



Wireless Mesh Networks Performance

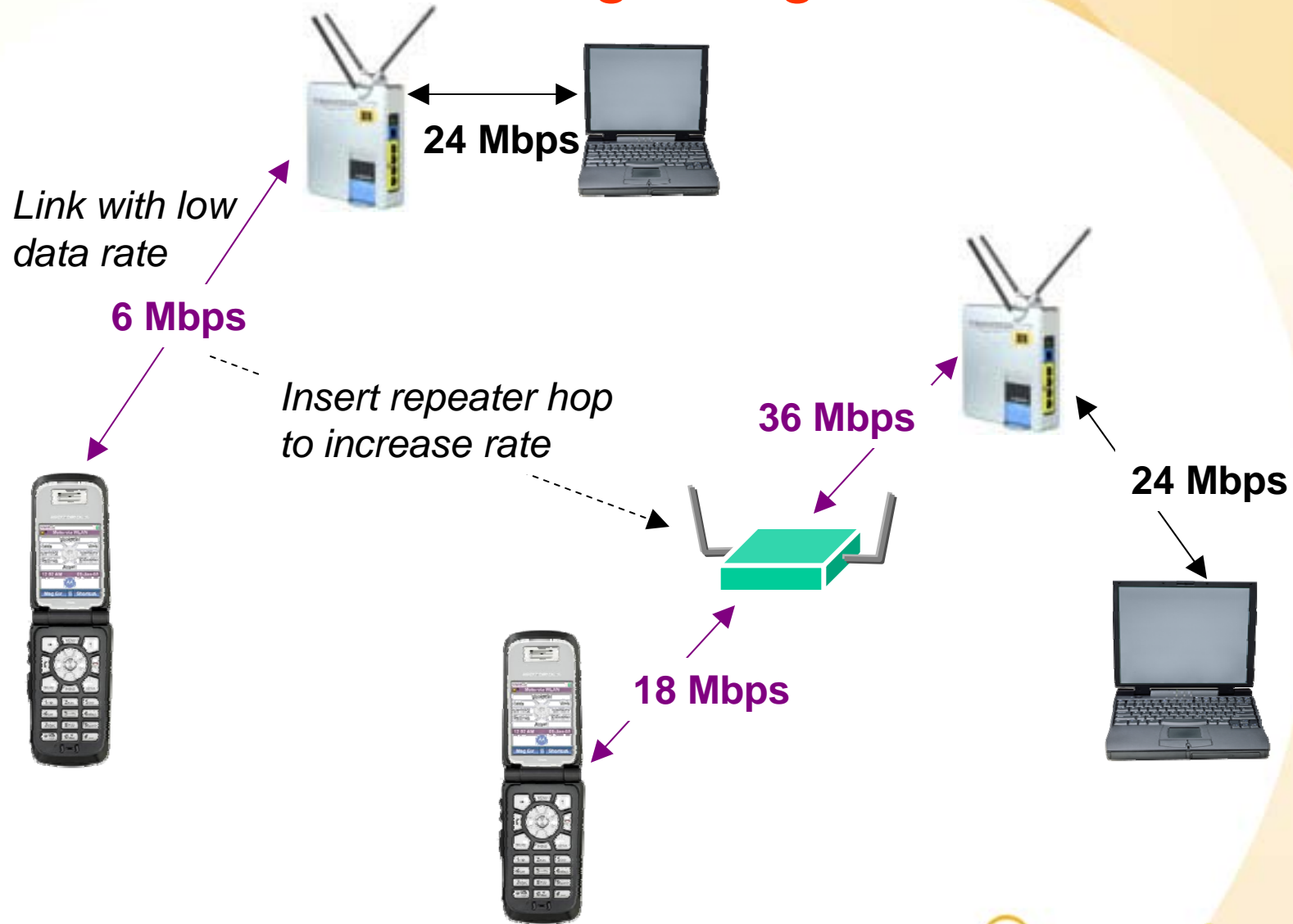
VON Mesh Networking Panel

March 2007

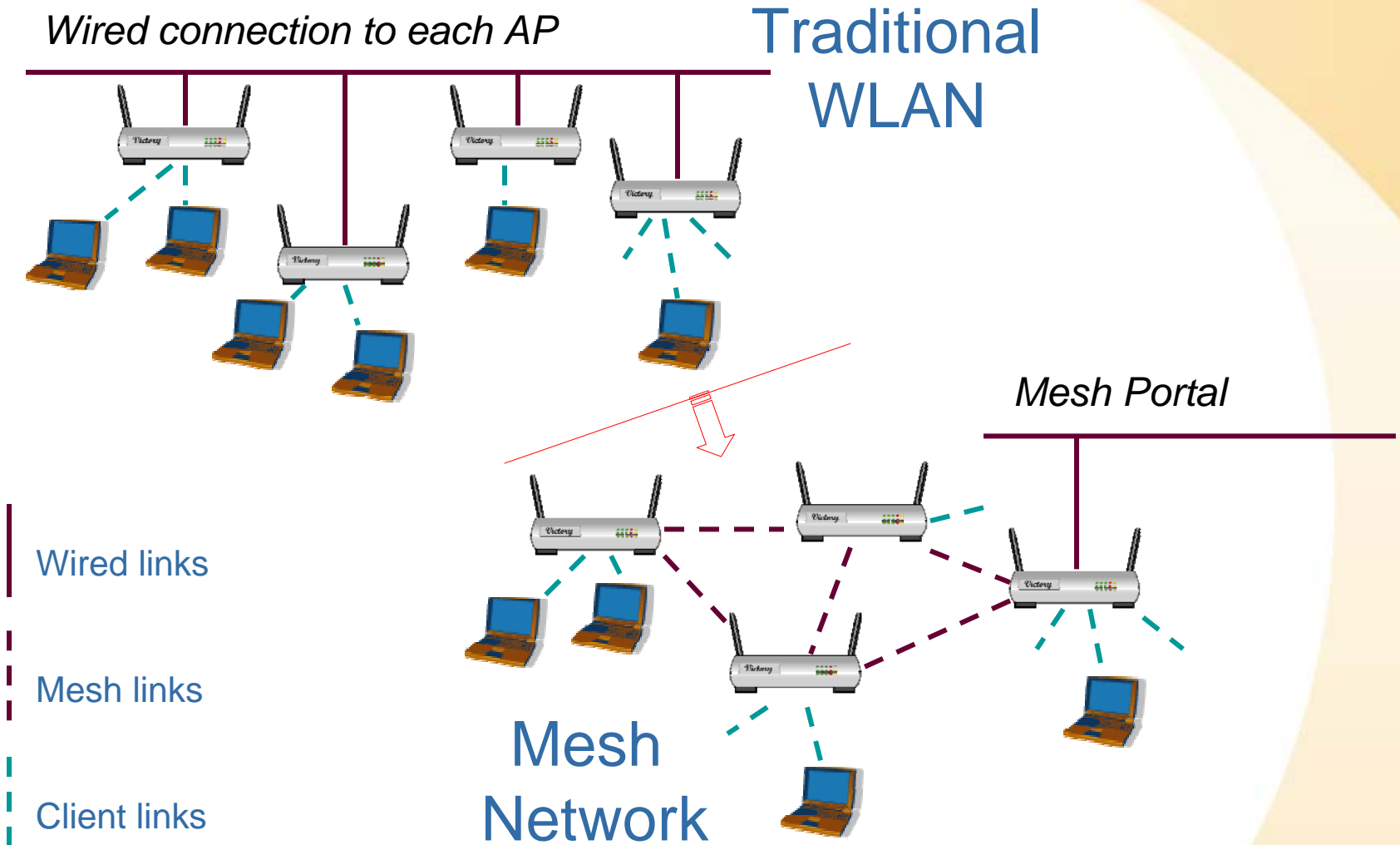
Fanny Mlinarsky, octoScope



Mesh – Modest Beginnings



Mesh – Evolution



Mesh Networking Applications

- Municipal Internet
- Security surveillance, emergency response
- First responder mobile ad-hoc
- DoD Airborne Network

