Comosef

Cherfaoui
Ducourthial

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Cooperative alert generation and propagation in vehicular networks

Cooperation preserves privacy

V. Cherfaoui & B. Ducourthial

This work is related to the Comosef Celtic Plus project
Cooperative Mobility for the Service of the Future
with the help of engineers D. Bloquel, S. Bonnet and T. Fuhrmann

Sorbonne universités
Université de Technologie de Compiègne
UMR CNRS UTC 7253 Heudiasyc

Paris, July 2017

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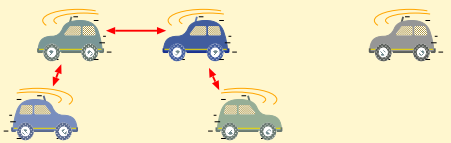
2. Pilot in Compiègne
3. Distributed data fusion
4. Cooperative communication architecture
5. Conclusion



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Comosef project

Cooperative Mobility for the Service of the Future

- European Celtic Plus project
  - Coordinator: Pekka Eloranta
  - 9 million euros, 94 person-years
  - 7 countries, 21 partners
  - 11 pilots

- Mobisoft Oy
- Finnish Meteorological Institute
- Infotripla Oy
- Taipale Telematics
- VTT
- Centria

- CRP Henri Tudor
- HITEC Luxembourg S.A.
- Entreprise des Postes et Telecommunications Luxembourg

- Technical University of Cluj-Napoca
- AROBS Transilvania Software

- UBRIDGE

- IKUSI – Angel Iglesias S.A.
- CBT Comunicación & Multimedia
- INNOVALIA

- ISBAK A.S.
- KocSistems
- Otokar

- UTC Lab. Heudiasyc
- Viveris Technologies
- Thales Communication & security

CoMoSef

Celtic-Plus
Smart Connected World

French consortium

- Viveris Technologies
  CAN bus decoding, embedded architecture
- Thales Communication and Security
  Optimizing data diffusion from RSU, network coding
- Université de Technologie de Compiègne
  CNRS Heudiasyc 7253
  Cooperative alert generation and propagation in VANET

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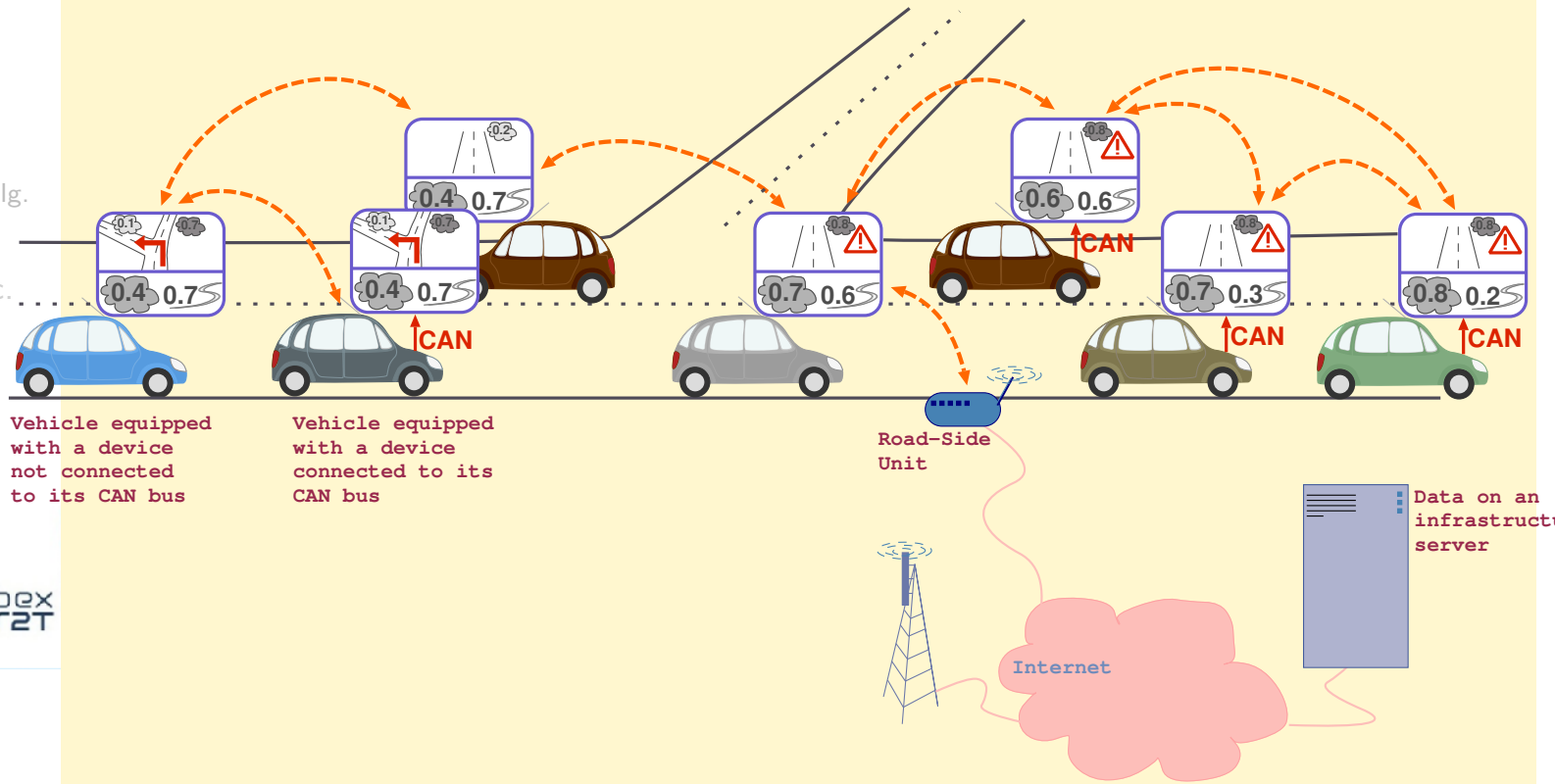
French pilot

- Inputs from CAN bus of vehicles
- Distributed data fusion
- Alert propagation to vehicles/infrastructure



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Université de Technologie de Compiègne

CNRS Heudiasyc

- Université de Technologie de Compiègne
  ∼4500 students, master degree (engineer diploma), PhD
  http://www.utc.fr
  - One of the first French engineering school for computer science
  - Close to Paris and Charles de Gaulle airport

- Heudiasyc lab from the UTC & CNRS
  Equipex Robotex, Labex MS2T
  https://www.hds.utc.fr

- Dynamic networks study
  https://airplug.hds.utc.fr

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Our approach

- Dynamic networks are differents
  - Very short communication timer
  - Unknown neighbors
- Example:
  - Confidence in the information
  - Security
  - Data sharing, data collect
  - Messages routing
- Impact
  - Protocol design
  - Modeling and proofs
  - Embedded architecture
  - Evaluation methodology
- Our tools:
  - Airplug Software Distribution
  - Communicating embedded disposals

https://www.hds.utc.fr/airplug

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Research projects related to dynamic networks

- Collecting water meters data using vehicles
  Grant Aceda with Amiens city 2016-2017
- Cooperative architecture for smart cities
  Agreement with Compiègne city 2015-
- Cooperation in a fleet of drones
  FUI Airmès (I. Fantoni) 2015-2018
- Modeling and proofs in dynamic networks
  Regional grant Toredy 2015-2018
- European Celtic-Plus project Comosef (2013-2016)
- Cooperative perception for road safety
  ANR Percoive (A. Victorino) 2008-2011
- Co-operative Systems for Road Safety
  European project SafeSPOT (M. Shawky) 2006-2010
- Data gathering from VANET to infrastructure
  Industrial grant FTR&D 2008-2010
- Distributed applications for dynamic networks
  Regional grant Toredy 2007-2010
- Network services for com. between mobiles objects
  Industrial grant Orange lab 2004-2008

UTC/CNRS Heudiasyc

Scientific contributions related to dynamic networks

- Dynamic p-graphs [Ad Hoc Networks 2016]
- Detecting icy roads [IEEE ITS 2016]
- Adaptive inter-messages delay [WiMob 2016]
- Robustness of distributed data fusion [SRDS 2016]
- Mobile measure of the pollution [IWCMC 2015]
- Cooperative approach near RSU [IWCMC 2014]
- Keepalive service in VANET [WCNC 2014]
- Distributed data fusion [SSS 2012]
- Data collect on the road [IV 2012]
- Performances in a convoy of vehicles [VTC 2011]
- Vehicular networks emulation [ICCCN 2010]
- Distributed dynamic group service [SPAA 2010]
- V2I architecture [Mobiwac 2010]
- Simulation of vehicular networks [VTC 2010]
- Road experiments [VTC 2009]
- Messages forwarding [IEEE TVT 2007]

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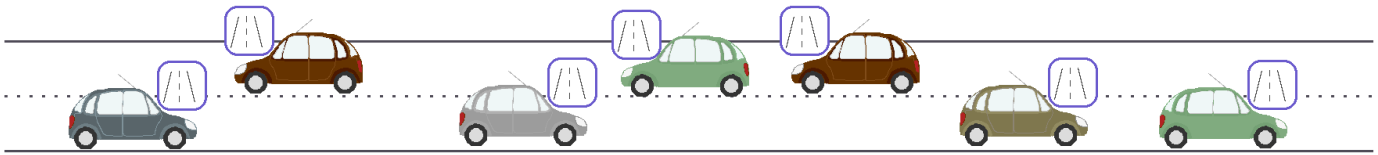

- Vehicular network

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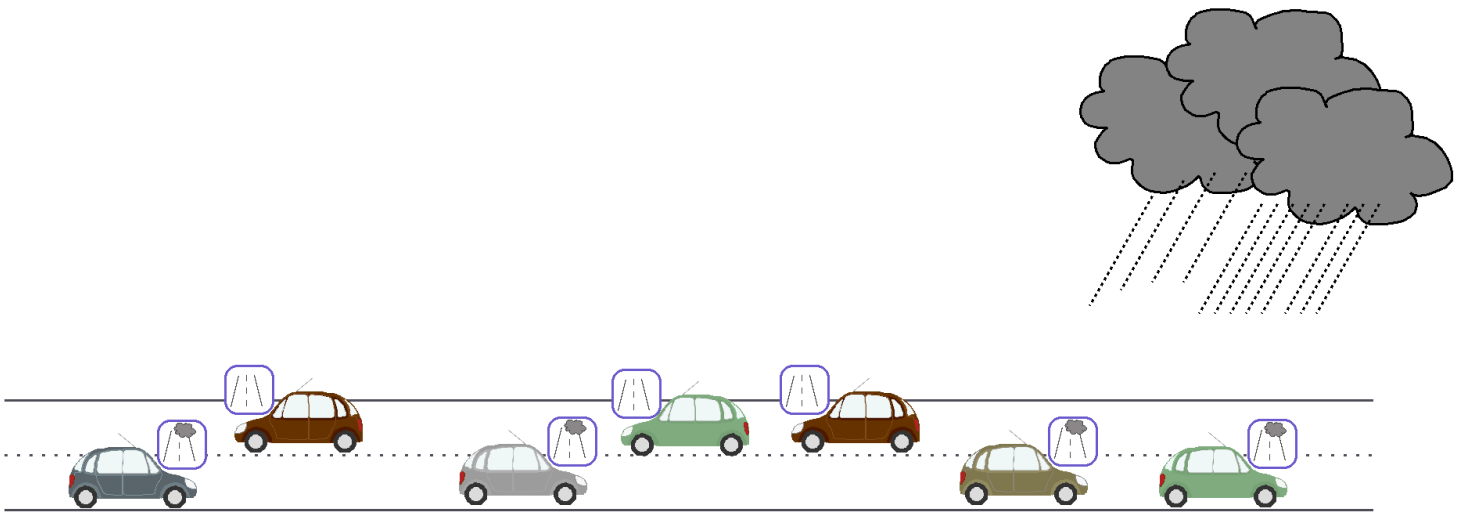

- Vehicular network
- Detecting potential danger

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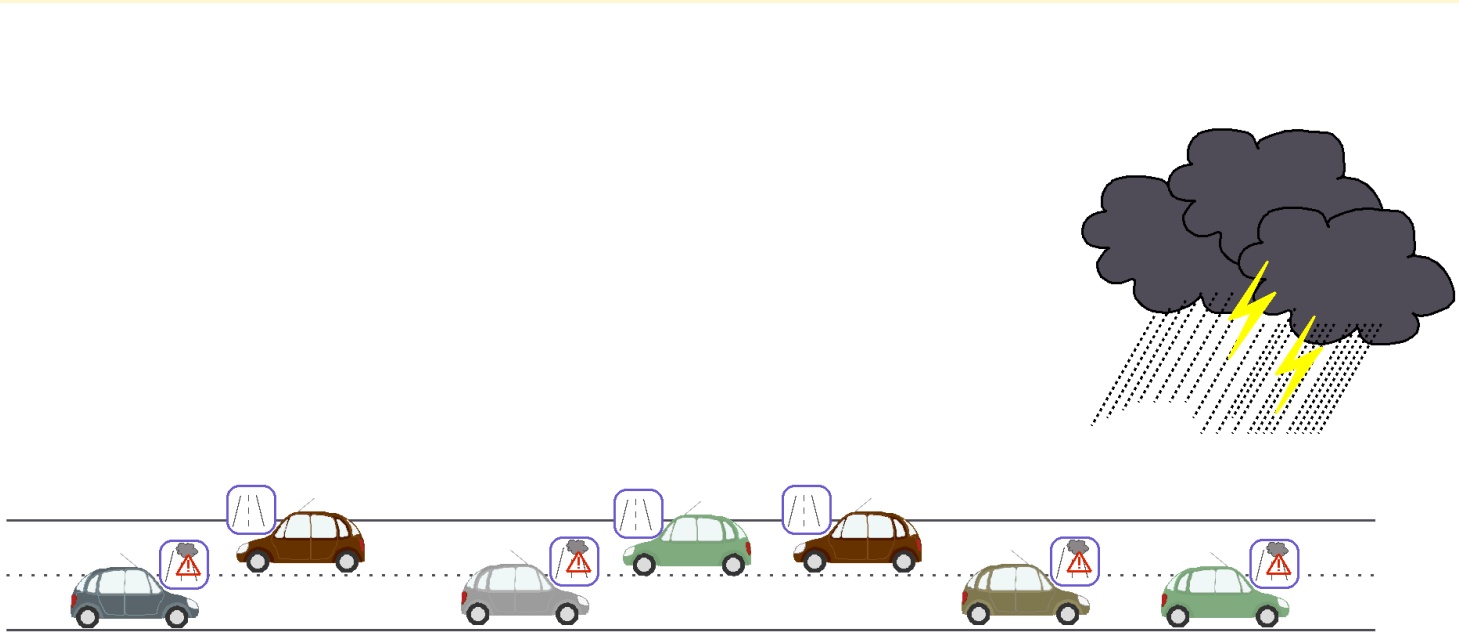

- Vehicular network
- Detecting potential danger
- Warning only concerned vehicles

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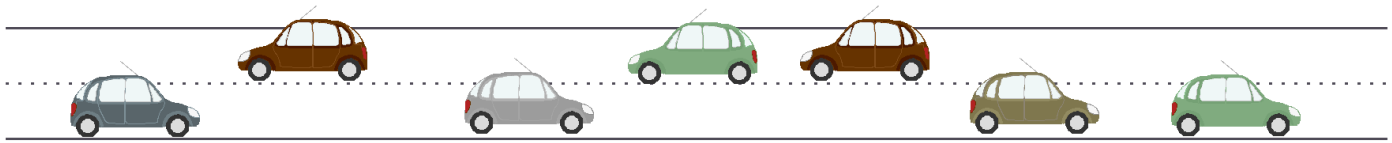
Architecture: vehicle as a source



- Vehicle as a source of information

Pilot in Compiègne

Architecture: vehicle as a source

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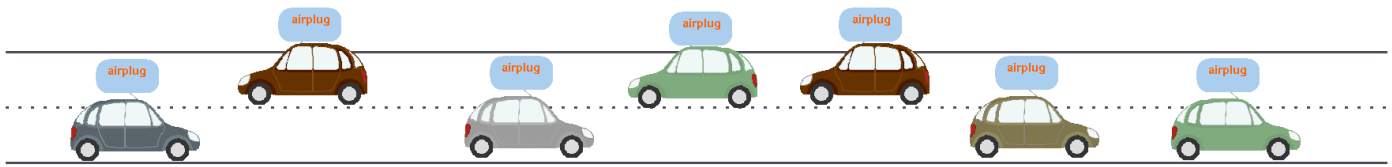

