Vehicular Delay-Tolerant Networks
An Overview

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Rede Temática de Comunicações Móveis (RTCM) – 10º Seminário

Faculdade de Ciências da Universidade do Porto, Portugal, June 23th, 2009

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Outline

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- Vehicular Delay-Tolerant Networks
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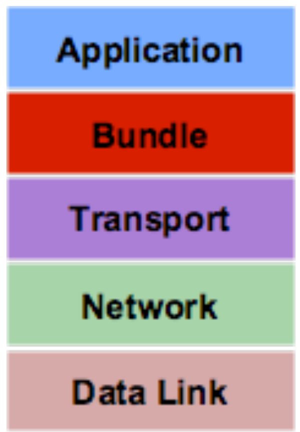
Delay-Tolerant Network (DTN)

- Overlays a protocol layer called *bundle layer* that it is meant to provide internetworking on heterogeneous networks operating on different transmission media
- Store-and-forward paradigm
- Enables communication even in the following situations:
  - Sparse connectivity
  - Long or variable delay
  - Intermittent connectivity
  - Asymmetric data rate
  - High latency
  - High error rates
  - No end-to-end connectivity



Delay-Tolerant Network (DTN)

- Opportunistic Networks
  - Opportunistic contact opportunities
  - End-to-end paths exist over time
  - Intermittent connectivity is common
  - Long propagation delays

  - Some examples:
    - Data MULEs
    - Ocean Sensor Networks
    - Wildlife Tracking Sensor Networks
    - Military Ad-hoc Networks
    - People Networks
    - **Vehicular Networks**

Vehicular Delay-Tolerant Networks

- Application of the Delay-Tolerant Network concept to transit networks
- Vehicles are opportunistically exploited to offer a message relaying service
- Provide low-cost connectivity in scenarios where telecommunications infrastructure is unreliable or not available due to disconnected areas, natural disaster, or emergency situations
- Non-real time applications

Proposal of a VDTN Layered Architecture

- We propose the VDTN layered architecture, where *Bundle Layer* is located under the *Network Layer*, aggregating incoming IP packets into bundle messages.

- VDTN uses **out-of-band signaling**

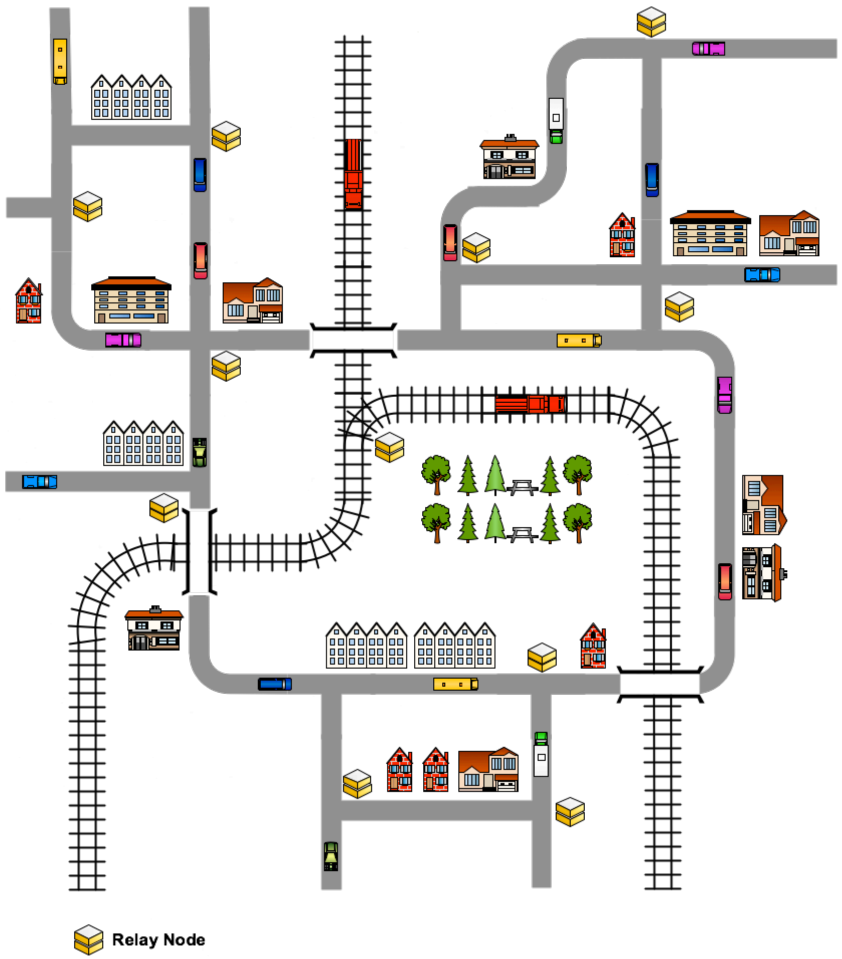
  - **Data plane** is responsible for the transport of incoming packets, which are aggregated into data bundles

