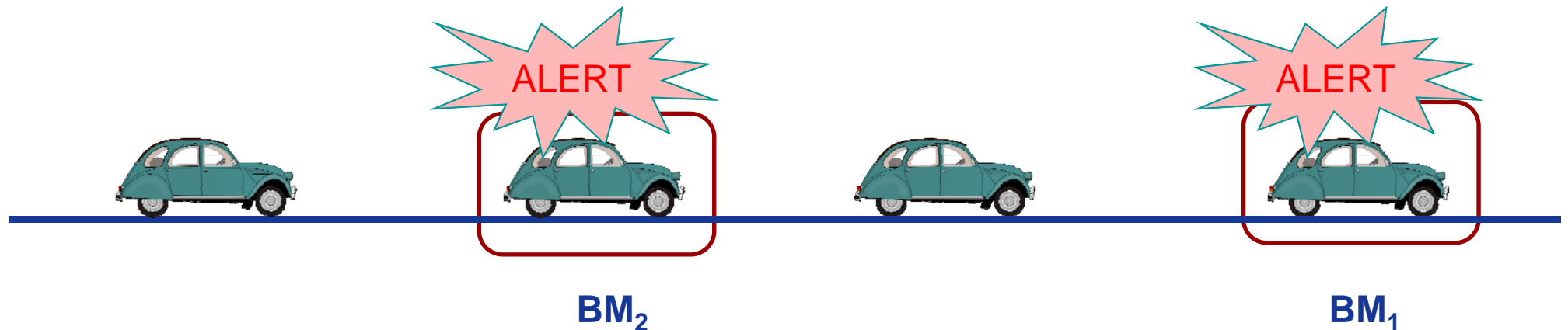
**CONS:** Additional *delay* and *collisions* caused by the distributed contention ...



# Proactive Multi-hop Broadcast Schemes

## ❖ Proactive multi-hop broadcast schemes:

- They identify a dynamic virtual backbone inside the VANET through a distributed **clustering** schemes.
- Alert messages are rebroadcasted by *Backbone Members (BMs)* only.



- PRO:** No contention required for message forwarding (reduced delay)
- CONS:**
- **Overhead** for backbone creation and maintenance
  - How to **choose** the backbone **members** in an optimal way?



# Dynamic-Assisted MAC Protocol (**DBA-MAC**)

## GOALS:

- **Combine** the benefits of pro-active and reactive broadcast schemes
- **Exploit** the presence of a backbone structure inside the VANET

## *Cross-Layer* Solution

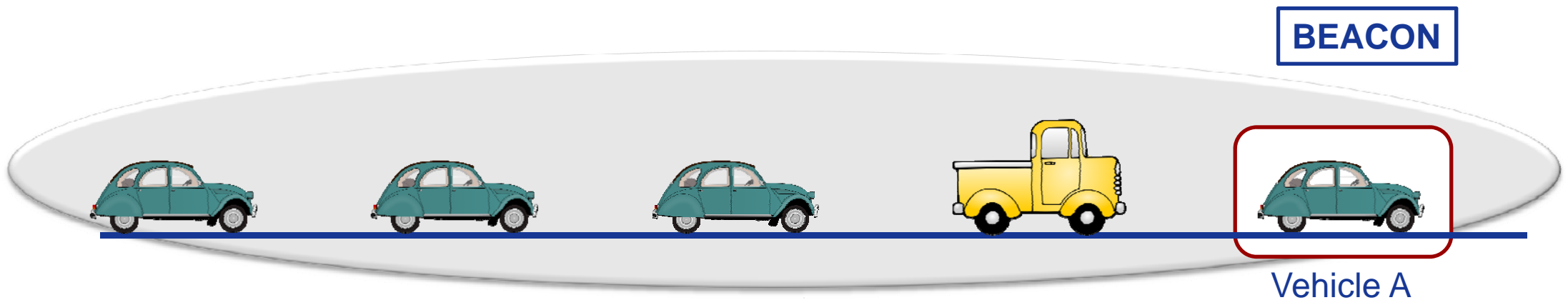
**2.5 Layer. Distributed algorithm for Backbone Creation and Maintenance in a VANET**

*MAC Layer.* Sender-oriented MAC scheme exploiting the presence of the backbone (Dynamic Backbone-Assisted MAC)



# DBA-MAC: **Clustering** Creation Process

- ❖ **STEP 0:** Vehicle A elects itself as **Backbone Member (BM)** and broadcasts a **BEACON** message.



- ❖ Each vehicle B verifies if its *elegible* to be **next-hop** of the backbone:

$$|v_A - v_B| < v_{\max} \quad \text{and} \quad \theta < \theta_{\max}$$

Difference in *speed*

Current *angle* between the directions of the vehicles

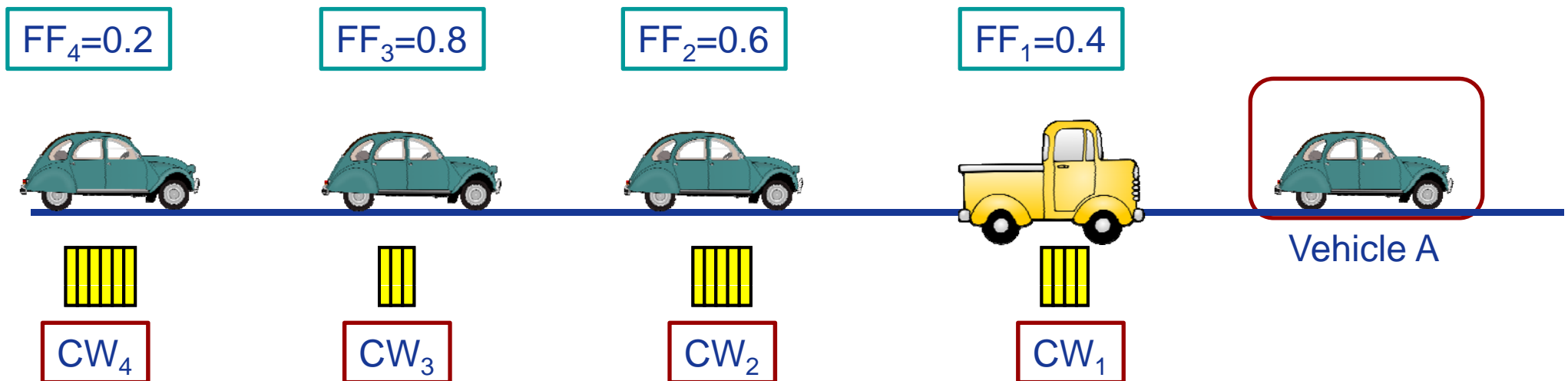


# DBA-MAC: **Clustering** Creation Process

❖ **STEP 1:** Each vehicle B computes a **Fit Factor (FF)** that gives the rank to become the next-hop node of vehicle A.

❖ Based on the FF, vehicle B adjusts its *Contention Window* ( $CW_B$ ):

$$CW_B = (1 - FF_B) * (CW_{MAX} - CW_{Min}) + CW_{Min}$$

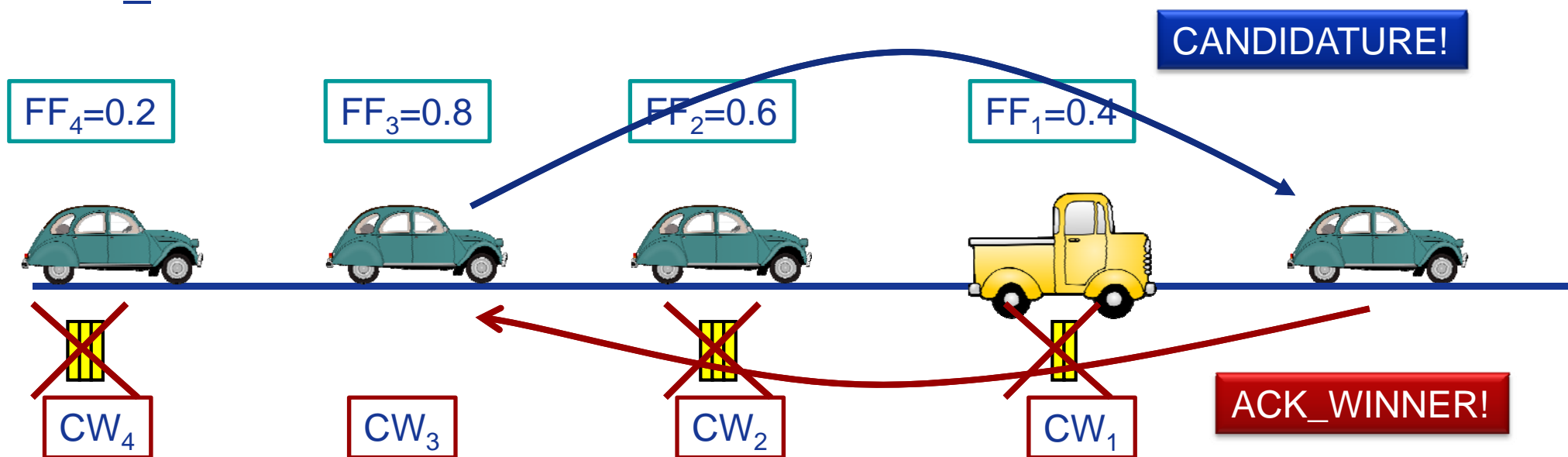






# DBA-MAC: **Clustering** Creation Process

- ❖ **STEP 2:** When the backoff value is zero, vehicle B transmits a **CANDIDATURE** message to vehicle A and waits to receive an **ACK\_WINNER** from A.

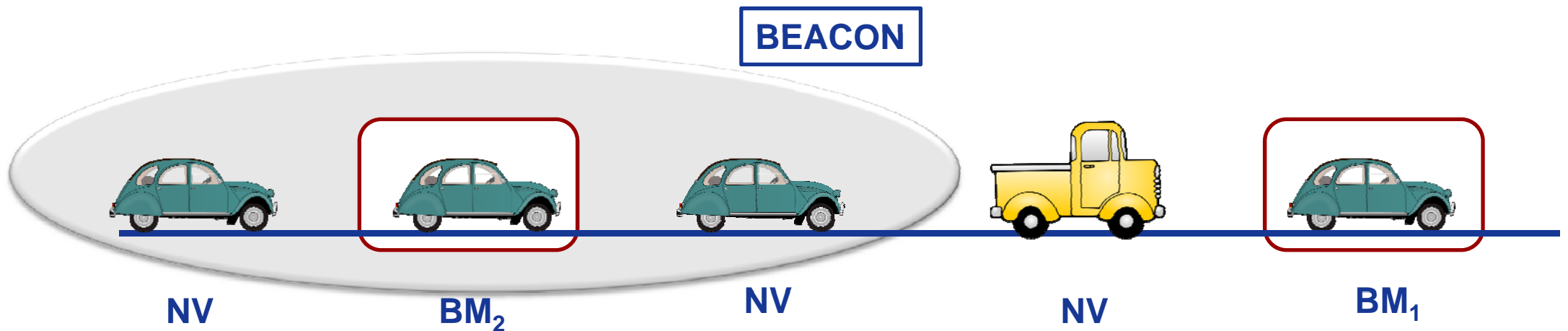


A vehicle cancels its transmission attempt in case it overhears a **CANDIDATURE** message from another vehicle.



