Our Assumptions on the Disaster Infrastructure

- Ad-hoc net spontaneously established in a disaster area to evacuate victims and aid emergency response crews.

- Various devices participate in the disaster ad-hoc nets.
  - Victims carry their own devices.
  - Emergency response crews carry and/or wear devices.
  - Emergency vehicles (e.g. fire truck, ambulance) carry devices.
  - Sensors are densely scattered (e.g. scattered from helicopters).
Our Assumptions on the System Characteristics

• Large scale with a number of
  – people/organizations
  – devices
  – software objects
  • Objects represent devices, execute device-specific functions (e.g. temperature sensing), or carry information (e.g. map, a building’s floor plan and air contamination).

• Heterogeneous
  – processing, memory and networking capabilities of devices
  – functionalities of software objects

• Dynamic
  – changing network connectivity, density, and traffic
  • Connectivity and density change due to movement of users/devices and additional deployment of devices and software objects.
  • Traffic changes depending on the rescue operation stages
    – e.g. The traffic among temperature sensors increases while fire occurs.
  – intermittent availability of devices and software objects

Research Goals

• To design an application architecture which
  – meets key requirements of applications running on disaster response networks (i.e. large-scale, heterogeneous and dynamic networks).
  – diminishes the maintenance/administration burden of disaster response network applications.
A New Application Architecture

• Key requirements in disaster response network applications
  – *scalability* in terms of # of objects/devises/users,
  – *adaptability* to dynamic changes in network conditions
  – *availability/survivability* from failures
  – *simplicity* to develop and maintain.

• The Bio-Networking Architecture
  – applies biological concepts and mechanisms to network application design
    • Biological systems already have above required characteristics

Cyber-Entity (CE)

• Biological individual = Cyber-entity (CE) (objects)
  – Abstraction of system components (e.g., victim, rescuer, service, etc.)
  – provides service (e.g. temperature sensing, providing information such as building’s floor plan).
  – autonomous with simple behaviors
    • migration, replication, reproduction, death, energy exchange, relationship establishment, discovery

• Application
  – constructed from a collection of interacting cyber-entities
Biological Concepts Applied

• Emergence
  – Useful group behavior (e.g. adaptability and survivability) emerges from autonomous local interaction of individuals with simple behaviors.

• Lifecycle
  – energy gain/consumption/exchange
    • CE gains energy in exchange for providing its service.
    • It expends energy for using resources (e.g. CPU and memory) and performing behaviors (e.g. migration and replication)

• Adaptation and evolution
  – CEs evolve by generating behavioral diversity and executing natural selection.
  – replication (with mutation), reproduction (with mutation and/or crossover) of CEs

• Decentralized system organization
  – to increase scalability and robustness
  – e.g., decentralized discovery
    • Each CE keeps relationships with others. Discovery is performed based on CE’s unique ID and attributes through relationships in a peer-to-peer manner.

Application Scenario 1: Wildfire

• Disposable sensors are scattered over an affected area
  – e.g. temperature, wind force, oxygen, smoke sensing
  – Some of them are broken if they fall into a fire.
  – The CEs within sensors do their sensing tasks and maintain relationships with each other.

• Each fire fighter has devises (e.g. info pad, sensors).
  – The CEs within the devises may
    • direct the fire fighter to a place to extinguish a flame, even when visibility is not good, by interacting with scattered sensor CEs.
      – The CEs may suggest a safer (i.e. lower temperature, less air contaminant) route to the place from multiple options.
    • display the current positions of the fire fighter and other fighters by interacting with other fighters’ CEs and the CEs that provide map information.
    • display the current area affected by fire(s) by interacting with sensor CEs.
    • sense what is happening nearby (e.g. approaching blaze) by interacting with neighboring sensor CEs, and alert the crew that.
Application Scenario 2: Building Collapse

- The CEs within victims’ devises may
  - find rescuers through passing advertisement (e.g. “I’m here” beacon) or asking its relationship partners (they will ask their partners in turn).
  - provide an evacuation path to the victim by interacting with sensor CEs.
  - obtain the first aid treatment information for injured victims by discovering and inquiring the CEs that provides the information.

- The CEs within rescuers’ devises may
  - locate victims, represented by CEs, through passing advertisement or asking its relationship partners (they will ask their partners in turn).
  - display a street map or building floor plans depending on the rescuer’s current position.
  - examine what is happening near the rescuer (e.g. gas leaking and approaching blaze) by discovering and inquiring nearby sensor CEs.

- A CE that provides any information may
  - adjust its population through replication, reproduction and natural selection (energy exchange) depending on the demand;
  - adjust its location through migration (e.g. toward users) and resource sensing (e.g. more CEs on the devises that provide more resources).

Current Status and Future Work

- Current status
  - Design and implementation of a platform software
    - OMG standardization (Super Distributed Objects group)
  - Distributed (i.e. peer-to-peer) discovery
  - Adaptation and evolution
  - Service interface description language
  - Mathematical stability analysis

- Future work
  - Deployment and empirical study
  - Reconfigurable middleware