

# Dependability Evaluation of mobile applications

## Connectivity Dynamics in Vehicular Freeway Scenarios

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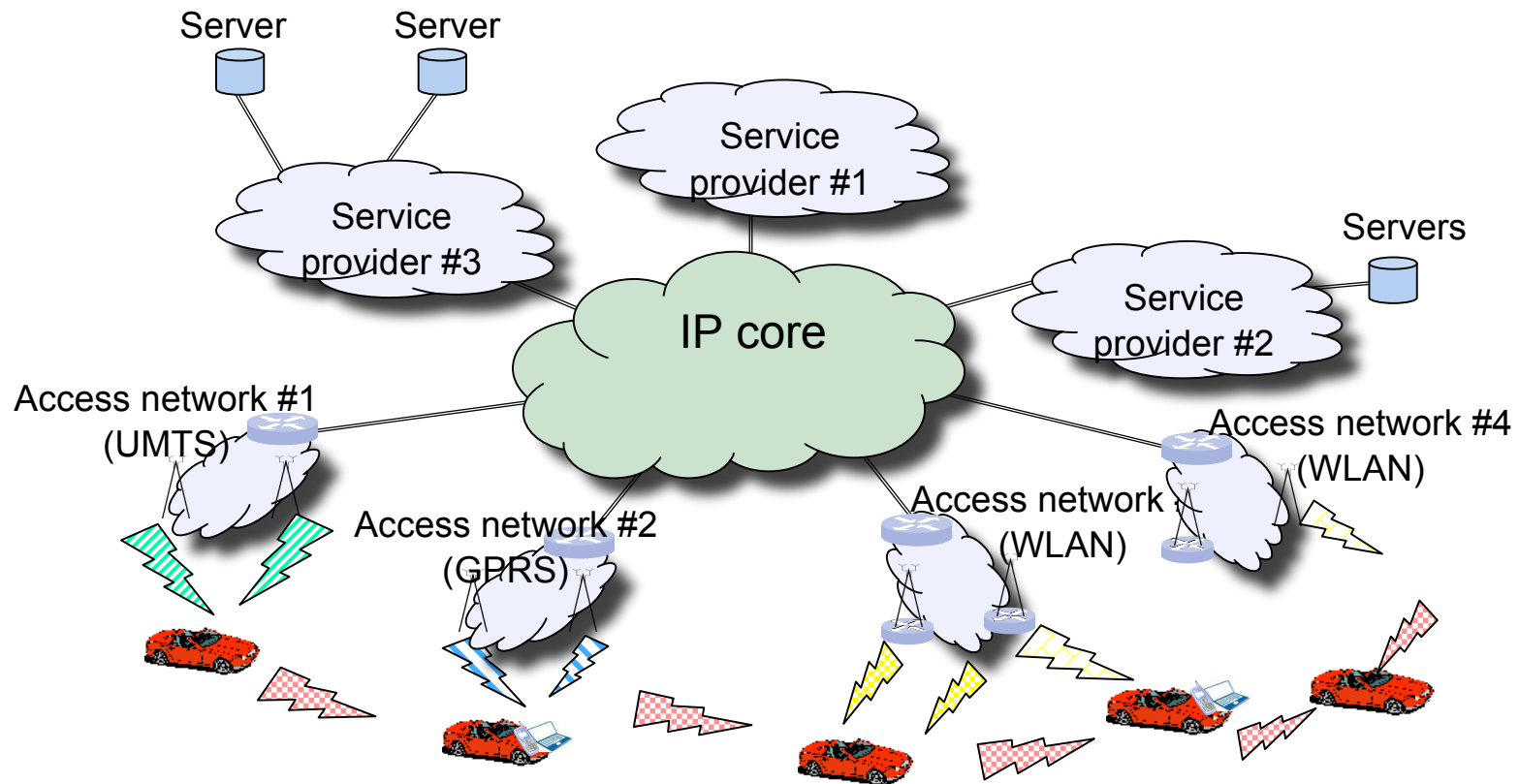




