On the Scalability Problem of Highway Ad hoc Network

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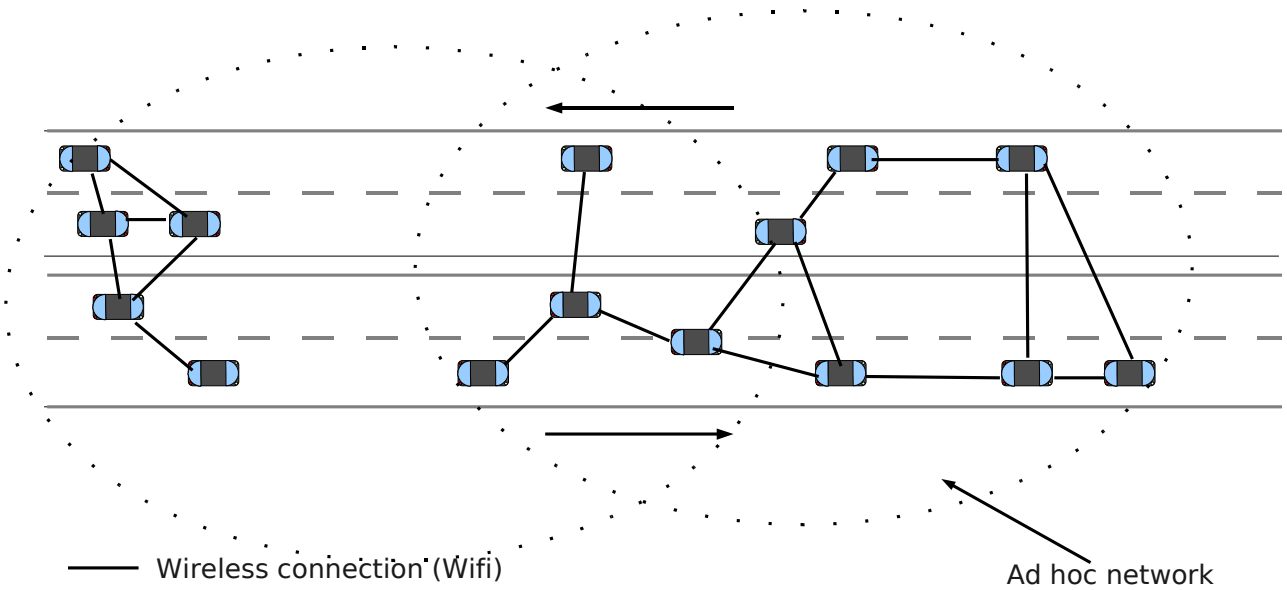
Vehicular network on a highway

- Our study concerns vehicules moving in the same direction on a highway with at least two lanes
- The vehicles move along the lanes and communicate using radio links among themselves.
- In our study, we are only interested in **inter-vehicular communications**.



Vehicular ad hoc network on a highway

The network **topology** is unusual.

- It consists of **a line**
- The **spatial re-use** is very limited.
- The consequence poses a **problem for the scalability** of a vehicular network on a highway.

Scalability with a reactive ad hoc protocol (topology-based)

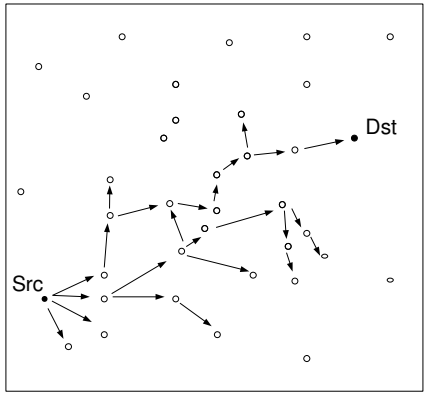
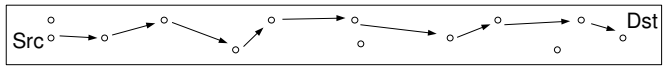
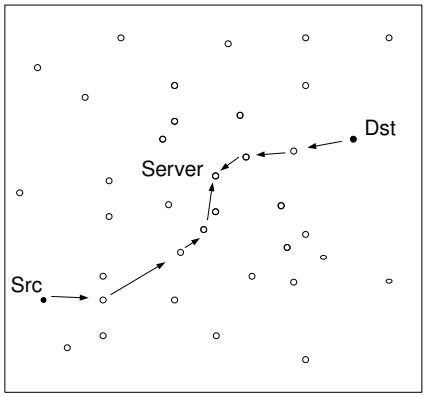
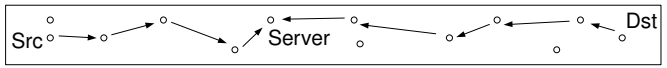
- When a source wants to obtain a path to the destination, it sends a **Route Request** (RREQ) message on the network.
- To limit the overhead and to avoid the saturation of the network, the protocols set a TTL (Time To Live) limit for the broadcasted messages.
- The scalability is limited : if the number of hops between two nodes is more than TTL value, the nodes cannot communicate.

