Lowering the Barrier to Wireless and Mobile Experimentation

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Key Idea

- One or more shared wireless testbeds
  - Would greatly enhance experimental wireless research
  - Are practical
  - Research in wireless can have *impact*
- Same for sensors
- Same for mobility
  - But with added complexities and expense
- "W/S/M" = wireless/sensor/mobile

The Opportunity: W/S/M are Ripe for Research Impact

- New areas, lots of open problems
  - Constrained resources
    - Power
    - Bandwidth
  - …
- Burgeoning importance
  - WiFi, Sensors, Military, …
- Not ossified!

Barriers to Wireless & Mobile Experimentation

- Poor simulation models, lack of validation
  - Indoor propagation models especially
  - No models of new technologies
- Lack of realistic mobile scenarios
  - Randomized, simulated
- Tedious experimental setup
  - Wireless horrible like wired, but worse
  - Mobile even worse
- Lack of availability and scale

Current State of the World

- Mobicom community doesn't build systems
  - Almost all is simulation
  - Limited impact?
- A few mobile testbeds proposed, not built
- Wireless and sensor testbeds
  - Only at UCLA, USC, Intel Research, Rutgers, …
  - Small to modest scale
  - Not shared or remotely accessible
  - Not automated

W/S/M Testbed Opportunities

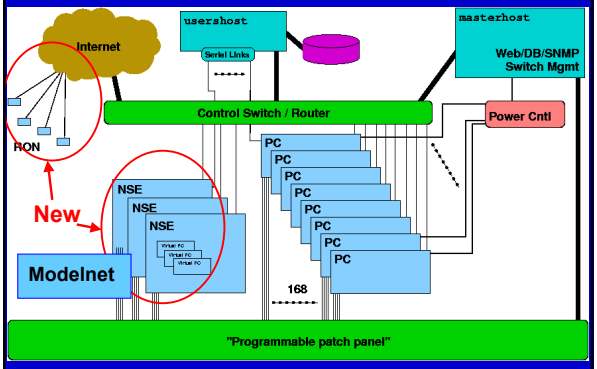
- Emulab/Netbed automation, control, uniform and rich interface
  - "OS for network experimentation"
- Limited scale realistic in these domains

Netbed/Emulab Background

- An instrument for experimental CS research: networks, dist systems, smart storage systems, OS's, …
- Universally available to any remote experimenter (via Web, ssh)
- Space-shared and time-shared
- All node software replaceable by users
- *Simple to use!*

Stats (as of June 2002, now ~10 more)

- 48 *active* projects, from 35 institutions
- 18 additional projects registered
- 276 registered users
- July 01 – June 02, users:
  - Ran 2176 "experiments"
  - Allocated 17,299 nodes
  - Exchanged 2115 email msgs with our operations staff
- About 40/30/30%
  dist sys/activenets/traditional networking
- Resulting papers at SOSP, OSDI, Infocom, ICDCS, …
- 3 networking classes



Lesson: value of sophisticated software for *efficiency*

- Versus manual configuration:
  - 3.5 hours manual vs. 3 minutes (70x)
- To serve the last 12 months' load, without time-sharing cluster would have required 1064 nodes instead of 168.
- Without space-sharing, would have required 19.1 years instead of 1.
- Scaling of local (emulated) expt creation:
  2.2 minutes for 1 node,
  6.6 minutes for 80 nodes (3.3 secs/node)
- Simulated node/link scaling via *nse:* 90-100x

Lesson: "an OS/VM for network experimentation"

- Same software easily maps to other mechanisms!
  - Emulated nodes and links
  - Wide-area nodes and links
  - Virtual machines
  - Simulated nodes and links
  - ModelNet (coming)
  - Wireless and mobile
- Next: evolve software into components

Common Abstractions, Map to Different Mechanisms

- Nodes
  - Machines, Accts, VMs
- Addresses
  - IPv4, IPv6, link, port, …
- Links
  - VLANs, tunnels, Internet paths, special channels or HW
- Topology
- Topology generators
- Queues
- Queuing disciplines
- Traffic generators
- Applications
- Monitors: links, nodes
- Topology, traffic vis.
- Routing
- Events
- Sync, startup, replay
- Control channel/net

Common Abstractions (cont'd)

- "Experiment"
  - Config, active entities
  - Life cycle
  - Default environment
  - Customization:
    - Per-expt
    - Per-node
    - Per-run
  - Hard state
  - Soft state
  - Initial/clean state
- Restart
  - Node, Apps, Traf gens, events
- Projects
- Users
  - PI, TA/lieut, members
  - Credentials (keys)
- Experiments

Ok, enough history…

What about Wireless & Mobility?

