Smart Teams

Local, Distributed Strategies for Self-Organizing Robotic Exploration Teams

Presented by
Jaroslaw Kutylowski

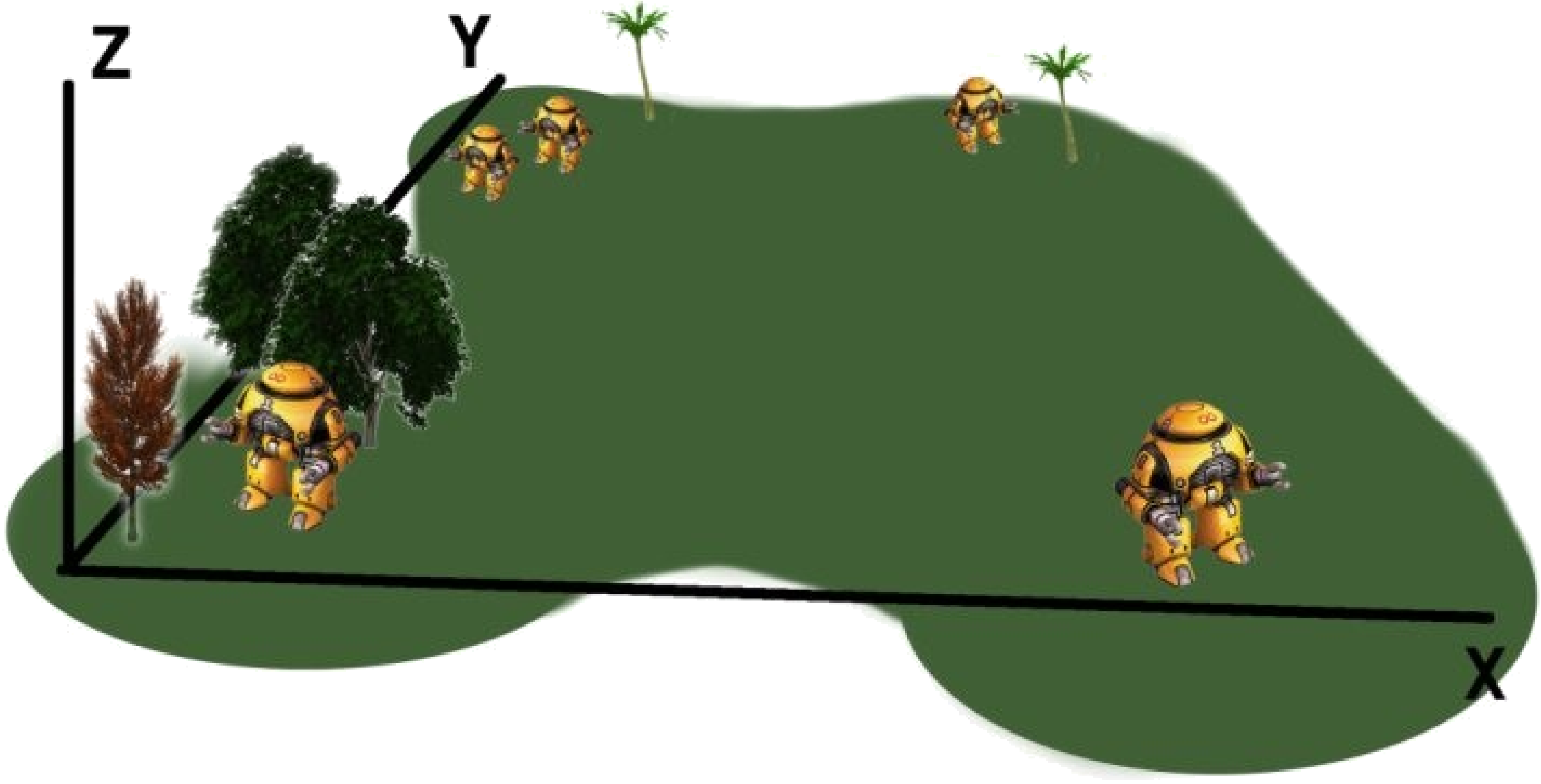
University of Paderborn

- Friedhelm Meyer auf der Heide
- Miroslaw Dynia
- Jaroslaw Kutylowski

University of Freiburg

- Christian Schindelhauer
- Chia-Ching Ooi

Smart Teams



Smart Teams

A Smart Team is

- a group of mobile robots,
- which can self-organize based on local, simple rules and
- jointly perform a given mission with a global objective