- Highly-Dependable IP-based NETworks and Services
- FP6 Specific Targeted Research Project (STREP)
- Jan. 2006 - March 2009
- 9 partners - 8 european projects
  - Industry : 4 , Research Labs & Universities : 5
  - Industrial Advisory Board : BMW (G), Nokia (F), Renault, France Telecom, Intects (I), Siemens (G)



# HIDENETS: Context and objectives

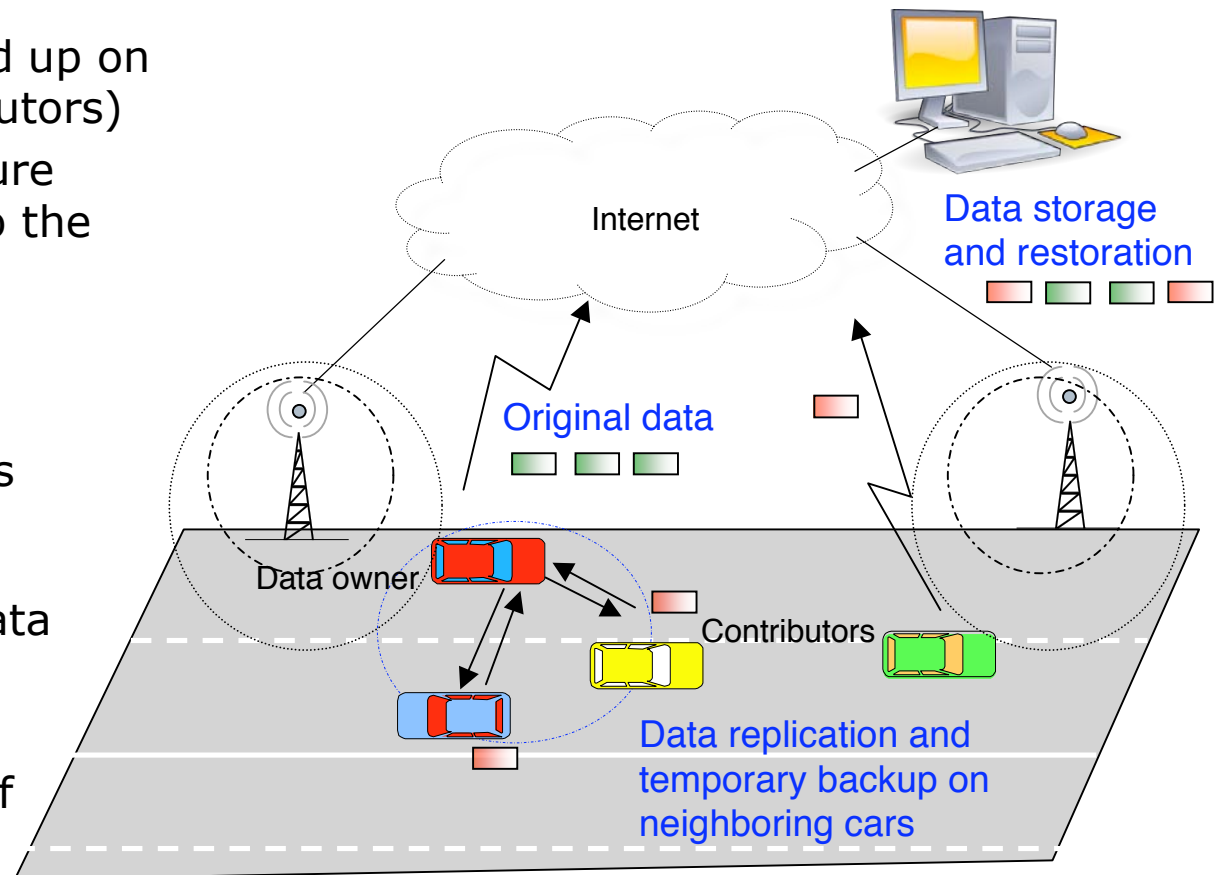


- **Develop and analyze** end-to-end system dependable solutions for scalable distributed applications and mobility aware services
- Automotive Applications
  - Car-to-car communication with server-based infrastructure

