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 loosing 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?
    - $\text{deg}(\text{self-org}) = I(X; Y), \forall X, Y$
Nanotubes and the Internet

- How does information flow at the microscopic level fundamentally differ from macroscopic communication?
- Human hair fragment with nanotube network ⇔ 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?
S. F. Bush and Y. Li.
Graph spectra of carbon nanotube networks: Molecular communication.