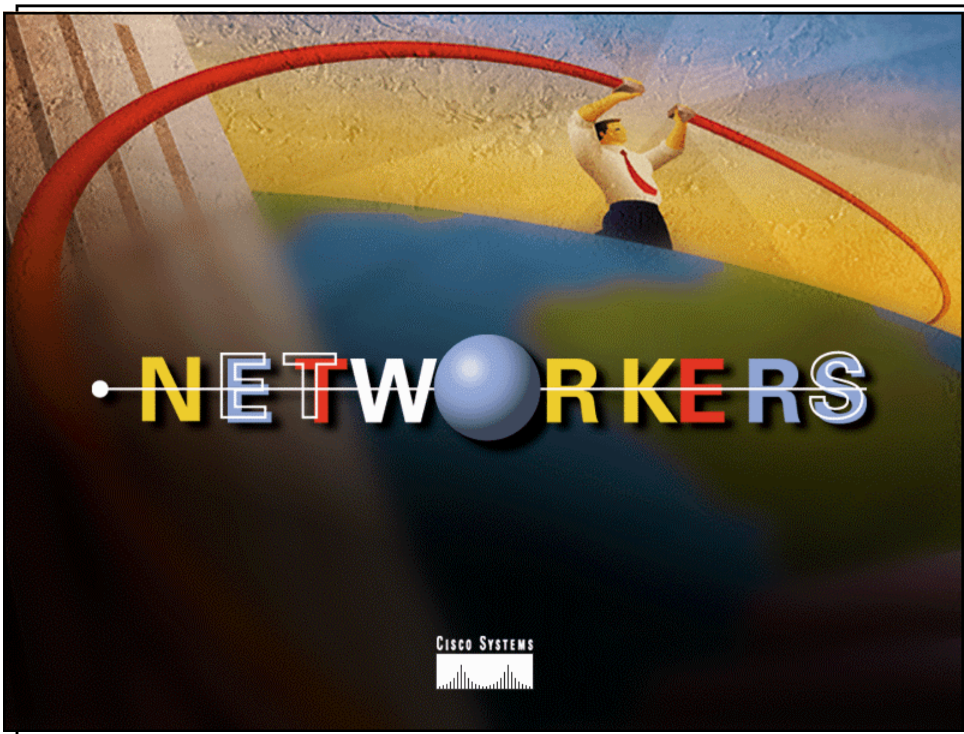
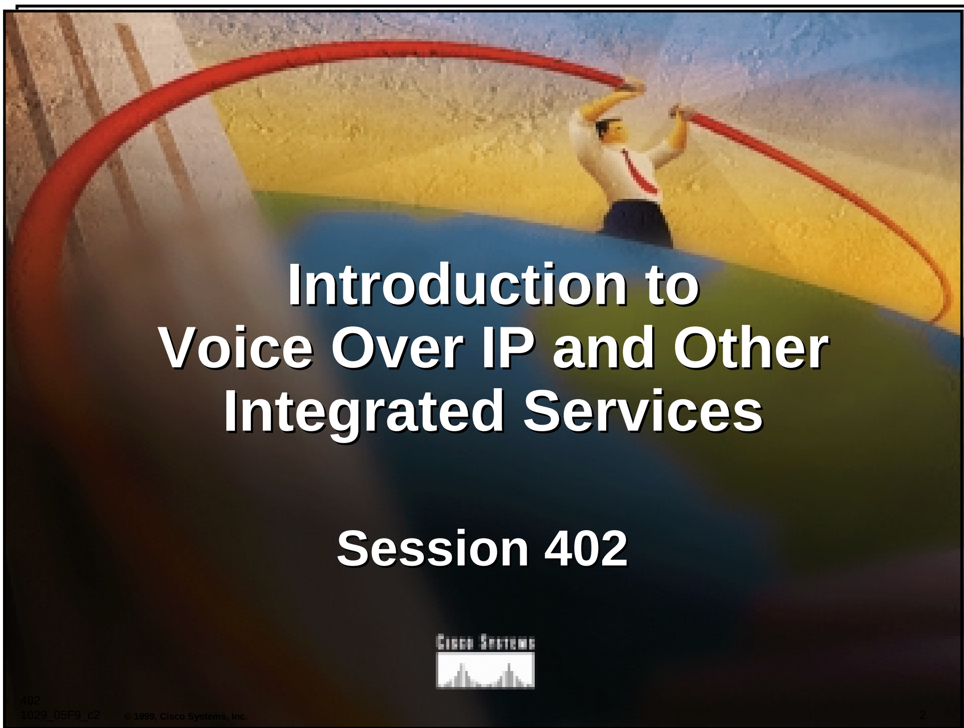

NETWORKERS
Cisco Systems


Introduction to
Voice Over IP and Other
Integrated Services
Session 402
Cisco Systems

Introduction

“Voice Is “Just” Another Latency-Sensitive IP Application”

www.cisco.com

Agenda

- Why Multiservice Networks?
- What Is Multiservice?
  - Voice Networking Overview
  - Voice Over Data Network Transport Mechanisms
  - Multiservice Network Architectures
- How Does Voice Over IP Transport Work?
  - Applications
  - Challenges and Solutions
- How Does an IP Phone System Work?
- When Can I Implement IP Multiservice?

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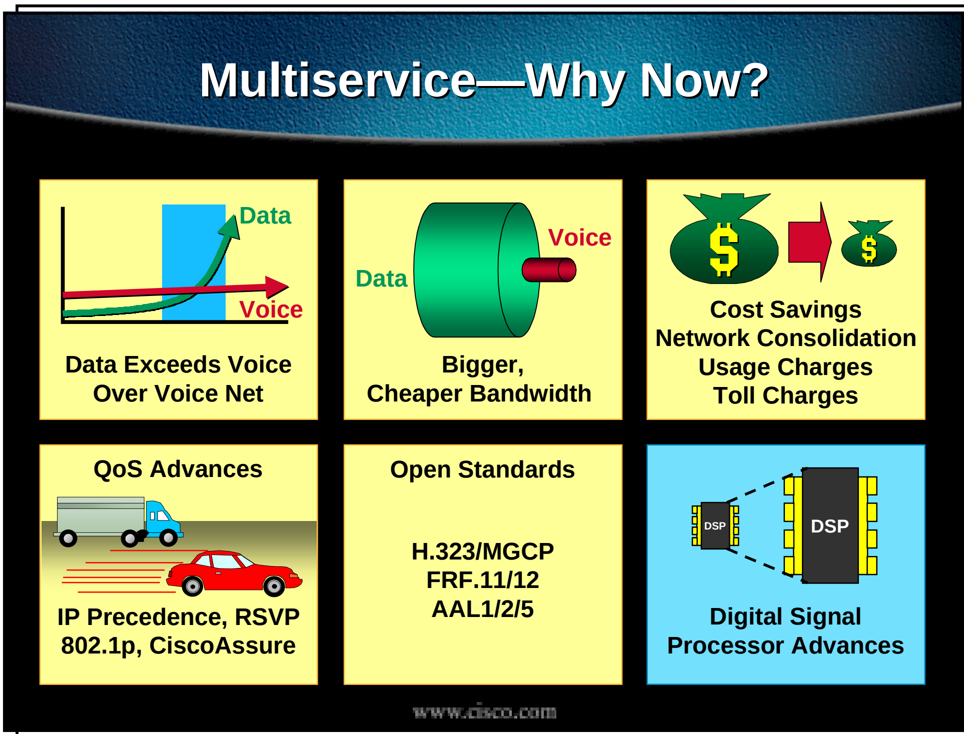
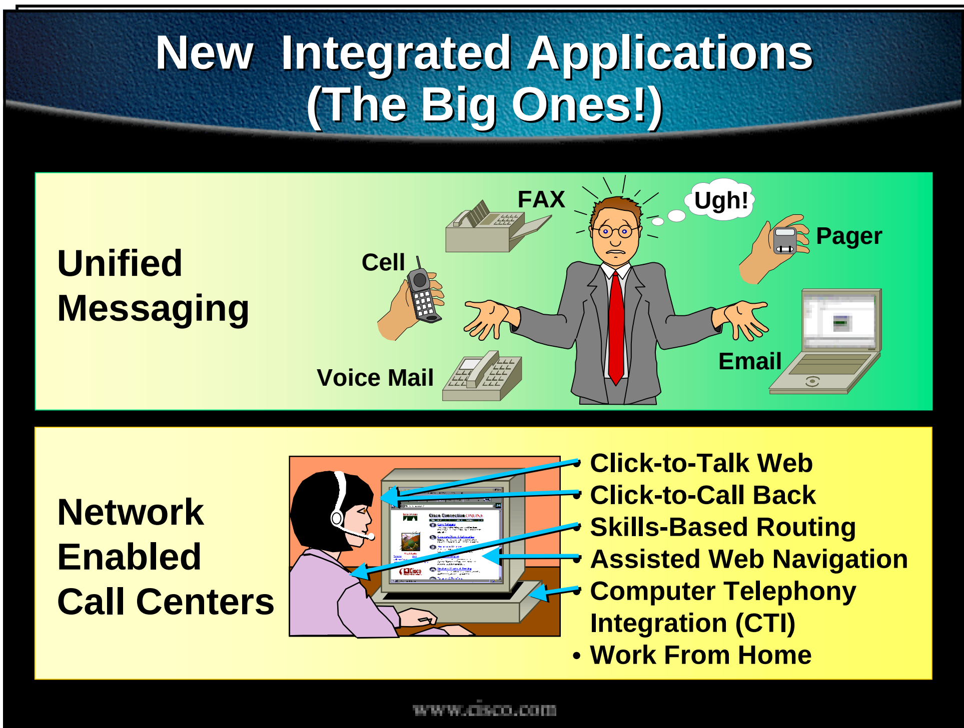