- Vehicle as a source of information
  - Airplug framework

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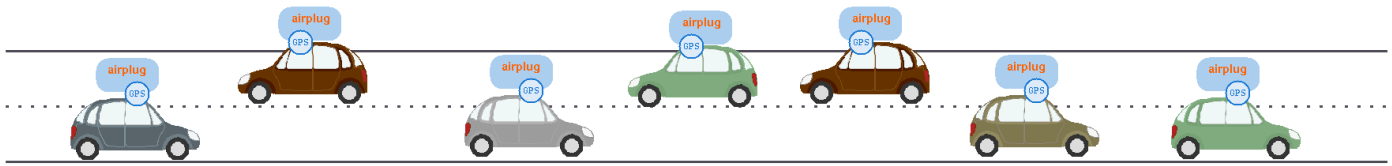
Architecture: vehicle as a source



- Vehicle as a source of information
  - Airplug framework
  - GPS device and app

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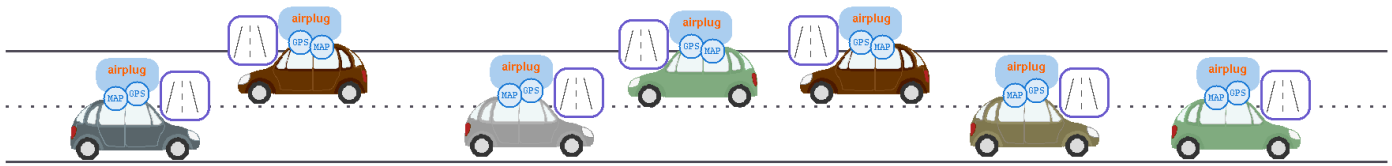
Architecture: vehicle as a source



- Vehicle as a source of information
  - Airplug framework
  - GPS device and app
  - MAP app

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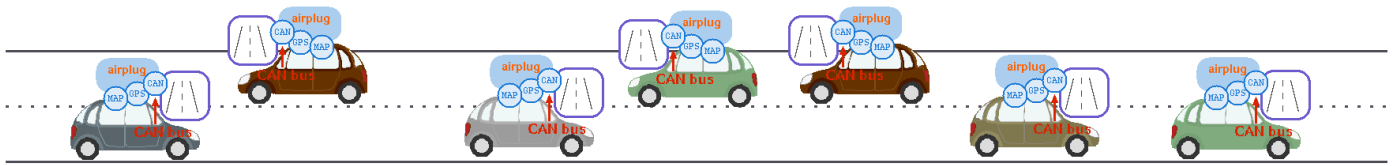
Architecture: vehicle as a source



- Vehicle as a source of information
  - Airplug framework
  - GPS device and app
  - MAP app
  - CAN app

Viveris & Heudiasyc

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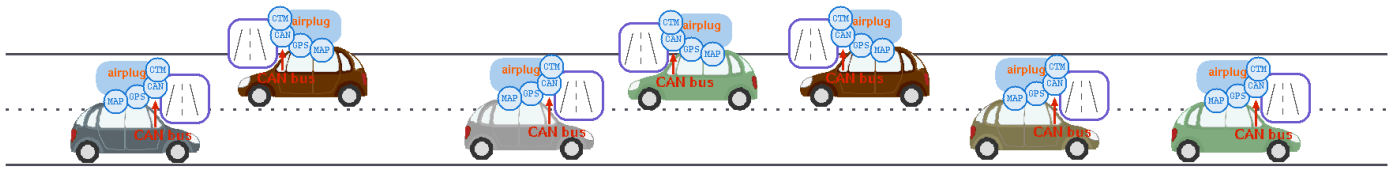

- Vehicle as a source of information
  - Airplug framework
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  - MAP app
  - CAN app
  - CTM app: local confidence in the danger

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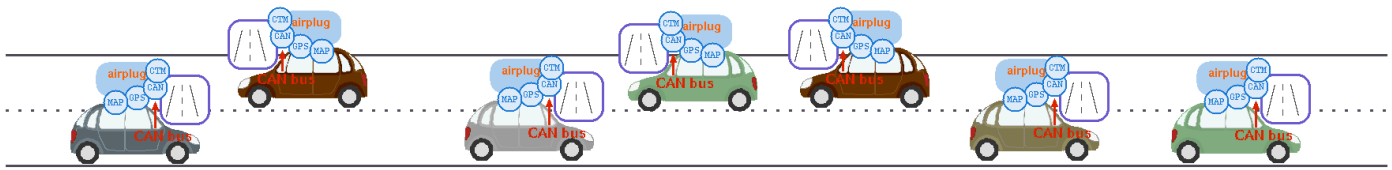
Architecture: cooperative detection of danger



- Cooperative detection of a danger

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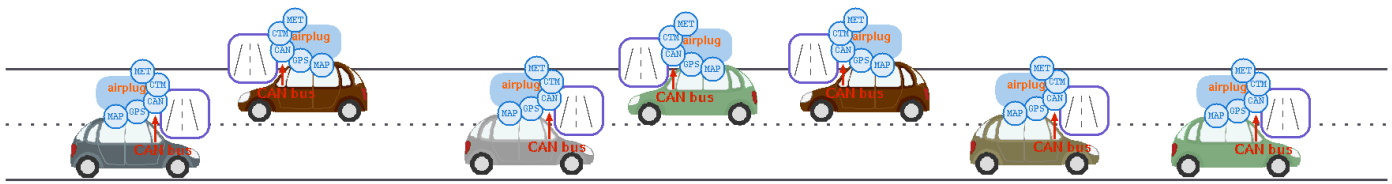
Architecture: cooperative detection of danger



- Cooperative detection of a danger
  - MET app: robust distributed data fusion

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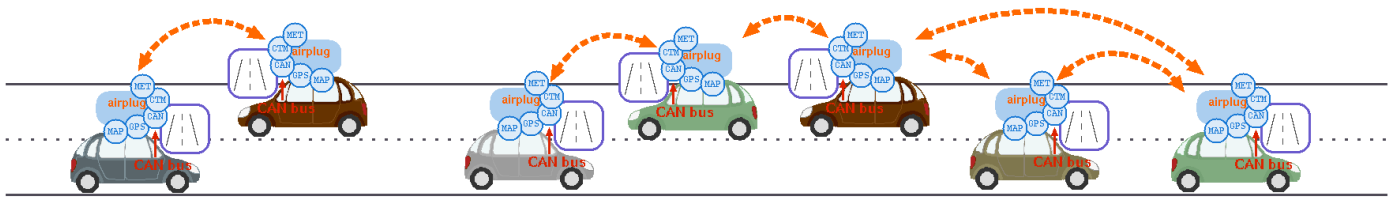

- Cooperative detection of a danger
  - MET app: robust distributed data fusion

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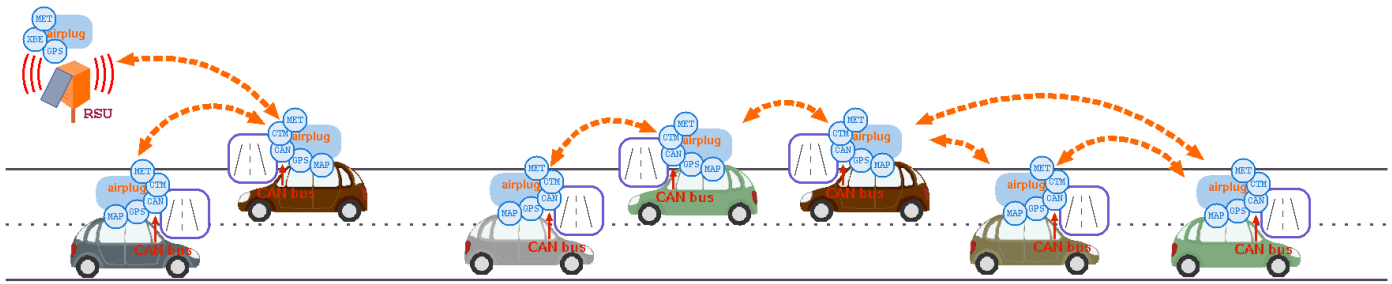

- Cooperative detection of a danger
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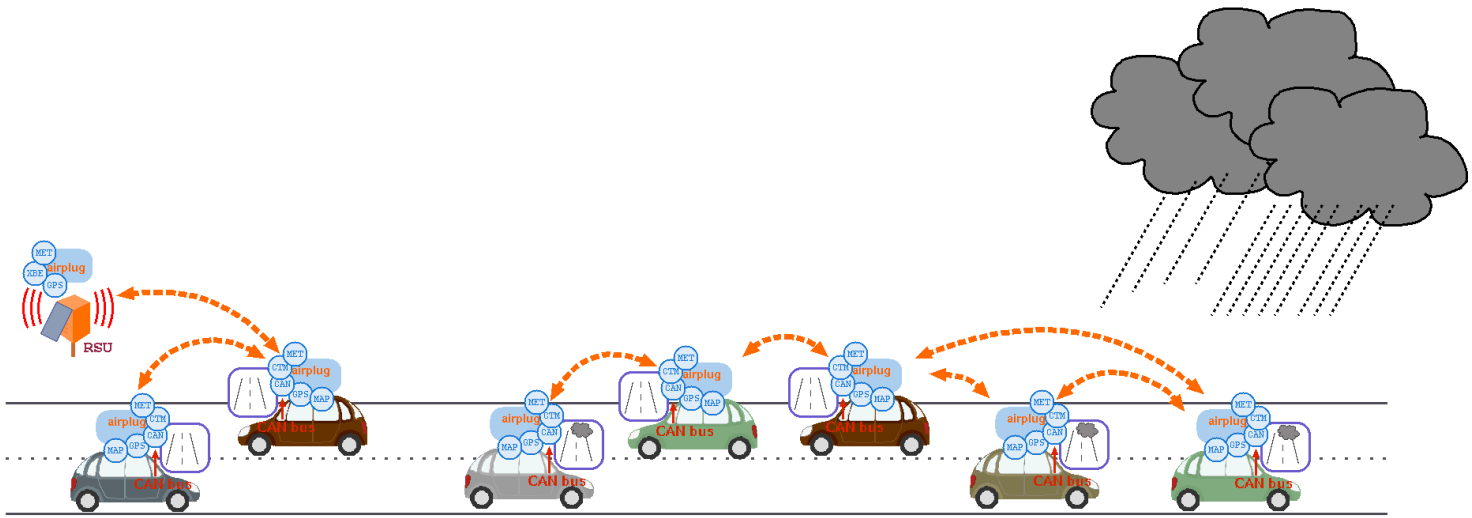

- Cooperative detection of a danger
  - MET app: robust distributed data fusion
  - Updating the local confidence
    Reading the windscreen wipers speed on the CAN bus

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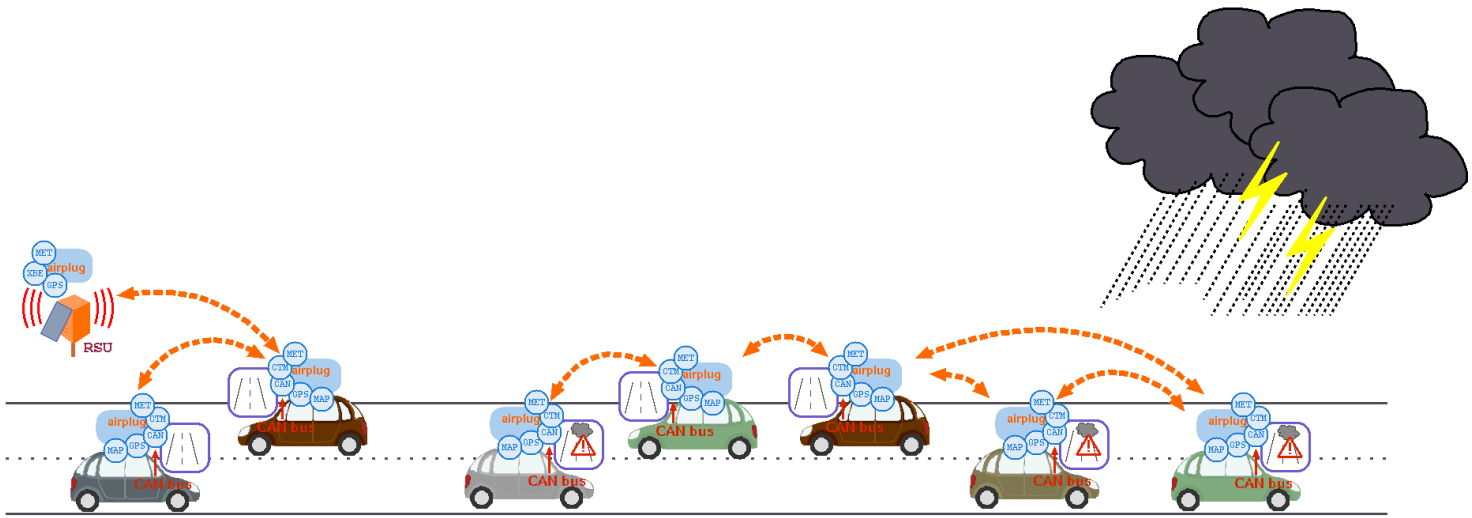

- Cooperative detection of a danger
  - MET app: robust distributed data fusion
  - Updating the local confidence
    Reading the windscreen wipers speed on the CAN bus
  - Detecting a danger
    Computed distributed confidence larger than a threshold

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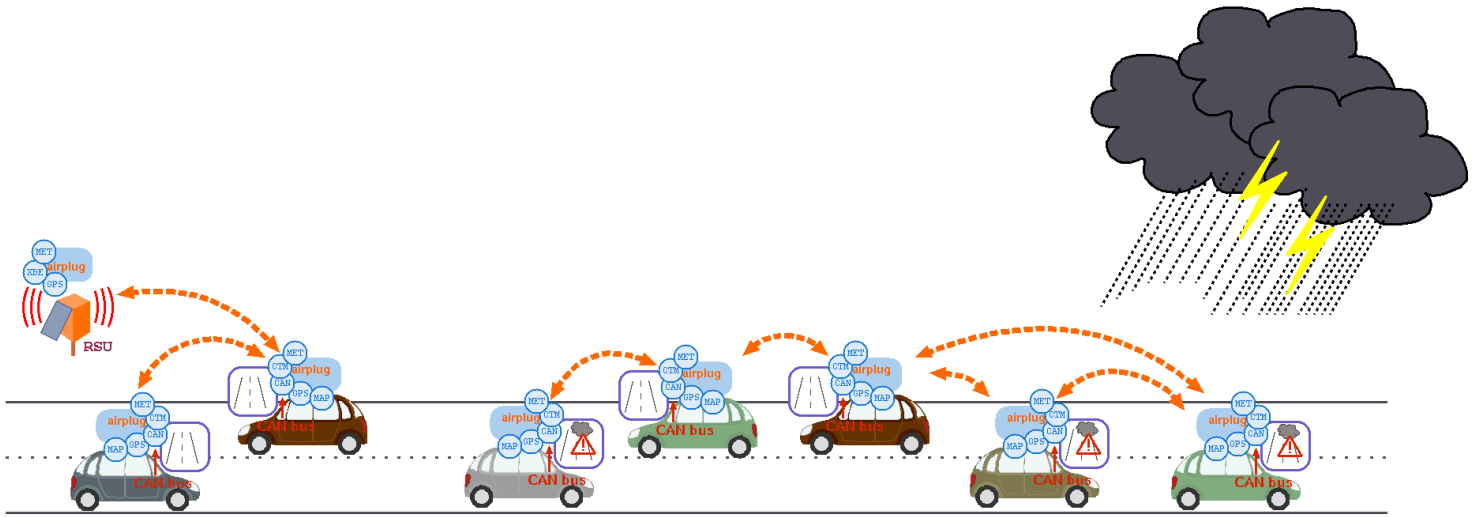

