Voice over IP (VoIP)
Past, Present … Future

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VoIP History

- 1995:
  - Vocaltec in Israel introduced the first VoIP product (InternetPhone)
- 1998:
  - Less than 1% of calls in U.S. made using VoIP
  - Switching equipment introduced by Cisco, Nortel, and Lucent
- 2000:
  - More than 3% of calls made using VoIP

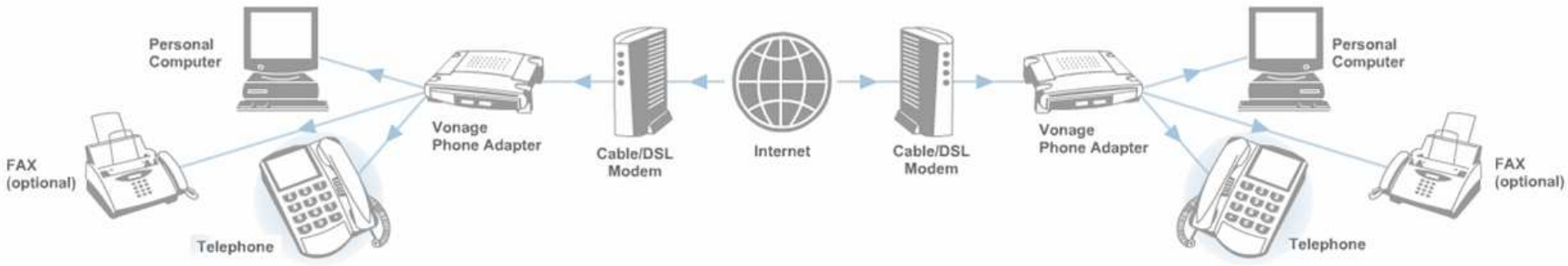
VoIP History – Contd.

- 2005:
  - major voice quality issues addressed by prioritizing voice over data traffic
  - Projected revenue from VoIP equipment sales is $3 billion
  - $8.5 billion dollars revenue from VoIP equipment by 2008

Source: ***http://www.whichvoip.com/voip/articles/voip_history.htm***

How does VoIP work?

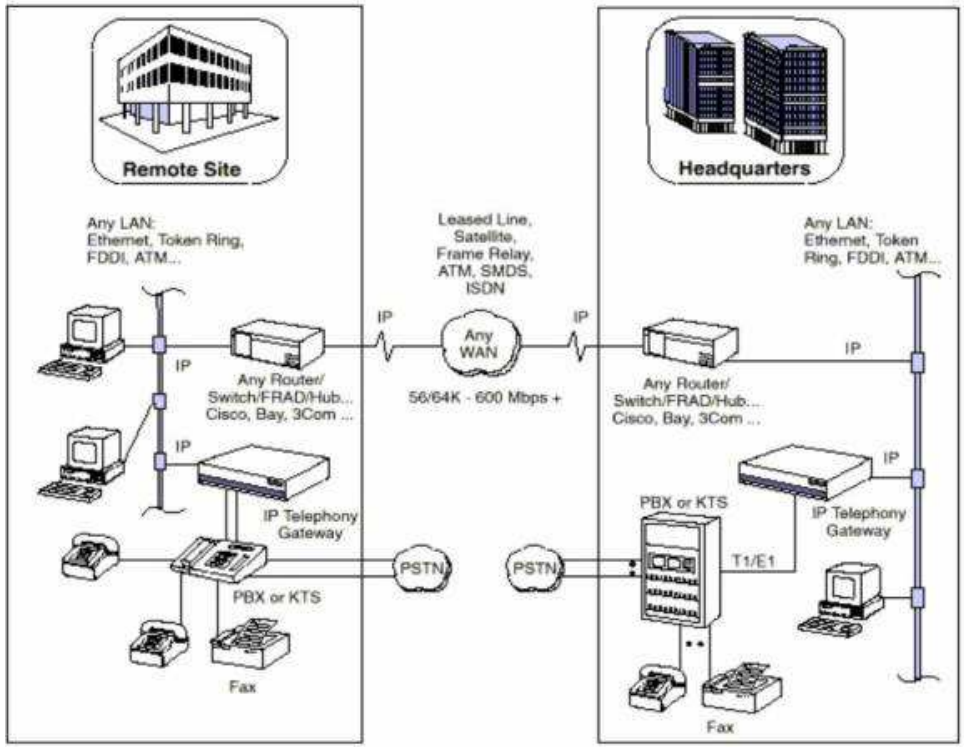
- Communication over internet
- Phone Adaptor
  - Translating voice signal into data packets
- Gateways used to connect to PSTN



Source: ***http://isds.bus.lsu.edu/CVOC/Projects/TechLibrary/VoiceOver/index.htm***

How does VoIP work?

- IP-Private Branch Exchange (IP-PBX)
  - Connection to Internet or PSTN



Source: ***http://www.slac.stanford.edu/xorg/icfa/icfa-net-paper-jan06/***

Business Case for VoIP

- Potential VoIP Market
  - Businesses and households
    - Low cost
    - Quality of service: Comparable with traditional PSTN
    - Ease of implementation
- VoIP Driving Forces
  - Cost
  - Internet Growth
  - Features
- VoIP Obstacles
  - Quality of Service (QoS)
  - Security
  - Standardization

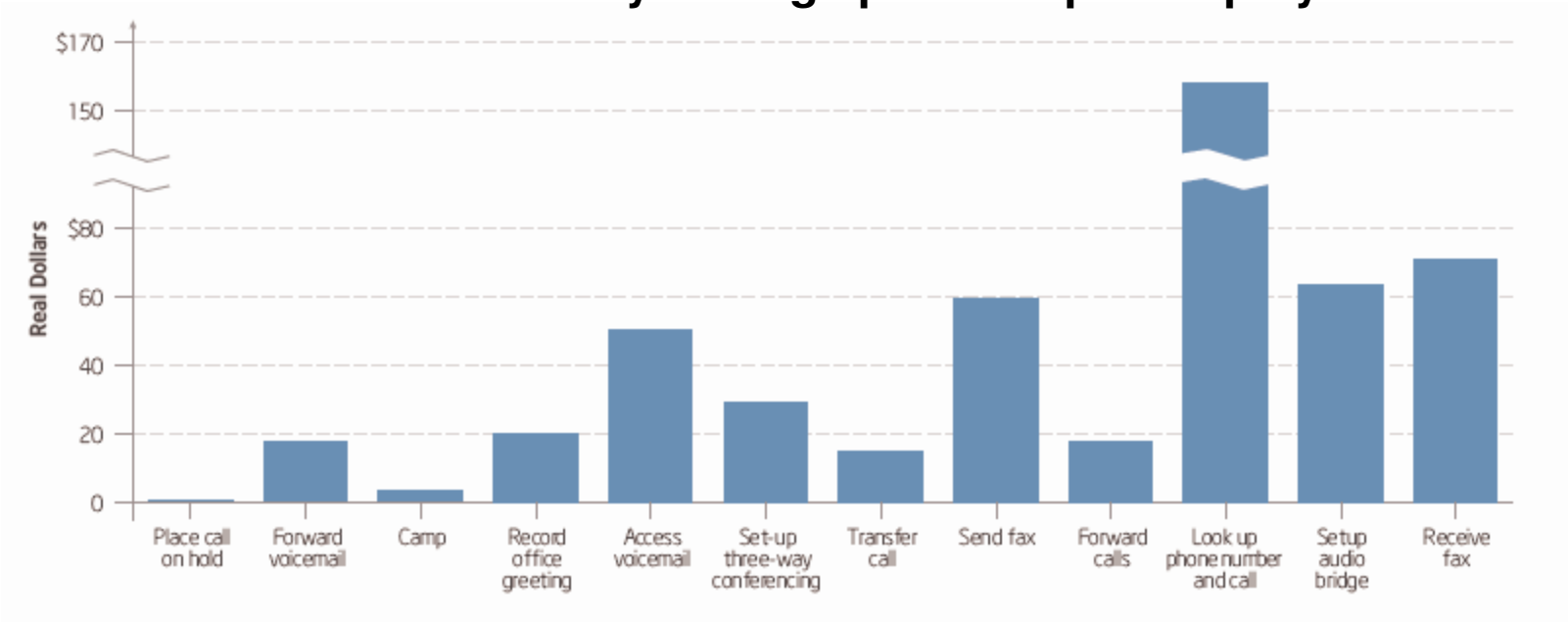
VoIP Driving Forces

- Cost saving advantages
  - Cheap Long-Distance calls by rerouting through the internet
    - Companies save up to 90% on long-distance calls
  - Ease of network maintenance and expansion
    - Higher flexibility
    - Less support staff
    - 34% to 44% lower cost of network administration
  - Higher Productivity
    - Unified Auto Attendant: call transfer during periods of high call volume

Source: "Voice over IP Reveloutionizing the way business communicates", Netlojix 2004

VoIP Driving Forces – Contd.

