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Informe Ejecutivo

Título: VANET-1.4-2009 Problema de la optimización de la transferencia de ficheros, *OFTC*, (resolución)

Resumen: En este informe se presentan detalles sobre la resolución del problema de optimización de la transferencia de ficheros en redes vehiculares conocido también como problema OFTC *Optimal File Transfer Configuration.* Con ello se pretende ofrecer la configuración óptima del protocolo *VDTP (Vehicular Data Transfer Protocol)* que se calcula automáticamente mediante el uso cinco algoritmos metaheurísticos (SA, GA, DE, PSO y ES).

Objetivos:

1. Describir la estrategia empleada para resolver el problema OFTC.
2. Definir los experimentos llevados a cabo.
3. Presentar los resultados obtenidos reolviendo el problema OFTC.

Conclusiones:

1. Las configuraciones del protocolo VDTP obtenidas de forma automática mejoran los resultados de las mismas obtenidas por los expertos.
2. PSO reduce en un 19% el tiempo de transferencia en el escenario Urbano y un 25.43% en el Interurbano, comparando los resultados con los mismos obtenidos por las configuraciones manual de los expertos.

Relación con entregables:

CO: VANET-2.0-2009 (simultáneo o aconsejable de leer)

Málaga, December 22nd, 2009

Executive Summary

TITLE: VANET-1.4-2009 Optimal File Transfer Configuration problem (resolution)

ABSTRACT: This report presents the results of solving the *Optimal File Transfer Configuration* problem, offering an optimal configuration of *VDTP (Vehicular Data Transfer Protocol)* computed automatically by using five metaheuristics (SA, GA, DE, PSO, and ES).

GOALS:

1. Presenting the optimization framework used to solve the OFTC problem.
2. Defining the experiments carried out.
3. Showing the results of solving OFTC.

CONCLUSIONS:

1. The automatically computed VDTP configurations outperforms the ones obtained by the human experts.
2. PSO can reduce 19% of the transmission time in Urban and 25.43% in Highway with regards to human experts configuration.

RELATION WITH DELIVERABLES: CO: VANET-2.0-2009 (advisable reading)

Optimal File Transfer Configuration problem (resolution)

DIRICOM

December 2009

1 Introduction

VANETs deals with a set of vehicles and roadside units (traffic lights, signs, etc.) which are able to communicate with each other without requiring any underlying infrastructure. Such networks use IEEE 802.11 standards which implies that the nodes communicate within a limited range while moving, thus exhibiting a topology that may change quickly and in unpredictable ways. Therefore, it is crucial to provide the user with an efficient configuration of the communication protocols in order to offer the best quality of service (QoS) possible.

In the present deliverable, we solve the Optimal File Transfer Configuration (OFTC) problem in VANETs, which deals with the optimization of VDTP (*Vehicular Data Transport Protocol*) [3]. This problem have been defined with the aim of optimizing the transmission time, the number of lost packets, and the amount of data transferred in realistic VANET scenarios. We face the OFTC with five representative state-of-the-art optimization techniques and compare their performance. These algorithms are: Particle Swarm Optimization (PSO), Differential Evolution (DE), Genetic Algorithm (GA), Evolutionary Strategy (ES), and Simulated Annealing (SA). For our tests, two typical environment instances of VANETs for urban and highway scenarios have been defined.

This document is organized as follows: in Section 2, we introduce the optimization framework used to solve the OFTC problem. Next, in Section 3, we present the experiments carried out. In Section 4, we show the main results of solving this optimization problem. Finally, in Section 5, we draw some conclusions about the Optimal File Transfer Configuration problem.

2 Optimization Framework

The optimization framework used to solve this problem is composed by basically two main parts: an optimization algorithm and a simulation procedure. The optimization part is carried out by (independently) one metaheuristic algorithm (SA, GA, DE, PSO or ES). All of them are specially adapted to find optimal (or cuasi-optimal) solutions in continuous search spaces (which is the case in this work). The simulation process is a way of assigning a quantitative quality value to the factors regulating VDTP, thus leading to optimal configurations of this protocol tailored to a given scenario. This procedure is carried out by means of the *ns-2* [9] simulator in which we have implemented the VDTP protocol for sending files in VANETs.