- Cooperative propagation of the danger

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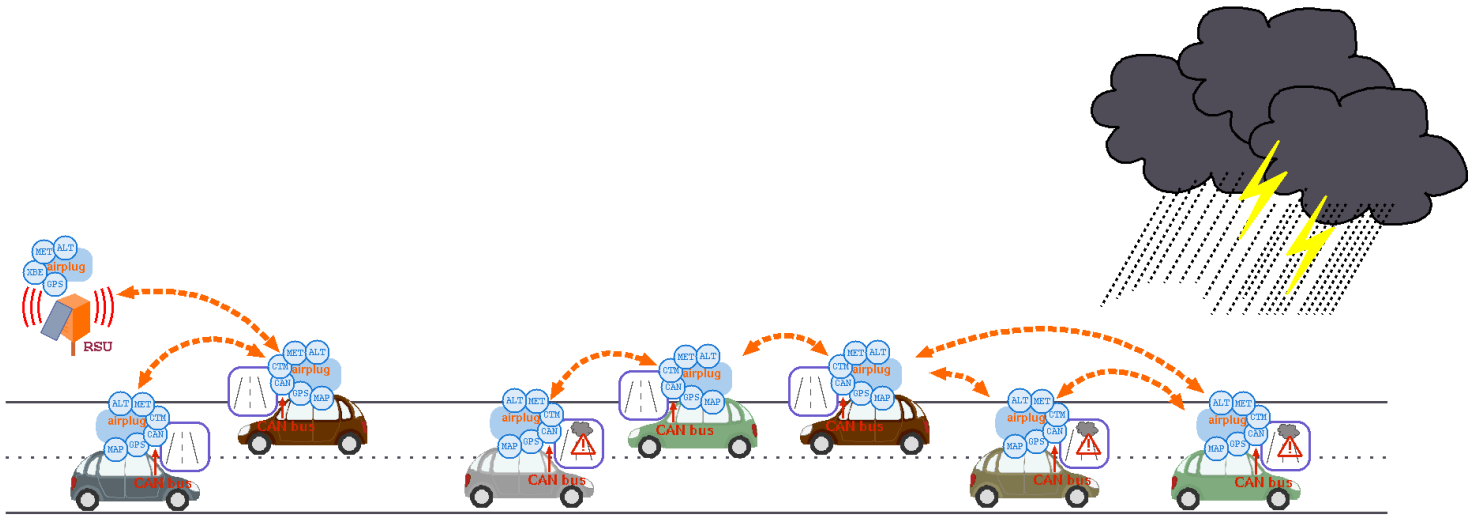

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  - ALT app: generating an propagating an alert

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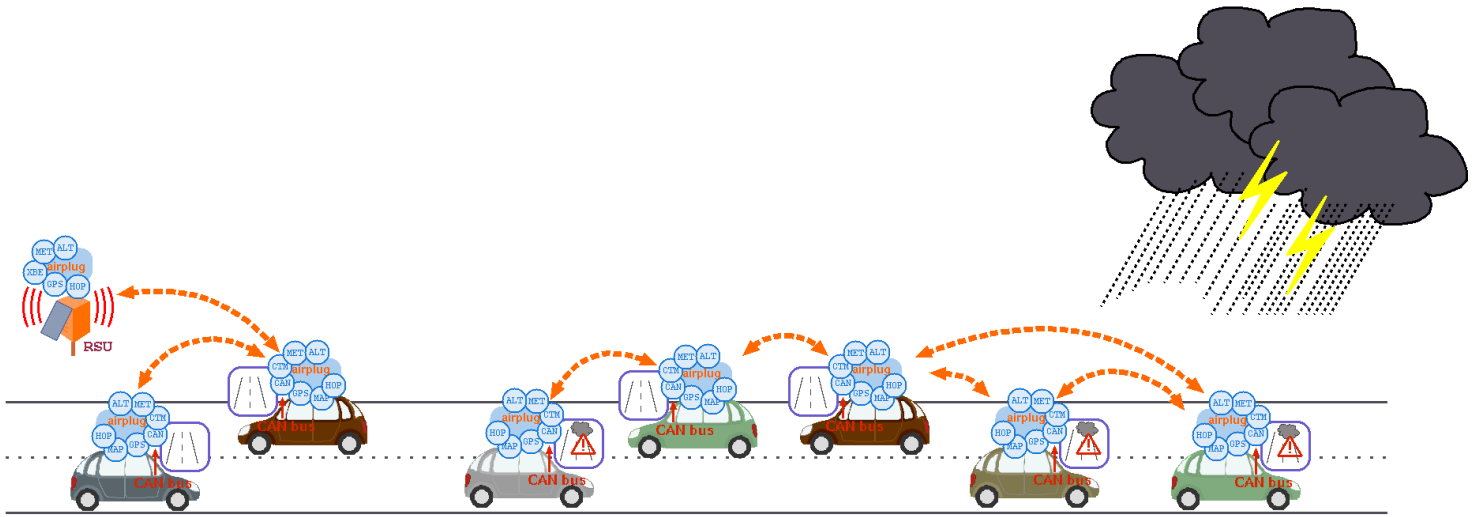

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  - ALT app: generating an propagating an alert
  - HOP app: smart conditionnal retransmission

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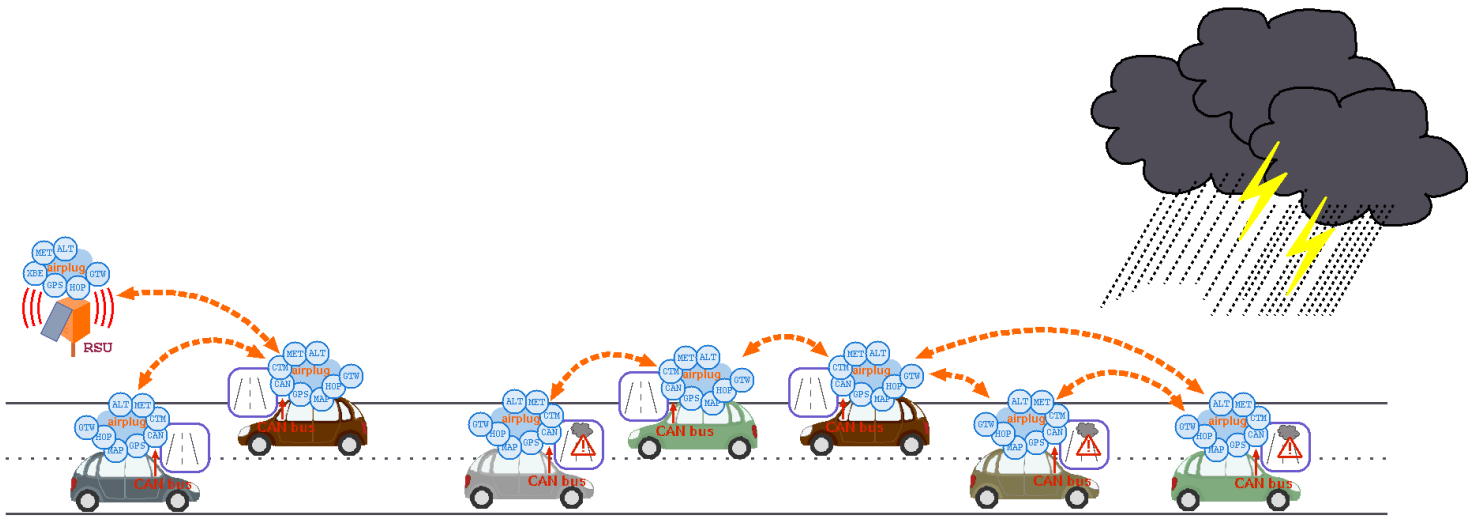

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  - ALT app: generating an propagating an alert
  - HOP app: smart conditionnal retransmission
  - GTW app: searching for Internet gateway

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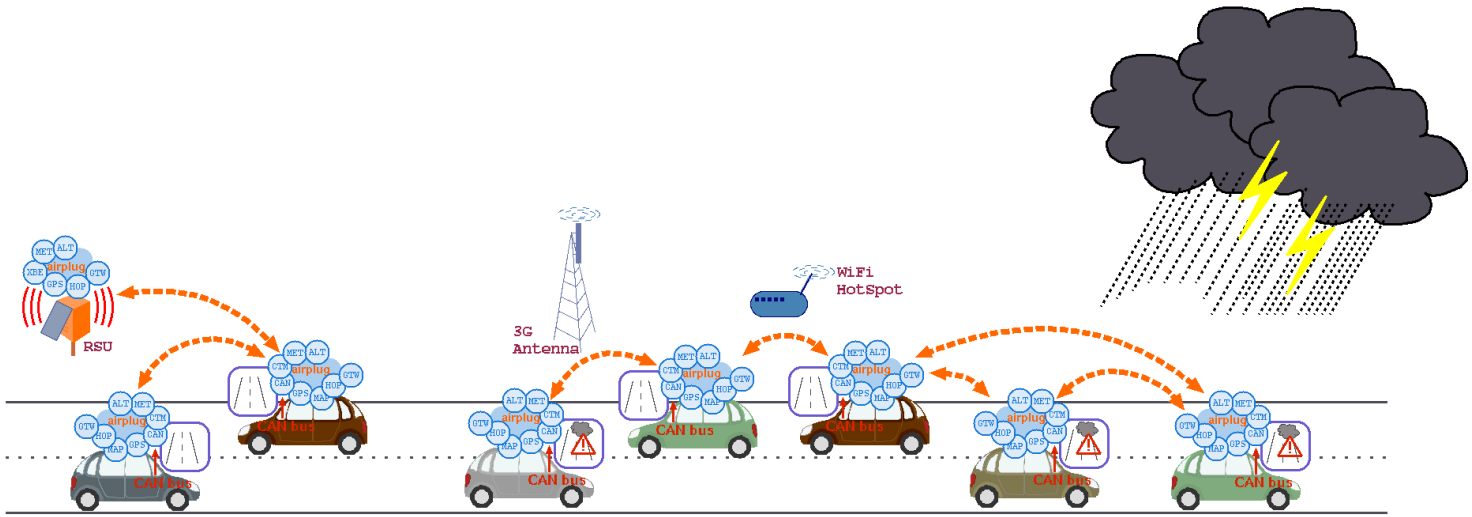

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  - ALT app: generating an propagating an alert
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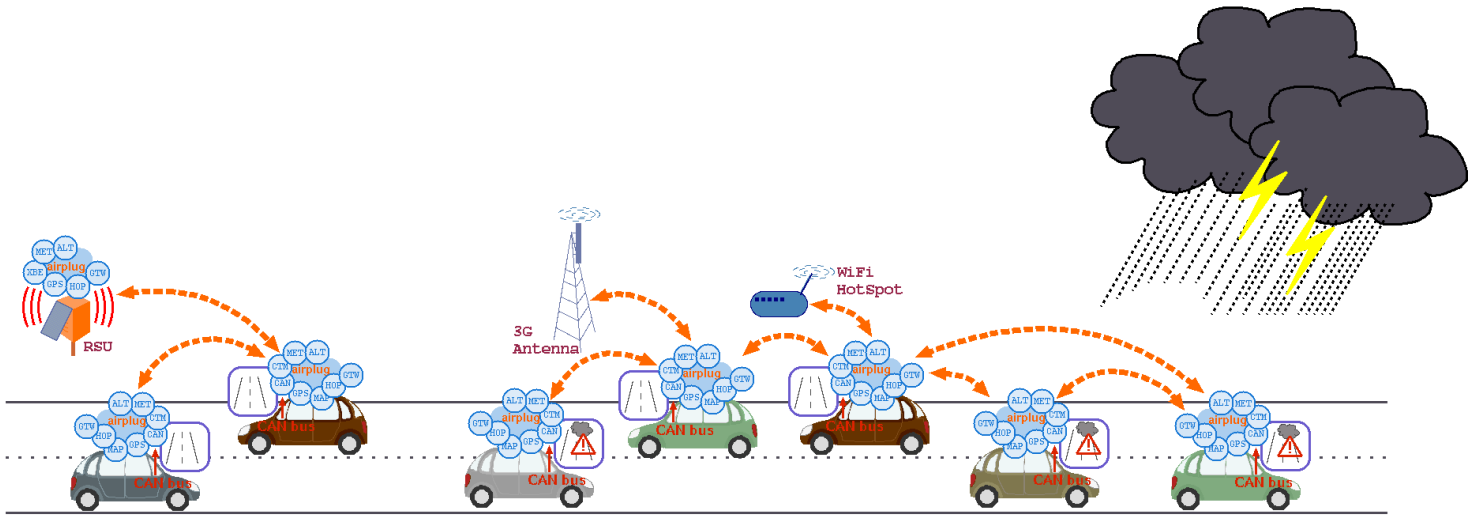

- Cooperative propagation of the danger
  - ALT app: generating an propagating an alert
  - HOP app: smart conditionnal retransmission
  - GTW app: searching for Internet gateway

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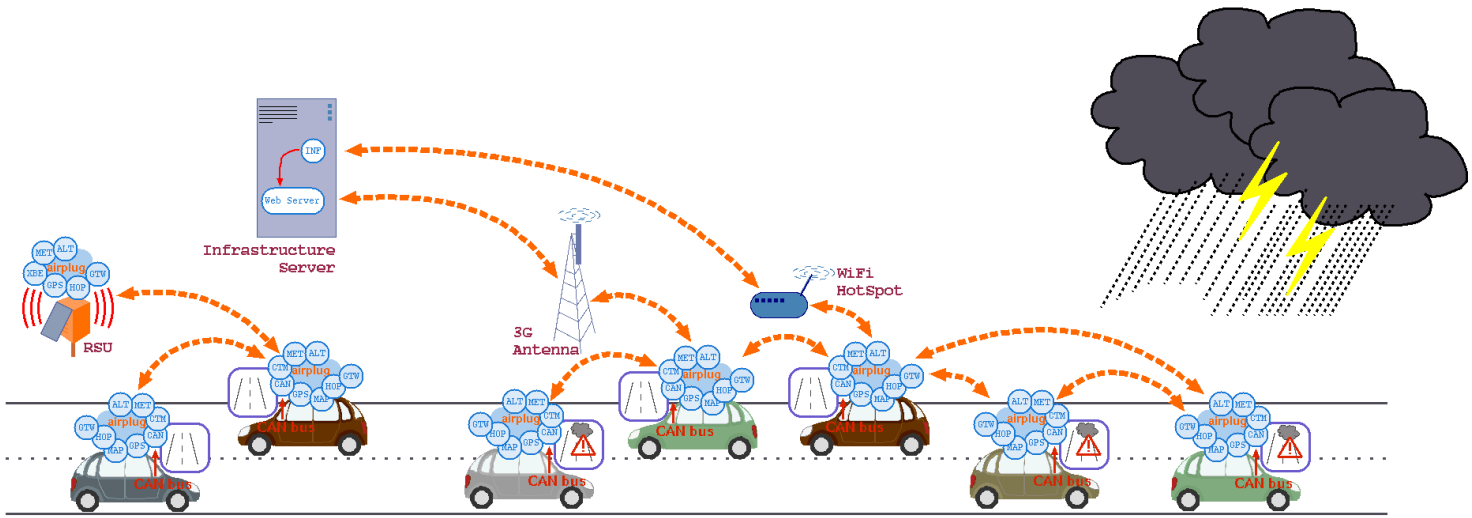
Architecture: cooperative propagation of an alert



- Cooperative propagation of the danger
  - ALT app: generating an propagating an alert
  - HOP app: smart conditionnal retransmission
  - GTW app: searching for Internet gateway
  - Web app: warning web clients

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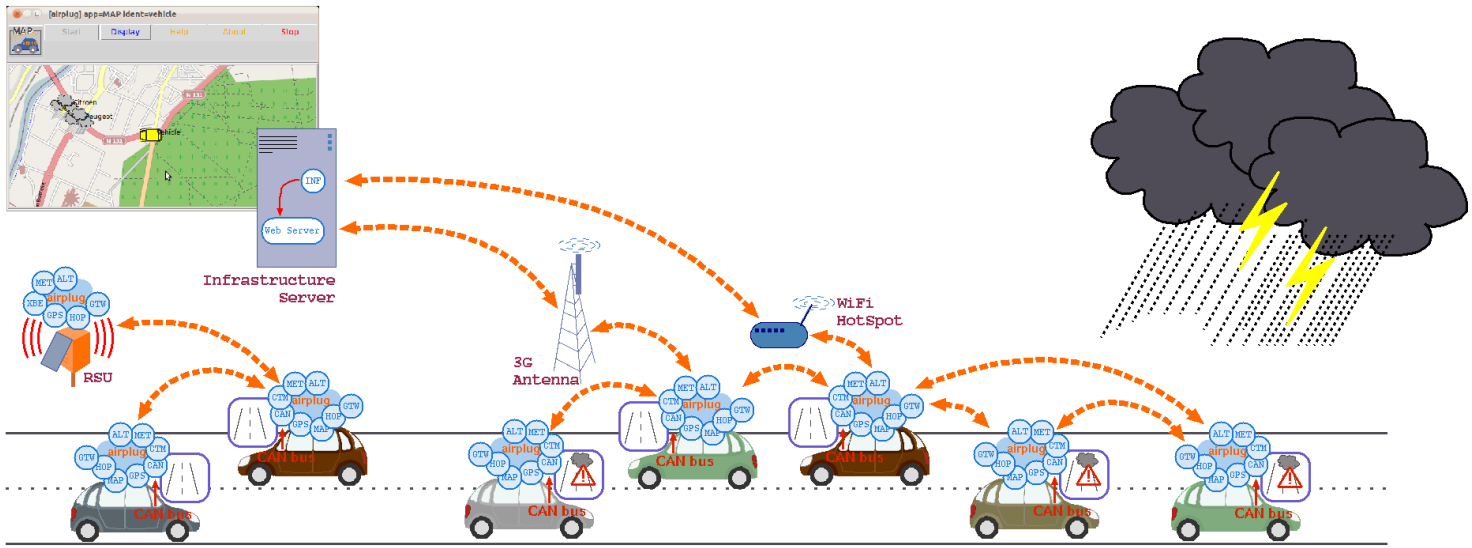