Remark : Increasing the TTL with network size is not a good solution because the overhead increases with the network size.

Scalability with a geographic ad hoc protocol (position-based)

- With a geographical protocol, the source node must know the geographical position of the destination. Thus, the source node broadcasts a LREQ (Location request) message on the network.
- This process is similar to the path finding process in the reactive protocol.
- Some variant protocols have been proposed to solve the scalability problem : XYLS, GLS (Geographical Location Service), GHLS (Geographical Hashing Location Service) ...
- **BUT** these protocols make an assumption on the planar topology of networks. For a linear configuration, the scalability problem is not solved.

Location Request Transmission

	Planar Topology	Linear Topology
Basic Protocol		
GHLS Protocol (rendez-vous protocol)		

Scalability of a vehicular ad hoc network

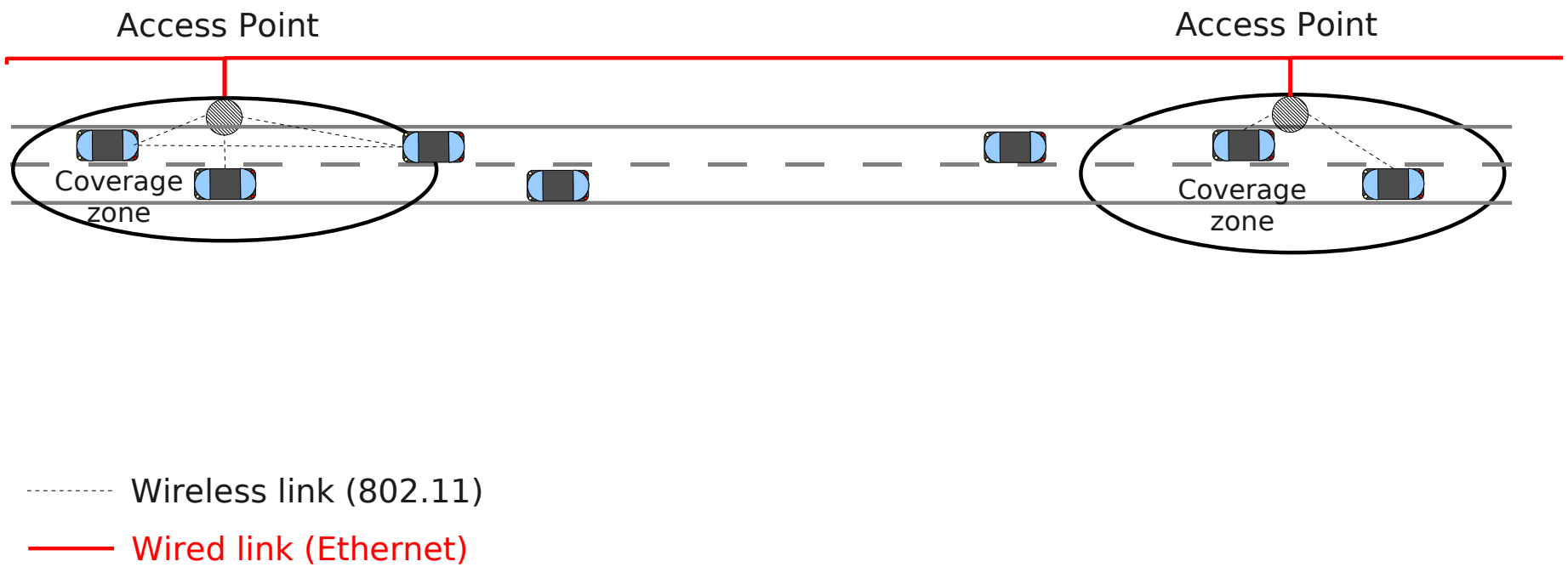
Problem of scalability

With a reactive or a geographic ad hoc protocol, the scalability problem is similar in a linear configuration.

