A Parallel Hybrid Genetic Algorithm on Cloud Computing for the Vehicle Routing Problem with Time Windows

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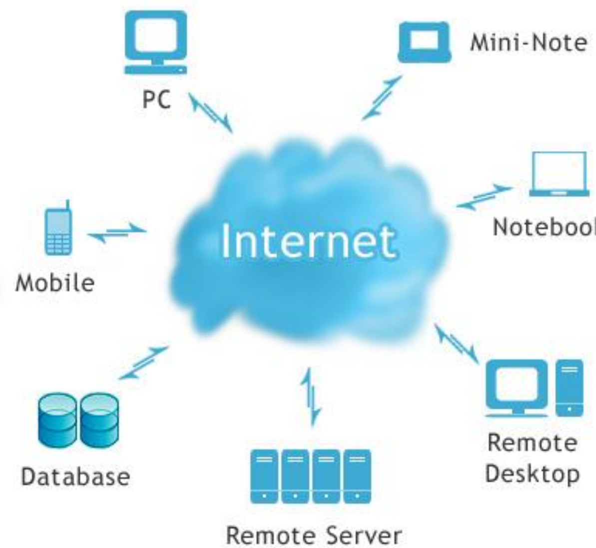
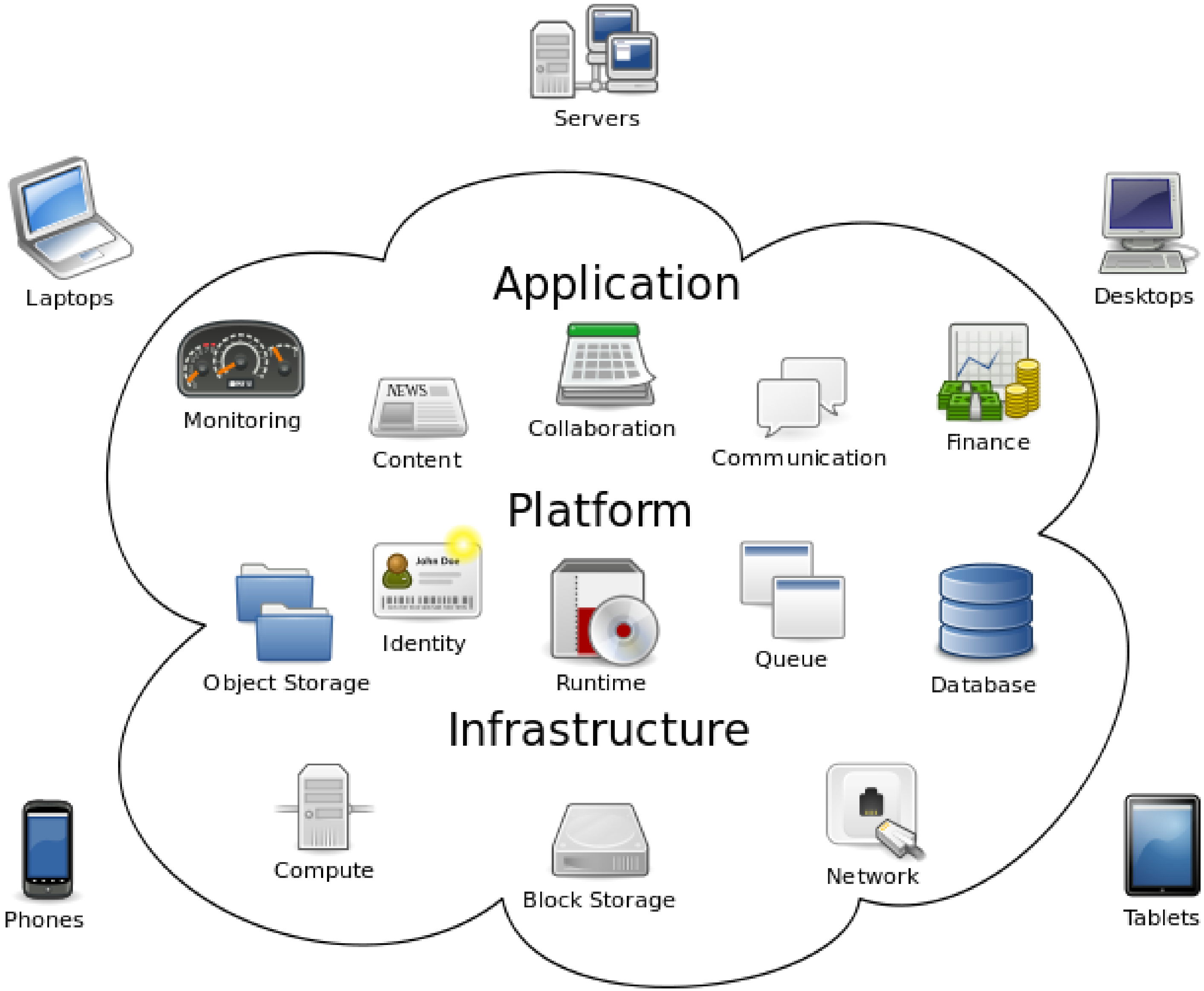
Cloud Computing

- Cloud computing basically relates to the use of computational resources as a service, rather than a product.

