Communications in Vehicular Networks: Opportunities for Optimization and Learning

http://neo.lcc.uma.es

University of Málaga, Spain
Objective of a global optimization problem:

\[ f(\overline{x}) \rightarrow \max : \text{find a vector} \ \overline{x}^* \]
\[ \text{such that} \ \forall \overline{x} \in M : f(\overline{x}) \leq f(\overline{x}^*) := f^* \]

- Minimizing is also possible
- Vectors can map to other data structures
Introduction (II)

Where can optimization problems be found?

1. Distribute "n" electrons on a sphere.
2. Jobs (execution time).
3. CPU's set.

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<td>10</td>
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Introduction (III)

Optimization Algorithms

- Exact
- Ad-hoc Heuristic
- Metaheuristic

- Calculus
- Enumerative
- Trajectory
- Population

- Direct
- Indirect
- DP
- B&B
- SA
- VNS
- EA
- ACO
- TS
- PSO

- nature inspired in red

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Introduction (IV)

- Selection
- Recombination
- Mutation
- Insertion

Tentative Sol. Population
Evolutionary Algorithm

\[ t := 0; \]
\[ \text{initialize} \ [P(t)]; \]
\[ \text{evaluate} \ [P(t)]; \]

\[ \textbf{while not end condition do} \]
\[ P'(t) := \text{variation} \ [P(t)]; \]
\[ \text{evaluate} \ [P'(t)]; \]
\[ P(t+1) := \text{selection} \ [P'(t) \cup Q]; \]
\[ t := t +1; \]

end while
Introduction (VI)

Optim. Focus

Convex Combination
Metric Space

Global best
New position
Best known

Solution Vector
Search Angles
Standard Deviation
Inspiration

Present Solution
New Solution

procedure ACOMetaheuristic
ScheduleActivities
ConstructAntsSolutions
UpdatePheromones
DaemonActions // optional
end ScheduleActivities
end procedure

(0,2; -1,4; 3,5) → Solution Vector
(1,0; 10,3; 7,2) → Standard Deviation
(1,7; 0,3; 2,1) → Search Angles

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Introduction (VII)

NAS: Natural Advanced Solutions

Four main ways of making an algorithm more efficient and accurate:

- **Parallel:**
  Clusters, Grid computing, multicore, FPGAs, GPUs…

- **Hybrid:**
  Combining algorithms, operators, representations: problem knowledge

- **Multiobjective:**
  Modelling explicitly several conflicting objective functions with Pareto’s concept of dominance

- **Dynamic:**
  Solve a problem that changes in time and adapt previous solutions to the new scenarios
CARLINK: Architecture

UMA scope
CARLINK: VanetMobiSim versus ns-2

- **Simulator tools for CARLINK**
  Testing and Validation of new protocols and applications

- **VanetMobiSim**
  Traffic Simulator generates realistic Traces
  - Micro-mobility models
  - Macro-mobility models
  - Open Source
  - Specific for VANETs.

- **ns-2**
  Network Simulator generates Statistics
  - Open Source
  - Widely accepted network simulator
  - Simulation over a wide range of protocols
CARLINK: JANE – Java Ad-hoc Network Env.

- A Tool for Implementing Real Ad-hoc Network Applications

From Simulation to Real World

1. Simulation Mode
   - Simulated Environment
   - Simulated User Actions

2. Hybrid Mode
   - Simulated Environment
   - Real User Actions

3. Platform Mode
   - Real Environment
   - Real User Actions

Software Development Cycle

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CARLINK: Real Scenario and Simulations

• Simulation Parameters:

- Link Layer Specifications:
  * IEEE 802.11b Physical and MAC Layer
  * Wireless Network Cards Output Power: 12dBm
  * Wireless Antennas Gain: 7dBi

- VDTP Protocol for transferring data between MEUs

- Mobility Models
  * Scenario A
  * Scenario B
CARLINK: Simulation vs. Real World

- **Static tests** transferring files between two vehicles
- Two scenarios considered: laboratory and parking

Data exchange at reasonable speeds for up to 100m (without obstacles)

Fall in the performance with obstacles
CARLINK: Actual Applications

Finding and Sharing Files (FSF)

This application allows the exchange of files among vehicles (a very important service in any application).

Features:

- Deal with the fragmentation of the files
- Adapt to topology network changes
- Fault tolerance to short connection problems

Gaming (e.g., Puzzle-Bubble)

A simple game in which users must remove all bubbles in screen. Deleted bubbles are sent to the other players.

Features:

- Short communications among players
- The number of players can vary dynamically

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DIRICOM: Andalusian Project (2008-2012)

http://diricom.lcc.uma.es

Information Dissemination

Website

Small Devices

Traffic Control Centre

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• VANET Protocol Optimization:

- VANET communications imply: highly dynamic topology, limitations in coverage, bandwidth, and energy consumption, network congestion, frequent disconnection, and others…

- An optimal configuration of the communication protocols can improve the quality-of-service (QoS) of the network

- Using NAS (intelligent automatic tools) to face the huge number of possible protocol configurations