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  - Web clients warned

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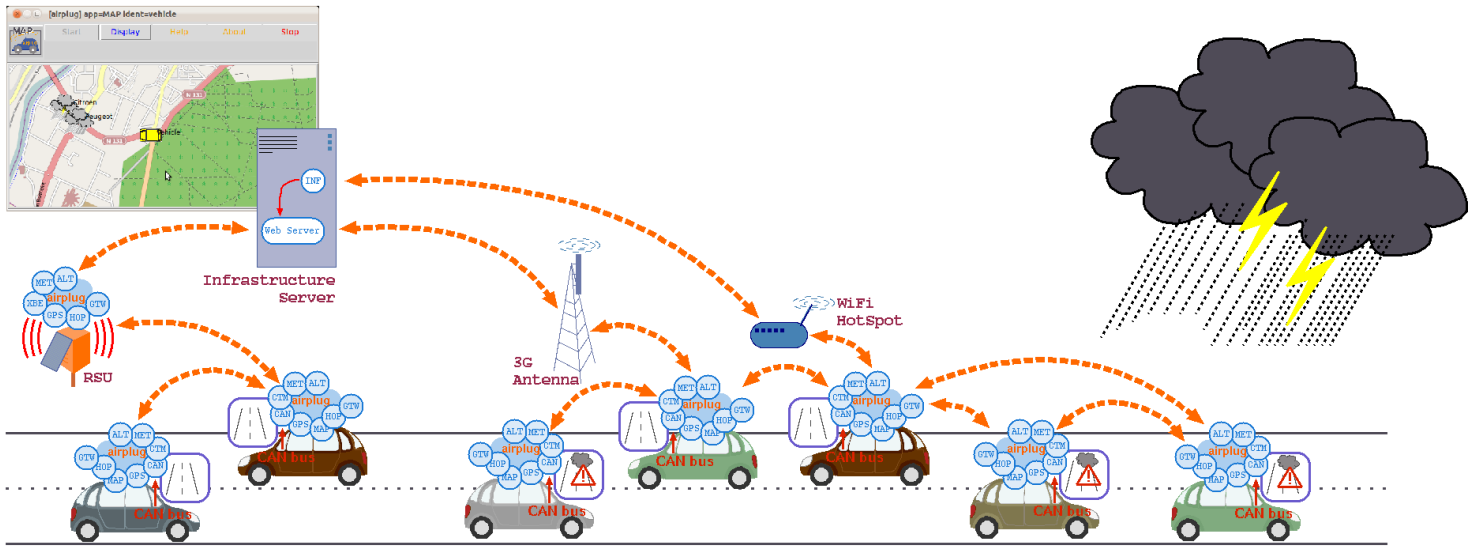

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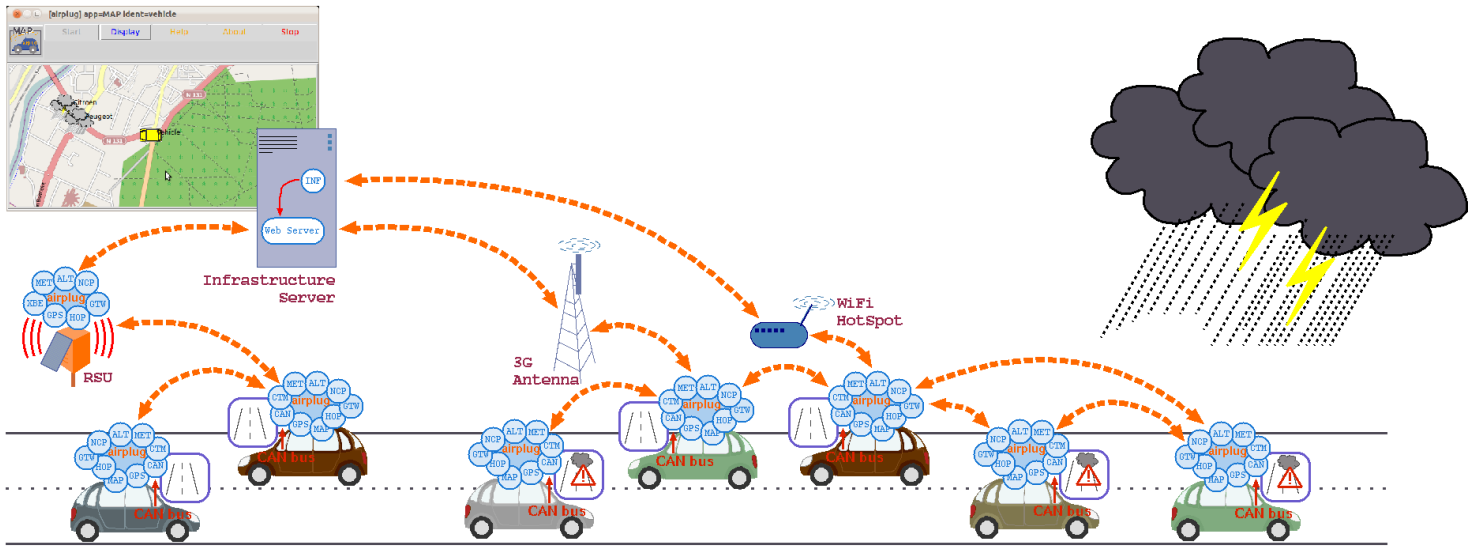

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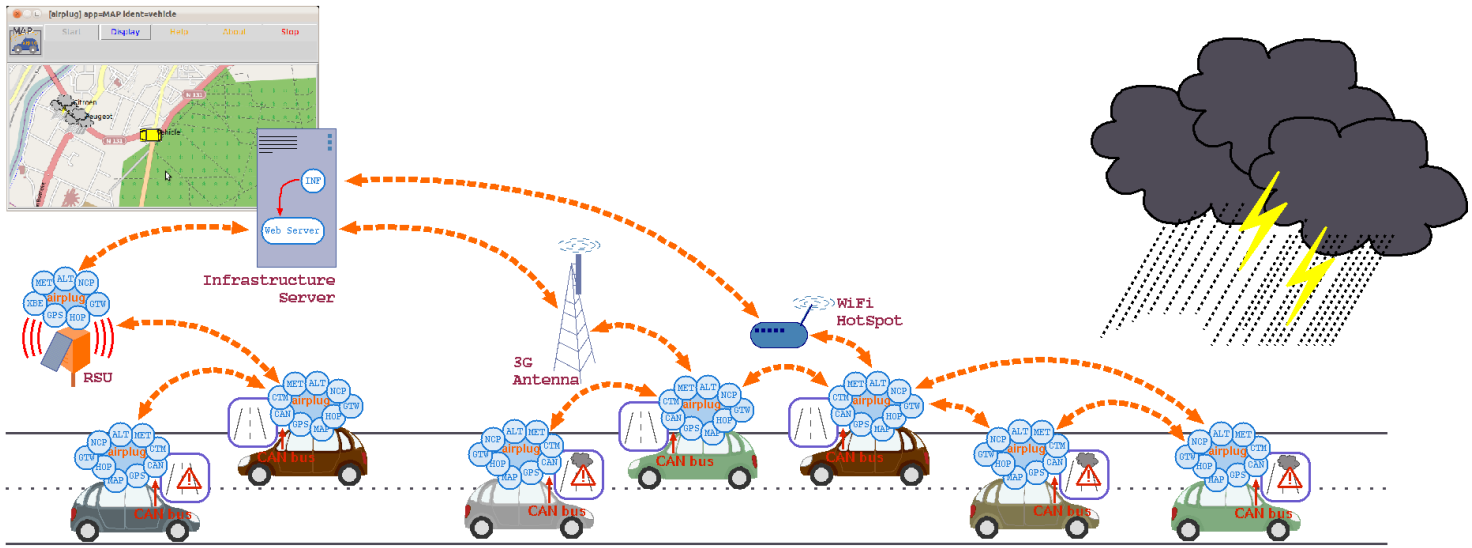
Architecture: cooperative propagation of an alert



- Cooperative propagation of the danger
  - ALT app: generating an propagating an alert
  - HOP app: smart conditionnal retransmission
  - GTW app: searching for Internet gateway
  - Web app: warning web clients
  - Web clients warned
  - Far vehicles warned using road side units

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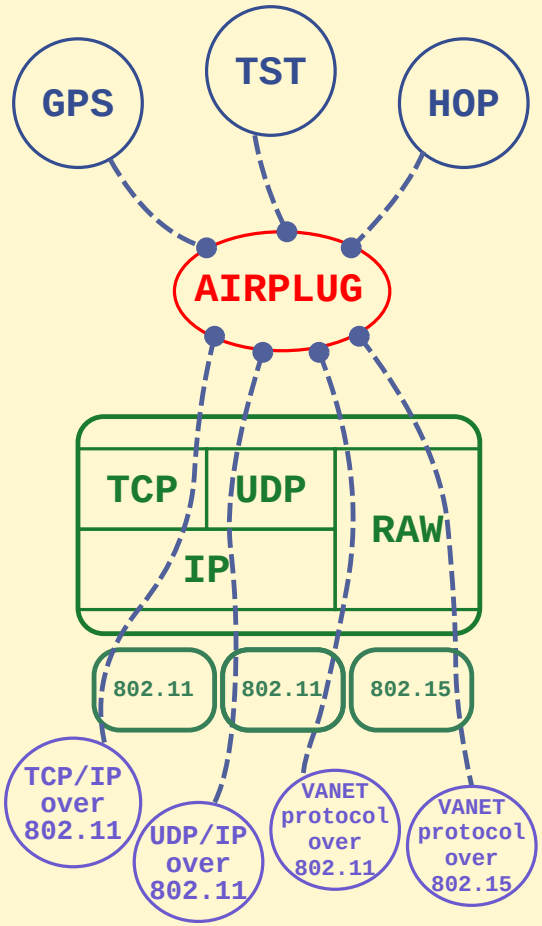
Pilot in Compiègne

Airplug framework 1

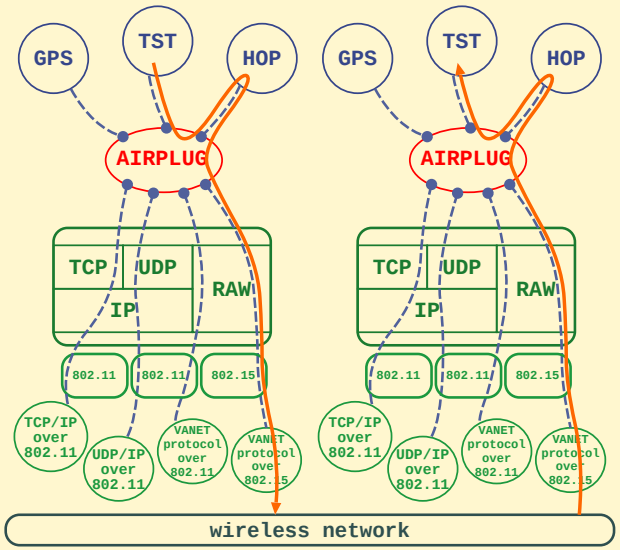


- Core program
  - User-space process
  - Networking
- Applications
  - User-space process
  - Any language
  - Read on stdin
  - Write on stdout
  - API close to IEEE WSMP
- Robustness
  - Tasks and OS independence
- Portability
  - Posix compliant
  - Validated on GNU/Linux

Pilot in Compiègne

Airplug framework 2

- Designing new protocols
  - Developed in user space processes
  - Cross-layer solutions facilitated



- Airplug software distribution
  - LEGO: many applications that can be combined
  - Tools to ease packaging, prototyping and studies

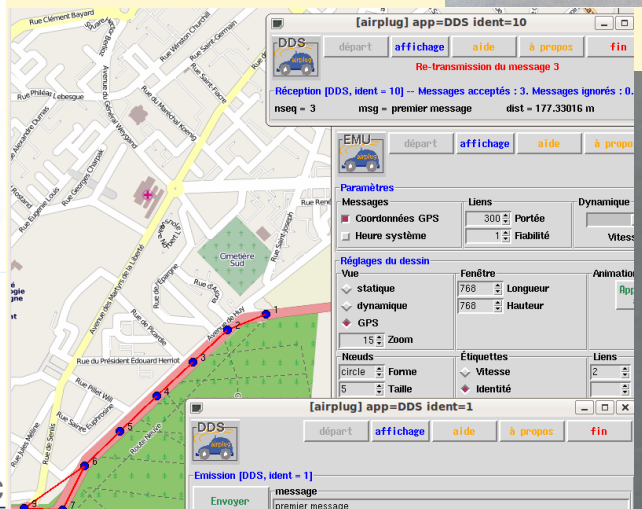
https://airplug.hds.utc.fr

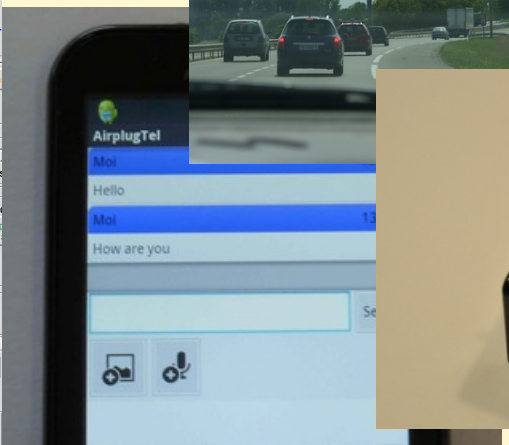
Pilot in Compiègne

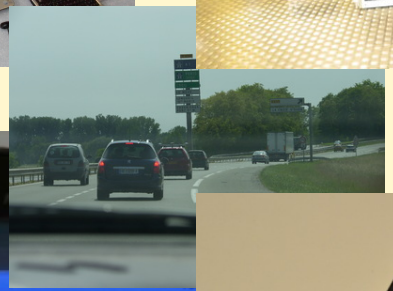
Airplug framework 3

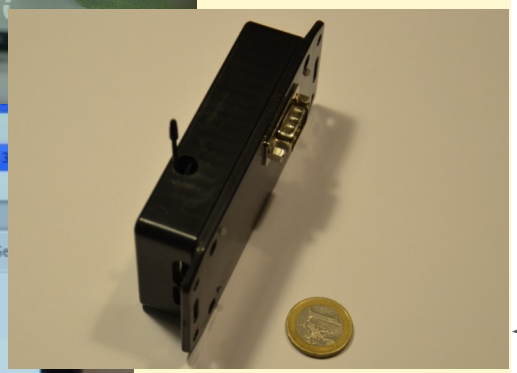
- Airplug-term $\rightsquigarrow$ rapid prototyping
- Airplug-emu $\rightsquigarrow$ study by emulation
- Airplug-live $\rightsquigarrow$ real experiments (vehicles, UAV)

$+$ remote, notk...









