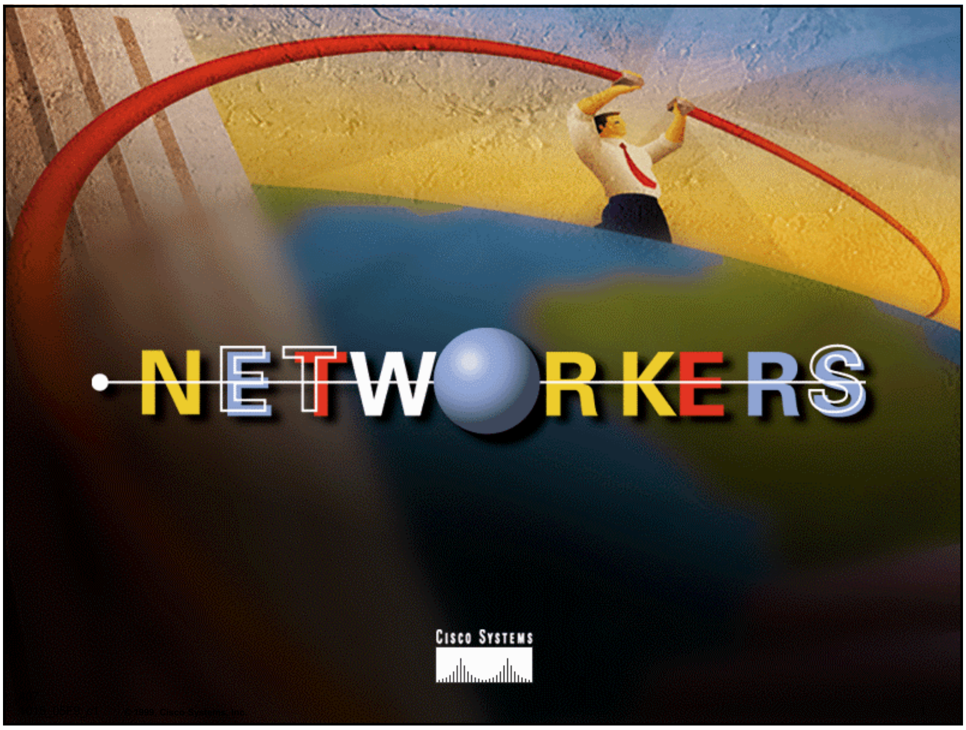
NETWORKERS
Cisco Systems


Traffic Engineering for Voice over Integrated Service Networks
Session 407
Cisco Systems

Voice Is Not a Network

- Voice is an application
- Voice traffic engineering is used to plan for a certain level of service
- It is applicable to both circuit switched and packet-based networks

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Agenda

- Basic Voice Traffic Engineering
- How Costs Impact Trunk Groups
- How to apply Voice Traffic Engineering to a Packet-Based Data Network

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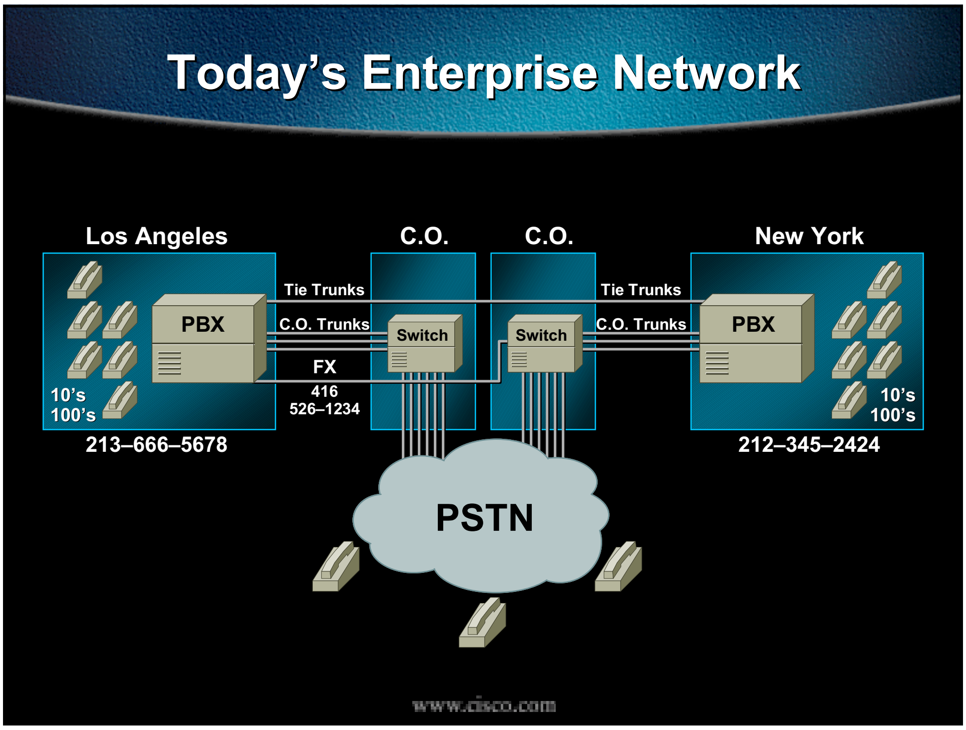
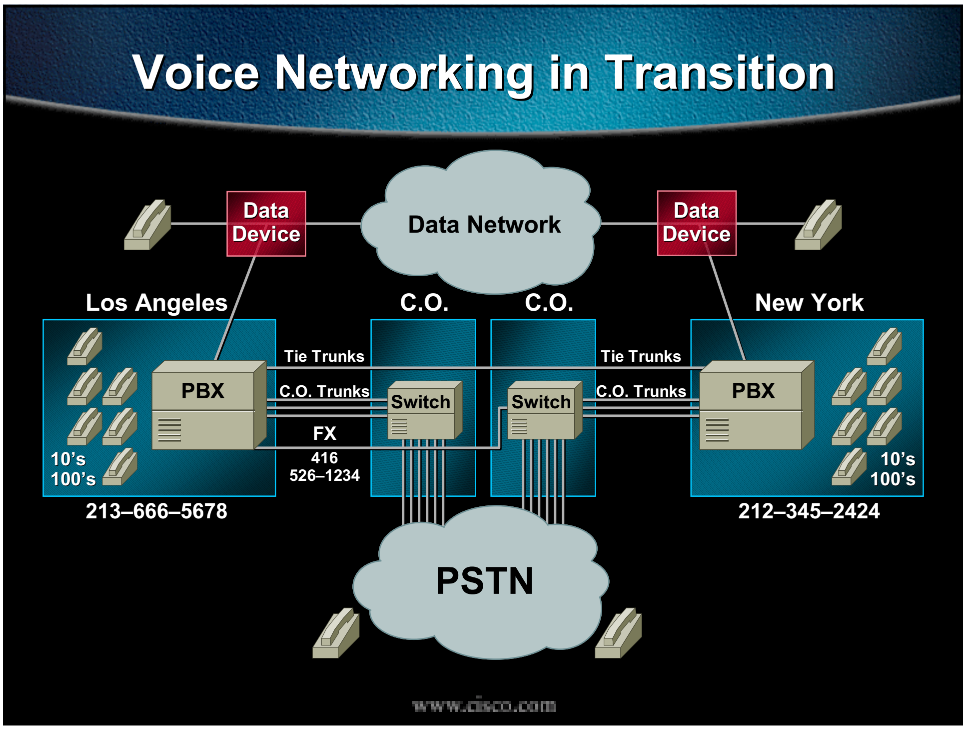

