Improving QoS of VoIP over Wireless Networks (IQ-VW)

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CS522 – 12/09/2002

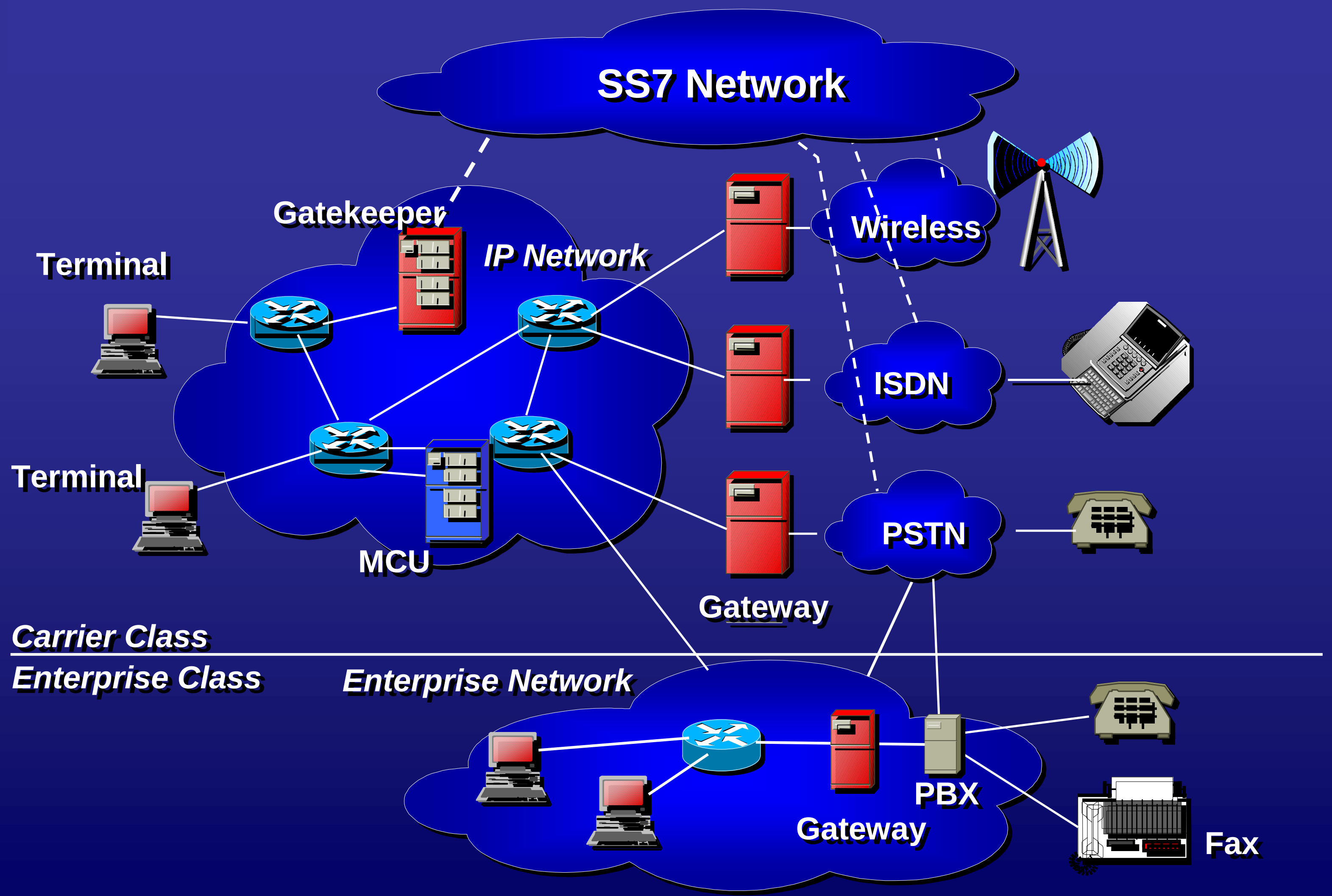
Agenda

- Voice over IP (VoIP): Why?
- VoIP Protocols: H.323 and SIP
- Quality of Service (QoS)
- Wireless Networks
- Testbed Configuration
- Testing Scenarios
- QoS Test Results
- Comments

Why Voice over IP?

- Reduce toll costs for long-distance telephone calls
- Helps consolidate separate voice and data networks for cost-effectiveness and bandwidth utilization.
- Provides features not available in traditional voice telephony, such as video conferencing and simultaneous data transmission (e.g. whiteboard) for true multimedia communications.
- Provides integration between data and telephony applications for business -- “click to talk” on a web site for ordering or customer support.