  - **Control plane** allows the exchange of control information at the connection setup phase in order to determine and adjust a connection's requested characteristics

  - Distinct planes suggests that they can operate independently using their own layers and protocols

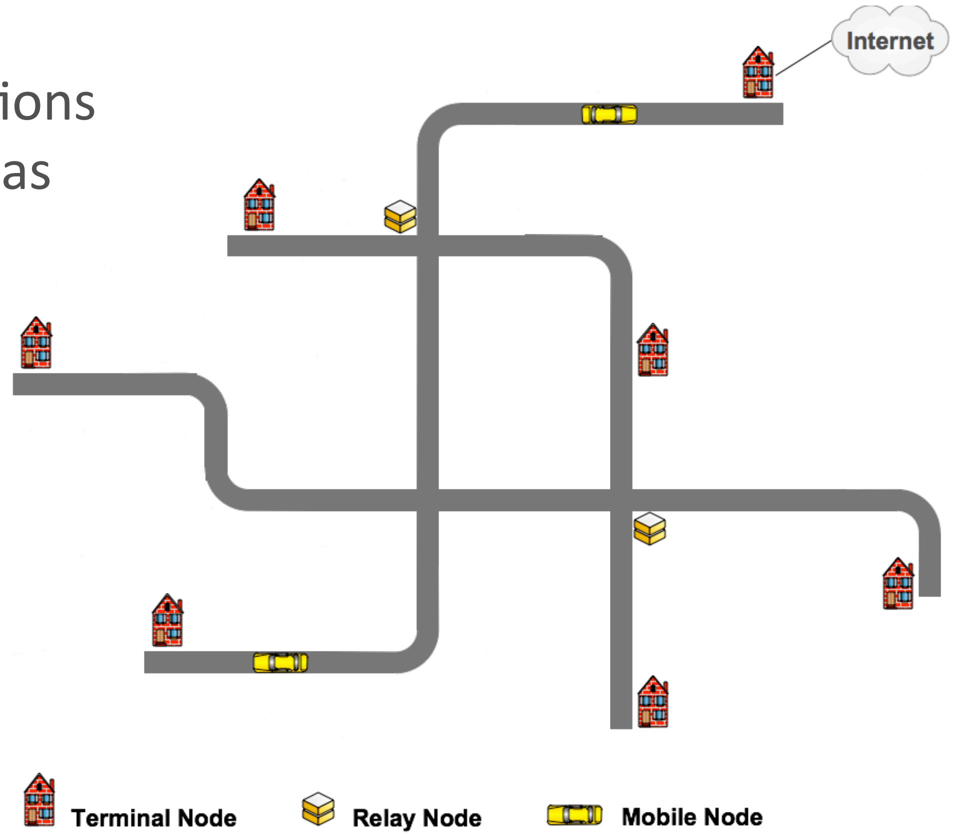
Application Scenarios

- **Urban Scenario**
  - Possible applications
    - Traffic condition monitoring
    - Collision avoidance
    - Emergency message dissemination
    - Advertisements
    - Gather data collected by vehicles like road pavement defects



Application Scenarios

- **Rural Connectivity**
  - Providing data communications to undeveloped remote areas
    - E-mail
    - Voice mail
    - Web access
    - Telemedicine
    - Data collection applications