# Distributed Black Box Application

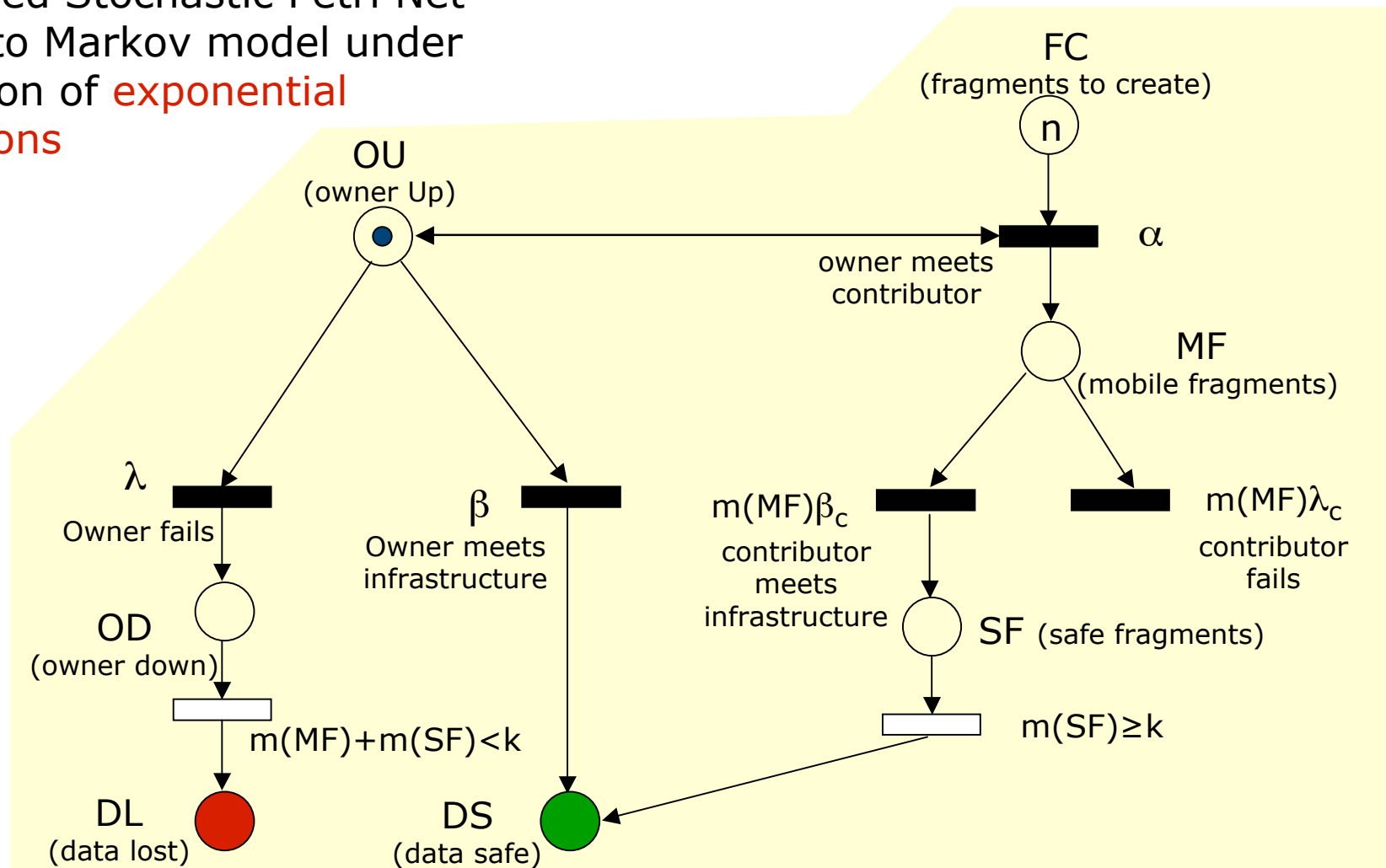
## Scenario

- Data owner collects data at regular intervals
- Data replicated and backed up on neighbouring cars (contributors)
- Data stored on infrastructure when access is available to the owner or the contributors
- Data replication based on erasure codes (n,k)
  - n: number of fragments generated
  - k: minimum number of fragments to restore data
- Evaluation
  - Comparative analysis of replication strategies
  - Measure: Probability of data loss



