Landmark Overlays for Urban Vehicular Routing Environments

Kevin C. Lee⁺, Michael Le⁺, Jérôme Härri*, Mario Gerla⁺

⁺ Network Research Lab, University of California
Los Angeles, California, USA

* University of Karlsruhe in the Karlsruhe Institute of Technology
Karlsruhe, Germany

2nd IEEE Symposium on Wireless Vehicular Communications
Calgary, Canada, September 21st - 22nd 2008
Motivation

- Geographic Routing:
  - routes packets based on geographic information of the source, relays and destination
    - Based on a greedy forwarding approach
  - Efficient in this situation:
    - and in this one ??
Motivation

- A second phase called "recovery" exists.

- Urban Vehicular Routing Environment

- Need to route on road segments only!
  - GPSR: Greedy often fails. Mostly recovery mode
  - GPCR: specific improvement for urban routing
    - greedy mode even in recovery
    - routing decisions taken at intersections only!
Motivation

- However, what happens in this case?
  - Low communication density on road segments not detectable!
  - End-to-End route optimization impossible!

- Two challenges for urban geo-routing
  1. **Intra-road communication density estimation**
  2. **Global junction routing**

- Using the concept of overlay routing could help!
  - **Geo-reactive overlay (GSR, Lochert et al., 2003))**: opens a junction-based path on demand
  - **Geo-geographic overlay (GyTAR Jerbi et al. 2007))**: finds the best overlay node greedily
LOUVRE Functional Blocks

- Geo-proactive overlay
  - **Overlay nodes**: Road junctions
  - **Overlay links**: Road segment between junctions
  - Proactive Dijkstra shortest path on the overlay
  - Geographic routing on the underlay

- P2P density Estimation

  - **Scalability**:
    - Finite number of road density
    - TX rate adaptation based on a threshold

  - **Freshness**:
    - Density expires after some time
    - Density gets more accurate with proximity to the road
• Proactive Overlay Routes Creation

• Scalability:
  ◦ Overlay links considered when sufficient communication density
    • Avoids road element with local maxima!
  ◦ Grid-limited overlay topology
    • Optimal src-dest on the same grid
    • Optimal overlay gateway node to reach neighboring grids
For S to reach D, roads 5, 2, 3, 8, and 11 are followed.
Conventional geographic routing fails when greedily delivering through road 4
due to the lack of relays after road 4.
The dotted arrows show LOUVRE routing from S in grid 1 to D’ in grid 2.
Evaluation

- 1000m x 1000m Washington D.C. map
- 100 nodes, 20% to 50% mobility
- 1460-byte CBR
- IEEE 802.11a, Tx range: 250m
- No radio communication between adjacent roads
- Measurement of PDR, Hop Count, and Latency with 95% confidence intervals
Remarks on Vehicular Distribution

Yet, hard to configure and to vary the accumulations.

- We used an artifact: Static nodes at intersection and mobile nodes between intersections
- More static (resp. less mobile) => more crowded intersections

High accumulations at intersections
Performance Evaluation

- LOUVRE has global vision of density distribution and local maxima, thus highest PDR
- Hop count a bit higher than GPCR due to delivery of unsuccessful packets by GPCR
- Decreasing gap of hop count in increasing mobility (better distribution of cars) implies LOUVRE’s capabilities with non-uniformly distributed traffic!!!
Conclusion

- LOUVRE is a tradeoff between stateless and stateful routing
  - stateless: efficient vehicular routing
  - stateful: larger vision of urban routing pitfalls
- LOUVRE is an overlay routing approach
  - overlay: proactive routing between overlay nodes based on vehicular communication density
  - underlay: geographic routing between overlay nodes
- LOUVRE performs better than the benchmark protocols GPSR and GPCR
  - Drop before fail approach for unreachable destination
  - Faster delivery to reachable destination as avoiding a recovery mode
- Future work:
  - Compare LOUVRE with other urban overlay approaches (GyTar, GSR)
  - Study the impact of more realistic propagation models
  - Improve the density estimation functional block
Remarks on Vehicular Radio Propagation

- In this work, we used a ‘Two-ray ground’ (TRG) propagation
  - More realistic: Nakagami-m propagation

- Yet, Nakagami-m overestimates the probability of reception w.r.t TRG.
  - With Nakagami, we will have a slightly lower density estimation

Source: Mittag et al., ACM VANET 2008
LOUVRE Functional Blocks

- P2P density Estimation

- Scalability:
  - Finite number of road density
  - TX rate adaptation based on a threshold

- Freshness:
  - Density expires after some time
  - Density gets more accurate with proximity to the road

- Proactive Overlay Routes Creation

Records # unique Neighbors
Computes and TX density
Road A

Accuracy decreases
density expires

S

Overlay routes

S
Landmark Overlays for Urban Vehicular Routing Environments

- **LOUVRE**: Geo-proactive overlay
  - **Overlay nodes**: Road junctions
  - **Overlay links**: Road segment between junctions
  - Proactive end-to-end route optimality on the overlay
  - Efficient geographic routing on the underlay

- **Scalability**:
  - Overlay links considered when sufficient communication density
    - Avoids road element with local maxima!
  - Grid-limited overlay topology
    - Optimal src-dest on the same grid
    - Optimal overlay gateway node to reach neighboring grids