Today's Enterprise Network
Los Angeles
C.O.
C.O.
New York
Tie Trunks
C.O. Trunks
Switch
FX
416
526–1234
Switch
Tie Trunks
C.O. Trunks
PBX
PBX
10's
100's
10's
100's
213–666–5678
212–345–2424
PSTN
www.cisco.com


Voice Networking in Transition
Data Device
Data Network
Data Device
Los Angeles
C.O.
C.O.
New York
Tie Trunks
C.O. Trunks
Switch
FX
416
526–1234
Switch
Tie Trunks
C.O. Trunks
PBX
PBX
10's
100's
10's
100's
213–666–5678
212–345–2424
PSTN
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Traffic Engineering: 4–Step Process

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Step 1: Obtain Voice Traffic

- Carrier bills
- Traffic reports from PBX
  - CDR (Call Detail Report)
  - Reports are specific to PBX manufacturer
- Carrier design studies or traffic reports
- Third party software and hardware

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Sample CDR Report

Tran_date	Duration	ckt	Dialing_no	Dialed_no	Charge	Ext	Facility	PBX
08/01/97-00:05:00	2	30	61445	1181352196009	0.68	0	IDDD_SJ1	SJ1
08/01/97-00:07:00	2	1	71820	1181352196009	0.68	0	IDDD_SJ1	SJ1
08/01/97-00:31:00	1	30	77456	1181352196028	0.34	0	IDDD_SJ1	SJ1
08/29/97-23:35:00	1	30	77458	1181352196028	0.34	0	IDDD_SJ1	SJ1
08/30/97-04:29:00	2	6	66151	1181352196028	0.68	0	IDDD_SJ1	SJ1
08/30/97-20:50:36	2	30	61035	1181352196009	1.02	0	IDDD_SJ1	SJ1
	———	—	———					
	Query Summary							
	———	—	———					
Total Calls:	595							
Total Minutes:	2382.3							
Total Cost:	900.17							

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Step 2: Profiling the Traffic—Group into Categories

- Inbound vs. outbound
- Call distance
  - Local
  - Long distance
  - International
- Type of call
  - Example: fax

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Defining the Traffic Flow

$$A = C \times T$$

A, The Traffic Flow Is the Product of:

- C: The Number of Calls Originated During a Period of 1 Hour
- T: The Average Holding Time of the Call

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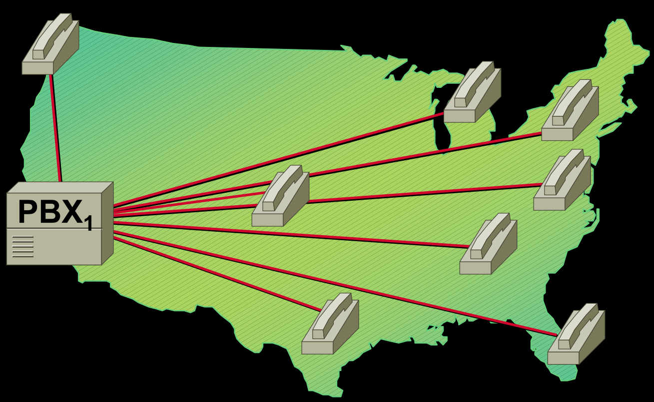
For Example

- 200 calls of an average duration of two minutes are generated during a period of one hour
- The traffic flow is equal to 400 call-minutes per hour



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Converting to a Common Measurement

- Converting call-minutes to call-hours, divide by 60
- In our example: 400/60 = 6.67 call-hours
- Typically we use erlangs, which is defined as the continuous use of a circuit for one hour
- Another common measurement is CCS (Centum call seconds or 100 call seconds)

  1 erlang = 36 CCS

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Traffic Variation

Traffic Varies by Hour, Day, Month and Year

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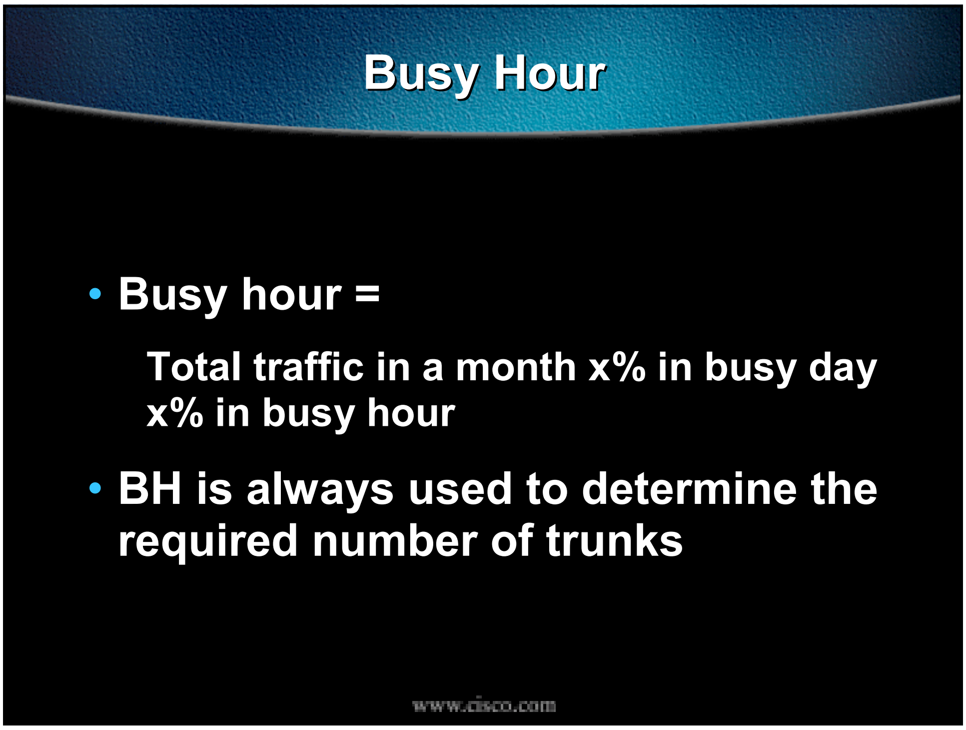
Busy Hour
• Busy hour =
Total traffic in a month x% in busy day x% in busy hour
• BH is always used to determine the required number of trunks
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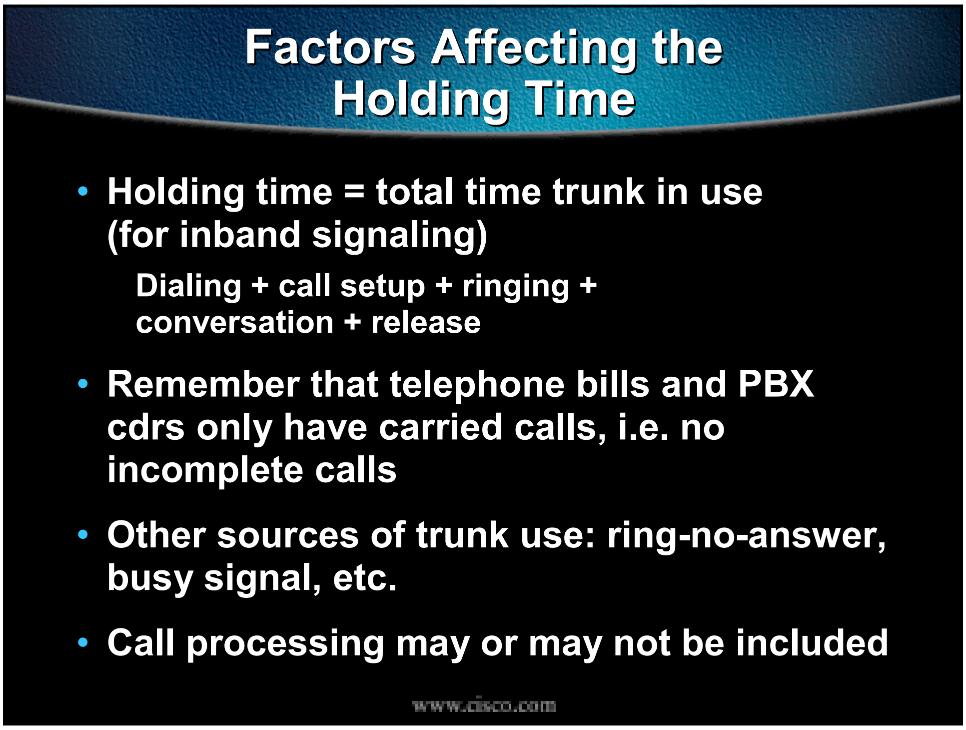
Factors Affecting the Holding Time
• Holding time = total time trunk in use (for inband signaling)
Dialing + call setup + ringing + conversation + release
• Remember that telephone bills and PBX cdrs only have carried calls, i.e. no incomplete calls
• Other sources of trunk use: ring-no-answer, busy signal, etc.
• Call processing may or may not be included
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Adjusting the Holding Time

