Vehicular Delay-Tolerant Networks
An Introduction

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Introduction

- **Vehicular Networks**
  - Vehicles are opportunistically exploited to offer a message relaying service
  - **Characterized by**
    - Highly dynamic network topology
    - Short contact durations
    - Connectivity disruption
    - Intermittent connectivity
    - Network partition
    - Potential non existence of a end-to-end path

Introduction

- Vehicular networks are one example of networks that benefit from the application of the **Delay-Tolerant Network** concept. Other examples:

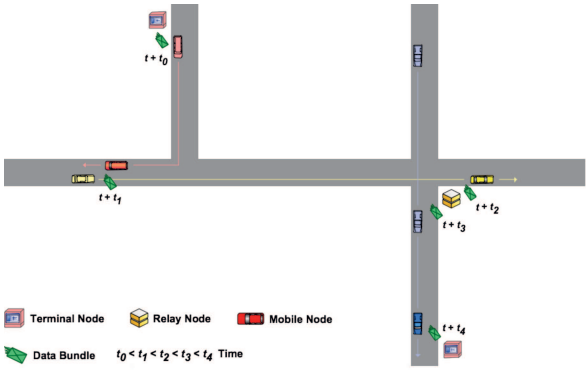




- **Vehicular Delay-Tolerant Network (VDTN) architecture** has been proposed to deal with challenging vehicular communication scenarios
  - Provide low-cost connectivity in scenarios where telecommunications infrastructure is unreliable or not available due to disconnected areas, natural disaster, or emergency situations

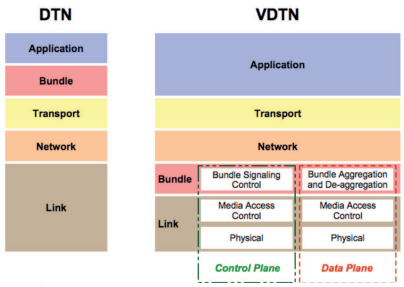
VDTN Layered Architecture

- Based on the principle of asynchronous, bundle-oriented communication from the DTN architecture
  - **Store-carry-and-forward** paradigm



VDTN Layered Architecture

- However, the design of the VDTN network architecture, and its protocol layering, presents unique characteristics:
  - **IP over DTN approach**
  - **Control plane and data plane decoupling**
  - **Out-of-band signaling**

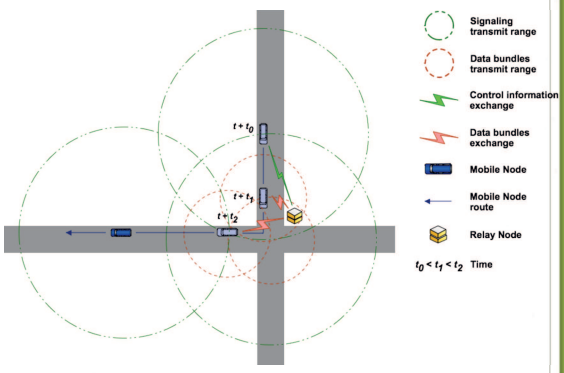


VDTN Layered Architecture

- **Control plane and data plane separation**
  - **Control plane functions**
    - Signaling messages exchange, node localization, resources reservation (at the data plane) and routing, among others
  - **Data plane functions**
    - Buffer management and scheduling, traffic classification, data aggregation/ de-aggregation, and forwarding, among others
  - **Distinct planes suggests that they can operate independently using their own layers and protocols**

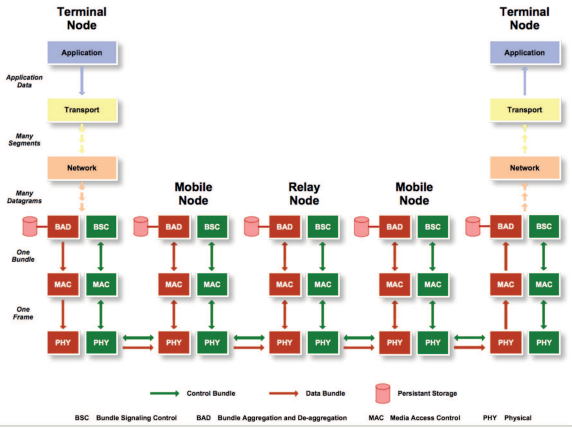
VDTN Layered Architecture

- **Out-of-band signaling**
  - **Control plane**
    - Uses a separate, dedicated, low-power, low bandwidth, and long-range link to exchange signaling information
  - **Data plane**
    - Uses a high-power, high bandwidth, and short-range link to exchange data bundles



