COLOMBO

Cooperative Self-Organizing System for low Carbon Mobility at low Penetration Rates

Work Package 1

Approaches for Low Penetration C2X Traffic Surveillance Systems

Webinar, 24th April 2014

Jérôme Härri, Xiaoguang Li, Thrasyvoulos Spyropoulos

WP 1 - Low Penetration Rate Cooperative V2X Traffic Surveillance

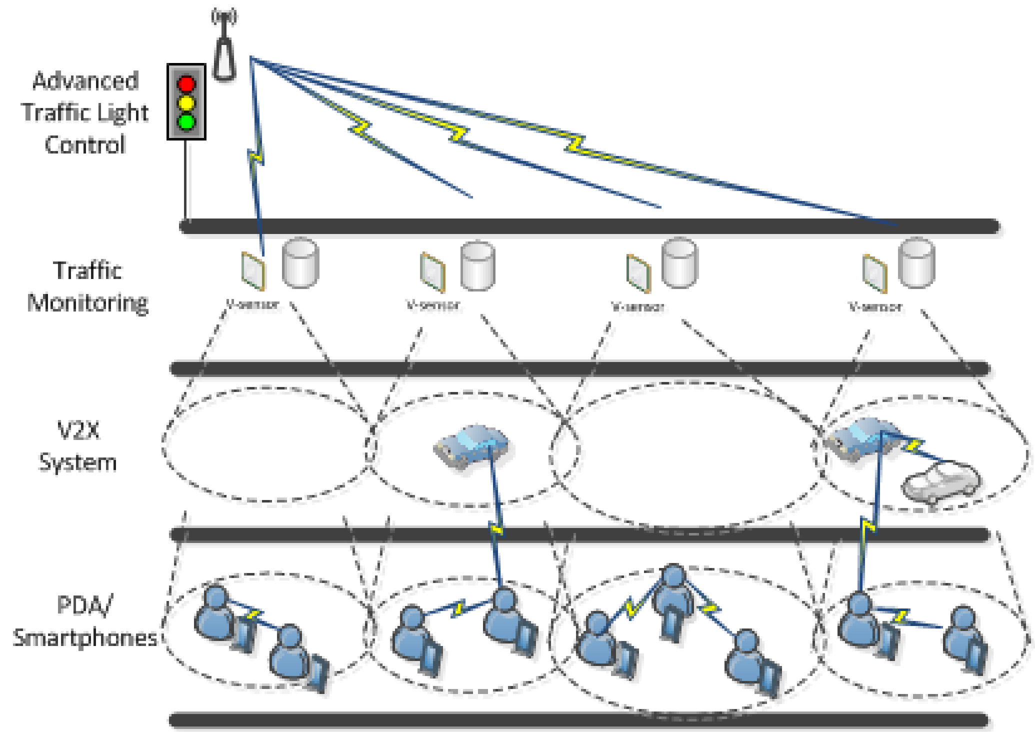
- **Objectives**:
  - Classify vehicles in three classes as function of traffic sensing capabilities –
    - Class A – vehicles not participating to traffic surveillance
    - Class B – vehicles equipped with sensors but not C2X
    - Class C – vehicles equipped with C2X technologies
  - Develop Traffic monitoring system from data gathering, fusion and dissemination of traffic data obtained from class B and C vehicles, assisted by infrastructure nodes
- Involved Partners:
  - **EUR**, DLR, UNIBO, ULB, PEEK, TUG
- For Year 1:
  - **Deliverables**:
    - D1.1: Scenario Specification and Required Modifications to Simulation Tools [M12]
  - **Milestones**:
    - M1.1: Reference Scenarios specified and integrated into SUMO, PHEM and iTETRIS [M12]