Multiservice—Why Now?
Data
Voice
Data Exceeds Voice
Over Voice Net
Voice
Data
Bigger,
Cheaper Bandwidth
Cost Savings
Network Consolidation
Usage Charges
Toll Charges
QoS Advances
IP Precedence, RSVP
802.1p, CiscoAssure
Open Standards
H.323/MGCP
FRF.11/12
AAL1/2/5
DSP
DSP
Digital Signal
Processor Advances
www.cisco.com


New Integrated Applications
(The Big Ones!)
Unified
Messaging
FAX
Ugh!
Pager
Cell
Voice Mail
Email
Network
Enabled
Call Centers
Click-to-Talk Web
Click-to-Call Back
Skills-Based Routing
Assisted Web Navigation
Computer Telephony
Integration (CTI)
• Work From Home
www.cisco.com

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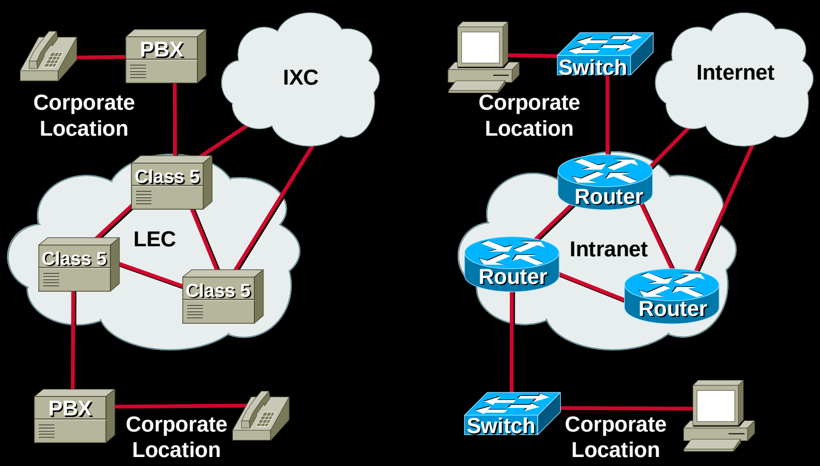
Telephony and Data Architecture Fundamentals Comparison



Corporate Voice Network with PBXs (Private Branch Exchange)

Corporate Data Network with Switches and Routers

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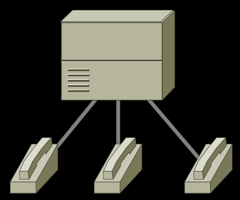
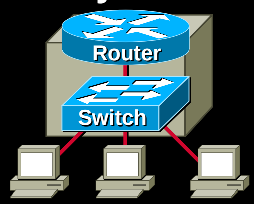
Voice and Data Switching Comparison

Class 5 Switch



- Handset aggregator
- All telephones get a single analog/digital line (DS0)
- All devices have a phone number defined on the switch
- All devices can simultaneously make a call (calls < trunk DS0s)
- Path selection based on static least cost routing or ARS

Multilayer Switch



- Computer aggregator
- All devices get dedicated bandwidth 10/100/1000 Mbps (autonegotiation)
- All devices have an IP address defined on the host
- All devices run at full line rate (bandwidth < uplink)
- Path selection based on dynamic routing protocol lowest cost

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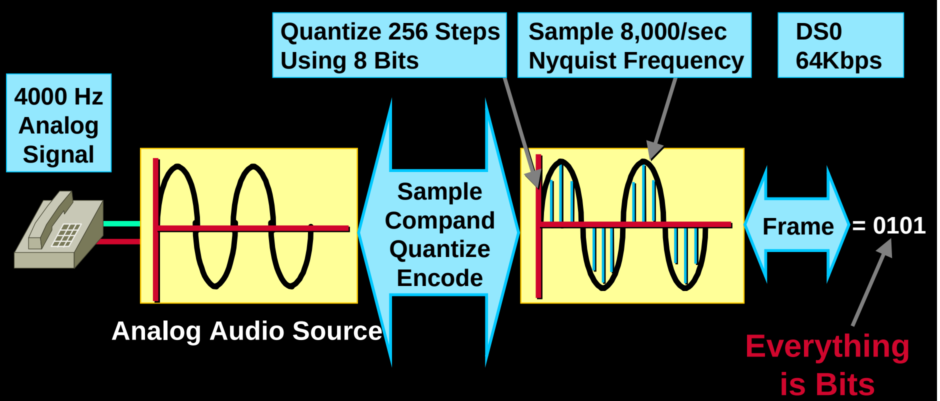
Voice Network Least Common Denominator



Pulse Code Modulation (PCM)
DS0

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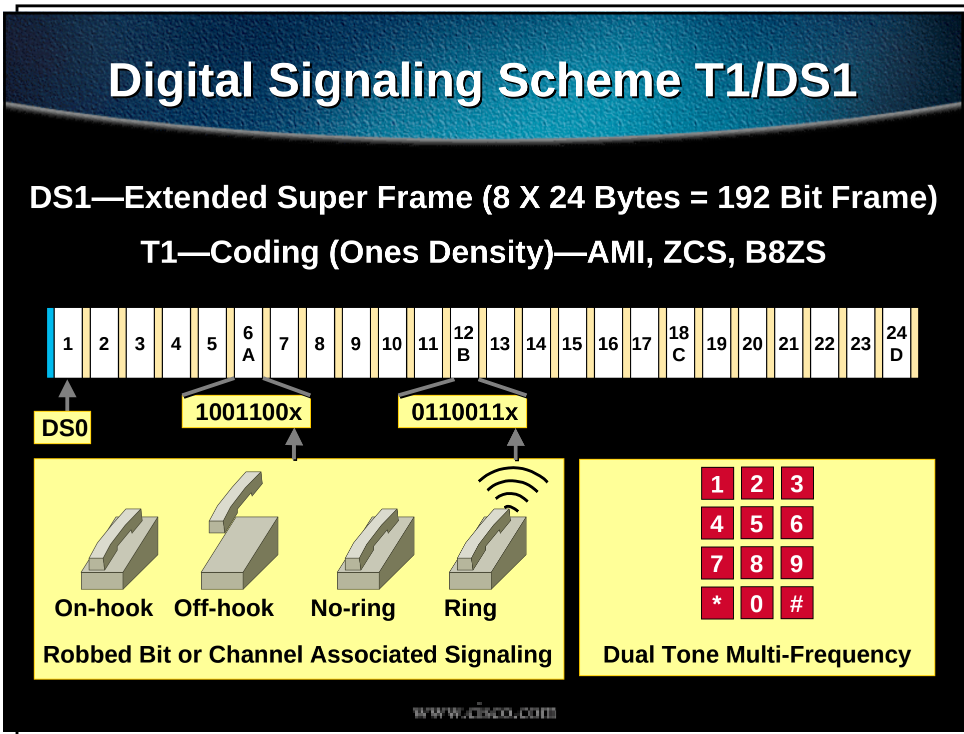
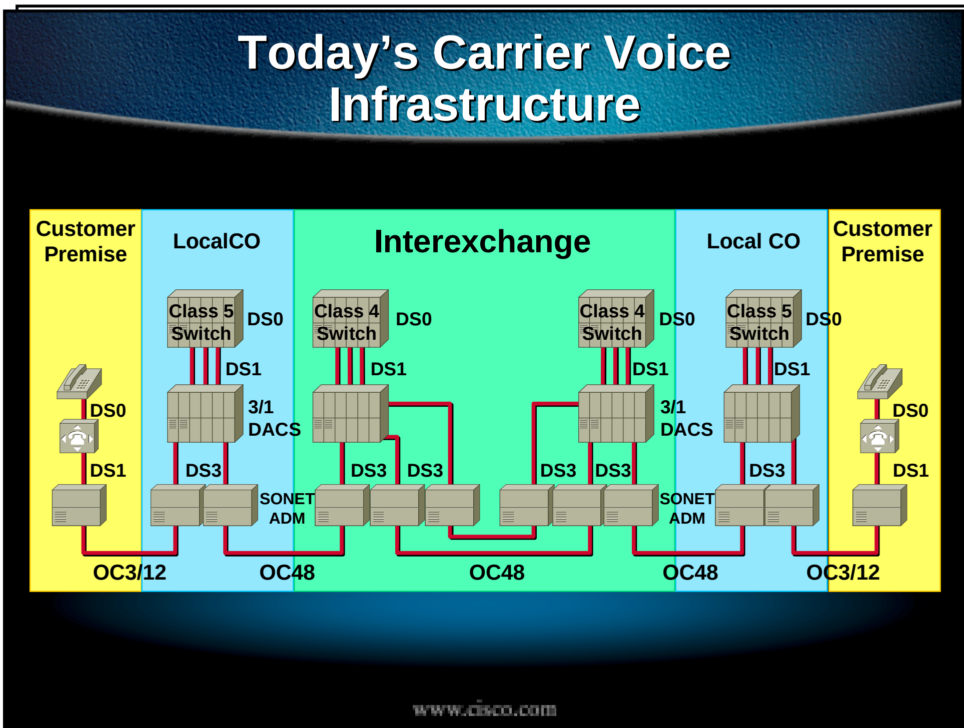