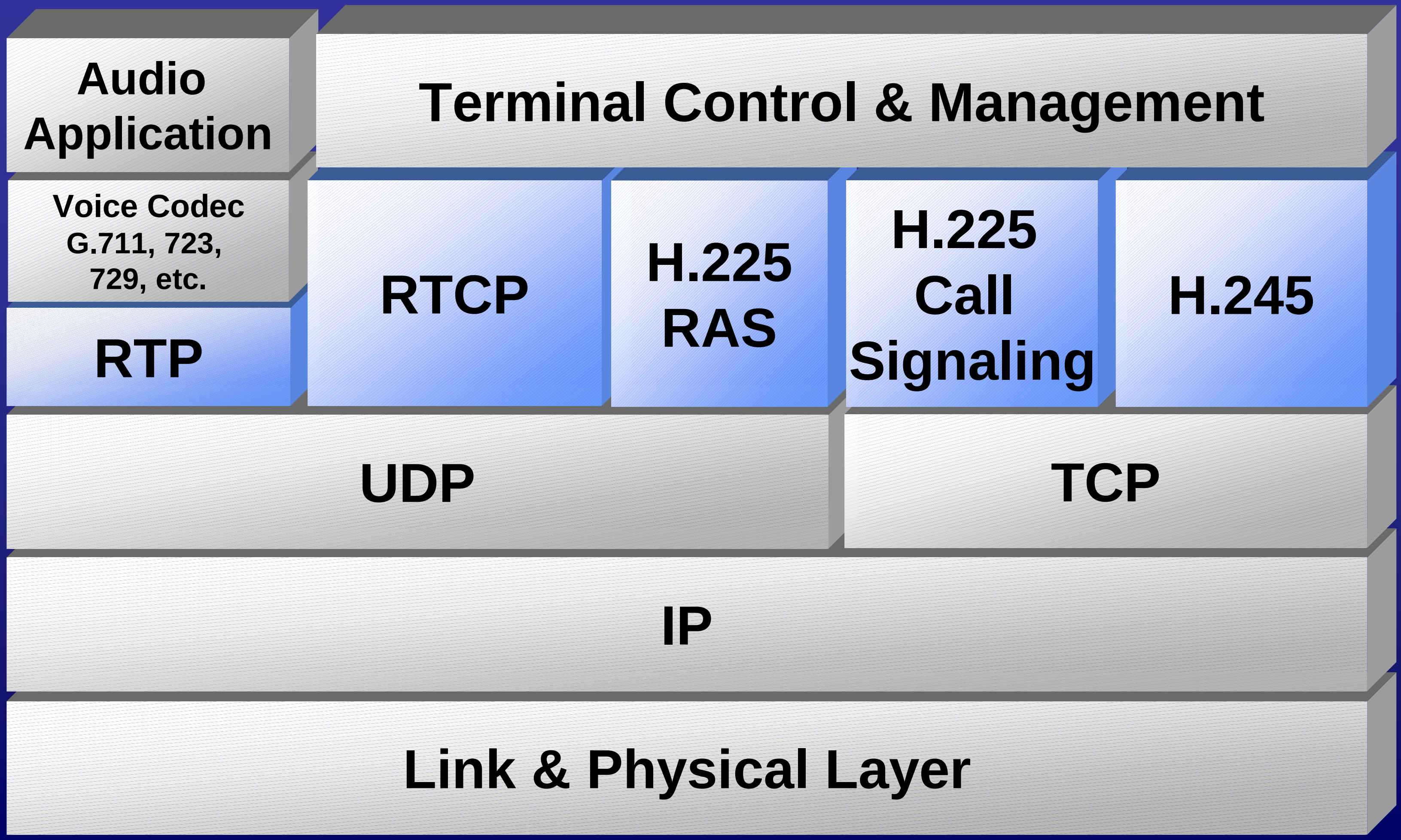
Voice over IP Network Components



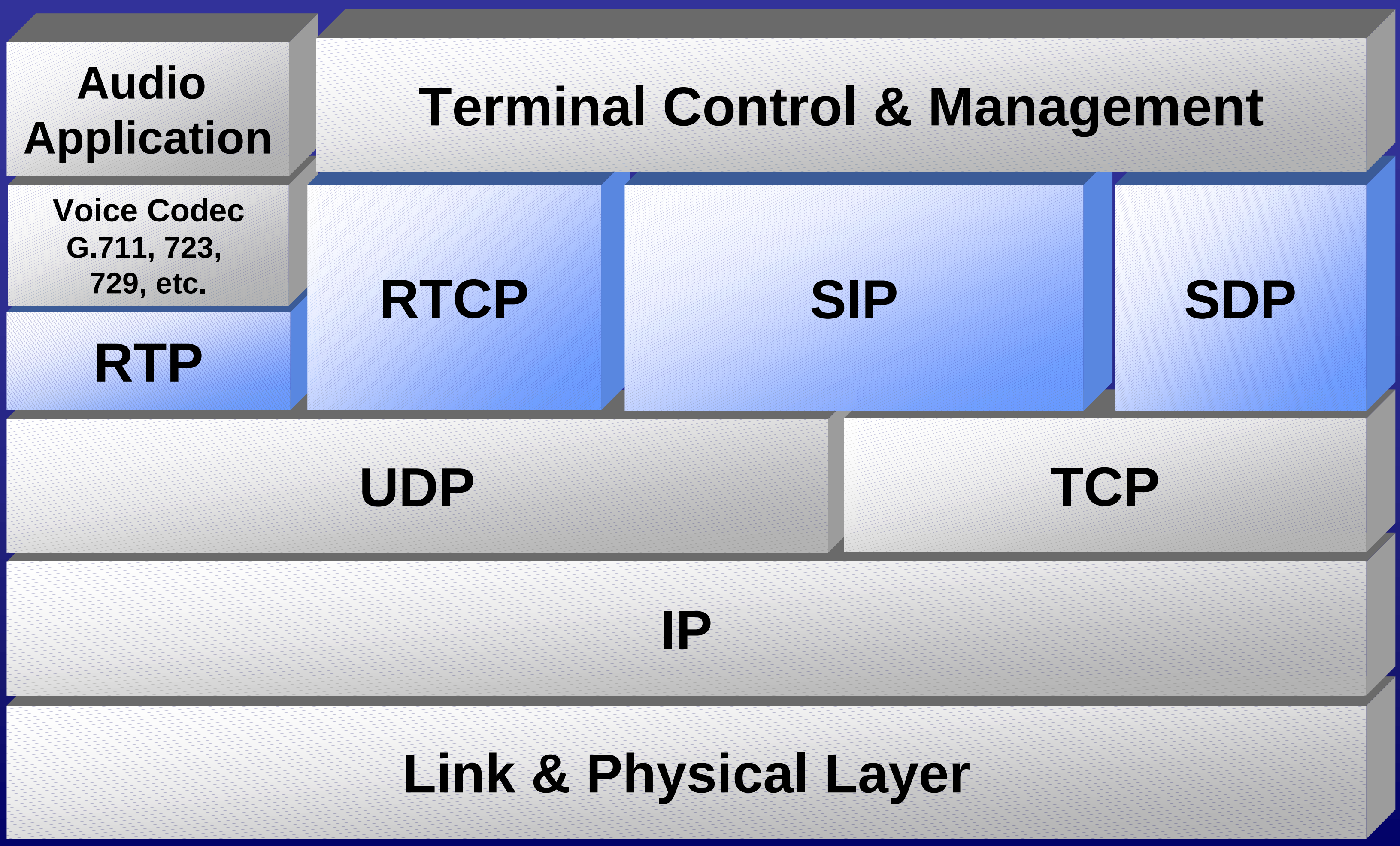
Voice over IP - The Standards Battle

- **H.323**
  - Primary standard for enterprise networks
  - Supported in many carrier networks
- **SIP - Session Initiation Protocol**
  - Common for IP phones and PCs
  - Gaining popularity as signaling protocol due to its versatility

