Evolutionary Power-Aware Routing in VANETs using Monte-Carlo Simulation

Optimization Issues in Energy Efficient Distributed Systems (HPCS 2012)

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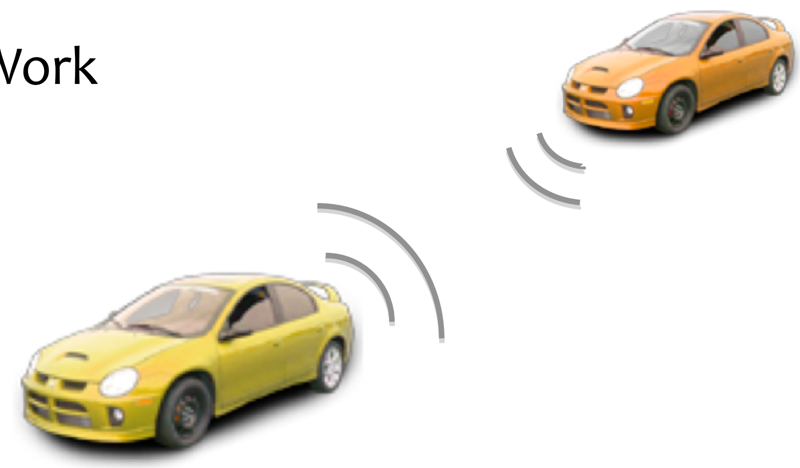
Outline

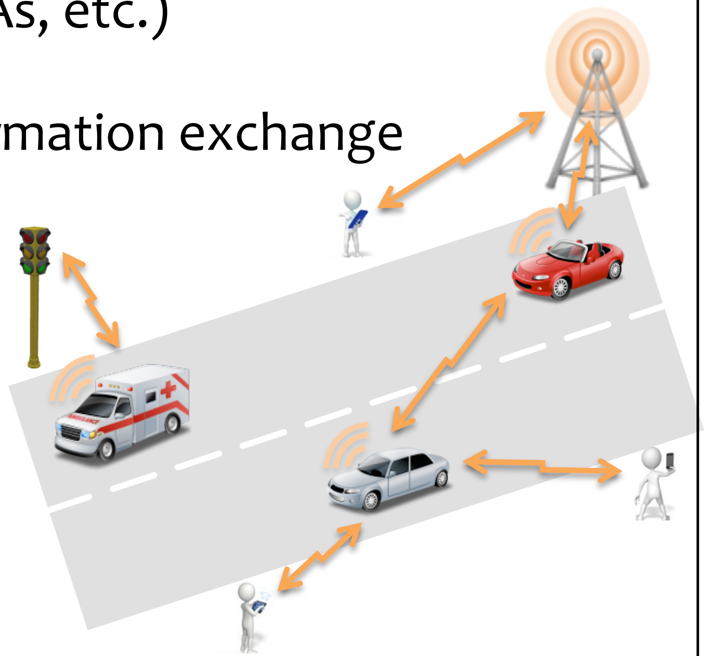


1. Introduction. VANETs and Energy Issues

➢ **Vehicular ad hoc networks** (**VANETs**) are self-configuring wireless ad hoc networks in which the nodes are **vehicles**, elements of **roadside**, **sensors**, and **pedestrian** personal devices (smartphones, PDAs, etc.)

➢ Deployed to enable up-to-minute road traffic information exchange

- Transport Efficiency
- Safety



➢ VANETs involve devices fed with **limited power sources**. Therefore, power-aware network architectures and protocols are highly desirable

➢ The **routing protocol** affects the **nodes power consumption** in two ways:

- The **protocol operation** → amount of energy used to compute the routing paths
- The **computed routing paths** → the terminals power consumption when forwarding packets

1. Introduction. Motivation

- We study the application of **Differential Evolution (DE)** to compute **power-aware routing protocol configurations**

- The optimization process is guided by evaluating tentative solutions (protocol parameterizations) by means of **VANET simulations**
  - **Stochastic propagation models** that produce different results when evaluating the same VANET scenario (up to 57% for some metrics and scenarios)

- A number of simulations of the same scenario is performed applying **Monte-Carlo method** to evaluate a solution

- As the VANET simulations require **high computational costs** the simulations are performed in **parallel** using different process units of a cluster

2. Power-Aware AODV. Problem Definition

- Finding the best AODV configurations to enable **green communications** in VANETs is the main subject of this work