Solution : Use a **hybrid** ad hoc network

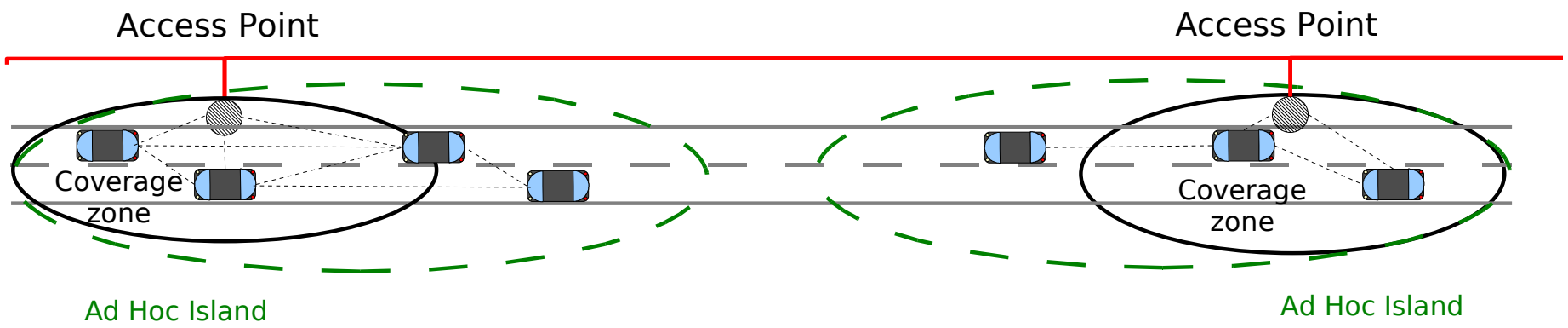
Architecture

We consider this architecture



Architecture

We consider this architecture



Ad hoc Protocol Modifications

Ad hoc protocol is not adapted for a hierarchical hybrid architecture

- Our choice is an adaptation of DSR wich is a reactive protocol
- Several features are added :
  - Access point discovery : reactive or proactive
  - Node registration to the access point
  - Variable TTL limit according to access point density
- During a path find process, the access points can send the correct path with a RREP message

Ad hoc Protocol Modifications : performance

What is the performance with this protocol ?

1. With these new features, what is the overhead compared to a flat routing ad hoc protocol (basic DSR) ?
2. What is the optimal density of the access points : trade-off between deployment cost / performance

Simulation

Using the Jist/Swans simulator :

- DSR implementation has been extended and adapted to our protocol for hybrid ad hoc networks.
- Integration of a realistic mobility vehicular traffic simulator.

We consider :

- On average, one pair of vehicles communicates for every kilometer.
- Radio coverage fixed to 250m
- The simulation scenario consists of varying values of access points (AP) , highway lengths and traffic densities.

The confidence interval is computed from multiple samples for each simulation scenario.