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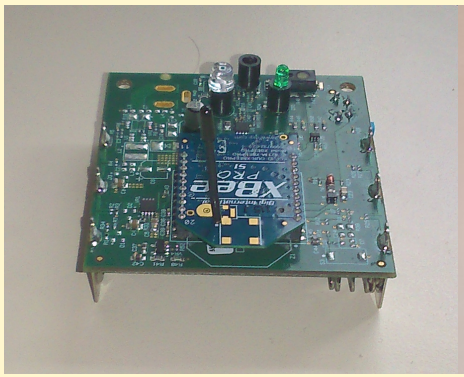
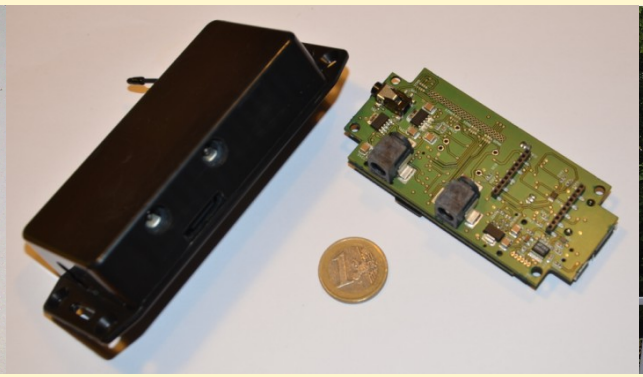
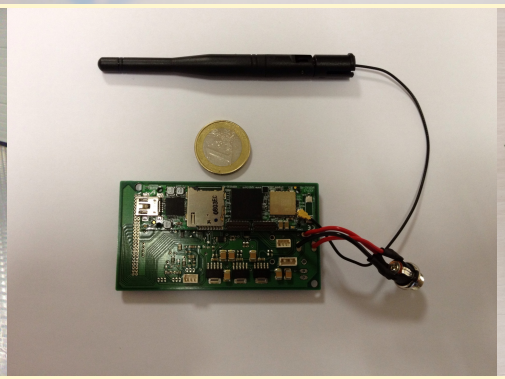
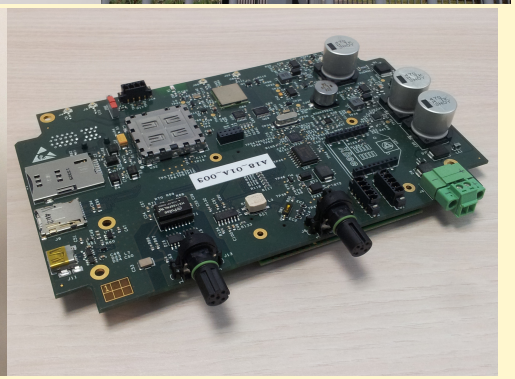
Road tests









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Distributed data fusion

Data fusion introduction

- Several sources of information
  - How to deal with?
  - Could disagree
  - Take benefit of all of them
- Imperfect measures
  - Can we trust data?
  - Imprecision
  - Uncertainty
  - Ambiguity

Distributed data fusion

Data fusion introduction

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- How to deal with imprecise and uncertain data?
  - Imprecision :
    Set Membership Approach uncertainty?
  - Aleatory uncertainty :
    Probability theory imprecision?
  - Theory of Belief Function: generalizes both
    Also known as Dempster-Shafer Theory of Evidence

- Belief Function Framework
  - Information modeling
  - Combination rules

[Dempster 1968, Shafer 1976, Smets 1990s]

Distributed data fusion

Data fusion introduction

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- Data X with value in Ω
- Representation of X
  - (value, confidence)
  - value: subset of Ω
  - confidence: indication on the reliability of the item of information
- Interest:
  - Imprecision of $X \rightsquigarrow$ value
  - Uncertainty of $X \rightsquigarrow$ confidence

[Dubois, Prade 1988]

		Confidence	
		certain	uncertain
Value	precise	20	probably 20
	imprecise	between 15 and 25	probably between 15 and 25

Distributed data fusion

Data fusion introduction

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- Frame of discernment: set Ω
- Basic belief assignment
  - Mass function
    - $m^{\Omega} : \mathcal{P}(\Omega) \rightarrow [0,1]$
    - $\sum_{X \subset \Omega} m^{\Omega}(X) = 1$
  - Our algorithm: vector of weights
- Dempster operator
  - Emphases the agreement of reliable and independent sources [Smets 1990,Shafer 1976]
    $m_{1 \textcircled{\cap} 2}(A) = \sum_{B \cap C = A} m_1(B) \cdot m_2(C)$
  - Spread the conflict over other sets [Dempster]
- Cautious operator [Denoeux 2008]
  - Do not assume independent sources
  - Least commitment principle
  - Avoid the *data incest*

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Distributed data fusion

Example of Basic Belief Assignment 1/3

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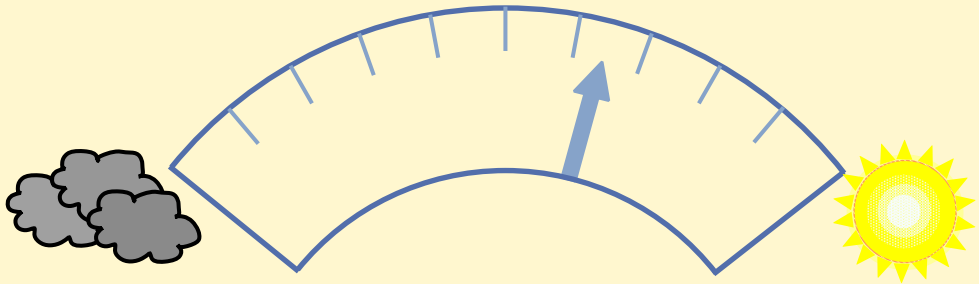
- Pressure measurement



- Weather forecast
  - Compare current measure with the last one

Distributed data fusion

Example of Basic Belief Assignment 2/3

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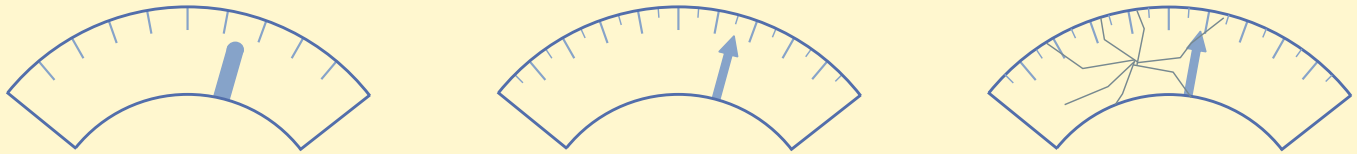
- Barometer?

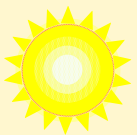


- Measure:
  - Pressure measurement: interval $I \subset \mathbb{R}^+$
  - Pressure gradient: interval $\Delta I \subset \mathbb{R}$
  - *Simple* mass function:
    - Only two subsets: ΔI and $\mathbb{R}$
    - $\mathbb{R}$: lack of knowledge
    - $m^{\mathbb{R}}(\Delta I) = 1 - \alpha$
    - $m^{\mathbb{R}}(\mathbb{R}) = \alpha$
    - α: uncertainty of the barometer

Distributed data fusion

Example of Basic Belief Assignment 3/3

- Coarsening
  - Finite frame of discernment instead of $\Delta I \subset \mathbb{R}$
  - Example: $\Omega = \{wet, cloud, sun\}$
  - Mass function:

$\Delta I << 0$	$\Delta I < 0$	$\Delta I \approx 0$	$\Delta I > 0$	$\Delta I >> 0$
				
$\{wet\}$	$\{wet, cloud\}$	$\{wet, cloud, sun\}$	$\{cloud, sun\}$	$\{sun\}$

- Combination
  - Several independent measures can be combined using the Dempster rule
- Decision
  - From mass to *pignistic* probability
    $P(A) = \sum_{\emptyset \neq B \subset \Omega} m(B) \frac{|A \cap B|}{|B|}$

Distributed data fusion

Example of Basic Belief Assignment 3/3

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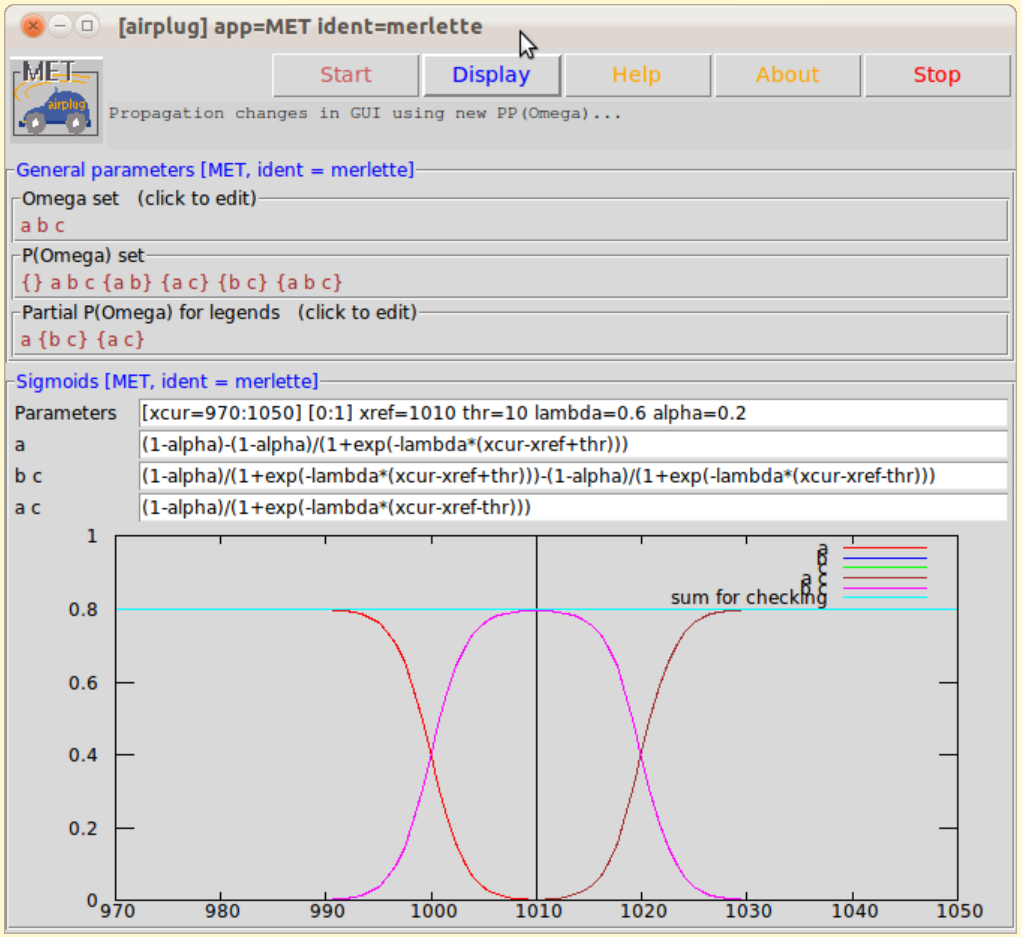
- Sigmoids



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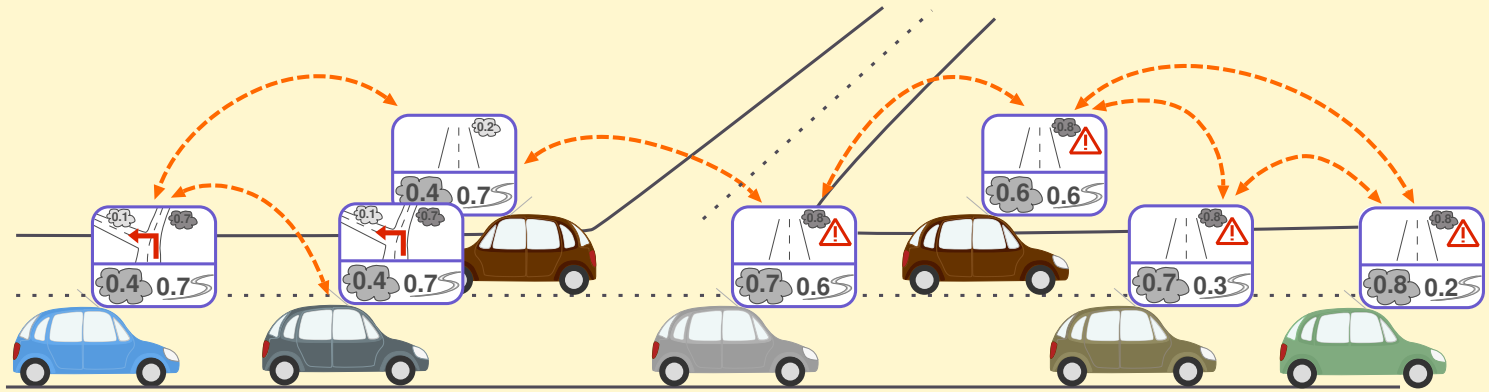
Distributed data fusion

Distributed algorithm: motivation

- Distributed approach for data fusion
  - Direct confidence (regularly) produced locally
    Using an external uncertain device
  - Node's confidence computed using other values

  - Avoiding data collection
  - Locality
    - One result per node
    - Depends on its position in the network



Distributed data fusion

Distributed algorithm: example

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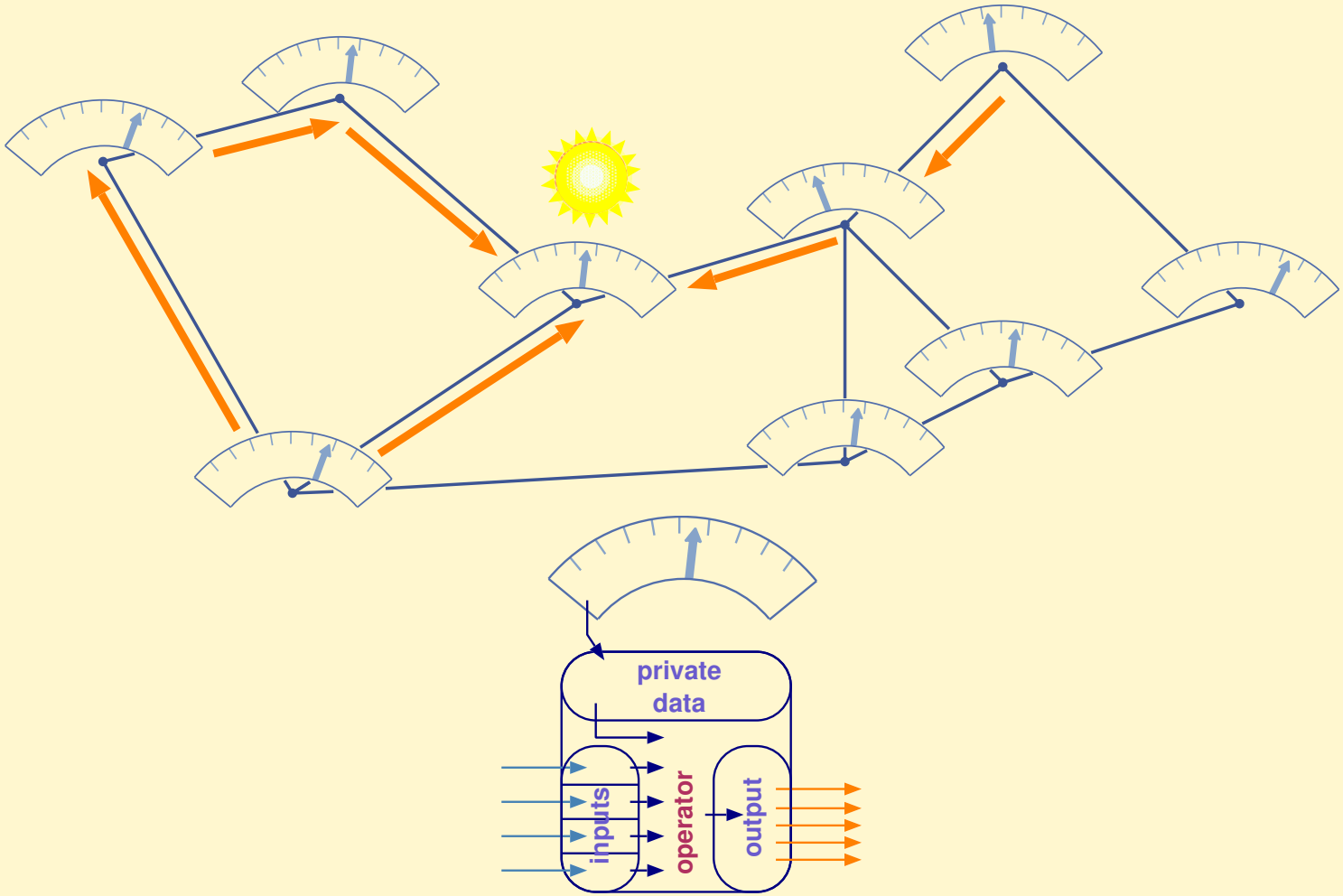
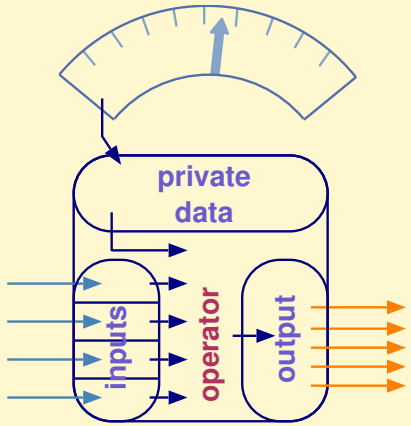
- Result on any node v now depends on all other nodes, not only its neighbors.



