Wide Open Spaces
or
Mostly Wireless, Most of the Time

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Mostly Wireless—Most Links in the Connection Will Be Wireless

- WLANs
- WLAN Cells
- WLAN/WiMax
- Wireless Mesh Networks
- Mobile Ad Hoc Networks

Most of the Time—The Time Spent in the Wireless Links Will be Greater than in the Wireline Connection

- One way coast to coast propagation delay of 15 msec
- Total one way delay budget of 250 msec

Applications of Interest—More than Just Data or Streaming Media

- Conversational voice communications
  - Two-Way
  - Latency Sensitive
- Two-Way Conversational video communications—Video Telephony
- Laptop or Handheld Handsets

Issues for Voice Communications

- Voice Codec
  - Bit Rate
  - Quality
  - Complexity
- Latency
- Packet Loss Concealment
- Tandem Connections of Codecs

Issues for Two-Way Video Communications

- Video Codec
  - Bit Rate
  - Quality
  - Encoder Complexity
- Latency
- Packet Loss Concealment
- Transcoding

Why Voice/Video Over IP-Based WLANs/WiMax/Ad Hoc/Mesh Networks?

- Voice is the preferred mode of human communication
- Video Standards are now in place
- World-wide Access
- Already Integrated with IP Backbone
- Currently Inexpensive
- Room to Innovate!

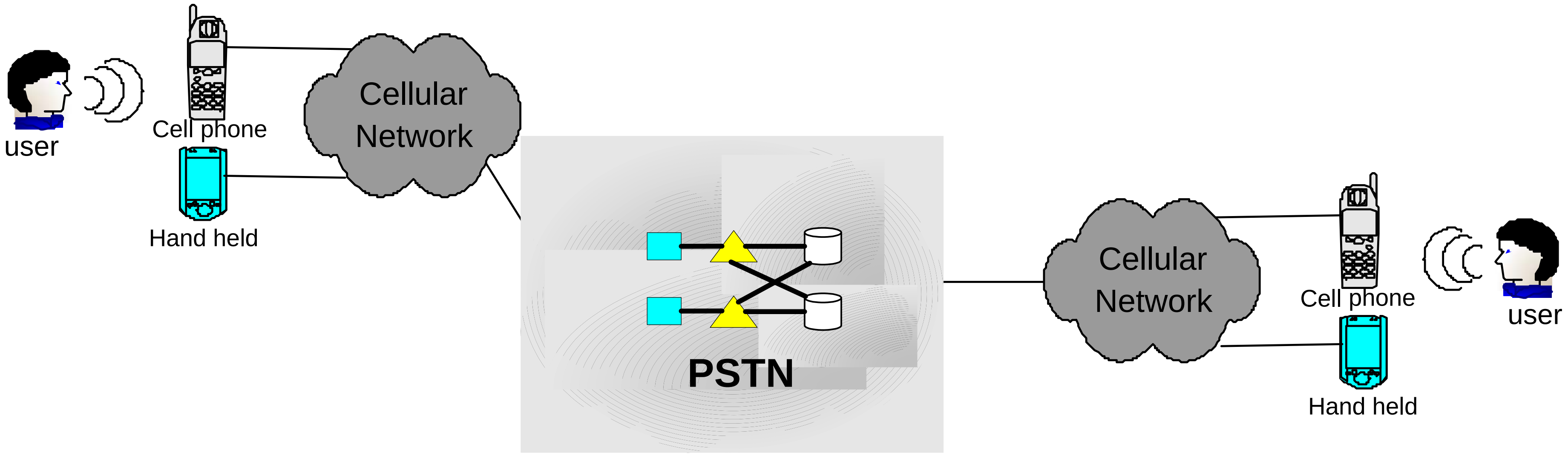
Why Not Just Digital Cellular for Wireless Voice/Video?