- The most common service models are: Software as a Service, Platform as a Service, Network as a Service, Infrastructure as a Service.





Cloud Computing

Evolutionary Computation in the Cloud Era

- Massively parallel data processing environment is becoming popular in cloud computing.
- Cloud systems may even offer tens of thousands of virtual machines, terabytes of memories and exabytes of storages.
- Using this IaaS to tackle large scale optimization problems have gathered momentum on both theoretical and empirical studies.

Evolutionary Computation in the Cloud Era

- The idea is to scale up Evolutionary Computation (EC) algorithms to solve large scale global optimization (LSGO) problems.
- LSGO are real-world problems and involve a large number of decision variables. Example: VRPTW.
- The performance of EC for handling LSGO problems still remains an open question.

Vehicle Routing Problem with Time Windows

- The VRPTW is a generalization of VRP, which is also a generalization of the classic TSP.

- Problem definitions:
  - Determine a set of vehicle routes of minimum total cost.
  - Each vehicle starts and ends at the depot (warehouse).
  - Each customer is visited exactly once.
  - The total demand handled by any vehicle does not exceed its capacity.
  - Customers impose an earliest arrival time and a latest arrival time constraints.
  - Homogeneous fleet.

Vehicle Routing Problem with Time Windows

- From a computational complexity view, VRP are difficult to handle.
- Since the VRP is NP-hard, by restriction, the VRPTW is NP-hard.
- Thus obtaining optimal solutions by the use of exact methods requires unacceptable computational time.
- Heuristic methods are by far more attractive.

Evolutionary Computation applied to VRPTW

- Genetic Sectoring (Thangiah, 1993):
  - method was used to find the set of clusters that reduced the travel time of the vehicles .
- GENEROUS (Potvin and Bengio, 1993):
  - exploits the general methodology used in GA by substituting specific VRP operators .
- Multi-Parametric (1+1)-ES (Mester, 2006):
  - combines ES with local search methods as “adaptative variable neighborhood” and “dichotomous route combinations”.
- C. Prins, “A simple and effective evolutionary algorithm for the vehicle routing problem,” *Computers & Operations Research*, vol. 31, no. 12, pp. 1985 – 2002, 2004.

The Parallel Hybrid Model

- To exploit the maximum resource capabilities of cloud computation, the proposed hybrid GA is parallelized, divided into many smaller and asynchronous tasks.

- The idea behind the chosing of a steady-state GA for this work is to avoid the concept of generation.

- The waiting for the next generation can be the bottleneck of the gerational approach.

- In a steady-state GA, newly generated children can participate in reproduction as soon as they enter the current population.

The Parallel Hybrid Model

- All solutions are coded to a permutation *S* of *n* customers without route delimiters.
- This simple encoding is appealing because there obviously exists one optimal sequence.
- Classical well-known operators for solving TSP can be applied without complications.

The Parallel Hybrid Model

- For constructing the initial population, there are three different methods:

1. Completely random sequence;
2. Construction process proposed by Russell, 1996;
3. Push-Forward Insertion Heuristic (PFIH) detailed on Thangiah, 1999, proposed by Solomon, 1987;

- **Note:** methods 2 and 3 have being randomized to avoid equal individuals in the initial population.

The Parallel Hybrid Model

- The chromosomes are selected for mating by the rules of a binary tournament.

- The chromosome codification allows the application of classical permutation crossover operators, like the order crossover (OX).

- There are two mutation procedures.
  1. The first mutation is a Local Search (LS).
  2. The second mutation is a simple elementary perturbation over the child.