Agenda - Low Penetration Rate Cooperative V2X Traffic Surveillance

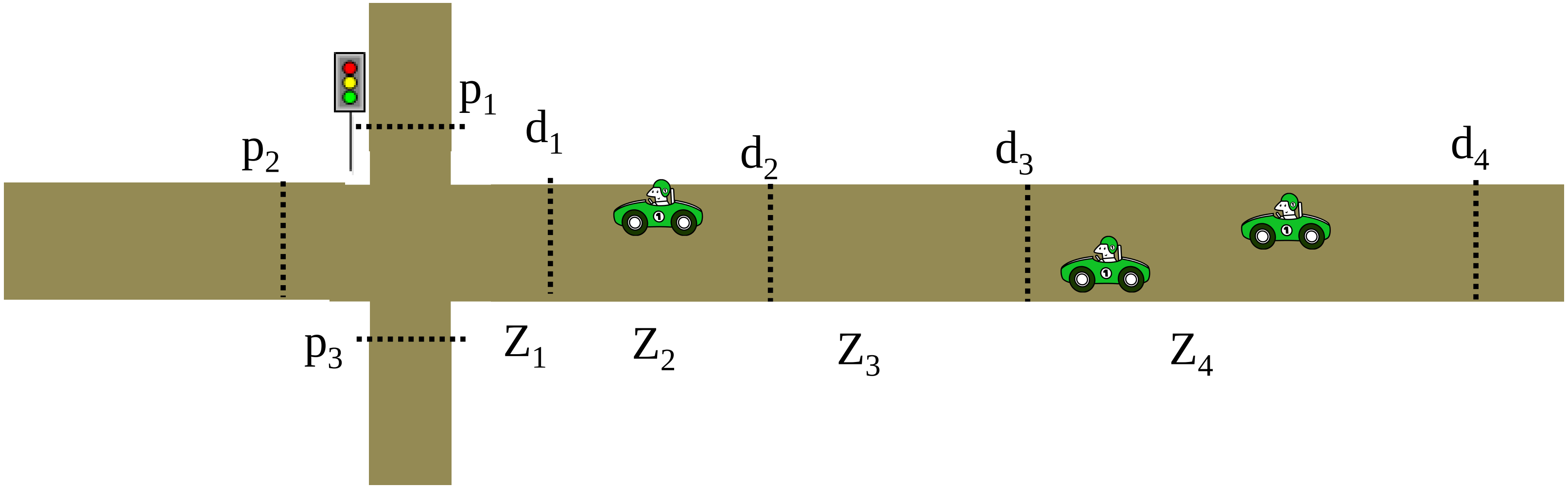
- Low Penetration Rate Cooperative V2X Traffic Surveillance
  - Low C2X Penetration
  - Rely on WiFi-Direct or Bluetooth devices
  - Multiple types of GPS devices
- Objective:
  - Traffic Volumes / Traffic Dynamics (speed) in given zones
- Approaches followed in WP1
  - **Clustering & Data Fusion** –
    - Vehicles cluster and let a cluster-head estimate the cluster dynamics
  - **C2X Message Propagation** –
    - Vehicles send messages and estimate the density & speed from its propagation rate

Virtual Sensor Approach for Cooperative Traffic Surveillance

- Virtual Sensors represent a zone where the traffic light needs traffic volumes
  - Virtual Sensors only have a 'virtual' existence from an artificial zone defining their coverage
- V2X vehicles (class C) in each zone will exchange traffic data to consolidate traffic volumes
  - Consolidated volumes are transmitted to the RSU (direct, multi-hop)
  - Dissemination is transparent to RSU
- Low V2X penetration is compensated by Smartphones held by drivers and pedestrians and communicating with WiFi-Direct



