# The NESTOR Project

Automating Configuration Mgmt

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## Self-Organizing Networks

- Self-organizing = adapt to changes
- ANets are self-organizing: change is the only constant
- Adaptation requires independent mechanism
- NESTOR provides self-organizing capabilities to networks
  - Maintains a model of network: objects-relationships
  - Detects changes
  - Adapts to changes by propagation among related objects
  - Controls propagation through constraints

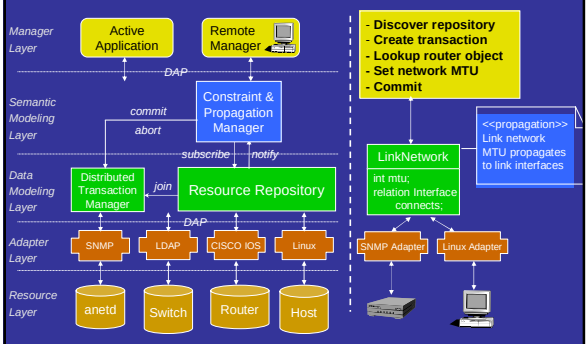


## Results

- Technology Results
  - NESTOR core technologies:
    - Unified data & semantic model for self-configuring networks
    - Programmable change policies: change propagation + constraints
    - Architecture
  - Network Management apps: enable mobile users
  - Security apps: maintain security through changes in use
- Impact
  - Telcordia Technologies: smart firewalls
  - ANET Demos: UCLA/Utah/UCB
  - ABONE [soon]



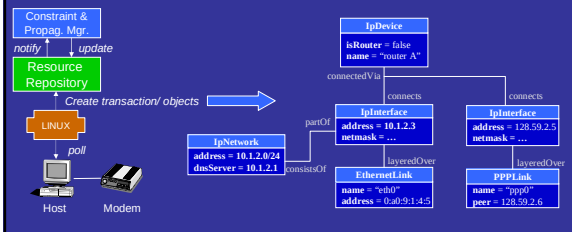
## NESTOR Architecture & Operations






## Modeling the World

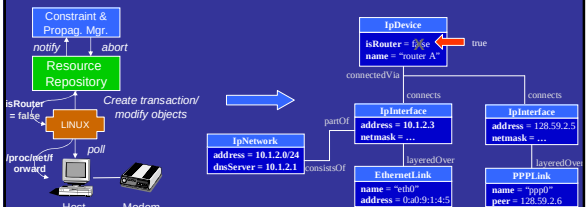
- Adapters poll devices/services
- Changes reflected as model updates
- Constraints & propagation rules trigger before model commit





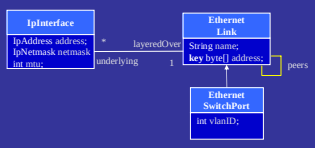

## Modeling the World (2)

- Real world issues:
  - No isolation
  - Compensating transactions
  - Management application starvation (priority issue)
- Assumptions on agent behavior required



## NESTOR Data Modeling

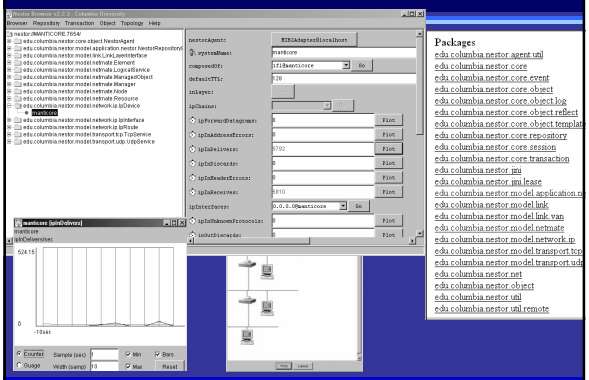
- Unified object-relation data model
  - Classes model static configuration (specialization through inheritance)
  - Relations model dynamic deployment
  - Challenge: defining unified schema




- Does not express semantic information
  - E.g., interface IP address must match network mask
  - E.g., interface MTU is should match the router's MTU



## User Interface & API






## NESTOR Constraints & Propagation

- Constraints on valid configuration (declarative)
  - Example: IP interface netmask must match address

```
IpInterface->allInstances
->select(i | (i.address != null) and
             (i.netmask != null) )
->forAll(i | i.netmask.matches(i.address))
```