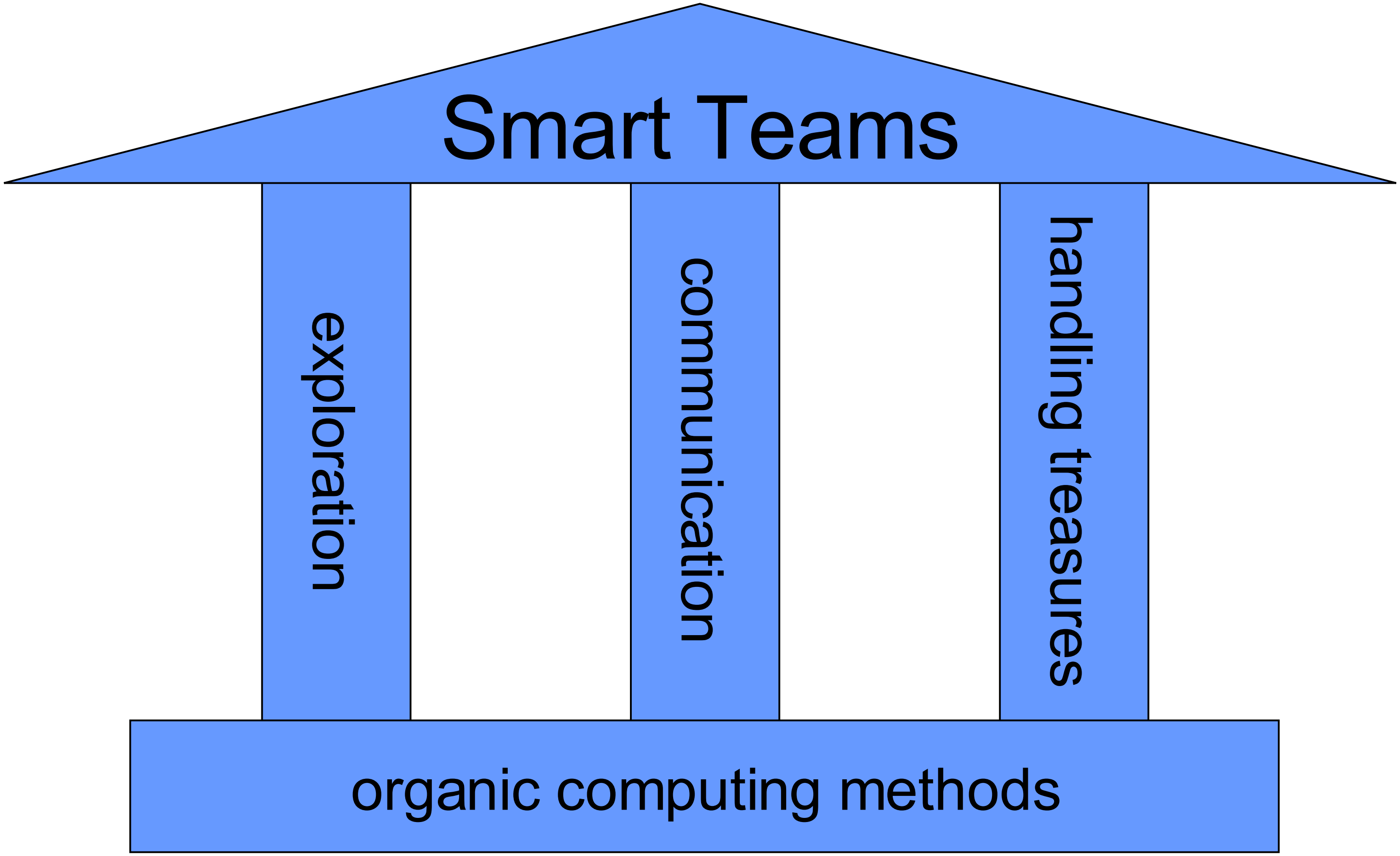
Task

- explore an unknown terrain while
- maintaining a robust and energy efficient communication network and
- excavating and transporting treasures

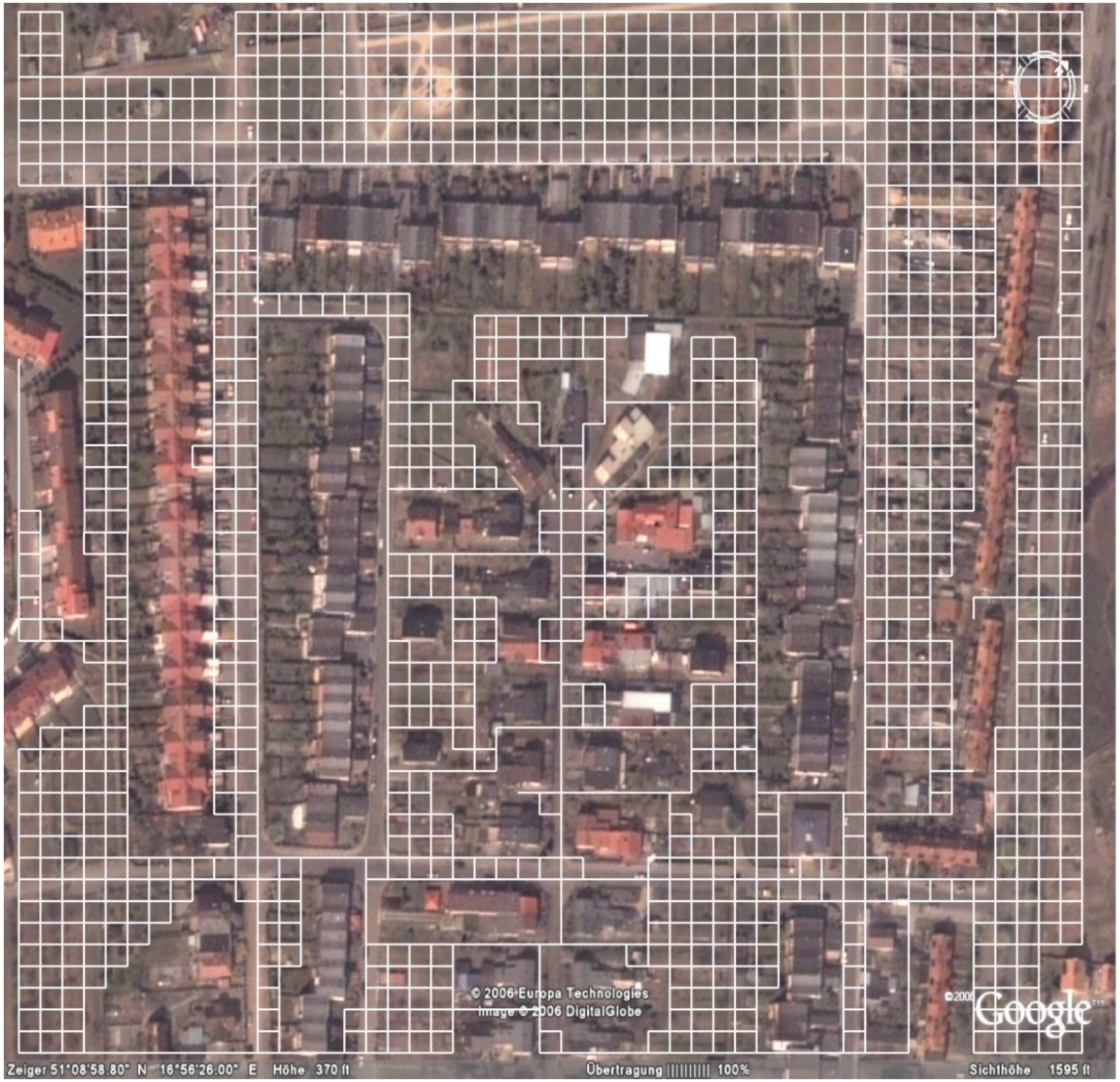
Constraints

- the communication range is bounded
- robots have to decide based on local knowledge; no central coordination
- these distributed, local strategies have to result in an globally good result

