QoSCOM präsentiert

80. K-STAMMTISCH

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Metaheuristics

Ways to solve complex problems

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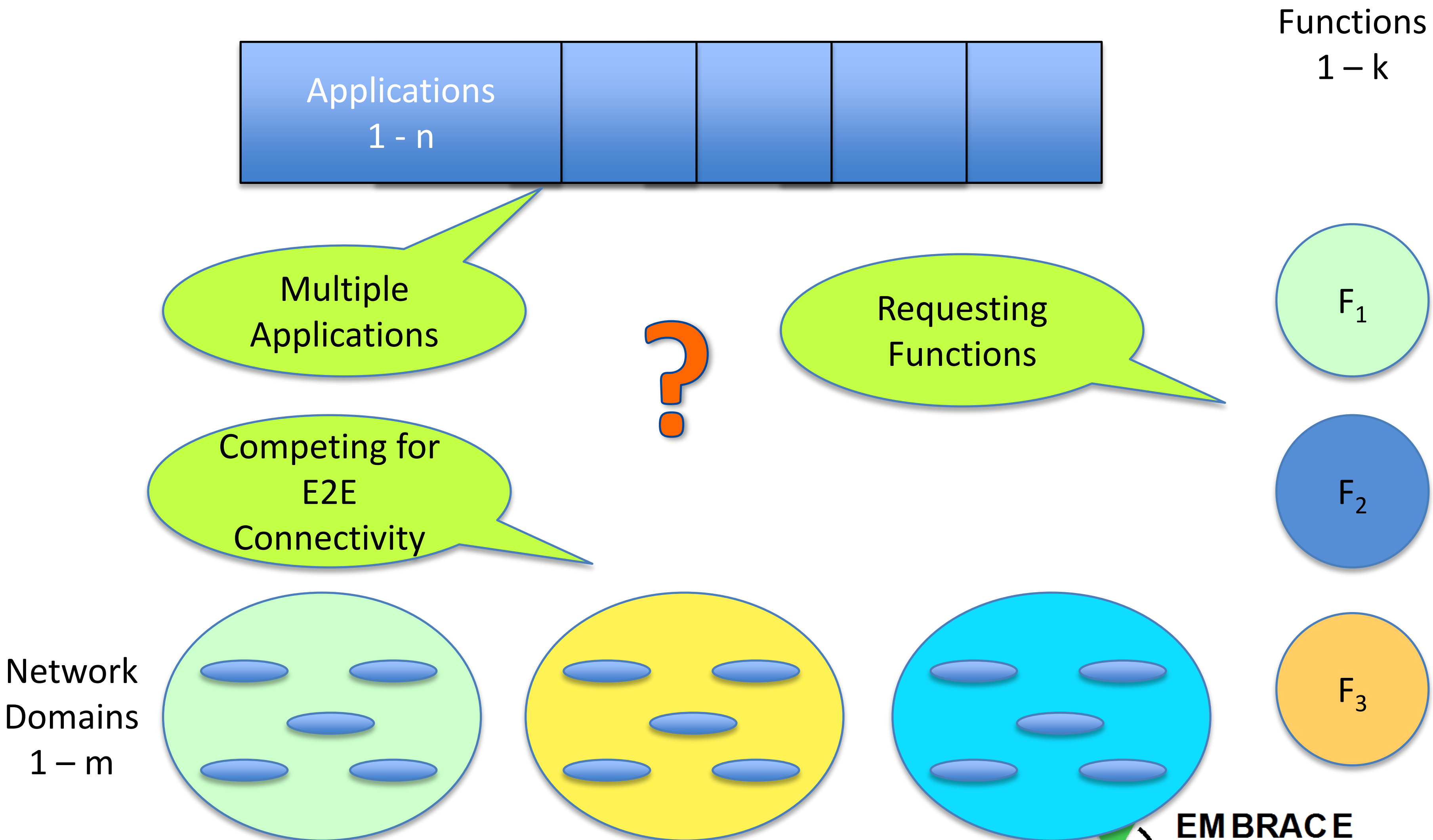
The Challenge (Applications)