Comparison with basic DSR

We consider three ad hoc routing protocols

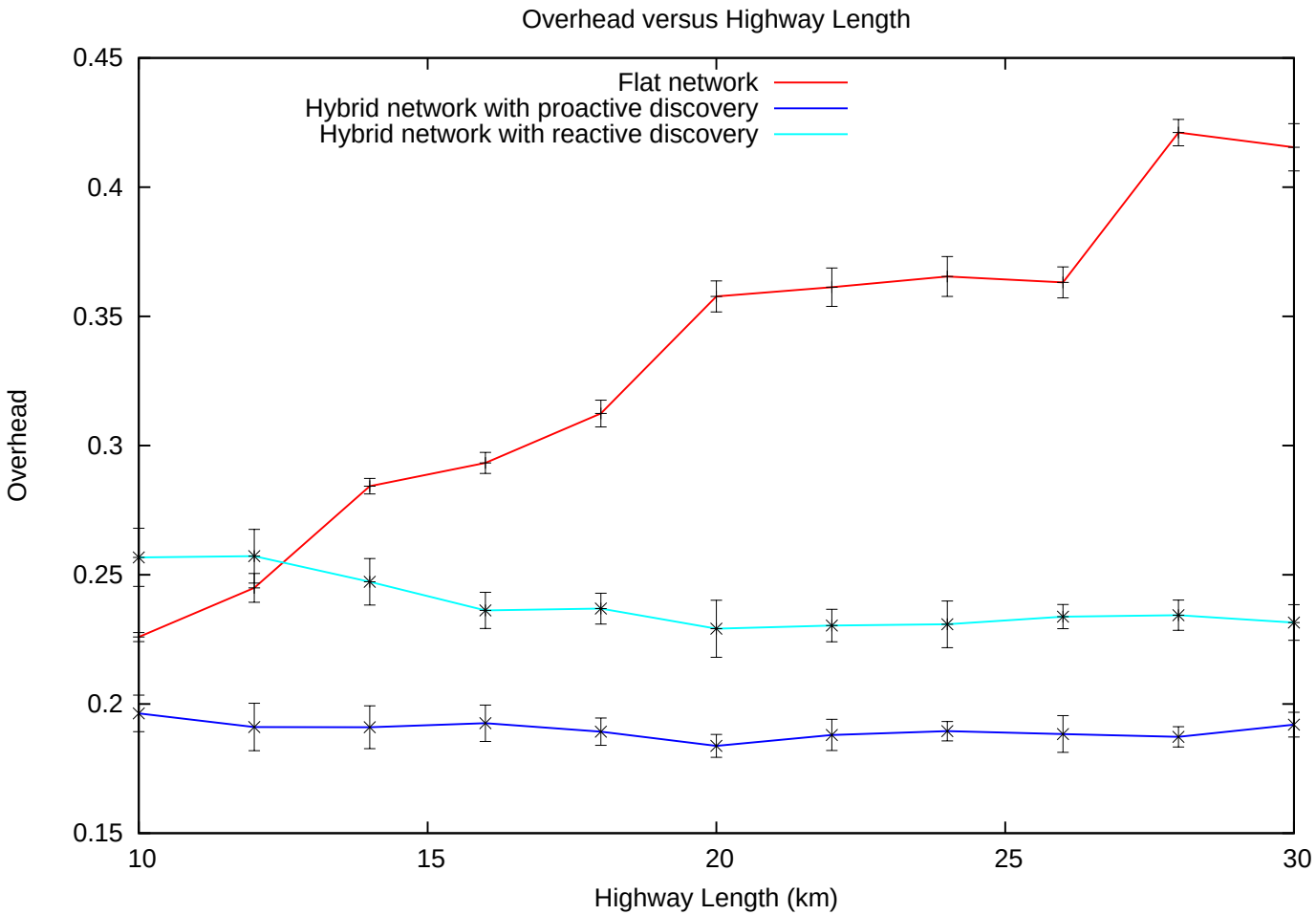
- **Flat network** : Basic DSR used. Wired links connect the access points.
- **Hierarchical network** : Adapted DSR protocol is used.
- With a hierarchical network, two cases are possible :
  - At regular intervals, the access point sends an advertisement message on the sub-network (**proactive discovery**).
  - The node sends a request discovery to know the accessible access points (**reactive discovery**).