VDTN Layered Architecture

- **Transmission of control bundles and data bundles, between network nodes**



Application Scenarios

- **Urban Scenario**
  - Various possible applications
    - Disseminate information advertisements
    - Disseminate safety related information
    - Distribute multimedia content
    - Monitoring networks to collect data

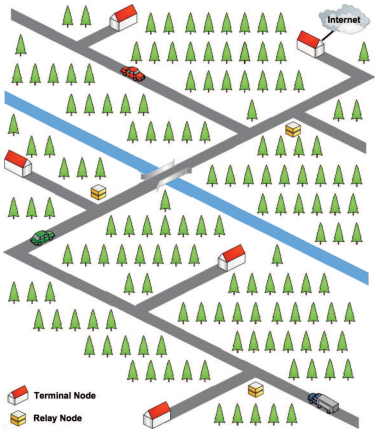
Application Scenarios

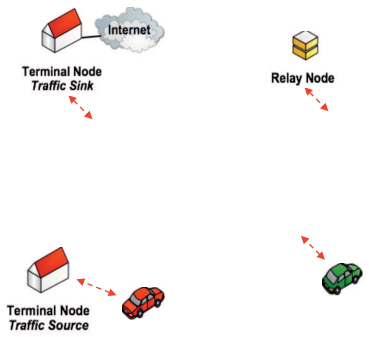
- **Rural Connectivity**
  - Providing data communications to undeveloped remote areas
    - E-mail
    - Voice mail
    - Web access
    - Telemedicine
    - Data collection applications

- **Disaster recovery networks**

How it works…

- **Rural Connectivity Scenario**



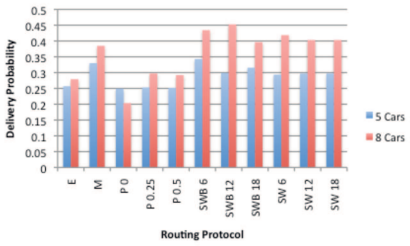


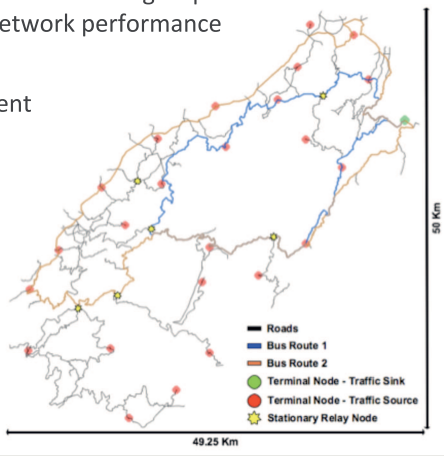
Challenging Issues

- 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, random, predictable)
  - Node cooperation
  - Traffic differentiation
  - Routing and forwarding protocols
  - Buffer management schemes
  - Caching mechanisms
  - …

Movement Models

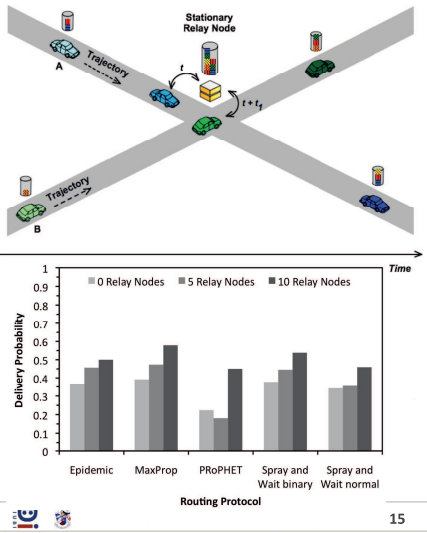
- We studied the impact of different numbers and groups of vehicles with specific movement models on the network performance
  - Random waypoint
  - Shortest path map based movement
  - Map route movement