Smart Teams

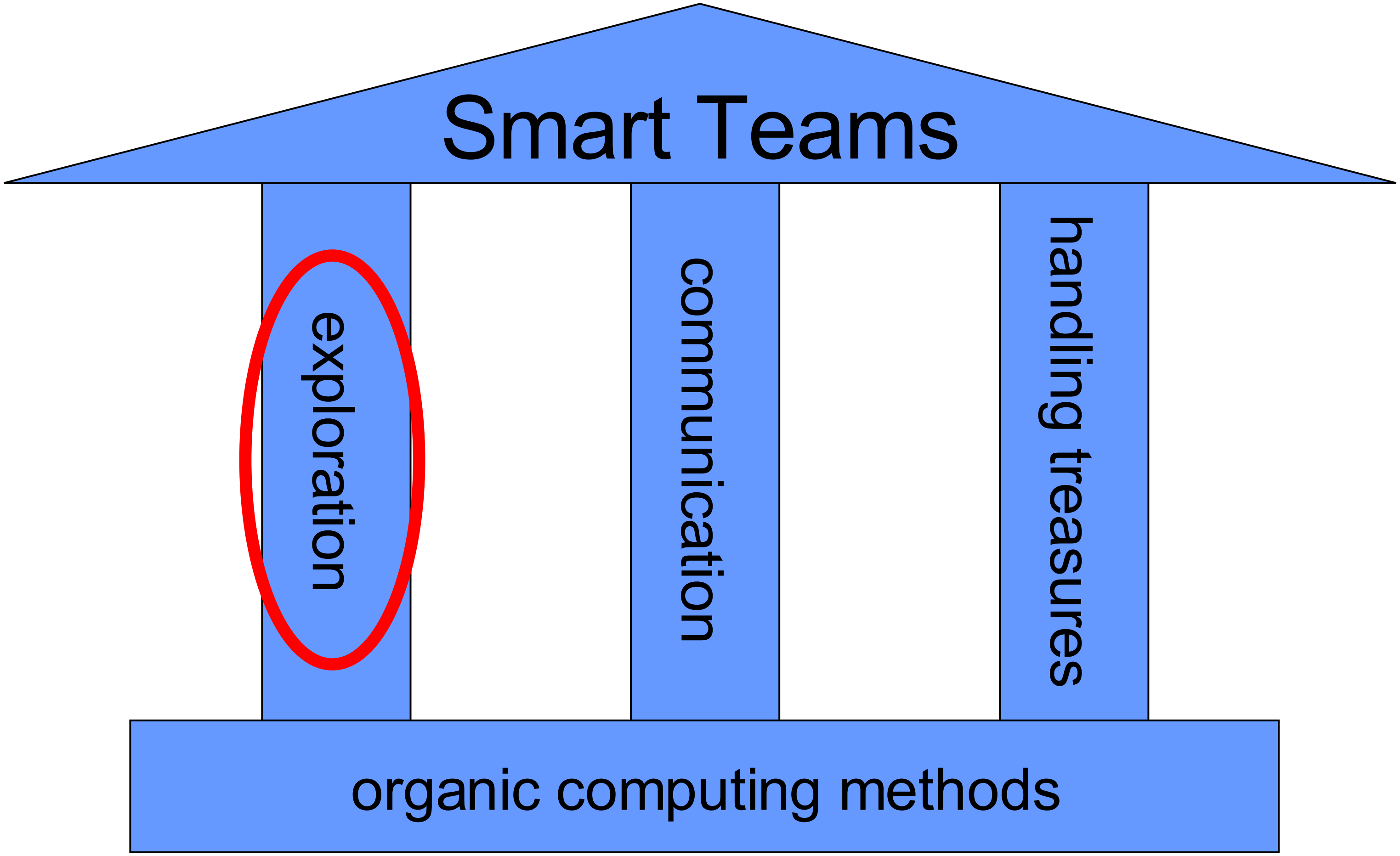

Smart Teams
exploration
communication
handling treasures
organic computing methods

General model



Exploration

HEINZ NIXDORF INSTITUTE
University of Paderborn
Algorithms and Complexity



Exploration

Given

- group of k robots,
- placed in base station,
- jointly explore unknown terrain, and
- finally return to base station.

Questions

- How to exploit the full parallel power of k robots, i.e. how to do the exploration k times faster than one robot would do?
- How to explore the whole terrain without using too much energy?

Exploration

Model

- Arbitrary tree, or
- Sparse tree
  - having at most h^2 nodes in distance h of any node
  - cannot grow extremely fast
- Moving over edge takes unit time
- Unlimited number of robots can move over an edge