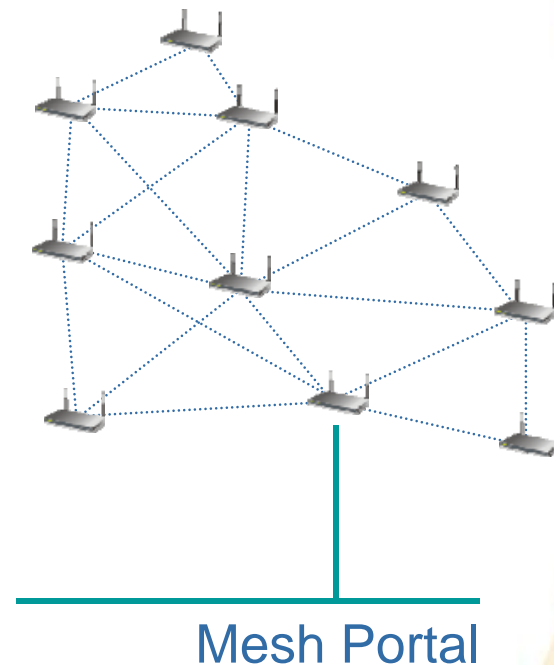


IEEE 802.11s Mesh Standard

- Wireless Distribution System with automatic topology learning and wireless path configuration
- Self-forming, self-healing, dynamic routing
- ~32 nodes to make routing algorithms computationally manageable
- Extension of 802.11i security and 802.11e QoS protocol to operate in a distributed rather than centralized topology