Distributed data fusion

Distributed algorithm: details



Upon (local) timer expiration

$\mathtt{PRIV}_v \leftarrow$ current direct confidence

$\mathtt{OUT}_v \leftarrow \mathtt{PRIV}_v$

for each entry u in $\mathtt{IN}_v$ **do**

  $\mathtt{OUT}_v \leftarrow \mathtt{OUT}_v \oslash r(\mathtt{IN}_v[u])$

end for

push($\mathtt{OUT}_v$ **)**

Reset $\mathtt{IN}_v$

Restart the timer

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Distributed data fusion

Distributed algorithm: characteristics

- Our distributed data fusion algorithm [SSS2012]
  - Combine all direct confidences of the system
  - Relies on local periodic broadcast
  - Discount received information
    ⇝ confidence decreases according to the distance

- Characteristics
  - Finite data set
    Discretization + adapted operators
  - Asynchronous and anonymous system
  - Unreliable message passing system

  - Intermittent faults on memories/messages
  - Crash faults on nodes

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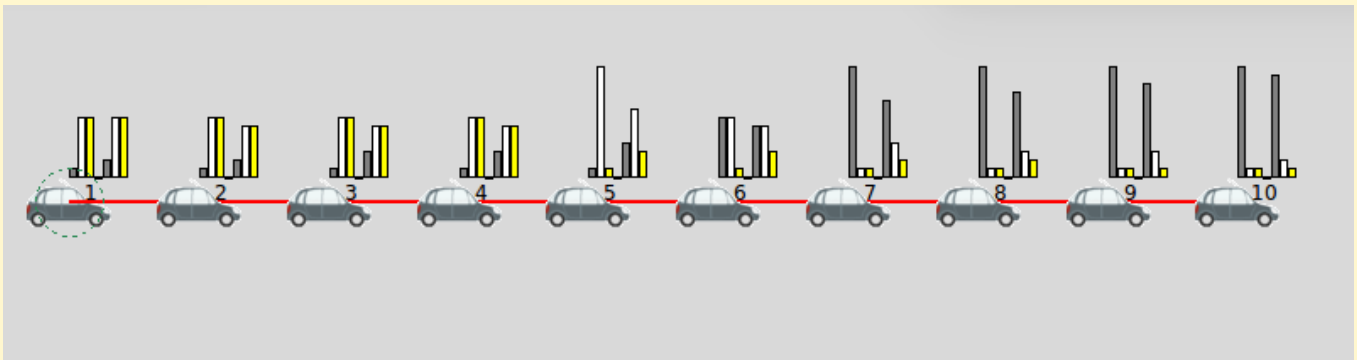
Distributed data fusion

Properties: locality

- Discounting **r**
  - Local computation: $\mathtt{OUT}_v \leftarrow \mathtt{OUT}_v \circledcirc r(\mathtt{IN}_v[u])$
  - $\circledcirc$: cautious operator defined on weights
  - r : discounting function
    - Decreases the information
    - Application-dependent
- Without discounting
  - A single result per connected component
- With discounting
  - Limited influence of a node
  - Locality of the result



Distributed data fusion

Properties: robustness

- Self-stabilization [SSS2005, SSS2007]
  - $\triangleleft$: r-operator defined by $x \triangleleft y = x \oslash r(y)$
  - Condition 1: endomorphism
    $\mathbf{r}(\mathbf{w}_1 \oslash \mathbf{w}_2) = \mathbf{r}(\mathbf{w}_1) \oslash \mathbf{r}(\mathbf{w}_2)$
  - Condition 2: expansion
    $\mathbf{w} \prec_{\oslash} \mathbf{r}(\mathbf{w})$
- Without discounting
  - No convergence after a fault
    In a message, in a memory or in the input device
- With discounting
  - Convergence in finite time after the transient failure ceases

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Properties: complexity

- Stabilization time — supposing a synchronous system
  - $O(k + D)$
  - k: defined by $r^k(\text{smallest value}) = \text{largest value}$
  - D: diameter of the stabilized topology

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   - Strategy for dynamic networks
   - One-to-many communication (V2V)
   - Vehicle to Infrastructure communication (V2I)
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4 Cooperative communication architecture
- Strategy for dynamic networks
- One-to-many communication (V2V)
- Vehicle to Infrastructure communication (V2I)

Cooperative communication architecture

Strategy for dynamic networks 1/2

- Dynamic network: topology? address?
- One-to-one communication (V2-1V)
  - Known receiver? $\rightsquigarrow$ fix or already encountered
  - Maintaining a path
- One-to-many communication (V2-nV)
  - Sending a message without knowing the receiver ...and without trying to know it
  - Sending to receiver(s) defined by conditions
- Vehicle-to-infrastructure communication (V2I)
  - Sharing the gateways toward Internet
  - Enlarging their range
  - Cooperative approach
    - First try by yourself (waiting for a gateway)
    - Else request help from others

Cooperative communication architecture

Strategy for dynamic networks 2/2

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- Choosing the next hop
  - Neighborhood is unstable
  - Learning from the neighborhood is costly
- Sender-side
  - Exchange messages to learn about the neighbors
  - Select a neighbor
  - Send the message to the selected neighbor
  - Consume bandwidth
  - The neighborhood may have change
- Receiver-side
  - Send the message to all neighbors
  - Each neighbor decides whether it is concerned or not

    Solutions to avoid several retransmission if required

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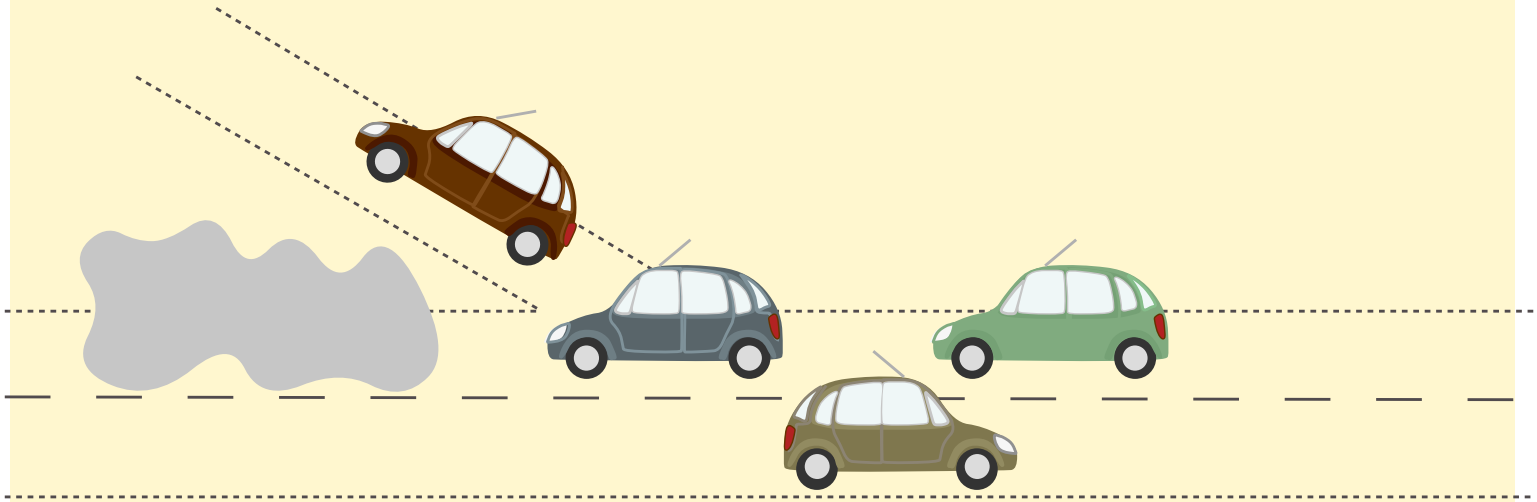

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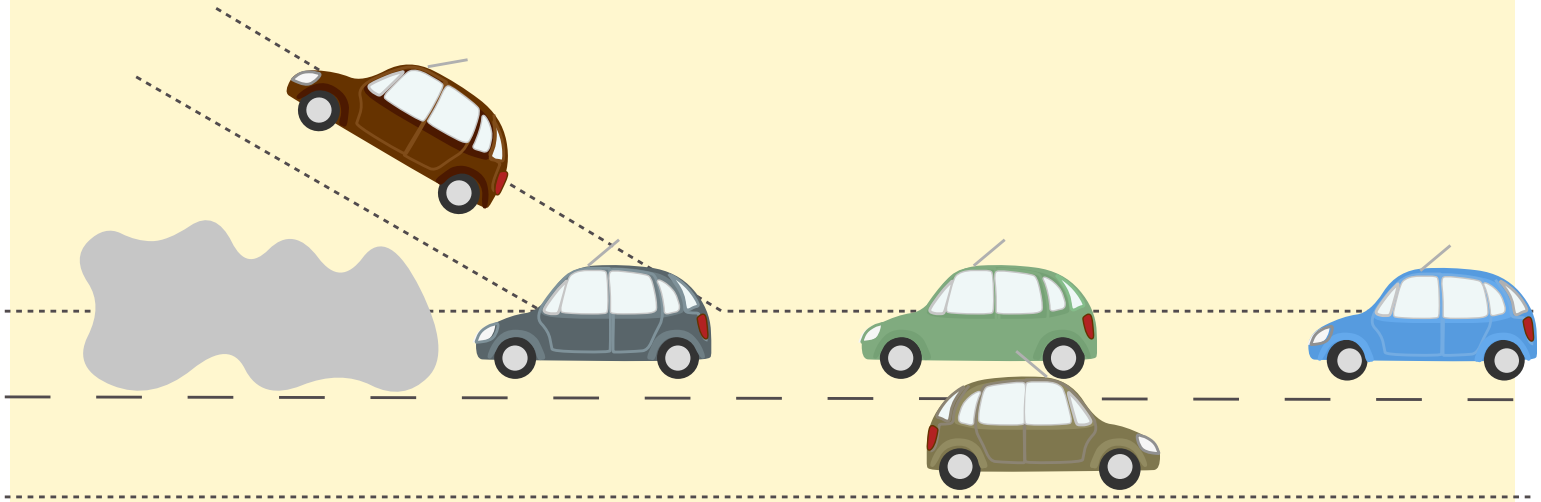

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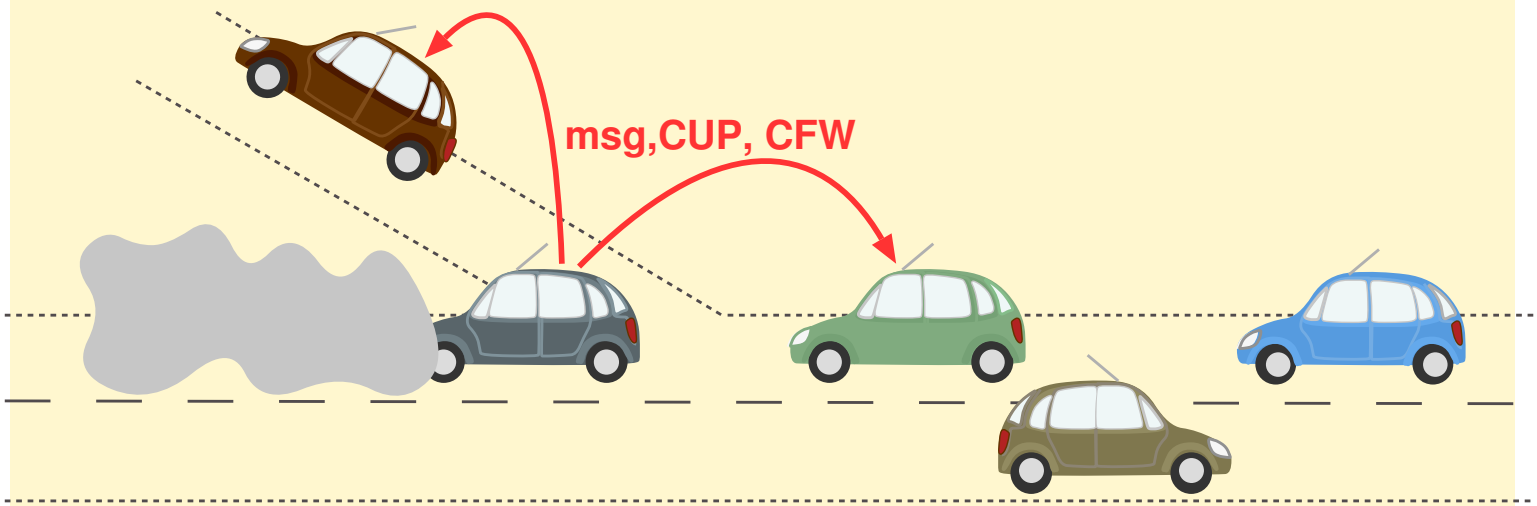

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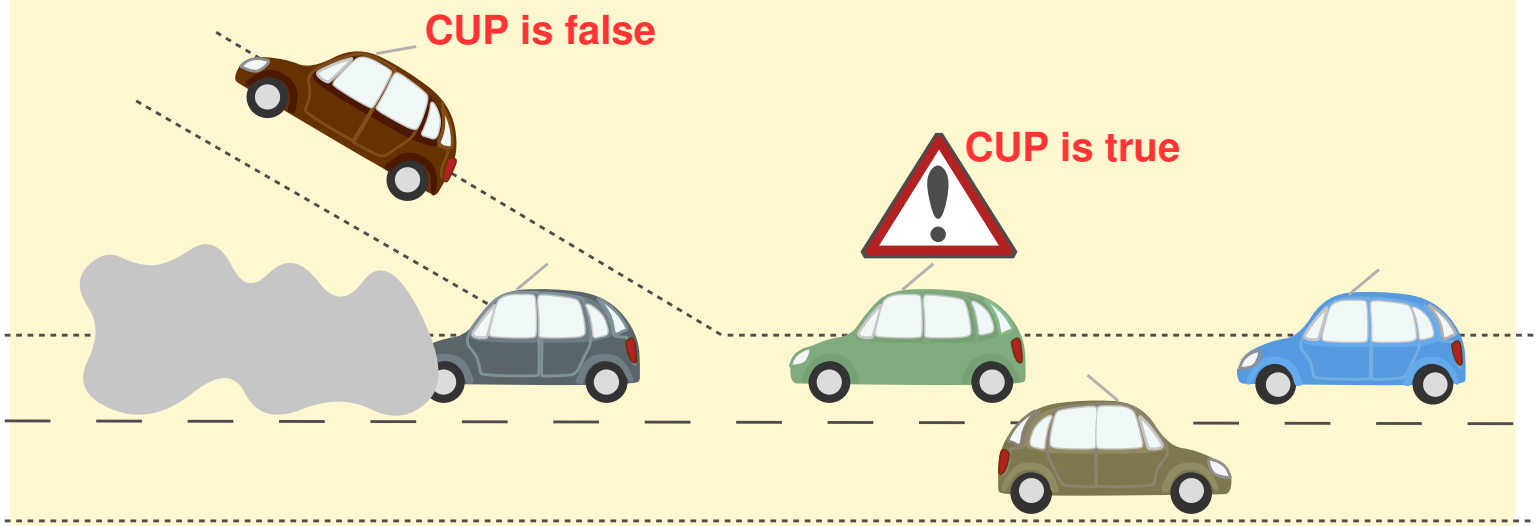

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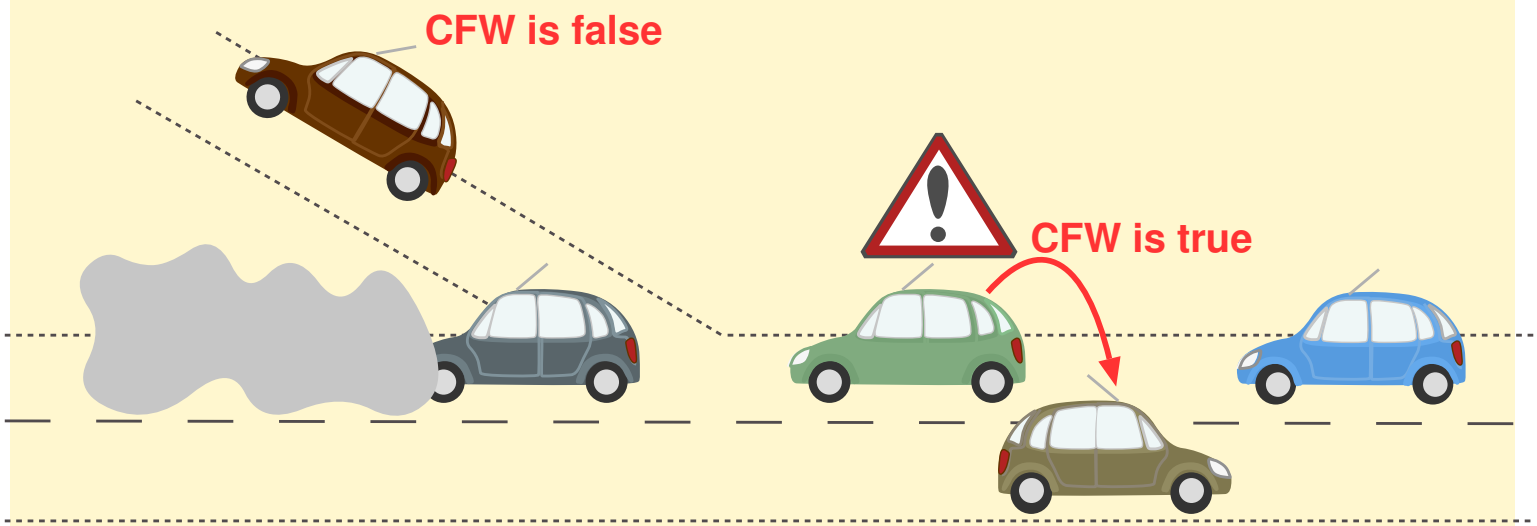