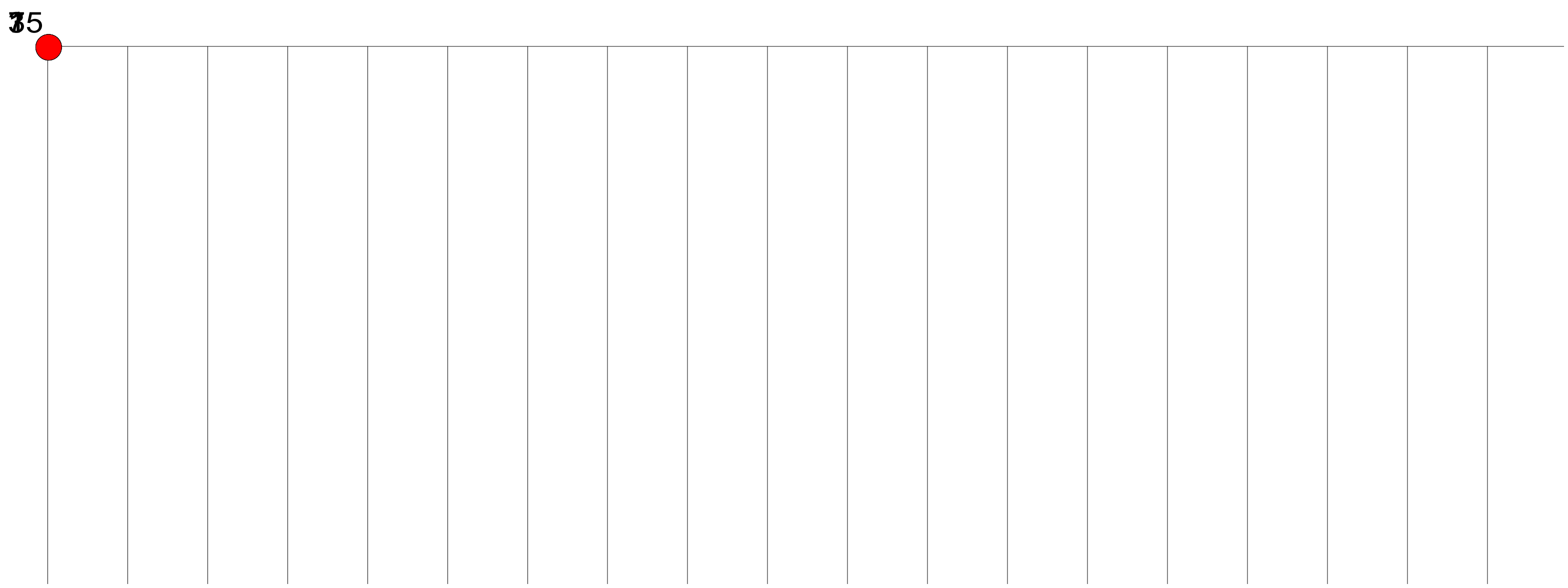
Cost measures

- Time to visit all nodes by at least one robot
- Length of path travelled by a single robot

Exploration

Simple algorithm

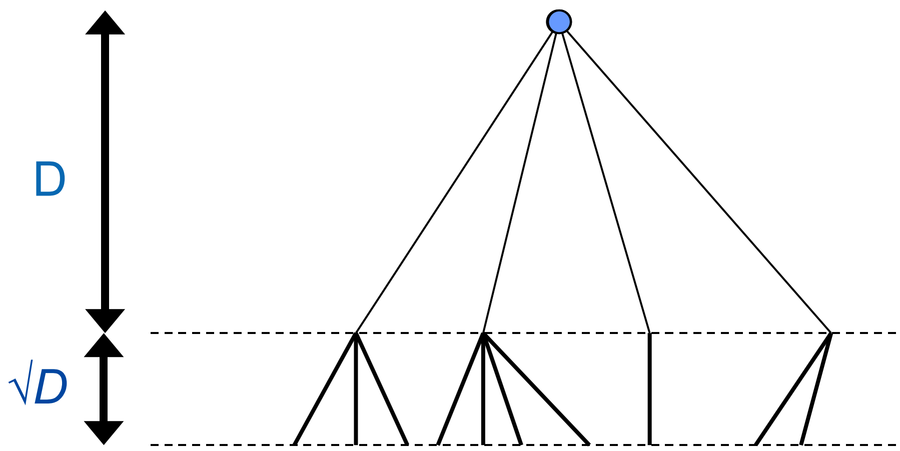
- At each crossing divide robots equally onto children
- Go back after reaching dead-end
- Exploration takes (in worst case) *k/log k* time more than optimally



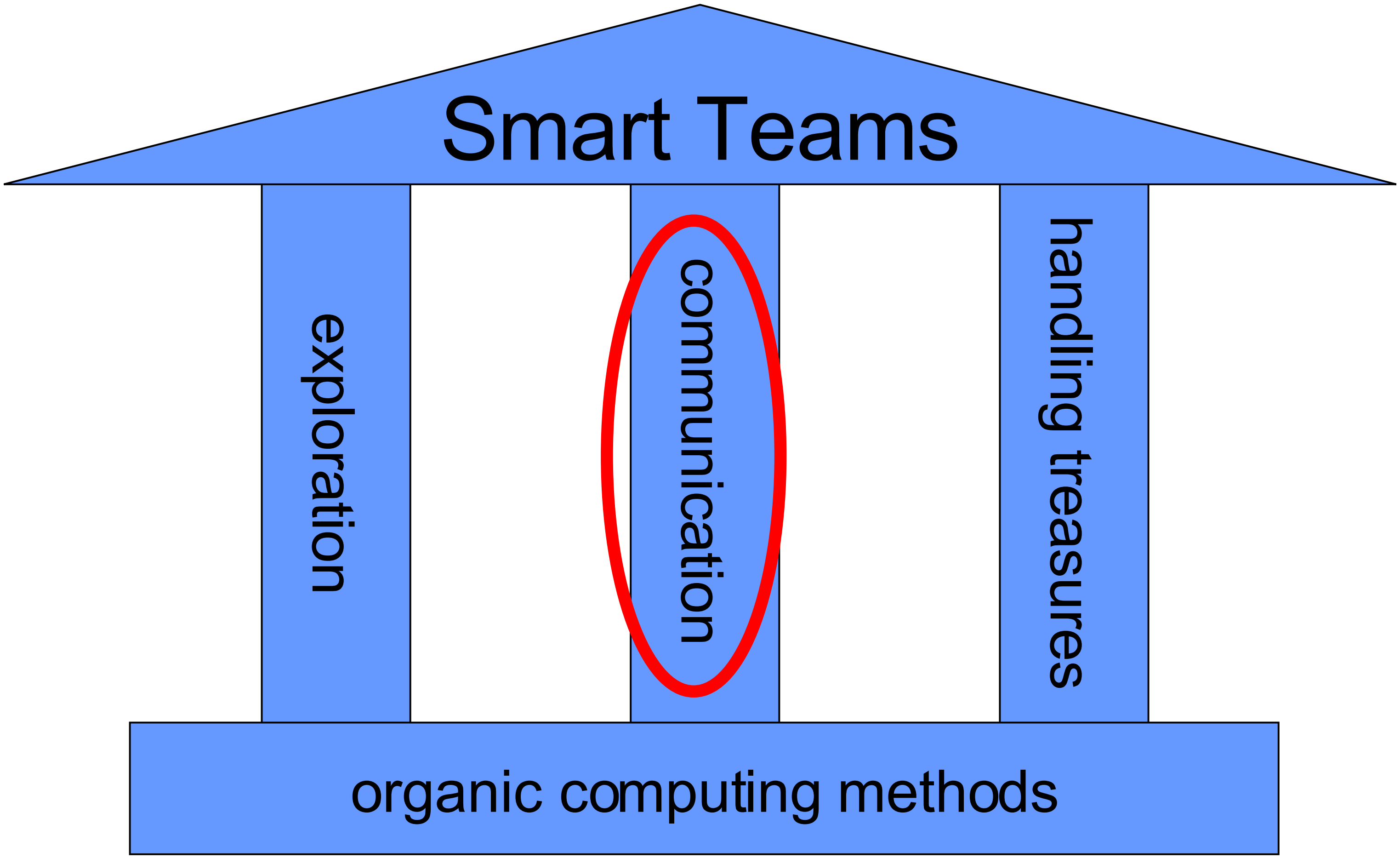
HEINZ NIXDORF INSTITUTE
University of Paderborn
Algorithms and Complexity