- Disaster recovery networks

Challenging Issues

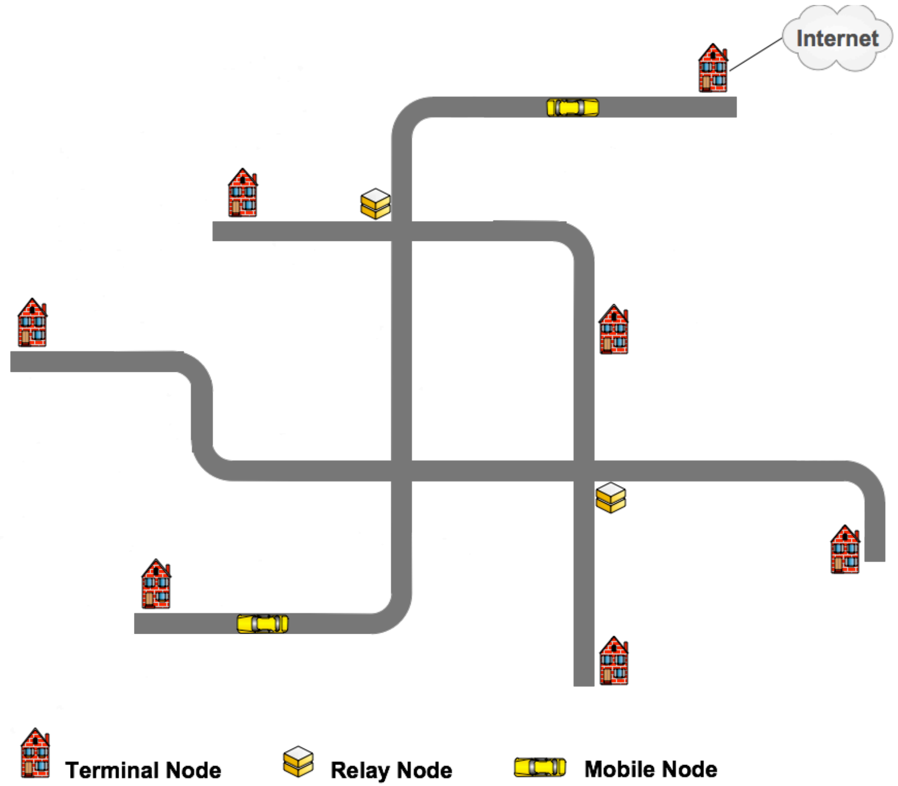
- Different application scenarios raise a number of challenging issues:
  - Network topology (known or not)
  - Node type (mobile, stationary)
  - Node design (energy constraints, storage capacity, physical link data rate, and transmission range)
  - Node mobility pattern (deterministic, stochastic, predictable)
  - Node cooperation
  - Traffic (static, dynamic)
  - Routing and forwarding protocols
  - Buffer management schemes
  - Caching mechanisms

Our Contributions

- Propose VDTN Architecture and its corresponding Layered Architecture
- Stationary Relay Nodes
- Movement Models
- Storage Capacity Constraints
- Scheduling and Dropping Policies