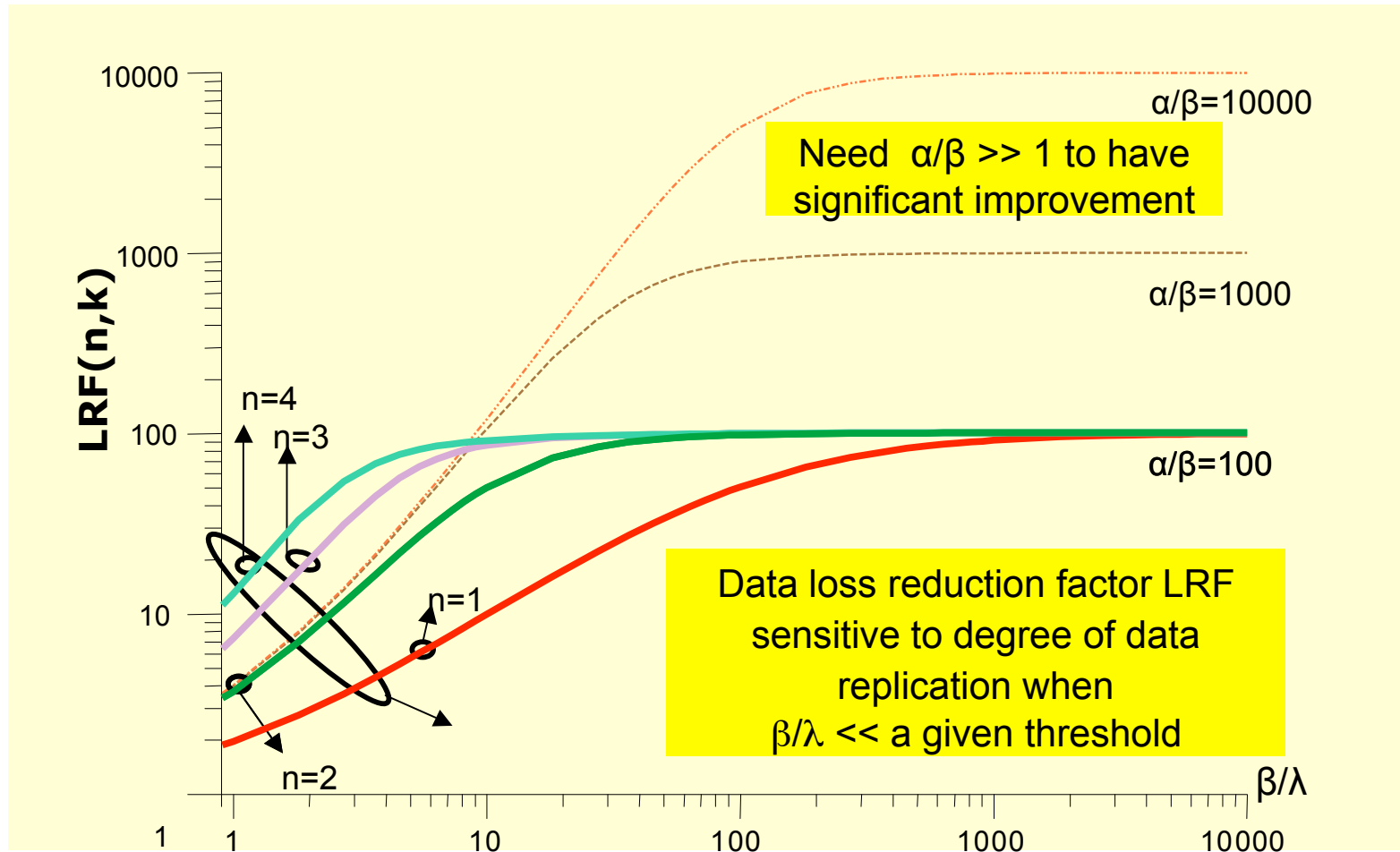
# GSPN model for (n,k) erasure codes

Generalized Stochastic Petri Net mapped to Markov model under assumption of **exponential distributions**



# Example results from GSPN model

Comparison: with/without cooperative backup  
LRF(n,k) = data loss reduction factor



# Analysis of node encounters distribution

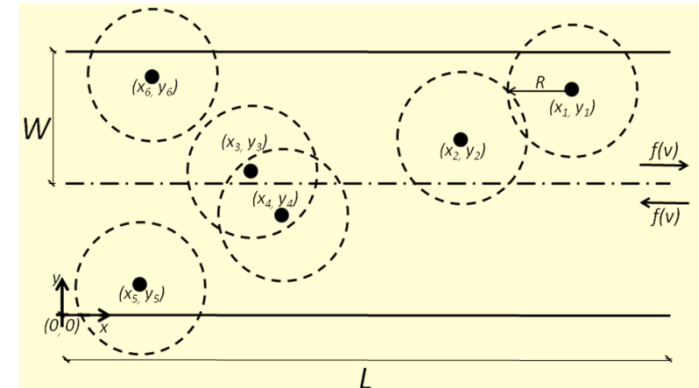
## 1. Analytical proof of *Poisson* encounter process

- Cars move independently according to speed distribution  $f(v)$ 