Karlsruhe-Express algorithm

- Explores the graph in chunks (chunks have increasing size)
- Rebalances robots after each chunk
- Exploration takes (in worst case) $\sqrt{D}$ time more than optimally



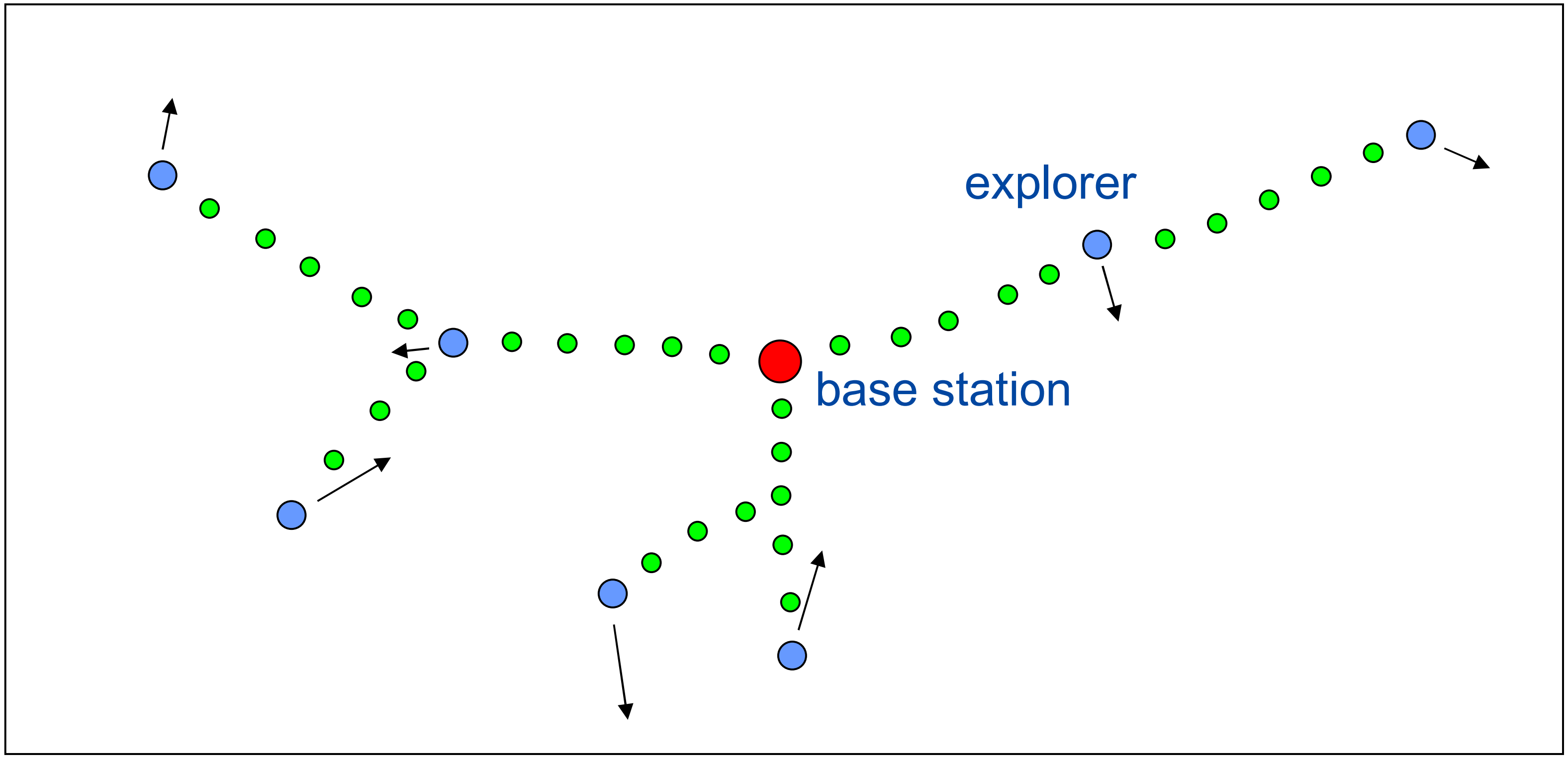
Communication



HEINZ NIXDORF INSTITUTE
University of Paderborn
Algorithms and Complexity

Scenario

- mobile relay stations guaranteeing connectivity between explorers



Communication

Scenario

- mobile relay stations guaranteeing connectivity between explorers

Overall goal

- keep connectivity between explorers and base station
- use few relay stations
- develop local, distributed strategies

Communication

Puzzle pieces constituting the "Communication" pillar

- maintaining single links (chains) effectively
- maintaining a tree structure efficiently
- keeping resources (relays) at proper places in the structure

Communication

Model for communication chains

- base station and one explorer
- explorer moving
- relay stations maintain a chain between explorer and base station

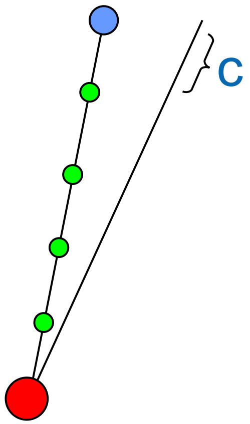
Strategies for relay stations

- Go-To-The-Middle
- Chase-Explorer
- Chase-Explorer-With-Obstacles

HEINZ NIXDORF INSTITUTE
University of Paderborn
Algorithms and Complexity

Chase-Explorer

- needs GPS or compass
- some communication if obstacles present



Communication

Go-To-The-Middle

- fully local
- weak performance

↔

Chase-Explorer

- less locality
- optimal performance

Open questions

- better performance without sacrificing locality?
- general lower bound for local, memoryless strategies?