Annual Productivity Savings per Task per Employee



Estimated Annual Productivity Gains

Productivity Metric	Gains
Time gain per user	2.7 days per year
Productivity gain per user	$480
Productivity gain at a 650-user site	$312,000

Source: Intel, "the business case for enterprise VoIP"

VoIP Driving Forces – Contd.

- Improvements by switching to VoIP
  - Measurable, real-world user productivity benefits
  - Greater voice messaging accessibility
  - Lower total cost of ownership (TCO)
  - Immediate and long-term hard cost savings
  - Reduced expense of telecom administrator moves, adds, and changes
  - Simplified management of servers, systems, endpoints, and network
  - Greater Flexibility of component selection

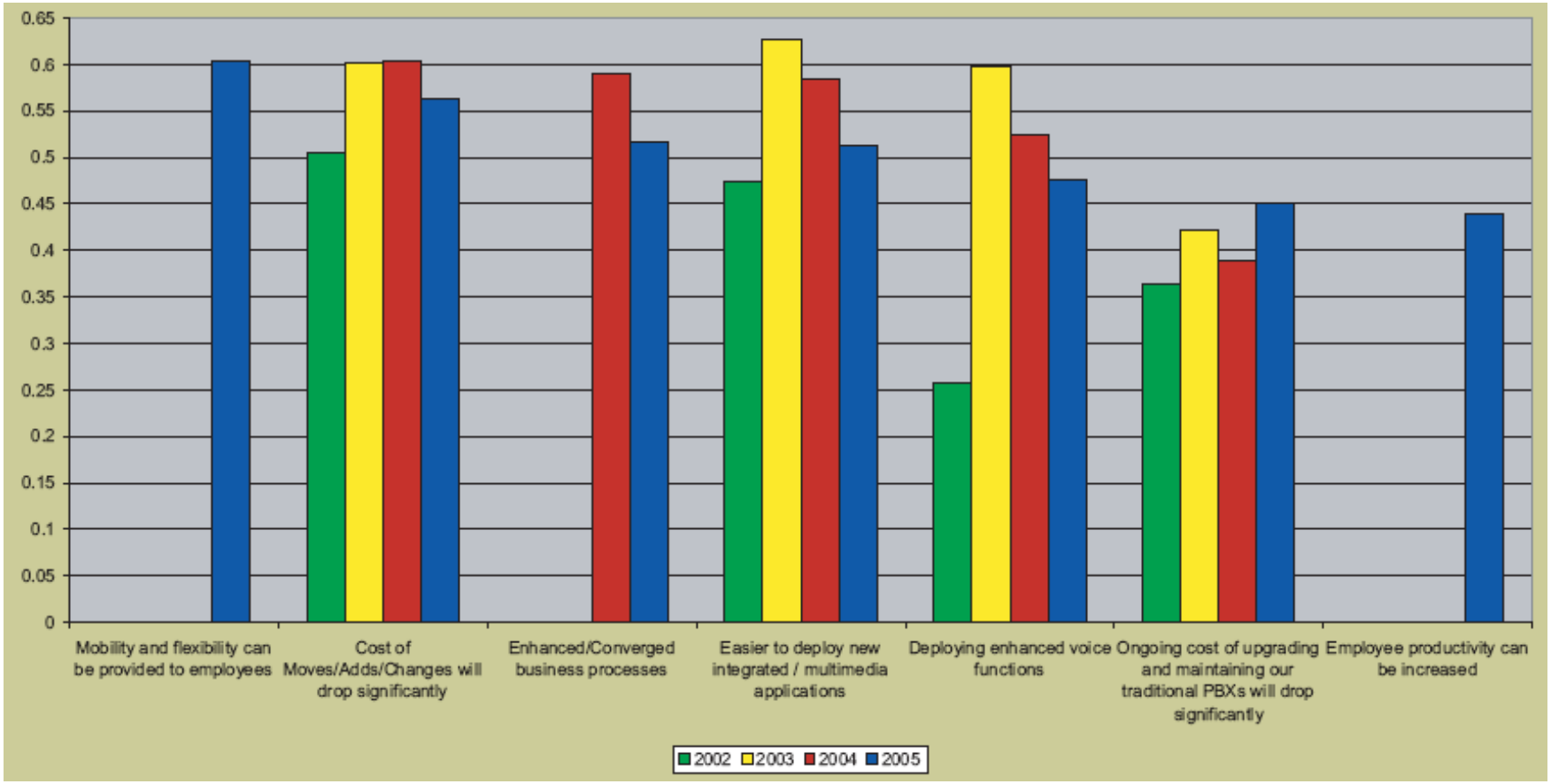
Source: Intel, "the business case for enterprise VoIP"

VoIP Driving Forces – Contd.

- Features
  - Traditional features: caller ID, call transfer, call waiting, redial, call hold, etc.
  - Extra features:
    - User Web Portal: user access to a call long containing inbound and outbound calls, company directory, phone numbers and missed calls (as .wav files)
    - Click-to-call: contact clients, replay messages with click of a button
    - Find me/Follow me: Prioritize your calls, reroute important calls

VoIP Driving Forces – Contd.

Top Expected Benefits of Deployment of VoIP



Source: 2005/2006 state-of-the-market report

World Internet Usage Growth

World Internet Usage and Population Statistics						
World Region	**Population**	**Population % of the world**	**Internet Usage**	**% population**	**Usage % of the world**	**% growth from 2000-2005**
Africa	915,210,928	14.1 %	23,649,000	2.6 %	2.3 %	**423.9 %**
Asia	3,667,774,066	56.4 %	364,270,713	9.9 %	35.6 %	**218.7 %**
Europe	807,289,020	12.4 %	291,600,898	36.1 %	28.5 %	**177.5 %**
Middle East	190,084,161	2.9 %	18,203,500	9.6 %	1.8 %	**454.2 %**
North America	331,473,276	5.1 %	227,303,680	68.6 %	22.2 %	**110.3 %**
Latin America/ Caribbean	553,908,632	8.5 %	79,962,809	14.4 %	7.8 %	**342.5 %**
Oceabia/ Australia	33,956,977	0.5 %	17,872,707	52.6 %	1.7 %	**134.6 %**
World Total	6,499,697,060	100.0 %	**1,022,863,307**	15.7 %	100.0 %	**183.4 %**

Source: http://www.internetworldstats.com/ (updated March 2006)

