Genetic Algorithm-based Optimization of Service Composition and Deployment

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SIPE08 Workshop

Overview

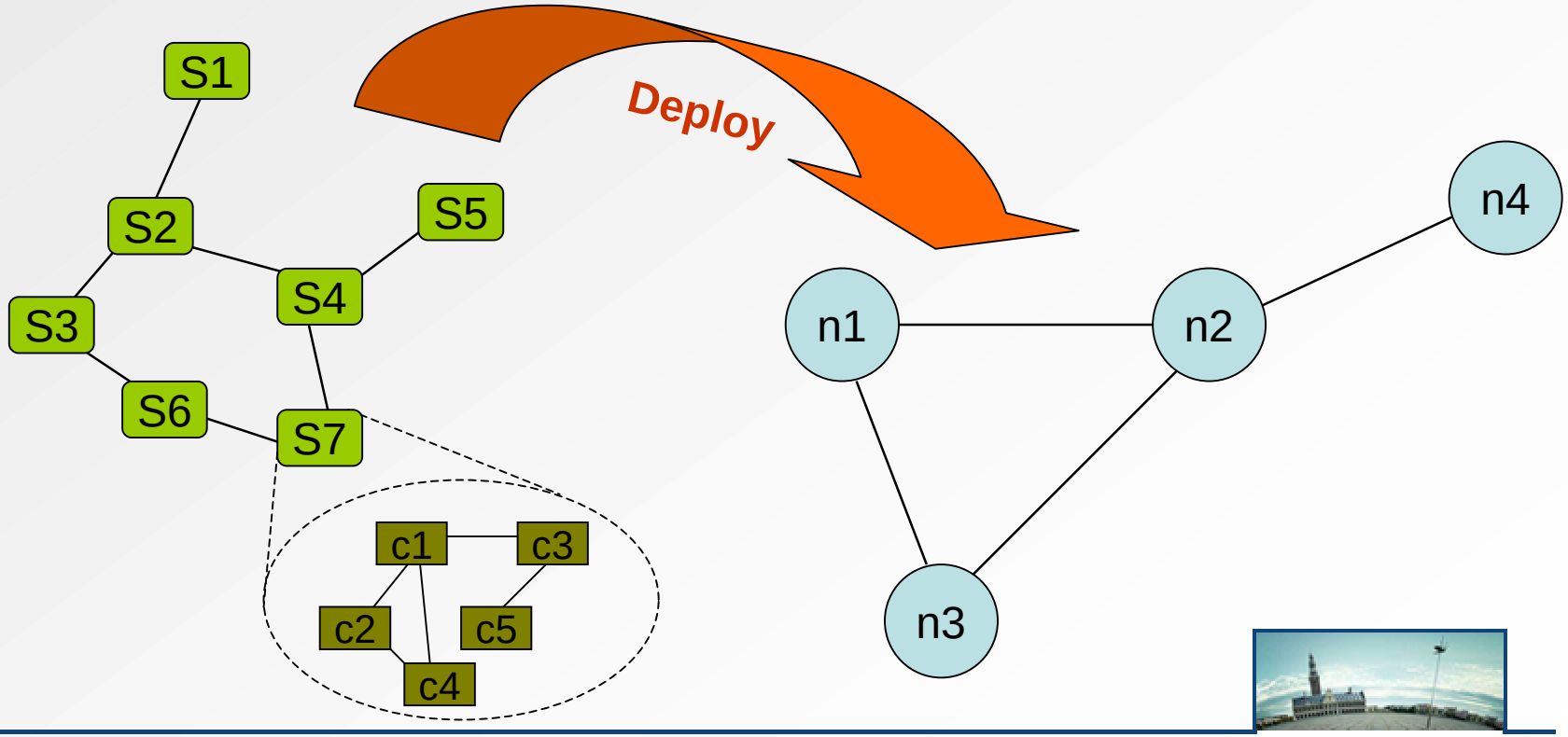
1. Introduction
2. Requirements and motivating application
3. Genetic Algorithms
4. Service composition and deployment
5. Conclusions