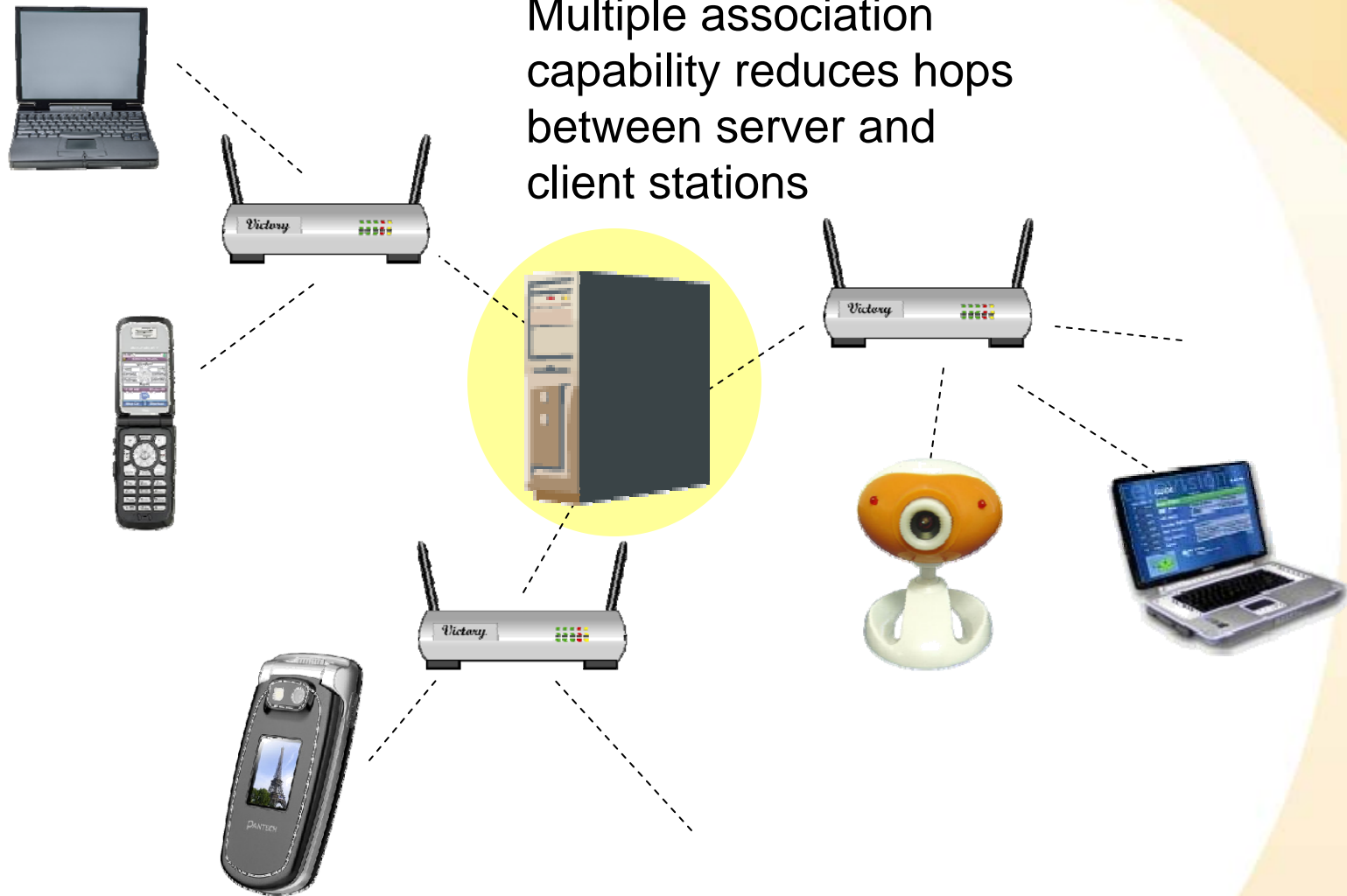


<http://grouper.ieee.org/groups/802/11>

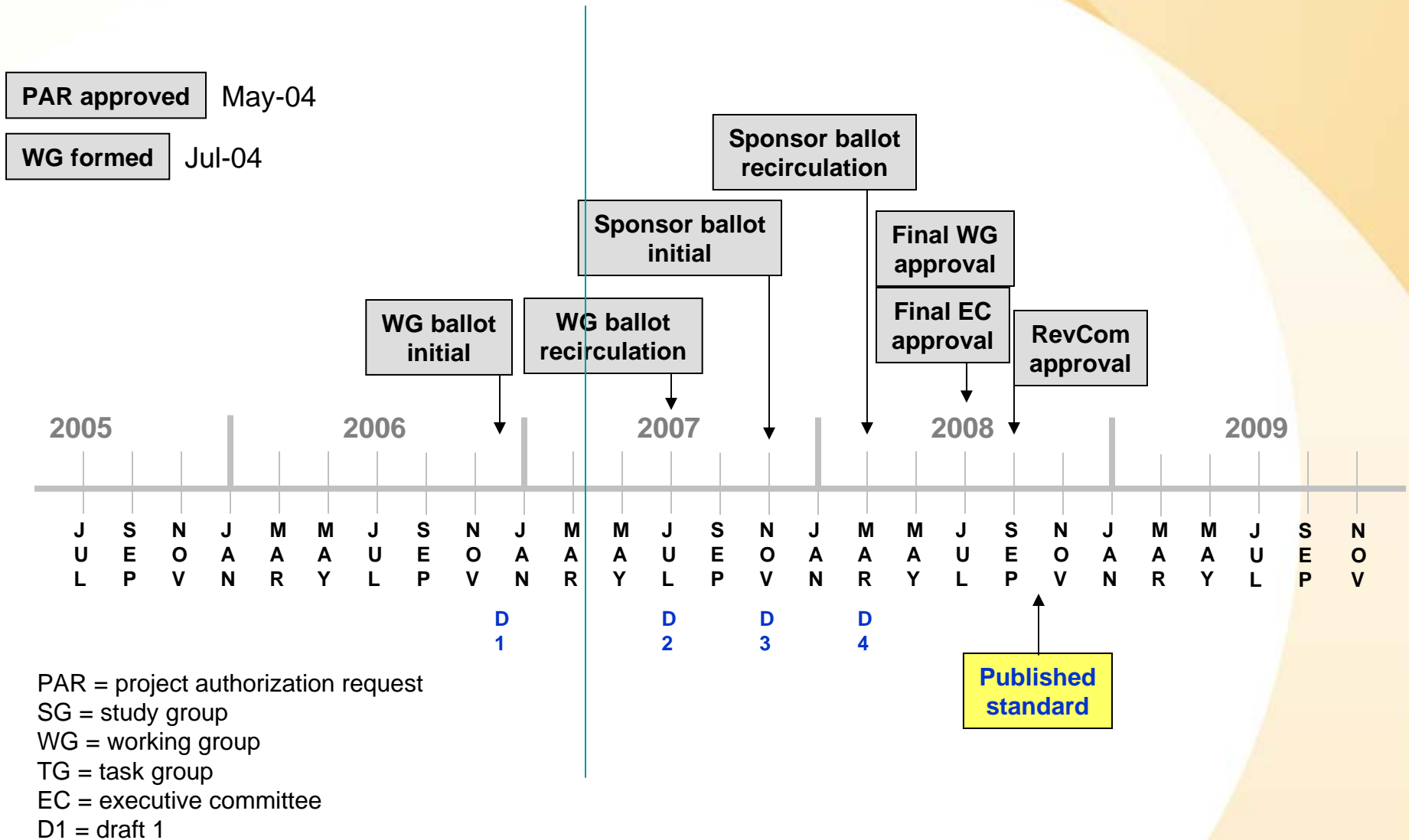


802.11s Mesh Enhanced Stations

Multiple association capability reduces hops between server and client stations



IEEE 802.11s Standard Timeline



IEEE 802.16 and 802.15 Mesh Standards*

- 802.16j and 802.15.5 are also standardizing mesh topologies
- 802.16j is not an ad-hoc mesh, but a relay to extend the range between a CPE and a base station
- 802.16 links being planed in ad-hoc mesh networks



* 802.16 = WiMAX; 802.15 = WPAN (Wireless Personal Area Network)