- Add 10% to 16% to length of all calls—to account for overhead
- Call billing: 6 second vs. 1 minute increments
- PBXs that use 1 minute increments round upwards; calls on average will have 30 seconds of extra hold time per call

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For Example

A Bill Shows 404 Calls Totaled 1834 Minutes
Billing Is in One Minute Increments
What Is the Adjusted Traffic?

404 x (0.5) = 202
1834 - 202 = 1632 “Real Traffic”

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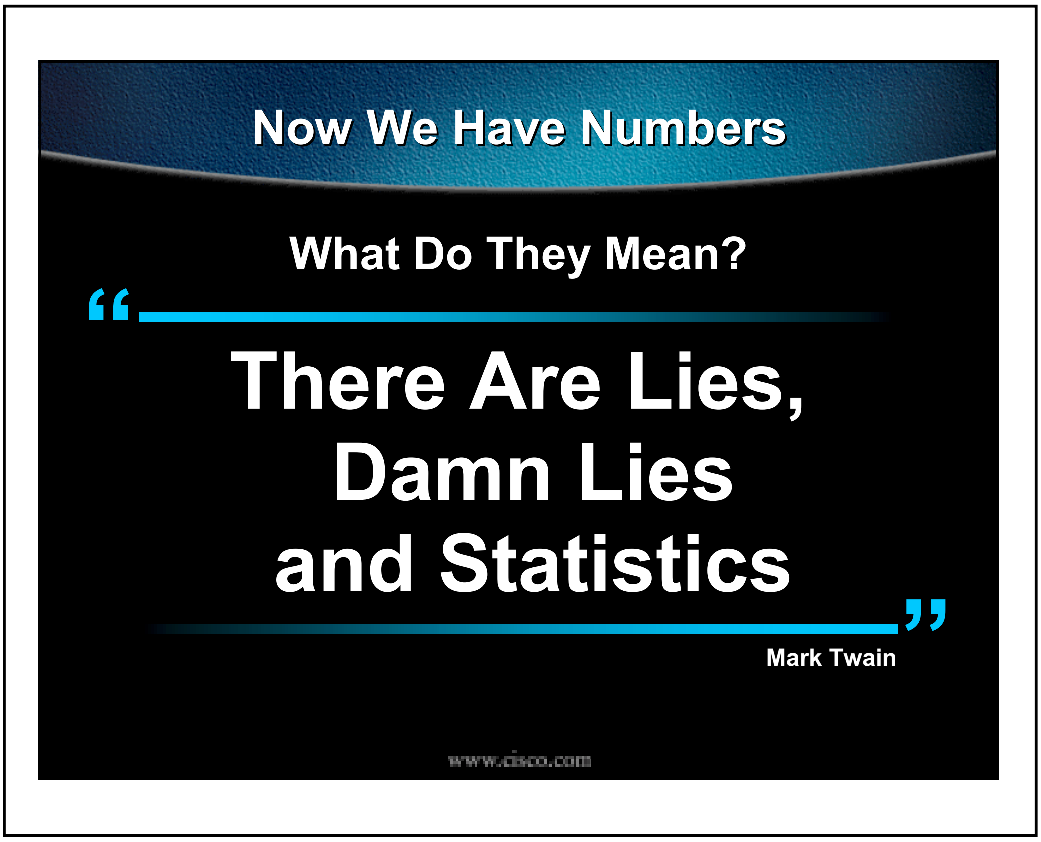