Technical Challenges

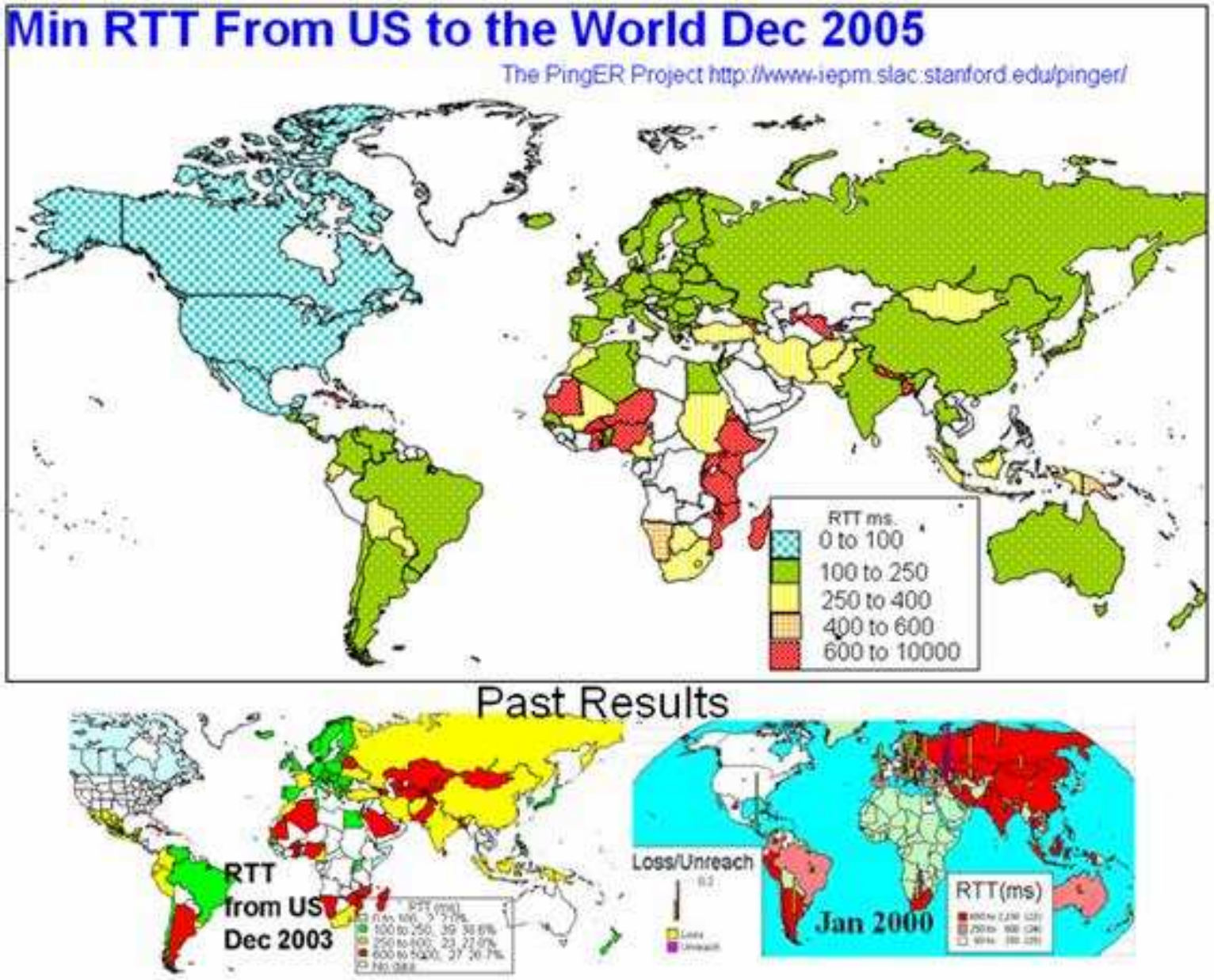
Quality of Service

Security

Standardization

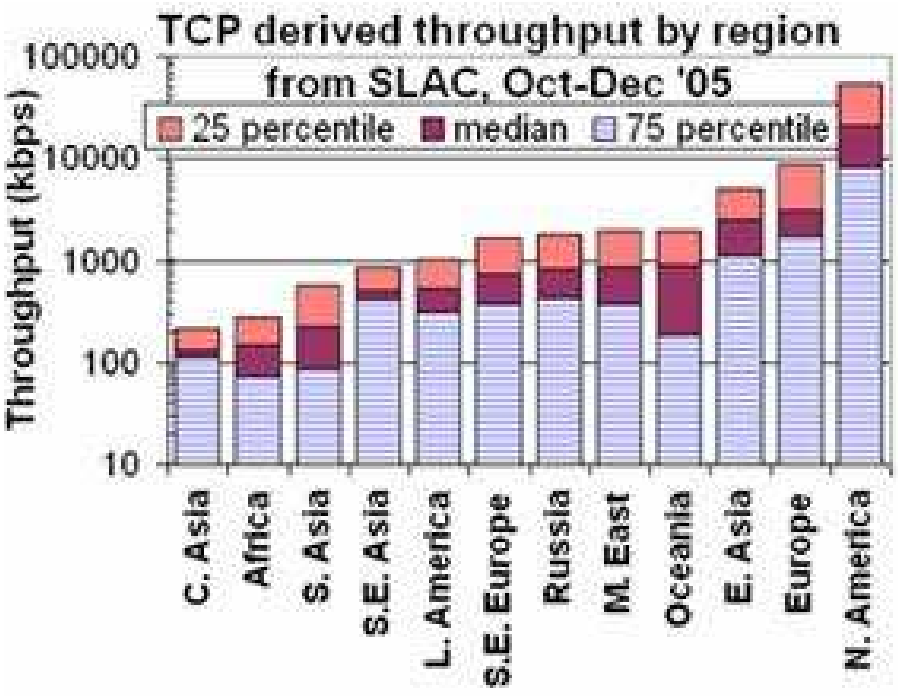
Quality of Service (QoS)

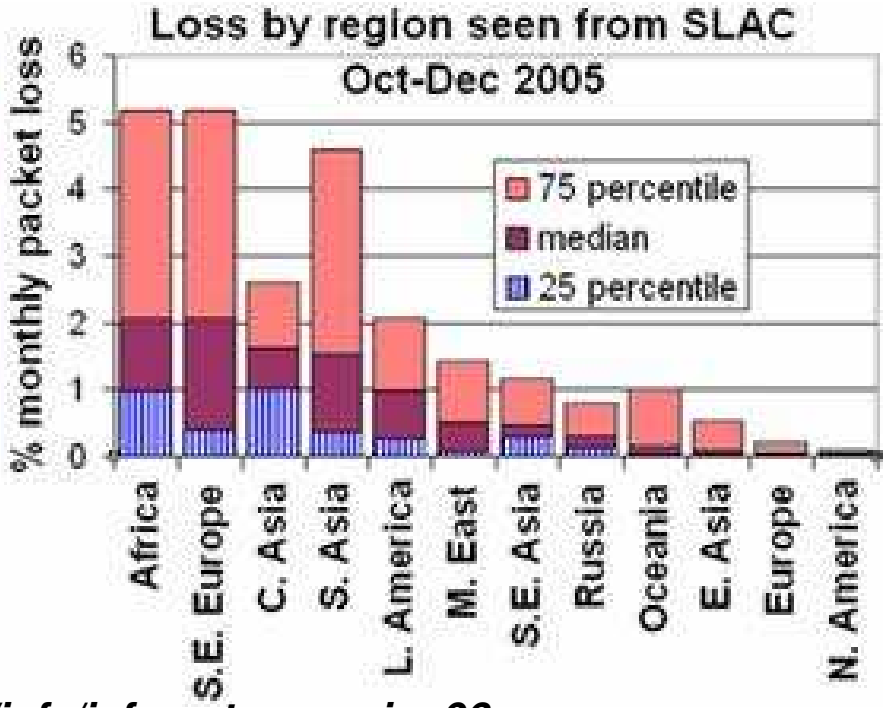
- Quality factors
  - Latency 150ms max (150-250 usable, 400 too much)
  - Jitter 75ms max
  - Packet Loss 3% max loss
- Reliability
  - POTS 99.999% (5 min down per year)
  - Private IP networks 94%, public internet 61%