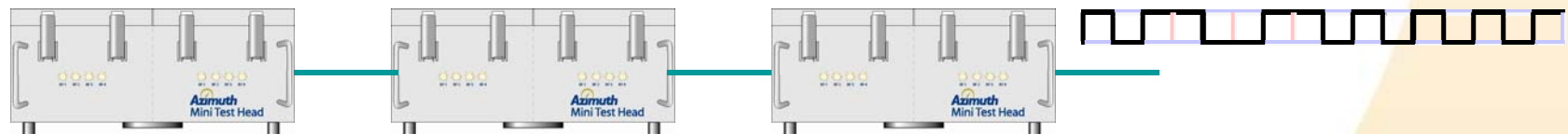
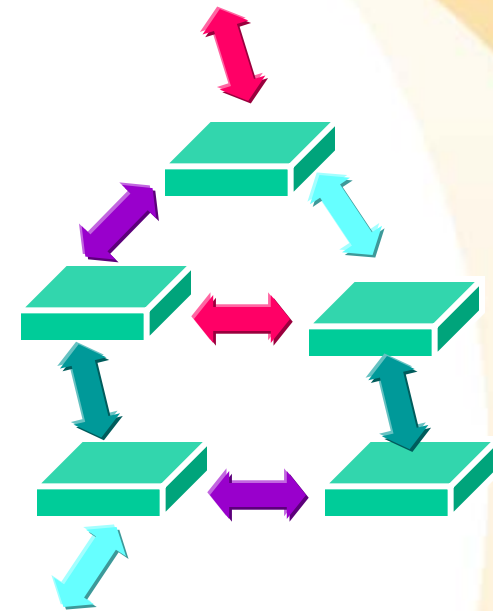
Lightly Regulated Band for 802.11, 802.16

- March 2005 FCC offered 50 MHz at 3650 to 3700 MHz for *contention-based protocol*
- 802.11y meets FCC requirement; 802.16h is working to comply
- 21st century regulation geared for digital communications
 - multiple services to share the band in an orderly way

- ❖ **300 Million licenses** one for every person or company
- ❖ **\$300 per license for 10 years**
- ❖ **Registered stations (base stations): 1 W/MHz, ~15 km**
- ❖ **Unregistered stations (handsets, laptops): 40 mW/MHz, 1-1.5 km**