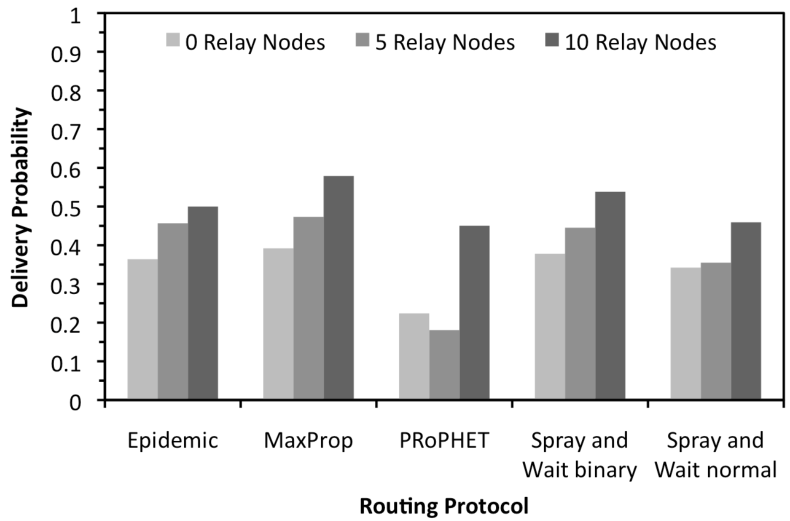
Stationary Relay Nodes

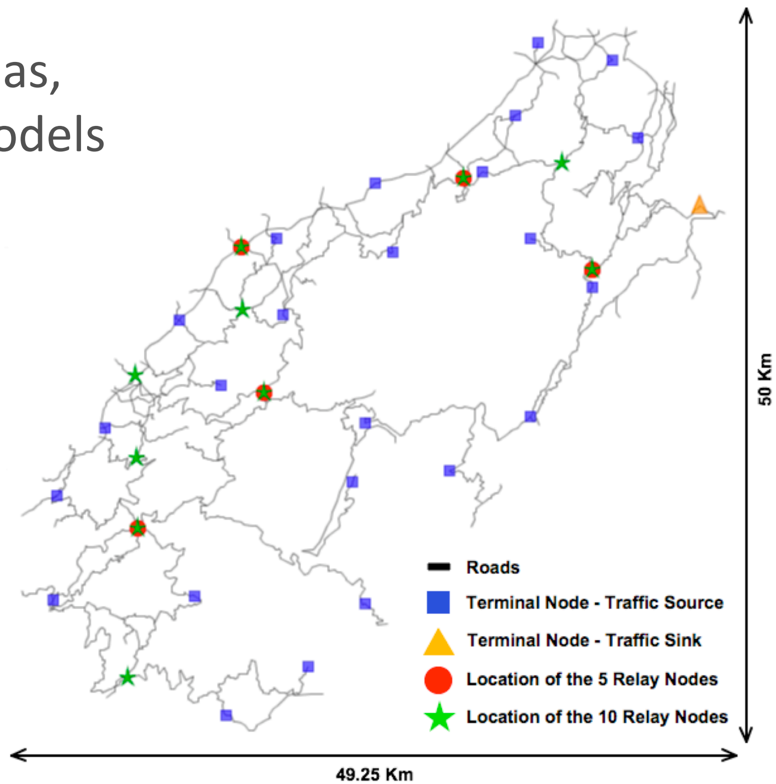
- *Store-carry-and-forward* paradigm may have to be complemented with the introduction of **stationary relay nodes**, in networks with low node density.
  - Creates additional transmission opportunities
  - Contributes to increase message delivery ratio and decrease message delivery delay



Stationary Relay Nodes

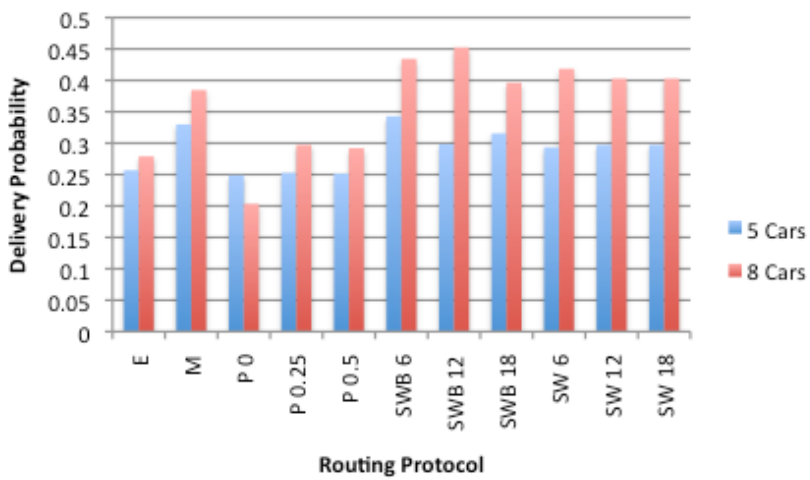
- We evaluated the impact of adding stationary relay nodes over the performance of DTN routing protocols applied to VDTNs
- Different application scenarios, map areas, node density, and vehicle movement models