# DBA-MAC: **Clustering** Creation Process

- ❖ **STEP 3:** Vehicle B elects itself as Backbone Member (**BM**) and broadcasts a BEACON to **propagate** backward the backbone creation process.



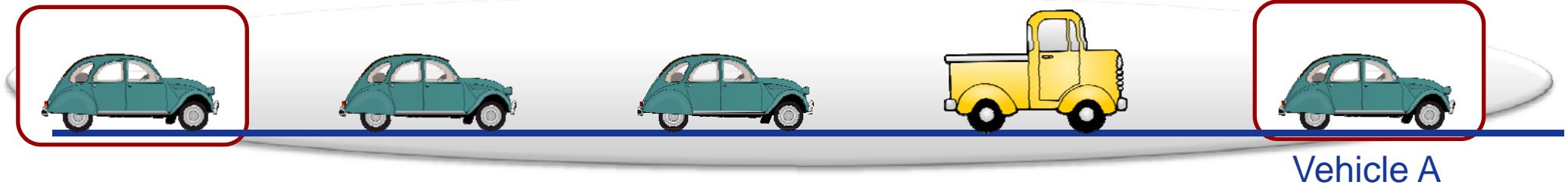
After the creation process, each vehicle is assigned a role in the backbone: Backbone Member (**BM**) or Normal Vehicle (**NV**).



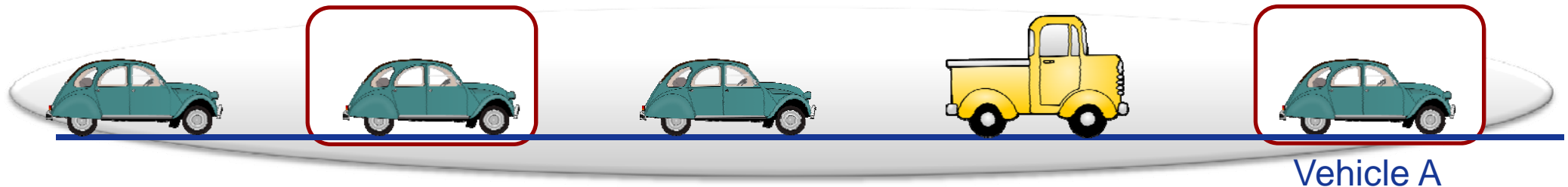
# Metrics for Backbone Members Selection

- ❖ **PROBLEM:** - How to determine the backbone members?
  - How to define the FF metric?

**METRIC 1** (Hop minimization). Choose the farthest neighbour of vehicle A.



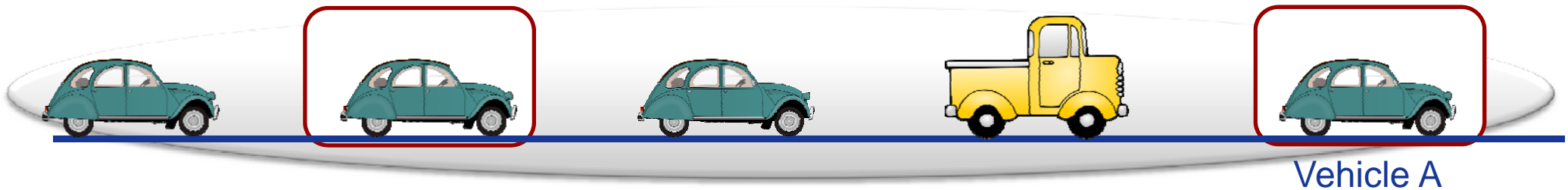
**METRIC 2** (Delay minimization). Choose the link providing the lowest delivery delay.