Digital Signaling Scheme T1/DS1
DS1—Extended Super Frame (8 X 24 Bytes = 192 Bit Frame)
T1—Coding (Ones Density)—AMI, ZCS, B8ZS
1 2 3 4 5 6 A 7 8 9 10 11 12 B 13 14 15 16 17 18 C 19 20 21 22 23 24 D
DS0
1001100x
0110011x
On-hook
Off-hook
No-ring
Ring
Robbed Bit or Channel Associated Signaling
1 2 3
4 5 6
7 8 9
* 0 #
Dual Tone Multi-Frequency
www.cisco.com


Today's Carrier Voice Infrastructure
Customer Premise
LocalCO
Interexchange
Local CO
Customer Premise
Class 5 Switch
DS0
Class 4 Switch
DS0
Class 4 Switch
DS0
Class 5 Switch
DS0
DS1
DS1
DS1
DS1
DS0
DS0
3/1 DACS
3/1 DACS
DS1
DS1
DS3
DS3
DS3
DS3
DS3
DS3
SONET ADM
SONET ADM
OC3/12
OC48
OC48
OC48
OC3/12
www.cisco.com

Voice Transport Mechanisms

Layer 3—VoIP

- Operates in heterogeneous network (ubiquitous)
- Connectionless (requires sequence numbers)
- “Soft” QoS
- Layer 2 and 3 overhead
- Standards-based H.323 (MGCP coming)

Layer 2—VoFR, VoATM

- Requires rigid homogenous network or L2 gateways
- Connection oriented (frames arrive in order)
- “Hard” QoS
- Layer 2 overhead
- Standards based (FRF.11/12, ATM AAL1/2/5)

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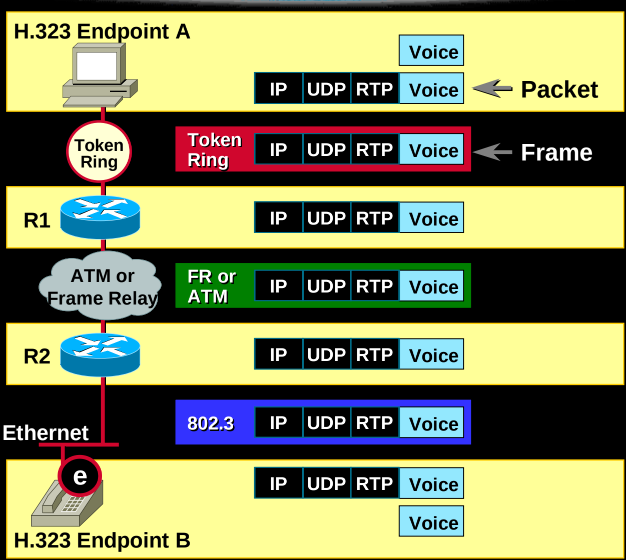
IP Ubiquity



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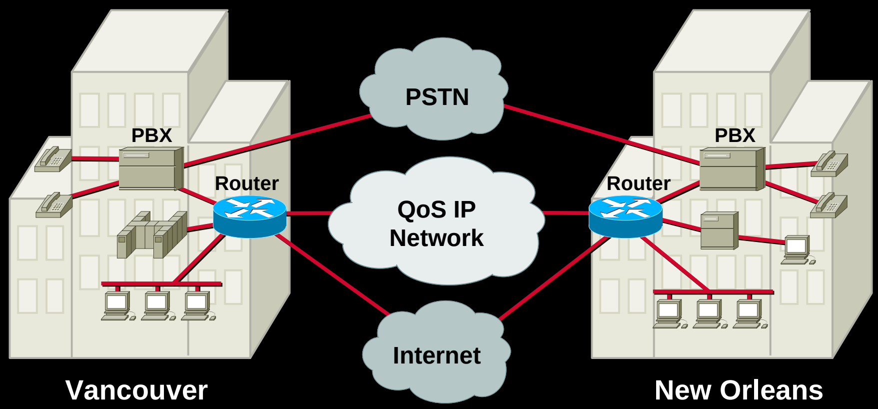
Enterprise Multiservice IP Core Backbone



Reduced Toll/Circuit Costs
Infrastructure Consolidation
Efficient Bandwidth Consumption

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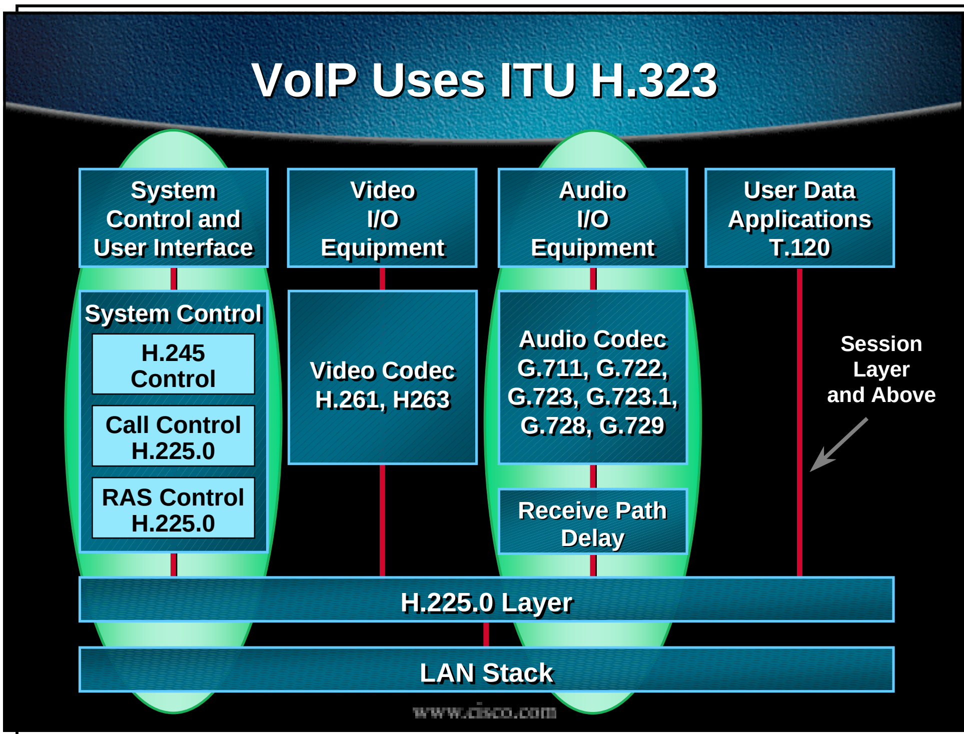
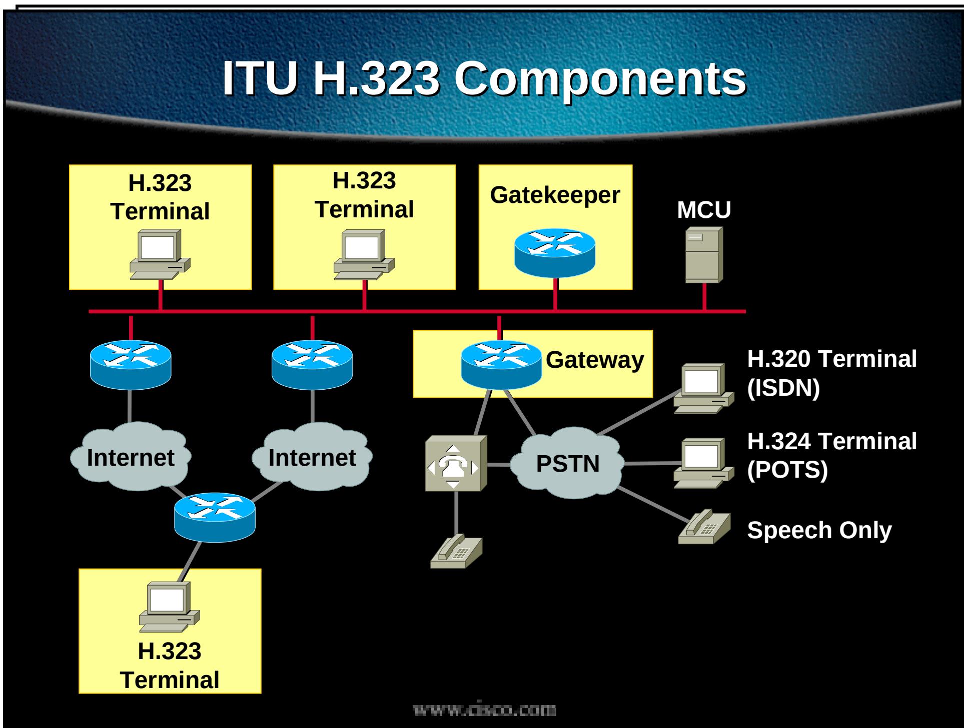