  - opposite directions on upper and lower half
- Initial placement of cars according to a spatial *Poisson* process ( $\rho$ : car density)
- Fixed communication radius for the cars:  $R$

$$\text{encounter rate } \alpha = \rho * E|V|$$

## 2. *Poisson* distribution confirmed by simulation of more complex scenarios with independent movement of cars

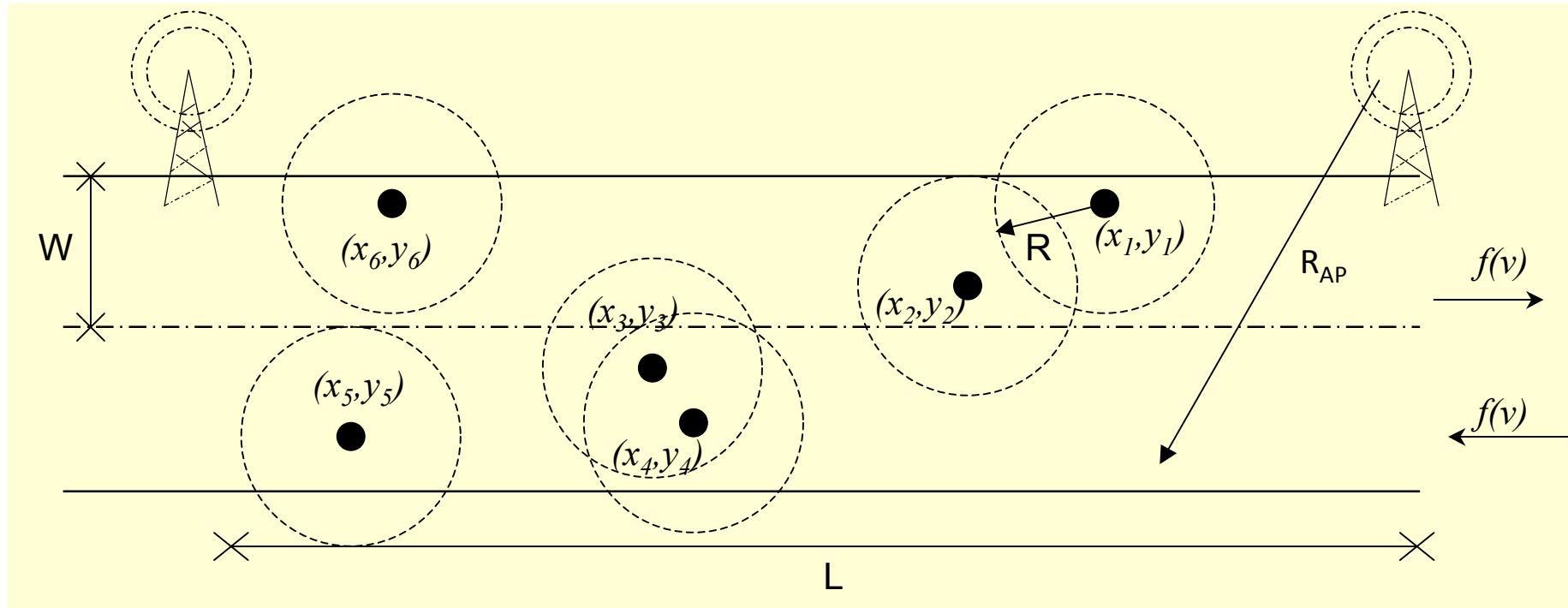
- single-hop and multi-hops scenarios
- connectivity duration analysis