Introduction

- Mobile systems
  - Sense and react to context information
  - To adapt to changing user needs and availability of resources
- Architecture-centric approach
- Services implemented as a collection of component types
- Evaluation of all possible service variants is not feasible
  - Scalable approach needed

Introduction

- Deploy a composition of abstract services
- as concrete services
- onto a set of connected nodes



Requirements

- Self-organization of service deployment configuration through learning
- Deal with scalability in number of variants
- Limited resources on mobile devices
- Limited or costly bandwidth situations
- Distribute adaptation reasoning among nodes
- Models include QoS properties of software and hardware

Motivating application

- *InstantSocial*
- Distributed platform for sharing content, gaming, ...
- Formed by devices joining federation ad-hoc
- Perceived by users as ordinary site
- Services are scattered across nearby devices and integrated by distributed application server
- Server consists of dynamic composition of services (also replicated)
- Network configuration evolves: services are redeployed or migrated to other devices

Genetic Algorithms

- GA is part of evolutionary computing
  - rapidly growing area of artificial intelligence
  - inspired by Darwin's evolution theory
    - solution to a problem evolves towards better fitness
- Evolutionary Computing
  - introduced in the 1960s by I. **Rechenberg**
    - in "***Evolution strategies***"
- Genetic Algorithms
  - invented by John **Holland**
    - "***Adaption in Natural and Artificial Systems***" (1975)
  - in 1992 John **Koza** called his method:
    - "***genetic programming***" (GP)

Biological Background

- Chromosomes:
  - are present in each cell of living organisms
  - consist of genes, which are blocks of DNA strings
    - presenting a model of the whole organism
  - **genome** is a complete set of organism's chromosomes
- Reproduction:
  - recombination or **crossover**:
    - a whole new chromosome is formed from parent genes
  - **mutation**:
    - elements of DNA are slightly changed: "copy-errors"
  - **fitness**:
    - measured by success of the organism in its life

Encoding

Encoding of a chromosome

- usually binary or integer string
- each element represents a characteristic of the solution
  - Chromosome 1: 1101100100110110
  - Chromosome 2: 1001111000011110
  - ...
- e.g. knapsack problem as binary encoding
  - 1 on position *i* : object *i* in knapsack
  - 0 on position *i* : object *i* not in knapsack

Search Space

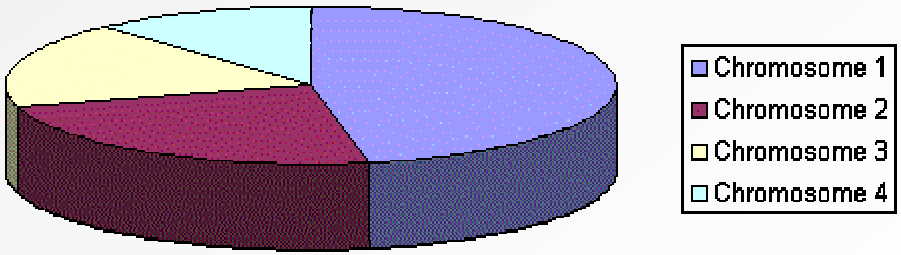
- Goal:
  - “Find the solution that is best among other solutions”
- Search space:
  - the space of all feasible solutions
  - each solution is marked by its “fitness” for the problem
- NP-hard problems:
  - not solvable in “polynomial time”
  - where to start looking for a solution?
  - approximation with polynomial algorithm:
    - "guess" the solution
      - by some nondeterministic algorithm
    - and then check it (calculate feasibility & fitness)