Our Approach: Exploit a Dense Mesh of Devices

- **Density enables broad range of emulation**
- **Wireless**
  - Deploy devices throughout building or campus or desert
  - Employ diversity: 900 MHz, IEEE 802.11, software radios
  - Separate control plane, including power
- **Mobile**
  - Leverage passive "couriers"
    - Assign PDAs to students walking to class
    - Equip public transit system with higher-end devices
  - Provides a realistic mobile testbed

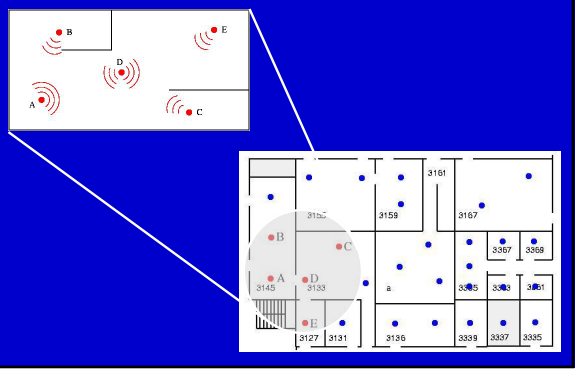
Primary Challenges

- User interface
  - Combinatorial optimization challenge
- RF interference

Three Possible User Interfaces

- **Manually select from deployed devices**
  - **Red (taken), Yellow (some interference), Green (avail)**
- **Specify desired spatial layout**
  - Netbed selects closest mapping
- **Specify desired device and path properties**
  - Netbed selects closest approximation

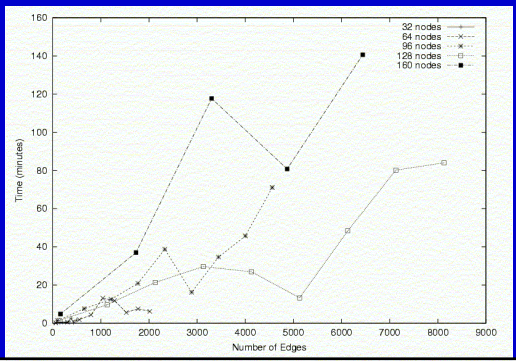
Virtual to Physical Mapping



Find Best Matching Links

1. Measure NxN path characteristics (e.g. power, interference, bit error rate)
2. Users requests certain node/link characteristics
3. Use combinatorial optimization approach to find best matching set of nodes & links

Find Best Matching Set: Scaling of Genetic Algorithm



Problem: Interference

- Inherent!
  - Popular technologies are of the most interest but the most likely to be present
- Three reasonable recourses:
  - Isolated geographic area/building
    - Hanger, desert
  - Negotiating for exclusive access to some channels
  - Study upcoming technologies instead

Possible Dual Role for Sensors

1. Objects of research themselves
2. Aid the RF research:
   - Monitor the physical environment and RF characteristics, simultaneously, for very long times. E.g,
     - People present?
     - Door open or closed?
     - Rain?
     - Temperature
   - Derive models for the environmental dependencies of RF characteristics

Mobility

- Passive couriers that move semi-predictably in time and space
  - Students to classes
  - Busses on roads
- Robots – RC cars

Mobile Scenarios

- Reproducible?
  - Not perfect
  - "Somewhat repeatable"
  - The perfect is the enemy of the good!

Provides Realistic Mobile Scenarios!

- Turn apparent drawback into an asset
- By definition, provides behavior representative of real world
- No inaccurate simulation models
- Regular, not repeatable. Study predictability of group movements: important for ad hoc networking

Summary

- Shared wireless/sensor/mobile testbeds could have large impact
- Programmatic control, automated mgmt, and complete virtualization yield a
  - Qualitatively new environment
  - That opens up new possibilities
- Opportunity for impact