## 3. Mobility with dependencies between vehicles

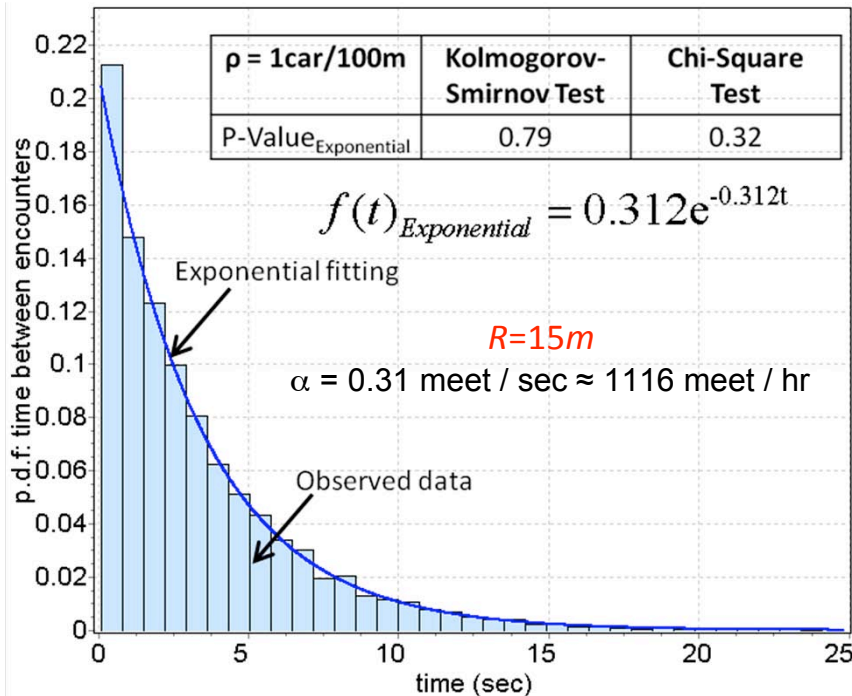
- variable speeds, cars can get slowed down by cars in front of them, cars can change lanes, correlation between cars trajectories
- encounters described by non-homogeneous *Poisson* process