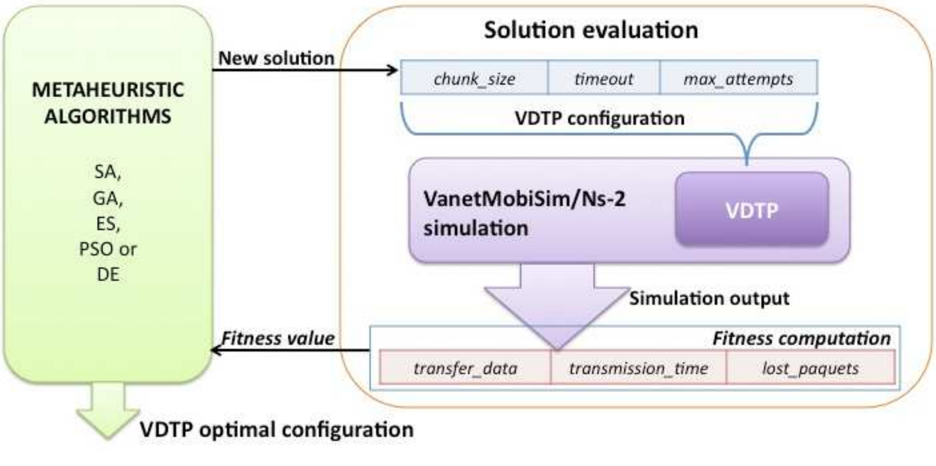

Figure 1: Representation of how the Optimal File Transfer Configuration problem is solved by using an *Optimization Technique* and $Ns-2$.

In each optimization algorithm, the evaluation of each solution is carried out by means of the simulation component. As Figure 1 illustrates, when a given algorithm generates a new solution it is immediately used for configuring the VDTP. This configuration evaluates the quality of the solution by using the received *retransmission time*, *chunk size*, and *total number of attempts* [8]. Then, *ns-2* is started and maps a given VANET scenario instance, taking its time in evaluating the scenario with buildings, signal loss, obstacles, vehicles, speed, covered area, etc., under the circumstances defined by the three control parameters optimized by the algorithm. After the simulation, *ns-2* returns the global information about the *transmission time* required for sending the file, the *number of lost packets* generated during the simulation, and the *amount of data* exchanged between vehicles. This information is used to compute the *fitness* function.

2.1 Fitness Function

Since *ns-2* operates by simulating (and averaging) many potential variations scenario all fitting the actual vehicle system, there is a possibility of obtaining different fitness values even using the same VDTP configuration (solution). Therefore, in order to provide each solution with a fitness value as reliable as possible, a single evaluation of one solution requires $N = 10$ internal simulations, computing the global fitness (F) as the mean of all *ns-2* results (Equation 1).

$$F = \frac{1}{N}\sum_{i=1}^{N}\frac{transmission\_time_i + lost\_packets_i}{\log(data\_transferred_i + C)} \tag{1}$$

In this equation, $i \in [1 \cdots 10]$ is the number of simulations per solution evaluation. The factor $C = 2$ avoids division zero if there is no data transference, preventing a possible error in the fitness calculation. The data transferred is presented in logarithmic scale in order to make up for the difference in the range of values. This way, the algorithm looks for minimizing the global fitness[1].

3 Experiments

We have used the implementation of the five algorithms provided by MALLBA [2], a C++ based framework of metaheuristics for solving optimization problems. The simulation phase is carried out by running *ns-2* simulator v-2.31 [9]. For the experiments, we made 30 independent runs of each algorithm on machines with Pentium IV 2.4 GHz core, 1 GB of RAM and O.S Linux Fedora core 6.