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Optimization Challenge

SINGLE APPLICATION

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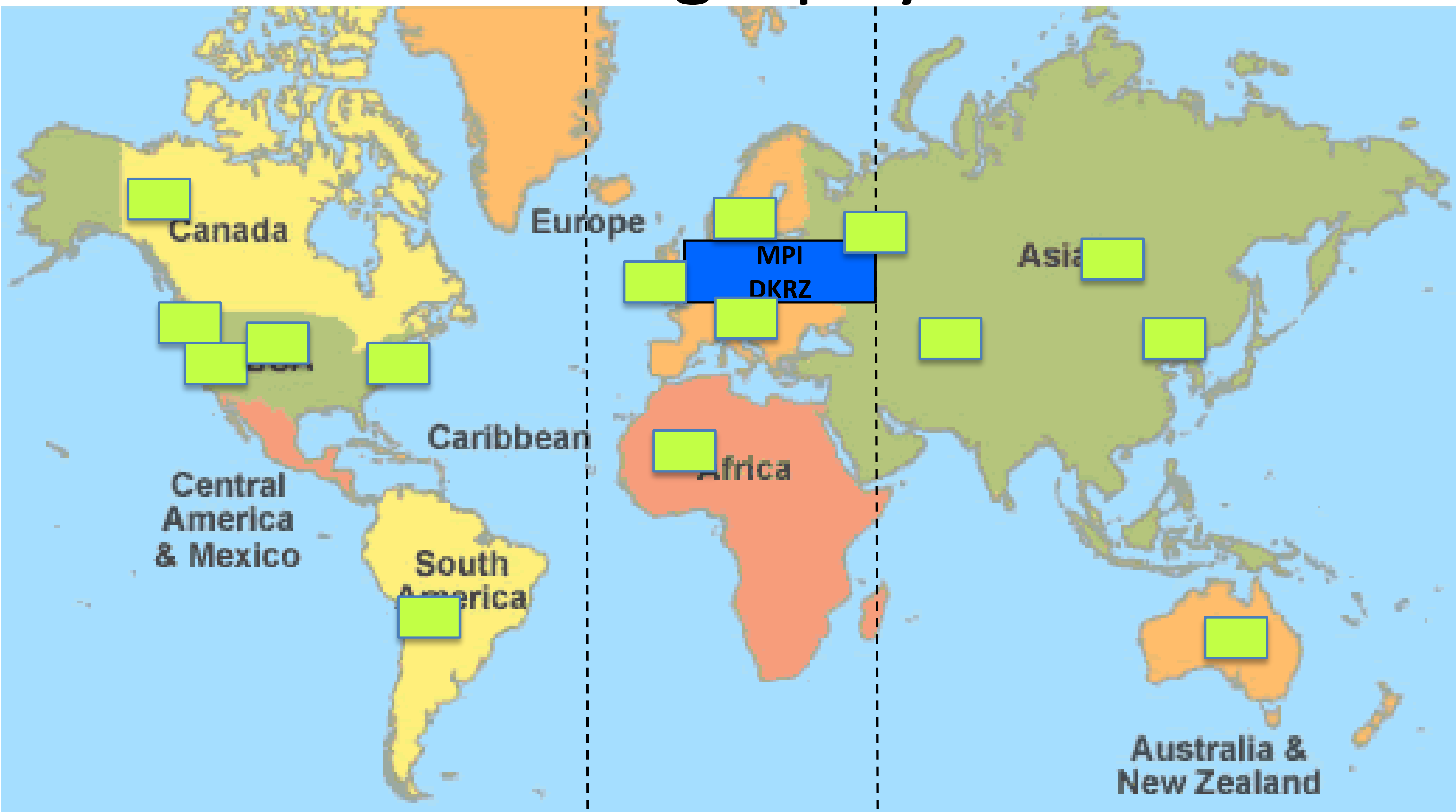
Single Application Case

- No competition for resources
  - It is possible to allocate optimal storage
    - both intermediate
    - and permanent
  - It is possible to allocate optimal compute capacity
    - At a designated instance in time
    - For a required period of time
  - It is possible to allocate required network resources
    - Taking into account bandwidth
    - and other QoS parameters

In this case a global optimum is achievable

Single Application Climate Research Geography



The Americas **Europe** **Asia**

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Single Application Climate Research Resources

- Each green rectangle depicts a research site
- At each of the research sites there is availability of
  - Intermediate storage
  - Compute capacity
  - Possibly virtualized network functions required during runtime of an evaluation
- Final (result) storage is determined in advance

Single Application Climate Research Optimization

- Determine evaluation sequence
- Accordingly determine for given instances and periods of time
  - Virtualized services required
  - Intermediate storage required
  - Compute capacity required
- Check availability of required resources
- Check reachability of required resources
- Design optimal solution by e.g. iteration (Global Optimum)

Single Application Climate Research Prerequisites for Global Optimum

- No competion for any type of resource
  - Storage
  - Compute capacity
  - Virtualized services
- Guaranteed network availabilty

In this case a global optimum is achievable!
But is thr process efficient?