H.323 Protocol Stack



SIP Protocol Stack

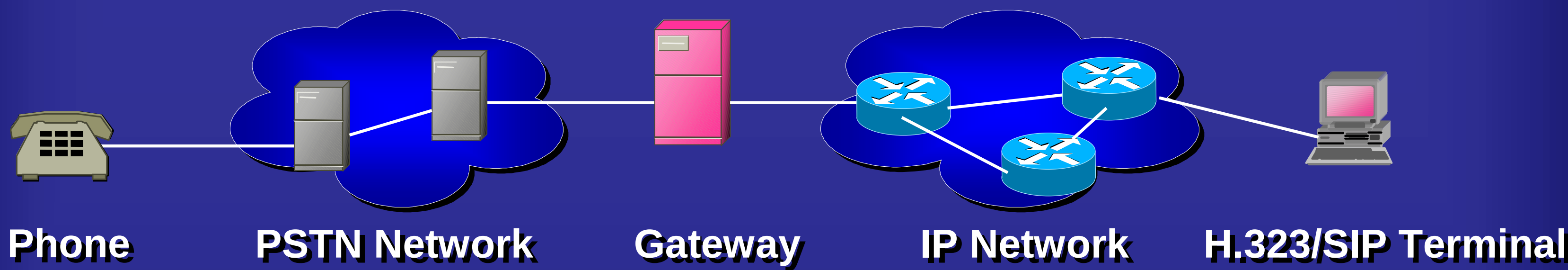


Codec: Speech to Data

Algorithm	G.723.1	G.729	G.728	G.726
Rate (Kbs)	5.3 - 6.3	8	16	32
Complexity	Highest	High	Lower	Low

Compare with 64Kbs end to end

Quality of Service



Service Quality	Voice Quality	

• Offered Service
• Reachability
• Availability
• Reliability
• Price
	Traditional PSTN
	• Level
	• Delay
	• Echo
	• Clarity:
	  • Intelligibility
	  • Noise
	  • Fading
	  • Cross talk
		In addition in IP Networks
		• Delay
		• Delay-Jitter
		• Clarity:
		  • Packet Loss
		  • Bandwidth
		  • Compression

Wireless Networks

- 802.11 is an IEEE standard for wireless LANs
- 802.11a and 802.11b are two variants of the standard
- Most recent variant: 802.11g (compatible with 802.11b)

802.11a

- Operates in the 5 GHz frequency band
- Supports bandwidths up to 54 MB, range of 150+ feet
- Has 12 data channels
- Uses Orthogonal Frequency Division Multiplexing (OFDM)
- Performs at short distances
- Incompatible with 802.11b

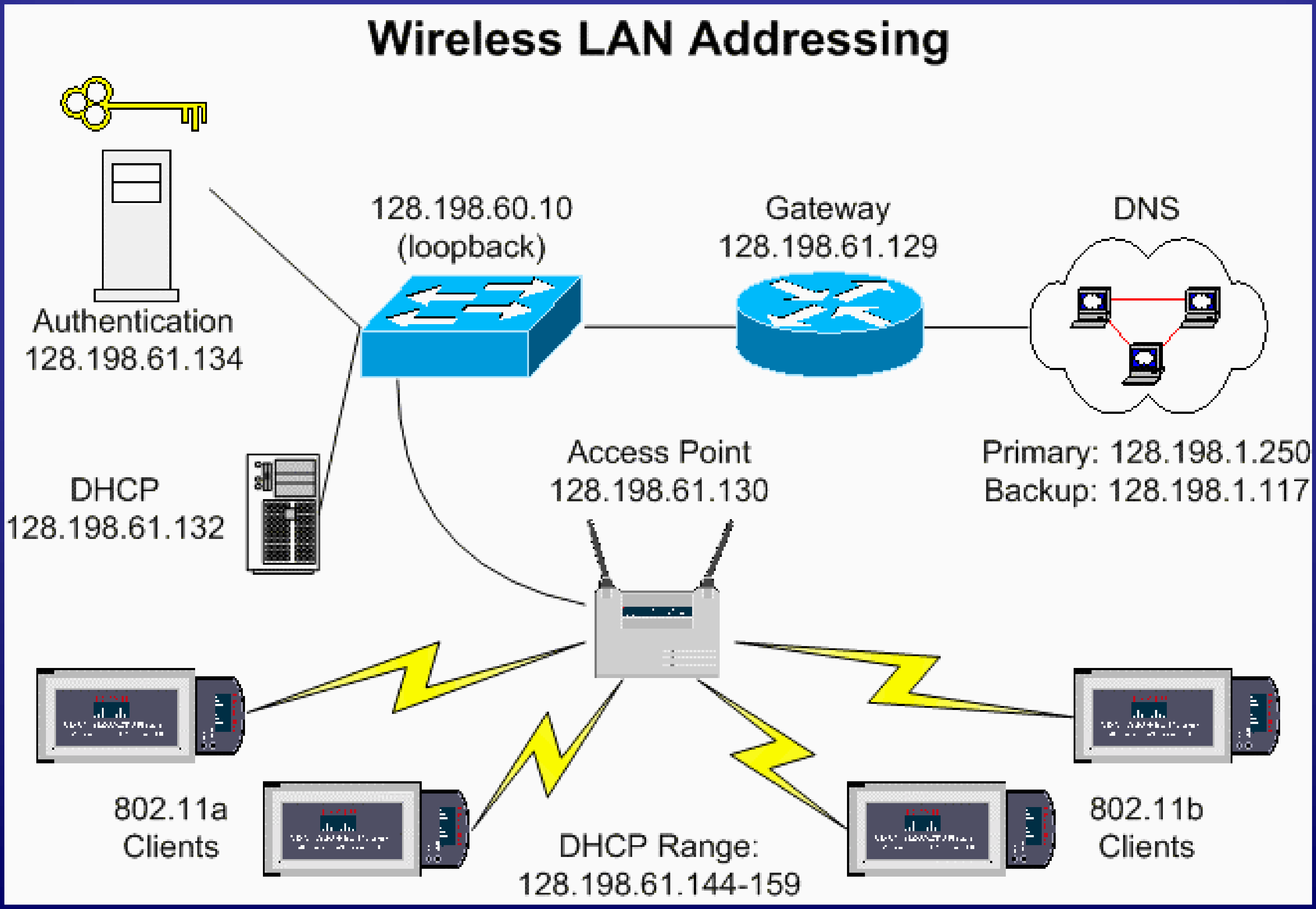
802.11b

- Operates in the 2.4 GHz frequency band
- Supports bandwidths up to 11 MB , range of 150+ feet
- Has 3 data channels
- Uses Direct Sequence Spread Spectrum modulation (DSSS)
- Handles long distances better than 802.11a