Performance of a Mesh Network

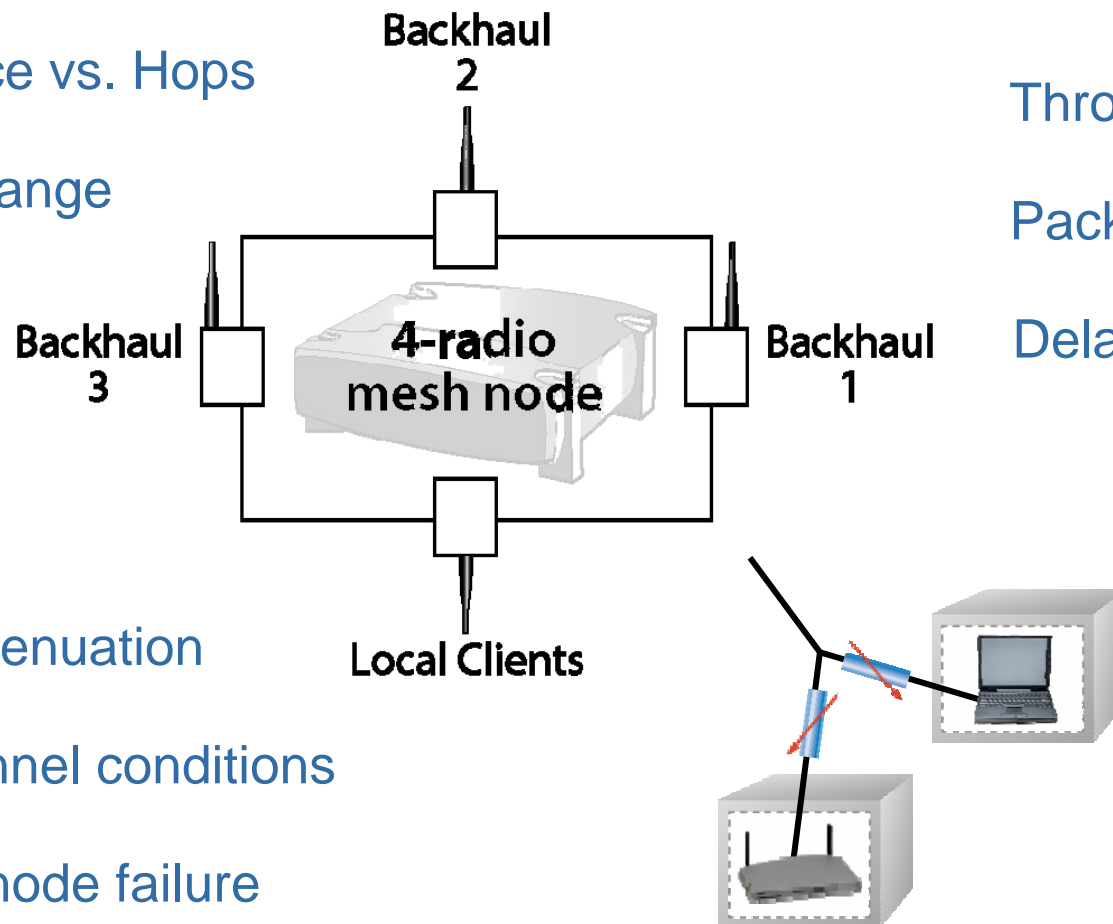
- Multi-radio vs. single radio
- Throughput, QoS vs. *range*
- Throughput, QoS vs. *hops*
- Self-healing, self-forming
- Routing efficiency
- Dealing with interference