Performance evaluation

Two metrics are used to evaluate performances :

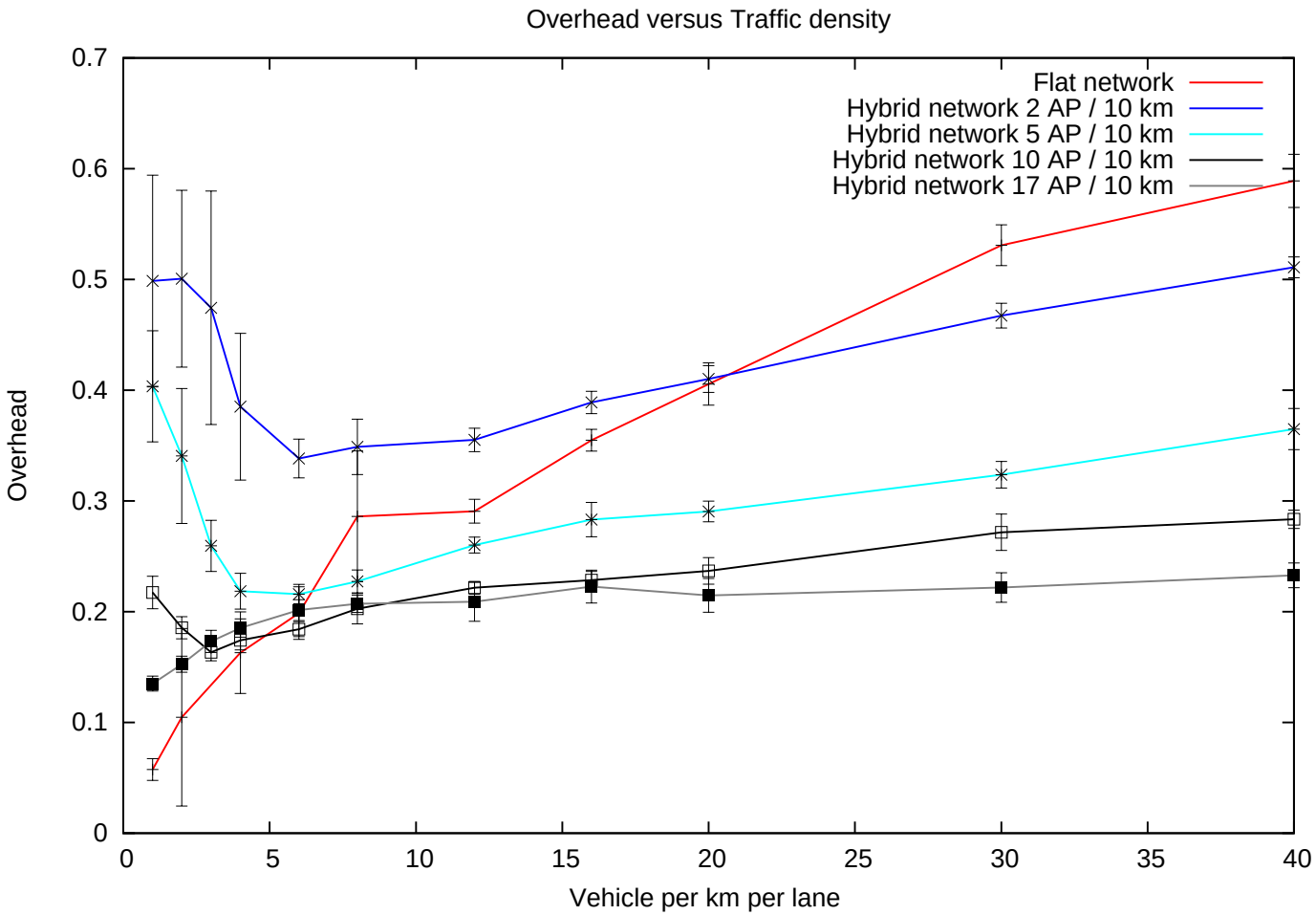
- **Overhead** : Total length of overhead data / Total length of packet data.
- **Throughput** : Average rate of successful message delivery