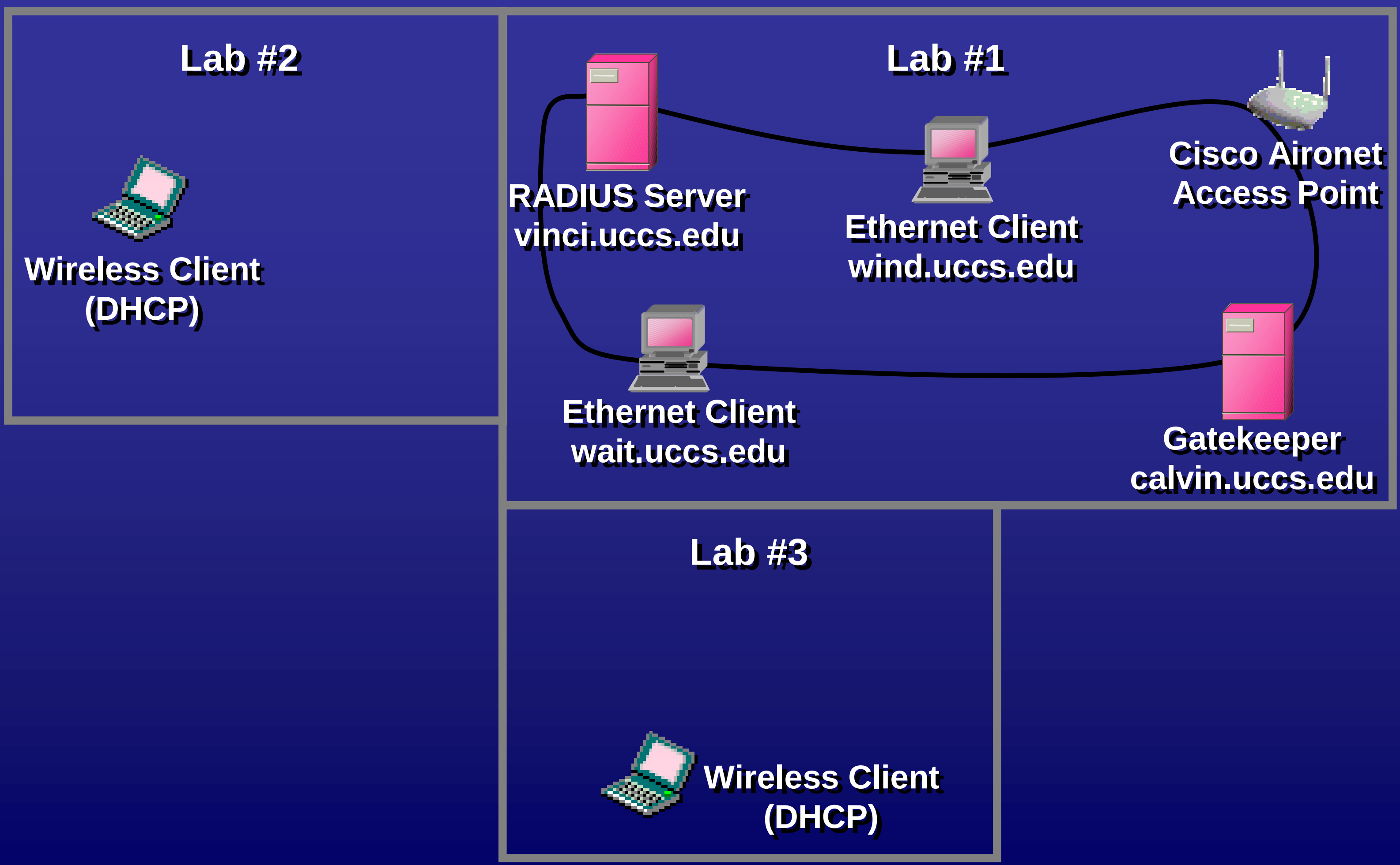
Wireless Network Security

- Vulnerabilities:
  - Unauthorized user access
  - Eavesdropping (network can be tapped using a sniffer)
- Authentication: EAP (Extensible Authentication Protocol)
  - EAP interacts with a Remote Authentication Dial-In User Service (RADIUS) server to provide authentication for wireless client devices.
- Encryption: WEP (Wired Equivalent Privacy)
  - Scrambles the communication between the access point and client devices to keep the communication private.
  - Both the access point and client devices use the same WEP key to encrypt and decrypt radio signals.

