Perspectives on Network Management

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Outline of the talk

- What is network management?
- What is the operator's perspective?
- What is the EMANICS NoE?
- What about autonomic networks?
- Discussion

Network Landscape

- Forwarding plane:
 - Fast forwarding of packets (ideally in light speed)
 - Implementations are all hardware and increasingly optical
 - Operates on very small time scales (us-ms)
- Control plane:
 - Everything that directly controls the forwarding plane
 - Routing, signaling, admission control, flow classification, ...
 - Operates on larger time scales (ms-s)
- Management plane:
 - Control of the control plane
 - Management of the overall network infrastructure
 - Operates on relatively large time scales (s-d)

Network Management

- Monitoring (thresholding, alarm generation, ...)
 - Fault management (event correlation, root cause analysis)
 - Configuration (generation, distribution, activation, ...)
 - Policy-based management (languages, translations, ...)
 - Distributed management (delegation, data fusion, ...)
 - Security management (keys, access control lists, ...)
 - Business aspects (accounting, billing, charging, ...)
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- Protocols and technologies (CMIP/SNMP/COPS/CIM/...)
 - Application to specific domains (optical, wireless, cable, xDSL, 802, ... networks; voice, video, grid, ... services)

Requirements

- Scalability
- Robustness
- Heterogeneity
- Short technology life-cycles
 - need to understand the managed technology first
 - hence, management is always (too?) late
- Standards are desirable
 - but take long to develop (see above) and
 - only few of them are successful in the market

Cyclic Design Model

- Iterative design process
- Management functions grow and change over time

Stake Holders

- Operators
 - NANOG, RIPE, ...
- Vendors
 - Alcatel, Cisco, Juniper, Lucent, Nortel, ...
- Standardization Bodies
 - IETF, ITU-T, DMTF, OASIS, TMF, ETSI, 3GPP, ...
- Researchers
 - Universities and industrial research centers
- Research organizations and groups
 - IEEE ComSoc CNOM, IFIP WG 6.6, ...
 - IRTF NMRG, EMANICS NoE, ...

Operator's Perspective

- Simplicity Principle
- Amplification Principle
- Coupling Principle
- Complexity Spiral

➤ Consult RFC 3439 for more details...

Simplicity Principle

- Complexity is the primary mechanism which impedes efficient scaling, and as a result is the primary driver of increases in both capital expenditures (CAPEX) and operational expenditures (OPEX).
- Keep the network core (the forwarding and control plane functions) as simple as possible so that it scales well.

Amplification Principle

- There are non-linearities which occur at large scale which do not occur at small to medium scale.
- In many large networks, even small things can and do cause huge events.
- What applies to small systems does not apply to large ones.

Coupling Principle

- As systems get larger, they often exhibit increased interdependence between components.
- The more events that simultaneously occur, the larger the likelihood that two or more will interact.
- This phenomenon has also been termed "unforeseen feature interaction".

Complexity Spiral

- The evolution of protocols can lead to a robustness / complexity / fragility spiral where complexity added for robustness also adds new fragilities, which in turn leads to new and thus spiraling complexities.
- Follow the Simplicity Principle and achieve robustness by removing complexity, thereby breaking the complexity spiral.

Increasing Complexity

SNMPv1 (RFC 1157)	8573 words
SNMPv2c (RFC 1901, 1905-06)	12797 words
SNMPv3 (RFC 3411-3417)	91077 words
Radius (RFC 2138)	15205 words
Diameter (RFC 3588)	43334 words

- Observation:
 - Engineers seem to like introducing complexities
 - Standardization bodies such as the IETF are dominated by engineers...

Research vs. Operators

EMANICS

- European network on **MAN**agement solutions for the Internet and **C**omplex **S**ervices
- 14 partners (relatively small European network)
- Integration / Dissemination
- Joint Research
 - Scalable Management
 - Economic Management
 - Autonomic Management
- More information: <http://www.emanics.org/>

Autonomic Networks

- Vision:
 - Networks provide **predictive** services
 - Networks **adapt** themselves **to changes** in the environment
 - Networks **organize themselves** without much human involvement and explicit management

Configuration Mgmt

Configuration Reality

- Configuration management often ad-hoc
- Common strategy: “fix it when it breaks”
- Operator and configuration errors are a significant cause of service failures
 - If 80% of unscheduled outages are caused by people or process errors, there is only a 20% window in which to optimize technology.
 - See references for some evidence!