Genetic Algorithm

1. **[Start]** Generate random population of *n* chromosomes
2. **[Fitness]** Evaluate the fitness *f(x)* of each chromosome *x*
3. **[New population]** Create a new population
   repeat the following steps until the new population is complete:
   1. **[Selection]** Select two parent chromosomes from a population according to their fitness (the better fitness, the bigger chance to be selected)
   2. **[Crossover]** With a crossover probability cross over the parents to form a new offspring (children).
      If no crossover was performed, offspring is an exact copy of parents.
   3. **[Mutation]** With a mutation probability mutate new offspring at each locus (locus = position in chromosome).
   4. **[Accepting]** Place new offspring in a new population
4. **[Replace]** Use new generated population for a further run of algorithm
5. **[Test]** If the end condition is satisfied, **stop**, and return the best solution in current population
6. **[Loop]** Go to step **2**

GA parameters

- Population size:
  - small: exploration of search space is limited
  - large: algorithm slows down
- Elitism:
  - at least one best solution is copied without changes,
  - so the best solution found can survive to end of run.
- Parent selection:
  - probability based on fitness of chromosome
    - e.g. roulette wheel selection:



Crossover

- Goal:
  - selecting genes from parent chromosomes
  - creating a new offspring
- Random crossover point:
  - Chromosome 1 : 11011 | 00100110110
  - Chromosome 2 : 10011 | 11000011110
  - Offspring 1 : 11011 | 11000011110
  - Offspring 2 : 10011 | 00100110110
- Crossover probability:
  - offspring population fraction generated by crossover
    - e.g.: 70% crossover and 30% copies of parents

Mutation

- Goal:
  - prevents all solutions from falling into a local optimum
- Random changes to the new offspring:
  - Original offspring 1: 1101111000011110
  - Original offspring 2: 1101100100110110
  - Mutated offspring 1: 1100111000011110
  - Mutated offspring 2: 1101101100110100
- Mutation probability:
  - fraction of a chromosome that is mutated

Two-Step Solution

1. Service Composition Step
   - which concrete services can we allocate on each node?
     - given the abstract services that we want to use

2. Service Allocation Step
   - which nodes do we deploy the concrete services on?
     - taking into account:
       - communication costs
       - distance to feasible composite deployment