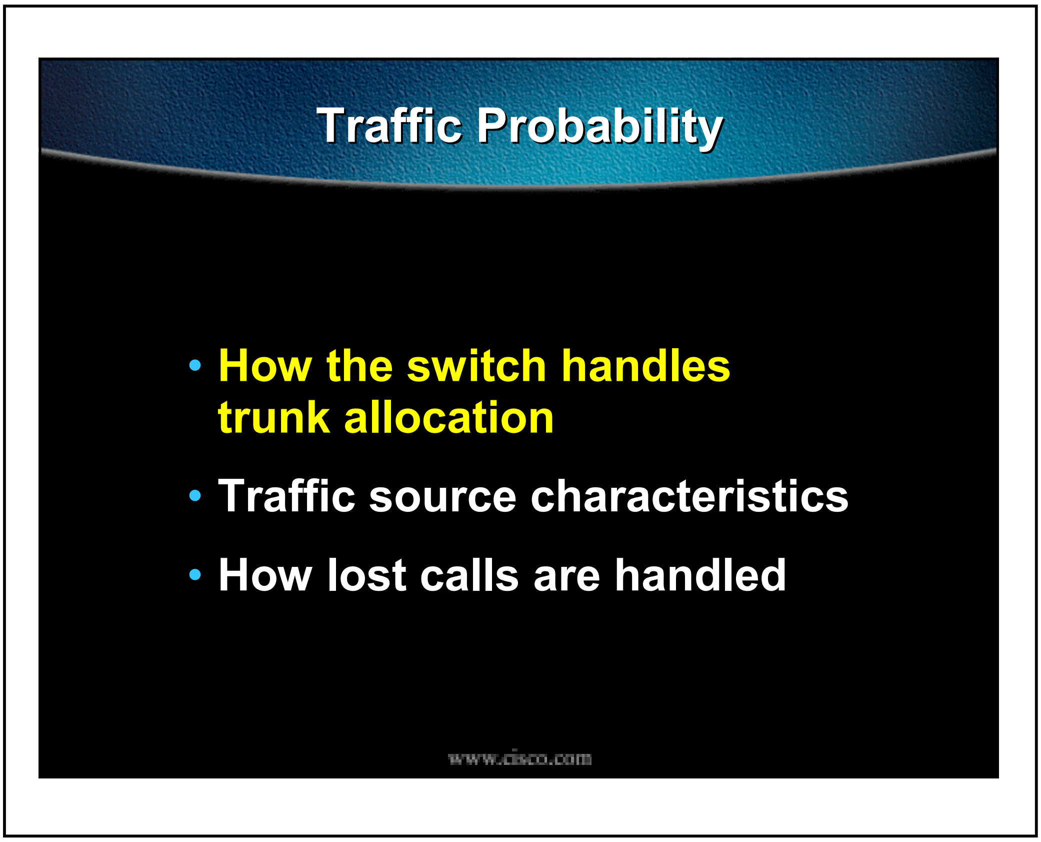
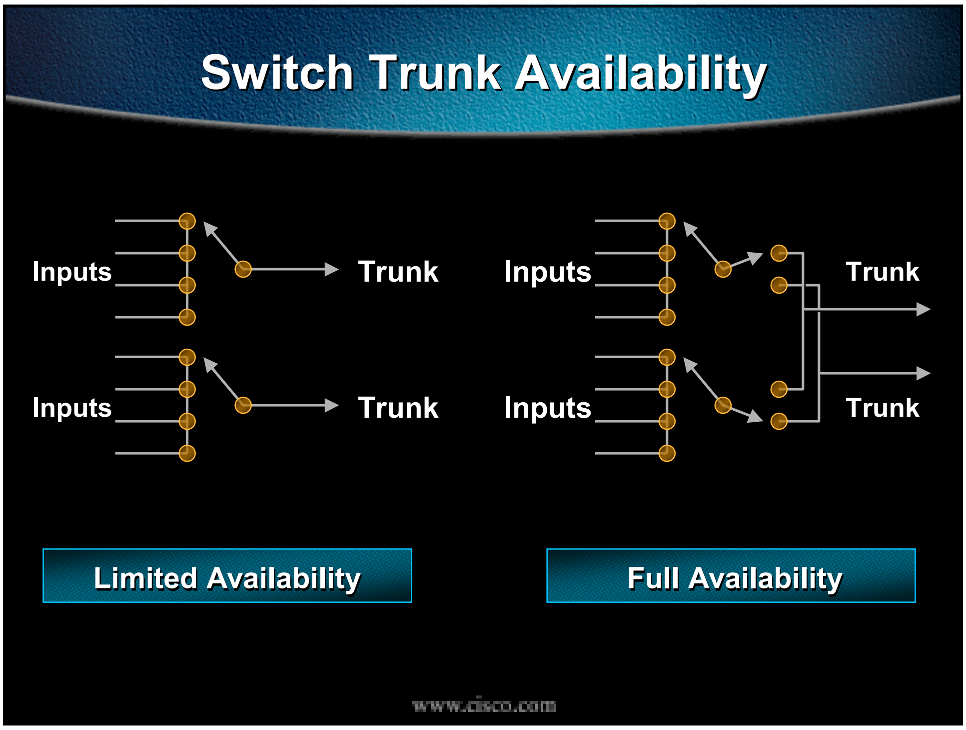
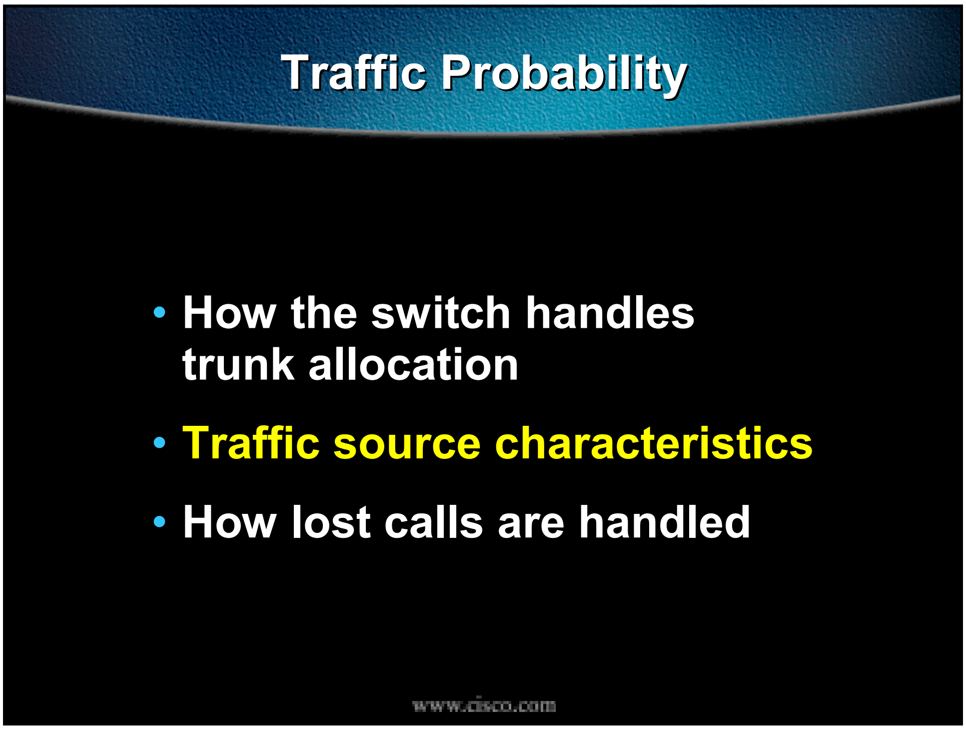

Now We Have Numbers
What Do They Mean?
"There Are Lies,
Damn Lies
and Statistics"
Mark Twain
www.cisco.com


Traffic Probability
• How the switch handles trunk allocation
• Traffic source characteristics
• How lost calls are handled
www.cisco.com


Switch Trunk Availability
Inputs
Trunk
Inputs
Trunk
Inputs
Trunk
Inputs
Trunk
Limited Availability
Full Availability
www.cisco.com