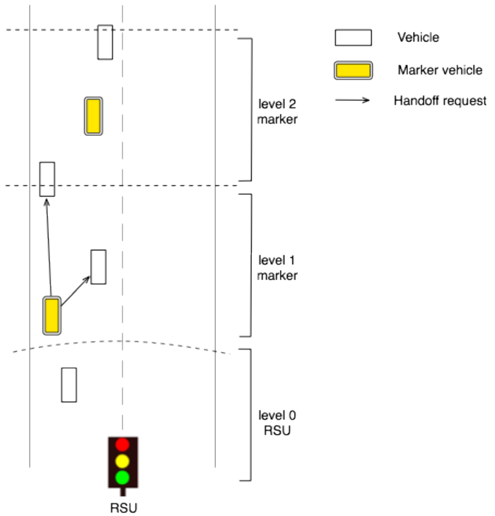
Data Requirements from a TLC perspective



- d_x – measuring distances before TLC
- p_x – measuring distances after TLC
- Z_x – measured zones $[p_{x-1} – p_x]$, $[d_{x-1} ; d_x]$
- Traffic Dynamics –
  - Average speed in Z_x
  - Average Density of Cars in Z_x

Clustering & Data Fusion Approach

- Step 1: Cars need to form clusters in Z_x
  - A car must be elected Cluster Head in each Zone
  - Two approaches: Reactive vs. Proactive
- Step 2: Cluster head gathers data from its neighbors
  - average number of neighbors (in neighbor table)
  - average speed
- Step 3: Data is consolidated through fusion technics
- Step 4: Consolidated Data is sent to TLC



- Hypothesis (so far):
  - One single zone so far
  - The single zone is range of a TLC (direct communication)

Clustering - Reactive protocol (for each direction)

- Distributed Auction:
  - Each ‘activated’ node sends a **LeaderRequest** message
  - Each node counts the **number of neighbors** in its range by **counting** the number of **LeaderRequests** it receives
  - The node with the **maximum number of LeaderRequest** assume to be **Leader**
  - **Leader** sends a **IamLeader** message to other nodes and activate the **Group Leadership/Membership Protocol**
    - Any node receiving this message activate the **Group Membership Protocol**

- Activation:
  - Upon reception of ***a beacon from an RSU***
  - Upon reception of a LeaderRequest message from any other node

Clustering - Proactive protocol (for each direction)

- **(periodic) *Node Mapping Protocol (NMP)***
  - maintains a mapping of neighboring vehicles by periodically sending a beacon with information from neighbors (***id, position, speed, direction, and number of known nodes)***
  - Each vehicle can ***autonomously determine whether it is the best candidate***
  - The node with **larger neighbor** set becomes **leader**

- **Activation:**
  - Upon reception of ***a beacon from an RSU***
    - either invites a "good" node with many neighbors to take the leadership
    - or starts a timer with a duration inversely proportional to the number of nodes in its range;
  - This process favors the election of **nodes with the highest number of nodes** in their radius of action

C2X Message Propagation

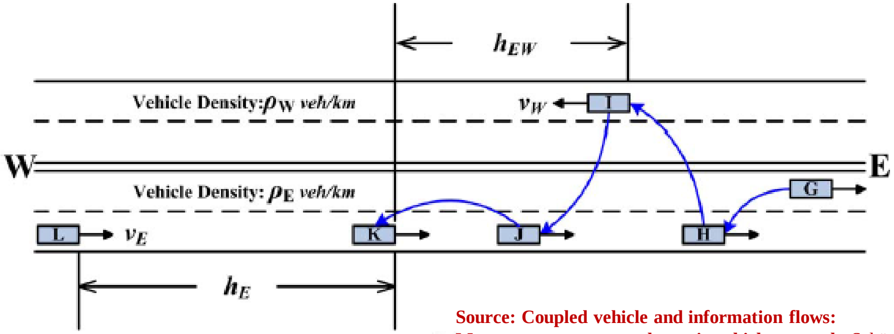
- Observation: **Coupled vehicle and information flows**
- Based on two information flow strategies:
  - **Instantaneous relay**: a message is relayed immediately if there is a neighbor in range with better progress
  - **Carry**: a vehicle carries a message until a better relay is found
    - As soon as a better relay is found, move back to 1)

