DEGAS (Distributed EnerGy conscious Ad hoc and Space networking) Group

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Current Research Projects

- **NSF: Ad hoc Networking with Swarm Intelligence**
  - Unicast and multicast routing
  - Topology control
  - Energy conservation
  - Cross-feature and cross-layer issues
- **NSF: Scalable Wireless Testbed (joint with UCLA, UCSD, UCSB, UCD, UCR, USC)**
  - Transport layer issues – Cellular SCTP and Ad hoc SCTP
- **NSF: CAREER-Survivable Hybrid Networks**
  - Hybrid routing and transport protocols
  - Trajectory control
  - Utility maximization of TCP over wireless links
- **ARL: Ad hoc Networking with Power and Directionality Control**
  - Topology control with directional antenna
  - Broadcast and multicast with directional antenna

Swarm Intelligence

Without reinforcement, pheromone evaporates ***(negative feedback)***

- Ants likely choose paths with higher pheromone intensity
- Trail gets reinforced ***(positive feedback)***

Ants lay pheromone

skip

Swarm Intelligence

But some may choose alternate paths with small probability ***(amplification of fluctuation)***

Most ants follow trail with highest intensity

Pheromone Trail

skip

Essence of Swarm Intelligence

- Positive and negative feedback
  - search good solutions and stabilize the results
- Amplification of fluctuation
  - discover new solutions and adapt to changing environment
- Multiple interactions
  - Allows collaborations among distributed entities to coordinate and self-organize

A distributed adaptive control system

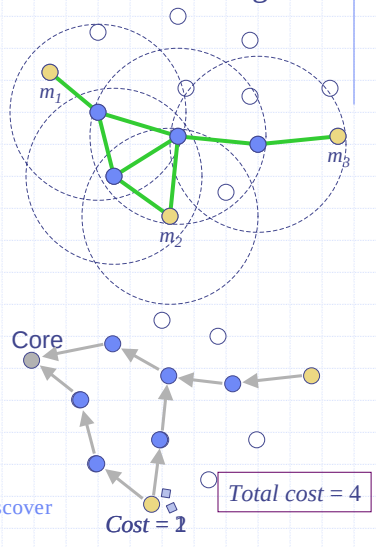
Ad hoc **N**etworking with **SI** (**ANSI**)

- Unicast routing (ANSI)
- Multicast routing (**MANSI**)
- Topology control (**ABTC**)
- Energy conservation (ABEC)
- Feature interactions – cross-layer and cross-feature

MANSI

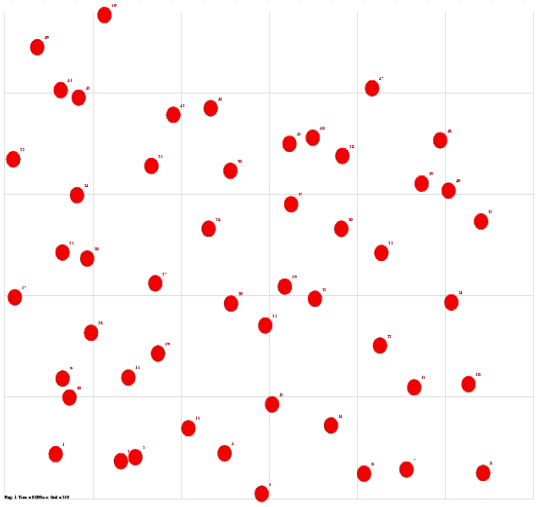
⇨ ***M***ulticast for ***A***d hoc ***N***etworks with ***S***warm ***I***ntelligence

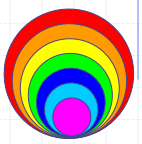
- MANSI extracts a subset of nodes, called a **forwarding set**, for rebroadcasting data packets
  - ➔ Mesh-based, reactive protocol
- *Issue:* A minimum forwarding set is hard to compute
- *Approach:* Use SI-based technique as a heuristic to opportunistically explore and learn new paths that lead to forwarding set of lower cost
- In high mobility areas, more nodes are requested to form a forwarding set to increase reliability



Ants *opportunistically* discover other paths

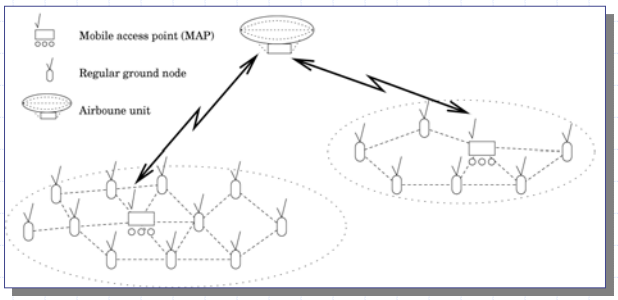
ABTC: Ant-Based Topology Control





Trajectory Control for MAPs in MANET

- Rugged terrains or specific mission requirements can cause a network to be partitioned into isolated islands of nodes
  - Nodes in different partitions still need to communicate



- Network Model
  - **Mobile Access Points (MAP)** resides in each partition
  - MAPs are highly capable nodes and always connected via airborne unit(s) in order to bridge partitions together
  - MAPs' movement can be controlled by a trajectory control algorithm

Trajectory Control Algorithms

- ***Location-based (LTC)***
  - GPS is required at regular nodes and MAP
  - Each node maintains a list of its downstream nodes with respect to the tree generated by MAP announcement
  - Weighted geometric centroid of each subtree is computed recursively and combined all the way to MAP
  - MAP navigates to the weighted centroid of the entire partition

Future Research

- **Salutogenic approach to robust P2P systems over mobile ad hoc and wireless sensor networks**
  - Apply biological metaphors to design functional primitives that can be composed to build robust P2P systems over MANET and SN
- **Toward virtual and open spectrum**
  - Dynamic spectrum management architecture and protocols
  - Software-defined radio