Virtual Traffic Lights - Can they be trusted?

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(Acknowledgements to my former PhD students Negin Fathollahnejad and Raul Barbosa)

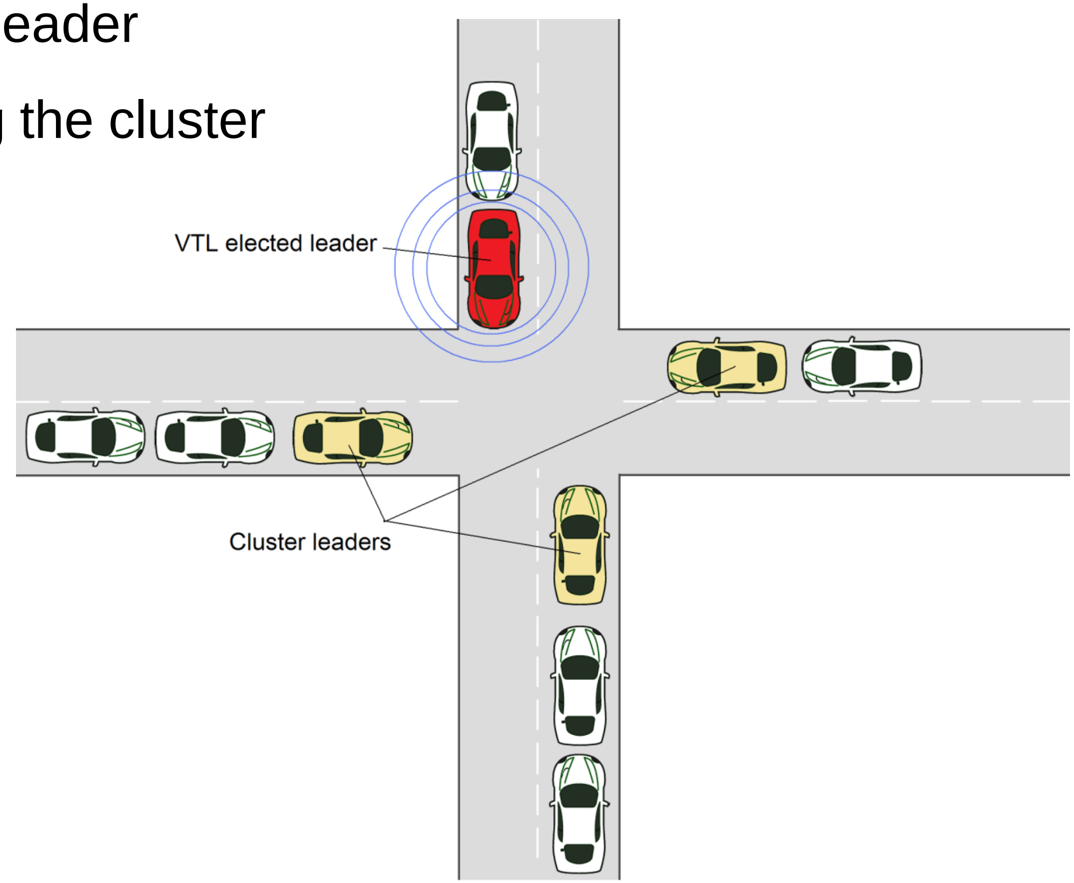
Position statement – Joint DSML and SSIV panel, June 25, 2018

What is a Virtual Traffic Light (VTL)?

- A Virtual Traffic Light is a self-organizing traffic control system.
- It allows road vehicles passing an intersection to implement the function of a traffic light without any roadside installation.
- Relies entirely on wireless vehicle-to-vehicle (V2V) communication.
- No central control

VTL concept by Ferreira et al. (2010)

- Traffic controlled by a VTL leader
- VTL leaders elected among the cluster leaders
- No central control



Key functions:

