SAFARI

Scalable architecture for ad hoc routing & internetworking

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Ad hoc networking

Connectivity (failing)
Mobility (ubiquitous)
Organization (overwhelming)
Challenges in Large ad hoc networks

- Large routing tables vs extensive searches
- Long routes break more often
- Promising approaches
  - Hierarchical structures
  - Landmarks and anchors
SAFARI Goals

**Scale** to ten-thousands of nodes
Self-organizing, adaptive

Higher lever services
Applications
Integrate available Network Infrastructure
SAFARI Architecture

...in a nutshell
Buoys emit beacons

- Nodes *self-elect* to become a *buoy*
Buoys emit beacons

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- Nodes **self-elect** to become a **buoy**
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- Buoys emit beacons
Cell formation

- Nodes *cluster* around closest buoy
  - Distance: Hop counts of beacon
Cell formation

- Nodes cluster around closest buoy
  - ...forming cells
Hierarchy

- Buoys *self-elect* to become *level-2 buoys*
Hierarchy

- Buoys self-elect to become level-2 buoys
- **1-buoys** cluster around closest 2-buoy
Hierarchy

- Buoys self-elect to become level-2 buoys
- 1-buoys cluster around closest 2-buoy
- Inherit and iterate
Coordinates

- **Hierarchy** of cells: coordinates
Coordinates

- Hierarchy of cells: coordinates
Coordinates

- Hierarchy of cells: coordinates
- Inserted in p2p fashion
Hybrid routing

• Look up coordinate of receiver
Hybrid routing

• Look up coordinate of receiver
• Route towards **buoys** of receiver
  – Back-trace the beacon
  – Local route repair

(receiver sender)
Hybrid routing

- Look up coordinate of receiver
- Route towards **buoys** of receiver
  - Route towards receiver’s buoy of highest level different from own
Hybrid routing

- Look up coordinate of receiver
- Route towards **buoys** of receiver
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Hybrid routing

- Look up coordinate of receiver
- Route towards **buoys** of receiver
- In the receiver’s cell: On demand (**DSR**)
Safari Scalability

- **Hierarchical Structure**
- **Transparency**
  - structure-routing-overlay
- **Hybrid routing**
  - Local: *on-demand*
    - Less coordinate updates
  - Global: proactive yet *distributed*
    - Small routing tables (*towards* buoys)
    - Small packet header (coordinate, no route)
Ongoing Projects

Transition and Equilibrium
Maintenance and Operation
Simulation and Experiment
Transition and Equilibrium

• Buoy formation 101
  – Node self-elects if no buoy is close
  – Buoy retires if too close to other buoy

• Transitions:
  – Cold start at failure of wireless infra-structure
  – Merging and partitioning of network

• Equilibrium:
  – Buoy changes/hand-over due to failure/mobility

• Overhead:
  – Beacon
  – Coordinate updates
Start-up: Car parking problem

• Cars arrive at random locations
• Park if gap is sufficiently long

• Street will reach \textit{jamming limit}
• \textit{Renyi}: on average 74.75\% of space occupied
Helicopter parking problem

- Placing discs in the plane
- Feder:
  - On average 54.7% of spaced occupied
  - Convergence rate to jamming limit

- Safari:
  - Number of buoys forming \( \sim \frac{1}{\text{designed distance}} \)
  - Rate of convergence to equilibrium
    #buoys still to form \( \sim \frac{1}{\sqrt{t}} \)
Maintenance and Operation

• Buoy fluctuations due to mobility
  – Using a simple collision model for a gas

Time evolution of # of buoys:

\[
\frac{dN(t)}{dt} = -\frac{R_v N(t)^2}{\sqrt{2A}}
\]

\[
\frac{1}{N(t)} = \frac{1}{N} + \frac{R_v t}{\sqrt{2A}}
\]

– Provides the fluctuation rate in equilibrium

• Route repair / routing overhead
• Coordinate insertion and update
• Buoy hand-over
Future work
Future

• Designed experiments
• Test-bed
• Applications and higher level services
  – Adapted to provided structure
• Topology and mobility awareness (node/network)
  – Reactive (Overhear) and proactive (Beacon)
  – For buoy formation and routing
  – For optimal and adaptive configuration
• Analytical models
  – For mobility
  – For adaptive hierarchical structure
  – For connectivity
  – Traffic: Space-time-mobility-fading
• Security and Malicious behavior
• Sensor networks
• Integration of wired Infra-structure

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