- AODV is a routing protocol for mobile ad hoc networks used in VANETs
  AODV RFC 3561

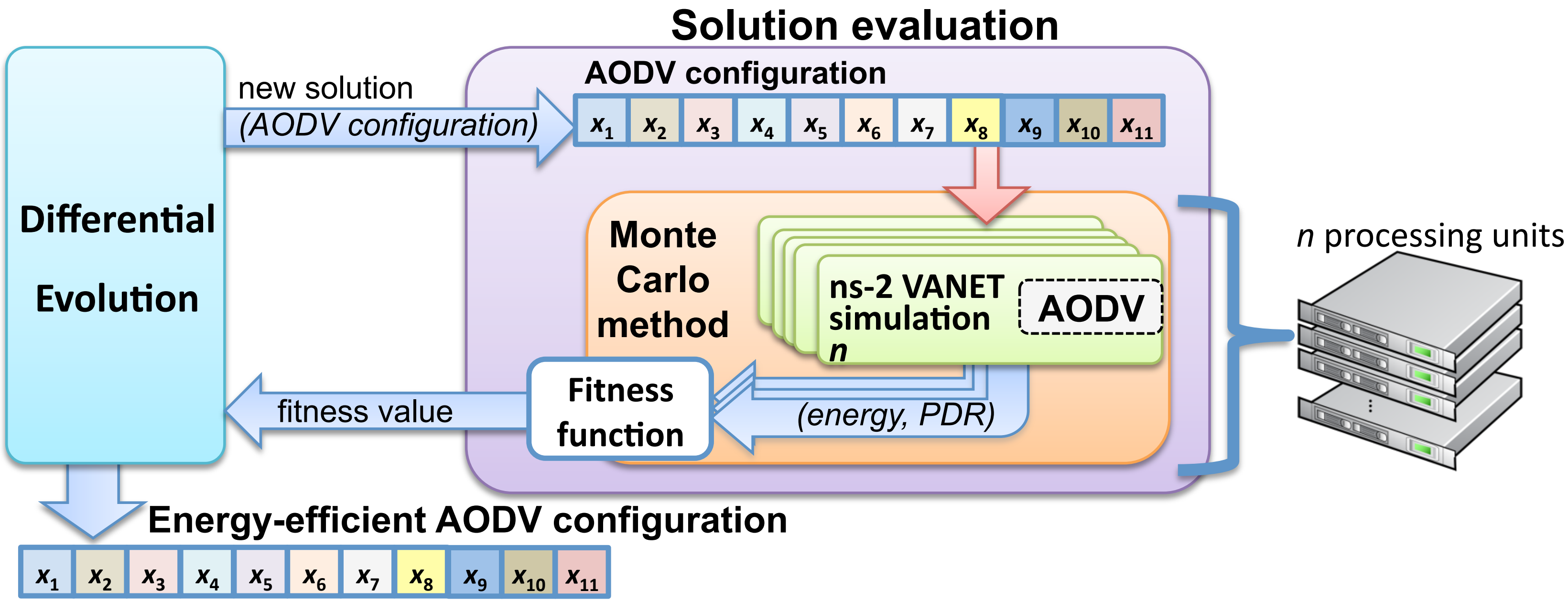
- An excessive energy consumption reduction can lead to protocol **malfunction**
  - QoS restriction → Maximum allowed **PDR degradation 15%** (over the standard)

parameter	RFC value	type	range
HELLO_INTERVAL	1.0 s	real	[1.0, 20.0]
ACTIVE_ROUTE_TIMEOUT	3.0 s	real	[1.0, 20.0]
MY_ROUTE_TIMEOUT	6.0 s	real	[1.0, 40.0]
NODE_TRAVERSAL_TIME	0.04 s	real	[0.01, 15.0]
MAX_RREQ_TIMEOUT	10.0 s	real	[1.0, 100.0]
NET_DIAMETER	35	integer	[3, 100]
ALLOWED_HELLO_LOSS	2	integer	[0, 20]
REQ_RETRIES	2	integer	[0, 20]
TTL_START	1	integer	[1, 40]
TTL_INCREMENT	2	integer	[1, 20]
TTL_THRESHOLD	7	integer	[1, 60]