- Cost
- Usually High Latency
- High Speed Mobiles Still a Focus
- Never Just Digital Cellular—Always Tandeming with Other Networks
- Heavily Standardized
- Intellectual Property Laden

Current Networks for Voice and Video Communications

- Public Switched Telephone Network (PSTN)
- Digital Cellular
- Wireline Packet-Switched Networks
- Wireless Local Area Networks
- Tandem Connections of all of the above

Tandem Digital Cellular with PSTN



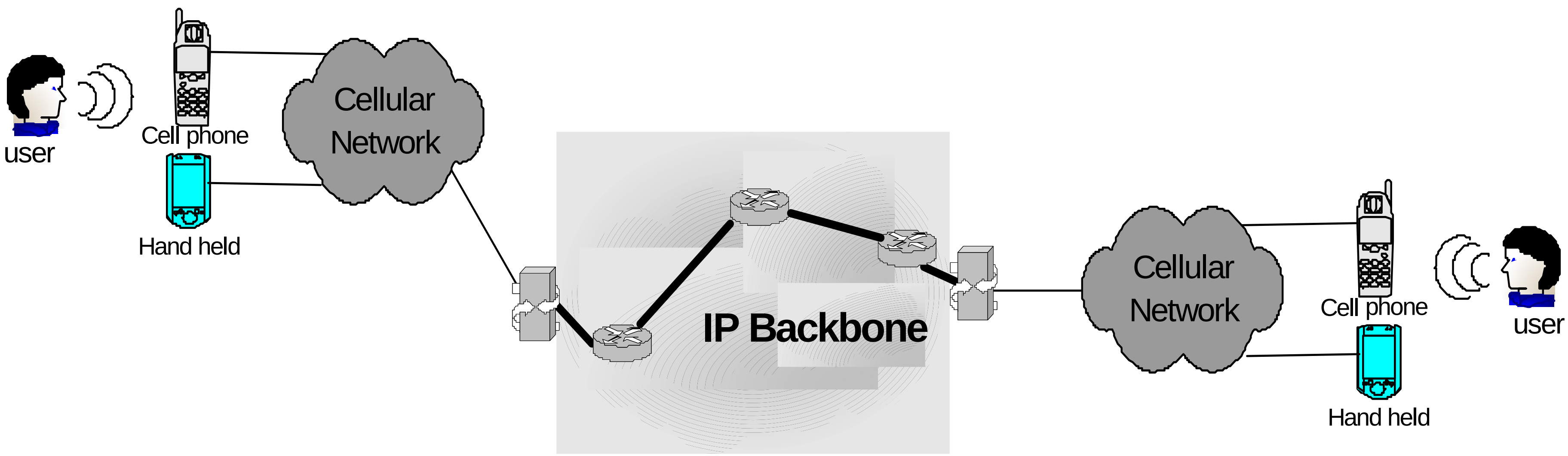
Digital Cellular Through PSTN/Wireline VoIP to Digital Cellular

Original	AMR-NB	G.711	AMR-NB x G.711 x AMR-NB
	PESQ MOS = 3.847	PESQ MOS = 4.127	PESQ MOS = 3.623

Note:

1) AMR-NB is operated at 12.2kbps

Tandem Digital Cellular and Wireline IP



Digital Cellular Through Wireline VoIP to Digital Cellular

Original

G.729
PESQ MOS = 3.514

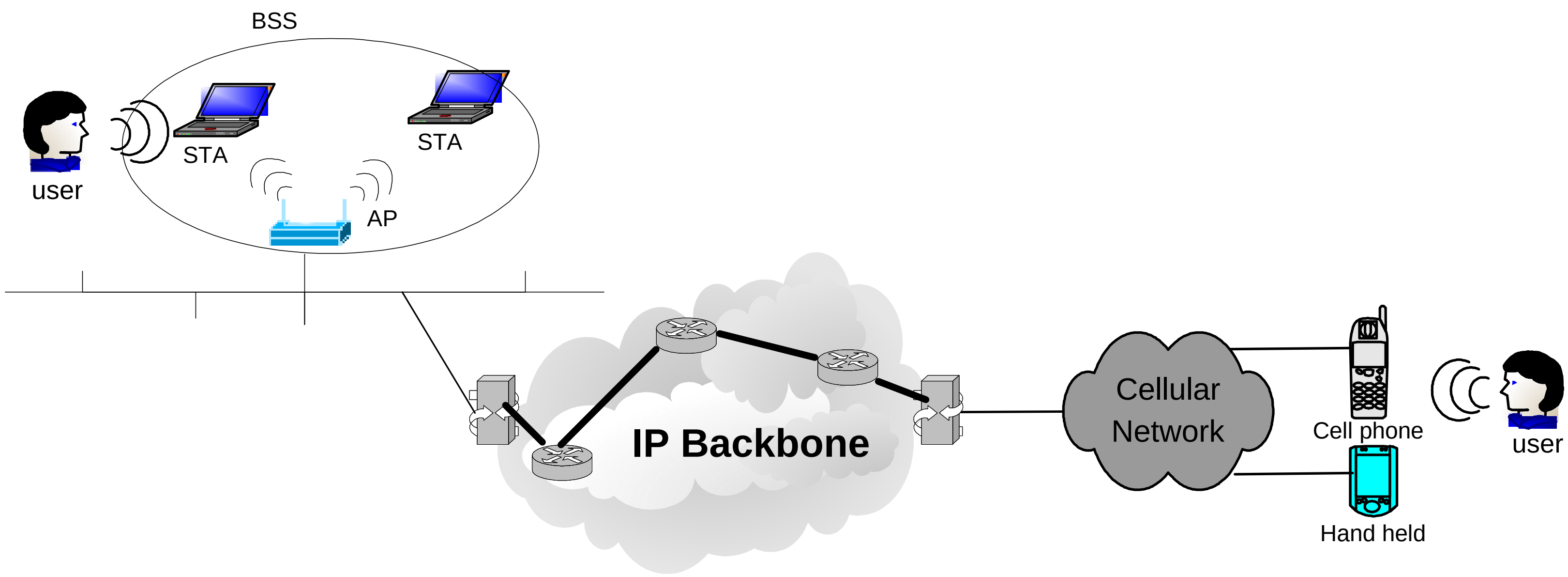
AMR-NB
PESQ MOS = 3.525

AMR-NB x G.729 x AMR-NB
PESQ MOS = 3.091

Note: 1) AMR-NB codec operated at 7.95 kbps

2) VMR codec operated in narrowband mode at default rate

Tandem Digital Cellular, Wireline IP, and WLANs



Digital Cellular Through Wireline VoIP into Voice Over WLAN

AMR-NB x G.711 x G.729
PESQ MOS = 3.283

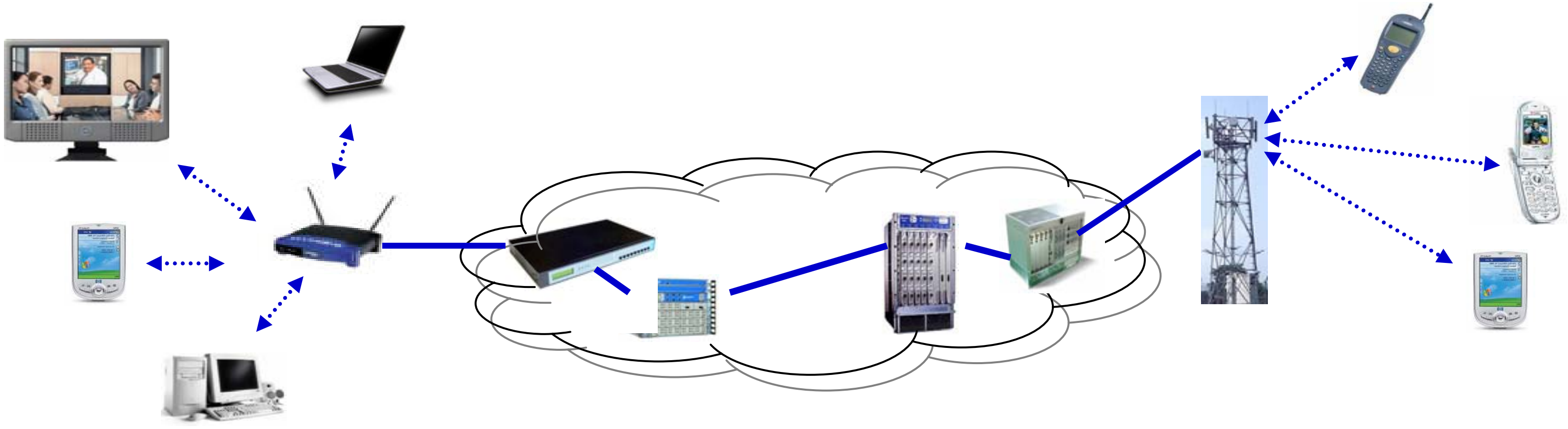
AMR-NB x G.729 x G.711
PESQ MOS = 3.226

AMR-NB x G.729 x G.729
PESQ MOS = 2.803

Note:

1) AMR-NB is operated at 7.95 kbps

General Multihop Heterogeneous Network--Today



Video Transcoding Example

Coded in H.264 at 329kbps

CIF, 20 frames/sec, high resolution

Decoded then re-encoded in H.264 at 168kbps

CIF, 20 frames/sec, low resolution

Video Transcoding Example

Decoded then re-encoded in H.264 at 167kbps

CIF, 6.7 frames/sec, high resolution

Decoded then re-encoded in H.264 at 111kbps

QCIF, 20frames/sec, high resolution

Characteristics of These Heterogeneous (Multihop) Networks

- Different Physical Layers
- Different Protocols
- Possible Transcoding at Network Interfaces
- Not Jointly Designed
- Not Jointly Standardized
- No One Entity Responsible

Next Generation Networks for Voice and Video

- WLAN/WiMax
- WLAN Cells
- Wireless Mesh Networks
- Mobile Ad Hoc Networks
- Tandem Connections of These Networks

IEEE 802.11x

- 802.11 Specification of WLAN MAC and PHY layers
- 802.11a PHY layers at 5 GHz (54 Mbps OFDM)
- 802.11b 11 Mbps DSSS at 2.4 GHz
- 802.11c Improvements of the MAC layer
- 802.11d Update (frequency spectrum regulations)
- 802.11e Improvements of the MAC layer (QoS)
- 802.11f Inter-Access Point Protocol (IAPP)
- 802.11g Higher Data rate (>20 Mbps) at 2.4 GHz
- 802.11h Dynamic Channel Selection and Transmit Power Control mechanisms
- 802.11i Authentication and Security
- 802.11n High Throughput Wireless networking (> 100 Mbps) – to be ratified by 2005-06