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Default Values</th>
<th>Range</th>
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<tbody>
<tr>
<td>ACTIVE_ROUTE_TIMEOUT</td>
<td>3.0 s</td>
<td>1.0...10.0</td>
</tr>
<tr>
<td>ALLOWED_HELLO_LOSS</td>
<td>2 HELLO packets</td>
<td>1...10</td>
</tr>
<tr>
<td>MY_ROUTE_TIMEOUT</td>
<td>2.0×ACTIVE_ROUTE_TIMEOUT</td>
<td>1.0...10.0</td>
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<tr>
<td>NET_DIAMETER</td>
<td>35 nodes</td>
<td>1...50</td>
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<tr>
<td>NODE_TRAVERSAL_TIME</td>
<td>0.04 s</td>
<td>0.01...1.0</td>
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<tr>
<td>NET_TRAVERSAL_TIME</td>
<td>2.0×NODE_TRAVERSAL_TIME×NET_DIAMETER</td>
<td>1.0...10.0</td>
</tr>
<tr>
<td>RREQ RETRIES</td>
<td>2 tries</td>
<td>1...10</td>
</tr>
<tr>
<td>RREQ_RATELIMIT</td>
<td>10.0 kbps</td>
<td>1.0...10.0</td>
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<td>TTL START</td>
<td>1.0 s</td>
<td>1.0...10.0</td>
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<tr>
<td>TTL_INCREMENT</td>
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<tr>
<td>TTL_THRESHOLD</td>
<td>7.0 s</td>
<td>1.0...20.0</td>
</tr>
</tbody>
</table>

AODV RFC 3561
DIRICOM: Automatic Tuning of Protocols

- Optimization Framework:

Natural Advanced Solutions
- Ant Colony Optimization
- Particle Swarm Optimization
- Genetic Algorithms

Others...

Optimization Algorithms

Solution Evaluation

Protocol configuration
\[ x_0, x_1, x_2, x_3, x_4, \ldots \]

New solution/configuration

Ns-2 VANET simulation

VANET communication protocols

Fitness evaluation
\[ f_0, f_1, f_2, f_3, \ldots \]

Ns-2 trace analysis

Communication metrics

Optimal protocol configuration
\[ x_0, x_1, x_2, x_3, x_4, \ldots \]

Real world VANET scenarios

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**DIRICOM: Optimal Broadcasting**

- **QoS VANET Protocol Optimization:**

  \[
  \text{fitness} = w_1 \cdot (-PDR) + w_2 \cdot NRL + w_3 \cdot AEED \cdot C
  \]

  - Packet Delivery Ratio
  - Network Routing Load
  - Average End-to-End Delay

![Graph showing median performance and effective data rate over number of evaluations and for different scenarios.](chart.png)
DIRICOM: Green-Communications

- VANETs Energy Consumption Optimization:

  \[ \text{fitness} = \text{energy\_consumption} \]

![Energy Consumed Grouped by Urban Scenarios](image-url)
DIRICOM: Outdoor Testbeds

- From simulation to real world results:
  
  - Different file transfers by using optimized protocols in urban areas from Málaga downtown and in highway
  
  - Testing the accuracy of ns-2 VANET simulations
DIRICOM: Outdoor Testbeds

- From simulation to real world results:

  - The real world test results confirm the simulation ones
- MANETs
  - Stations usually are laptops, handholds, PDAs, or mobile phones
  - Mobility of stations → dynamic topology of the network

- Metropolitan MANETs
  - High Density Areas (HDA): areas with high station density
  - HDAs can appear and disappear from the network

- Optimization Problem
  - Fine-tune of a broadcasting strategy called DFCN
  - Target: metropolitan MANETs

- Multiobjective metaheuristics
  - EAs: NSGA-II, SPEA2, cMOGA
  - Scatter Search: AbYSS
  - PSO: MOPSO
DIRICOM: Geodata Processing in OTLC

Index
- Optim. Focus
- CARLINK
- DIRICOM
- D0
- New Ideas
- Others

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DIRICOM: Actual Results in OTLC

30 Traffic Logics - 300 Vehicles

Number of Vehicles

Number of Iterations

0 50 100 150 200 250 300

Number of Vehicles

Trip Time

0 50 100 150 200 250 300

SUMO

PSO

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DIRICOM: Connectivity and Transport

Data Mining

Miniaturized Vehicles

Dynamic VRP

Alternative Routes

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DESTINO CERO: Next Steps in Intelligent Transport

Data mining for detecting conflictive zones

Reducing CO\textsubscript{2} emissions in cities
New Ideas: Multidisciplinary Applications
New Ideas: Optimally Located Info Panels

Welcome to Málaga
Ongoing events:
• Festival de Cine Málaga (17th – 24th de April)
• ...
- **Objective:** find a counterexample for a safety property in a concurrent model

- Safety properties are those expressed by an LTL formula of the form:

$$f = \square p$$

where $p$ is a past formula (with only past operators)

- **Finding one counterexample** $\equiv$ finding one accepting state in the intersection Büchi automaton (graph exploration problem)
- Number of states very large even for small models

- For example: Dijkstra Dining Philosophers
  - \( n \) philosophers \( \rightarrow 3^n \) states
  - 20 philosophers \( \rightarrow 1039 \) GB for storing the states
ACOhg is a new Ant Colony Optimization model that can be applied to optimization problems with an unknown and/or very large construction graph.

Who can really find errors?

<table>
<thead>
<tr>
<th>Models</th>
<th>BFS</th>
<th>DFS</th>
<th>A*</th>
<th>BF</th>
<th>ACOhg</th>
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<td>marriers20</td>
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ACOhg is a very robust algorithm for this problem and it outperforms traditional algorithm from the model checking domain.
Others: Logistics

Mediterranean Sea

MÁLAGA

dynamic
Others: Wireless Sensor Networks

SunSpot

MicaZ mote

Corresponding sites

Selected sites

List of available sites

Selected sites

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End of Presentation

Málaga