2. Power-Aware AODV. Methodology

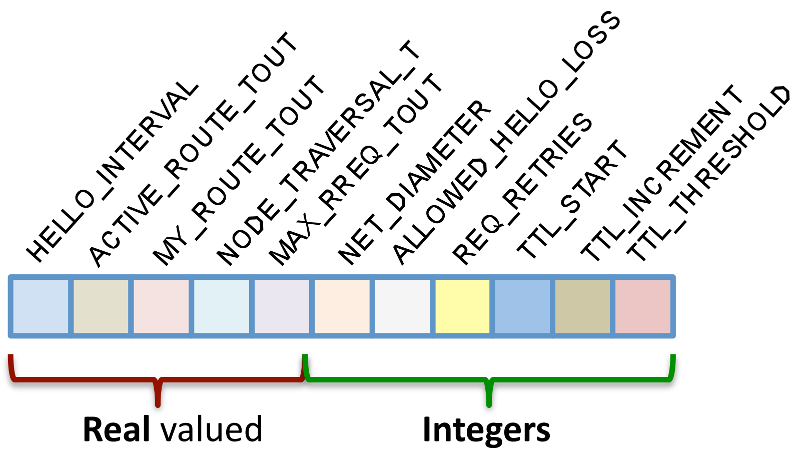
➢ Automatic optimization tool coupling **Differential Evolution (DE)** and **Monte-Carlo VANET simulation**

➢ **Methodology**



2. Power-Aware AODV. Optimization Method Details

➢ Problem Encoding:



parameter	type	range
HELLO_INTERVAL	real	[1.0, 20.0]
ACTIVE_ROUTE_TIMEOUT	real	[1.0, 20.0]
MY_ROUTE_TIMEOUT	real	[1.0, 40.0]
NODE_TRAVERSAL_TIME	real	[0.01, 15.0]
MAX_RREQ_TIMEOUT	real	[1.0, 100.0]
NET_DIAMETER	integer	[3, 100]
ALLOWED_HELLO_LOSS	integer	[0, 20]
REQ_RETRIES	integer	[0, 20]
TTL_START	integer	[1, 40]
TTL_INCREMENT	integer	[1, 20]
TTL_THRESHOLD	integer	[1, 60]

➢ Fitness Function:

$$F(s) = \Delta + \left(\omega_1 \times \frac{E(s)}{E_{RFC}} + \omega_2 \times \frac{PDR(s)}{PDR_{MAX}} \right)$$

Δ=0.1, ω_1=0.9, and ω_2=-0.1

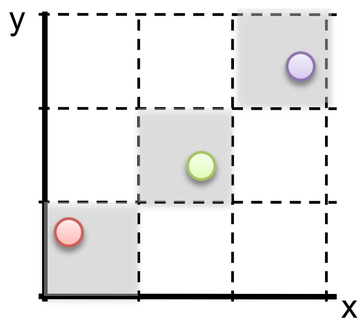
Penalization model (PDR degradation > 15%)

$$F_P(s) = F(s) + \left((PDR_W - PDR(s)) \times \frac{E(s)}{E_{RFC}} \right)$$

2. Power-Aware AODV. Optimization Method Details

➢Initialization:

Uniform initialization to assure that the initial population contains individuals from different areas of the search space. It splits the search space into *pop_size* (number of individuals) **diagonal subspaces**.



➢Crossover:

We used **Blend Crossover Operator (*BLX*-α)**, a well-known recombination operator for real coded EAs

2. Power-Aware AODV. Fitness Evaluation

➢Realistic VANET simulations should reflect real world interactions. In this sense, stochastic signal propagation models are used. In our work, we have used the **Nakagami propagation model.**

The simulation results are non-deterministic (deviations up to 57%)

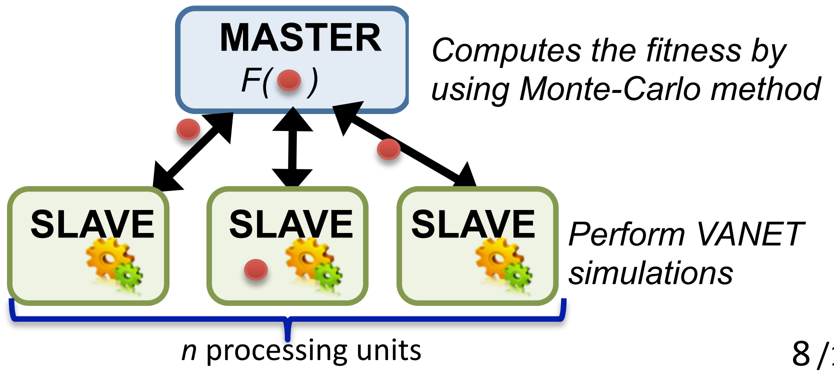
➢**Monte-Carlo simulation** is used to perform more accurate fitness evaluations. Energy and PDR are computed repeating *n* times the simulation

$$energy = \frac{\sum_{i=1}^{n} energy_i}{n} \qquad PDR = \frac{\sum_{i=1}^{n} PDR_i}{n}$$

