Swarm-based routing to achieve dependable networks

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Dependability of all-IP networks
A multi-disciplinary workshop

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Introduction

- Objectives
  - Understanding how swarm based routing works
  - Pros & Cons vs. "standard routing"
  - Combination with stochastic optimization; the CE-Ants
  - Activities at NTNU

- Outline
  - Routing
  - Swarm based routing
  - CE-Ants, The mathematical foundation without any math.
  - Examples
    - Primary-backup
    - The BISON demo
    - Dealing with network dynamics
  - Closing
Routing

- Currently in the Internet
  - Intradomain; OSPF, IS-IS (Link weight)
  - Interdomain; BGP (Distance vector), Policies
  - Based on Dijkstra’s shortest path algorithm

- Requirements
  - One or more paths between end nodes
  - Fast/immediate re-establishment of paths after failures
  - Optimal resource usage; Adaptation to topology & traffic load
  - Inherent robustness and stability

Swarm based routing

- Small simple mobile agents (ants)
- Swarms of co-operating agents
- Indirect communication
- One specie per task/policy
- Collective problem solving / optimization / arbitration
History

- **Nature inspired; Routing and load balancing**
  - Steward & Appleby, 1994
  - Schoonderwoerd & al., 1996
  - Subramanian & al., 1997
  - ...

- **Nature inspired; Optimization**
  - Colorni & al., 1991
  - Dorigo & Di Caro 1997
  - ...

- **Rare event theory; Optimization**
  - Rubinstein, 1999
  - ...

- **Optimization based distributed path management**
  - Helvik & Wittner, 2001
  - ...

Some Results


- **Di Caro and Dorigo.** *AntNet: Distributed Stigmergetic Control for Communications Networks.* Artificial Intelligence Research, 1998.


Finding the optimal path by "pure chance" is a rare event.

- Importance sampling like technique is used to find good solutions (combination of paths).

- Routing probabilities are gradually tuned by
  - Minimizing the cross entropy (Kullback-Leibler distance) between these and the optimal importance sampling probabilities.
  - Putting gradually increasing weight on good solutions.

- Autoregressive computations.
- Simplified computation by low order approximations.
  - Efficient.
  - Low memory requirements.
  - Compact & simple implementation.

- Distributed & autonomous operation.
- Target specific heuristics.

Simple agent code! Really robust!!
Primary back-up; Shared resource principle

- Primary and backup paths btw. i and l, and j and n
- Capacity of link j, k

- One species per path type (e.g. 4)
- Objectives/policies
  - Fault-free ➔ no overload
  - Single link failure ➔ no overload
  - Primary and back-ups ➔ disjoint
  - Common primary link ➔ disjoint back-ups
- Policies heuristically embedded in ant/agent behaviour
Activities

Done
- Hamilton cycles in (sparse) networks; NP-hard proof of concept
- Preparing primary and back-up paths; Load distribution
  - Implementing policies
- P-cycles (Hamiltonian) [More to be done]
- Resource search with QoS constraints; Scalability [More !]
- Stochastic routing

On-going
- Dependability evaluation
- Dynamic networks (Topology and traffic changes); Adaptivity
- Demonstrator / Laboratory

On the agenda
- Wireless mesh networks
- Dependability differentiation
  - ... and more ...

Swarm intelligence based routing
AntPing - demo

PEH, April 06
BISON final review meeting, Paris, France
Adaptability

- Topology changes
  - Failure & repairs
  - Rearranging
- Traffic
  - Load
  - Interests
- Prototype trace
  - Stochastic routing
  - Stigmetrics remembered in nodes
    → Fast reroute
  - Some limitations in prototype implementation

Recent publications; Recommended reading


Remaining challenges

- Scalability
  - Node storage of “stigmetrics”
  - Feasibility for interdomain routing
  - Multiple requirements

- Security!

- Acceptance by network operators
  - Guaranteeing convergence and stability
  - First use for monitoring and management advice (AntPing)

- Trade offs
  - “Optimality” of routing
  - Time / responsiveness
  - Resource utilization

- … and more
Concluding remarks

- Another routing / path management paradigm
- Distributed, adaptive and inherently robust
- My provide resilience “features” in the future internet overcoming
  - Limitation of the “shortest” path
  - The restoration delay
  - Centralized planning and/or management
- Still work to be done

Questions?