3.1 Instances: VANET Scenarios

We have created two simulation VANET scenarios (instances) from real urban and highway areas of Málaga, Spain (selected areas in Figure 2). We have defined this two distinct scenarios since the characteristics of the movement of vehicles for these two scenarios are different enough to affect the transfer of files. For example, in urban areas the vehicles density is higher and these vehicles travel at lower speeds than in interurban environments, increasing the likelihood that the transfers are carried out successfully in urban than in the highways. Therefore, we can analyze in both scenarios the behavior and performance of the compared algorithms, as well as the differences in the resulting VDTP configurations in terms of communication efficiency. Furthermore, we can compare these automatically generated configurations against the ones used in the real experiments by human experts in CARLINK [5, 6].

The resulted communication environments of both instances were defined in the *ns-2* simulator following the VANET specifications of devices and protocols, which are summarized in Table 1.

Table 1: VANET instance specification

Parameter	Value
Link Layer: transceiver	PROXIM ORiNOCO PCMCIA (IEEE 802.11b)
Link Layer: antenna gain	7 dBi (Omnidirectional)
Mac protocol	IEEE 802.11b
Routing Protocol	DSR
Transport Protocol	UDP
Application Protocol	VDTP
File transfers	20 sessions

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[1] A multi-objective evaluation [7] was not taken into account since objectives are not necessarily opposed in this work.

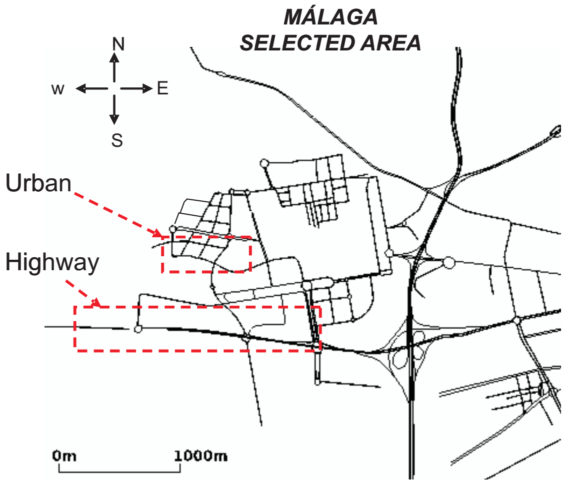

Figure 2: Selected area map of Málaga for our VANET instances. Urban and Highway surfaces are enclosed by dotted lines

3.1.1 Urban

The Urban instance covers an area of 120,000 m^2 including buildings and semaphores. We have used *VanetMobiSim*[4] for generating a realistic simulation mobility model where vehicles move randomly according to real traffic rules. A number of 30 vehicles move with a velocity between 30 km/h and 50 km/h, and 20 of them trying to send and receive a file of 1,024 kBytes.

3.1.2 Highway

The Highway instance covers a stretch of 1 km with two directions without buildings and semaphores. In this case, the absence of obstacles is made up for the handicap of the high speed of vehicles, which also interferes the communication among vehicles. We have also used *VanetMobiSim*[4] for generating a realistic simulation mobility model where vehicles move randomly according to real traffic rules. In the Highway VANET, a number of 30 vehicles move with a velocity between 80 km/h and 110 km/h, and 20 of them trying to send and receive a file of 1,024 kBytes size.

3.2 Parameter Settings

In our experiments, all studied algorithms were configured in order to perform 1,000 solution evaluations per run. At each one of these solution evaluations, *ns-2* performs 10 independent simulations of the target scenario with the same protocol configuration as stated in Section 2.1. Therefore, the population based algorithms (PSO, DE, GA, and (μ, λ)-ES) were configured with 20 individuals, performing 50 generational steps.

Table 2: Parameterization of the optimization algorithms

Algorithm	Parameter	Symbol	Value
PSO	Local Coefficient	φ_1	2·rand(0.1)
	Social Coefficient	φ_2	2·rand(0.1)
	Inertia Weigh	w	0.5
DE	Crossover Probability	Cr	0.9
	Mutation Factor	μ	0.1
GA	Crossover Probability	P_{cros}	0.8
	Mutation Probability	P_{mut}	0.2
ES	Crossover Probability	P_{cros}	0.9
	Mutation Probability	P_{mut}	0.1
SA	Temperature Decay	T	0.8

Table 2 summarizes the remaining parameters specific to each algorithm. These parameters were selected as the most accurate after a set of initial tuning experiments. In these, a number of 5 combinations of parameters per algorithm and VANET instance were tested performing 10 independent runs per combination, hence resulting a number of 500 additional executions.