Source: http://www.slac.stanford.edu/xorg/icfa/icfa-net-paper-jan06

VoIP Throughput and Loss

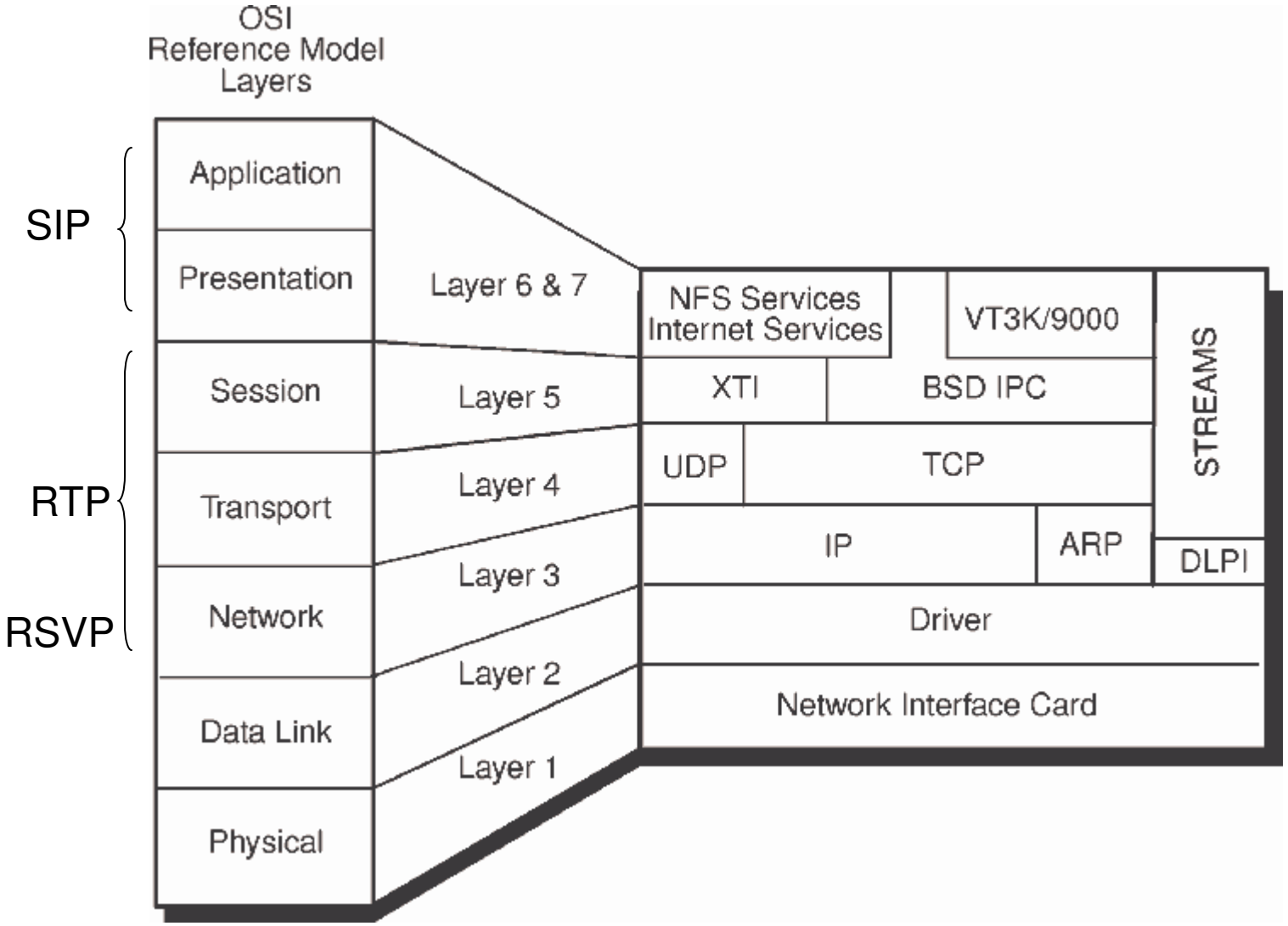




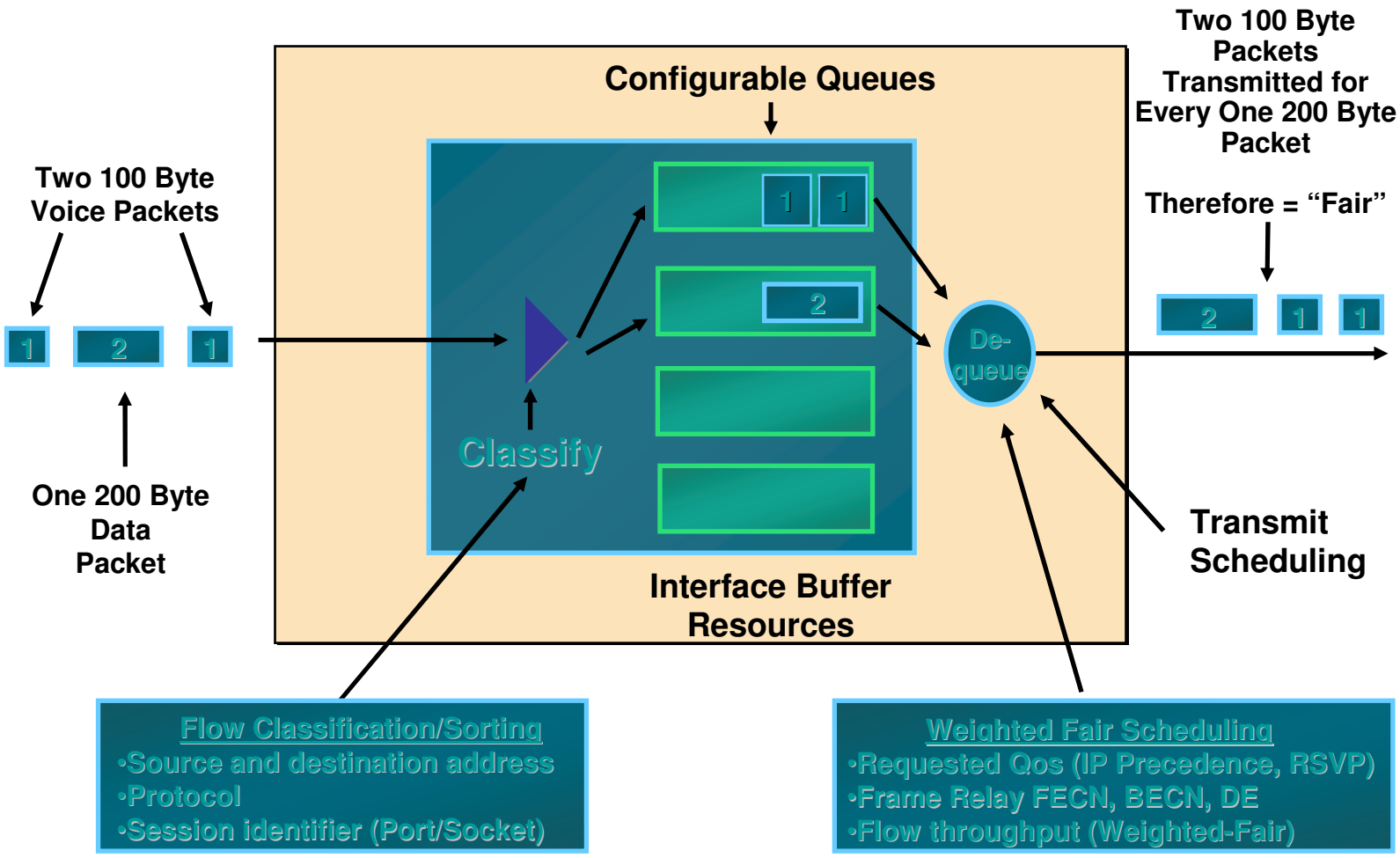
Source: http://www.slac.stanford.edu/xorg/icfa/icfa-net-paper-jan06