Traffic Probability
• How the switch handles trunk allocation
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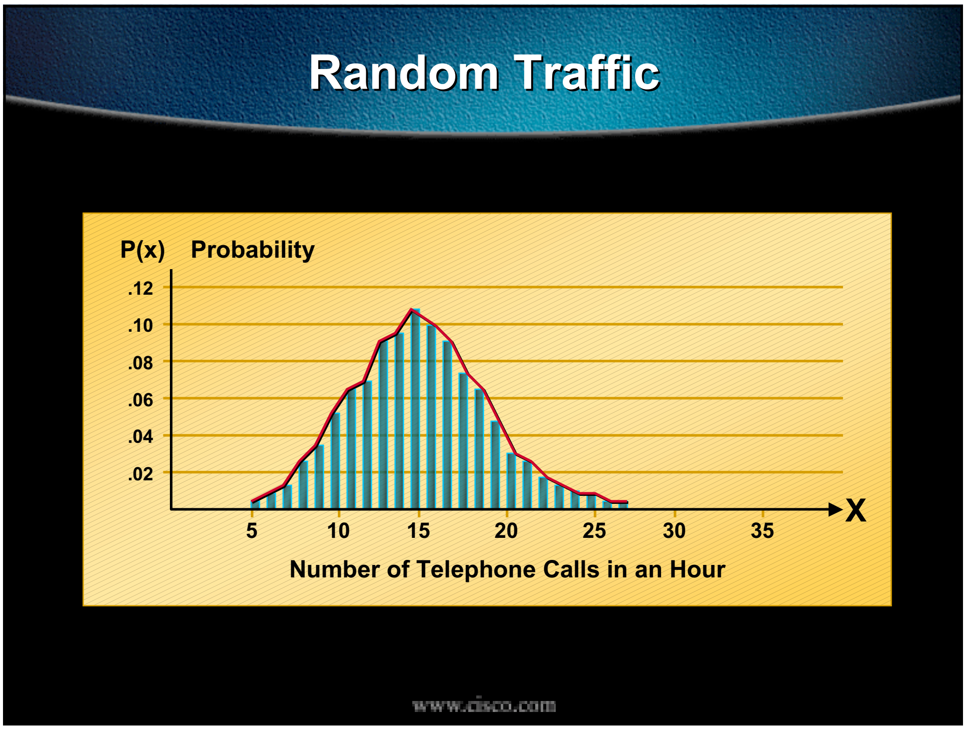
www.cisco.com


Random Traffic
P(x) Probability
.12
.10
.08
.06
.04
.02
5
10
15
20
25
30
35
X
Number of Telephone Calls in an Hour
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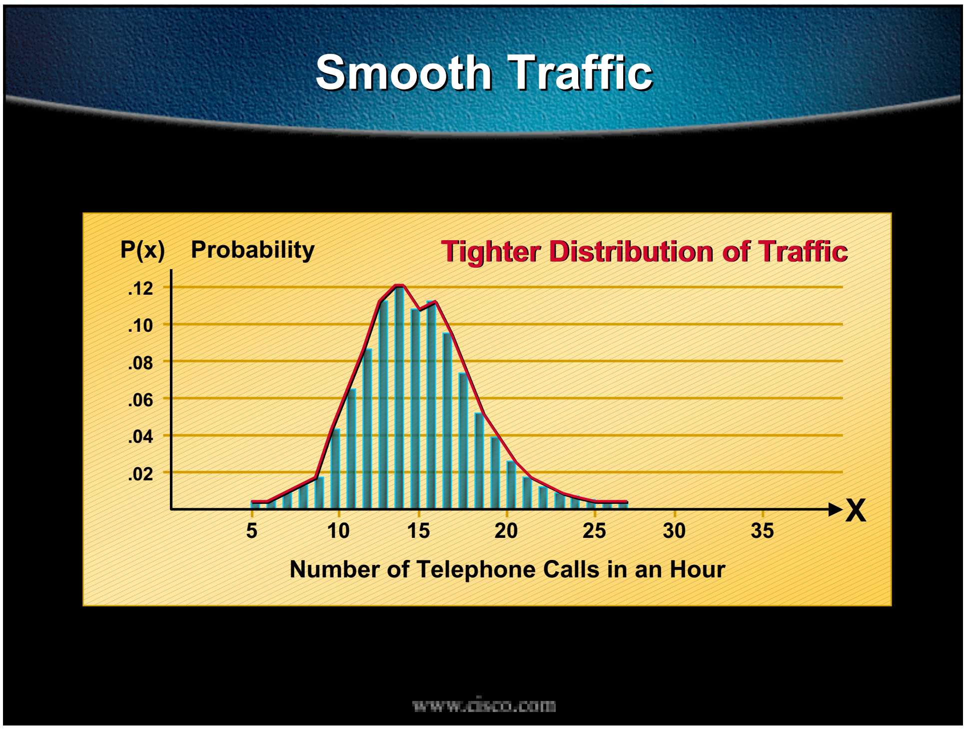
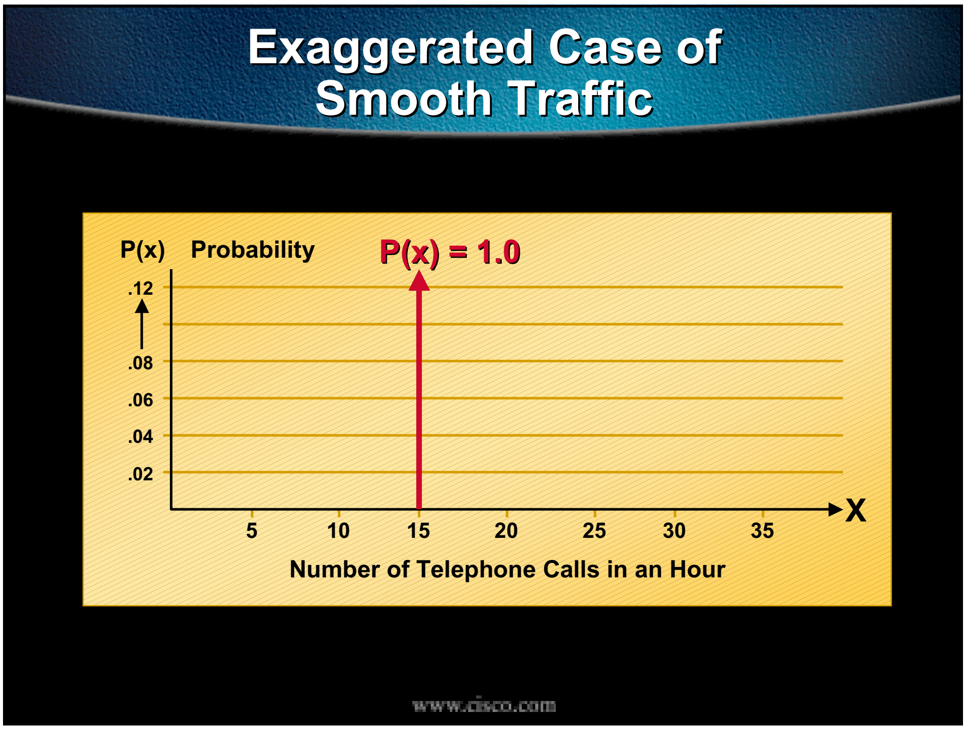
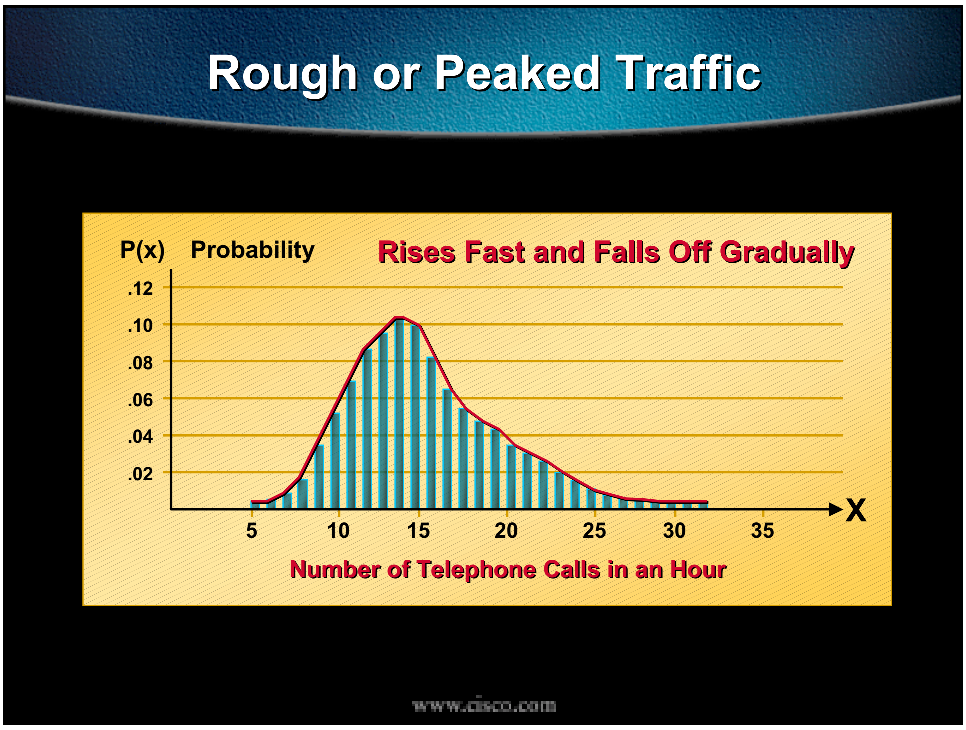

