Autonomic Management

Example Application Domain
Coping with complexity…

Our system programming paradigms, methods and management tools seem to be inadequate for handling the scale, complexity, dynamism and heterogeneity of emerging future network and systems.

Biological systems have evolved strategies to cope with dynamic, complex, highly uncertain constraints…

=> apply biological system concepts to solve unsolved problems in network management
Definitions

Autonomic

• Pertaining to an on demand operating environment that responds automatically to problems, security threats, and system failures
• Cf: self-adaptive, self-governing, self-managing, …

The term “autonomic” is derived from human biology – autonomic nervous system
• ANS monitors heartbeat, body temperature, …
  – *Without any conscious effort on one’s part!*

Nature has evolved to cope with scale, complexity, heterogeneity, dynamism and unpredictability, lack of guarantees
• self configuring, self optimizing, self healing, self protecting, highly decentralized, heterogeneous architectures that work !!!
Vision of Autonomic Computing (Management)

• Autonomic Computing:
  – Computing systems that can manage themselves given high-level objectives from administrators
  – Analogous to ‘human autonomic nervous system’ which governs our heart rate and body temperature
Autonomic Computing Attributes

Self-managing systems that deliver

Increased Responsiveness
Adapt to dynamically changing environments

Business Resiliency
Discover, diagnose, and act to prevent disruptions

Operational Efficiency
Tune resources and balance workloads to maximize use of IT resources

Secure Information and Resources
Anticipate, detect, identify, and protect against attacks
Autonomic architecture model (MAPE)

M: Monitor
A: Analyse
P: Plan
E: Execute

Loop
## Engineering Challenges

### Lifecycle
- Design, Test & Verification
- Installation & configuration
- Monitoring and Problem Determination
- Upgrading
- Managing Lifecycle

### Relationships among autonomic elements
- Specification (inputs/outputs etc.)
- Location
- Negotiation
- Provision
- Operation
- Termination
# How to get there...

<table>
<thead>
<tr>
<th>Level</th>
<th>Characteristics</th>
<th>Skills</th>
<th>Benefits</th>
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<tbody>
<tr>
<td><strong>Basic Level 1</strong></td>
<td>Multiple sources of system generated data</td>
<td>Requires extensive, highly skilled IT staff</td>
<td>Greater system awareness, Improved productivity</td>
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<tr>
<td><strong>Managed Level 2</strong></td>
<td>Consolidation of data and actions through management tools</td>
<td>IT staff analyzes and takes action</td>
<td>Reduced dependency on deep skills, Faster/better decision making</td>
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<tr>
<td><strong>Predictive Level 3</strong></td>
<td>System monitors, correlates and recommends actions</td>
<td>IT staff approves and initiates actions</td>
<td>Balanced human/system interaction, IT agility and resiliency</td>
</tr>
<tr>
<td><strong>Adaptive Level 4</strong></td>
<td>System monitors, correlates and takes action</td>
<td>IT staff manages performance against SLAs</td>
<td>Business policy drives IT management</td>
</tr>
<tr>
<td><strong>Autonomic Level 5</strong></td>
<td>Integrated components dynamically managed by business rules/policies</td>
<td>IT staff focuses on enabling business needs</td>
<td>Business agility and resiliency</td>
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Manual | Autonomic
A Question

What is the potential role of Ontologies in the Engineering of Autonomic Systems?
Key Aspects of an Autonomic System Model

Ontologies becoming lingua franca

This is where Autonomic Behaviour is defined
Example Application: WSN Failures Root Cause Identification

For a sensor network have many modes of failure due to routing data between sensors that are themselves failing due to power loss.

Want a self-managing network which can:
- Monitor for communications failures (and context)
- Identify the root cause from symptoms observed
- Determines the appropriate corrective actions
- Re-program the network
1. Create Failures Taxonomy

Modelled according to descriptions in [1].

Three most general concepts:

- **Failure**
  - *Absence of monitored traffic (sensor data).*
- **Network_Element**
  - *Models required network topology information.*
  - *Can be taken from WSN topology ontology.*
- **Root_Cause.**
  - *What causes this failure*
- **Symptom**
  - *Metrics gathered indicating abnormal things are happening.*

2. Define Properties associated with concepts

Properties associating with Failure:

- *id*
- *from_node*: The node where failure is detected
- *localized_source*: Most likely cause of this failure. “Self”, “Path” or “Sink”.
- *rating*: “Primary” or “Secondary”
- *primary_failure*: if not “Primary” then what is its primary cause.
- *root_cause*: the root cause associated with this failure.

Properties associating with Root_Cause:

- *id*
- *symptom*: symptoms.
Properties associated with concepts (cont.)

Properties associating with Symptom:
- *from_node*

Network topology/ nodes’ situation related:
- *lower_stream_node*
- *upper_stream_node*
- *isAlive*
- *hasGoodRouteToSink*
- *justRebooted*
3. Define Rules for Root Cause Identification

Rules (extracted from the decision tree and its following texts of [1]) are employed to perform root cause identification and source localization.

The rule 1-7:
  • Root cause identification.
  • Evaluated one by one in sequence.

The rule 8-10:
  • Root cause identification (dedicated for sink node).
  • Evaluated in parallel with the rule 1-7.