HEINZ NIXDORF INSTITUTE
University of Paderborn
Algorithms and Complexity

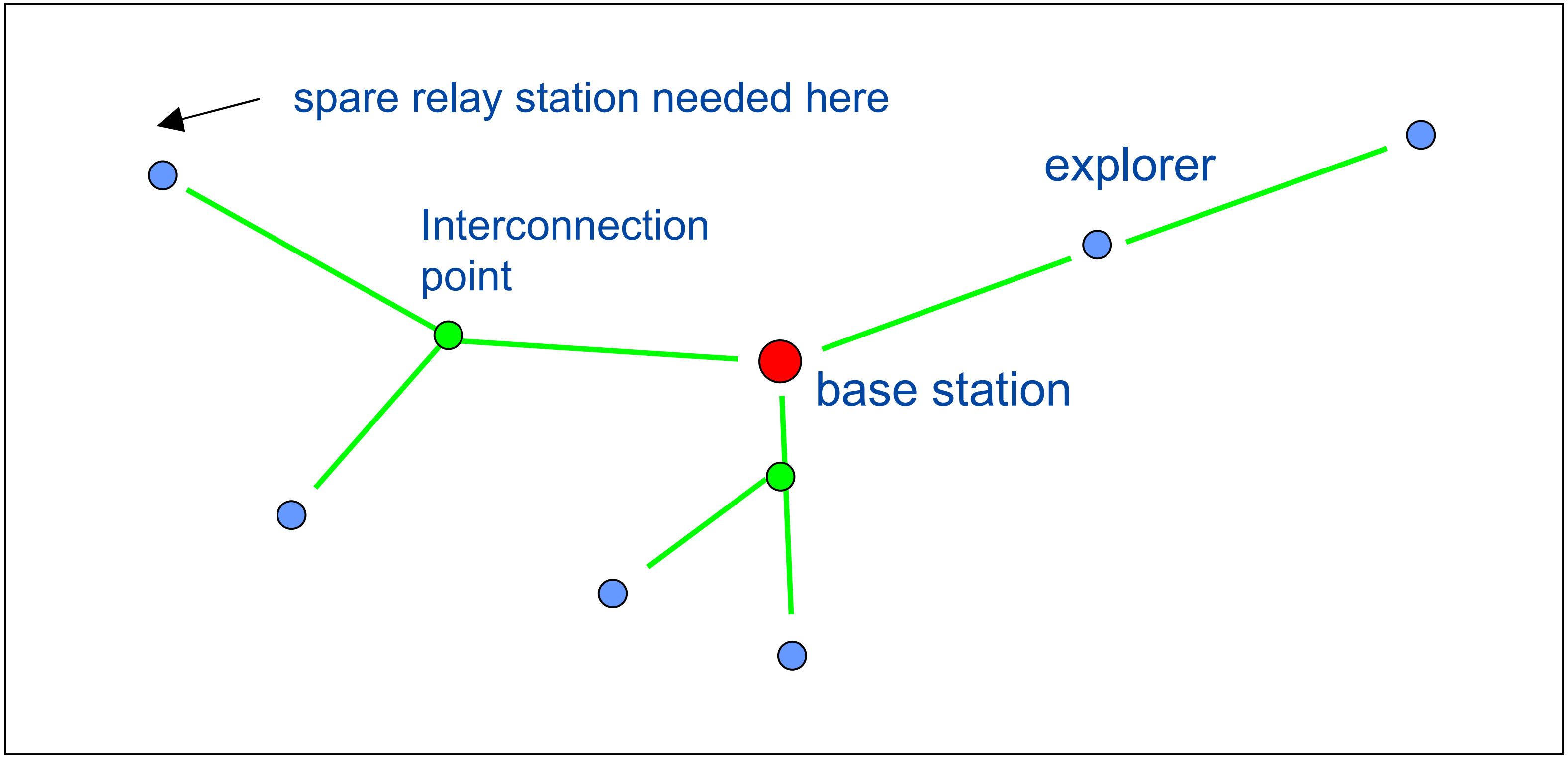
Puzzle pieces constituting the "Communication" filar

- maintaining single links (chains) effectively
- maintaining a tree structure efficiently
- keeping resources (relays) at proper places in the structure

HEINZ NIXDORF INSTITUTE
University of Paderborn
Algorithms and Complexity

Scenario

- communication tree between explorers given
- explorer moves – spare relay station needed
- no spare relay station – explorer must wait



Communication – Relay placement

HEINZ NIXDORF INSTITUTE
University of Paderborn
Algorithms and Complexity

Scenario

- communication tree between explorers given
- explorer moves – spare relay station needed
- no spare relay station – explorer must wait
- bounded number of relay stations
- online problem – we do not know how the edge lengths change in the future (how the explorers move)