Wireless Network Configuration



QoS Testbed – HW Configuration



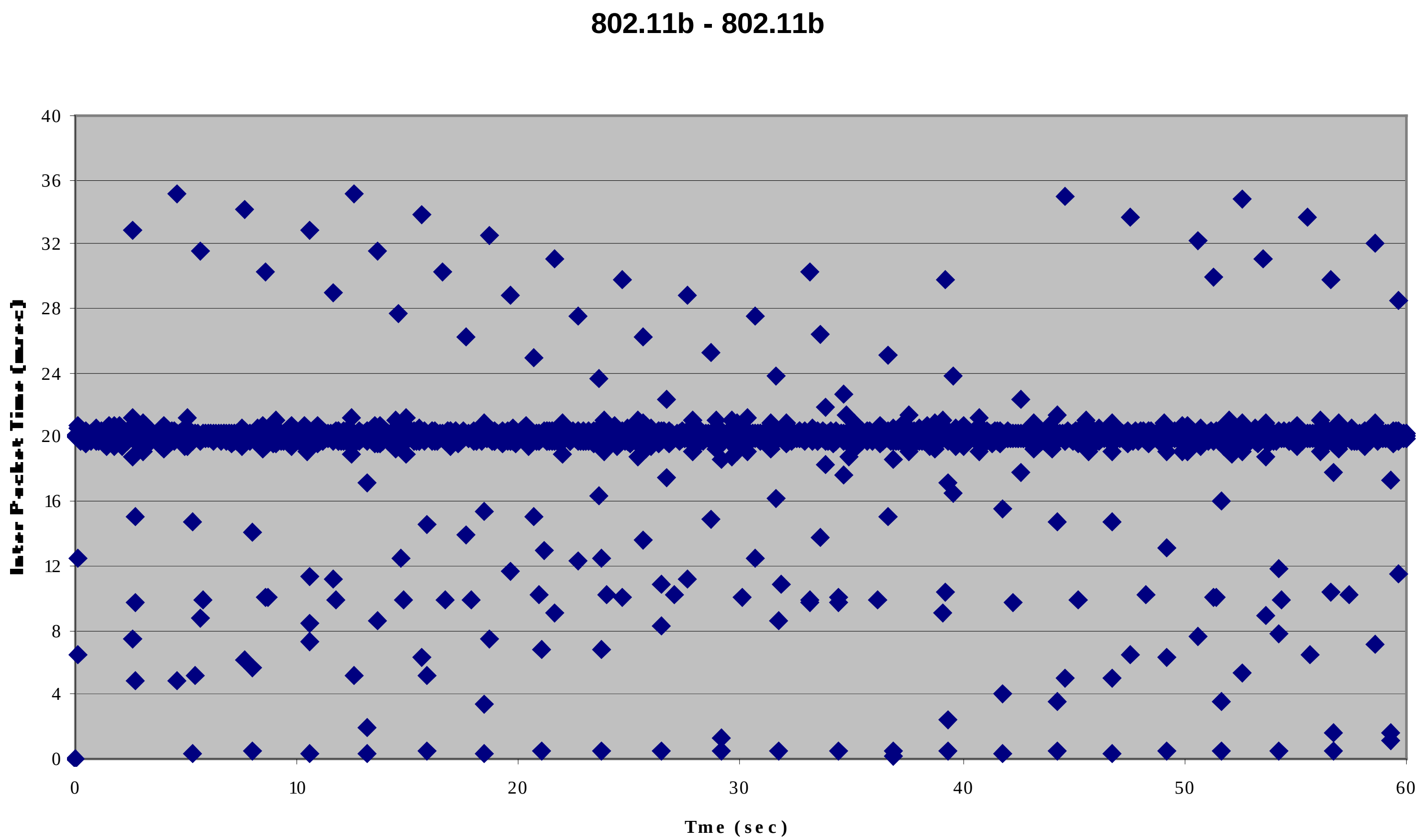
QoS Testbed – SW Configuration

- Public Domain Software
  - Gatekeeper: Vovida Open Communication Application Library (VOCAL)
  - VOCAL SIP to H.323 Converter: SIPH323CSGW
  - Clients: MSN Messenger 4.6 (allows use of communication services other than .Net Passport)
  - Network Analyzer: Ethereal
- Other Software:
  - QoS analysis tools provided by Daniel Hertrich
  - Voice over Misconfigured Internet Telephones (VOMIT)
  - Wavfix.c: Program to create WAVE file header. Used to replay captured voice data

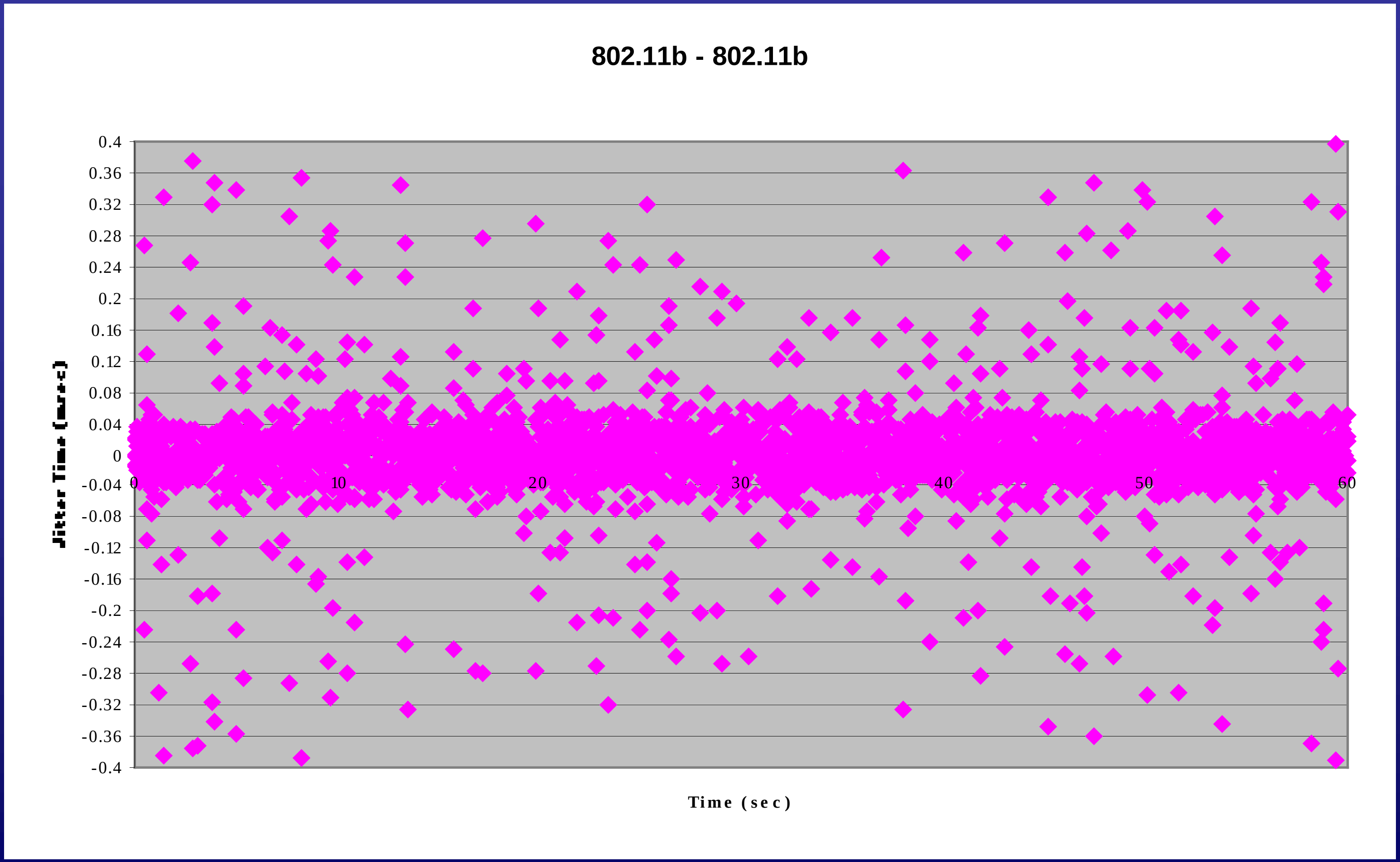
QoS Testing Scenarios

- Ethernet to Ethernet
- Ethernet to Wireless
  - Ethernet to 802.11a
  - Ethernet to 802.11b
  - Ethernet to 802.11b + Wireless security
- Wireless to Wireless
  - 802.11a to 802.11a
  - 802.11b to 802.11b
  - 802.11b to 802.11b + Wireless security
- Ten test runs per scenario. Sound files include speech (male and female) and music.

