Towards Autonomic Networking
Focusing on Knowledge Management

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Overview

- Autonomy in Computer Science
  - Computers
  - Autonomous Agents
  - Autonomic Computing
- Autonomic Networking
  - Piloting Plane
  - Knowledge Plane
  - Situatedness
- Piloting Plane Using a Situatedness-based Knowledge Plane for Autonomic Networking
  - Implementation
  - Applications

Autonomy In Computer Science

- The Purpose of Computers
  - Ted Nelson: “The purpose of computers is human freedom.” (even if “No one’s life has yet been simplified by a computer.”)
  - “To make life easier, to save labor on repetitive operations”
  - “The purpose of computers is to automate work”

- Automation
  - Automation (ancient Greek: = self dictated), is the use of control systems such as computers to control industrial machinery and processes, replacing human operators.

Autonomy In Computer Science

- One step beyond… Autonomy
  - Executing automatically predefined tasks is not enough!
    - Computers are expected to derive their own tasks from predefined goals.
  - Autonomous Agents
    - An autonomous agent is a system situated in, and part of, an environment, which senses that environment, and acts on it, over time, in pursuit of its own agenda. This agenda evolves from drives (or programmed goals). The agent acts to change the environment and influences what it senses at a later time.
    - Action Selection: “What to do next?”

- Situatedness
  - Autonomous Agents
    - Situatedness provides a framework for understanding the context in which an agent operates.

Applications

- Implementation
- Applications
Autonomy In Computer Science

- Autonomy

What’s next?... Autonomicity

- Being self-driven is not enough if our computers are not self-managed
  - Computers should be able to manage themselves without any human intervention ("No one’s life has yet been simplified by a computer.")

- Autonomic Computing Initiative
  - 2001: IBM research initiative
  - 2007: still a hot topic in Computer Science

Autonomous nervous system

- The autonomic nervous system is the part of the peripheral nervous system that controls homeostasis, that is the constancy of the content of tissues in gasses, ions and nutrients.
- Unconscious self-monitoring of human body activity
  - It does so mostly by controlling cardiovascular, digestive and respiratory functions, but also salivation, perspiration, diameter of the pupils

- Autonomicity = Self-management

And what about computers?

- Autonomicity = self-management
  - A system monitors itself, and manages itself

4 capabilities of an autonomic system

- Self-configuring
  - Automatically incorporate and coordinate new components
- Self-optimizing
  - Performance tuning
- Self-protecting
  - Anticipate and defend against security breaches
- Self-healing
  - Detect, diagnose and repair problems

Usual AI control loop

- Analyze
- Plan
- Execute

Autonomic Networking

- Networks ≠ Single Computers or Servers
  - Few parameters for each equipment
  - Simple state of each equipment
  - But...
  - Configuration does not make sense on one single equipment
  - Collaboration of all equipments in the network
  - Configuration has to be coherent over the whole network
Autonomic Networking

Need to take care of control algorithms
- Self-*

A new range of algorithms
- Input parameters:
  - The state of control algorithms
  - The parameters of control algorithms
- Output parameters:
  - The parameters of control algorithms

A new plane:
- The piloting plane

Autonomic Networking

Knowledge Plane
- A need for...
  - Self-manageable algorithms (control plane)
  - Self-managing algorithms (piloting plane)
  - In a dynamic context...
- ... involves a need for...
  - Knowledge!
  - A huge amount of information
  - Fresh, pertinent, rich
  - Avoid redundancy
  - Avoid waste of information

Autonomic Networking

Knowledge Plane
- Vertical mutualization
  - Get rid of redundancy
  - Benefit of all available information
- Horizontal mutualization
  - Optimize the diffusion of information

Autonomic Networking

Knowledge Plane
- Single knowledge management area
  - No more redundancy
  - Many more possibilities
    - Aggregate information
    - Deduce facts
    - Predict events

-> A Single Knowledge Plane might be much richer than the sum of all control protocols
Autonomic Networking

- Situatedness
  - Situated Agents
    - From AI research
    - Agent which perceives its own environment
    - Action based upon its own perception
  - Example from the robotics:
    - A robot searches for a cake in a house
      - Global view
        - Got the map
        - Built a plan, got the cake
        - Very sensitive to changes in the environment (house and/or cake)
      - Situated view
        - Ain’t got any map
        - Actually searching for the cake
        - Looking
        - Smelling
        - Touching
        - Behaves very well in a dynamic and/or unknown environment

- Situatedness in the networks
  - Global Knowledge: a single knowledge over the whole network
  - Situatedness: each agent makes its own representation of the network state

Autonomic Networking

- Why use situatedness in networking?

<table>
<thead>
<tr>
<th>Distance</th>
<th>Performance</th>
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<td>1</td>
<td>2</td>
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Piloting Plane / Situatedness

- Based Knowledge Plane
  - 1 router ↔ 1 agent
    - Perceives its own state
    - Exchanges messages with neighbors
    - Acts on parameters of its algorithms
  - Knowledge Plane
  - Piloting Plane

Piloting Plane / Situatedness

- Based Knowledge Plane
  - The router’s situatedness-based KP: a situated view
    - Self-centered topology
      - When something happens, a fact is generated in the KP, and placed in the topology
    - Facts can be shared with neighbors
      - When a router receives a message, a fact is generated in the KP, and placed in the topology
Piloting Plane / Situatedness Based Knowledge Plane

- Distributed Failure Diagnostic

  - Standard situation
    - If 1 link is broken, two « linkdown » SNMP traps are reported
    - ... plus all related overloads in the neighborhood!

<table>
<thead>
<tr>
<th>Linkdown(A,C)</th>
<th>Linkdown(A,C)</th>
<th>Linkdown(C,A)</th>
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<td>Linkdown(A,C)</td>
<td>Linkdown(C,A)</td>
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Rule:
IF Linkdown(X,Y) AND Linkdown(Y,X) AND X=Y AND X=Me
THEN « Report SingleLinkdown(X,Y) »

Piloting Plane / Situatedness Based Knowledge Plane

- Distributed Failure Diagnostic

  - Each node knows the connectivity of its neighbors (limit: 2 hops for example)
    - SingleLinkdown(A,C)

Rule:
IF Linkdown(X1,Y) AND Linkdown(X2,Y) AND Linkdown(X3,Y) AND X1>X2 AND X1>X3 AND X1=Me
THEN « Report SingleNodedown(Y) »

Collaborative LSP Routing

- Routing LSP so that the probability to reject new requests is minimal

  - Off-line algorithms
  - Global solutions based on complete information
    - OSPF-TE

  - Drawbacks: not dynamic at all!
Piloting Plane / Situatedness Based Knowledge Plane

- Collaborative LSP Routing
  - Each router knows the load of its neighbor’s interfaces
  - Each router setup the LSP for itself and forwards the request
    - Choice of the « next hop »
    - Based on my interfaces load
    - And my neighbor’s one

Conclusions

- Autonomic Networking
  - Trying to make the networks more self-managing

- A Pilot Plane
  - Each control algorithm has to be piloted
  - What, in human operators work, can be done automatically?
  - A new range of algorithms

- A Knowledge Plane
  - A single area for managing all knowledge
  - Knowledge for controlling
  - Knowledge for piloting

- Situatedness
  - New knowledge management approaches

- A Pilot Plane Using A Situatedness-based Knowledge Plane (For Autonomic Networking)
  - A key to scalability in highly dynamic environments?
  - Towards Autonomic Networking!