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
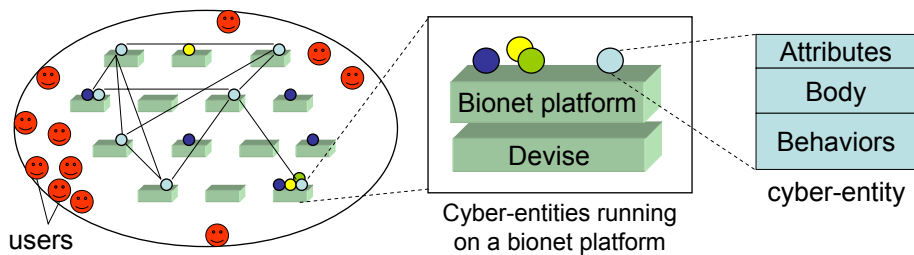
- Social networking
  - Biological systems (social systems)
    - Any two entities can be linked in a short path through relationships among entities.
      - not through any centralized entity (e.g. directory), rather in a decentralized manner.
      - six decrees of separation
  - The Bio-Networking 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

users

Bionet platform

Devise

Cyber-entities running on a bionet platform

Attributes
Body
Behaviors

cyber-entity

- 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

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
  - NSF (National Science Foundation)
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