VoIP Uses ITU H.323
System Control and User Interface
Video I/O Equipment
Audio I/O Equipment
User Data Applications T.120
System Control
H.245 Control
Call Control H.225.0
RAS Control H.225.0
Video Codec H.261, H263
Audio Codec G.711, G.722, G.723, G.723.1, G.728, G.729
Receive Path Delay
Session Layer and Above
H.225.0 Layer
LAN Stack
www.cisco.com


ITU H.323 Components
H.323 Terminal
H.323 Terminal
Gatekeeper
MCU
Gateway
H.320 Terminal (ISDN)
H.324 Terminal (POTS)
Speech Only
Internet
Internet
PSTN
H.323 Terminal
www.cisco.com

H.323 VoIP Layers

IP Layered Model		H.323 VoIP Model
User		Caller
Application		Email ID E.164 Phone No.
Presentation		Audio Codec (G.711, G.729, G.723.1,..)
Session		H.225, H.245, RTP, RTCP
TCP	UDP	UDP Port Number
IP		IP Address
Data Link		Frame Relay DLCI, 802.3 MAC, ATM VPI/VCI
Physical		V.35, T1, T3

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Voice CODEC Cheat Sheet

Encoding Compression	Mean Opinion Score	Native Bit Rate Kbps	Voice Quality	BW	DTMF	Dual Comp	CPU	Music on Hold
G.711 PCM	4.1	64	A	D	A	A	A	A
G.726 ADPCM	3.85	32	B	C	B	B	B	B
G.728 LD-CELP	3.61	16	C	B	B	C	C	C
G.729 CS-ACELP	3.92	8	A	A	B	B	C	C
G.729a CS-ACELP	3.7	8	B	A	C	C	B	D
G.723.1 ACELP	3.65	5.3	C	A	C	D	C	D

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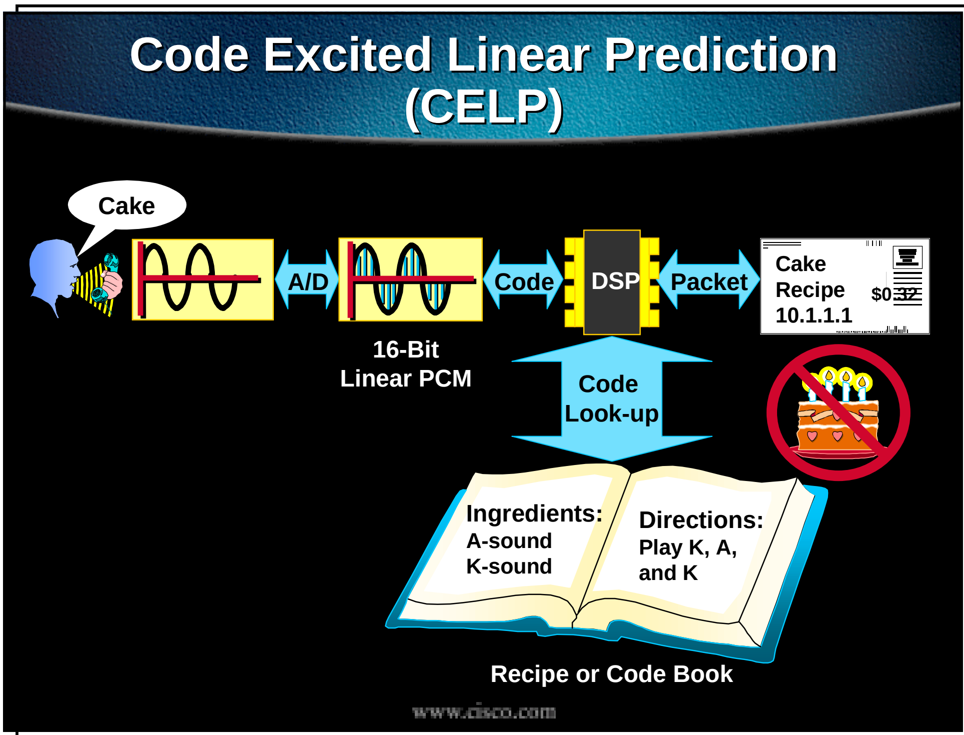
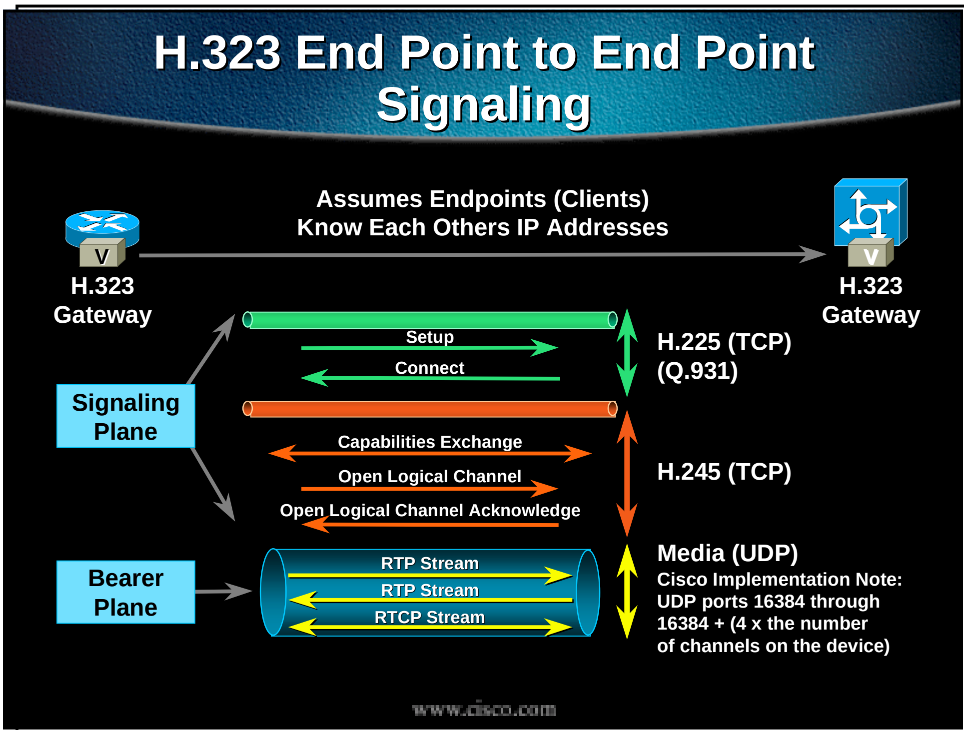

Code Excited Linear Prediction (CELP)
Cake
A/D
Code
DSP
Packet
Cake
Recipe
10.1.1.1
$0.32
16-Bit
Linear PCM
Code
Look-up
Ingredients:
A-sound
K-sound
Directions:
Play K, A,
and K
Recipe or Code Book
www.cisco.com


