An Overview of the Bio-Networking Architecture

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Motivation

• Computer network environment is seamlessly spanning locations engaged in human endeavor.
• Need a self-organizing network that supports
  – scalability in terms of # of objects and network nodes,
  – adaptability to changes in network conditions,
  – availability/survivability from massive failures and attacks,
  – simplicity to design and maintain.
• Our solution: apply biological concepts and mechanisms to network application design
  – Biological systems have overcome the above features.
    • e.g. bee colony, bird flock, fish school, etc.
• The Bio-Networking Architecture is a new framework
  – for developing large-scale, highly distributed, heterogeneous, and dynamic network applications.
Biological Concepts Applied

- Decentralized system organization
  - Biological systems
    - consist of autonomous entities (e.g. bees in a bee colony)
    - no centralized (leader) entity (e.g. a leader in a bird flock)
      - Decentralization increases scalability and survivability of biological systems.
  - The Bio-Networking Architecture
    - biological entities = cyber-entities (CEs)
      - the smallest component in an application
      - provides a functional service related to the application
      - autonomous with simple behaviors
        » replication, reproduction, migration, death, etc.
        » makes its own behavioral decision according to its own policy
    - no centralized entity among CEs

- Emergence
  - Biological systems
    - Useful group behavior (e.g. adaptability and survivability) emerges from autonomous local interaction of individuals with simple behaviors.
      - i.e. not by direction of a centralized (leader) entity
      - e.g. food gathering function
        » When a bee colony needs more food, a number of bees will go to the flower patches to gather nectar.
        » When food storage is near its capacity, only a few bees will leave the hive.
  - The Bio-Networking Architecture
    - CEs autonomously
      - sense local/nearby environment
        » e.g. existence of neighboring CEs, existence/movement of users, workload, availability of resources (e.g. memory space), etc.
      - invoke behaviors according to the condition in a local/nearby environment
      - interacts with each other
• Lifecycle
  – Biological systems
    • Each entity strives to seek and consume food for living.
    • Some entities replicate and/or reproduce children with partners.
  – The Bio-Networking Architecture
    • Each CE stores and expends energy for living.
      – gains energy in exchange for providing its service to other CEs
      – expends energy for performing its behaviors, utilizing resources (e.g. CPU and memory), and invoking another CE’s service.
    • Each CE replicates itself and reproduce a child with a partner.

• Evolution
  – Biological system
    • adjusts itself for environmental changes through species diversity and natural selection
  – The Bio-Networking Architecture
    • CEs evolve by
      – generating behavioral diversity among them, and
        » CEs with a variety of behavioral policies are created by human developers manually, or through mutation (during replication and reproduction) and crossover (during reproduction)
      – executing natural selection.
        » death from energy starvation
        » tendency to replicate/reproduce from energy abundance
• Social networking
  – Biological systems (social systems)
    • Any two entities can be linked in a short path through relationships among entities.
      – not through any centralized entity (e.g. directory), rather in a decentralized manner.
      – six degrees of separation
  – The Bio-Networking Architecture
    • CEs are linked with each other using relationships.
      – A relationship contains some properties about other CEs (e.g. unique ID, name, reference, service type, etc.)
    • Relationships are used for a CE to search other CEs.
      – Search queries originate from a CE, and travel from CE to CE through relationships.

CE’s Structure and Behaviors

• Attributes
  – ID
  – Relationship list
  – Author
  – …etc.
• Body
  – Executable code
  – Non-executable data

• Behaviors
  – Energy exchange and storage
  – Migration
  – Replication
  – Reproduction
  – Death
  – Relationship maintenance
  – Social networking (discovery)
  – Resource sensing

Cyber-entities running on a bionet platform
Design Strategies of the Bio-Networking Architecture

• Separate cyber-entity (CE) and Bio-Networking Platform (bionet platform),
  – Cyber-entity (CE)
    • mobile object (agent) that provides any service logic
  – Bionet platform
    • middleware system for deploying and executing cyber-entities

• Implement CE and bionet platform in Java

Current Status of the Bio-Networking Architecture Project

• Our group members have been working on
  – Design and implementation of the bionet platform
  – Distributed (i.e. peer-to-peer) discovery
    • Discovery mechanisms and simulations
    • Generic framework for various discovery mechanisms
  – Adaptation and evolution mechanisms
    • genetic algorithms
      – Simulations
      – Empirical study
    • Artificial immune system
      – Simulations
  – Dynamic composition of cyber-entities
  – Mathematical stability analysis
  – Standardization effort at the Object Management Group
Applications of the Bio-Networking Architecture

• Content distribution
  – Simulations done
  – now empirical deployment underway
• Web service
  – Simulations underway
• Peer-to-peer overlay networks
  – Simulations underway
  – empirical deployment underway
• Disaster response networks
  – Just started

Thank you

• All the papers/documents related to the Bio-Networking Architecture are available at:
  – netresearch.ics.uci.edu/bionet/
  – netresearch.ics.uci.edu/bionet/resources/platform/
• Sponsors
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