Optimization Challenge

MULTIPLE APPLICATIONS

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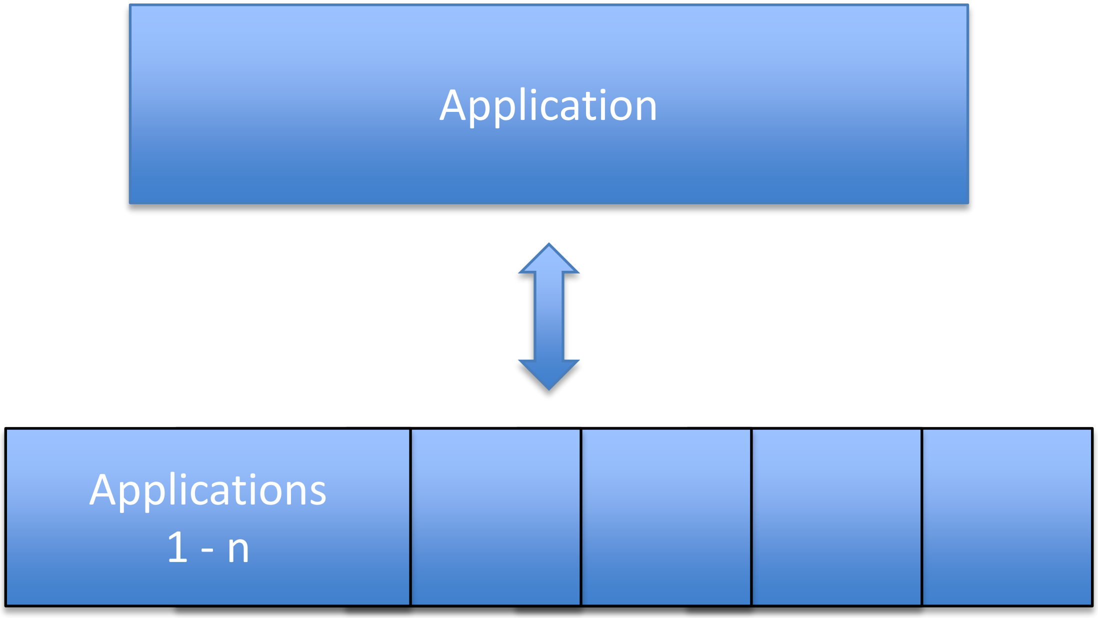
Multiple, Competing Applications



Vector of Requirements for a single Application

$$X = \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \\ x_5 \end{bmatrix}$$

- Precise Requirements, i.e. per element one value possible
- Variable Requirements, i.e. for at least one element an interval of values possible
- Negotiable Requirements, i.e.for at least one element runtime negotiations possible

Requirements Multiple Applications

$$X_1 = \begin{bmatrix} x_{11} \\ x_{12} \\ x_{13} \\ x_{14} \\ x_{15} \end{bmatrix} \qquad X_2 = \begin{bmatrix} x_{21} \\ x_{22} \\ x_{23} \\ x_{24} \\ x_{25} \end{bmatrix} \qquad X_3 = \begin{bmatrix} x_{31} \\ x_{32} \\ x_{33} \\ x_{34} \\ x_{35} \end{bmatrix}$$

Multiple Applications

- Some requests will be competing for resources
- Re e
- All ly ch
- For glo
  - timely fashion
  - There will be a set of good solutions, the best solution can be an element of this set