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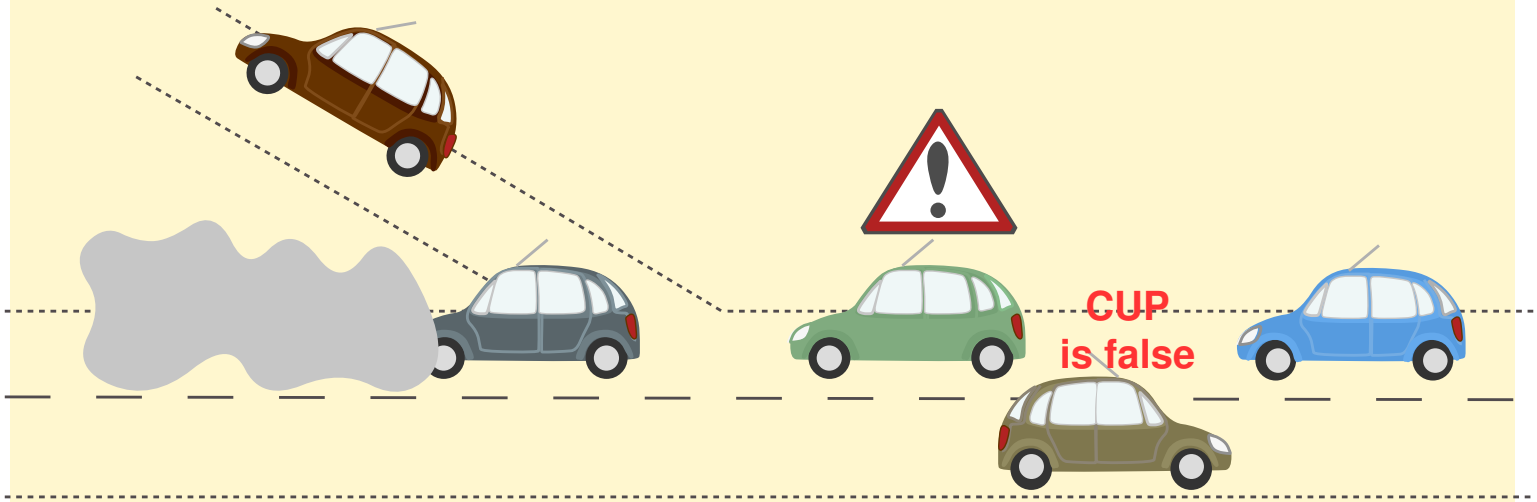

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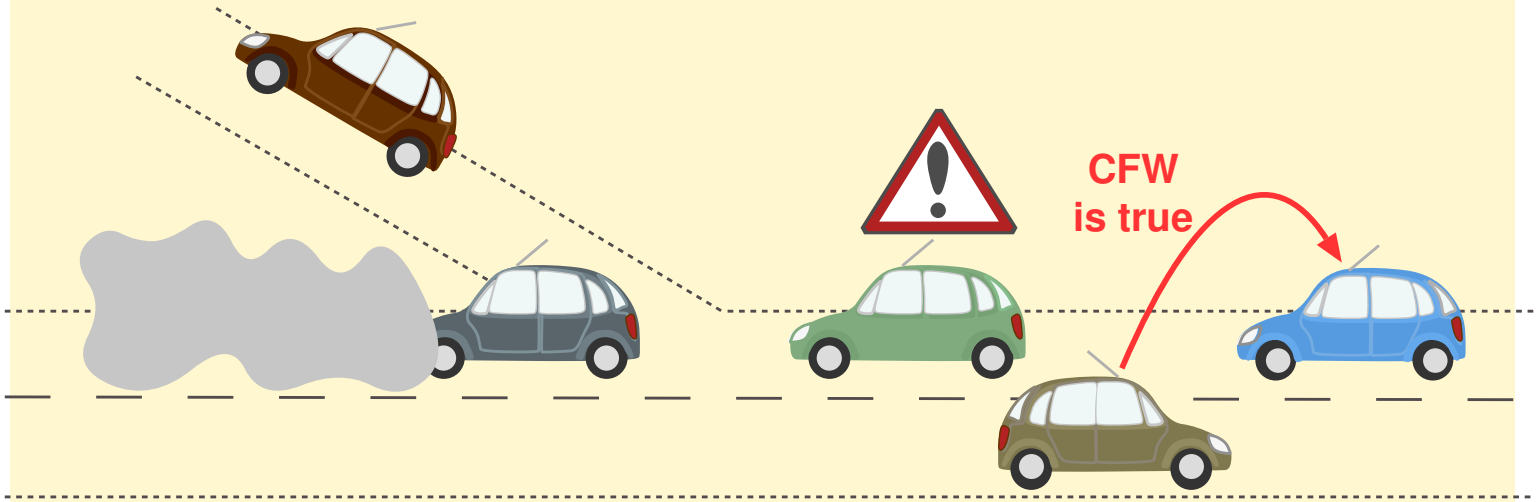

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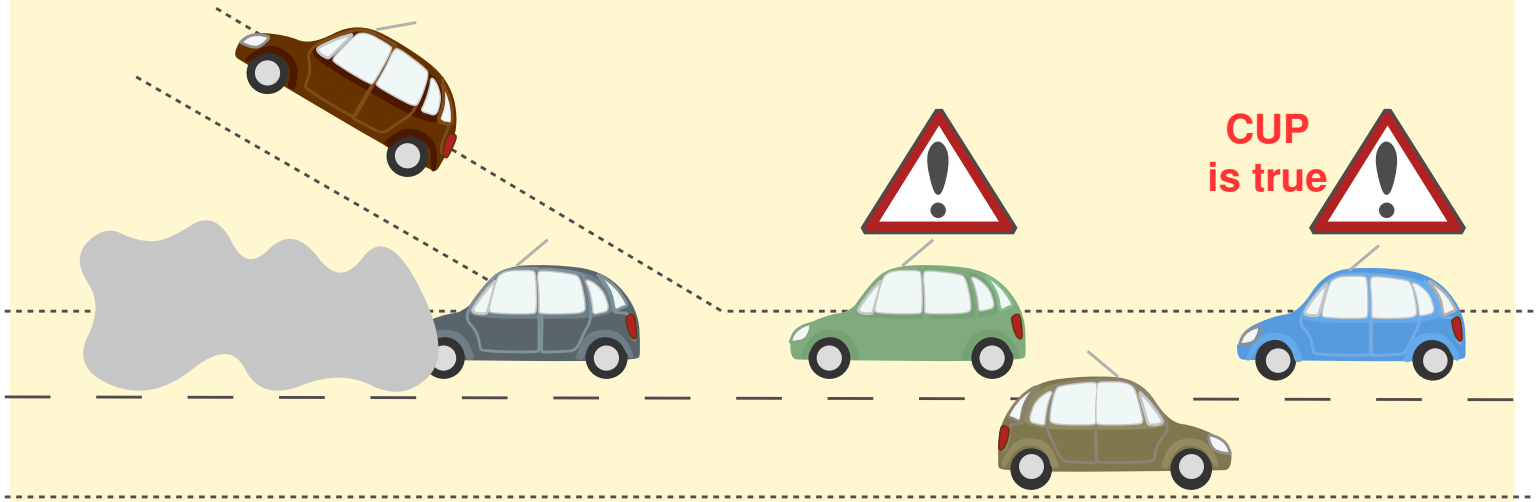

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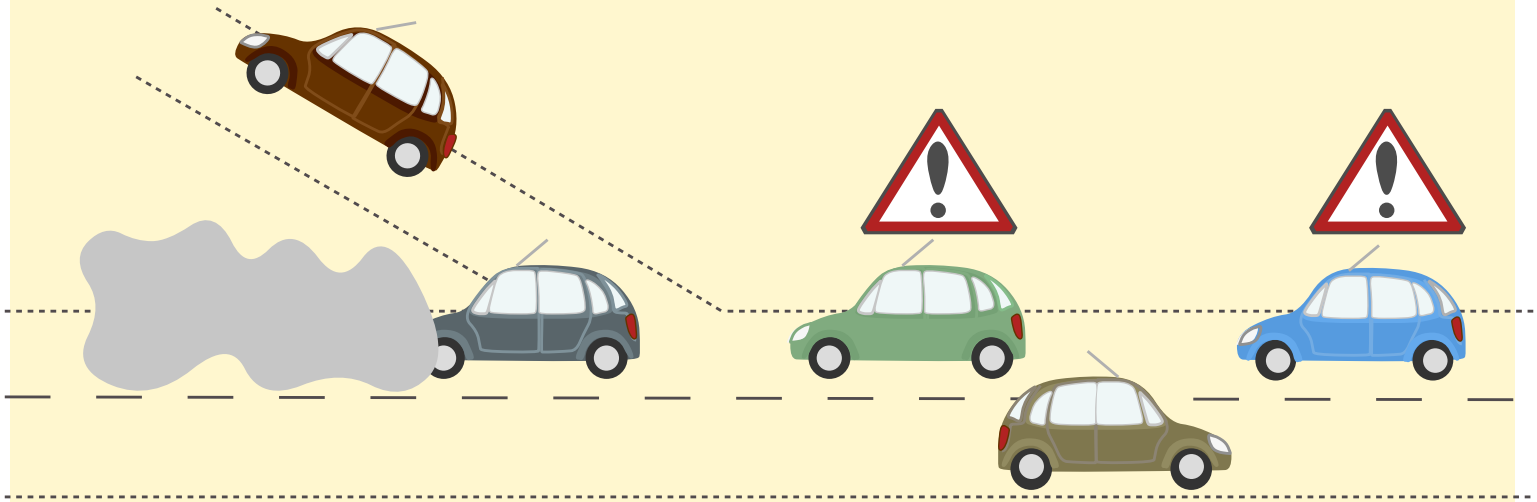

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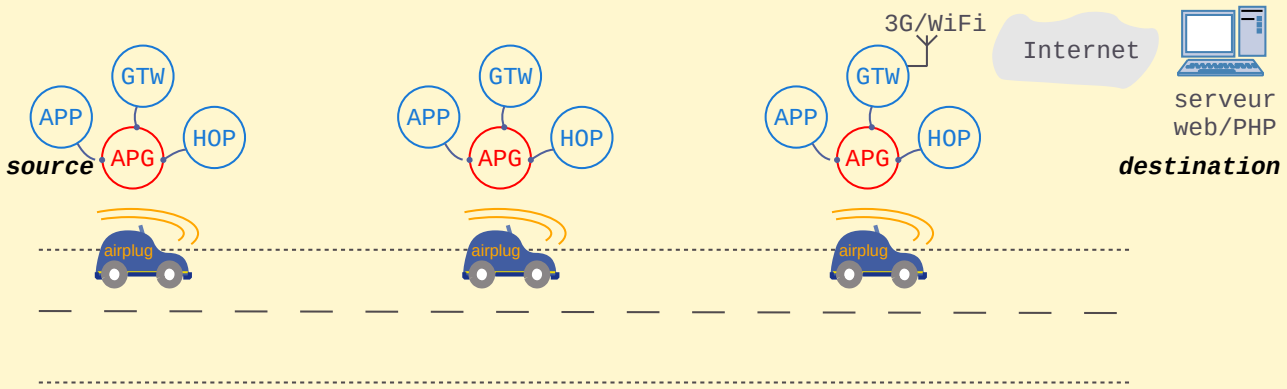

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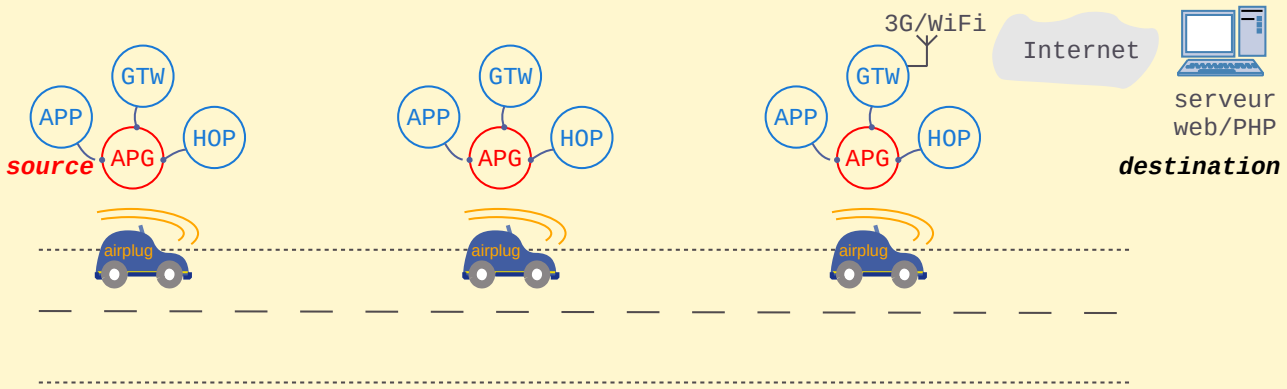

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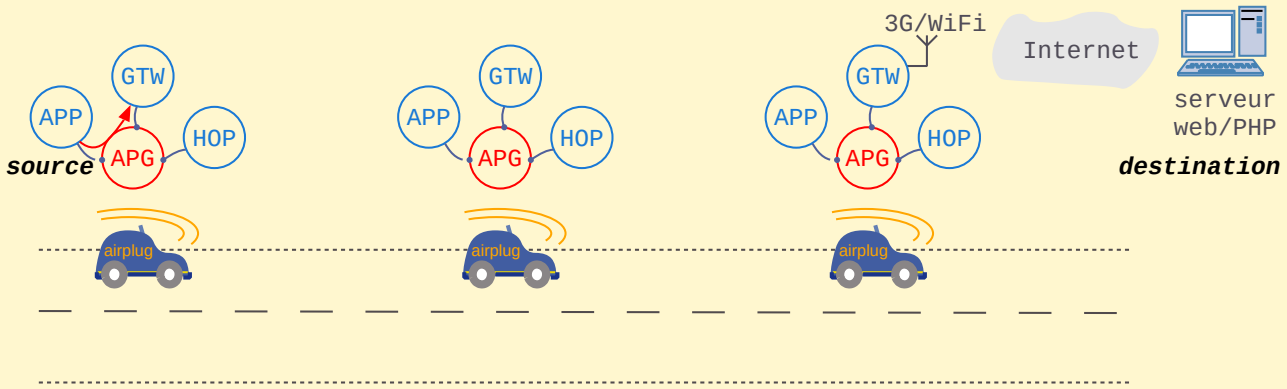

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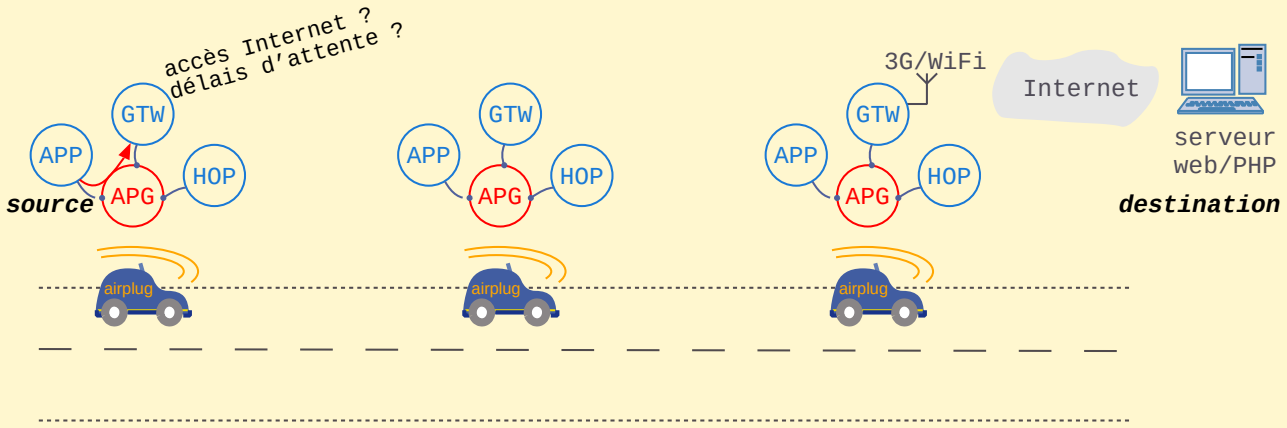