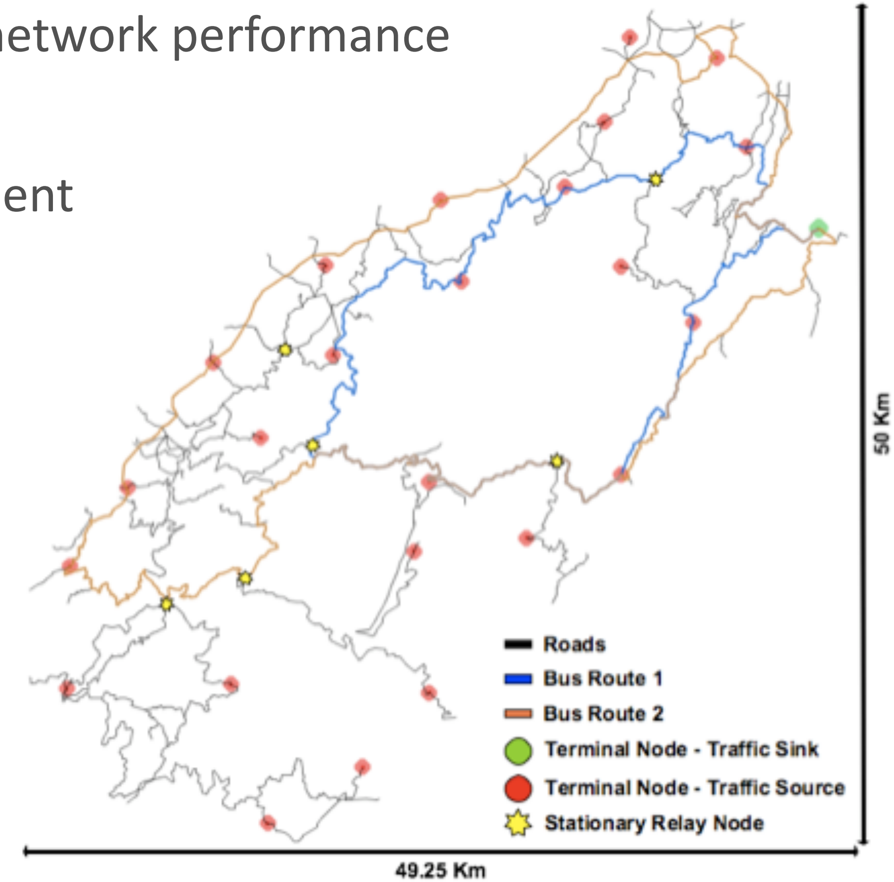




Movement Models

- We studied the impact of different numbers and groups of vehicles with specific movement models on the network performance
  - Random waypoint
  - Shortest path map based movement
  - Map route movement



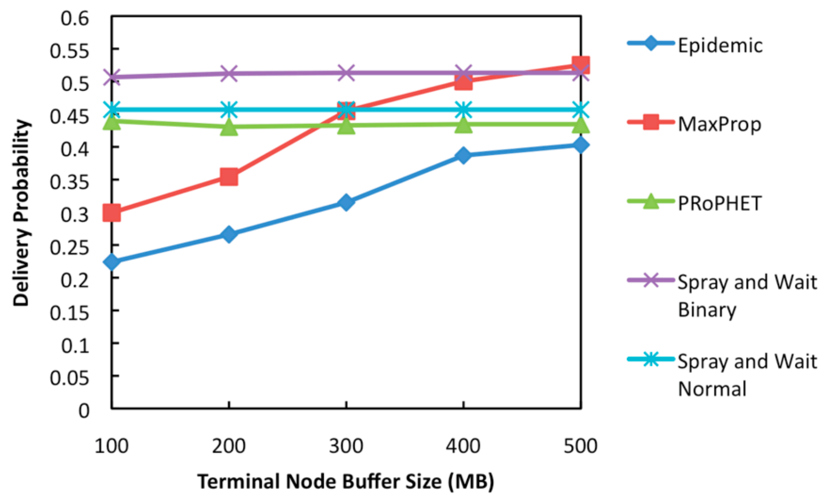


Resource-Constrained Networks

- To address the problem of intermittent connectivity, long-term message storage is combined with routing schemes that replicate messages
- These strategies can be inefficient in terms of network resource usage (e.g. bandwidth, storage)
- It is important to study how nodes use their buffers, when different replication schemes are used
- Efficient scheduling and dropping policies may be necessary to improve the overall network performance