Service composition

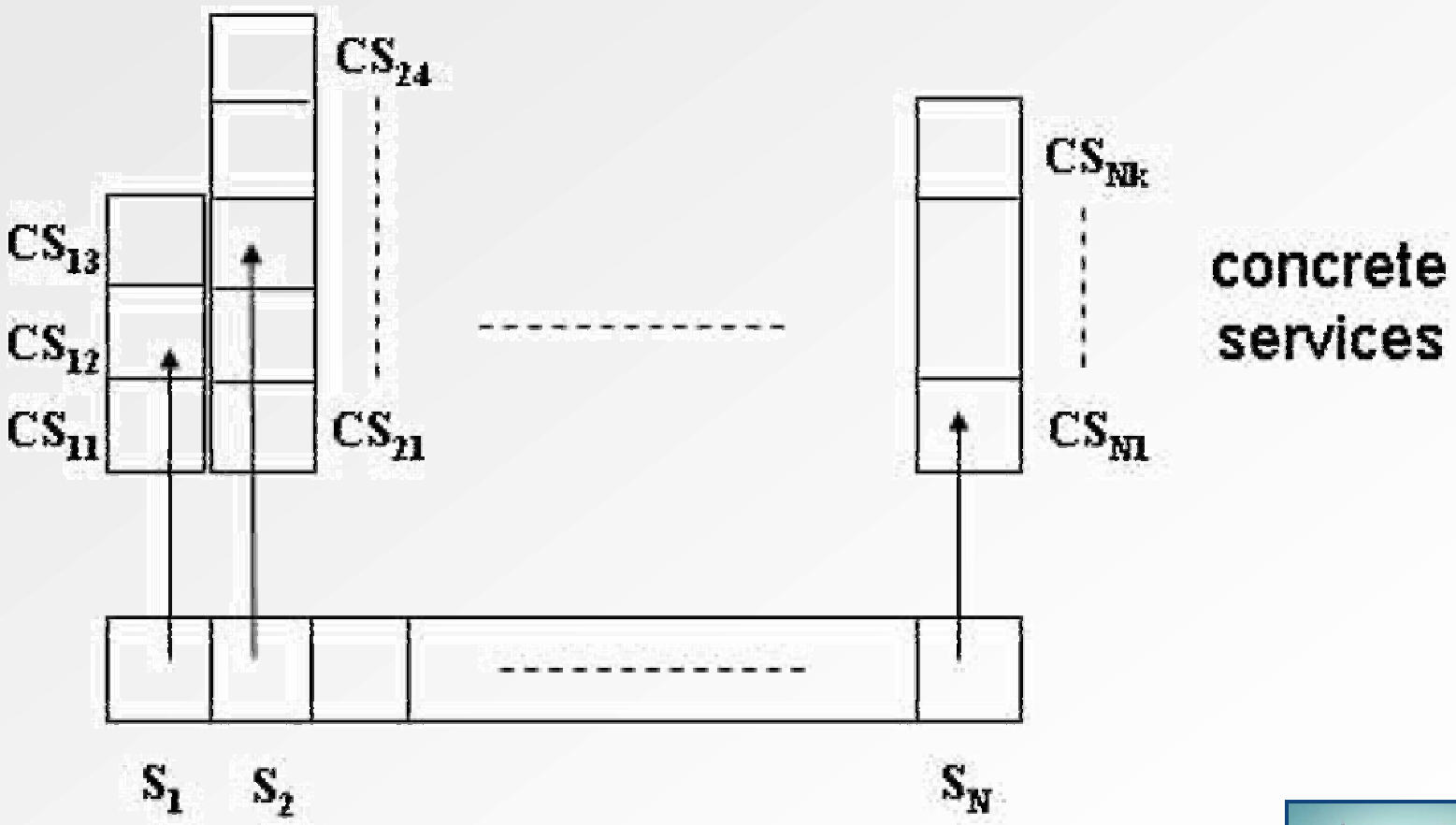
- Service composition
  - composed of abstract services
- Abstract Service
  - represents a service's functionality
  - has concrete services implementing the service
- Concrete Services
  - have their own QoS description
  - are implemented as set of components

Service Composition

- Perform a service selection step at each node
  - Calculate the optimal fitness of Service *i* on each node *i*
    - $F(g_{ij}) = F(S_{ij})$
  - not regarding communication cost
    - Bandwidth, latencies, remote deployment overhead, etc.
- Goal:
  - determine a set of concrete services
  - to be bound to the abstract services
- Requirements:
  1. QoS constraints in SLA need to be met
  2. other QoS parameters need to be optimized

Choosing Concrete Services using GA

Chromosome encoding:



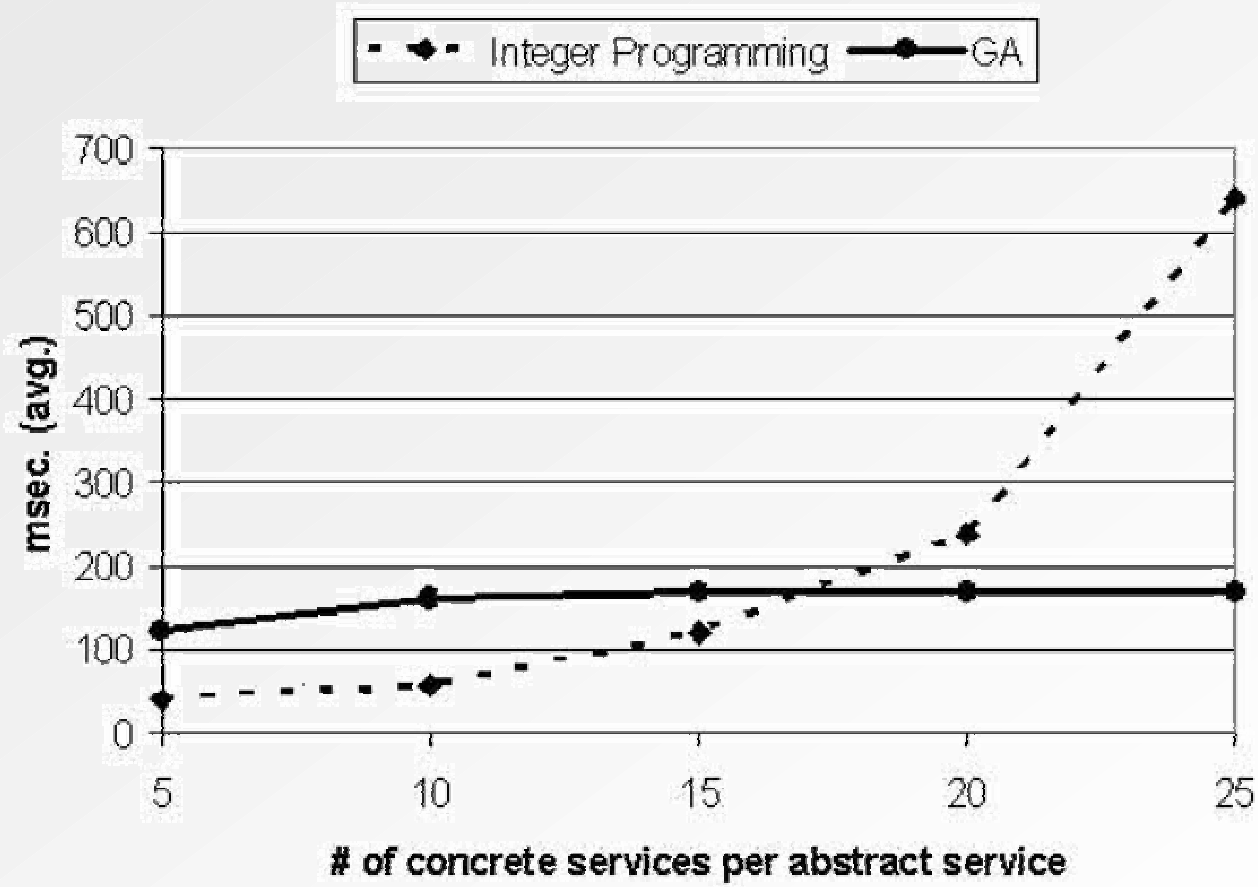
Fitness Function

- $F(g_{ij}) = Q(g_{ij}) – D(g_{ij})$

- $Q(g_{ij})$: weighted function of QoS parameters
- $Q(g_{ij}) = (w_1.Avail + w_2.Rel) / (w_3.Cost + w_4.Resp)$

- $D(g_{ij})$: distance from constraint satisfaction
- Constraints for the service variant to be able to run on node j