H.323 End Point to End Point Signaling
Assumes Endpoints (Clients)
Know Each Others IP Addresses
V
H.323
Gateway
V
H.323
Gateway
Signaling
Plane
Setup
Connect
H.225 (TCP)
(Q.931)
Capabilities Exchange
Open Logical Channel
Open Logical Channel Acknowledge
H.245 (TCP)
Bearer
Plane
RTP Stream
RTP Stream
RTCP Stream
Media (UDP)
Cisco Implementation Note:
UDP ports 16384 through
16384 + (4 x the number
of channels on the device)
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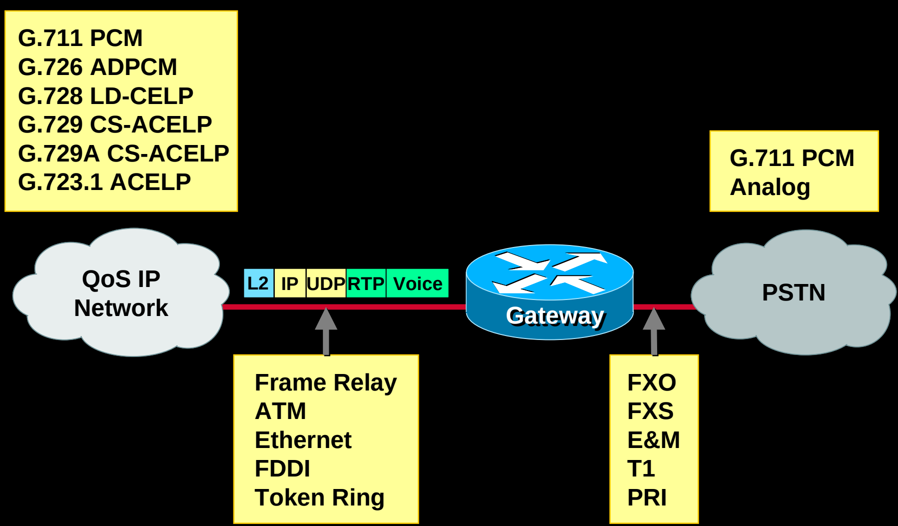
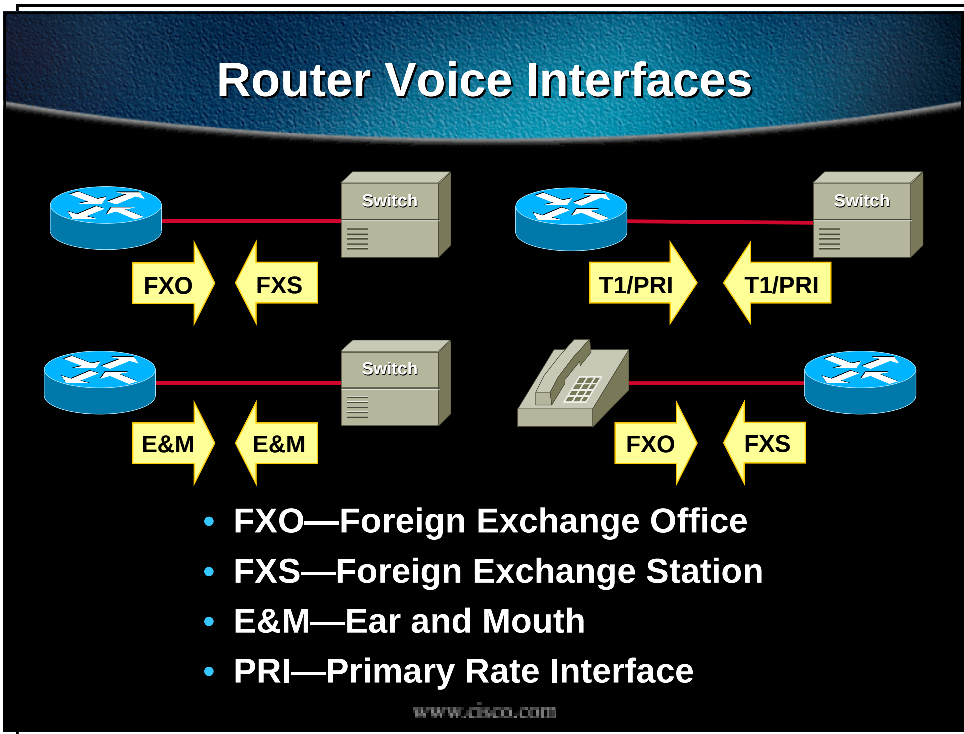
RTP/RTCP—RFCs 1889/1890

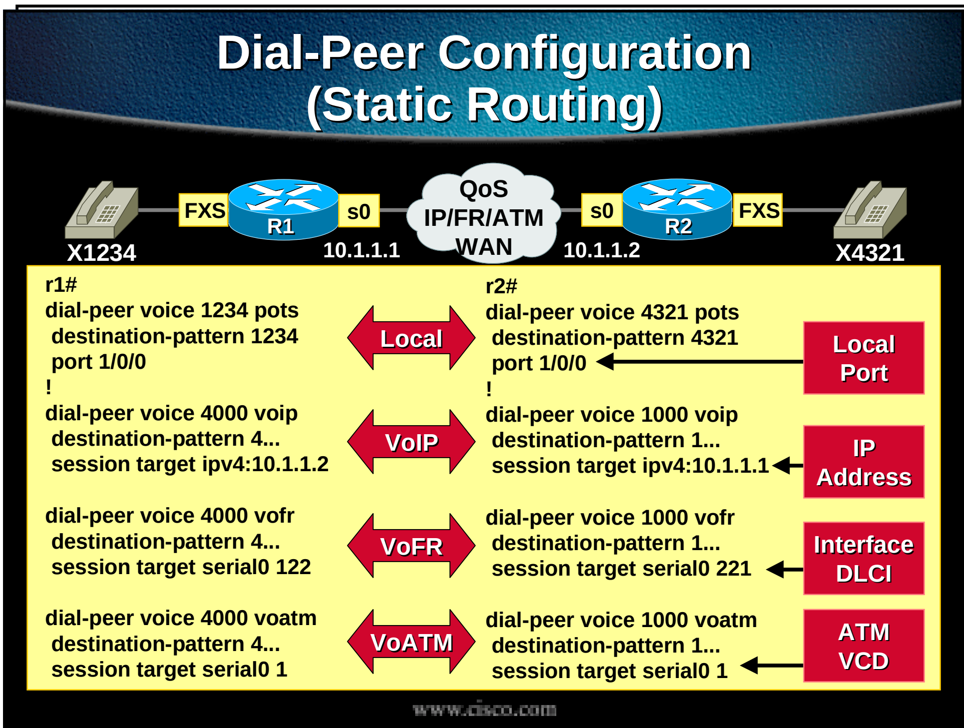
- End-to-end network transport function
  - Payload type identification—voice, video, compression type
  - Sequence numbering
  - Time stamping
  - Delivery monitoring
- RTCP (Real-Time Control Protocol)

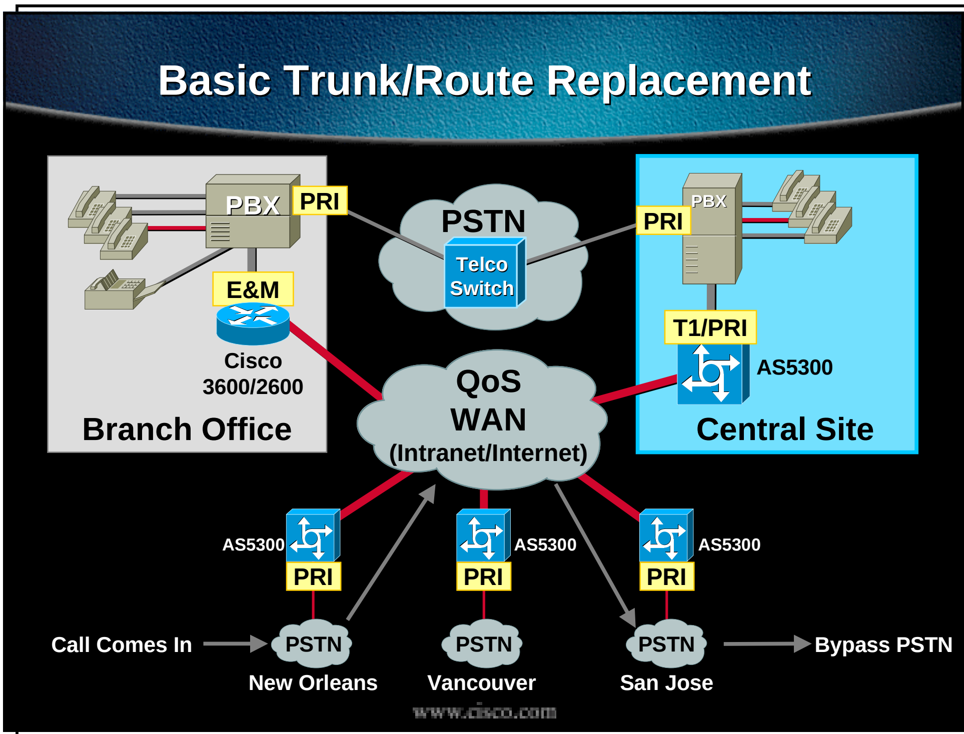
V E R		CC	M	Payload Type	Sequence Number
RTP Timestamp					
Synchronization Source (SSRC) ID					

H.323 Gateway

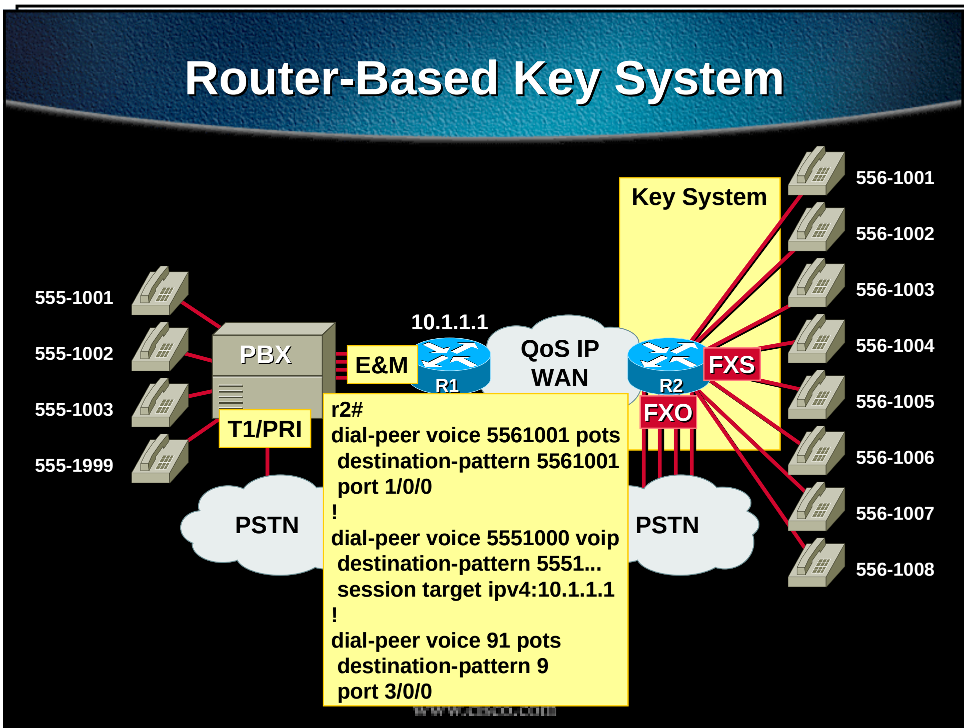



Router Voice Interfaces
Switch
Switch
FXO
FXS
T1/PRI
T1/PRI
Switch
E&M
E&M
FXO
FXS
• FXO—Foreign Exchange Office
• FXS—Foreign Exchange Station
• E&M—Ear and Mouth
• PRI—Primary Rate Interface
www.cisco.com