Controlled RF Environment Test

Performance vs. Hops
vs. Range

Throughput
Packet loss
Delay, jitter



Vary attenuation

Emulate channel conditions

Simulate node failure

Control network topology

Municipal Multipath Environment



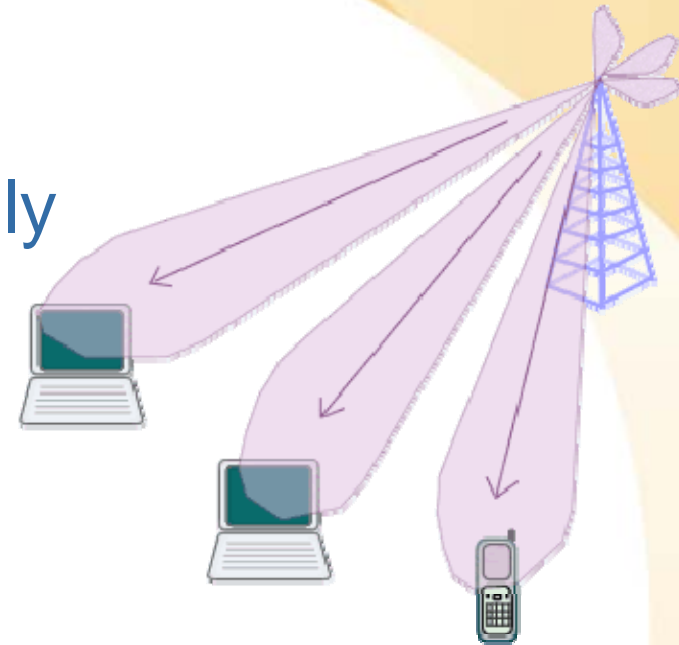
Wi-Fi and WiMAX Smart Antenna Technologies

- **Beamforming**

- Multiple antennas spatially shape the beam to improve coverage

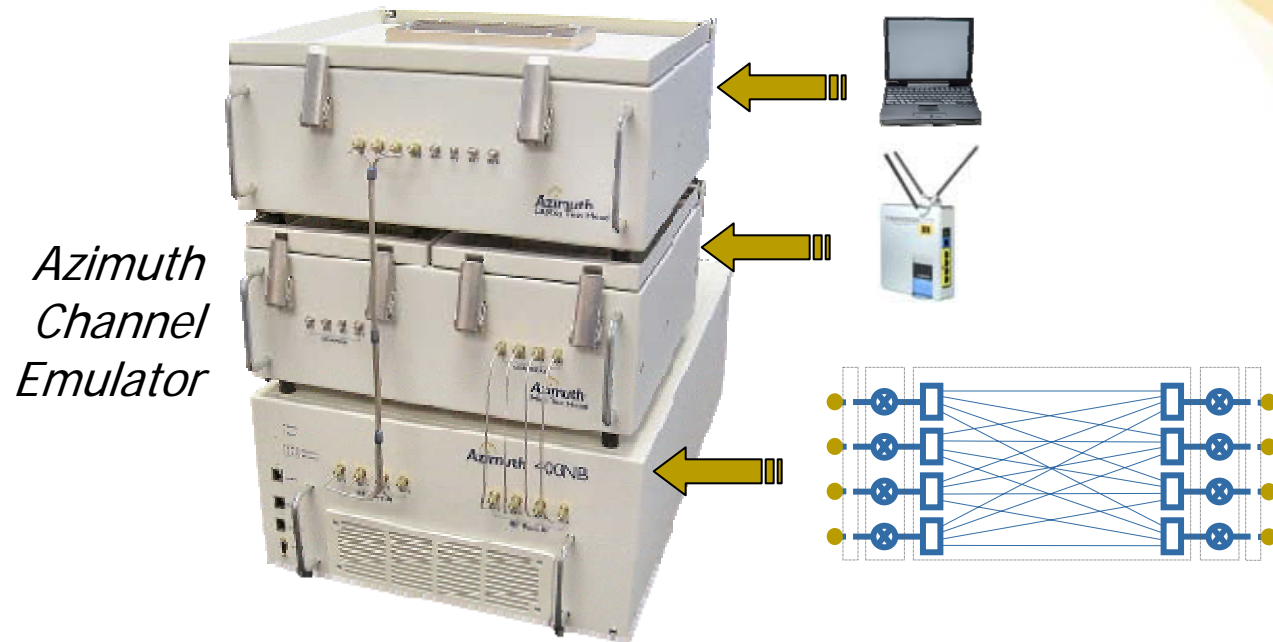
- **Spatial Multiplexing**

- Multiple streams are transmitted over multiple antennas
- In uplink single-antenna stations can transmit simultaneously



2x2 MIMO increases the peak data rate two-fold by transmitting two data streams.

Channel Emulation to Verify Range Performance



- MIMO channel emulation helps qualify radio link performance for emerging 802.11n and 802.16e radio technologies
- RF Isolation is required to prevent crosstalk among nodes under test

Testing for the Connected World

- Can you hear me now?



*More lab testing
less field trouble*