Also see: http://www.internettrafficreport.com/main.htm

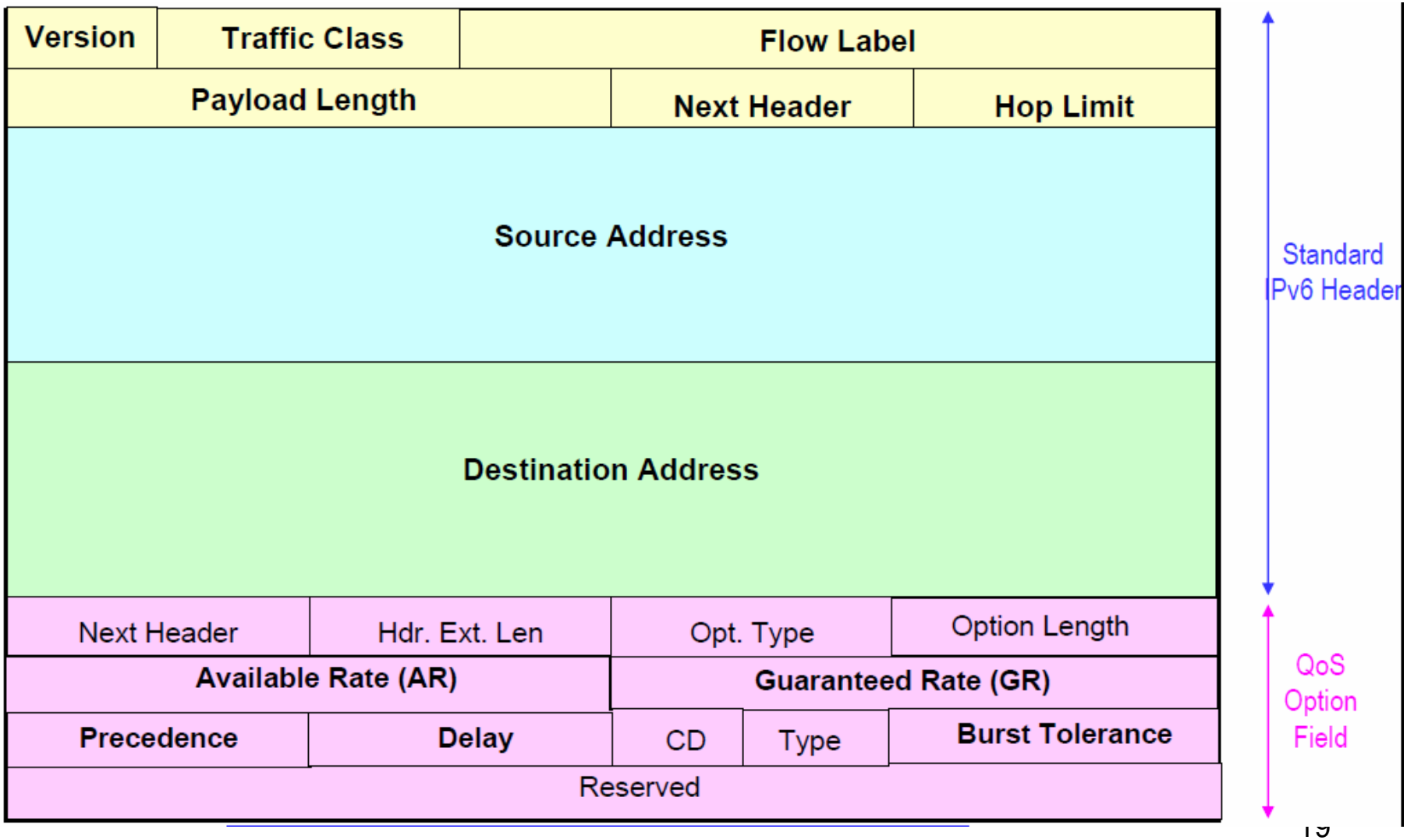
Internet Layers



Weighted Fair Queuing

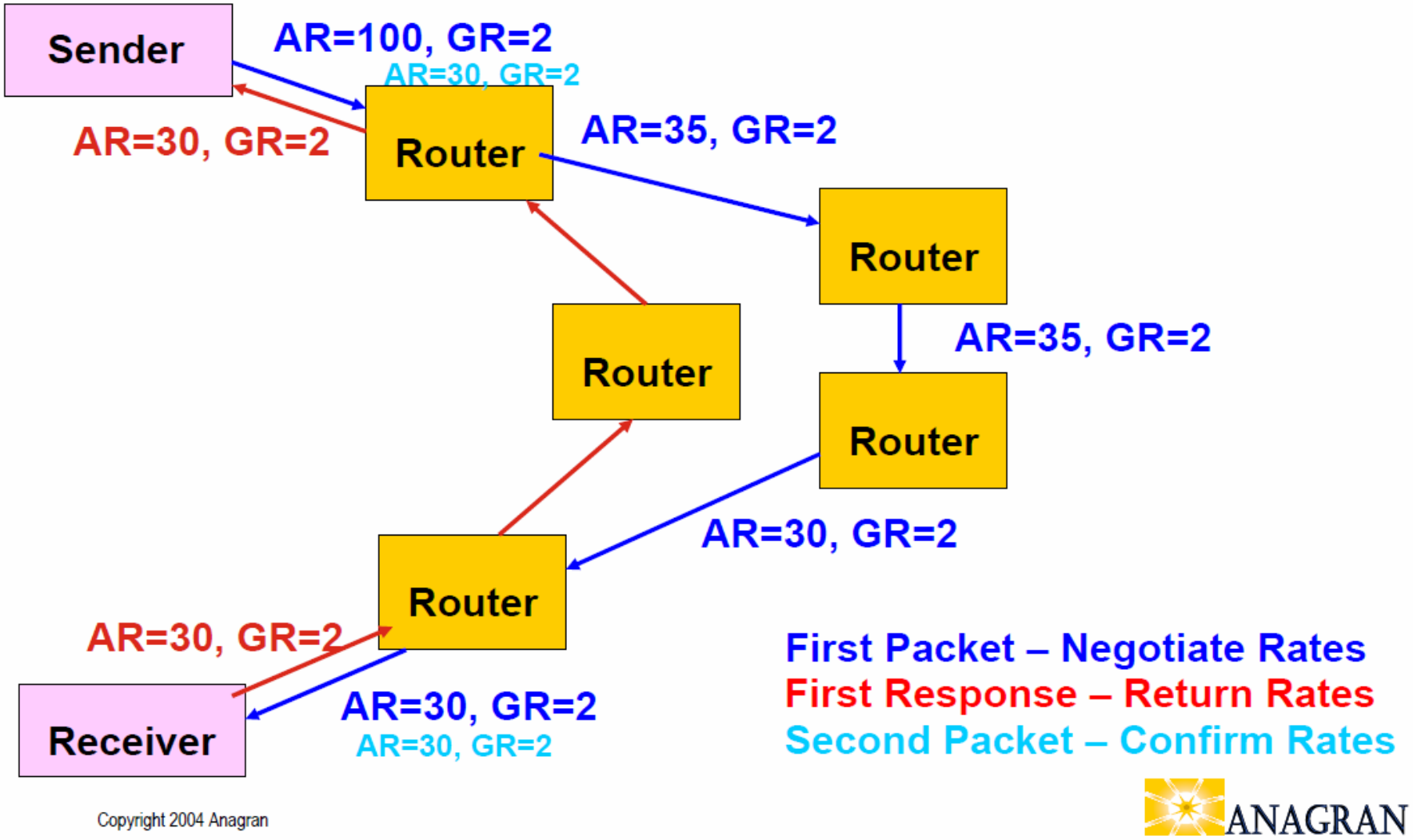


IPv6 QoS



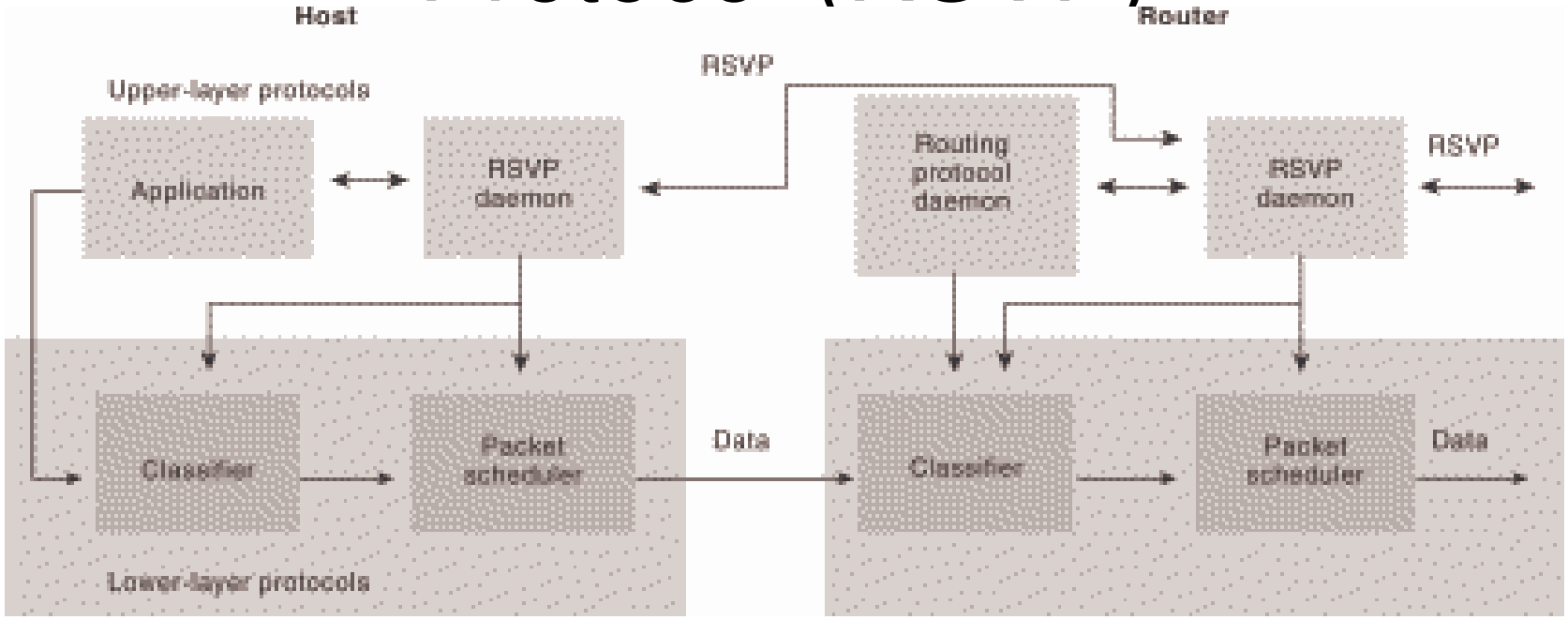
Roberts L.G., "IPv6 QoS Applications," *IPv6 Summit,* www.anagran.com (2004)