# Metrics for Backbone Member Selection

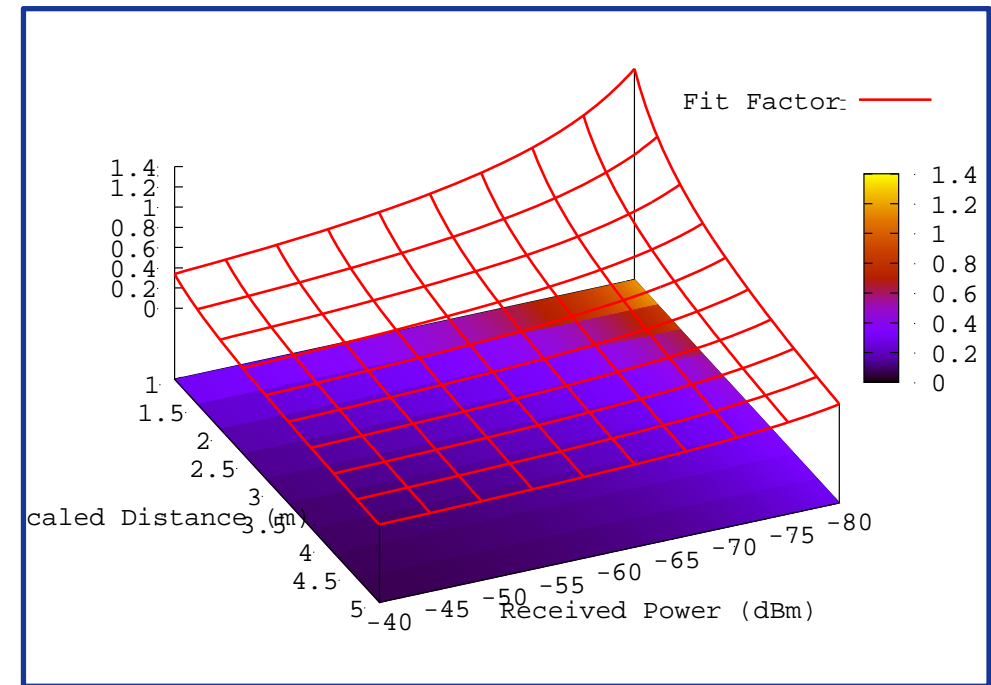
**METRIC 2 (Delay minimization).** Choose the link providing the lowest delivery delay.



$$FF(\psi, \eta) = \frac{1}{LB_{scaled}(\psi, \eta)} \cdot \frac{\Delta_d}{d}$$

Link-budget between vehicles A and B

Distance between vehicles A and B





# Dynamic-Assisted MAC Protocol (**DBA-MAC**)

## GOALS:

- **Combine** the benefits of pro-active and reactive broadcast schemes
- **Exploit** the presence of a backbone structure inside the VANET

## *Cross-Layer* Solution

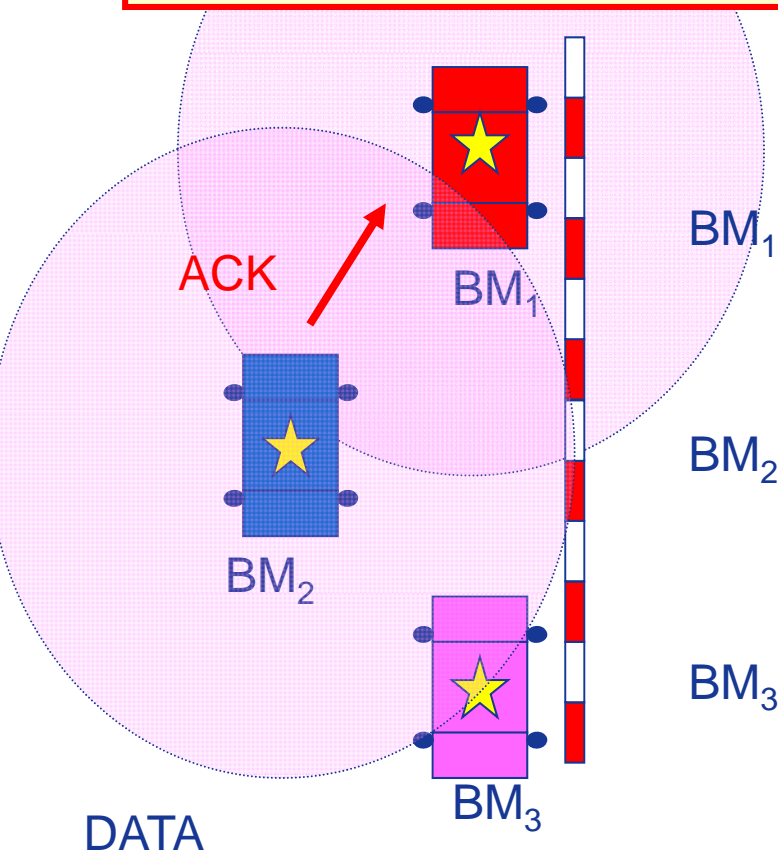
1. *2.5 Layer*: Distributed algorithm for Backbone Creation and Maintenance in a VANET
2. *MAC Layer*: **Sender-oriented MAC scheme exploiting the presence of the backbone structure (Dynamic Backbone-Assisted MAC)**