Overhead / Highway length



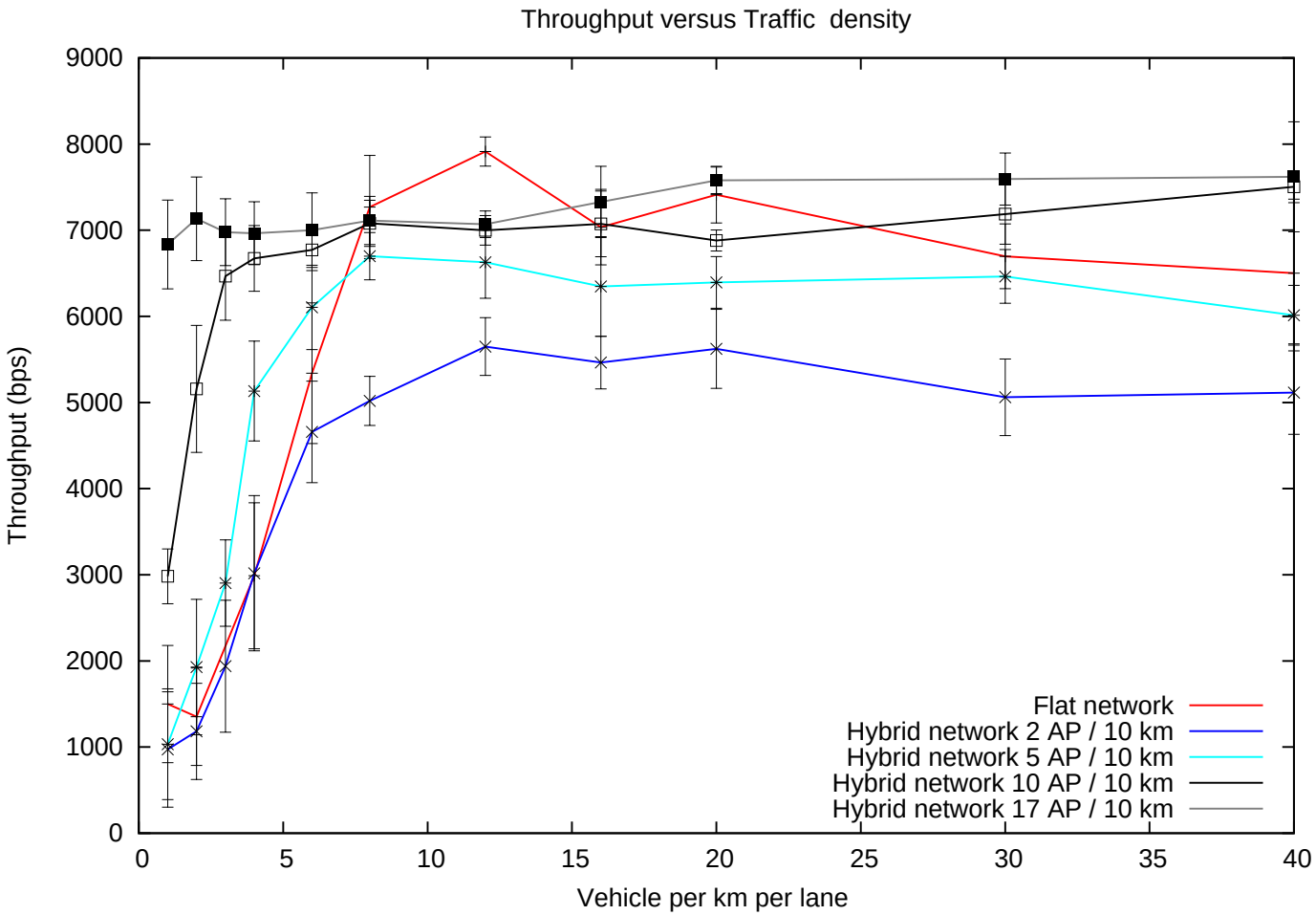
- The overhead for the flat network increases with road length.
- The overhead remains constant for both hybrid variants

Overhead / Vehicle density for highway 10 km



- Overhead for flat network grows with the density
- Above 8 v/km, the overhead of hybrid networks is lower than flat networks
- Above 10 AP, the overhead is relatively constant with density

Throughput / Vehicle density for highway 10 km



- Below 10 v/km, the throughput increases with the density
- The number of AP increases connectivity for lower density of vehicles
- Above 25 v/km, the throughput of hybrid networks with 10 AP is higher than that of flat the networks.