Goal

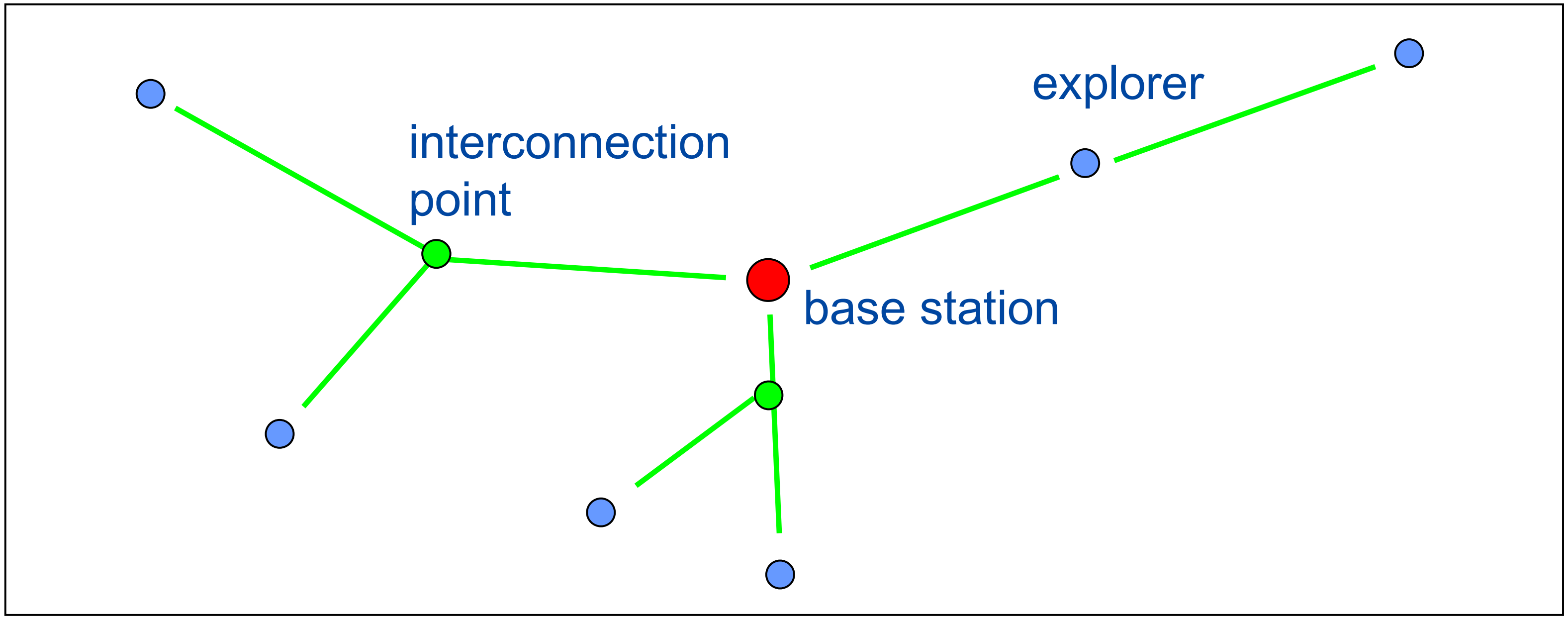
- distribute relay stations to explorers & interconnection points
- allow for best movement of explorers (no waiting)

Communication – Relay placement

HEINZ NIXDORF INSTITUTE
University of Paderborn
Algorithms and Complexity

Model

- adversary changes edge weights, tree structure does not change
- edge weight increase – spare relay must be available
- we count waiting time of explorers