# Simulation of connectivity dynamics

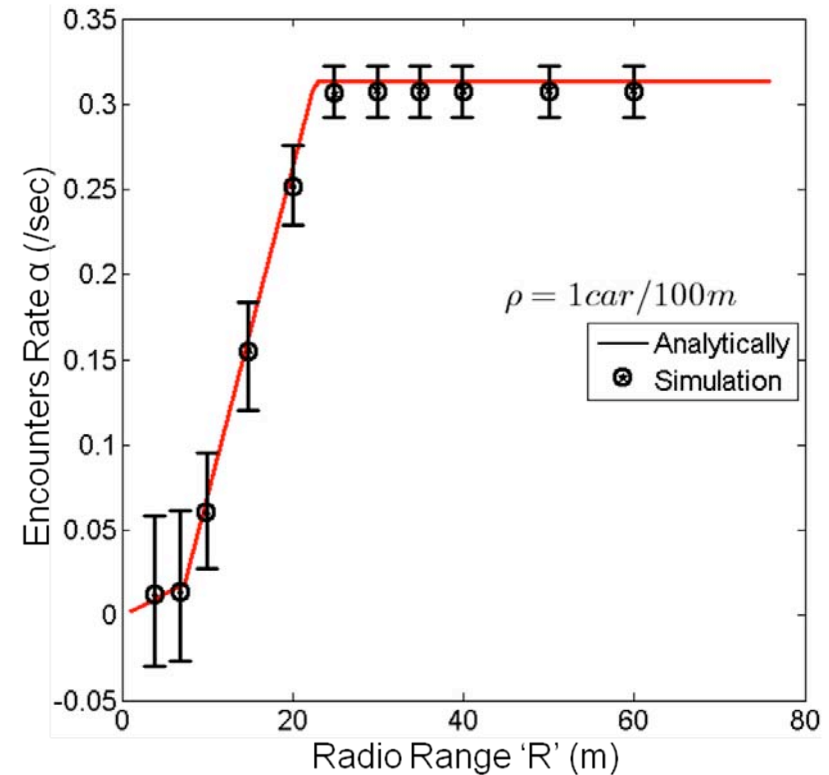


$V_{\min}=80\text{km/hr}$ ;  $V_{\max}=130\text{km/hr}$ ;  $V_1=108\text{km/hr}$ ;  $W=15\text{m}$ ;  $x_1=2500\text{m}$ ;  $y_1=5\text{m}$ ;  
 $\Delta t=0.1\text{sec}$ ;  $L=4000\text{m}$ ; **simulation steps=600\*300 times**;

# SIMULATION RESULTS: TIME TO ENCOUNTER A NEW NEIGHBOR



Empiric probability density function of the time between single-hop encounters for, car density  $\rho = 1\text{car}/100\text{m}$ : simulation results and comparison to an exponential distribution