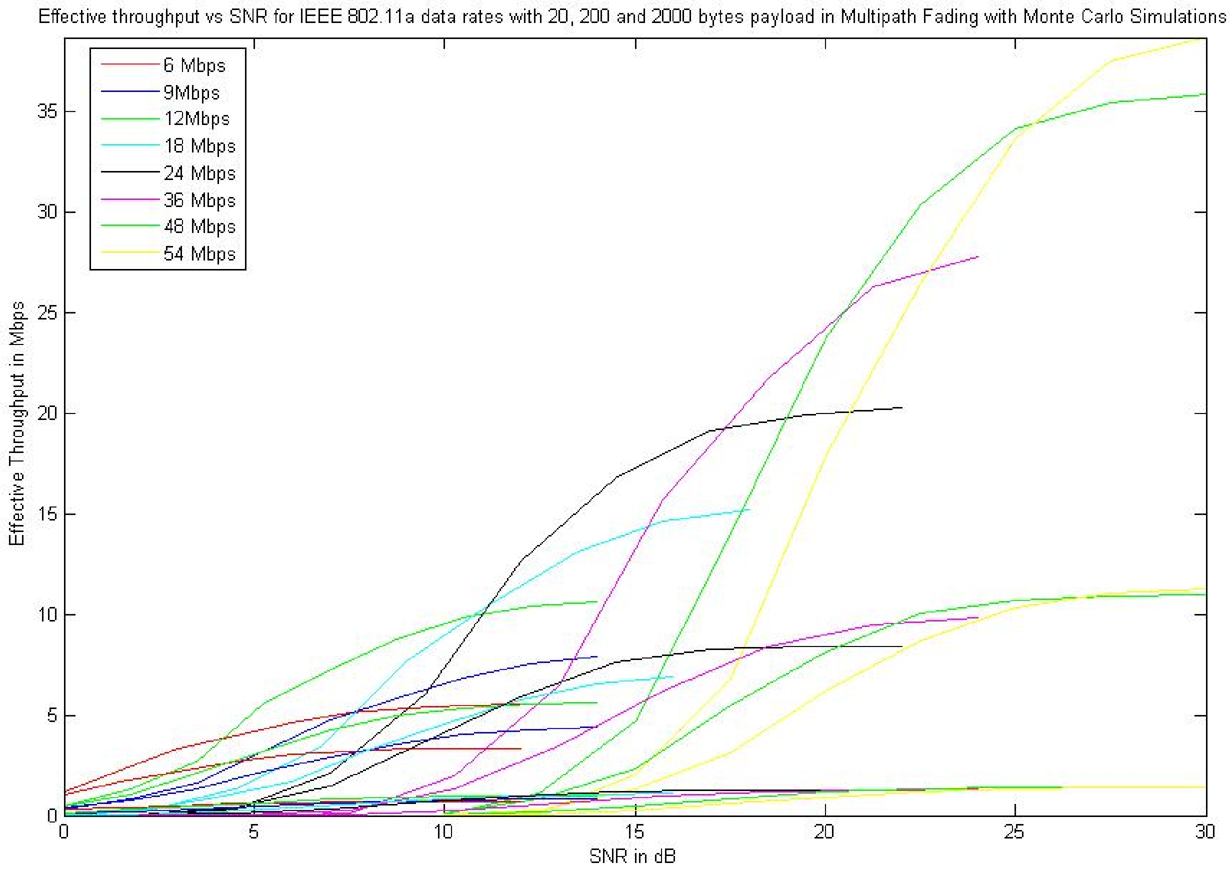
Active 802.11 Task Groups

- 802.11r: Fast Roaming
- 802.11s: Mesh Networking
- 802.11p: Wireless Access for Vehicular Environment
- 802.11u : Internetworking with External Networks
- 802.11v: Wireless Network Management
- 802.11k: Radio Resource Management
- 802.11t: Wireless Performance Prediction
- 802.11w: Providing Protected Management Frames

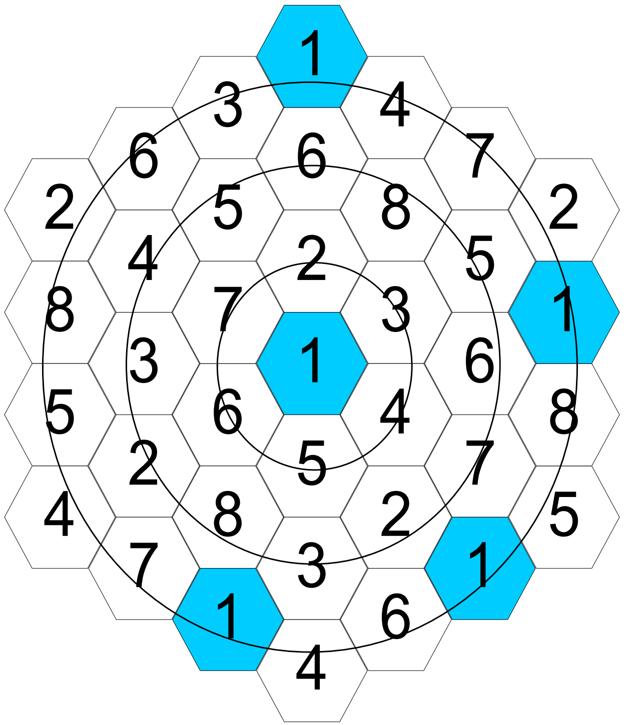
Payload Length Dependence for Different Traffic Classes