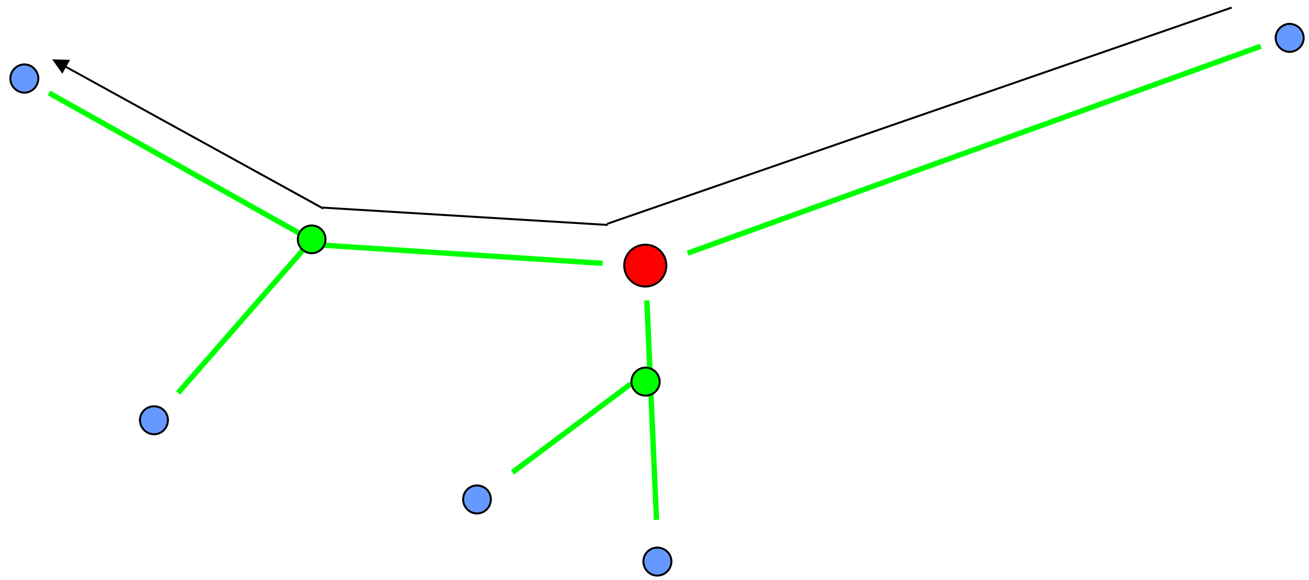


Communication – Relay placement

HEINZ NIXDORF INSTITUTE
University of Paderborn
Algorithms and Complexity

Pulling spare relays

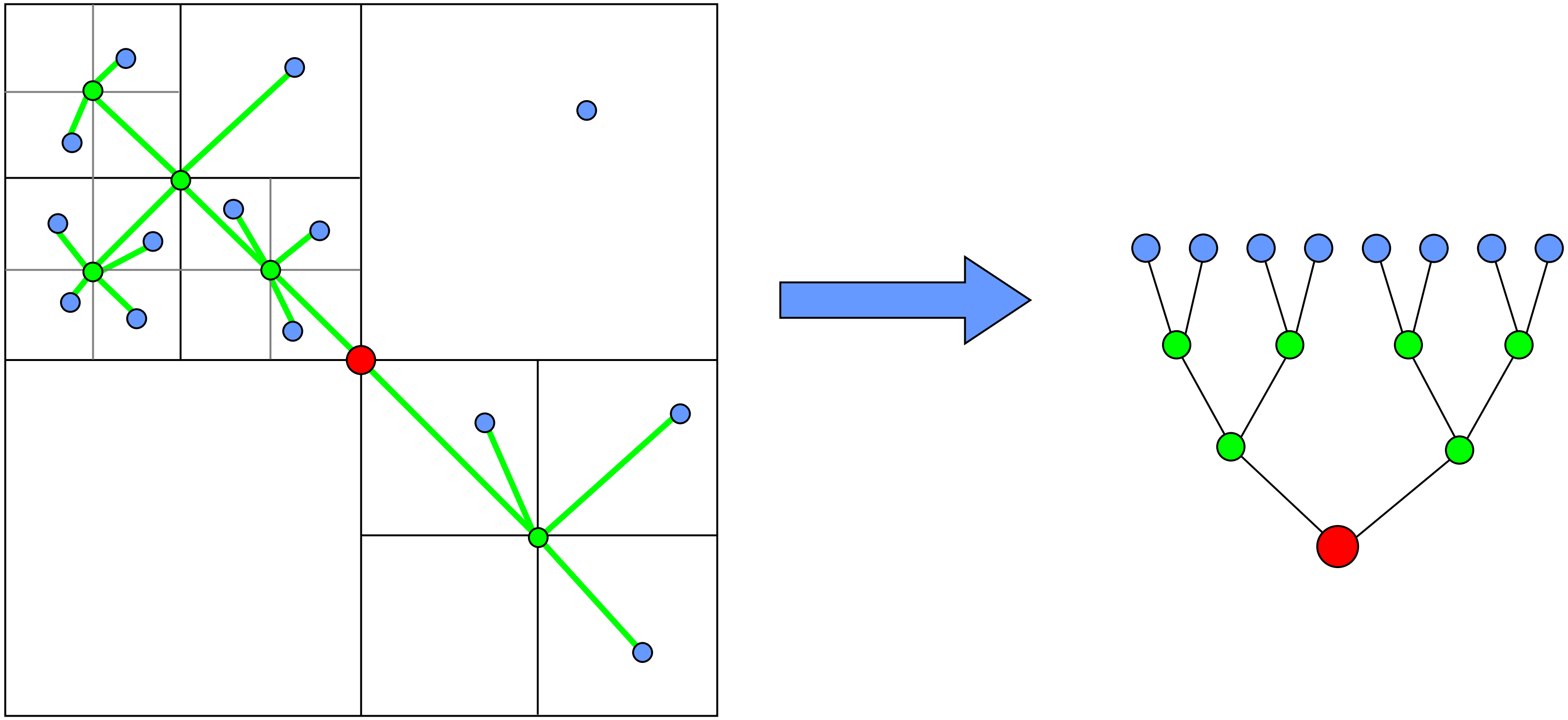
- similar to “string” pulling or electricity flow
- every node on pulling path moves one step forward
- only one pull operation per edge in one round
- moves one spare relay to pulling node



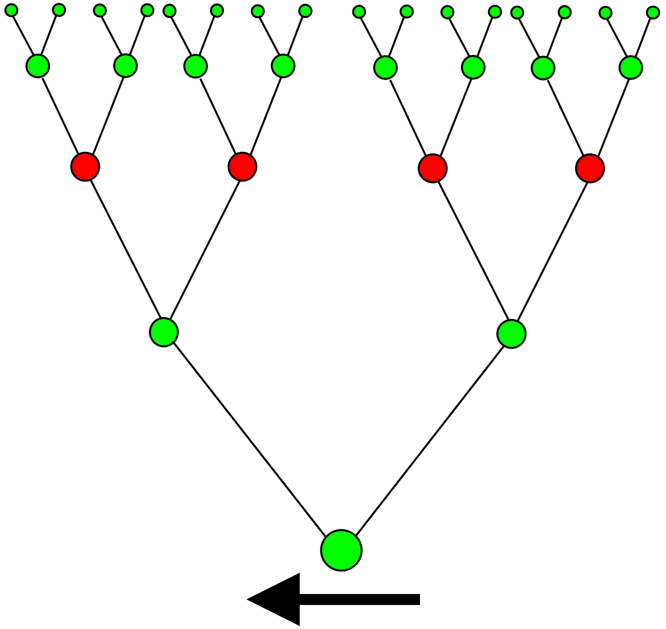
Communication – Relay placement

HEINZ NIXDORF INSTITUTE
University of Paderborn
Algorithms and Complexity

- *k* explorers
- tree with bounded degree (for simplicity 2)
- depth *D*
- models trees one encounters in practice



Communication – Relay placement



- every algorithm has to deal with this congestion (also the optimal one)
- investigate what happens if we do not know the future
- does this increase the congestion significantly?

Work done & Roadmap

Work done

- Theoretical foundation for exploration & communication
- SmartS simulator framework ready

Roadmap

- Extension of theoretical results
- Project Group on Smart Teams
  - extending SmartS
  - presents the algorithmic solutions developed
- Connecting SmartS and ns2/omnet simulators

Publications

M. Dynia, M. Korzeniowski, C. Schindelhauer
"Power-Aware Collective Tree Exploration" (ARCS'06)

M. Dynia, J. Kutylowski, F. Meyer auf der Heide, C. Schindelhauer
"Smart Robot Teams Exploring Sparse Trees" (MFCS'06)

M. Dynia, J. Kutylowski, P. Lorek, F. Meyer auf der Heide
"Maintaining Communication Between an Explorer and a Base Station" (BICC'06)

M. Dynia, M. Korzeniowski, J. Kutylowski
"Competitive Maintenance of MSTs in Dynamic Graphs" (submitted)

M. Dynia, J. Kutylowski, F. Meyer auf der Heide
"Efficient Connectivity Maintenance between an Explorer and a Base Station in Natural Terrain" (submitted)

Mini-workshop

We plan a mini-workshop on self-organizing, distributed systems

Partners:

- Sandor Fekete
- Stefan Fischer
- Martin Middendorf
- Dirk Timmermann

Everybody is invited to join, date will be fixed soon

Thank you for your attention!