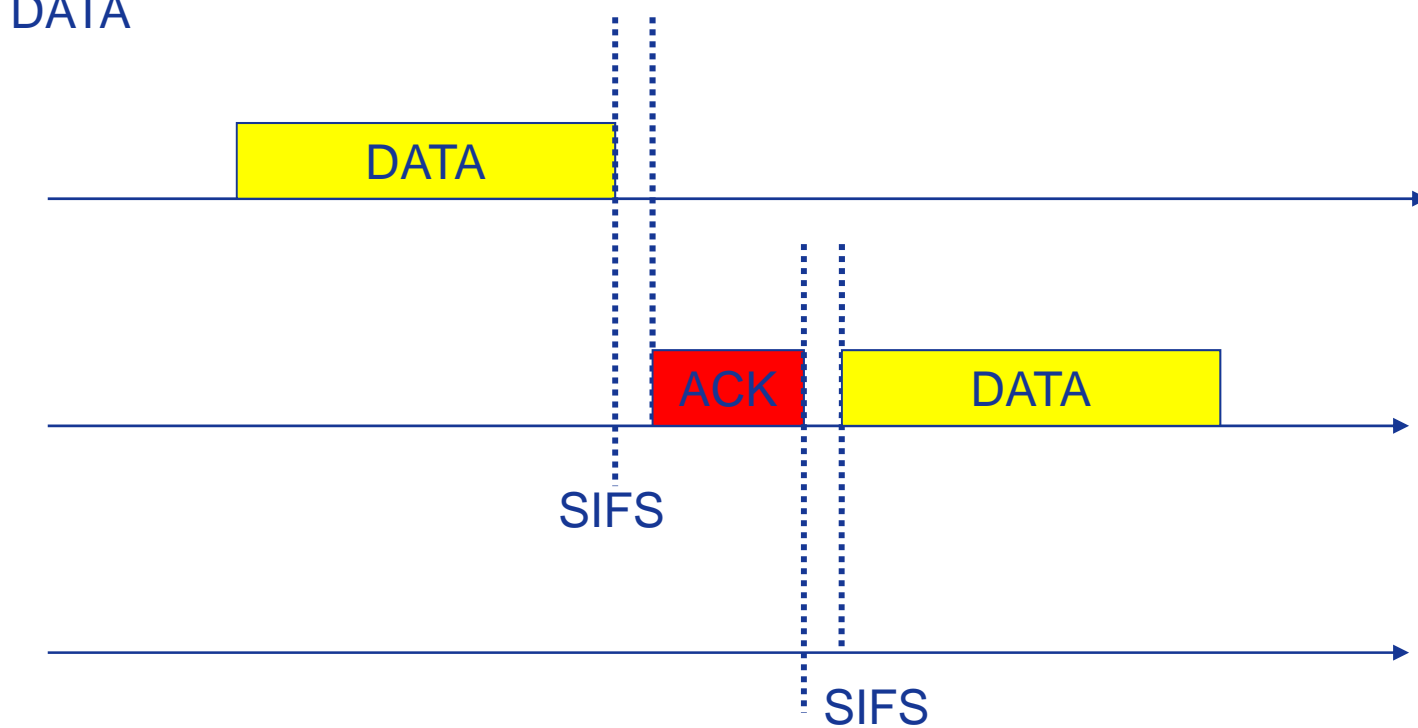
# Fast MultiHop Forwarding (**FMF**) Scheme

When  $BM_{i+1}$  receives a message from  $BM_i$

- ❖  $BM_{i+1}$  sends back an acknowledgment after a SIFS to  $BM_i$
- ❖  $BM_{i+1}$  immediately broadcasts the message toward  $BM_{i+2}$  (if any)



DATA





# Contention-Based Forwarding (CBF) Scheme

- The CBF Scheme is adopted as a background scheme when the backbone assisted FMF fails.
- The CBF scheme is adopted if a vehicle K receives an alert message:
  - K is a Normal Vehicle (NV)
  - K is a Backbone Member (BM) performing a retransmission
- The CW size is dynamically adjusted according to the backbone role:

$$\text{CW (NV)} = (1-d/R) * (\text{CW}_{\text{MAX}} - \text{CW}_{\text{Min}}) + \text{CW}_{\text{Min}}$$

$$\text{CW (BM)} = 4$$



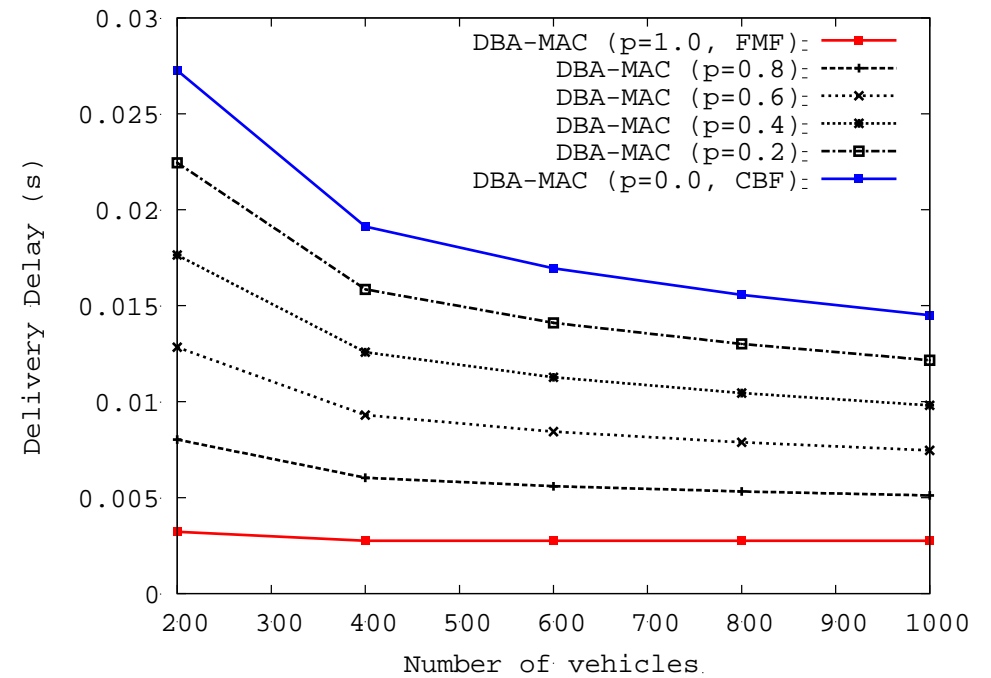
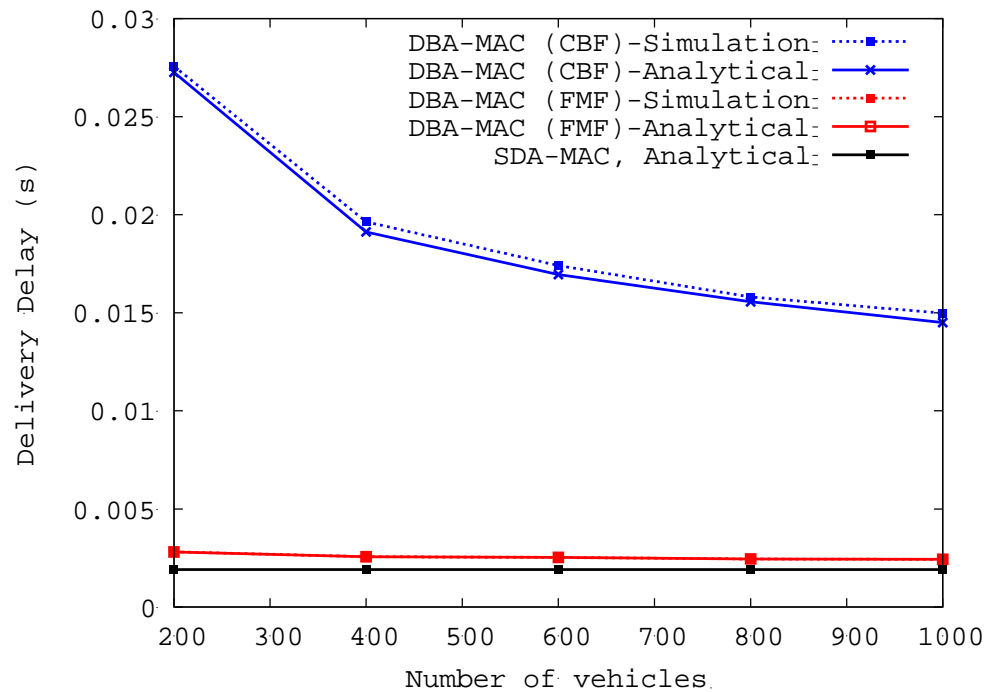
# Proactive Multi-hop Broadcast Schemes