The rule 11-12:
  • Root cause localization rule
Figure 3: Decision tree Sympathy uses to root-cause node failures once they have been detected.
How ontology fits into WSN faults management

Collect Metrics and Detect Failure

Detect Failures (modelled in OWL)

Root Cause Identification (rule engine)

Failure with root cause identified

Source localization (rule engine)

Failure with root cause identified and localized source assigned

Failure Report Ontology

APIs

Graphical Ontology Accessing Tools/Queries

Network Topology

Failure Taxonomy
How ontology fits into WSN faults management

Monitor

Collect Metrics and Detect Failure

Collect Metrics and Detect Failure

Detect Failures (modelled in OWL)

Root Cause Identification (rule engine)

Detect Failures (modelled in OWL)

Rule 1-7 (one by one)

Rule 8-10

Rule 11-12

Source localization (rule engine)

Knowledge

OWL Rules

OWL Rules

Knowledge

Failure Taxonomy

Network Topology

Plan/Execute

APIs

Failure Report Ontology

Graphical Ontology

Accessing Tools/Queries

Knowledge

Autonomic manager

Analyze

Plan

Execute
Question 2: How will we control autonomic systems?

Generally difficult to master the behaviour of the automated closed-looped systems with precision

=> Control theory?
Control

Control signals are continuously computed from the error signal, i.e. the difference between the actual behaviour of the plant (measured by its outputs) and its desired behaviour (specified by a reference signal).

Control actions must be computed indefinitely at a rate fast enough with respect to the process dynamics.

Behaviour of the controlled process never completely known.

The MAPE-K loop as a continuous control loop.

Autonomic Management
Need governance or meta-control methods and interfaces

Figure 6: The discrete control loop as a MAPEK diagram. (a): simple automaton-based manager; (b): exhibiting observability and controllability.
IBM Policy Based Autonomic Computing

Autonomic Manager

Editing Tools -> Policy Editor Storage

ACPL

Call Out Request

Policy Editor

Storage

AM Management Interfaces (WS-RP)

Managed Resource

CBE Events

Receive Notification

Perform Operation

Call Out Request

Autonomic Management

© Rob Brennan
Adaptive Service Element

A Reference Model to show how ontology based semantics can help integrate:

- service-oriented modelling
- resource-modelling
- policy-based management
- context-modelling

Resource is logically managed / wrapped by a service

Service Elements have well defined inputs and output and can be composed

Service Element’s operation and adaptation is dependent on its preconditions and effects

Adaptive behaviour can be:

- Context Driven
- Constrained by Policy

Not an ‘Autonomic Service Element’
Composite Autonomic System – combines:

- Service-oriented provision of value
- Policy-based governance
- Context-Awareness
- Resource management
Next Steps

Mixed initiative engineering and governance tools providing help with:

- Inconsistencies when integrating ontologies
- Incompleteness when building models
- Explaining reasons for policy conflicts
- Suggesting policy refinement paths
- Browsing/searching large populations of models
- Developing grounding mappings – including natural language processing
- Developing semantic interoperability mappings
- Version control

Tool design need a better understanding of tensions between optimal forms (including non-ontological) for:

- Sharing and integration
- Human comprehension
- Automated reasoning

Need to understand when to move from general purpose ontological tools and reasoners and to optimised-but-constrained versions
Aside: How is Network Management Research Defined? *

Smart and hyperconnected environments
Smart Cities
Smart Grid
Smart Homes
Cyber-Physical Systems
Internet of Things
Social Networks
Applications and case studies

Software-Defined Networking
• Advanced network virtualization
• Case studies and practical deployments
• Control plane programmability
• Data plane programmability
• Network functions virtualization
• Non-IP protocols
• Protocols, languages and frameworks (OpenFlow, Frenetic, OpenDaylight...)

* http://noms2016.ieee-noms.org/content/call-submissions
<table>
<thead>
<tr>
<th>Network management &amp; operational experience</th>
<th>Service management</th>
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<tbody>
<tr>
<td>• Ad-hoc networks</td>
<td>• Business management</td>
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<tr>
<td>• Automotive and Vehicular Networks</td>
<td>• Clouds</td>
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<tr>
<td>• Big Data in and for management</td>
<td>• Data center management</td>
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<tr>
<td>• Broadband access networks</td>
<td>• Data service management</td>
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<tr>
<td>• Cognitive Radio networks</td>
<td>• Hosting</td>
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<tr>
<td>• Data Centers</td>
<td>• Infrastructure as a Service, Management as a Service, Platform as a Service, Software as a Service</td>
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<tr>
<td>• e-Maintenace</td>
<td>• IT service management</td>
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<tr>
<td>• Future Internet</td>
<td>• Managed service provisioning</td>
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<tr>
<td>• Heterogeneous networks</td>
<td>• Multimedia service management</td>
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<tr>
<td>• Home networks</td>
<td>• OTT service management</td>
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<tr>
<td>• M2M networks</td>
<td>• Virtualized infrastructure management</td>
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<tr>
<td>• OSS/BSS development</td>
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<td>• Overlay networks</td>
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<td>• Personal area networks</td>
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<td>• Sensor networks</td>
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<tr>
<td>• Wireless &amp; mobile networks</td>
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### Functional areas
- Billing
- Deployment
- Diagnostics, Tracing, Troubleshooting
- Fault management
- Energy-efficiency/green management
- Service Assurance
- Service Fulfillment
- Service Level Management
- Security Management

### Management approaches
- Autonomic and self-management
- Best practices
- Centralized management
- Distributed management
- Integrated management
- Management architectures
- Organizational aspects
- Policy-based management
- Process oriented management
- IT service management (ITSM)
- Process engineering and frameworks (ITIL, CobIT, RiskIT, ValIT)
Technologies enabling management
• Data, information, and semantic modeling
• Message and software buses
• Middleware
• Mobile agents
• Protocols
• Software engineering for clouds
• Software product lines
• Virtualization
• Web services

Methodologies for network operations and management
• Control theory
• Data collection and aggregation
• Data mining
• Design and simulation
• Economic/finance theories
• Experimental approaches
• Machine learning
• Optimization theory
• Probability and stochastic processes, queuing theory
• Risk management
• Software engineering methodologies
• Visualization

Security & Security Management