

# Self-Organization and Nanoscale Networking

Workshop on Nanosensors  
Nano-Net 2008

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## Workshop Process

- ▶ Workshop is informal
- ▶ Need a scribe to summarize results
- ▶ Answer tough questions and deliver useful results
- ▶ Results (if any) from workshop will be placed on the website

## Suggested Workshop Objectives

1. How do we define nano-scale communication?
  - ▶ Is there a unique and common fundamental characterization?
2. What is the fundamental relation between nano-scale communication and self-organization?
3. Why have swarm-like and other “emergent” simulation software (e.g., Swarm and RePast) failed to provide significant insight?
  - ▶ ... after so many years of development and use?
4. What are the merits of existing hardware platforms and common testbeds for automated swarm inspection?
  - ▶ ...both nano and micro scale
5. What standards exist and which are needed to advance the engineering of nano-scale swarm inspection into mainstream use?

## Strawman Requirements for Swarm Inspection

Robotic CTQs: imaging problems such as, lighting, image registration (distributed), etc...

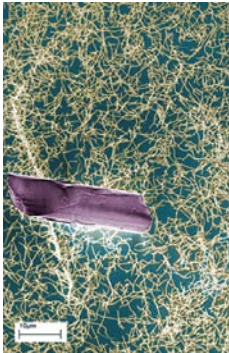
- ▶ Turbine/engine inspection
- ▶ Currently  $\approx 200$  inspections per year
- ▶ All tethered now– fear of losing a robot
- ▶ Snake robot– by “Magic”
- ▶ No autonomy
- ▶ Avoid taking engines apart– saves downtime
- ▶ Ultra-sound communication through devices
- ▶ “Pill” inspection concept

## Self-Organization and Communication Relationship

1. Should self-organization and nano-communication be considered orthogonal processes?
  2. What are common characteristics of nano-communication channels?
- ▶ Communication and Self-organization should be Fundamentally Related
    - ▶ Self-organization requires inherent communication: elements need to sense one another
    - ▶ Communication requires self-organization: routing/addressing/etc...
    - ▶ Can we find a simple mutual information relationship?
      - ▶  $deg(\text{self-org}) = I(X; Y), \forall X, Y$

## Nanotubes and the Internet

- ▶ How does information flow at the microscopic level fundamentally differ from macroscopic communication?
- ▶ Human hair fragment with nanotube network  $\Leftrightarrow$  the Internet

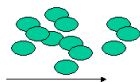


## Channel Mass Displacement

- ▶ How much mass (per bit) must be displaced to enable communication in each type of media?
- ▶ ...becomes significant as we scale down...

### Channel Mass Displacement

How much mass must be displaced per bit per second?



Diffusion



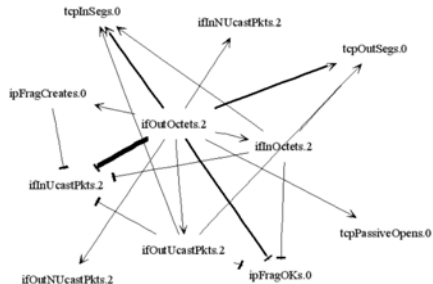
(EM) Waves



CNT Network

## Perturbation Analysis and Nano-scale Communication

- ▶ Interactome for molecular information flow (modulating concentration levels)
- ▶ Communication optimal with small perturbations – reducing mass displacement per bit



**Figure:** Inferred interactions of base upon perturbation in SNMP MIB variables when node under attack

## Tools and Platforms

I would like to learn more from you!

- ▶ Many biological diffusion simulators – which best for molecular channel modeling?
- ▶ Random nanotube layout: GE Mathematica simulator [1]
- ▶ Many quantum computing (network) simulators: Mathematica/Matlab packages
- ▶ Many agent based simulation tools: Swarm, Repast, etc...

## Suggestion for Joint Simulator

- ▶ I'm not aware of a free commonly available nanoscale communication simulation package
- ▶ Until we have a such a package, nano-scale self-organization studies will be severely hampered
- ▶ Propose standards/protocols?
- ▶ Work toward common simulation platform?
- ▶ Better incorporate nano-scale physics into the channel/system
  - ▶ Diffusion/nanotubes/etc...
  - ▶ Mass/attraction/viscosity/etc...
  - ▶ Need a better model of the nano-scale world

## Standards/Protocols

Where would the enabling standards come from? How do we make something happen?

- ▶ Workshops
- ▶ IEEE Emerging Technologies Subcommittee on Nano-scale Networks (meeting tomorrow at Noon)
- ▶ IEEE Nano-technology Standards Committee
- ▶ IETF
- ▶ Perhaps just need to define common interface to tools, SBML

## Conclusion

- ▶ Are these the right questions?



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Graph spectra of carbon nanotube networks: Molecular communication.

*In Materials Research Society 2006 Fall Proceedings, number 0951-E04-06, 2006.*