- Leader election
- Leader handover

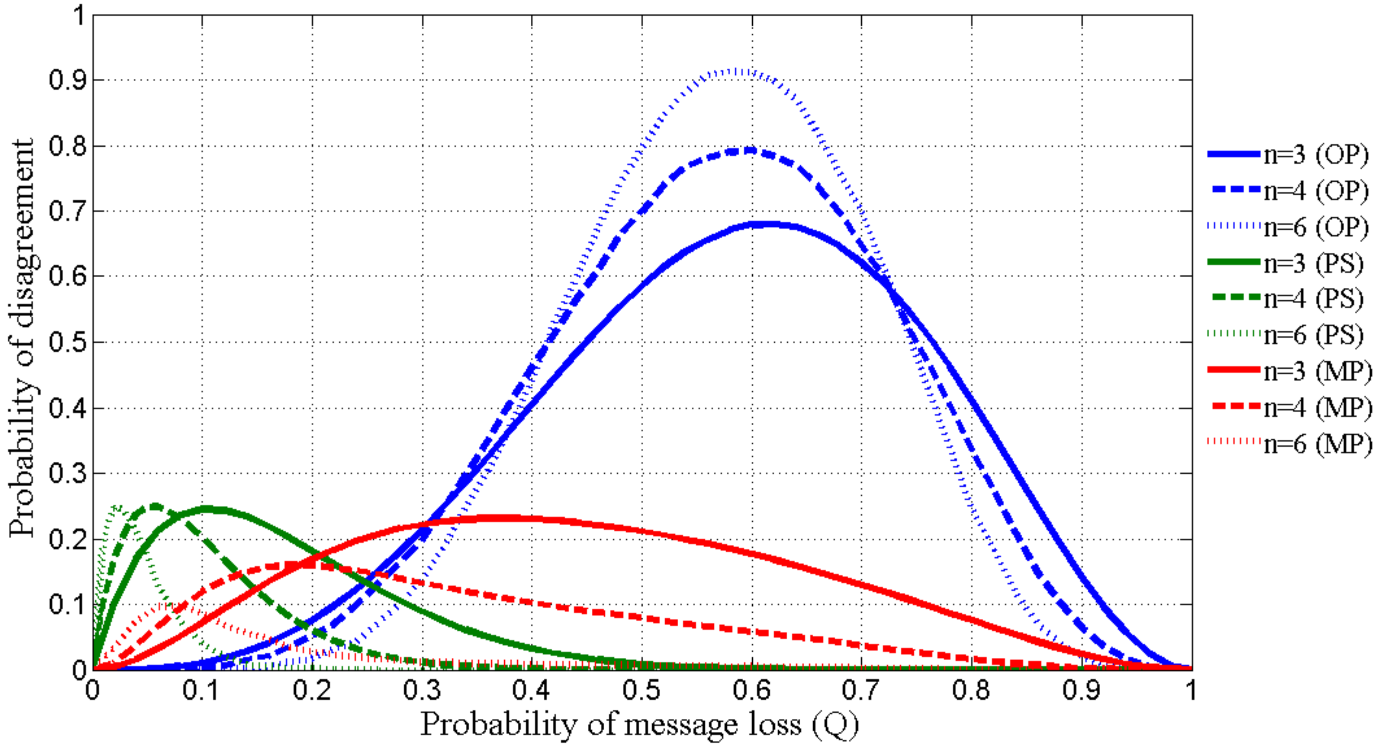
Challenges in designing Leader Election Protocols for VTL:s

- Wireless V2V networks are intrinsically unreliable
  - It is infeasible to assume an upper bound on the number of messages that may be lost during the execution of a leader election protocol (or any other type of protocol).
- Consensus cannot be guaranteed in presence of massive communication failures (message losses)
  - Impossibility result by Santoro & Widmayer, 1989
- System bootstrapping
  - The system (no. of nodes and their identities) is initially unknown to vehicles (nodes) approaching an intersection.

Possible system-wide outcomes for a leader election protocol

- **Agreement on a leader** - all nodes select *the same* leader.
- **Agreement on abort** - all nodes decide to abort due to insufficient information (too many messages have been lost).
- **Disagreement** – some nodes decide to abort and others decide on a leader.
- We can categorize disagreement in two main classes:
  - **Safe disagreement** - some nodes decides to abort and other nodes decide on *the same leader*.
  - **Unsafe disagreement** - at least two nodes decide on different leaders.

