Session III: Future Internet
Architecture and Protocols and
Integration of Mobile/Wireless/Sensor
Requirements
Agenda

• Waveform Agility and the Next Generation Internet
  – Ram Ramanathan

• Mobile IP and ad hoc networking in the Internet
  – Dave Johnson

• (Phy-Link) Layers in the Brave New World
  – Nitin Vaidya

• Networking in the small - Lessons for Internet at Large
  – Shalini Periyalwar

• Network X-ities for Wireless Networking
  – Jim Kurose

• Self Managing Wireless Networks
  – Victor Bahl

• Architectural Implications of Multi-dimensional scalability in Wireless Networks
  – Peter Steenkiste

• Architectural considerations of Location-aware networking
  – Marco Gruteser

• Learning Wireless Networks
  – Ramesh Rao

• Discussion
Themes

• What are the disruptive features of existing and emerging wireless networks?

• What impact do they have on the architecture of the Internet? Where does it break and what do we need that we don’t have?

• How can they be integrated into a next-generation architecture?

Breakout session at 9:45 tomorrow will further discuss these
Waveform Agility and the Next Generation Internet

Ram Ramanathan
Internetwork Research Department
BBN Technologies, Cambridge, MA
(ramanath@bbn.com)
Three disruptive trends
Increasing waveform diversity

• Waveform: The transmission/reception technology used for wireless communications, especially with respect to modulation, coding, spreading etc. (in other words the “physical layer protocol”)

• The diversity of available waveforms has been rapidly increasing
  – Beamforming
  – Multiple-Input Multiple-Output (MIMO)
  – Ultra-wide Band (UWB)
  – Orthogonal Frequency Division Multiplexing (OFDM)
  – Spectrum-adaptive/Heteromorphic waveforms

• Each is useful in its own way and very different from others
  – E.g. MIMO is great in multipath-rich urban environments, but introduces processing latency; UWB is high-capacity but short range

• The link *profile* created by each of these is unique in terms of capacity, latency, error rate, variation in latency and error rate, volatility, etc.
Software - Agile - Cognitive Radios

- **Software Radio**
  - Signal processing functions in software and so easily changeable
  - Many kinds, depending upon where hardware/software boundary exists (software defined, soft)

- **Waveform Agile Radio**
  - A particular way of using software radios
  - Sense environment and adapt transmission characteristics

- **Cognitive Radio**
  - Knows about itself, environment, policies, needs
  - Use reasoning and learning
Ad hoc / Mesh Networks

- Sudden increase in IEEE standards bodies interested in ad hoc / mesh networks, community wireless, vendors, etc.
  - 802.11s, 802.16a, 802.15.5, 802.20 ….

- Quite possible that the Internet will evolve to have a hybrid wired/wireless infrastructure
  - Wireless access points, special rooftop nodes, standardized wireless routers
The confluence of three disruptive trends
Waveform agility to topology control

- The variety in the profile of links, and hence paths, will be enormous

- “Link” is no longer just an input to control mechanisms (such as routing protocols), but also a parameter that can and needs to be controlled
Impact

- Mesh networks may only be stubs in the Internet
  - As is commonly depicted in most pictures

- But they could well be *transit* networks too?!
  - Increasing performance equality with wired networks may make them tempting alternate paths especially in regions of poor wireline connectivity (rural/remote areas)
  - Is already being designed into the next generation U.S military networks

- Waveform/link/topology agility and definability has a **major** impact on the architecture if the latter happens
  - Should a new architecture consider this possibility?
  - Does the impact depend upon architectural solution: e.g. overlays vs new end-to-end architecture?
Eventual Connectivity

• Deliver packets when network is disconnected at any particular period of time, but the union of the topologies over a period of time yields a connected network

• IRTF Delay Tolerant Networking and DARPA Disruption Toler. Netw.
  – Persistent store and forward with “custody transfer” of bundles
  – Scheduled links
  – Designed as an overlay network

• On-demand links
  – Links that are created by deliberate launching or movement of nodes
  – Message ferries
  – Data hauling
Some design implications for the Next Generation Internet due to the confluence of the three disruptive trends
Architectural Implications

• Instead of abstraction and hiding details of lower layers, the entire system must be cognizant of and exploit physical layer flexibility
  – Cross-layer and beyond to new layering

• Routing protocols should be able to control the topology of the wireless part of the network
  – Should be able to vary the communication waveforms and create desirable topologies
  – “Made to order” links, including using message ferries

• Transport protocols should incorporate feedback control mechanisms that are adaptive to a wide range of underlying-media characteristics
  – They must be (or must be overlaid with) delay-tolerant and disruption-tolerant (mechanisms)

• Spectrum-agile/cognitive radios require *policy framework* for accreditation
  – Architecture must support machine-encodable policies so that automatic conformance checking and behavior modification is possible
Summary

• Three trends are in play with significant combined impact
  – Waveform diversity
  – Agile/cognitive radios
  – Mesh networks

• Diverse, agile, controllable, tradeoff-able links….  
  – are not part of current Internet architecture…. 
  – but need to be in order to exploit the resources to the fullest

• Next generation architecture should allow for a high degree of flexibility, adaptivity
  – Rethink layering
  – Rethink the notion of “interfaces”/“links” not just as “input” but also a “parameter”
  – Think about reconfigurable hardware for experimental testbeds