Smooth Traffic
P(x) Probability
Tighter Distribution of Traffic
.12
.10
.08
.06
.04
.02
5
10
15
20
25
30
35
X
Number of Telephone Calls in an Hour
www.cisco.com


Exaggerated Case of Smooth Traffic
P(x) Probability
P(x) = 1.0
.12
.08
.06
.04
.02
5 10 15 20 25 30 35
X
Number of Telephone Calls in an Hour
www.cisco.com


Rough or Peaked Traffic
P(x) Probability
Rises Fast and Falls Off Gradually
.12
.10
.08
.06
.04
.02
5 10 15 20 25 30 35
X
Number of Telephone Calls in an Hour
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Number of Originating Sources

- Infinite—probability of call arrival is constant
- Finite—probability of call arrival varies with the number of sources already connected

10 Trunks and a Probability of .01 Poisson Distribution

Number of Sources	Traffic Capacity (Erlangs)
Infinite	4.13
100	4.26
75	4.35
50	4.51
25	4.84
20	5.08
15	5.64
13	6.03
11	6.95
10	10

Traffic Probability

- How the switch handles trunk allocation
- Traffic source characteristics
- How lost calls are handled

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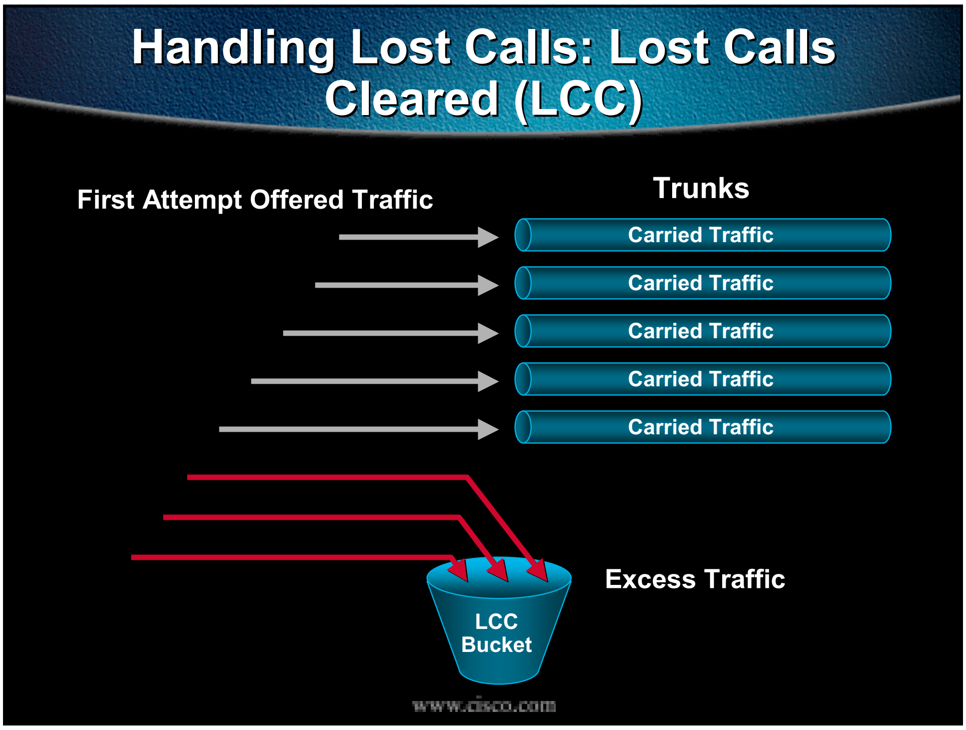
Handling Lost Calls: Lost Calls Cleared (LCC)
First Attempt Offered Traffic
Trunks
Carried Traffic
Carried Traffic
Carried Traffic
Carried Traffic
Carried Traffic
Excess Traffic
LCC Bucket
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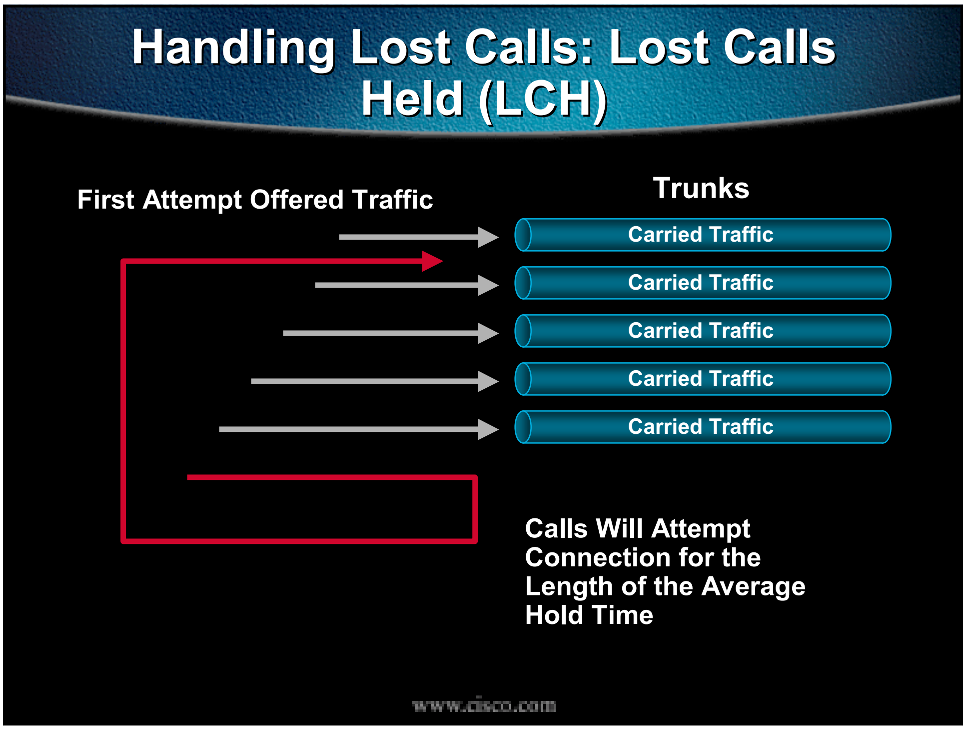
Handling Lost Calls: Lost Calls Held (LCH)
First Attempt Offered Traffic
Trunks
Carried Traffic
Carried Traffic
Carried Traffic
Carried Traffic
Carried Traffic
Calls Will Attempt Connection for the Length of the Average Hold Time
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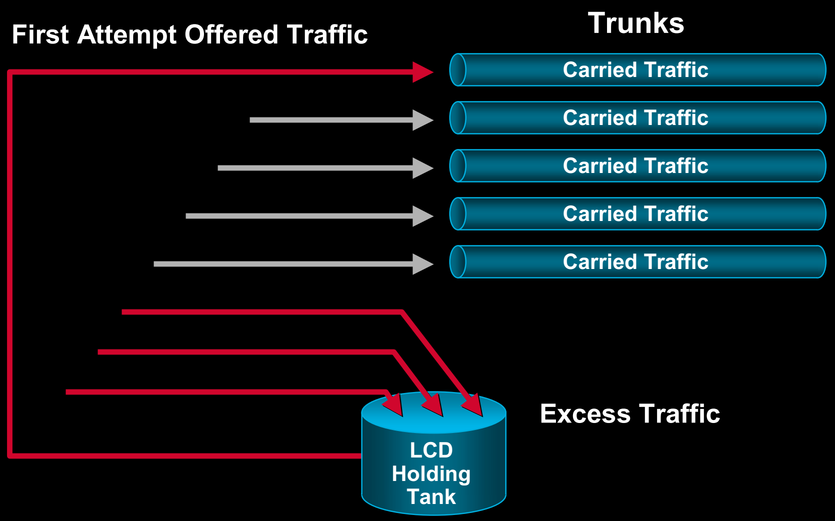
Handling Lost Calls: Lost Calls Delayed (LCD)