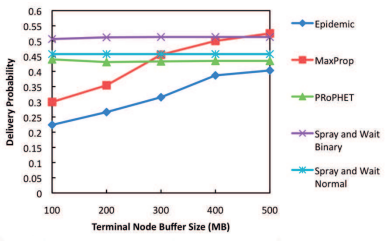
Stationary Relay Nodes

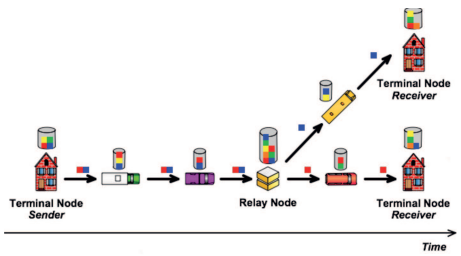
- The *store-carry-and-forward* paradigm may have to be complemented with the introduction of **stationary relay nodes**, in networks with low node density
  - Creates additional transmission opportunities
  - Contributes to increase bundle delivery ratio and decrease bundle delivery delay



Storage Capacity Constraints

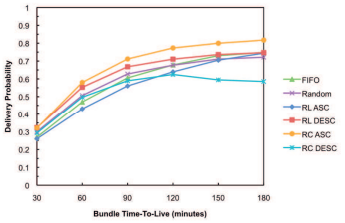
- To address the problem of intermittent connectivity, long-term storage can be combined with routing schemes that replicate bundles
- These strategies can be inefficient in terms of network resource usage (e.g. bandwidth, storage)
- We evaluated how the routing protocols replication strategies, react to the increase of the buffer size in *mobile nodes* and *terminal nodes*

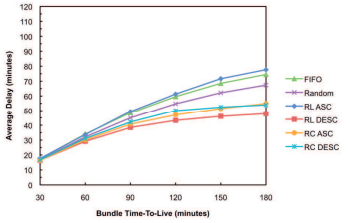


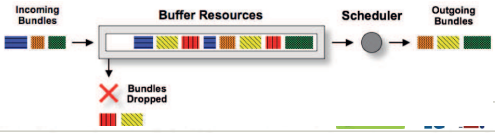


Scheduling and Dropping Policies

- **Scheduling Policies**
  - Decide the order by which bundles are transmitted at the contact opportunities
- **Dropping Policies**
  - Decide which bundles are discarded when a node's buffer is full
- These policies can optimize the limited system resources utilization, leading to performance improvement of the routing protocols







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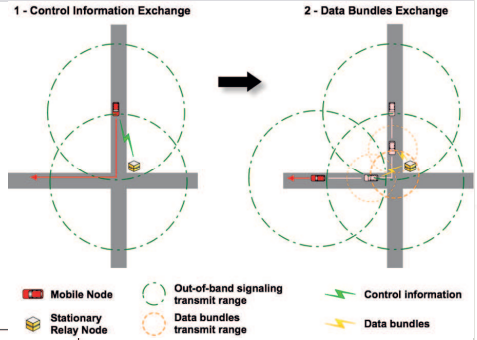
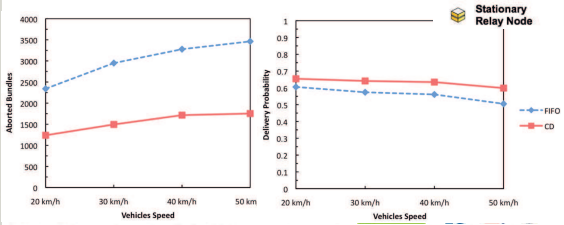
Exploiting Node Localization

- High node mobility, intermittent connectivity, and short contact durations **cause incomplete transmissions and the waste of link capacity**
- In a VDTN, nodes exchange real-time geographical location, current path and velocity, as signaling data, and use it to predict the contact period