➢As ns-2 VANET simulation require **large execution times** (minutes) we applied the parallel **multithreading master-slave** paradigm to run the *n* simulations over *n* processing units

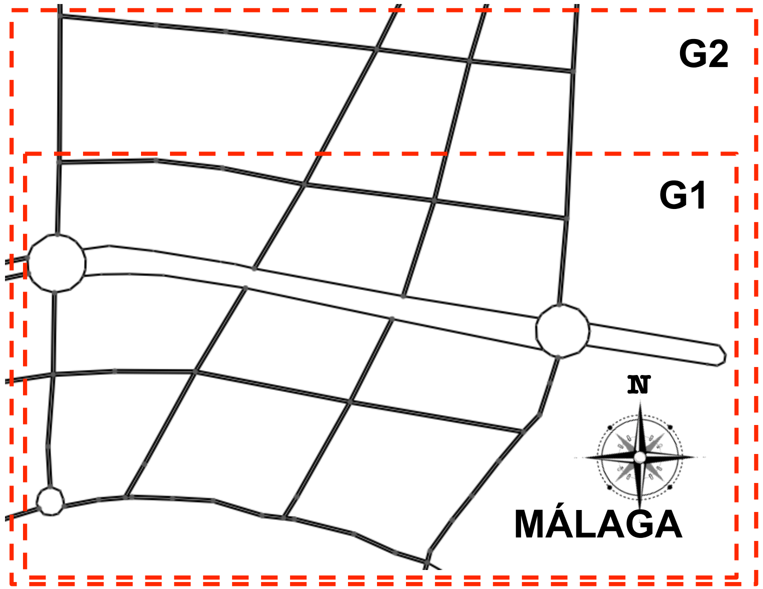
- Reducing drastically the required time to evaluate the solution fitness

In our work, ***n*=24**



3. Experimental Analysis. Experiments Definition

- VANET scenarios definition:
  - Geographical areas:
    - G1: 240,000 m^2
    - G2: 360,000 m^2
  - Number of nodes:
    - G1: 20
    - G2: 30, 45, and 60
  - Generated data traffic rate:
    - 128, 256, 512, and 1024 kbps



- Optimization scenario → **G1, 20, 512 kbps**

- DE (C++, MALLBA, and standard *pthread* library):
  - Population size = 8 individuals
  - Number of generations = 50
  - Crossover : probability = 0.9, α = 0.2

After performing DE configuration analysis experiments using **G1, 20, 128 kbps** scenario to find the best DE parameterization

3. Experimental Analysis. DE Optimization Results

➢ **Best configuration found:**

HELLO_INTERVAL=11.994, ACTIVE_ROUTE_TIMEOUT=12.439, MY_ROUTE_TIMEOUT=15.965, NODE_TRAVERSAL_TIME=8.106, MAX_RREQ_TIMEOUT=42.466, NET_DIAMETER=66, ALLOWED_HELLO_LOSS=6, REQ_RETRIES=9, TTL_START=12, TTL_INCREMENT=19, and TTL_THRESHOLD=54