Parameters	Value
Network Simulation Tool	Ns2 (version 2.34)
Mobility Simulation Tool	SUMO
Urban Map	{Manhattan, Bologna}
Risk Zone	1 Km
Frequency of ALERT	100s
Size of ALERT	32 bytes
Vehicle speed	[0-15] m/s
Frequency of BEACON	4 sec





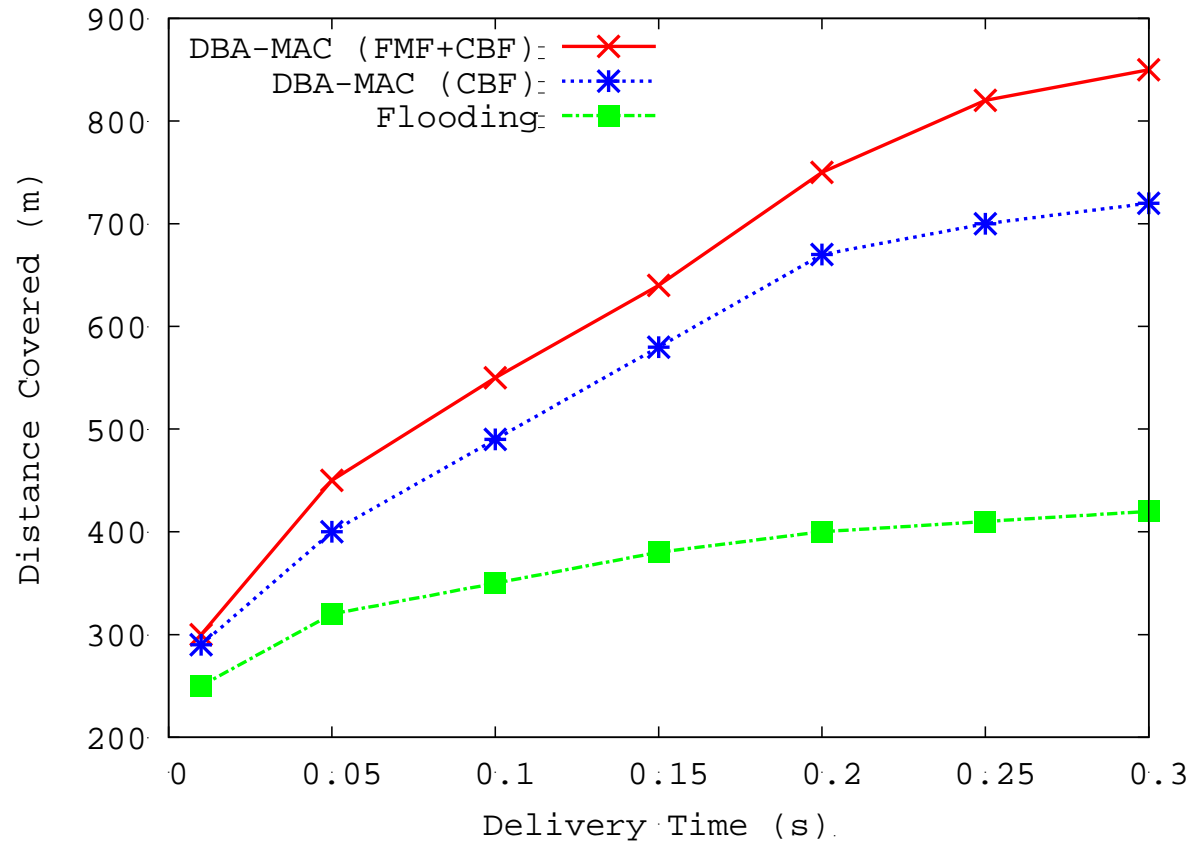
# DBA-MAC Analytical vs Simulations



... details of the analytical model of DBA-MAC in the paper ...