The impact of the Radio Range on the encounter rate  $\alpha$

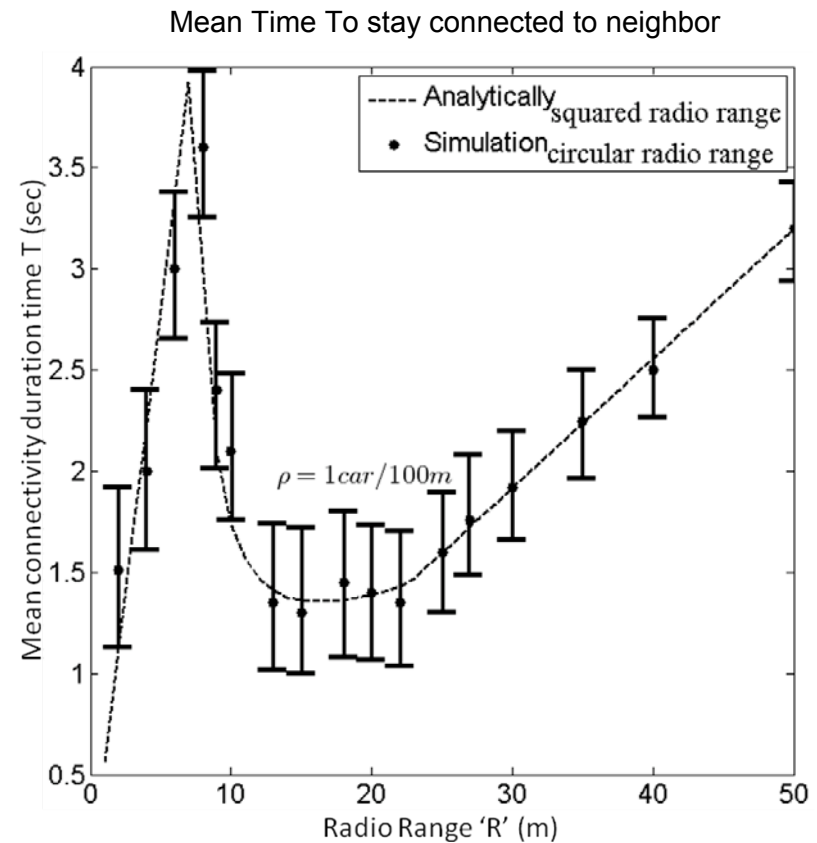
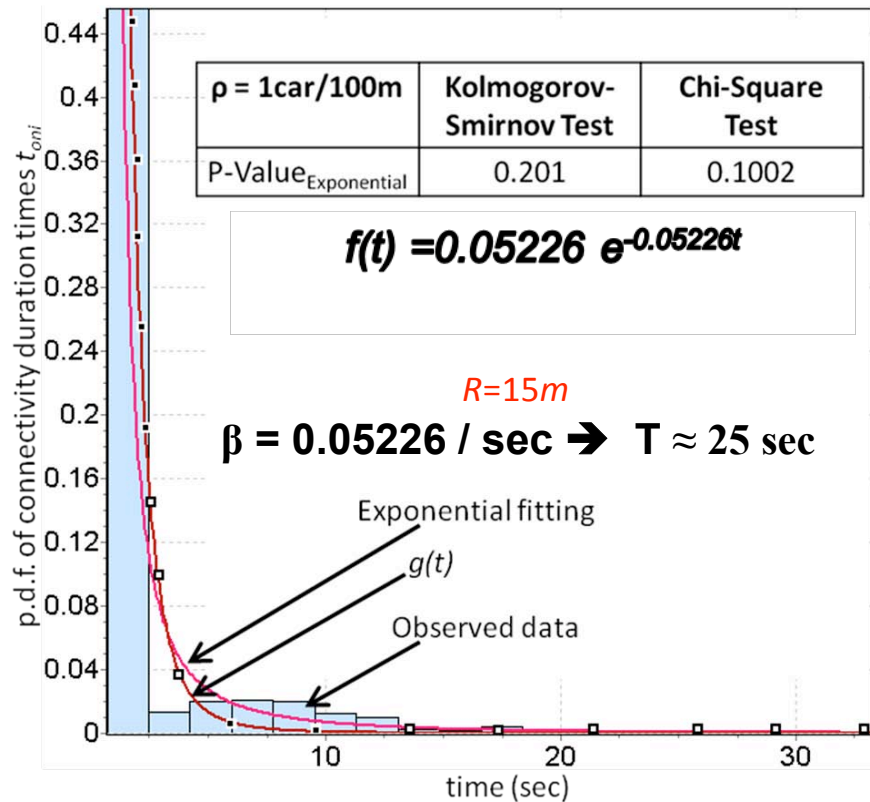
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# SIMULATION: CONNECTIVITY DURATION

T : connectivity duration random variable with p.d.f  $g(t)$

V: relative speed with p.d.f  $f(v)$

$$\rightarrow g(t) = f(2R/t) \frac{2R}{t^2}$$



# Future work

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- Assess sensitivity of results when the exponential distribution is not acceptable
- Analyse connectivity parameters distribution in other traffic scenarios (simulation, real traces)
- More general assumptions
  - Trust and cooperation wrt participating nodes
    - Selfish nodes, Remuneration/Penalties
  - Other dissemination strategies
    - more than one fragment per node, flooding,
  - Take into account Data freshness in data restoration strategies