We will have to look for Algorithms that provide us with means to find a

set of good solutions

Finding suboptimal solutions

HEURISTICS AND METAHEURISTICS

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Metaheuristics

- Explanation of Heuristics/Metaheuristics
  - Sufficient solution of given problem to be achieved
  - Opposed to formal approach to find global optimum
  - Opposed to iterative approach
  - In both cases:
    - Less computational effort
    - Less time to achieve result
- Heuristics are for a special problem, Metaheuristics are the generalized form

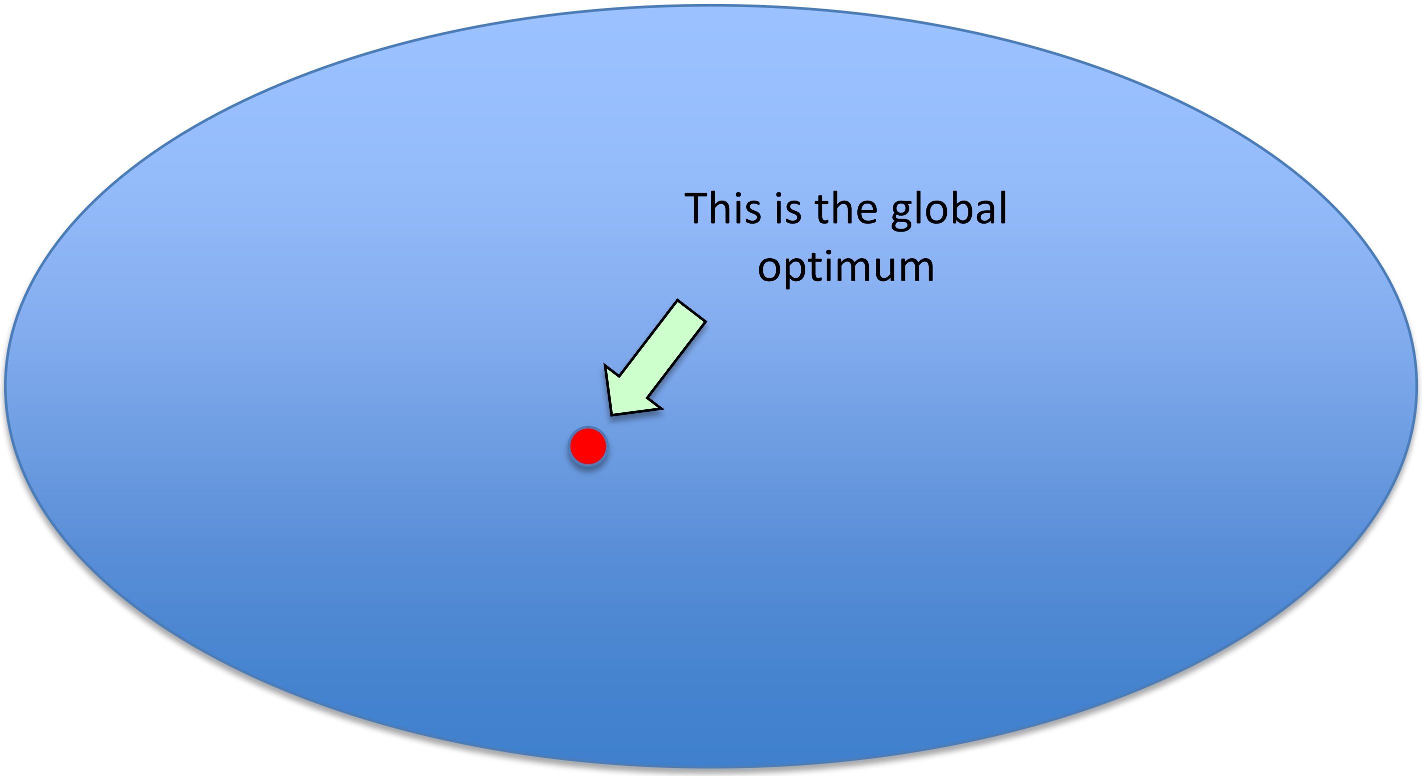
How does it work
Search Space Initialsation

- Two possible ways:
  - We have a solution that is not satisfactory
    - We then start changing parameters until we have a better solution
    - This is not done until we have the best solution, we have time- and resourceconstraints.
  - We have no initial solution
    - We then define a possible solution and start improving it
    - Again there are the time- and resourceconstraints