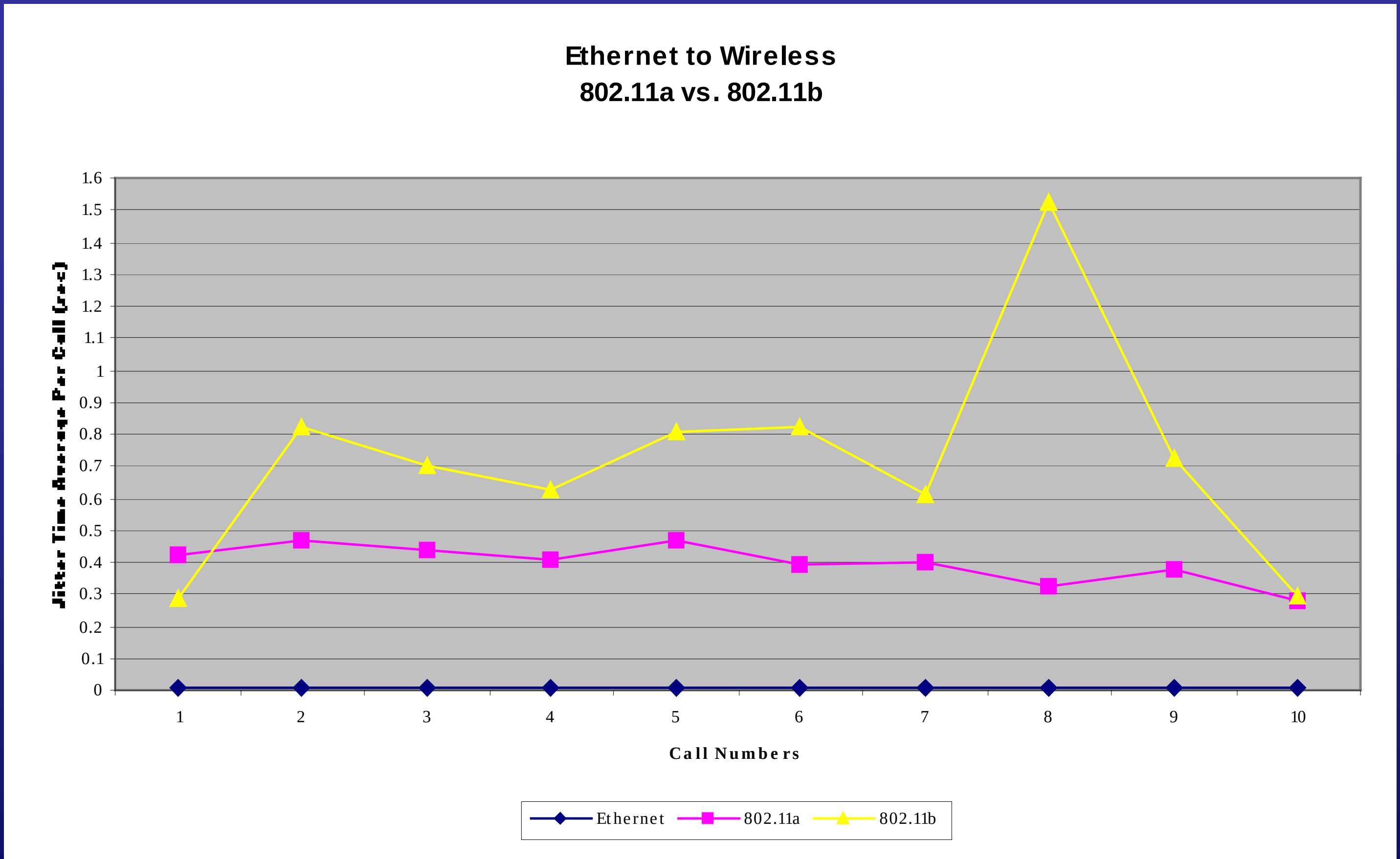
QoS Test Results
Sample Inter-packet Delay Graph