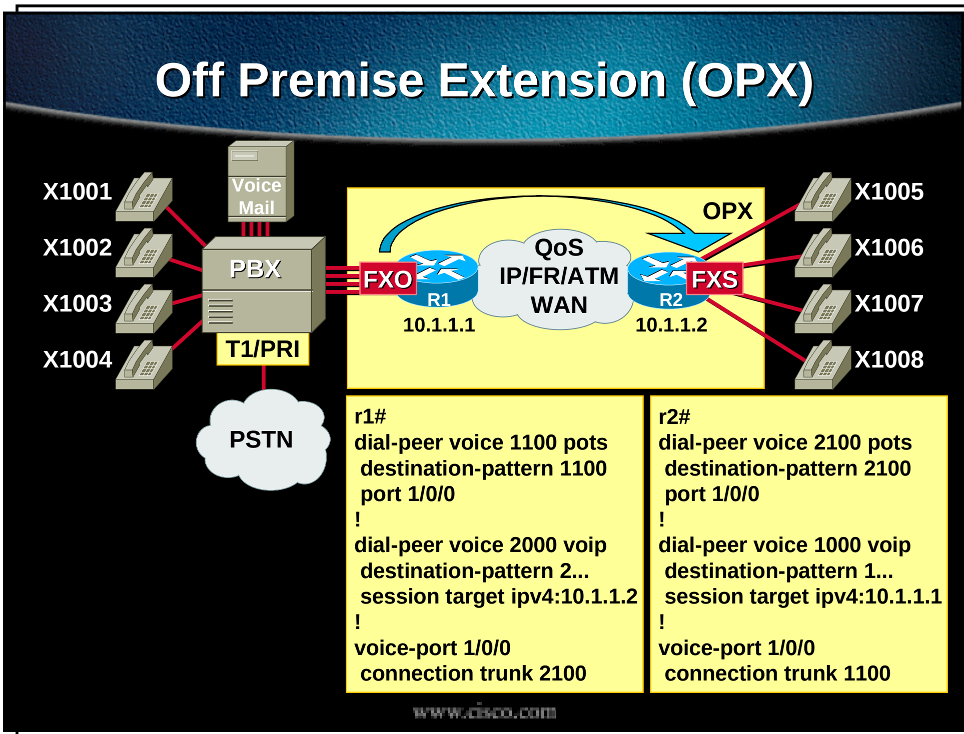

Dial-Peer Configuration (Static Routing)
FXS
R1
s0
QoS IP/FR/ATM WAN
s0
R2
FXS
X1234
10.1.1.1
10.1.1.2
X4321
r1#
dial-peer voice 1234 pots
destination-pattern 1234
port 1/0/0
!
dial-peer voice 4000 voip
destination-pattern 4...
session target ipv4:10.1.1.2
dial-peer voice 4000 vofr
destination-pattern 4...
session target serial0 122
dial-peer voice 4000 voatm
destination-pattern 4...
session target serial0 1
Local
VoIP
VoFR
VoATM
r2#
dial-peer voice 4321 pots
destination-pattern 4321
port 1/0/0
!
dial-peer voice 1000 voip
destination-pattern 1...
session target ipv4:10.1.1.1
dial-peer voice 1000 vofr
destination-pattern 1...
session target serial0 221
dial-peer voice 1000 voatm
destination-pattern 1...
session target serial0 1
Local Port
IP Address
Interface DLCI
ATM VCD
www.cisco.com

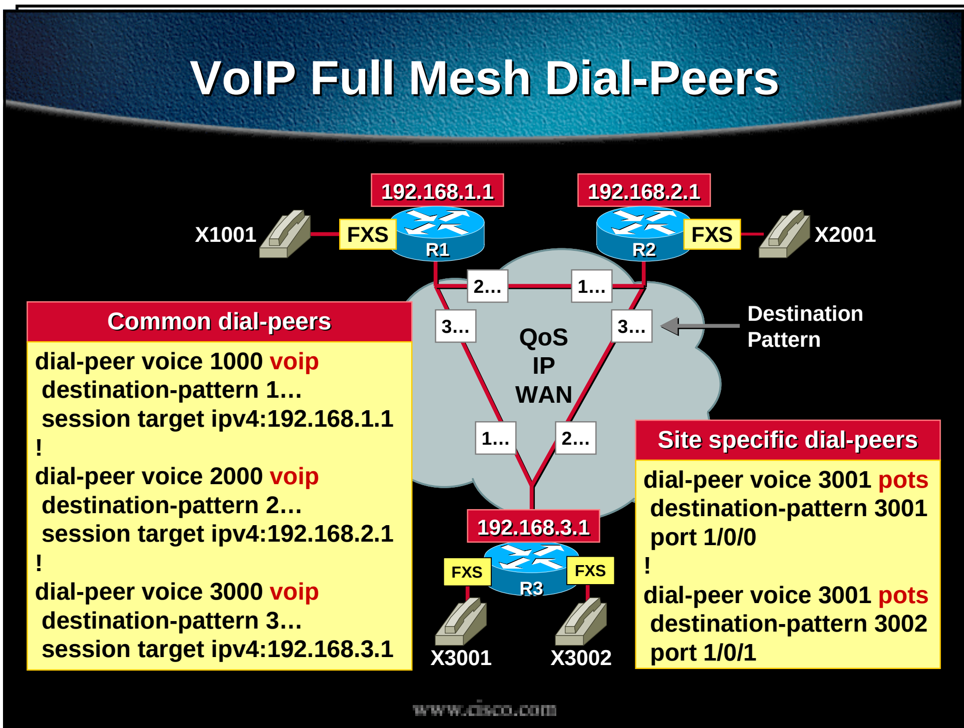


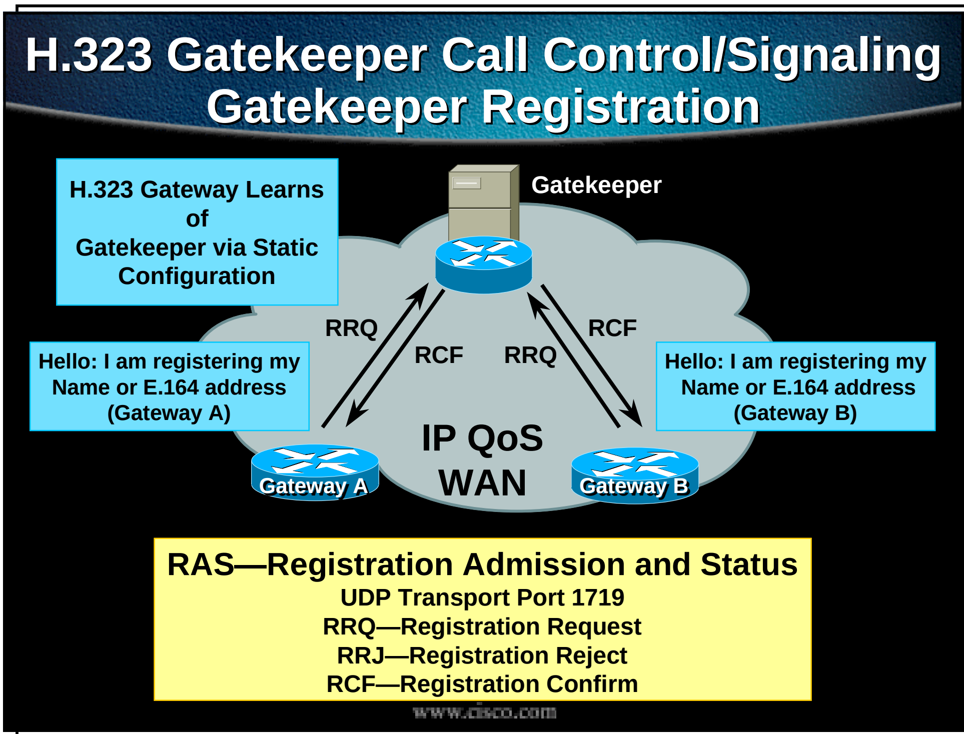
Basic Trunk/Route Replacement
PBX
PRI
E&M
Cisco
3600/2600
Branch Office
PSTN
Telco
Switch
QoS
WAN
(Intranet/Internet)
PBX
PRI
T1/PRI
AS5300
Central Site
AS5300
PRI
AS5300
PRI
AS5300
PRI
Call Comes In
PSTN
PSTN
PSTN
Bypass PSTN
New Orleans
Vancouver
San Jose
www.cisco.com