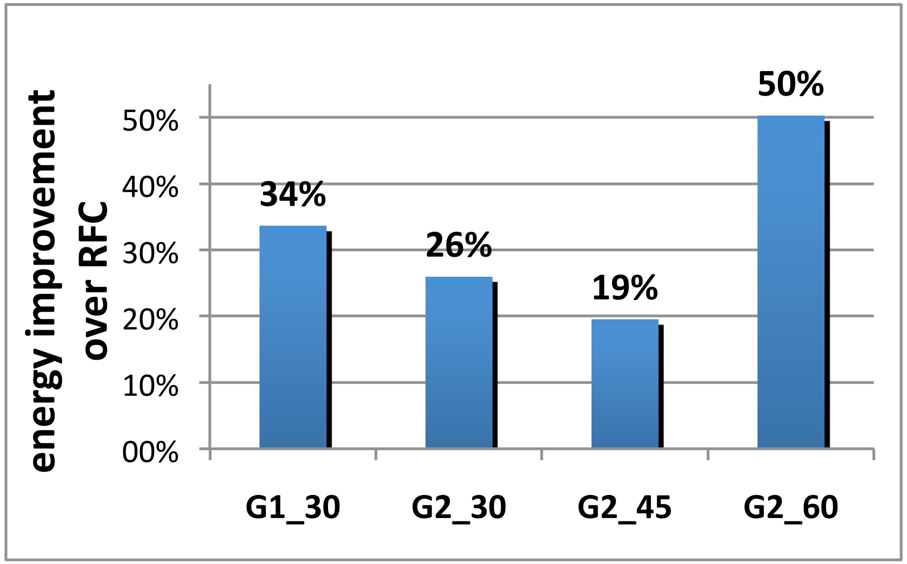
➢ **Main properties:**

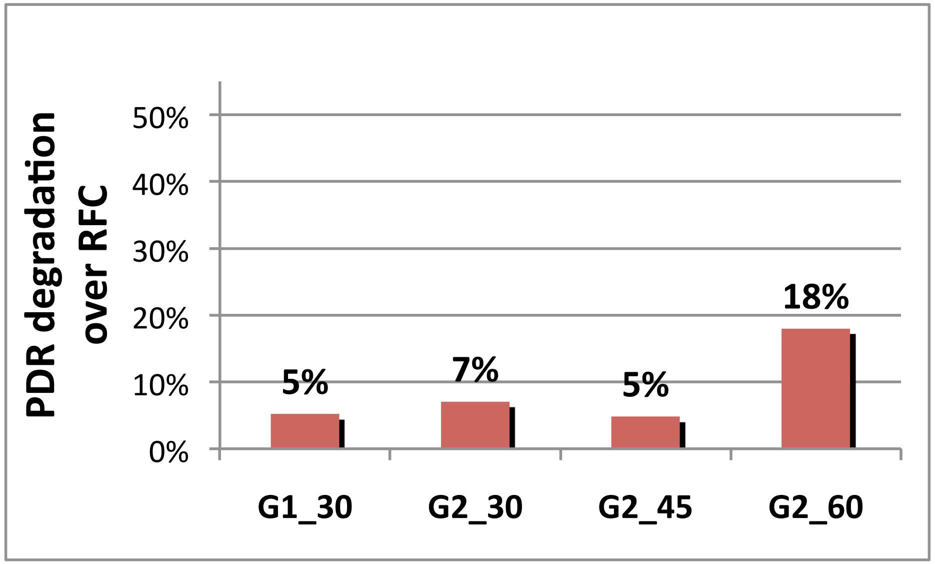
- it generates lower control traffic
- each node spends less time in the transmitting and the receiving states
- it manages longer paths since the network diameter and the time to live are larger
- it is more tolerant to disconnections and packet loss because it allows greater hello packet loss and it resend RREQ packets more times

➢ The average power consumption obtained with the optimized AODV configuration **reduced 33.55% the RFC energy requirements**, while the **PDR degradation was only 5.17%**

3. Experimental Analysis. Validation Results

- **Best energy-aware AODV** configuration vs **RFC 3561** over 9 scenarios in **G2** area
- Results:
  - **Average power consumption saving = 32.3%** / average PDR degradation = 8.8%
  - Largest energy reduction in greatest road traffic density (60 nodes, max = 68.9%)
    - Suffers from several drop in the PDR
  - Lowest energy savings in scenarios with the largest data rates (1024 Kbps)
  - **Kruskal-Wallis statistical test** results indicate that the energy improvements can be considered statistically **significant**





4. Conclusions and Future Work

- Automatic methodology for computing power-aware AODV configurations for VANETs, by coupling DE and Monte-Carlo method (ns-2 simulations)
- Main contribution:

  DE and a parallel master-slave Monte-Carlo simulation to reduce the variability of the configuration evaluation due to randomness in Nakagami model
- Main results:

  Significant reductions in power consumption when using the DE AODV energy-aware configuration (32.3% average, 68.9% best); average PDR degradation: 8.8%

- Promising methodology for automatic and efficient customization of VANET routing protocols

- Future work:
  - improve the search to reduce the QoS degradation in dense scenarios
  - use other fitness functions (new metrics, explicit multi-objective approaches)
  - parallelize the population evaluation to allow larger populations in DE
  - improve the results by using several scenarios to evaluate each configuration

Thank you for your attention…

Comments

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