IPv6 QoS



Roberts L.G., "IPv6 QoS Applications," *IPv6 Summit,* www.anagran.com (2004)

SIP->Resource reSerVation Protocol (RSVP)



Cottrell L., http://www.slac.stanford.edu/xorg/icfa/icfa-net-paper-jan06/, January (2006).

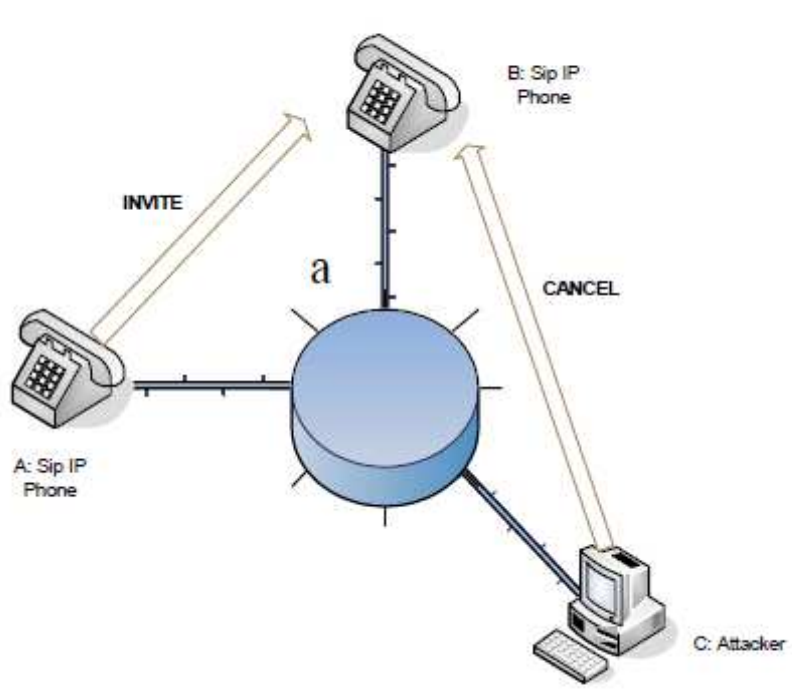
- Transport Layer
- Send flow descriptor for reservation
  - flowspec (for packet scheduler)
  - filterspec (for classifier)

Security

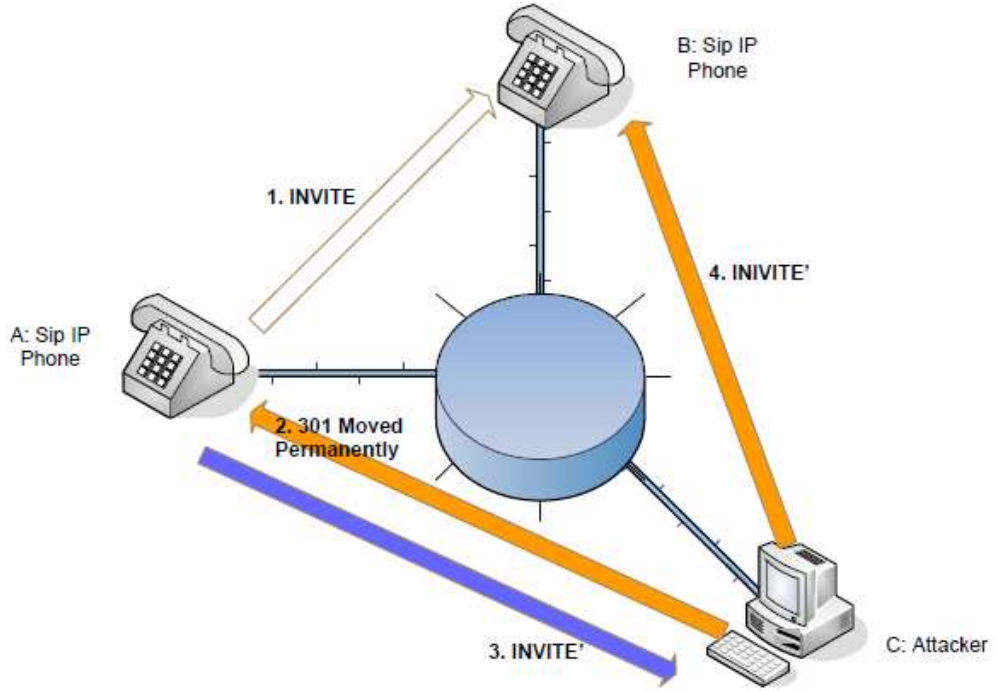
- Signaling Protocols Layer
  - SIP Denial of Service (DoS)
  - SIP Man in the Middle/Call Hijacking
- Transport Protocols Layer
  - Eavedropping
  - Packet Insertion Attacks
- Solutions
  - IPsec at network layer, Transport Layer Security (TLS)
  - Secure Real-Time Protocol (SRTP)

Security – Contd.

Denial of Service



Man in the Middle



Mihai A-S, XMCO Partners, http://www.xmcopartners.com (2004).

Standardization

- **H.323**
  - ITU-T (International Telecommunications Union)
  - Top-Down, very specific about protocol

- **SIP**
  - IETF (Internet Engineering Task Force)
  - Bottom up, gives mostly a session initiation framework, more flexible