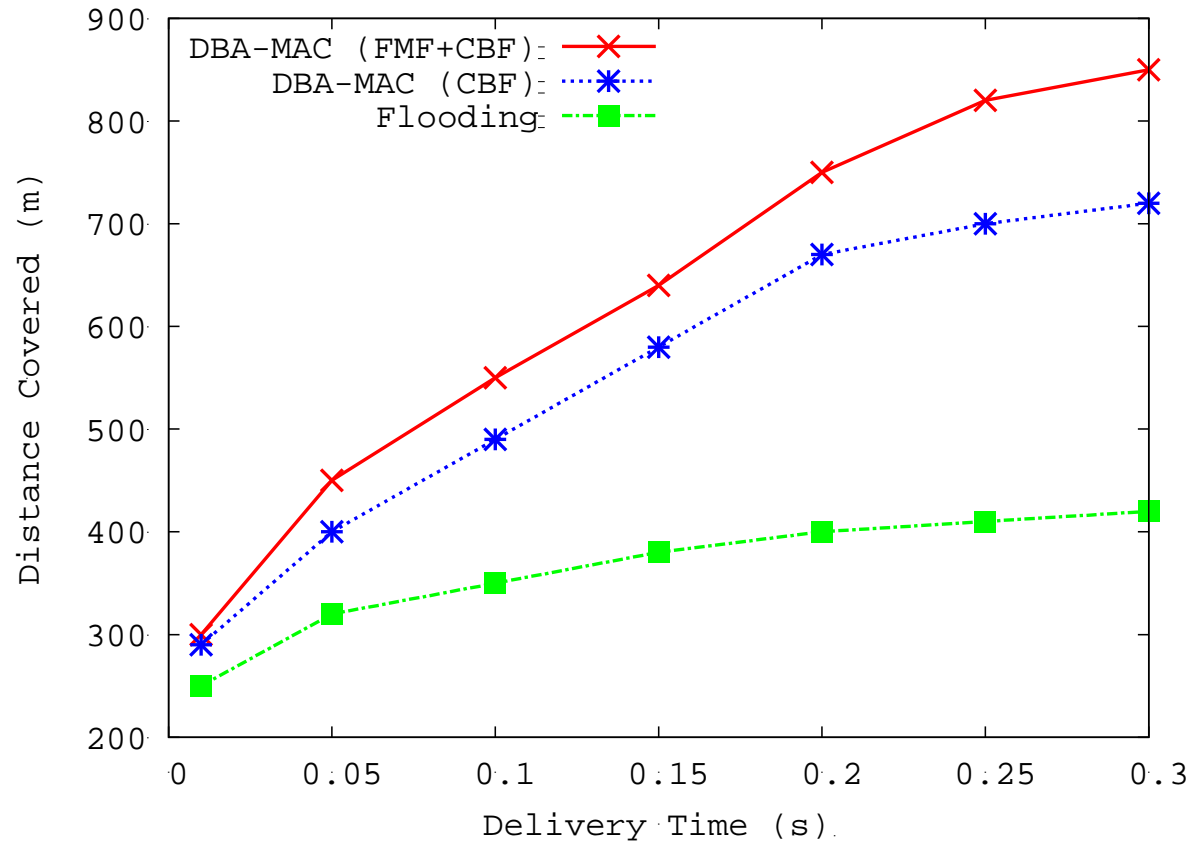
# DBA-MAC Evaluation: Delay (1)



The delivery delay vs distance covered (Manhattan)