4 Results and Comparisons

In this section we present the results obtained by the five studied algorithms when solving the Optimal File Transfer Configuration (OFTC) problem on VDTP.

4.1 Global Results

Table 3 shows the resulting fitness values regarding the Urban and Highway VANET scena-rios in terms of the mean, the standard deviation, the minimum (best fitness), the median, and the maximum (worst fitness) found in 30 independent runs of every algorithm.

For the Urban scenario, we can observe (in Table 3) that PSO obtained the best result in terms of the mean fitness. This smallest mean value leads us to believe that using the PSO the resulting VDTP ends in an efficient communication which is fast and accurate between vehicles. In addition, the best median and maximum values were also obtained by PSO, although the best minimum (e. g. the best VDTP configuration found for Urban) was reached by DE. This is an expected value, since DE generally shows a pronounced exploitative behavior (using a parametrization close to the standard one) [11], while PSO tends to have an explorative performance using a high inertia (as in this study $w = 0.5$) [1]. Similar results can be observed for the Highway scenario, in which PSO obtained the best mean fitness value again. For this instance, PSO also showed the lowest value of standard deviation. This implies a considerable advantage, since it provides our model with a high robustness, which is a crucial issue when designing VANETs. In terms of the minimum fitness, GA and DE obtained the best VDTP configurations for the Highway scenario. The worst configuration was obtained by ES.

Table 3: Final fitness values regarding the Urban and Highway VANET scenarios. Columns 3 contains the mean and standard deviation (Std. Dev.) of the fitness values in 30 independent runs. Columns 4, 5, and 6 show the minimum, median, and maximum values of fitness, respectively

Instance	Algorithm	Mean ± Std. Dev.	Minimum	Median	Maximum
Urban	PSO	**1.6346 ± 0.2899**	0.9077	**1.7809**	**1.8918**
	DE	1.7423 ± 0.3717	**0.7389**	1.8658	2.0228
	GA	1.9086 ± 0.2260	0.8799	1.9731	2.1614
	ES	2.1517 ± 0.1266	1.8862	2.1222	2.4246
	SA	2.7850 ± 0.8718	0.8730	2.1663	3.8025
Highway	PSO	**4.1761 ± 0.2556**	3.3301	4.2513	**4.4554**
	DE	4.6631 ± 0.9328	2.7145	4.2272	7.0531
	GA	4.3805 ± 0.8695	**2.5345**	4.1918	5.8608
	ES	5.7833 ± 0.9705	3.8836	6.1347	6.9421
	SA	4.4246 ± 0.7401	3.1498	**4.0855**	5.7922

In order to provide such comparison with statistical meaning, we have applied a Signed Rank (Wilcoxon) [12] statistical test to the distributions of the aforementioned results. We have used this non-parametric[2] test with confidence level of 95% (*p-value*=0.05), which leads us to ensure that these results are statistically different if they result in *p-value*<0.05. Table 4 contains the resulted *p-value* of applying the Signed Rank test to PSO (the one with the best mean fitness) in comparison with the remaining of algorithms, hence confirming the differences in results. In this table, the symbol ▲ means that PSO is statistically better than the compared algorithm, whereas the symbol △ means that PSO has a better rank than the compared algorithm, but without statistical difference.

As we can observe in Table 4, PSO is statistically better than all compared algorithms for the Urban instance. Only DE shows a *p-value* (0.047) close to 0.05, being lower in any case. Concerning the Highway instance, PSO shows the best rank, not far from GA and SA.