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Step 3: Determining the Number of Trunks

- Decide how many trunk groups we want based on how we profiled the traffic
- Determine grade of service for each group
- Apply probability tables or programs to calculate the number of trunks

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Large or Small Trunk Groups?

- Larger trunk groups are more efficient
- Volume discount benefits
- Iterative design approach

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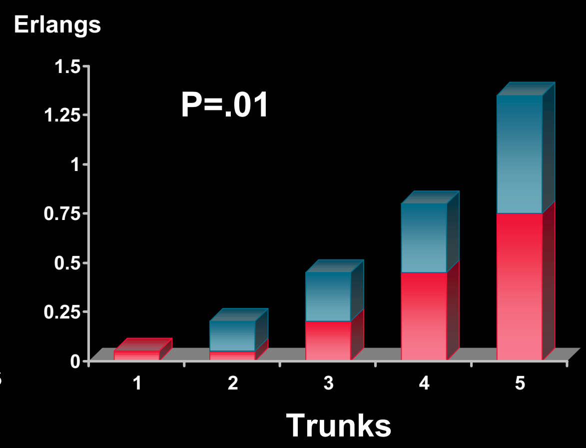
Theory of Large Trunk Groups

- Total capacity increases in a non-linear and not a linear fashion
- The incremental addition of one trunk approaches one erlang



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Grade of Service

- Grade of service based on the probability of blockage
- Based on the busy hour
- Grade of service differ between:
  - PBXs
  - Automatic call distribution with queuing

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Pick the Traffic Table or Program

- Number of sources: Finite and infinite
- Traffic characteristics: Random, smooth or rough
- How blocked calls are handled
- Switch availability