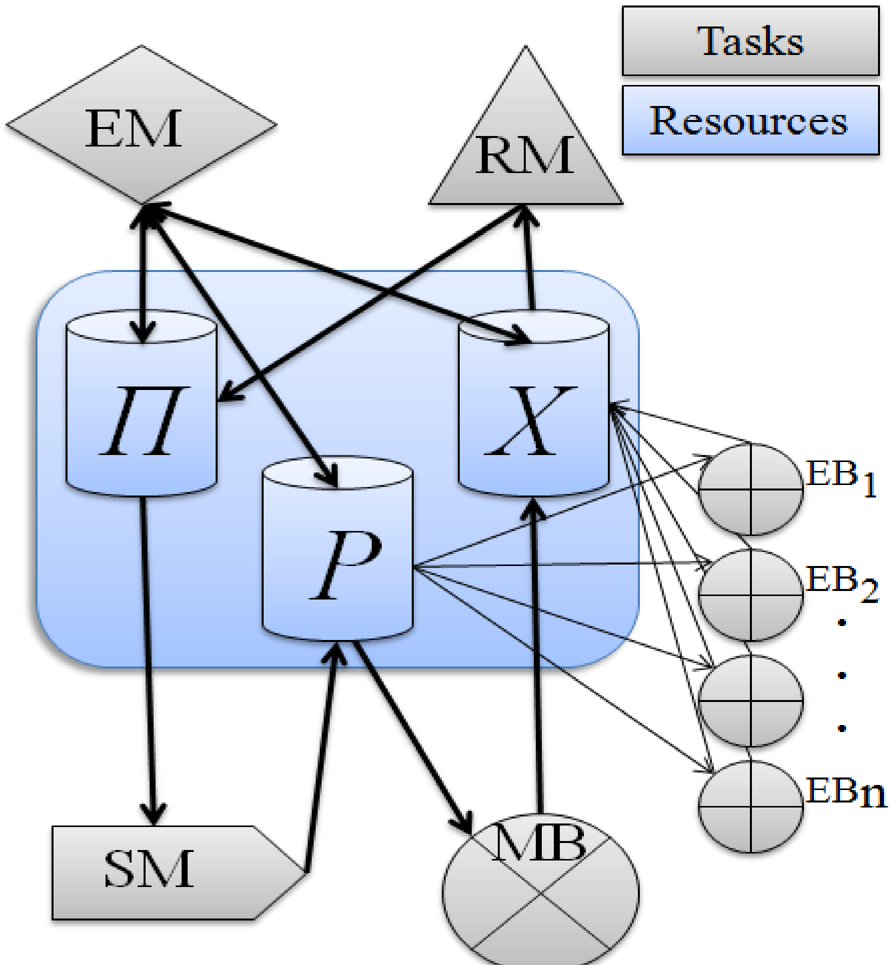
The Parallel Hybrid Model

- The basic genetic operators that compose the PHGA were divided into parallel procedures, named Tasks.

- Individuals arrays (i.e. population) are considered as shared resources:

1. **Π**: main population array.
2. **P**: parents array, selected for breeding, but not submitted to OX crossover yet.
3. **X**: children array, produced by reproduction, but not submitted to replacement yet

The Parallel Hybrid Model



- **EM**: Execution Manager
- **SM**: Selection Manager
- **MB**: Massive Breeder
- **EB**: Exploit Beeder
- **RM**: Replacement Manager

- **Π**: Population resource.
- **P**: Parents resource
- **X**: Children resource.

Results

- We set the population size $\sigma = 30$.
- The number of EB tasks $n_{eb} = 11$.
- The number of all other tasks was set to 1.
- The maximum number of breeds $m_{nb} = 30000$.
- The maximum number of breeds without improving the best solution $m_{wi} = 10000$.
- The maximum P size to $\sigma_P = 2n_{eb}$
- The maximum X size to $\sigma_X = \sigma$.

Results

TABLE I. PHGA RESULTS FOR SOLOMON'S [3] 100 CUSTOMERS C-TYPE INSTANCES

Problem	Best-Known		PHGA		Problem	Best-Known		PHGA	
	K	TD	K	TD		K	TD	K	TD
C101	10	**828.94**	10	**828.94**	C201	3	**591.56**	3	**591.56**
C102	10	**828.94**	10	853.61	C202	3	**591.56**	3	**591.56**
C103	10	**828.06**	11	974.54	C203	3	**591.17**	3	605.44
C104	10	**824.78**	11	1050.17	C204	3	**590.60**	4	730.72
C105	10	**828.94**	10	**828.94**	C205	3	**588.88**	4	618.57
C106	10	**828.94**	10	**828.94**	C206	3	**588.49**	3	**588.49**
C107	10	**828.94**	10	**828.94**	C207	3	**588.29**	3	**588.29**
C108	10	**828.94**	10	829.69	C208	3	**588.32**	3	588.49
C109	10	**828.94**	11	898.45					

Results

- The current parameters set allows, on average, the execution of 30 LS procedures for EB's tasks and 3 LS for MB task.
- In some sense the MB imposes the rhythm of the search process in PHGA due to the chosen parameters, such as the stopping criteria and mutation rates.
- Usually, when the MB finishes its last breed procedure, the EB's tasks are often performing their third or fourth LS.

Conclusions

- This paper proposes a different PHGA approach for VRPTW.
- The algorithm was developed to be executed on cloud computing web services providing an online application for real world problems.
- A new parallel scheme was proposed with shared resources of candidate solutions accessed by many asynchronous tasks.
- The algorithm was tested over the classical well-known benchmark and presented excellent results for some instances in a low computational time.

Obrigado!

André Siqueira Ruela (et al.)