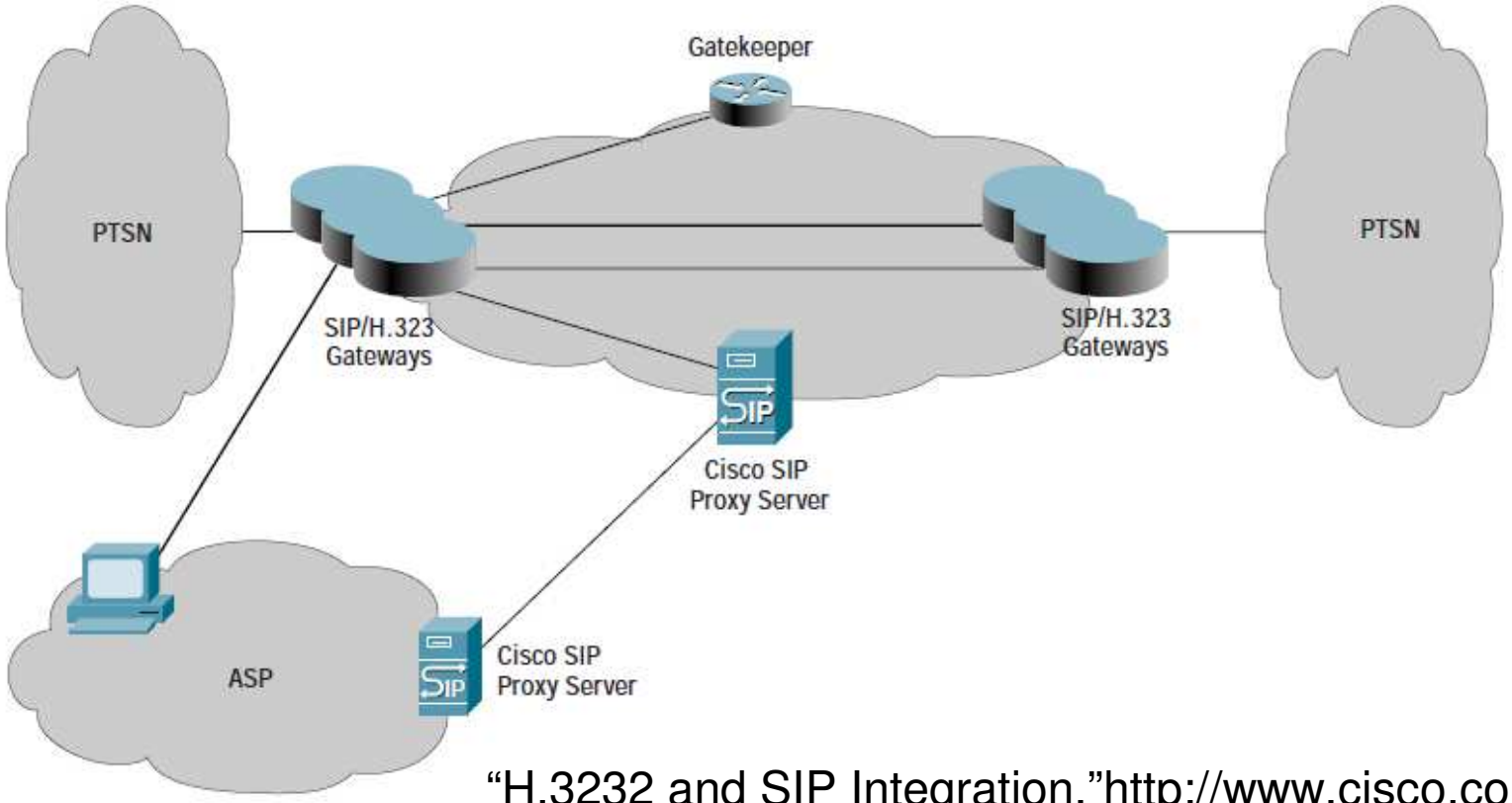
	Real-time data transmission	Call control	Feature Control			Signaling procedure variants	
			Framework	Extensions	Supplem. services		
SIP (IETF)	RTP/RTCP	SIP (SDP)	Call control framework*	REFER, INFO SUBSCRIBE, NOTIFY, UPDATE	Transfer* Call hold	—	SIP-INVITE transaction
H.323 (ITU-T)	RTP/RTCP	H.225.0, H.245	H.450.1	H.450.1	H.450.2–H.450.12	Basic call setup	Fast connect

*Not explicitly standardized as a supplementary service.

Glassman J. *IEEE Communications Surveys*, vol. 5, no. 3, pp.32-47 (2003)

Standardization

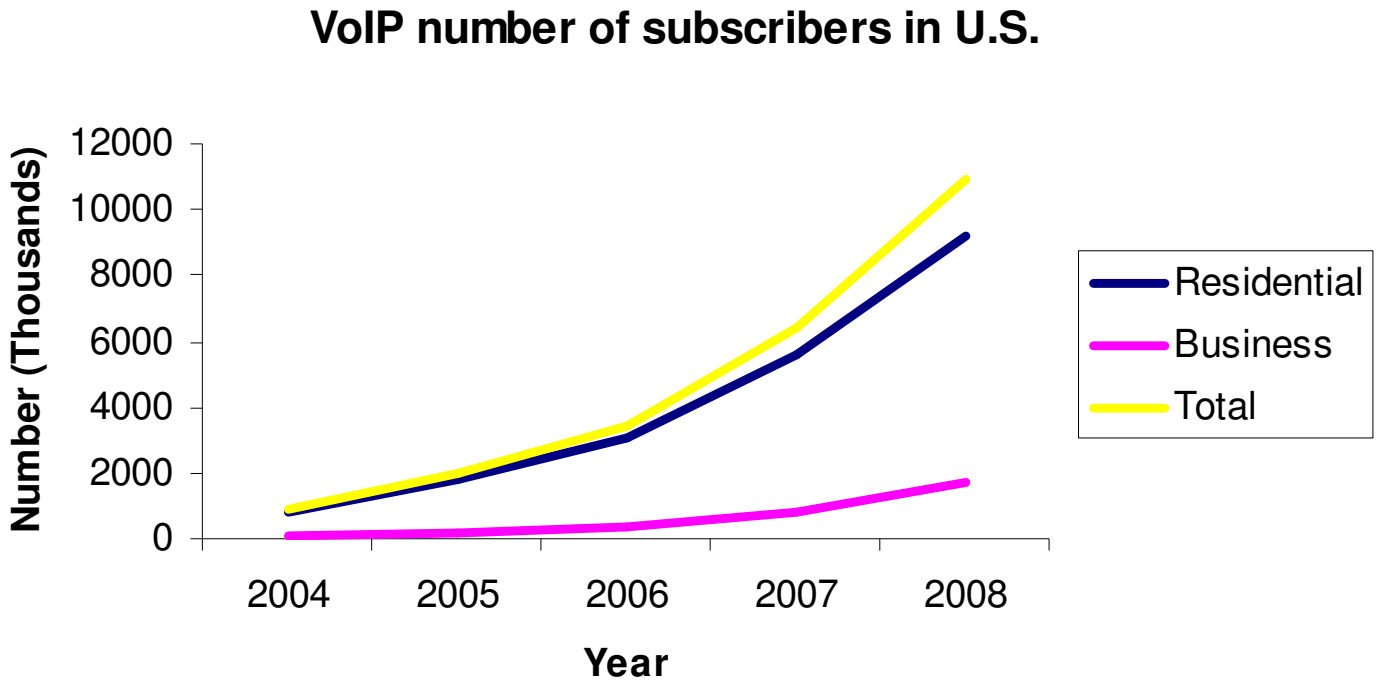
- H.323 older and better deployed
- SIP growing rapidly due to ease of merging data and voice
- Solution: Gateways that can convert between both



"H.3232 and SIP Integration,"http://www.cisco.com (2001)