QoS Test Results
Sample Jitter Time Graph

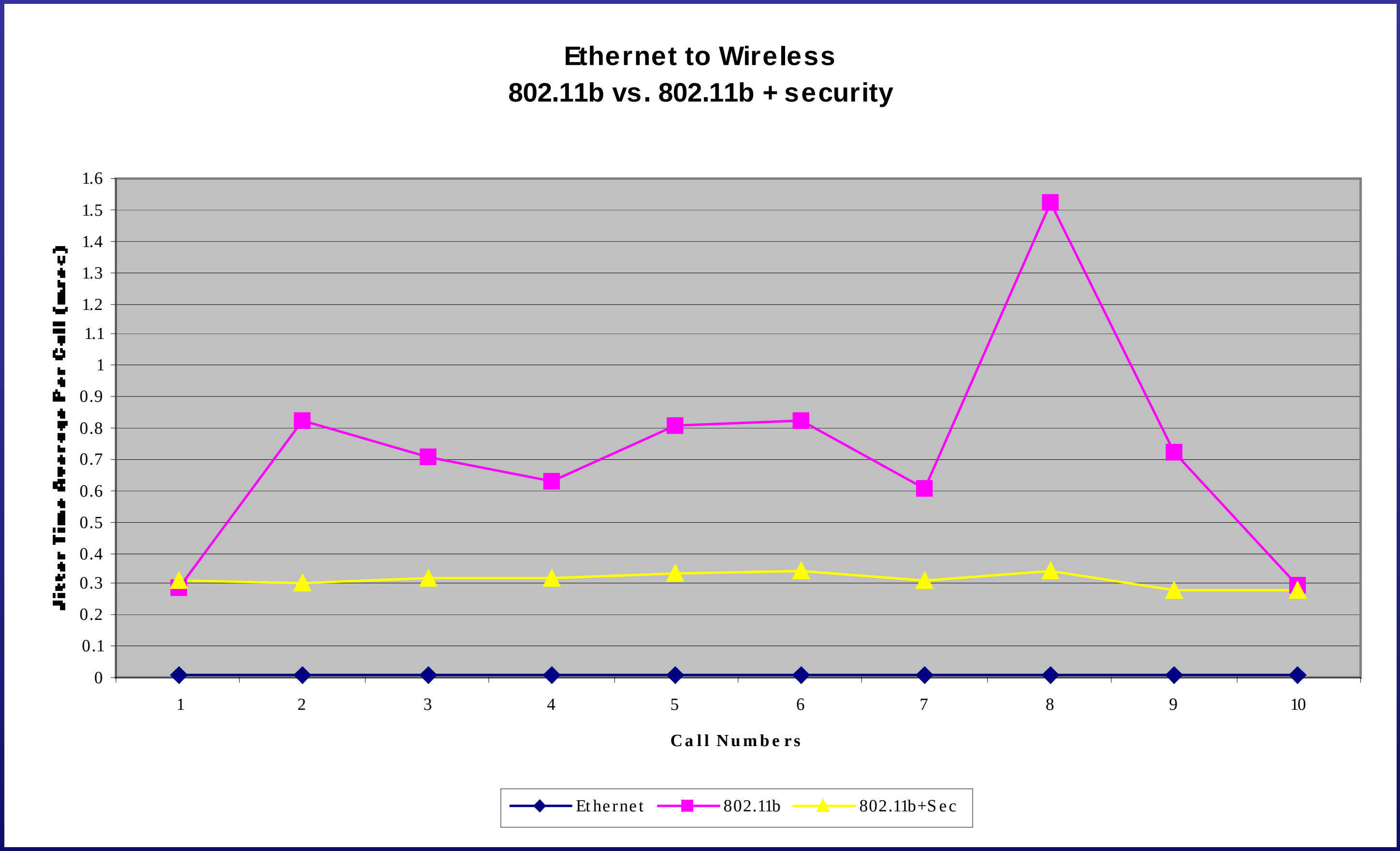


QoS Test Results: Average Jitter per Call Ethernet to Wireless (802.11a vs. 802.11b)



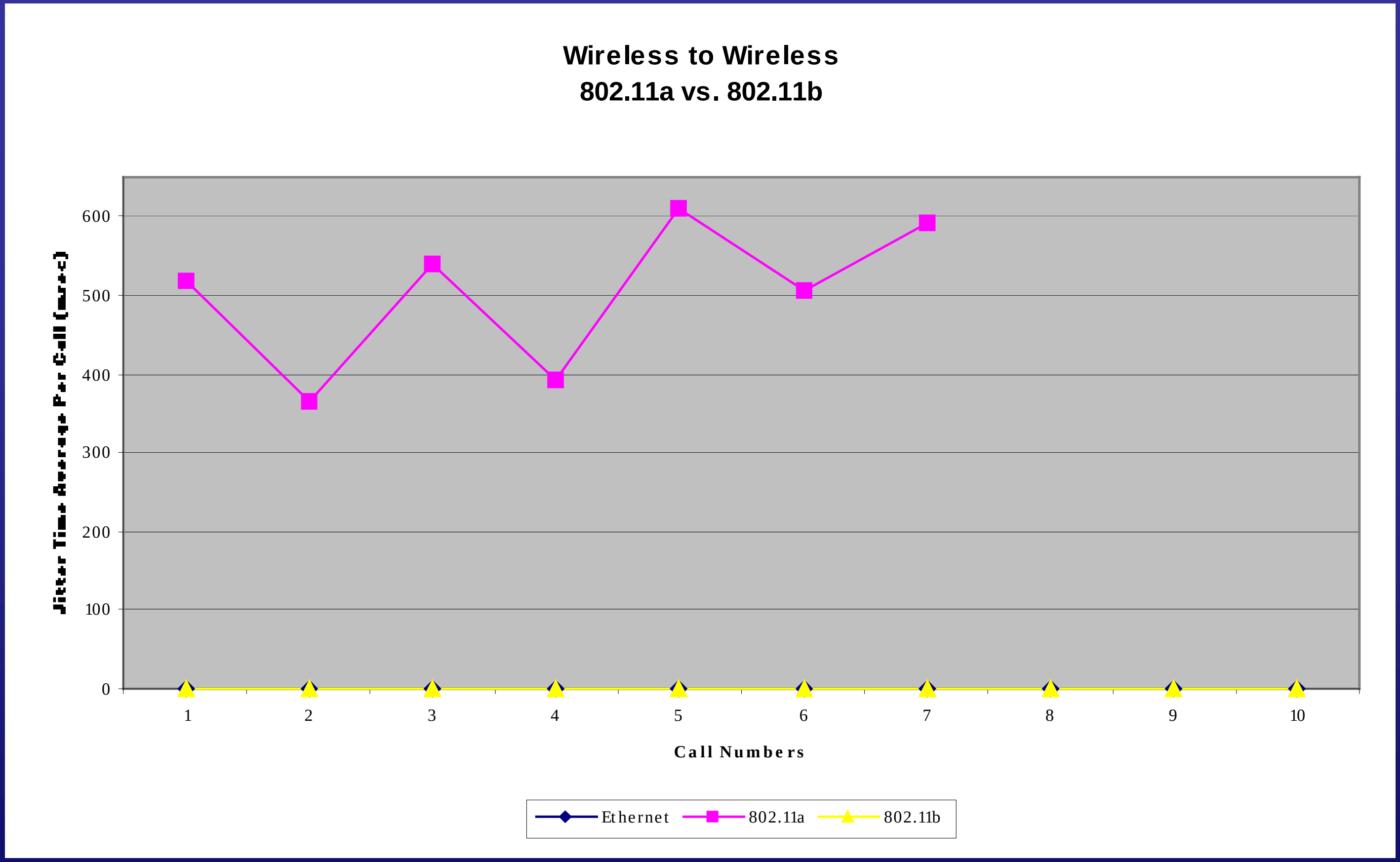
Distance from AP ~15-20 ft. Excellent signal strength with both 802.11a and 802.11b. 802.11a performed better than 802.11b.