Table 4: PSO versus other algorithms Signed Rank test with confidence level 95% (*p-value*= 0.05)

Algorithm	Urban		Highway	
	Test	*p-value*	Test	*p-value*
DE	▲	0.047	▲	0.001
GA	▲	0.001	△	0.453
ES	▲	0.001	▲	0.001
SA	▲	0.001	△	0.371

A general comparison can be made using the Friedman [10] statistical test by means of which the algorithms are sorted in a ranked list. Table 5 shows the Friedman ranking of the compared algorithms in Urban and Highway

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[2] The distributions violate the condition of normality required to apply parametric tests (Z Kolmogorov-Smirnov = 0.009)

instances (the best ranked algorithm is in the top). For Urban instance, PSO and DE are the best ranked algorithms, but showing SA the last position. Nevertheless, for Highway scenario, SA obtains the best rank, whereas PSO is located in the third position.

Theses statistical results lead us to think that, in spite of the global best behavior of PSO, the different requirements implicit to both instances implies that each algorithm can show quite different results depending on the VANET scenario on which it operates. For example, DE shows a competitive performance in Urban scenario whereas it is the second worst in Highway. The opposite example can be observed in GA and SA which show weak results in Urban but highly competitive ones in Highway. Therefore, the VANET designer can select the optimization model more suited to his/her requirements, and choose the best option for each studied VANET scenario.

Table 5: Friedman Rank test with confidence level 95%

Urban		Highway	
Algorithm	Rank	Algorithm	Rank
PSO	**1.27**	SA	**1.83**
DE	1.83	GA	1.97
GA	3.07	PSO	2.17
ES	4.33	DE	3.67
SA	4.50	ES	4.97

4.2 Performance Analysis

We present now a performance study which basically lies in analyzing the best fitness value, resulted from each function evaluation, during the whole evolution process of a given algorithm. Figure 3 illustrates the graphs of the best fitness values (communication cost) obtained through the median execution in Urban and Highway instances.

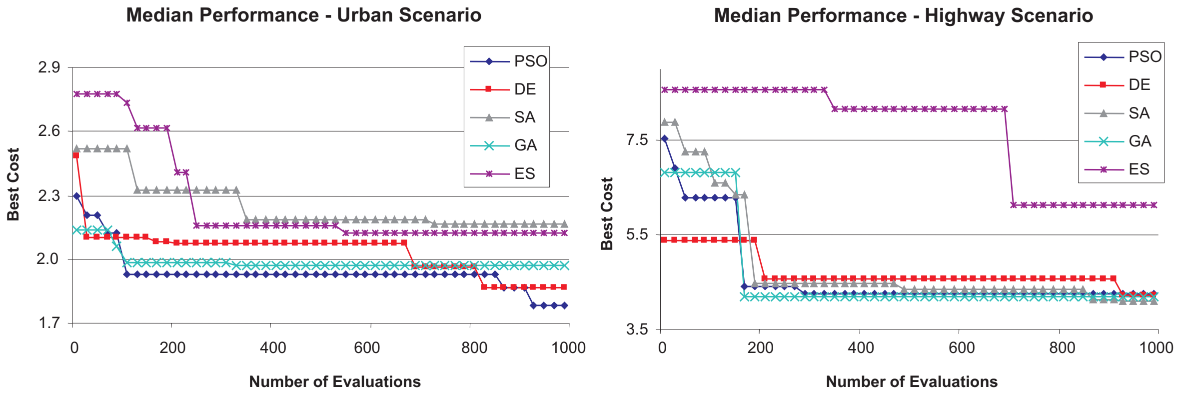

Figure 3: Median fitness performance in Urban and Highway scenarios.

We can observe in both graphics that PSO and DE tend to converge in the same range of solution evaluations, although they could improved their fitness even in the final steps of the evolution process. GA shows a similar trend as the former ones but it is subjected to an early stagnation.

Finally, the different behaviors observed in ES, and specifically in SA, for Urban and Highway instances confirm us the high dependency of such algorithms to each different VANET instance (they are not robust in this application).