- Related work:
  - Objective: estimation the **dissemination time** given **traffic density**
    - **Coupled vehicle and information flows: Message transporton a dynamic vehicle network,** Schönhof et al., Elsevier, 2006**)**
    - **Local density estimation and Dynamic Transmission Range assignment in VANET,** M. Artimiy, Trans. On ITS, 2007
    - **The Process of Information Propagation Along a Traffic Stream Through Intervehicle Communication,** Wang et al. IEEE Trans. On ITS, 2014

- For COLOMBO: converse approach
  - Objective: estimation of the **traffic density** given the **dissemination time**

C2X Message Propagation

- Information Disseminations:

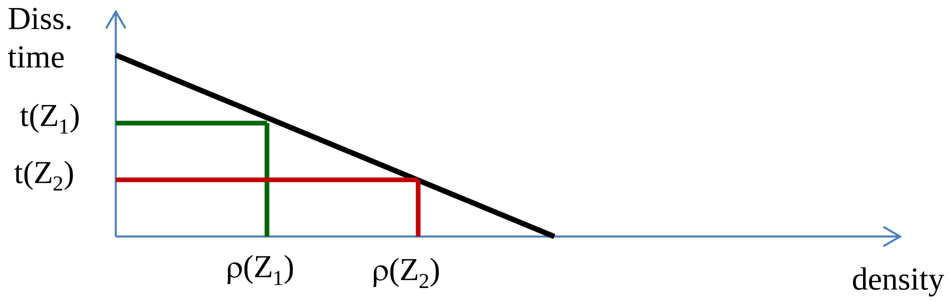


Source: Coupled vehicle and information flows: Message transporton a dynamic vehicle network, Schönhof et al., Elsevier, 2006

- Dissemination (rough sketch)
  - Carry: dissemination = vehicular speed
  - Relay: dissemination immediate = Multi-hop percolation exists
    - Laws of Physics: at least 1 vehicle every T^{range}
    - Density of vehicle may be estimated !
  - Hybrid: carry takes lead over relay