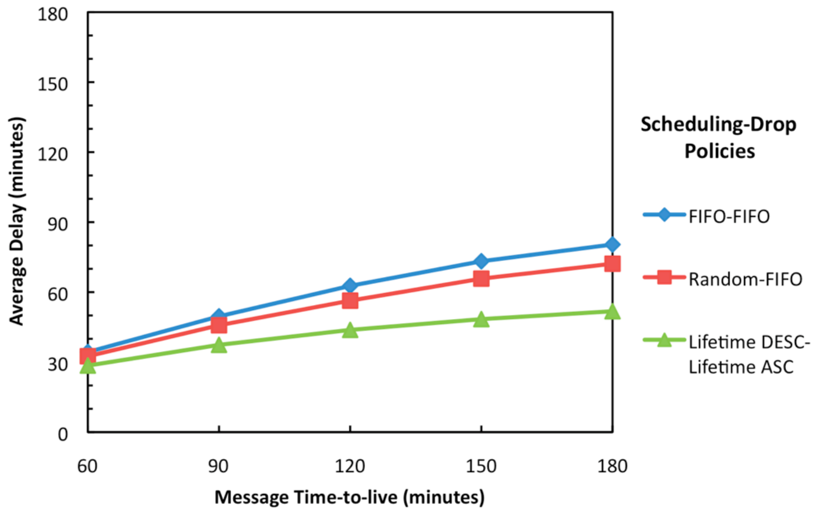
Storage Capacity Constraints

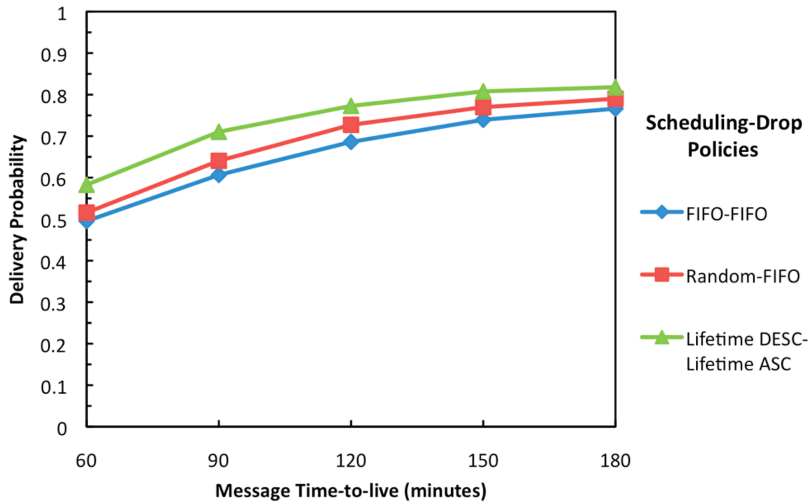
- We evaluated how the routing protocols message replication strategies, react to the increase of the buffer size in *mobile nodes* and *terminal nodes*



Scheduling and Dropping Policies

- We evaluated combinations of scheduling and dropping policies that would minimize the delivery delay over the messages in the network
- We also evaluated these policies from the perspective of their influence on the message delivery probability





Ongoing and Future Work

- **Hill-Climber (HC)** and **Genetic Algorithms (GA)**
  - Another approach to the relay node placement problem
- **Traffic Differentiation**
  - Traffic with diverse performance requirements
  - Investigate appropriate scheduling and dropping policies
  - Introduce Priority Class of Service routing capabilities to DTN routing protocols
- **Create a testbed (prototype) to evaluate and validate VDTNs**

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Thank you for your attention!