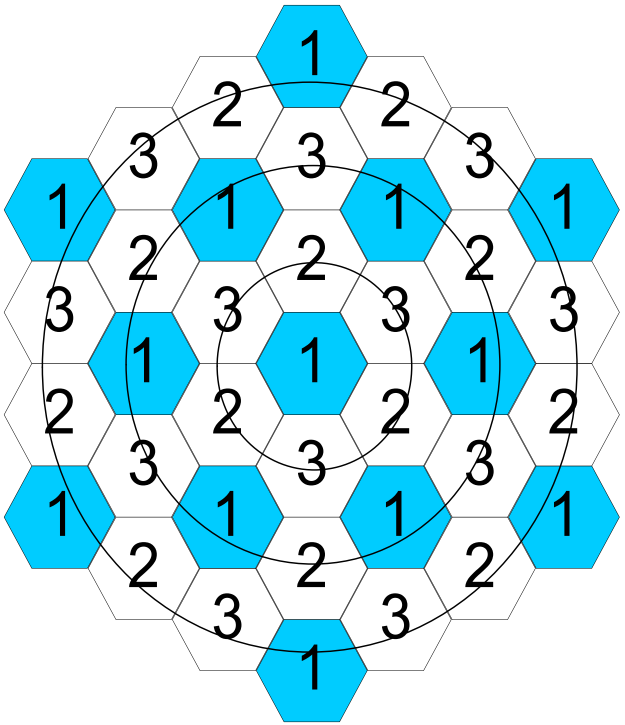
- Data—Maximum Throughput Obtained with Long Packets ~ 2000 Bytes
- Two-Way Video Communications—Payload Length ~ 400 to 1500 Bytes
- Conversational Voice Communications—Payload Length ~ 20 to 200 Bytes
- Packet Headers Become Significant