Present VoIP Market

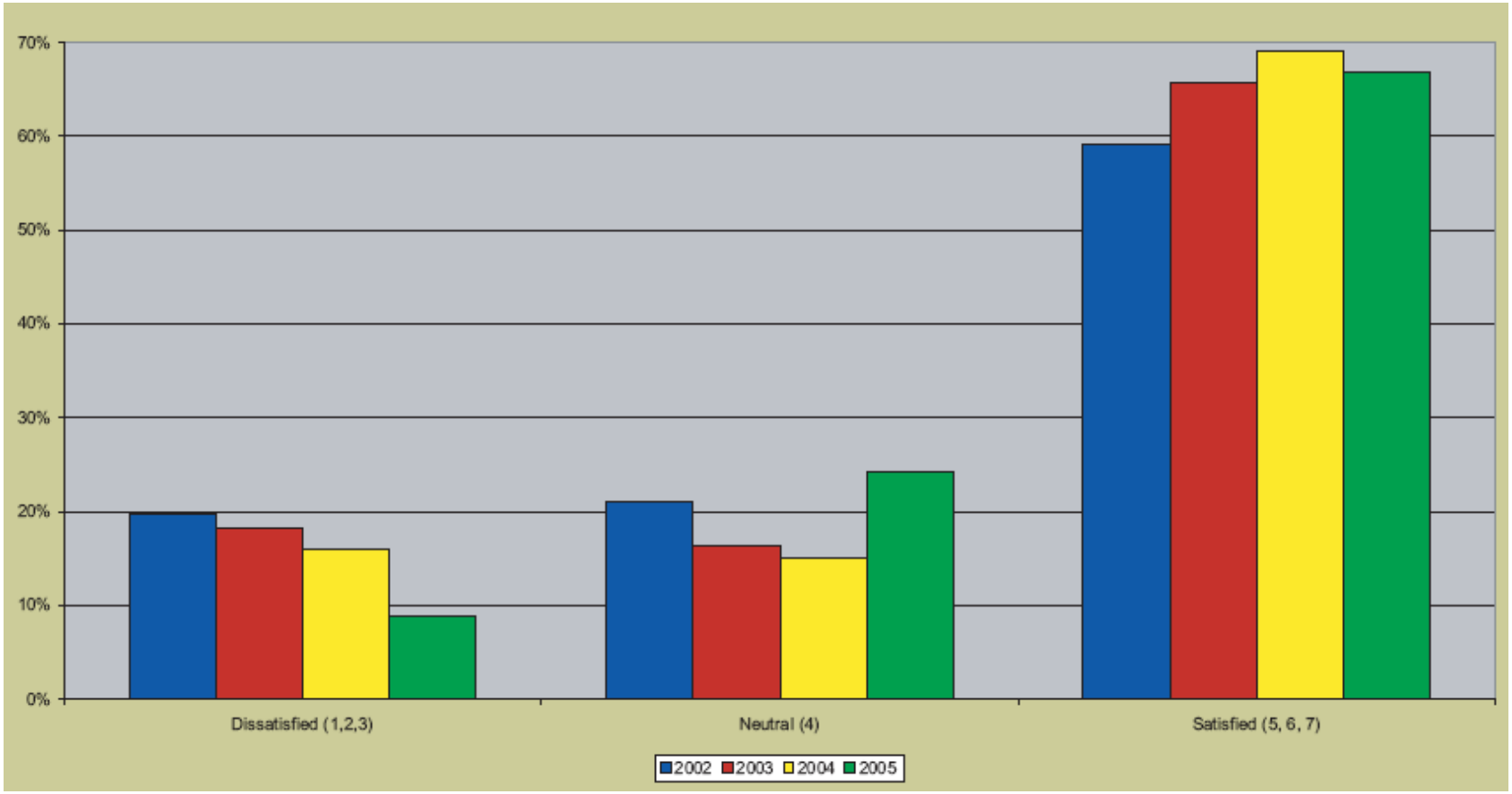
- Market indicators
  - Number of users



Source: www.infotechtrends.com

Present VoIP Market

Satisfaction with VoIP Implementation



Source: 2005/2006 VoIP State of the market report

Present VoIP Market – Contd.

- More than 400 VoIP providers (*March 2005*)
- VoIP service providers
  - Commercial providers
    - e.g. Vonage, Verizon's VoiceWing, and AT&T's CallVantage
    - Unlimited U.S. and Canada: $24.99, $24.95, and $29.99
  - Free services
    - Skype
    - Free World Dial up

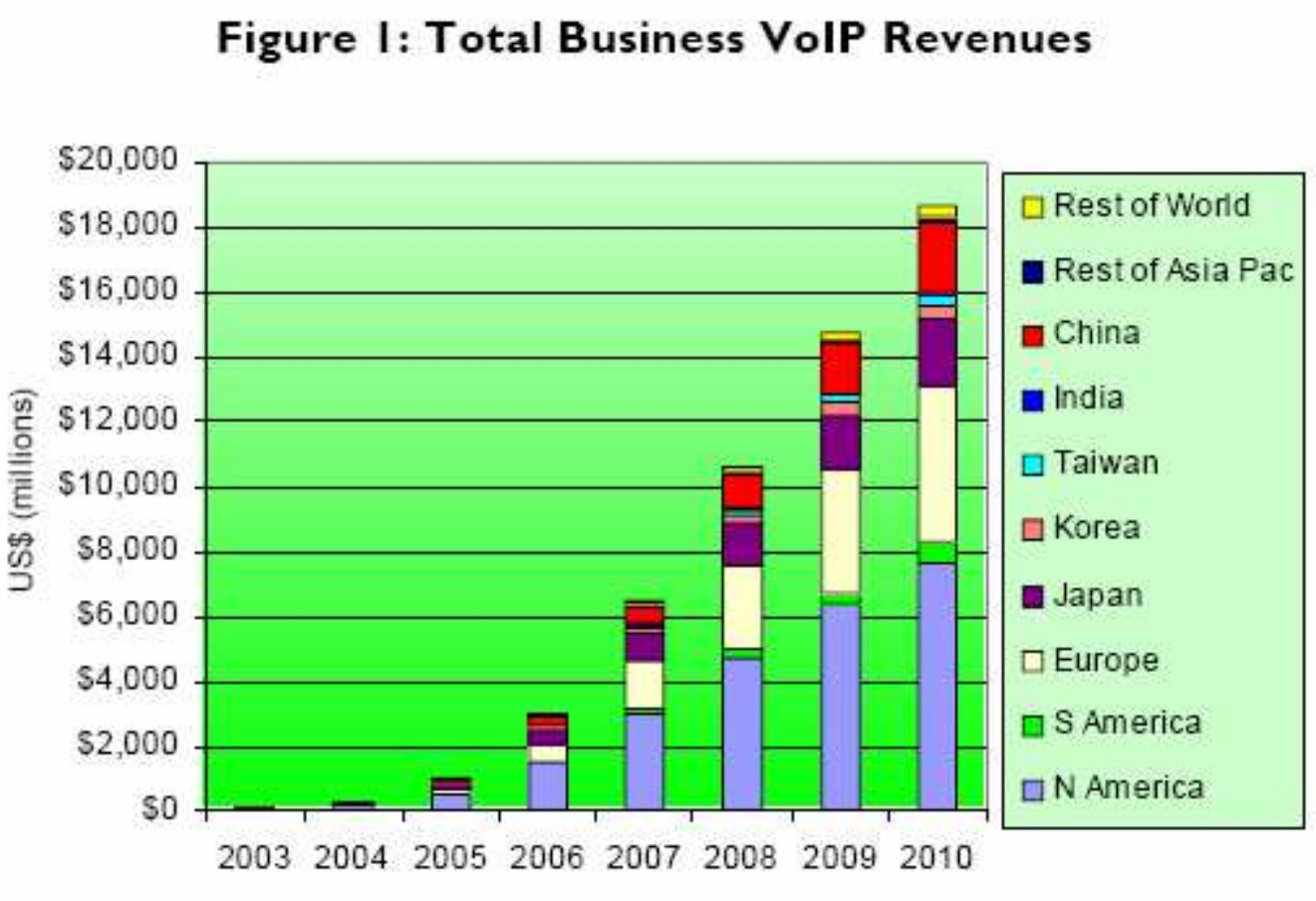
Example: Vonage Holdings Inc.

- More than 1.6 million subscribers in U.S., Canada, and U.K.
- One thousand new customers a day

Financial Highlights	
Revenue (2005)	269.20 M
Revenue Growth (1 yr)	237.70 %
Employees (2005)	1,355
Employee Growth (1 yr)	109.10%

Source: Yahoo! Finance

VoIP Business Growth



Source: Juniper research: VoIP … Deep Impact

VoIP Forecast

Regulation

Convergent Networks

Regulation

- Regulation and taxing can define the future of VoIP
- Must prove that it is inherently interstate and indivisible (thus limiting state regulation)
- Impact on city revenues
  - Chapter 283 fees are public-right-of-way, and a large source on city income

Regulation

- Must prove that it is an Information service subject to FCC Title II, not Telecomm under Title I
- Convergence makes classification difficult
- Required services:
  - E911, Disability Service, CALEA (communications assistance for law enforcement)

Network Convergence

- The future is Triple Play! Voice, Video, and Data
- Big competitors are Hybrid Fiber-Coax (cable companies), and Fiber to the Home (phone companies)

Project Lightspeed

VoIP: Disrupting Technology

Data cost

pico dollars/bit

Telephony	13,000
Web browsing	2500
Video Rental	75
TV (viewed)	4
TV (to home)	0.02

- There is still a market barrier to be breached before VVD becomes widespread
- VoIP could greatly change the cost of telephony

Conclusions

- Is VoIP going to continue to grow? YES!
- Will it replace standard telephony? Most likely!
- Will the increase in subscriber base make the market more competitive? Yes!
- Who will survive the competitive market? The incumbent technology providers (Telecomm or Cable) or new companies?