Conclusion and Perspectives

Proposal :

- Add a wired architecture with an adapted protocol to a vehicular network on highways

Results :

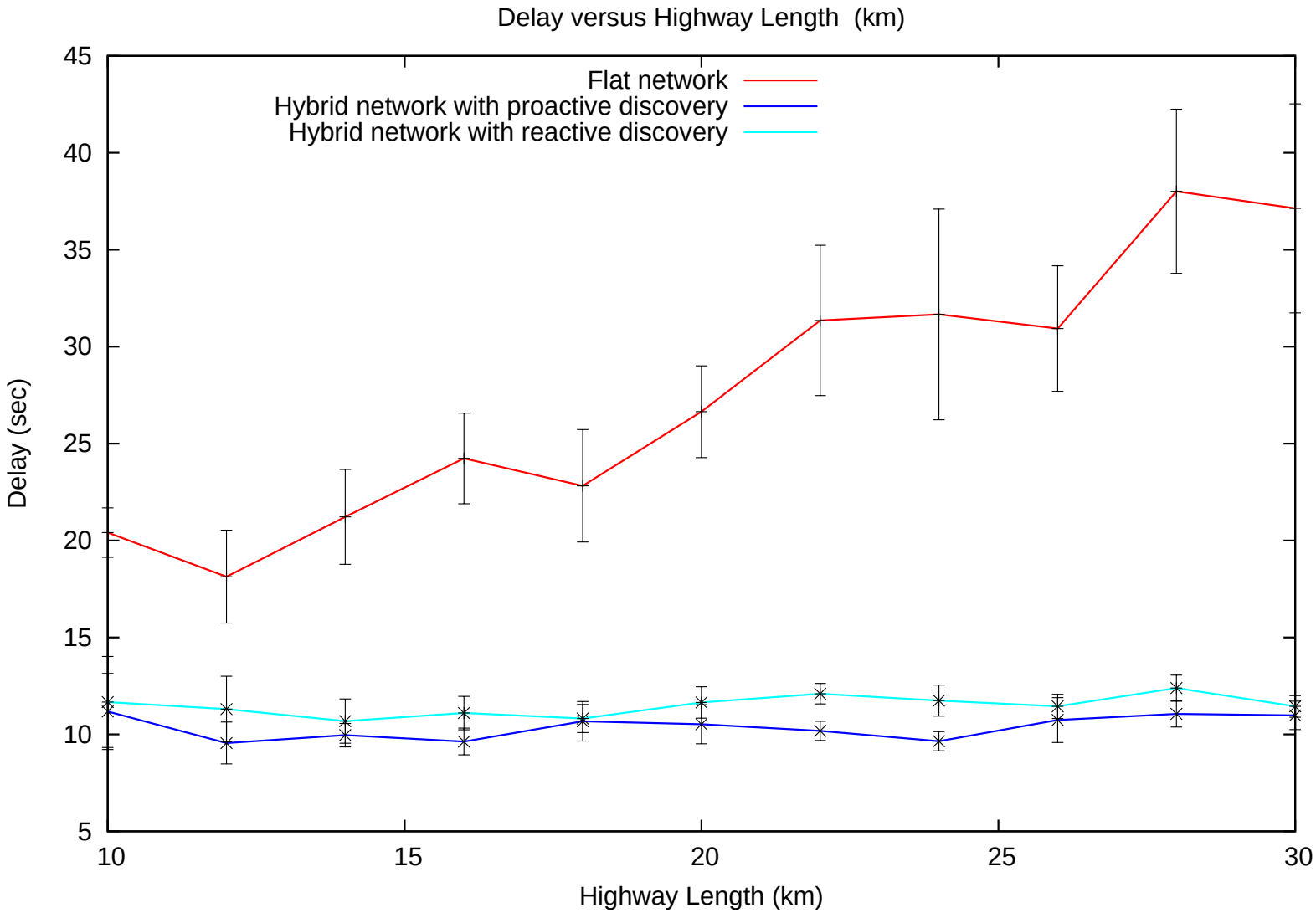
- The adapted protocol provides network scalability while limiting the overhead.
- We estimate that the number of optimal access points is about one per km with a coverage of 250m.