Throughput Comparison for Various Payload Sizes in Multipath Fading



802.11a and 802.11b Cells and Frequency Reuse

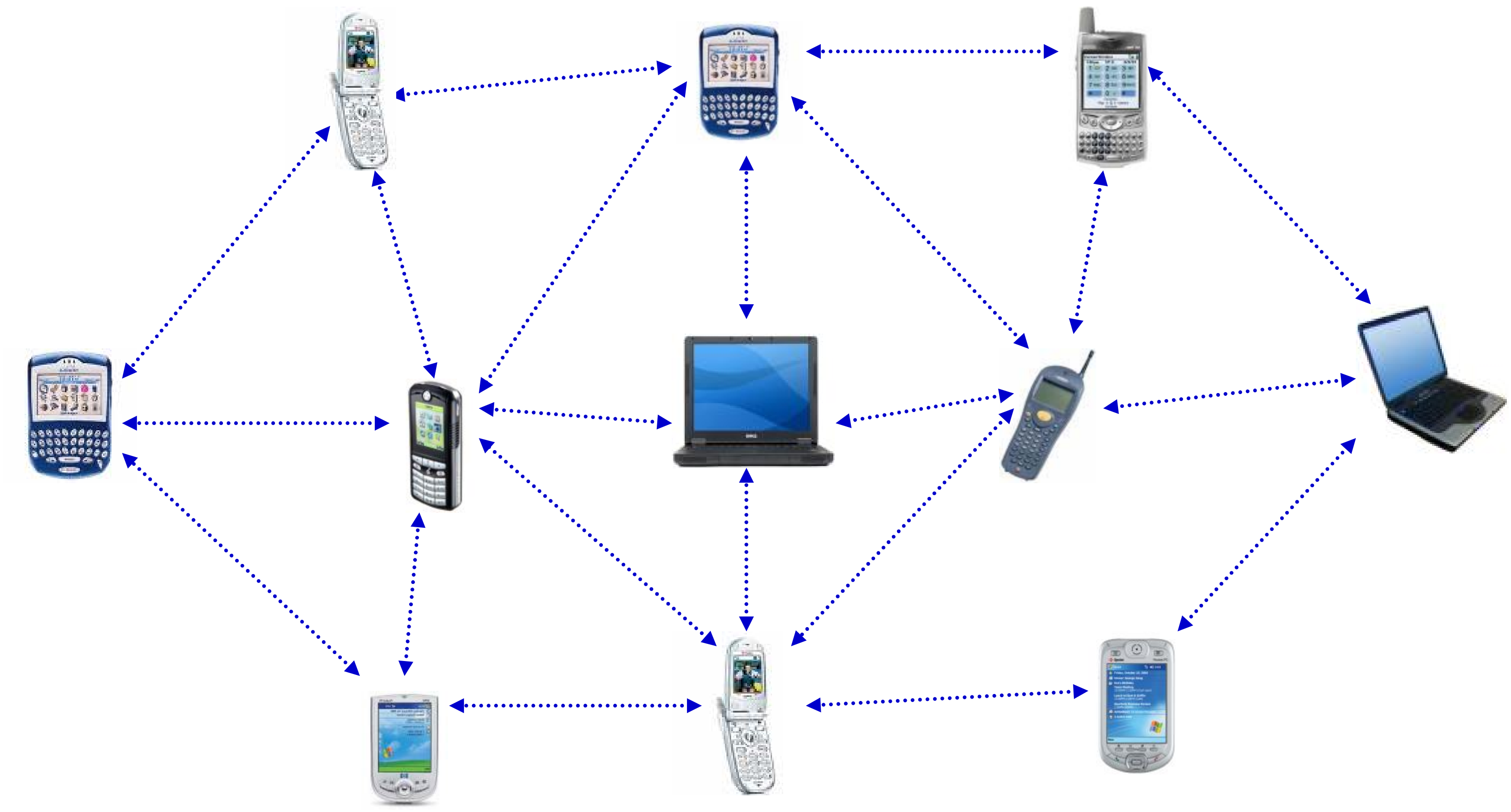




Multiple Channels and System Capacity

- Multiple Indoor/Outdoor Channels
- Reduced Co-Channel Interference (CCI)
- Increased System Throughput
- Larger Coverage Area for a Given Performance
- Useful for Deployment in Infrastructureless Areas