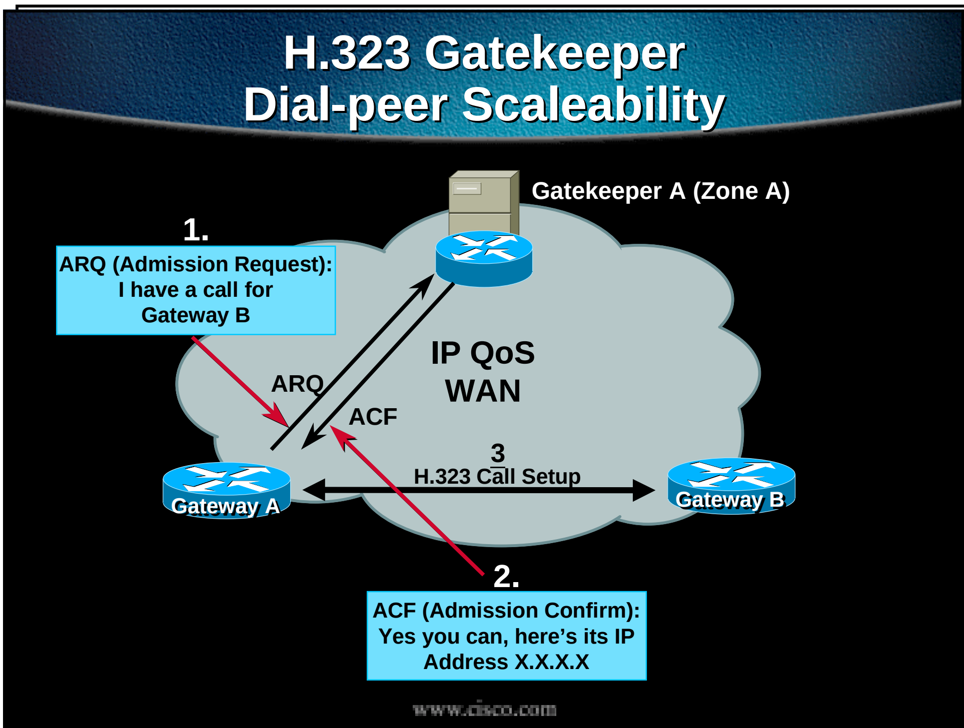


Router-Based Key System
Key System
556-1001
556-1002
556-1003
556-1004
556-1005
556-1006
556-1007
556-1008
555-1001
555-1002
555-1003
555-1999
PBX
T1/PRI
E&M
10.1.1.1
R1
QoS IP
WAN
R2
FXS
FXO
PSTN
PSTN
r2#
dial-peer voice 5561001 pots
destination-pattern 5561001
port 1/0/0
!
dial-peer voice 5551000 voip
destination-pattern 5551...
session target ipv4:10.1.1.1
!
dial-peer voice 91 pots
destination-pattern 9
port 3/0/0


Off Premise Extension (OPX)
X1001
X1002
X1003
X1004
Voice Mail
PBX
T1/PRI
PSTN
FXO
R1
10.1.1.1
QoS IP/FR/ATM WAN
OPX
R2
FXS
10.1.1.2
X1005
X1006
X1007
X1008
r1#
dial-peer voice 1100 pots
destination-pattern 1100
port 1/0/0
!
dial-peer voice 2000 voip
destination-pattern 2...
session target ipv4:10.1.1.2
!
voice-port 1/0/0
connection trunk 2100
r2#
dial-peer voice 2100 pots
destination-pattern 2100
port 1/0/0
!
dial-peer voice 1000 voip
destination-pattern 1...
session target ipv4:10.1.1.1
!
voice-port 1/0/0
connection trunk 1100
www.cisco.com


VoIP Full Mesh Dial-Peers
192.168.1.1
192.168.2.1
X1001
FXS
R1
R2
FXS
X2001
2...
1...
3...
3...
Destination Pattern
QoS IP WAN
1...
2...
192.168.3.1
FXS
FXS
R3
X3001
X3002
Common dial-peers
dial-peer voice 1000 voip
destination-pattern 1...
session target ipv4:192.168.1.1
!
dial-peer voice 2000 voip
destination-pattern 2...
session target ipv4:192.168.2.1
!
dial-peer voice 3000 voip
destination-pattern 3...
session target ipv4:192.168.3.1
Site specific dial-peers
dial-peer voice 3001 pots
destination-pattern 3001
port 1/0/0
!
dial-peer voice 3001 pots
destination-pattern 3002
port 1/0/1
www.cisco.com


H.323 Gatekeeper Call Control/Signaling
Gatekeeper Registration
H.323 Gateway Learns of Gatekeeper via Static Configuration
Gatekeeper
RRQ
RCF
RCF
RRQ
Hello: I am registering my Name or E.164 address (Gateway A)
Hello: I am registering my Name or E.164 address (Gateway B)
IP QoS WAN
Gateway A
Gateway B
RAS—Registration Admission and Status
UDP Transport Port 1719
RRQ—Registration Request
RRJ—Registration Reject
RCF—Registration Confirm
www.cisco.com


H.323 Gatekeeper
Dial-peer Scaleability
Gatekeeper A (Zone A)
1.
ARQ (Admission Request): I have a call for Gateway B
ARQ
ACF
IP QoS WAN
3
H.323 Call Setup
Gateway A
Gateway B
2.
ACF (Admission Confirm): Yes you can, here's its IP Address X.X.X.X
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VoIP Low Speed Link (<768 Kbps) Challenges and Solutions

Challenge	Cisco Solutions
Congestion Delay and Delay Jitter	**Intelligent Queuing** WFQ, IP Precedence, RSVP, Priority Queuing
Packet Residency Slow Link Freeze-out by Large Packets	**Interleaving** FRF.12, MLPPP, IP MTU Size Reduction, Faster Link
Bandwidth Consumption Header Size on Low Bandwidth Links	**Compression** Codecs, RTP Header Compression, Voice Activity Detection
WAN Oversubscription, Bursting	**Traffic Management** Router Traffic Shaping to CIR, High Priority PVC, Data Discard Eligibility

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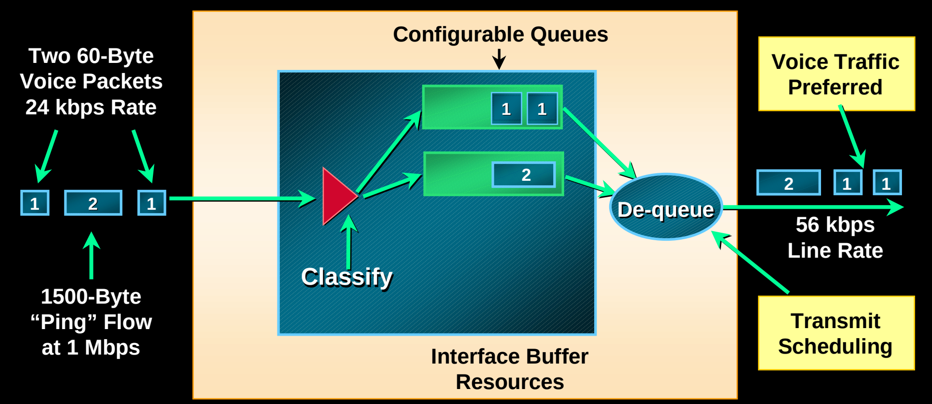
Congestion Avoidance Solutions Intelligent Queuing



Weighted Fair Queuing (WFQ)
Resource Reservation Protocol (RSVP)
Priority Queuing

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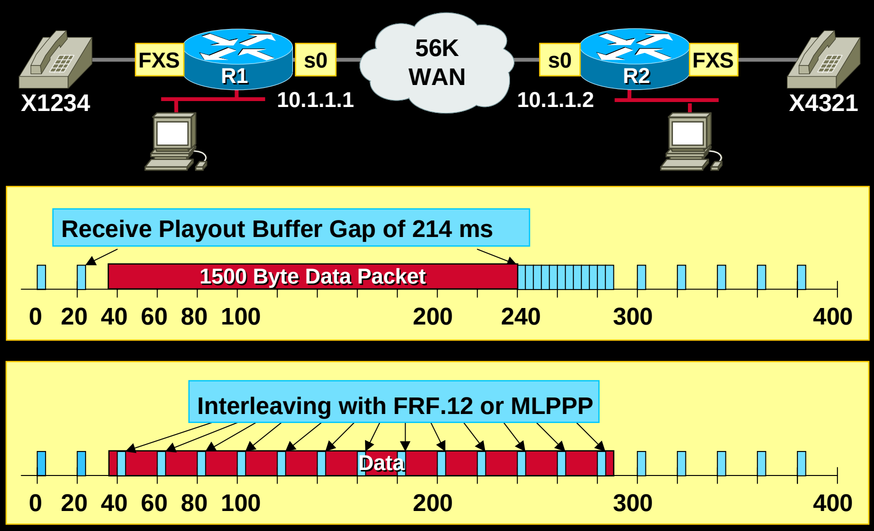
Packet Residency Solutions