QoS Test Results: Average Jitter per Call Ethernet to Wireless (with and without WEP)



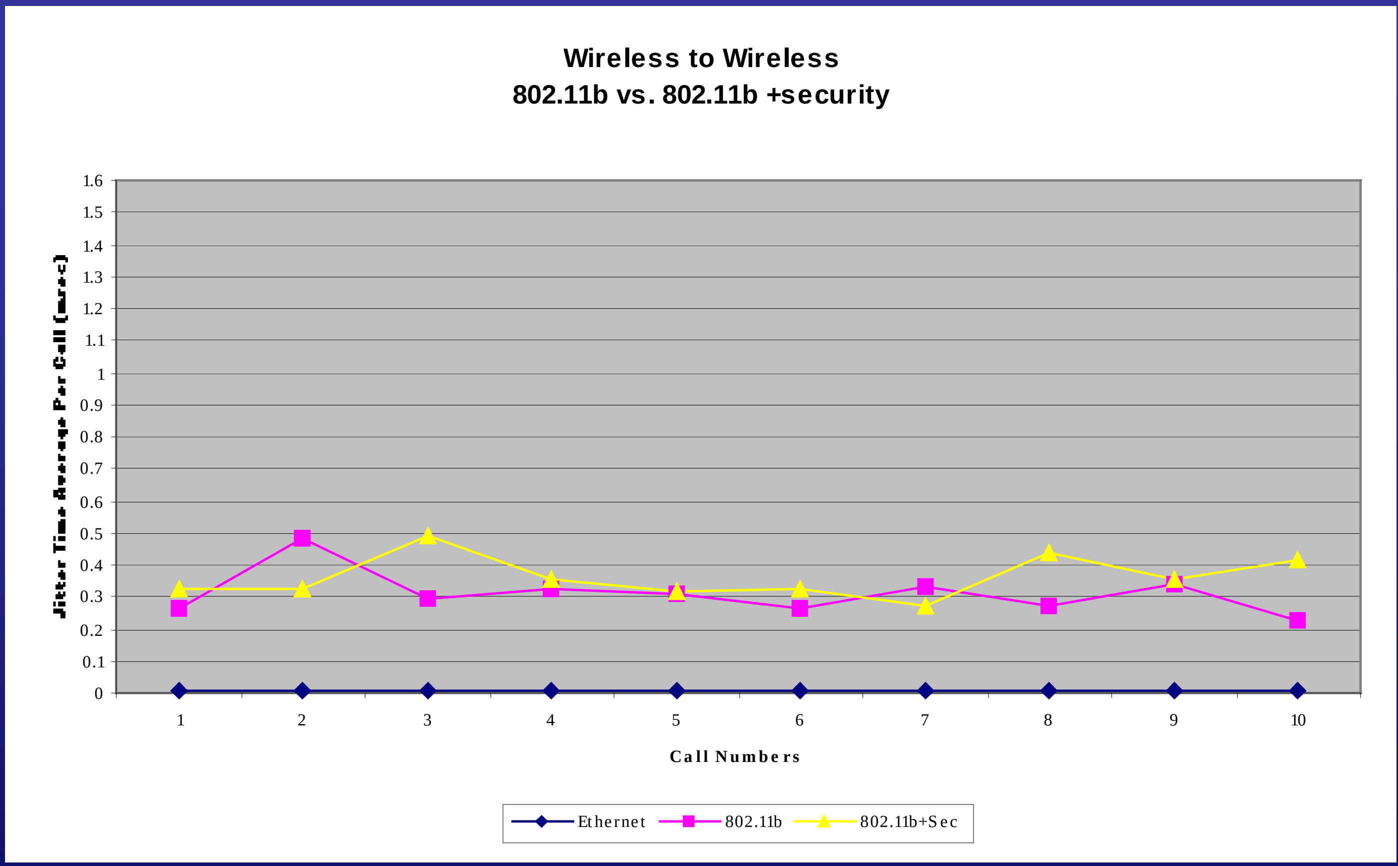
More research/testing needed to validate these results. Tests performed on different days (maybe different network load).

QoS Test Results: Average Jitter per Call Wireless to Wireless (802.11a vs. 802.11b)



Each client's distance from AP ~15-20 ft. Peer-to-peer ~30-40 ft. Poor signal strength for 802.11a, excellent for 802.11b.

QoS Test Results: Average Jitter per Call Wireless to Wireless (with and without WEP)



No significant difference in results. Need to investigate further to check at which point packets are captured by Winpcap.

QoS Test Results: Loss of Data

- No loss of data observed during all test runs (except the 802.11a to 802.11a test).
- Good subjective assessment of QoS (user listening to the received sound). Clear sound with no interruptions, with the exception of an initial delay.
- Poor signal strength during 802.11a to 802.11a test (20-40% on both ends).
- High data loss rate observed (for e.g., transmitted 196 out of 1434 packets). Loss rate of ~86-93%.
- Extremely poor sound quality (unintelligible, broken, …)
- Packets lost at the sender's end, as seen by Ethereal captured data. This needs to be investigated further as it affects interpretation of the results.

QoS Test Results: Observations

- Smooth sound quality for all test but 802.11a to 802.11a test, despite existing inter-packet delays and jitters.
- Replaying captured packets (after reassembling Wave file) reflected inconsistent delays, yet sound was clear at the receiving client.
- Sound quality improved by client's handling of timings (e.g., using RTP to synchronize relative timings).
- Quality variations were most perceived in test #7, which had highest overlap of speech and music.
- Loss of data has the highest effect on QoS.

Let's listen to a sample reassembled sound file … …

How to Improve QoS?

Problem	Solution
Delay and jitter	Separate queues for time sensitive traffic; RTP
Packet loss due to congestion	More bandwidth; Resource Reservation Protocol (RSVP); Differentiated Service (DiffServ); Multi-Protocol Label Switching (MPLS); RFC 2597 and RFC 2598

Future Research/Tests

- Inject background traffic
- Synchronize time on all testbed components and calculate initial connection delay
- Evaluate the effect of using different codecs
- PC-to-Phone quality testing
- Evaluate wireless network performance at different distances from the access point
- Evaluate wireless network performance using multiple access points with overlapping coverage
- Assess compatibility of 802.11 variants
- Evaluate existing QoS solutions (e.g., RSVP)
- Evaluate QoS of VoIP using H.323 clients
- Detect transmission sampling rate for replay based on timestamps of the captured packets
- Evaluate QoS of VoIP using a PDA client (might require porting a SIP client to a PDA)

References

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- Gast, Matthew (2002). 802.11 Wireless Networks: The Definitive Guide, O’Reilly Network.
- Hertrich, Daniel et al. (2001). “Evaluating QoS for Voice over IP in Wireless LANs”, Technical Report, Telecommunication Networks Group.
- Useful links: VoIP-WLAN-QoS Useful Links