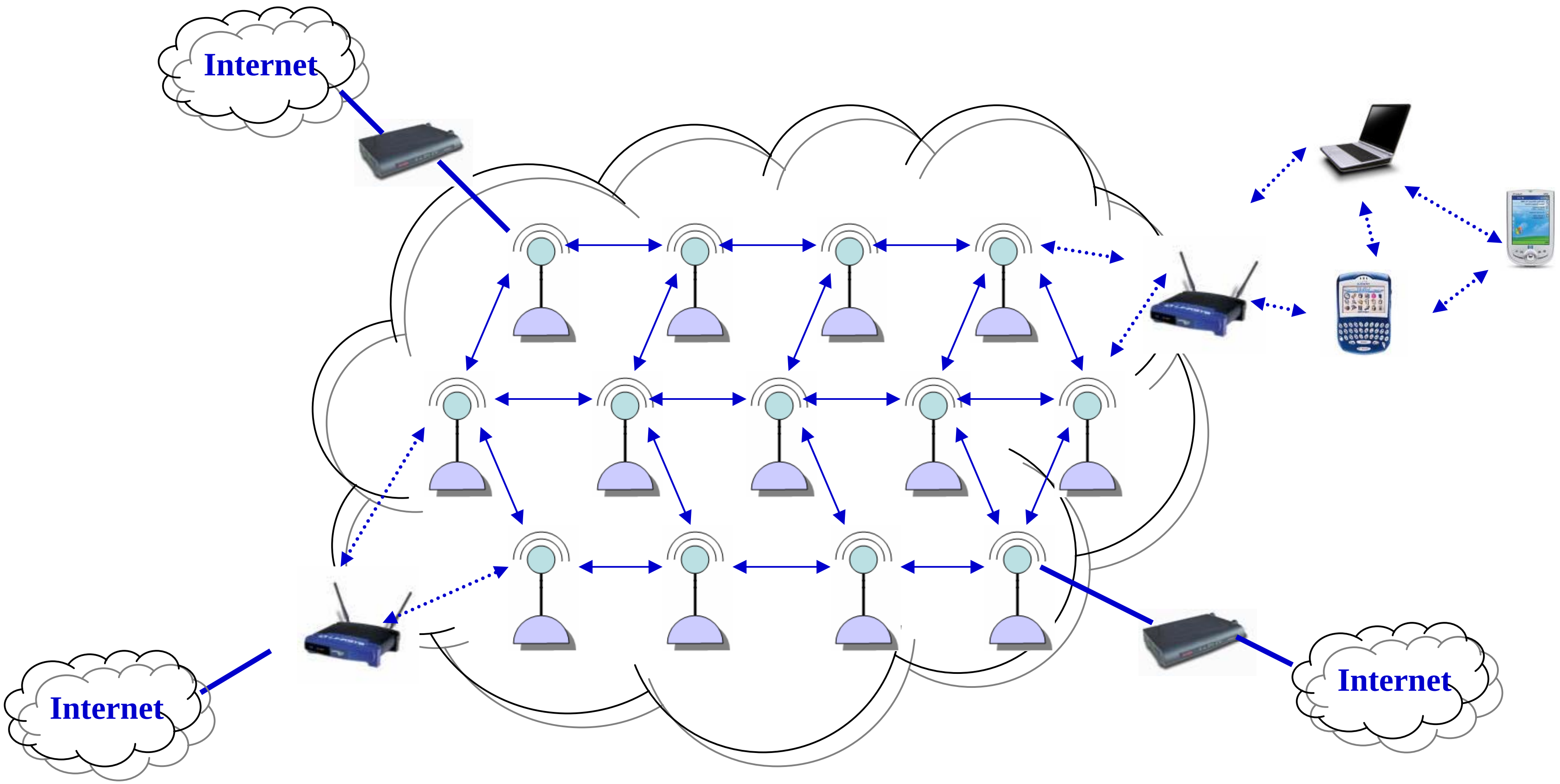
Wireless Ad Hoc Network



Characteristics of Ad Hoc Networks

- 802.11 Based
- Self-Organizing, Ever-Changing Architecture
- Each Router Node Can Generate Traffic
- Each User/Node is Battery-Power Limited
- Multiple Hops per Connection
- Multiple Routes
- Asymptotics Less Useful (compared to sensor networks)

Mesh Networks



Characteristics of Mesh Networks

- 802.11 Based
- Multiple Routes
- Multiple Hops
- Nodes can be placed for optimal performance
- Nodes may be plugged in to a power source
- Nodes do not generate traffic
- May serve as infrastructure networks (not constantly reconfigured)

Issues for Communications Networks

- Multiple Access
- Multiple Paths
- Multiple Antennas
- Multiple Radios (Carriers)
- Multiple Hops
- Multiple Descriptions/Source Diversity Compression
- Multiple Tandem Networks

Conclusions

- Wireless local area network (WLAN) access points are inefficient
- WLAN connections are very different from wireline connections
- **Multihop** wireless networks such as Mobile Ad hoc Networks and Mesh Networks are networks of the future
- Multihop **Heterogeneous** Networks will be prevalent

Conclusions (cont'd)

- Voice/Video over WLANs is not the same as Voice/Video over Wireline Packet Networks
- Tandem Free Operation will likely be difficult
- Asynchronous tandems of speech codecs will occur and occur today, incurring
  - Quality loss
  - Increased latency
- Transcoding of Video will be necessary

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