Concerning the mean run time that each algorithm spent in the experiments, Table 6 shows both the mean time in which the best solution was found T_{best}, and the global mean run time T_{run} for Urban and Highway scenarios. In general, SA shows the shortest times to find the best solution for the two VANET instances. We suspect that despite its temperature mechanism, SA quickly falls in local optima hence obtaining weak results in Urban scenario. Nevertheless, this behavior can be an advantage for Highway scenario where SA obtained accurate solutions with a fast performance. As expected in PSO and DE, they spent closed executions times for the two VANET instances since they have similar internal operations. This resemblance in time consumption was also registered in the two evolutionary algorithms, GA and ES.

As a summary, the algorithms use between 9.00E+03 and 4.76E+03 seconds for the Urban scenario (150 and 80 minutes, respectively), and between 2.19E+03 and 8.45E+02 seconds for Highway scenario (60 and 23 minutes, respectively). This relative low effort in the protocol design is completely justified by the subsequent benefits obtained in the global data transmission time and loss of packets once the VANET is physically deployed as observed in the following analysis.

Table 6: Mean execution time (seconds) per independent run of each algorithm for Urban and Highway scenarios

Instance	Algorithm	T_{best} (seconds)	T_{run} (seconds)
Urban	PSO	4.68E+03	7.95E+03
	DE	4.37E+03	7.12E+03
	GA	3.48E+03	6.68E+03
	ES	5.46E+03	9.00E+03
	SA	**2.18E+03**	**4.76E+03**
Highway	PSO	1.39E+03	2.19E+03
	DE	9.82E+02	2.10E+03
	GA	8.83E+02	1.56E+03
	ES	9.84E+02	1.47E+03
	SA	**5.85E+02**	**8.45E+02**

4.3 QoS Analysis

Finally, from the point of view of the worked VDTP configurations (solutions), we analyze the results in terms of the QoS indicators considered here: the transmission time, the number of lost packets, and the amount of data transferred induced in the designed VANET. In this sense, Table 7 shows the results after simulating the best solutions found by the studied algorithms. In addition, the last row of this table contains the results of simulating the configuration of VDTP that has been used in the scope of the CARLINK project (real word results with actual cars).

Table 7: VDTP configurations and simulation output values for the optimal fitness achieved (in the median execution) by all studied algorithms. The last row contains the results obtained in the scope of the CARLINK project

		VDTP Configuration			Simulation Results		
Instance	Algorithm	Chunk Size (Bytes)	Retrans. Time (seconds)	Attempts	Trans. Time (seconds)	Lost Packets	Data Transferred (kBytes)
Urban	PSO	41,358	10.00	3	**3.41**	**0.27**	1,024
	DE	28,278	6.00	9	3.59	0.63	1,024
	GA	31,196	3.83	9	3.61	**0.27**	1,024
	ES	23,433	10.00	8	3.50	**0.27**	1,024
	SA	19,756	6.43	3	4.22	0.36	1,024
	Human Experts	25,600	8.00	8	4.24	1.60	1,024
Highway	PSO	29,257	6.42	9	**24.67**	3.18	1,024
	DE	19,810	6.91	8	27.66	3.45	1,024
	GA	34,542	9.54	10	26.96	2.72	1,024
	ES	38,490	8.15	12	33.99	3.36	1,024
	SA	32,002	8.21	4	25.43	**2.54**	1,024
	Human Experts	25,600	10.00	10	33.08	3.27	1,024

For the Urban VANET, the VDTP configuration obtained by PSO (Chunk_Size=41,358 Bytes, Retransmission_Time=10 s, and number of Attempts=3) achieves the best performance in terms of transmission time and mean number of lost packets. Specifically, in comparison with the human experts configuration of CARLINK, PSO obtains a reduction in the transmission time of 0.83 seconds (19.5%) registering also a lower number of lost packets.

Nevertheless, it is in the Highway scenario were PSO obtains the higher time reduction of 8.41 seconds (25%) regarding the human experts configuration (from 33.08 s to 24.67 s). We must notice that, in spite of achieving the PSO a higher reduction in the transmission time than SA and GA, the fact of losing more packets (3.18 in PSO, 2.71 in GA and 2.54 in SA) in the global transference leads SA and GA to calculate a better fitness value (as shown in Table 3).

