Management of managed self-organizing network in network virtualization environment

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Outline of Talk

• Background
• Problem Statement
• Proposal: Managed self-organization
• Evaluation
• Conclusion
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Overview of Managed Self-Organizing Network

- **Aim:** Simplify management of network virtualization infrastructure through self-organization
- **Challenge:** Performance degradation due to resource contention
- **Proposal:** Architecture for stable accommodation self-organizing VNs

### Diagram Elements
- **VN Agent Controller**
- **Virtual networks**
  - VN#1
  - VN#2
  - VN#3
- **VN Agent**
- **PN Resource Manager**
- **Optical infrastructure** (physical networks)
- **VN quality monitoring**
- **Performance monitoring**
- **Feedback to activity**
- **Indirect control**
- **Performance monitoring**

### Abbreviations
- VN: Virtual network
- PN: Physical network
Background

- Network Virtualization provides controllability for users
- Users freely designs own topology for adaptability
- Introduce biology-inspired topology control scheme (=self-organization)

PN Resource Manger

VN topology designed by users

Biological system
Adaptive VNT reconfiguration

1. Initial Topology

VNT: Virtual Network Topology

Measurement

1. Optimized Topology
Background: Attractor selection-based control

1. Adaptability to unknown environmental changes
   - System finds attractor (=equilibrium point) through random search to adapt environmental changes.

2. Simplicity of control mechanism
   - Light-weight computation to find solutions
   - Works well with limited information.

Gene regulatory network (=Virtual networks)

Metabolic network (=Physical network)


Differential equation

\[
\frac{dx_i}{dt} = f \left( \sum_{j=1}^{n} W_{ij} x_j - \theta \right) \cdot v_g - x_i v_g + \eta
\]
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Our goal

- Establish resource management architecture for accommodating numerous VNs.

Some Design Principles
- Each VN is controlled according to self-organization for quick responsiveness.
  - VNs can freely acquire/delete virtual resources from PN for constructing optimal topology.
- Minimal Control: Ensure enough scalability in terms of network size and the number of VNs.
Problem we are solving

- High-performance network virtualization over optical network infrastructure.
  - Wavelength path between two V-nodes forms virtual link in VNT.
  - Dedicated wavelength resource is allocated to each VN for hard isolation.
- Key Question: Physical resource are limited. How to solve resource contention among numerous VNs?
  - Introduce minimal intervention for stability.
  ⇒ Design simple management architecture for self-organizing VNs.
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Our concept: Managed Self-Organizing System

- Limitations: Applying self-organization to multiple elements (i.e., VNs) can cause instability in case of emergency.
- Our solution: Introduce minimal control in resource allocation.

Self-Organizing System (SOS)
Has an ability to operate in a dynamically changing environment without centralized control.

Managed Self-Organizing System
Provides a range of operating regime by an external control while allowing a self-organization property

Fully distributed system
Emergence???
Self-organizing system
Self-organizing elements
Controller
Observation
Control
Hybrid control system
Self-organizing system
Self-organizing elements
Design approach

• **How to ensure scalability of resource management?**
  - To accommodate hundreds of VNs, we should avoid fully centralized control.
  - Introduce indirect control for resolving resource contention among self-organizing VNs.

• **Key observation for resource contention.**
  - *Same algorithm based on same information often cause synchronization.*
  \[ \Rightarrow \text{Inform different residual information to each VN for diversification.} \]
Resource management model

- Resource management system controls topology-awareness to each VN to avoid resource contention while allowing resource sharing to some resources.
  - Each VN utilize resources with “Right-to-use” privilege.
  - By combining resources with privilege, VN topology is created on-demand.
⇒ Virtual resource layer enables indirect control of self-organizing VNs.

VN is aware and can use resources with Right-to-use.

Physical resources aware to VNs

Assign Right-to-use to each wavelength

Virtual resource layer

Physical Link 1

Physical Link 2
Procedures for avoiding contention

1. Initial State
   - All resources are shared by VNs
   - VN can use every resource for constructing topology

2. Monitoring VN performance
   - Link load of VN is monitored.
   - If max load exceeds threshold, we consider resource contention occurred.

3. Regulate resource view
   - Regulate residual resource view for outperformed VN.
   - Allocate reserved resources for congested VN.

VN: Virtual Network
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Experimental Demonstration

- Developed network emulating systems for demonstrating our architecture.
  - Simulate behavior of multiple self-organizing VNs.
  - Generate traffic demand changes and topological failures.

**DUT**: Device under test  
**PN**: Physical network  
**VN**: Virtual network

**Diagram Description**

- **Algorithm** to VN topology
- **PN Resource Manager (DUT)**
- **VN Agent (DUT)**
- **GUI System**
- **Traffic Generator**
- **Virtual Networks**
- **Physical network**
- **VN Emulator function**
- **PN Emulator function**
- **VN DB**
Result 3: Asymptotic behavior

- Evaluate performance in simple 11-nodes Abilene topology.
  - SO fails to avoid resource contention.
  - Proposed mechanism quickly recovered performance by reallocating resources.
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Concluding remarks

• Summary:
  - Propose managed self-organizing network architecture
    · VNs controlled based on biological systems.
    · Require some mechanism for alleviating resource contention among VNs.
  - Basic idea is to regulate resource view for hot spot links
  - Simulation study demonstrated effectiveness of proposed algorithm
    · Quickly recovered performance due to sudden traffic change

• Future work:
  - Evaluate computation overhead of DRAMS.
  - Evaluation in large-scale network, more than 3 VNs.
Thank you for your attention

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