Perspective

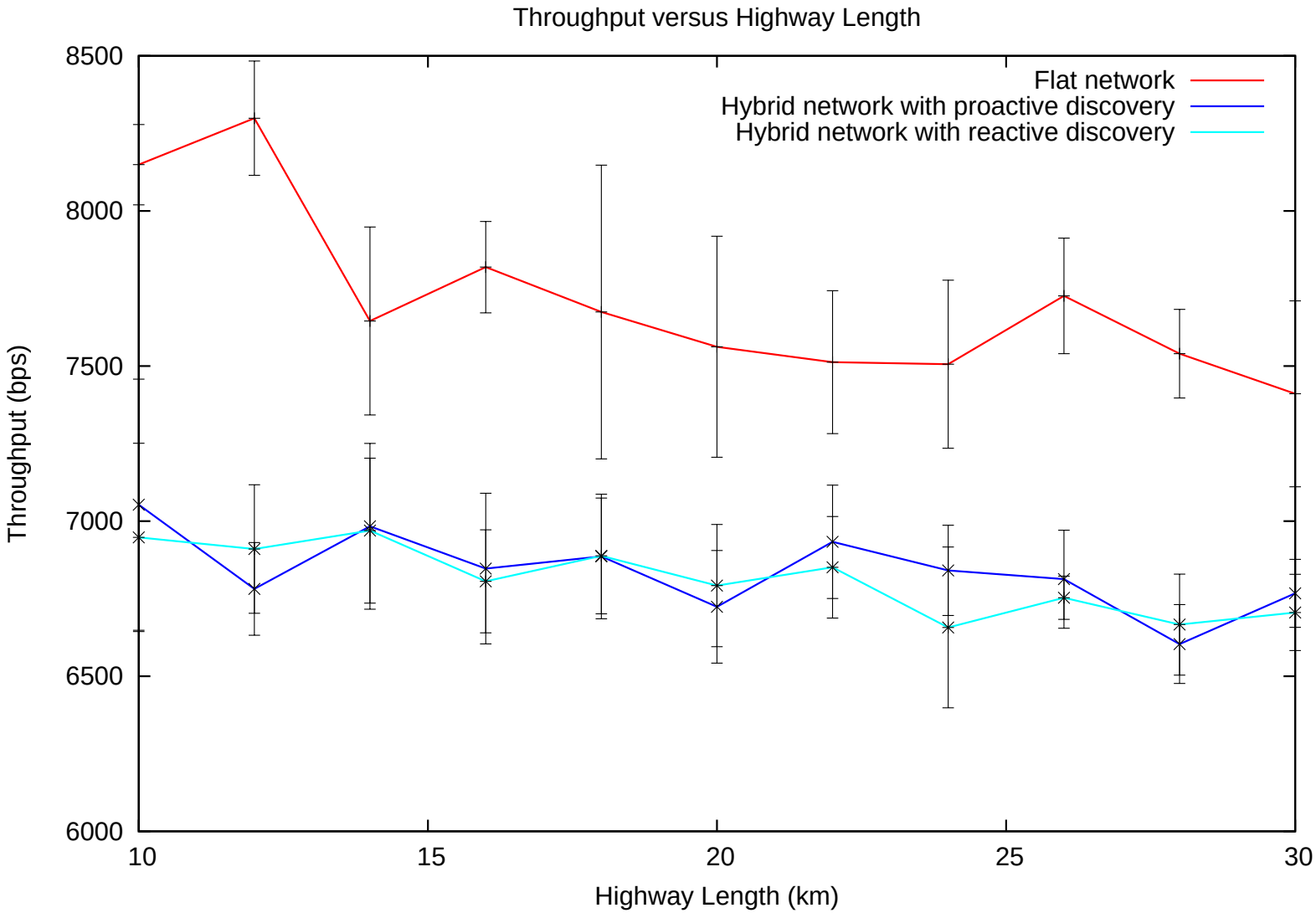
- Our future work will concern the improvement of handover processes and a new proposal for geographical routing protocol.

Questions ???

Delay / Road length



Throughput / Highway length



Simulation parameters

ApAdv Hello interval	500 ms
APAdv interval	5000 ms
APEntry timeout	7500 ms
Transport layer	UDP
Bitrate	10 kb/s CBR
Wireless Bandwith	11Mb/s
Wired Bandwith	100Mb/s
Radio range	250 m
Simulation time	90 s

Table: Fixed simulation parameters