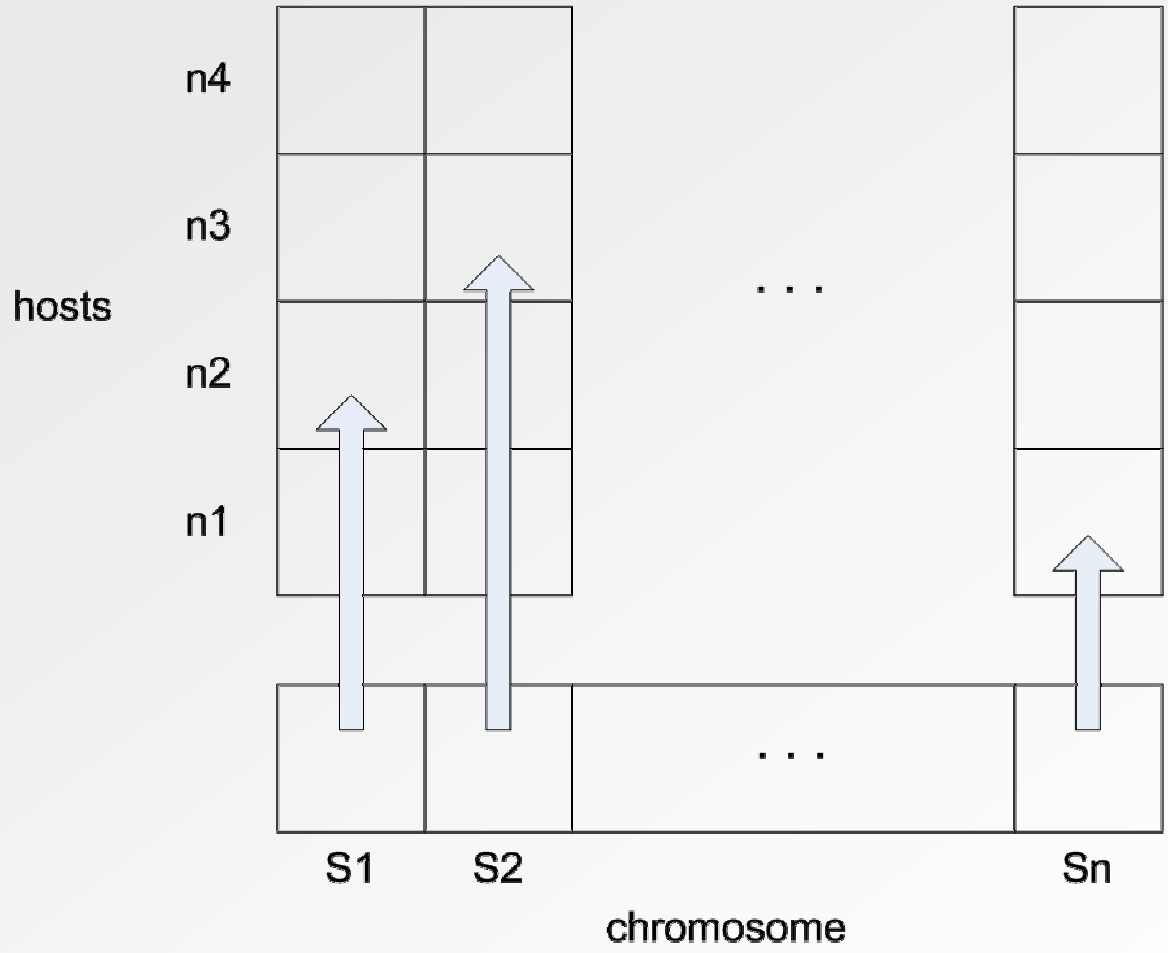
Comparison with Integer Programming



Step 2: Service Allocation Step

- Perform a service allocation step
  - Choose the node to allocate each service to
    - given $F(S_{ij})$
  - taking into account
    - communication costs
    - distance to feasible composite deployment

Step 2: Chromosome Encoding



Step 2: Fitness Function

- Fitness of allocation:

  $F(G) = \text{sum}(F(S_{ij})) - C(G) - D'(G)$

  - $F(S_{ij})$ = fitness of service deployment on each node
  - $C(G)$ = fitness of communication overhead
    - cost for bandwidth, latencies, etc.
  - $D'(G)$ = distance from feasible solution
    - penalty for QoS constraints that are not met

- Assumption:
  - $F(S_{ln}) + F(S_{kn}) = F(S_{ln}, S_{kn})$ *if* (S_{ln}, S_{kn}) is feasible
    - with (S_{ln}, S_{kn}) the composite deployment of S_l and S_k on host n
    - with $F(S_{ln}, S_{kn})$ the composite fitness of (S_{ln}, S_{kn})

Conclusions

- Scalable approach to compose and deploy services in a distributed way
- Future work: Implementation/evaluation in the middleware

Thank you

Questions?

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