Requirements

- Robustness
- Versioning and traceability
- Short switchover and rollback times
- Early conflict detection
- Minimize disruptions
- Maximize stability
- Network-wide configuration transactions

Protocol Aspects

- Variable-oriented protocols (e.g. SNMP)
 - Not suitable for configuration
- Object-oriented protocols (e.g. CORBA)
 - Not suitable for configuration
- Command-oriented protocols (e.g. CLIs)
 - De-facto interface, but no standards, lacks features
- Document-oriented protocols
 - Promising approach to treat configs as documents
 - Standardization underway (NETCONF)

NETCONF (IETF)

- NETCONF WG chartered three years ago to develop a network configuration protocol
- Juniper's JunoScript as a technology basis
- Involvement of major industry players
- Specifications approved as Proposed Standards
- Active discussion of implementation details
- Open prototype by INRIA, Nancy (EMANICS)

NETCONF Features

- Configurations are XML documents
- Operations to retrieve and patch configurations
- Multiple configuration datastores
 - Running, startup, and candidate configs
 - Only running is mandatory to implement
- Locking support (mandatory)
- Commit / rollback support (optional)
- Configuration validation support (optional)

NETCONF Layers

- Message security provided by the transport
- SSH is the mandatory to implement transport
- No standard configuration data models yet

NETCONF edit-config

- Powerful operation to modify a configuration
- Operation attributes at the XML element level specify the change requested for that element:
 - merge, replace, create, delete
- Test and validation options:
 - set, test-then-set,
- Error handling options:
 - stop-on-error, continue-on-error, rollback-on-error
- Confirmed commits with automatic rollback

NETCONF / SSH

```
S: <?xml version="1.0" encoding="UTF-8"?>
S: <hello>
S:   <capabilities>
S:     <capability>
S:       urn:ietf:params:xml:ns:netconf:base:1.0
S:     </capability>
S:     <capability>
S:       urn:ietf:params:ns:netconf:capability:startup:1.0
S:     </capability>
S:   </capabilities>
S:   <session-id>4<session-id>
S: </hello>
S: ]]>]]>
C: <?xml version="1.0" encoding="UTF-8"?>
C: <hello>
C:   <capabilities>
C:     <capability>
C:       urn:ietf:params:xml:ns:netconf:base:1.0
C:     </capability>
C:   </capabilities>
C: </hello>
C: ]]>]]>
```

NETCONF / SSH

```
C: <?xml version="1.0" encoding="UTF-8"?>
C: <rpc message-id="105"
C:     xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
C:   <get-config>
C:     <source><running/></source>
C:     <config xmlns="http://example.com/schema/1.2/config">
C:       <users/>
C:     </config>
C:   </get-config>
C: </rpc>
C: ]]>]]>
S: <?xml version="1.0" encoding="UTF-8"?>
S: <rpc-reply message-id="105"
S:     xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
S:   <config xmlns="http://example.com/schema/1.2/config">
S:     <users>
S:       <user><name>root</name><type>superuser</type></user>
S:       <user><name>fred</name><type>admin</type></user>
S:       <user><name>barney</name><type>admin</type></user>
S:     </users>
S:   </config>
S: </rpc-reply>
S: ]]>]]>
```

Configuration Mgmt

Configuration Languages

- Ideally, there would be a configuration language which can express network-wide configurations.
- Ideally, the language would be specific enough to allow effective tools to be build that can validate and translate configurations.
- Ideally, the language would be general enough to be used in many environments.

Policy Management

- Typically based on event / condition / action rules:
on <event> if <condition> do <action>
- Examples:
 - Ponder (Imperial College), based on formal logic
 - PCIM (IETF/DMTF), object-oriented extension to CIM
- However:
 - Large rule sets are hard to understand
 - Large rule sets typically contain conflicts
 - Translation of high-level policies to configurations often non-trivial (and a major cause for complicated rule sets)

Promise Theory

- Basic idea:
 - Devices are autonomous in their decisions
 - Devices may make promises to other devices
 - Devices can take advantage of promises by others
 - Graph-oriented framework and algorithms
- Promise theory makes dependencies explicit
- Promise theory assumes autonomy of devices
- Developed by Mark Burgess (EMANICS)

Other Related Topics

- Distributed monitoring
 - Distributed algorithms for data aggregation / fusion
- Exploiting P2P technologies
 - Self-organizing management overlays
 - Combine with ideas from self-stabilizing algorithms
- Trust relationships and reputation systems
 - Can we establish sufficient trust automatically?
 - Can we compute the reputation of a device?
- By putting things together, we hopefully move towards autonomic management

Conclusions

- Network management is an important area
- Consider management aspects of your work
- Search for simplicity, avoid complexity
- EMANICS and EuroNGI are relatives
- Remember RFC 1925:
 - With sufficient thrust, pigs fly just fine.
 - This does not mean we can afford the fuel costs.

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