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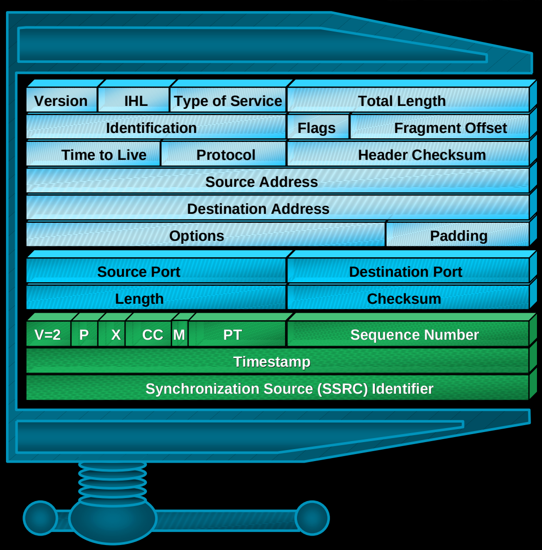
VoIP Bandwidth Solution



RTP Header Compression

- 20 ms @ 8 kbps yields 20-byte payload
- IP header 20; UDP header 8; RTP header 12

  2X payload!
- Header compression 40 bytes to 2 or 4 bytes
- Hop-by-Hop on slow links <512 kbps
- CRTP—Compressed Real-time Protocol

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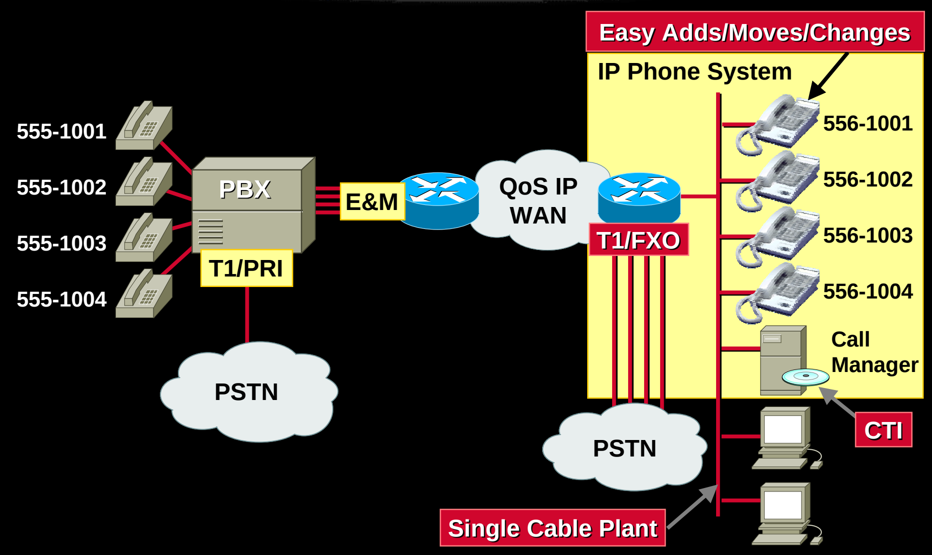
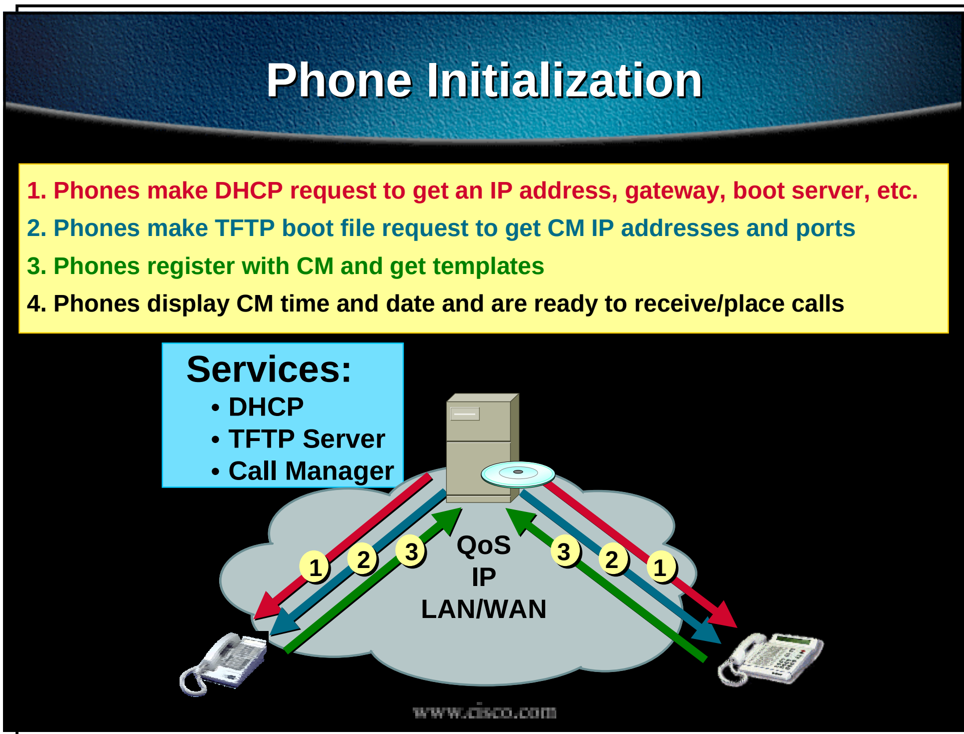
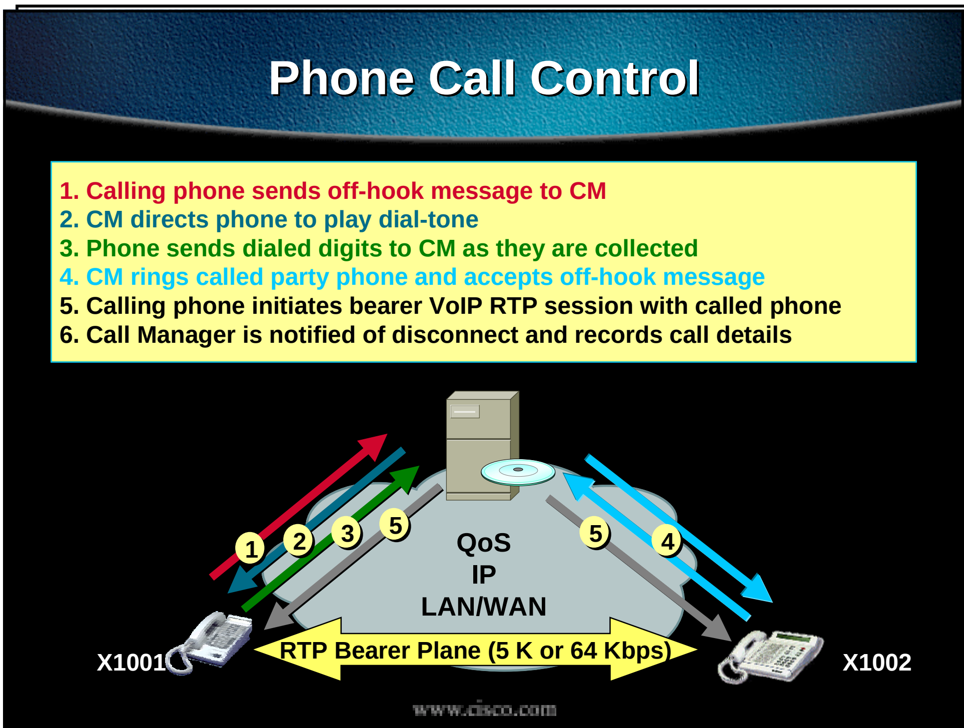
IP Phone System



www.cisco.com


Phone Initialization
1. Phones make DHCP request to get an IP address, gateway, boot server, etc.
2. Phones make TFTP boot file request to get CM IP addresses and ports
3. Phones register with CM and get templates
4. Phones display CM time and date and are ready to receive/place calls
Services:
• DHCP
• TFTP Server
• Call Manager
QoS
IP
LAN/WAN
1
2
3
3
2
1
www.cisco.com


Phone Call Control
1. Calling phone sends off-hook message to CM
2. CM directs phone to play dial-tone
3. Phone sends dialed digits to CM as they are collected
4. CM rings called party phone and accepts off-hook message
5. Calling phone initiates bearer VoIP RTP session with called phone
6. Call Manager is notified of disconnect and records call details
QoS
IP
LAN/WAN
1
2
3
5
5
4
X1001
RTP Bearer Plane (5 K or 64 Kbps)
X1002
www.cisco.com

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- When Can I Implement IP Multiservice?

Planning and Implementation

- Today
  - Tie-line replacement
  - Toll-bypass
  - Off Premise Extension (OPX)
  - Router key system replacement
  - Small office IP phone system (< 100 users)
- Tomorrow
  - Virtual call centers
  - Campus IP phone system (> 1000 users)
  - Enhanced integrated data/voice applications
  - Unified messaging

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