How does it Work
Single Path Metaheuristic vs. Population based Mataheuristic

- Single Path Metaheuristic
  - We improve one solution
  - We put up with a limited search space
- Population based Metaheuristic
  - We improve multiple solutions in parallel
  - In consquence we have an extended search space
- A limited search space results in a limited number of local optima, i.e. there is only a small chance to get near the global optimum

The Global Set of Solutions



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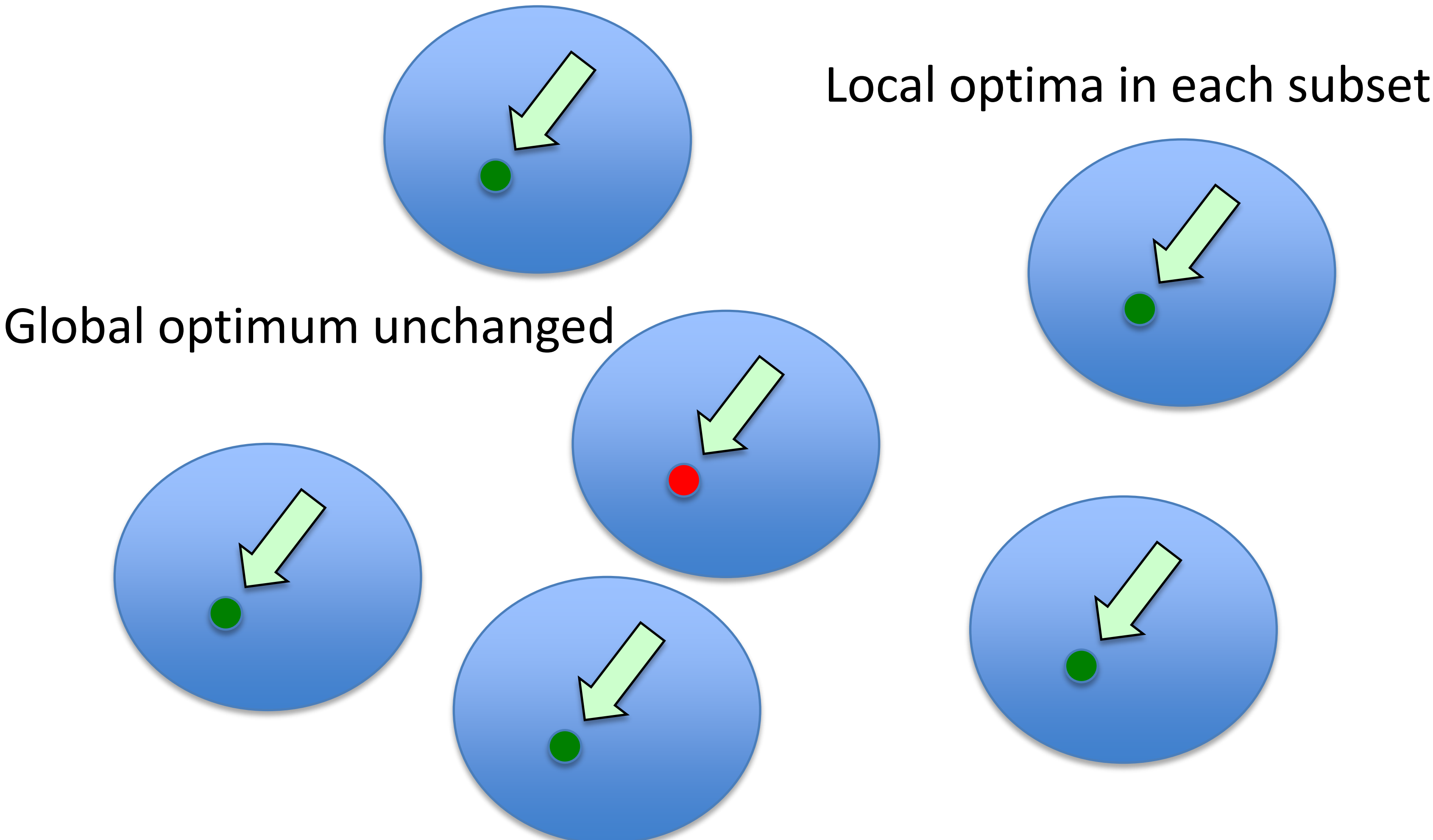
Subsets Relating to Certain Solution Paths