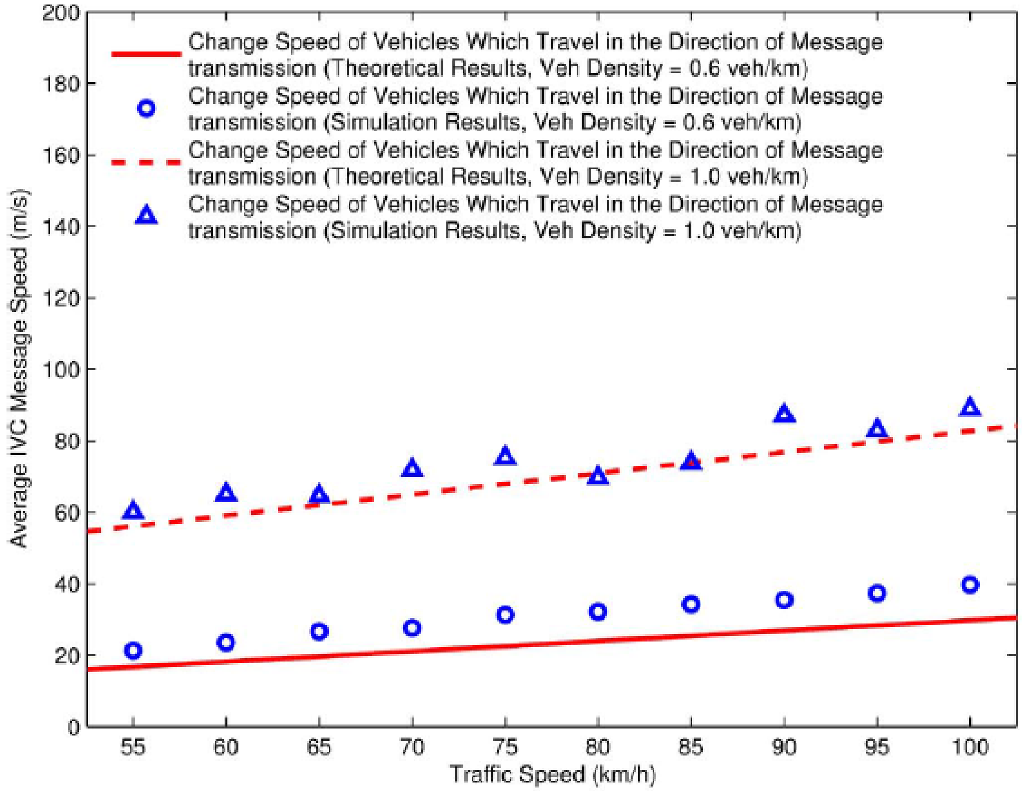
C2X Message Propagation

- Assumptions:
  - Vehicles follow laws of Physics
    - Speed depends on density and conversely
  - Opportunistic communication implicitly selects the farthest node
- Objectives (mockup)



C2X Propagation

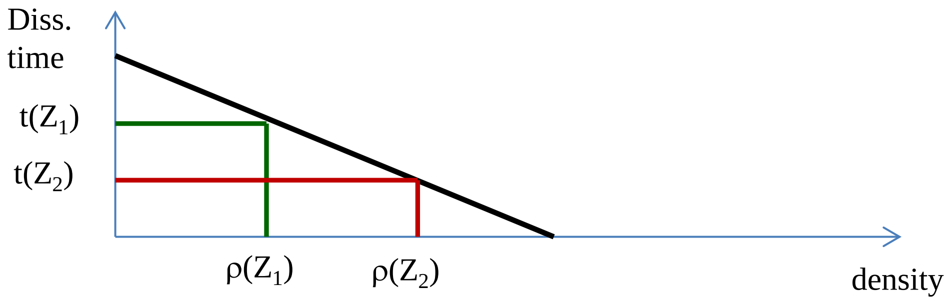
- Linear Relationship (from related work)



Source: The Process of Information Propagation Along a Traffic Stream Through Inter-vehicle Communication, Wang et al. IEEE Trans. On ITS, 2014

C2X Message Propagation

- Objectives (mockup)



- Process:
  - A node sends a message at the beginning of Z_x
  - The node is received by the another node at the end of Z_x
    - Hypothesis here: it is the RSU
  - The time difference (between sent & received): $t(Z_x)$
  - **Research Hypothesis**:
    - **Linear Mapping** between $t(Z_x)$ and $\rho(Z_x)$

C2X Message Propagation

- Process:
  - A node sends a message at the beginning of Z_x
  - The node is received by the another node at the end of Z_x
    - Hypothesis here: it is the RSU
  - The time difference (between sent & received): $t(Z_x)$
  - **Research Hypothesis**:
    - **Linear Mapping** between $t(Z_x)$ and $\rho(Z_x)$

- Benefits (some..):
  - Not directly based on GPS position – can also be used for any type of vehicular class !!
  - May implicitly handle **low penetration of vehicles**
  - May also implicitly handle '**ghost vehicles**'
    - Had to move 'over' them, but from the speed/density relationship, they are there…

Next Steps

- **Research Aspects**:
  - Linear Mapping: remains to be proven
  - Direction Detection :
    - First step: Message should only be propagated on the same direction as vehicles
      - Cannot select other propagation direction
    - Second step: No restriction
  - Low penetration:
    - A x% penetration can be added to the mapping model
      - X% probability of finding a C2X equipped in range (rather than 100%)
  - Zone aspects:
    - Adapting it to zones
    - Impact of dynamic traffic within a zone (transition between free-flow to congested)
  - Data Fusion:
    - Need to conduct sensitivity analysis of how traffic anomalies would change the mapping
    - Need to fusion multiple dissemination delays, potentially remove samples negatively influencing the value.