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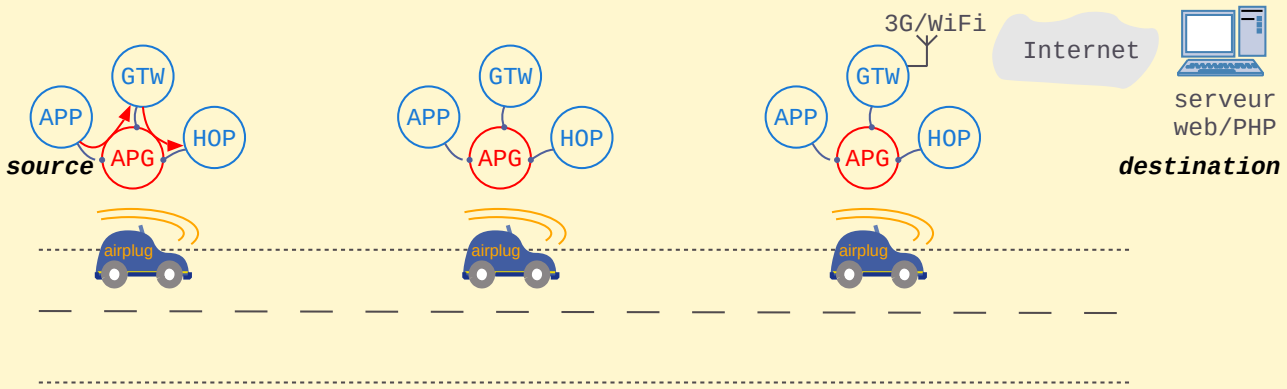

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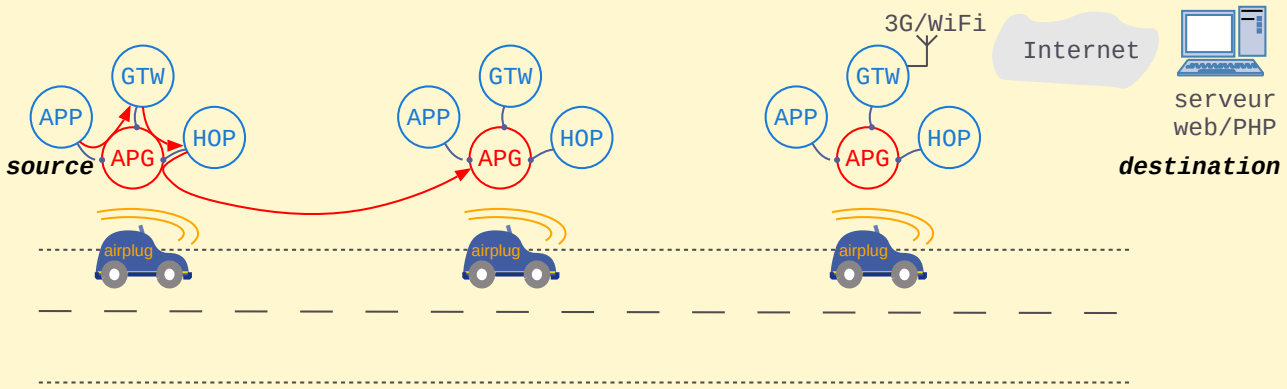

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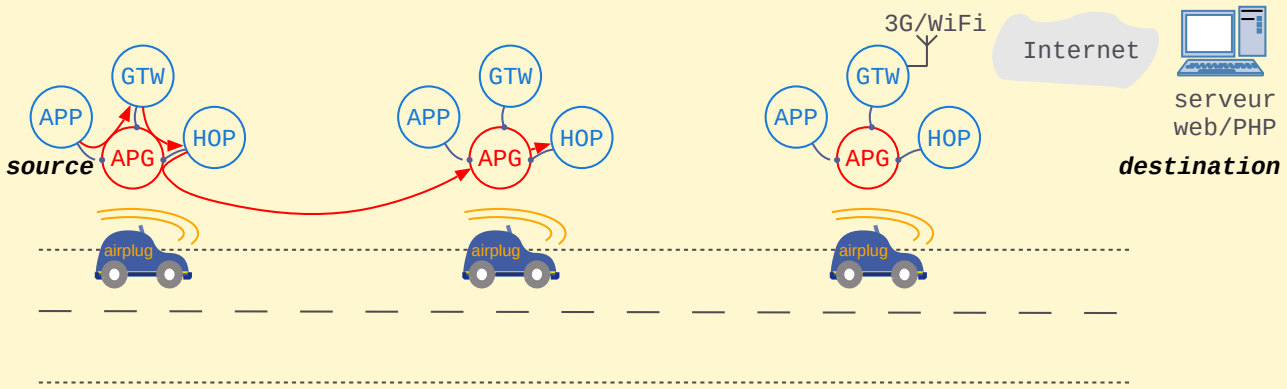

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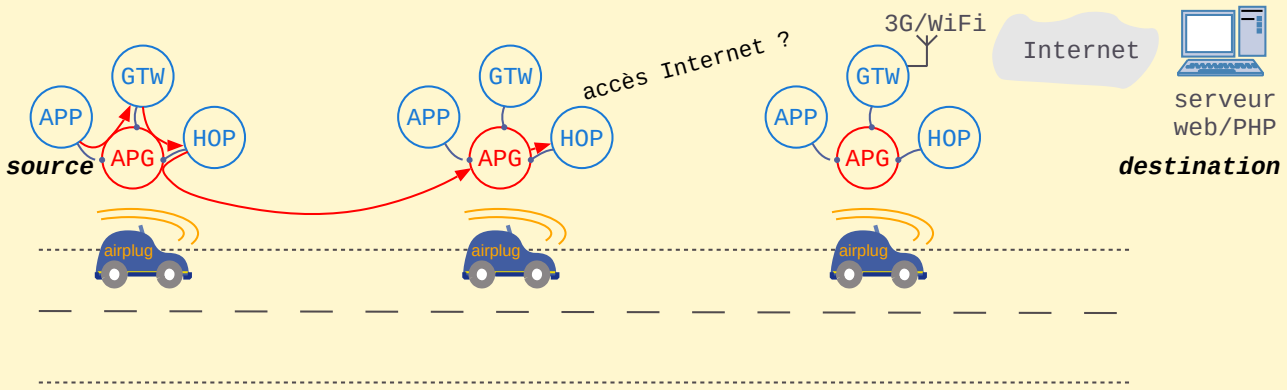

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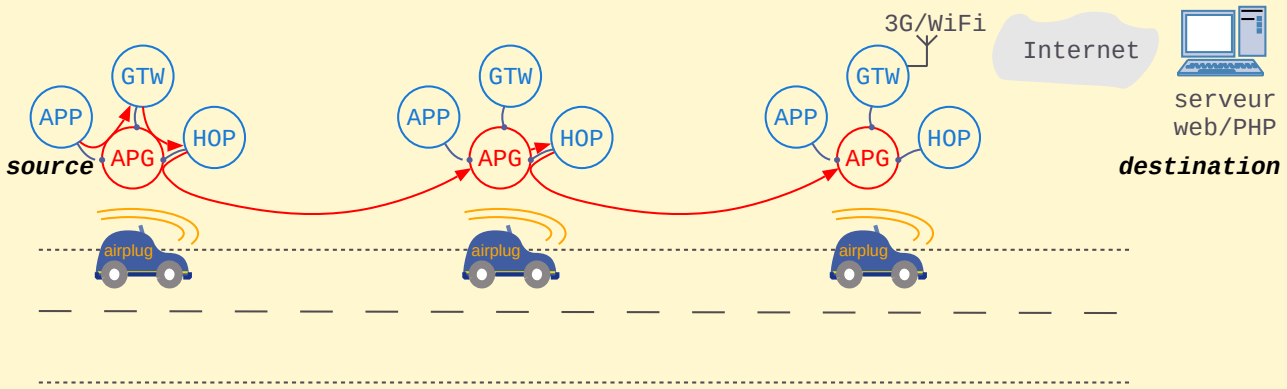

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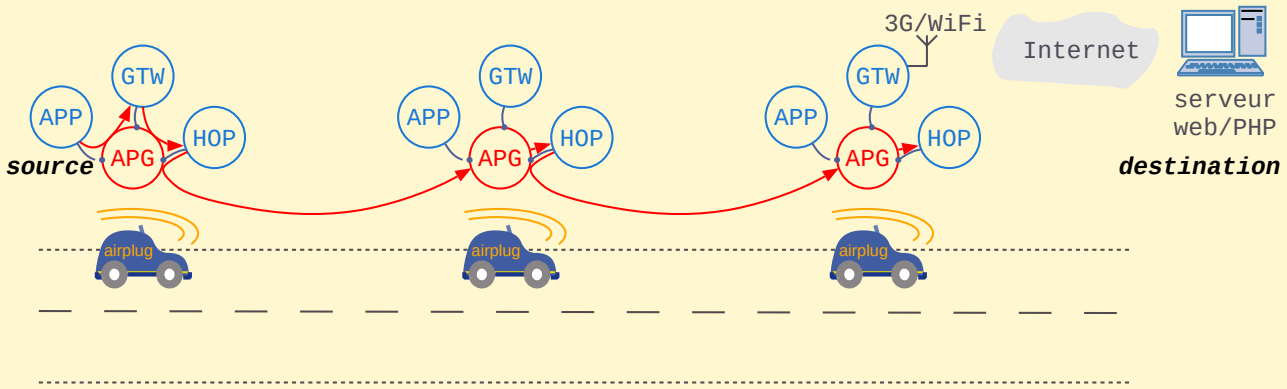

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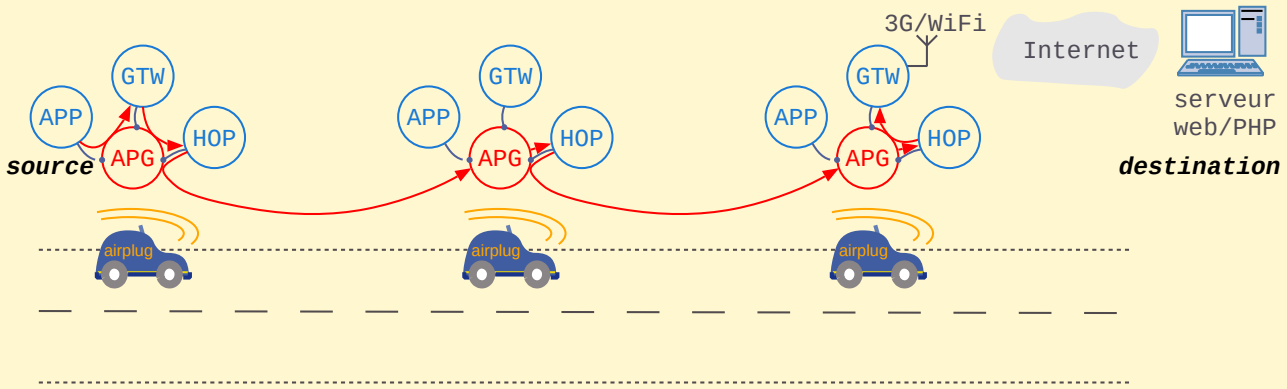

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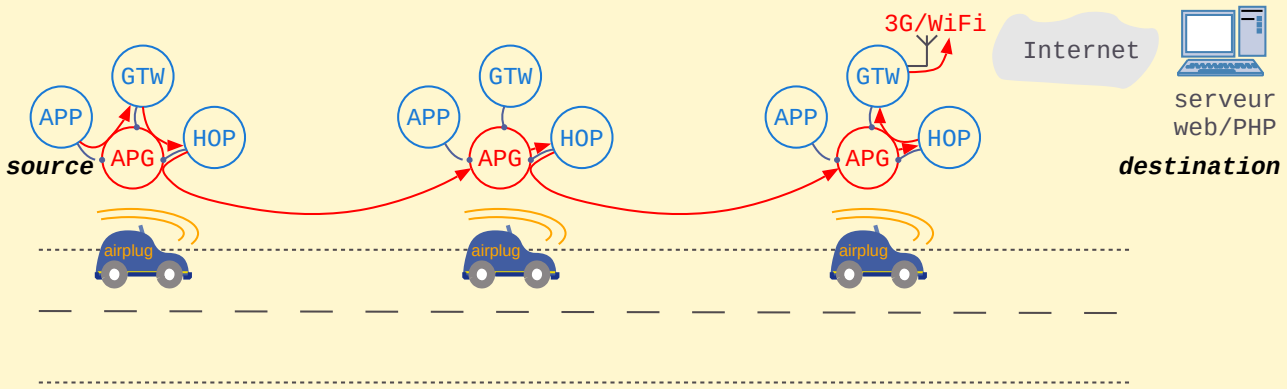

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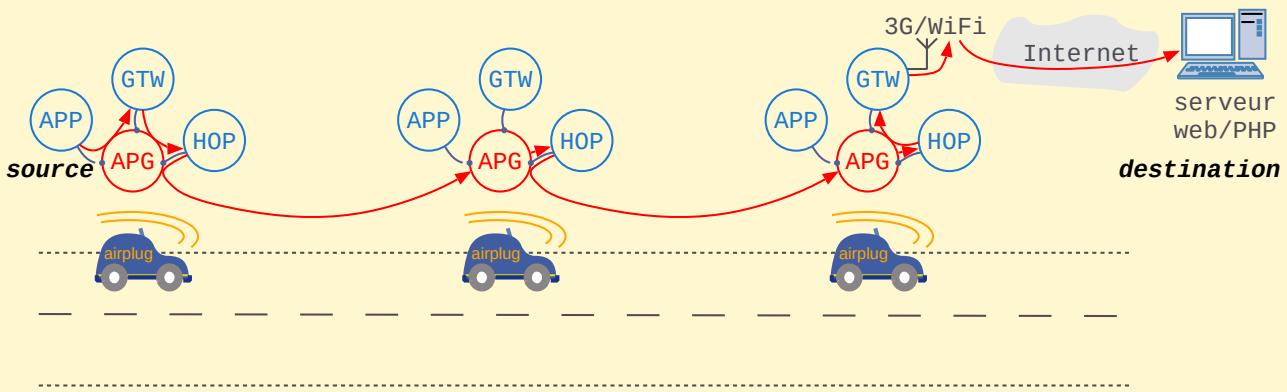

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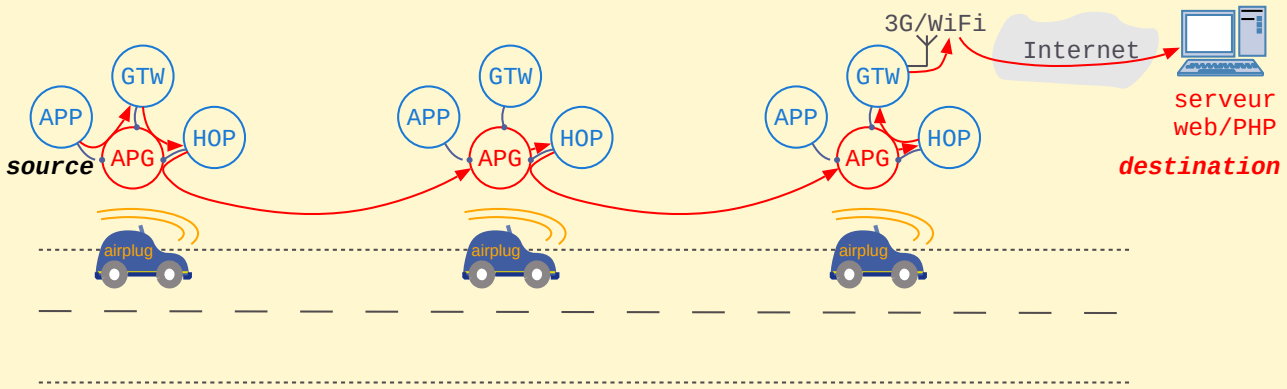

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3 Distributed data fusion

4 Cooperative communication architecture

5 Conclusion

Cooperative alert generation and propagation in vehicular networks

- Distributed data fusion
  - Robust algorithm avoiding the data collection
- Cooperative communication architecture
  - Vehicles cooperate to share and send info
- CoMoSeF project Celtic-Plus Office, DGE
  - From theory to practice with large experiment

- Cooperation preserves privacy
  Our experiments prove the usability of this approach

- Future works
  - Regional project *Toredy*
  - MS2T Labex project *Dapad*
  - CNRS PEPS OCAAA *Pecoredy*

Experiment

- Distributed data fusion
  - Enforce confidences in the rain event
- Decision phase
  - Pignistic probability $>$ threshold $\rightsquigarrow$ alert
- Alert propagation
  - Message forwarding based on conditions