Single Path vs. Population Path

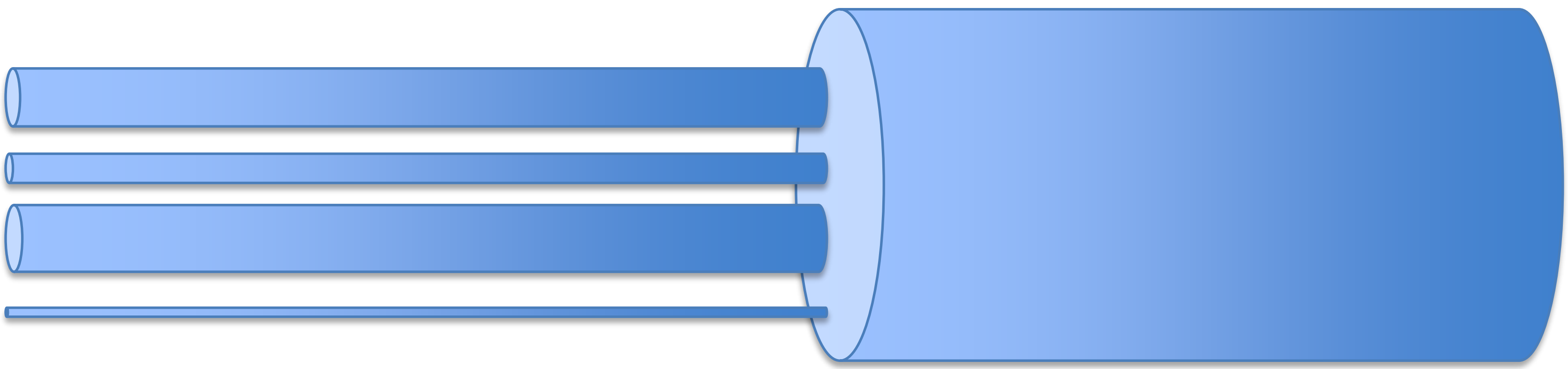
- As a first step we split up the solution set
  - Per subset there is at least one local optimum
  - The global optimum stays were it was
- In single path we search one subset
  - Selection difficult
  - Good chance to find local optimum
  - Small chance to find global optimum
- In population path we search multiple subsets
  - At least we don't miss the chance to get closer to a global optimum
  - However, the effort cannot be neglected

A Word about the Objective Function

- In a single application case we have to optimize allocation of multiple resources over time
  - The objective function is a time dependend compound of multiple sub objective functions.
  - The different sub objective functions have different weights, denoting their importance
- In a multi application case we have to introduce hierachical weights denoting the importance of the respective application

Single Application Objective Function

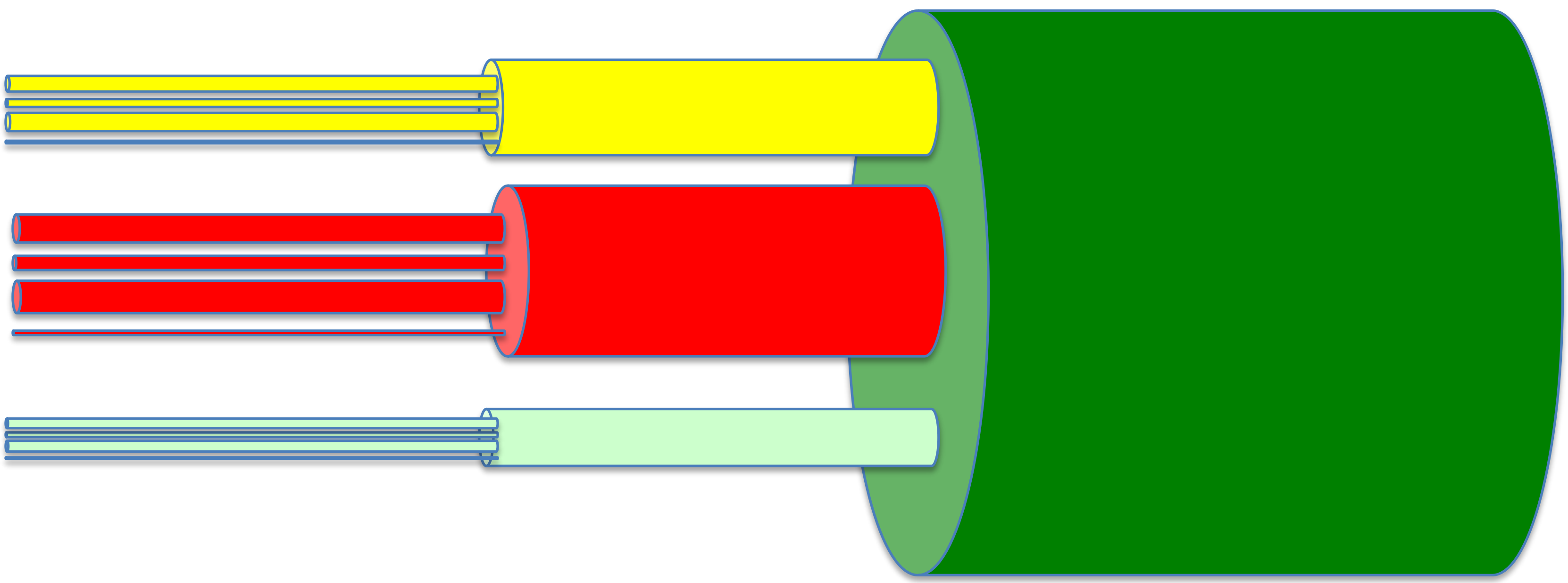
Sub Objective Functions　　Objective Function