- Configuration propagation rules (operational)
  - Example: Video active app. packet size ← interface MTU

```
MyVideoAA->allInstances
->forAll(app | app.packetSize :=
                app.connectedVia->
                          min(link | link.mtu))
```



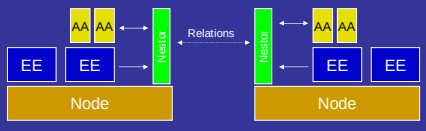
## Constraint & Propagation Challenges

- Simple navigation of relationships
- Propagation cycles
  - Change propagates over relations
  - Static analysis may be too conservative
- Bounding propagation
- Distribution of computation



## NESTOR-based AN Management

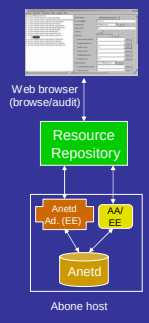
- Local NESTOR repository on each node
  - Standard (simple) models
- NodeOS, EEs, AAs discover local repository
  - Register objects, constraints, and propagation rules
  - Query repository to discover & configure needed services
  - Relations between AAs span repositories
- Unified instrumentation for security and accounting





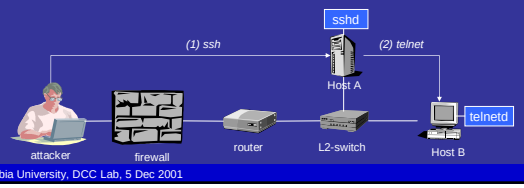

## NESTOR @ ABONE

- Anetd Adapter
  - Read/write configuration instrumentation
- Public "live" configuration browsing
  - Audit of configuration changes
- Virtual Active Networks (VANs)
  - Columbia 12-node VAN/ABONE test-bed
- EE/AA Author Instrumentation Kit
  - Load/unload/monitor EEs
  - Discover system configuration
  - Export instrumentation/constraints



## Telcordia Smart Firewalls

- DARPA DC Program (S. Rajagopalan PI)
- Difficult to ensure high-level service access policies
  - Manual configuration requiring security expertise
  - Networks are too dynamic
  - Current configuration tools cannot validate
  - Security polices must be enforced across multiple admin. domains
- Example: can someone telnet into network?





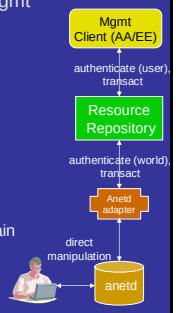

## Telcordia Smart Firewalls (2)

- Security policies
  - High level goals (allow/deny)
  - Invariants that must hold (not conditions-actions)
- Validation and Secure Change Management
  - Policy engine validates entire network configuration
  - Supports what-if queries
- Automatic policy enforcement using NESTOR
  - Network discovery/update, transactional commit
- Centralized user interface for network security administration



## NESTOR Security

- NESTOR provides security perimeter for mgmt
- Repository user authentication (X.509)
- Secure communications (TLS)
- Object-attribute level ACLs
  - Attribute/Relation/Constraint/Propagation
- Adapters trust repository
  - Real world treated as a user (with associated permissions)
- Propagation path analysis
  - Modeling (unified instrumentation) supports domain analysis






## API Summary

- Session
  - Repository discovery
- Nestor Repository
  - Create transaction
  - Create object
  - Lookup objects (by class/attribute)
  - Subscribe for changes
- Standard Model
  - Link, Network, Application layer objects
- Agent utilities
  - Morphing and polling



## Summary of Results

- Prototype implementation
  - Java/Jini based (>100K lines)
  - Distributed object-relation repository + standard API + standard model
  - Model compiler & constraint/propagation interpreter
  - Adapters: Linux, CISCO IOS, SNMP, LDAP, VAN, Anetd
  - Browser: repository, performance & topology visualization
  - Packaged & stable
- Demonstrations
  - DARPA (Princeton 1997, Seattle 1999, Atlanta 2000), USENIX Lisa'99
  - Telcordia demonstrations
- Technology Transfer
  - Telcordia Technologies: DARPA distributed firewall project
  - UCLA/UCB/Utah: DARPA Active Network integration demo
  - Soon: ABONE deployment



## Current Research & Plans

- Security features
- Propagation path analysis
  - Formal propagation model
  - Propagation domain analysis
- Public ABONE deployment
- Operational configuration recovery
- Auditing