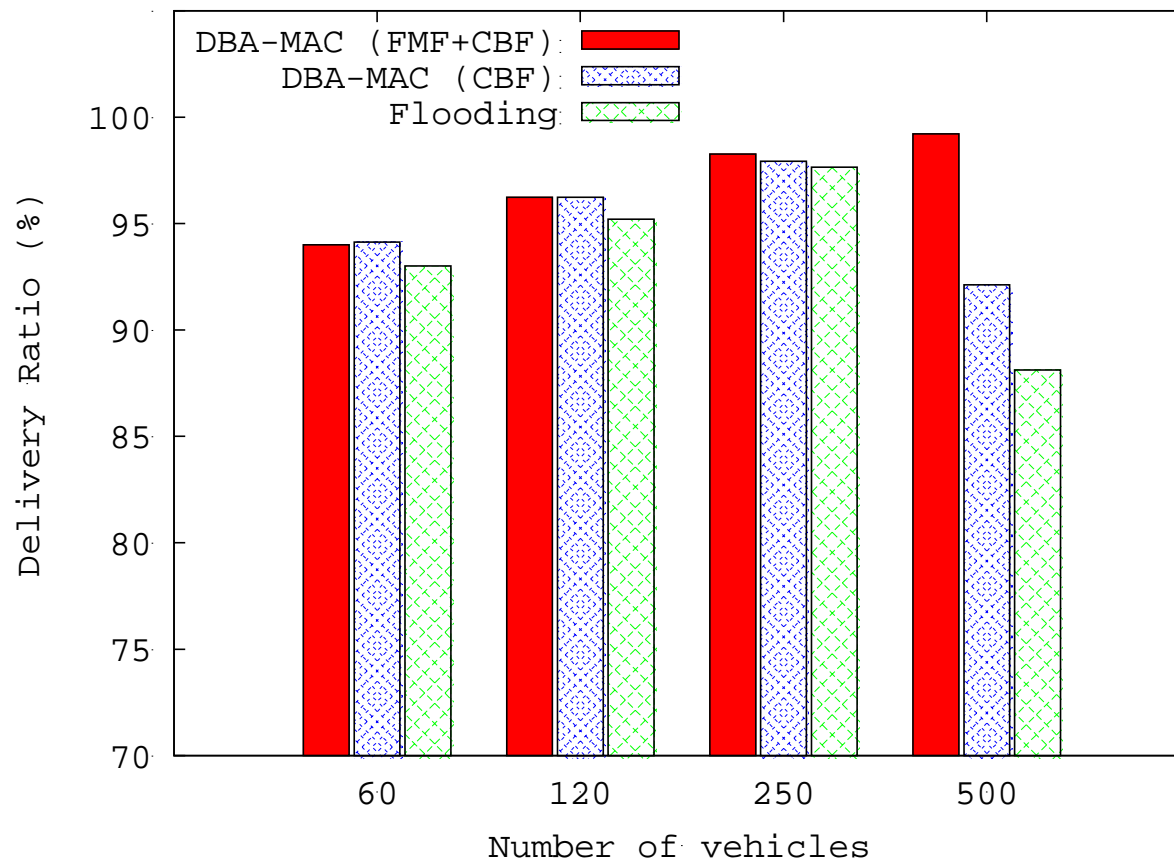
# DBA-MAC Evaluation: Delay (2)



The delivery delay vs distance covered (Manhattan)



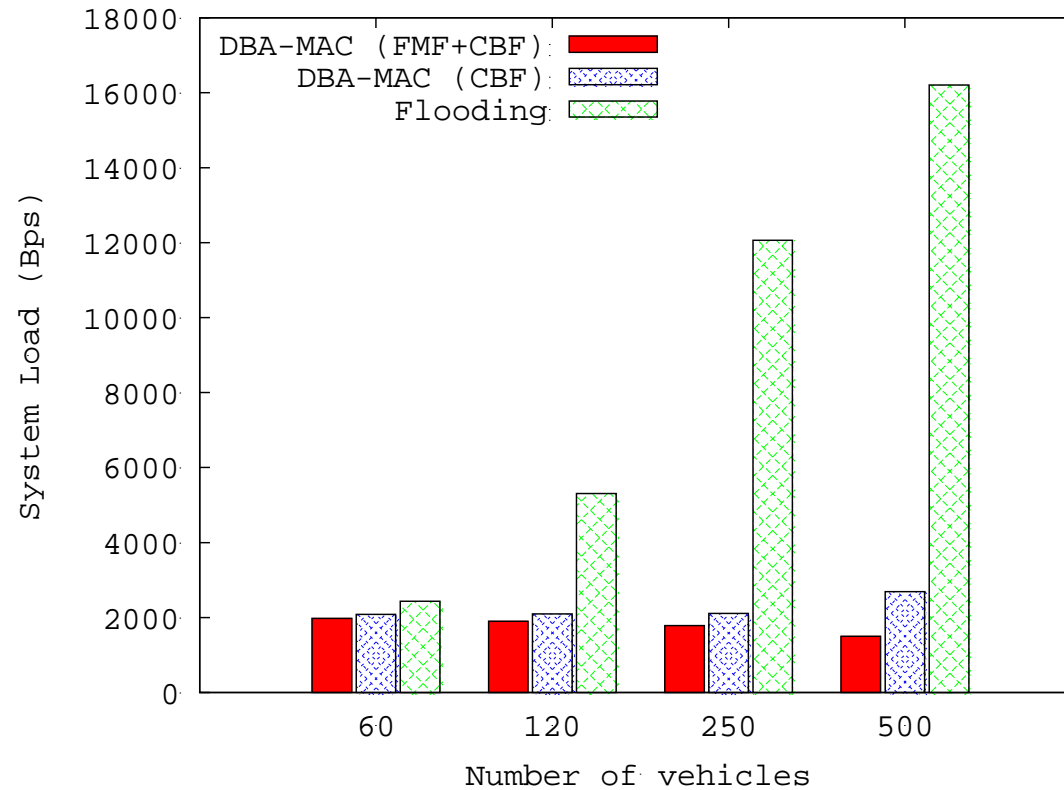
# DBA-MAC Evaluation: PDR



The **delivery ratio** vs number of vehicles (Manhattan)



# DBA-MAC Evaluation: System Load



The system load vs number of vehicles (Manhattan)



# Conclusions

- Dynamic Backbone Assisted MAC protocol for *fast* and *efficient information delivery* over multi-hop VANETs.
- **Cross-layer** information dissemination through a clustering algorithm and a fast-forward MAC protocol.
- **Future works:**
  - Analysis of DBA-MAC for non-safety applications
  - Implementation of DBA-MAC on a vehicular testbeds.



# THANKS!!!

For questions, please contact:

**[difelice@cs.unibo.it](mailto:difelice@cs.unibo.it)**

**[lbedogni@cs.unibo.it](mailto:lbedogni@cs.unibo.it)**

**[bononi@cs.unibo.it](mailto:bononi@cs.unibo.it)**