Hierarchical Objective Functions

Application related Objective Functions

Overall Objective Function



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Paths towards a solution

NATURE INSPIRED METAHEURISTICS

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What are we looking for?

- Optimized allocation of resources
- Swarm behavior to inspire us
  - Flight of birds
    - When flying large distances bird fly in a certain spatial arrangement to optimize energy consumption with regard to slipstream
  - Fish swarms
    - Swarms of fish use a spatial arrangment as camouflage
  - Fireflies
    - Fireflies attract their mating partners by flashing. In a swarm of fireflies this leads to a certain locally optimal arrangement of these insects

Swarm Arrangements

Flight of Birds

Fish swarm

Fireflies mating

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Firefly Swarm Behavior Assumptions

- All fireflies are unisex
  - One firefly will be attracted to all other fireflies
- They flash for the purpose of attracting mating partners
  - The brighter they flash the more attractiv they are
  - A less brighter one will be attracted by a brighter one
- As a result we have a swarm organisation that is satisfactory for the swarm. It will **not** be the globally optimal organisation

Ways to Formalize

- The objective function determines the flashing intensity
  - Low: be attracted
  - High: attract
- Initially the distribution of fireflies is randomly determined
- The fireflies will move until they are in an individually satisfactory position
- For the swarm this is not the global optimum, but a good or close to best distribution

Pseudocode

Objective function $f(\mathbf{x})$, $\mathbf{x} = (x_1, \cdots, x_D)^T$.
Initialize positions of fireflies $\mathbf{x}_i$ $(i = 1, 2, \cdots, M)$.
Light intensity I_i is determined by $f(\mathbf{x}_i)$, $I_i = f(\mathbf{x}_i)$.

Generation step $t = 0$.
while ($t <$ MaxGeneration $t_{\max}$) **do**
  for $i = 1$ to M, all M fireflies **do**
    for $j = 1$ to M, all M fireflies **do**
      if $I_i > I_j$ **then**
        Move firefly i toward j according to Eq.(2).
      end if
    end for j
  end for i
  Evaluate new solutions $f(\mathbf{x}_i)$.
  Rank the fireflies and find the current global best $\mathbf{g}_*$.
end while

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How to Apply to our Real World Problems

- We now know how fireflies find a sufficiently good mating distribution in a swarm
- Instead of moving firefly i to firefly j we have to:
  - Find appropriate storage allocation sequences
  - Find appropriate compute capacity sequences
  - Find appropriate network connectivity over a period of time
- All this is done within time constraints

Result

- The result will not be a global optimum
- It will not even be deterministic
  - 2 runs can figure out 2 different local optima
  - In some cases the result might even be a poor local optimum
- However, a second best solution is better than no solution at all

Wir stehen selbst enttäuscht und sehn betroffen
Den Vorhang zu und alle Fragen offen

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