1-of-n selection, n=3, 4, 6, R=2, receive omissions, perfect oracles => no unsafe disagreement

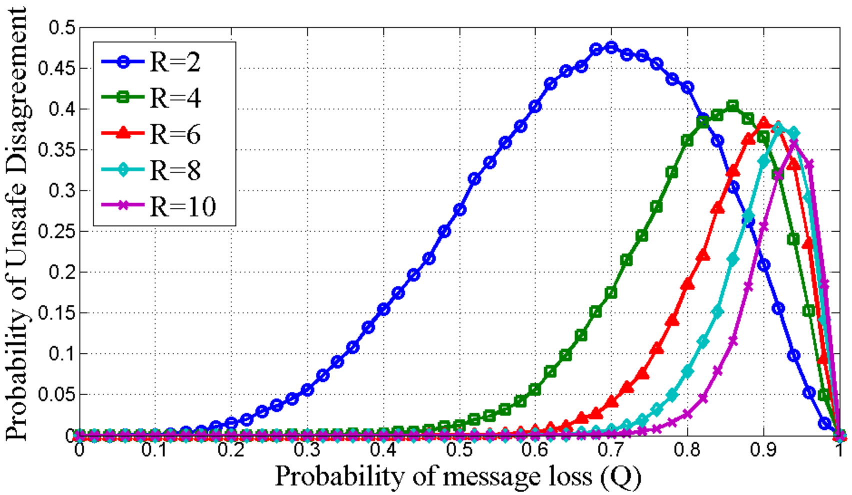


n = no. of nodes (cluster leaders)
R = no. of communication rounds
Q = probability of message lost at receiver (receive omissions)
Perfect oracles = all nodes have the correct view of the system size *n*.

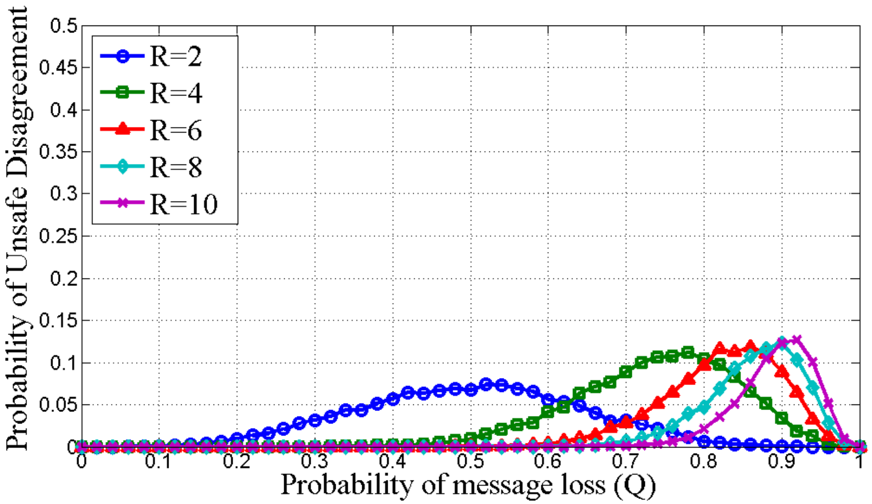
OP = optimistic decision criterion
PS = pessimistic decision criterion
MP = moderately pessimistic decision criterion

1-of-* selection, n=4, receive omissions, non-perfect oracles => unsafe disagreement possible

Increasing *R*, comparison of the decision criteria, *n=4*



Optimistic decision criterion



Pessimistic decision criterion

n = no. of nodes (cluster leaders)
R = no. of communication rounds
Q = probability of message lost at receiver (receive omissions)
Non-perfect oracles = not all nodes have the correct view of the system size *n*.

How can we build confidence in self-driving cars?

Many big challenges – a few are listed here:

- Validation of assumptions
  – Bridging the gap between field tests and modelling activities
- Realistic failure models
  – Big challenge for mobile wireless networks (safety and security)
  – Models of intrusions (security)
- System models / System-of-systems models
  – Classical synchronous and asynchronous models are still useful, but more realistic models need to be developed
  – How to model self-learning systems??? **Hugh challenge!**