A final analysis can be done concerning one main QoS indicator: the *effective transmission data rate (throughput)*[3] achieved. As we can observe in Figure 4, the VDTP configuration obtained by practically all algorithms in the two VANET scenarios obtained higher effective data rates than the human configured VDTP. Specifically, PSO achieves the highest effective data rate (300.29 kBytes/s in Urban and 41.54 kBytes/s in Highway). This clearly claims for the utilization of these automatic algorithms to help human designers. We again remind that the actual correction of effective data rates between cars are in the order of tens of kBytes/s, so our savings (58.79 kBytes/s in Urban and 10.5 kBytes/s in Highway) are truly meaningful in current real applications such as safety, traffic control, and weather predictions.

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[3] In our fitness function, instead of using the *throughput* as extra control parameter, we have broken down it into the transmission time and data transferred directly in order to count them separately and enhance the search process of the algorithms.

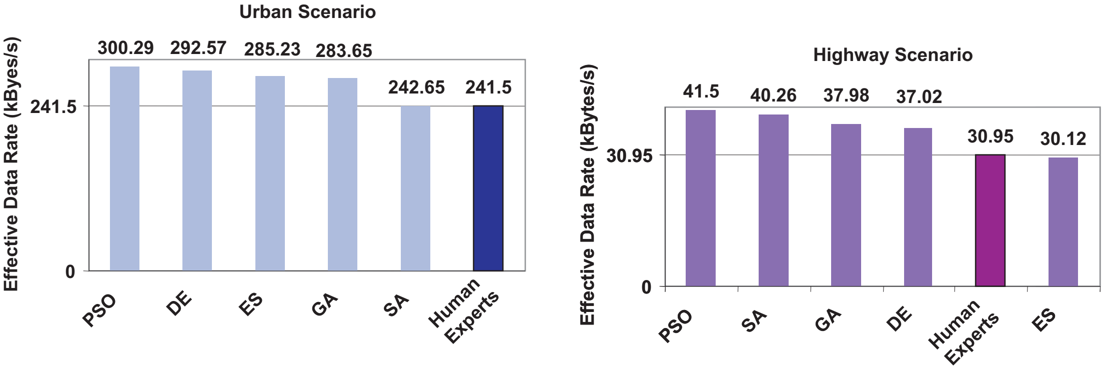

Figure 4: Effective transmission data rates (throughput) in Kbps achieved during the simulations of the final VDTP configurations in comparison with values given by human expert configurations of CARLINK consortium.

5 Conclusions

In this paper, we tackle the optimal File Transfer protocol Configuration (FTC) in VANETs by means of five popular metaheuristic algorithms. For this, we need a complex system accounting for a flexible simulation structure targeted for optimizing the transmission time, the number of lost packets, and the amount of data transferred in simulated and also realistic VANET scenarios.

The experiments, using *ns-2* (well-known VANET simulator), reveal that all algorithms are capable of efficiently solve the optimum FTC problem. In the comparisons, PSO performs statistically better than all algorithms in Urban and statistically better than DE and ES in Highway. In addition, GA and SA show a competitive performance in Highway. The scalability analysis shows that GA improves with the network size, whereas DE decreases its performance with large VANET instances. PSO keeps the best result even for larger instances.

From the point of view of its real world utilization, PSO can reduce 19% of the transmission time in Urban and 25.43% in Highway with regards to human experts configuration of CARLINK, while transmitting the same amount of data (1,024 kBytes). The highest effective data rates obtained by PSO (of 300.39 kBytes/s in comparison with 241.5 kBytes/s of human experts) and DE (292.57 kBytes/s) in Urban lead us to advise the final use of our automatic design algorithms.

As a matter of further work we are presently extending our benchmark with new VANET realistic instances (e.g., complete cities and highway knots). In addition, we are planning to define new optimized configuration schemes for other communication protocols such as: UDP, DSR, etc. which should efficiently support actual VANET design.

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