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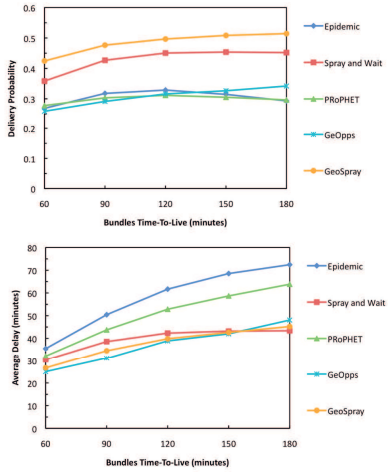
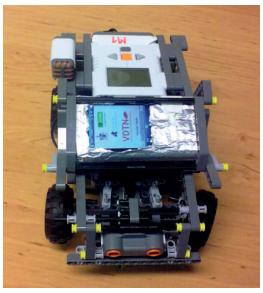
Geographic Routing

- The availability of in-vehicle navigation systems can also be explored to introduce geographic routing to VDTNs
- **GeoSpray**
  - Uses information about real-time geographical location, route and velocity to make routing decisions
  - Runs in the control plane
  - Routing information is exchanged via a long-range, low power, low bandwidth link
  - Data bundles are forwarded via a short-range, high power, high bandwidth link



Testbed - VDTN@Lab

- **Why do we need a testbed?**
  - For the emulation, demonstration, performance evaluation, and diagnose of protocol stacks and services
  - To prove the applicability of VDTNs over a wide range of environments
  - To have a basis of comparison with the results obtained by simulation
- **Prototype details**
  - Desktops or Laptops – terminal and relay nodes
  - LEGO MINDSTORMS NXT, and Asus PDA Phone P527 – mobile nodes
  - Bluetooth (control plane – signaling)
  - IEEE 802.11 (data plane – data bundles transmission)
  - .Net platform and C# programming language



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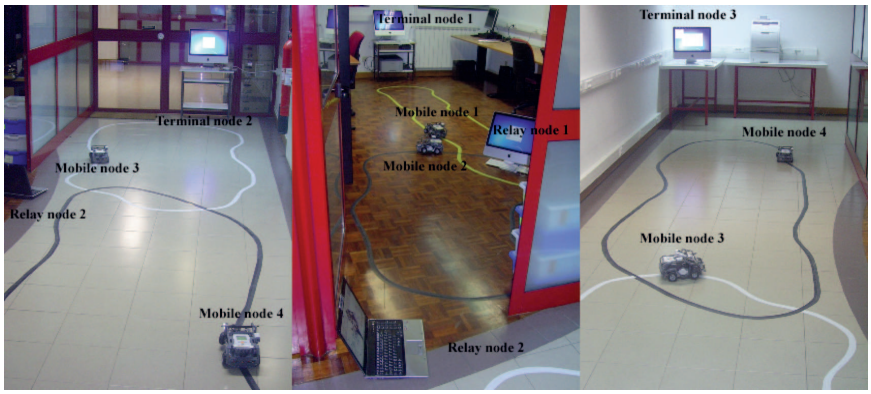

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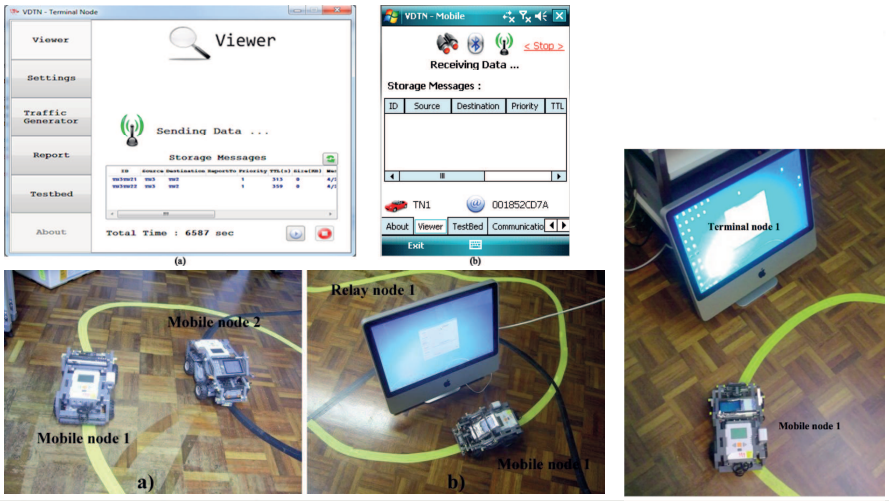

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Thank you for your attention!

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