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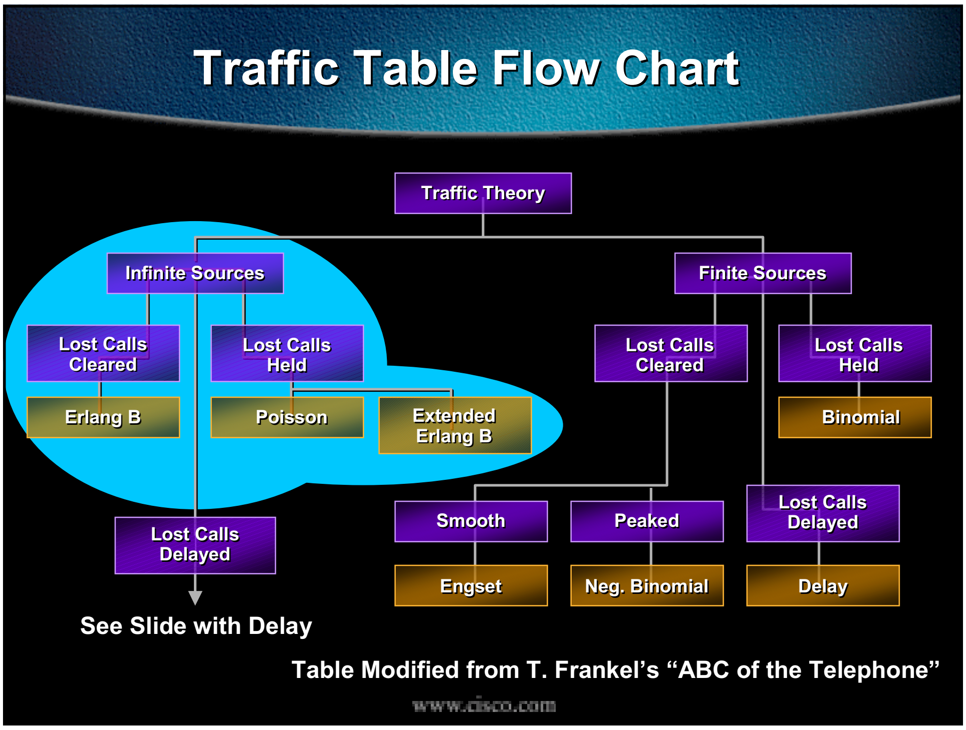
Traffic Table Flow Chart
Traffic Theory
Infinite Sources
Finite Sources
Lost Calls Cleared
Lost Calls Held
Lost Calls Cleared
Lost Calls Held
Erlang B
Poisson
Extended Erlang B
Binomial
Smooth
Peaked
Lost Calls Delayed
Lost Calls Delayed
Engset
Neg. Binomial
Delay
See Slide with Delay
Table Modified from T. Frankel's "ABC of the Telephone"
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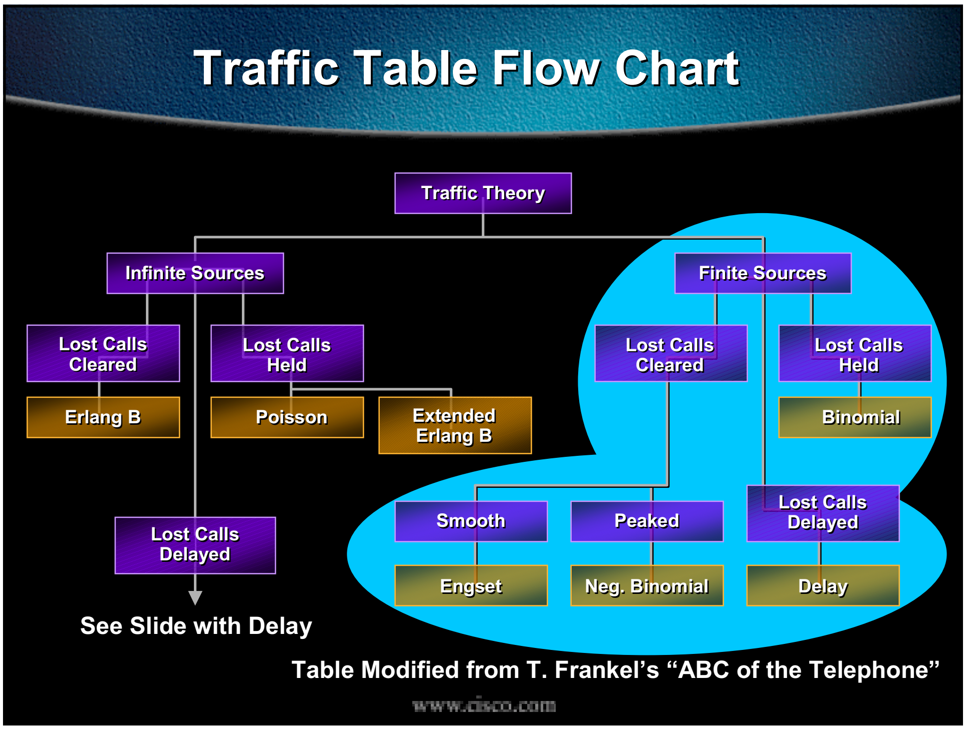
Traffic Table Flow Chart
Traffic Theory
Infinite Sources
Finite Sources
Lost Calls Cleared
Lost Calls Held
Lost Calls Cleared
Lost Calls Held
Erlang B
Poisson
Extended Erlang B
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Smooth
Peaked
Lost Calls Delayed
Lost Calls Delayed
Engset
Neg. Binomial
Delay
See Slide with Delay
Table Modified from T. Frankel's "ABC of the Telephone"
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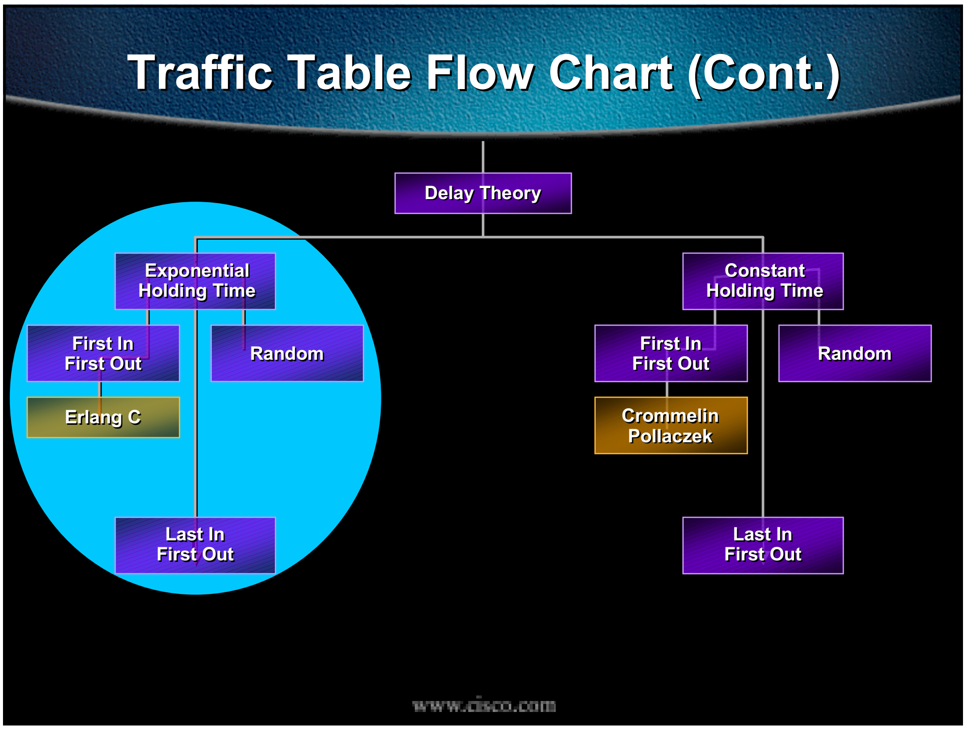

Erlang B

- Infinite sources
- Lost calls cleared
- Constant or exponential holding time
- Random traffic
- Application

  Outbound trunks with overflow, i.e. alternate routes are used
- Commonly used throughout the world

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Design Example #1

How Many Trunks to Handle this Traffic?

- 352 hours of first-attempt traffic in the month
- 22 business days/month
- 10% call processing
- 15% of traffic in busy hour
- Chance of blocking = 1%

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Design Example #1

First, What Is the Busy Hour?

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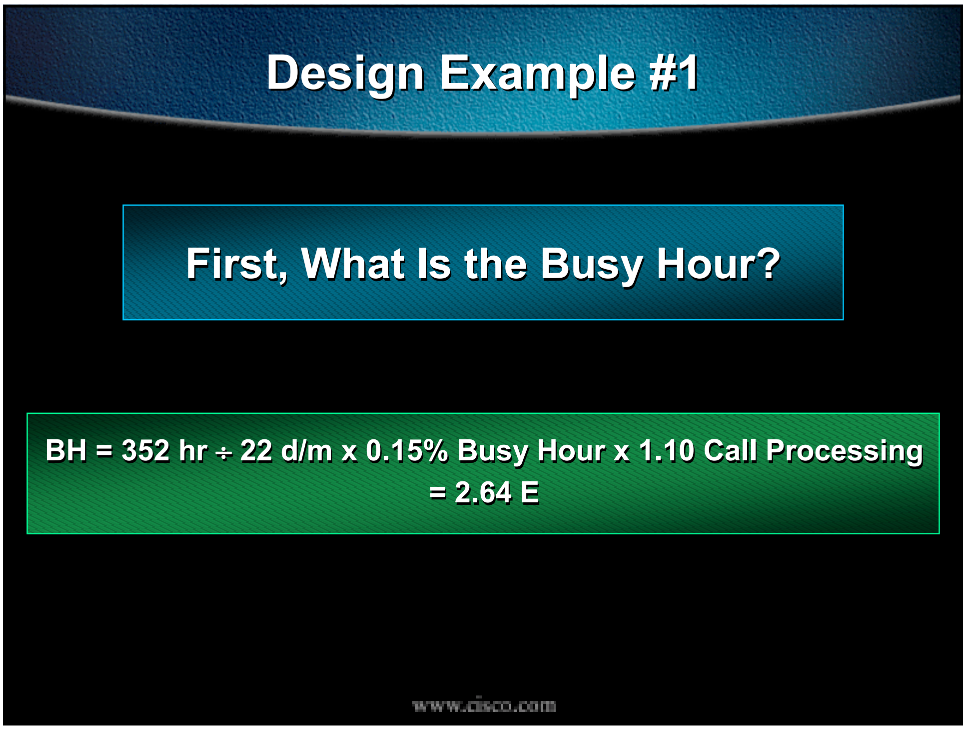
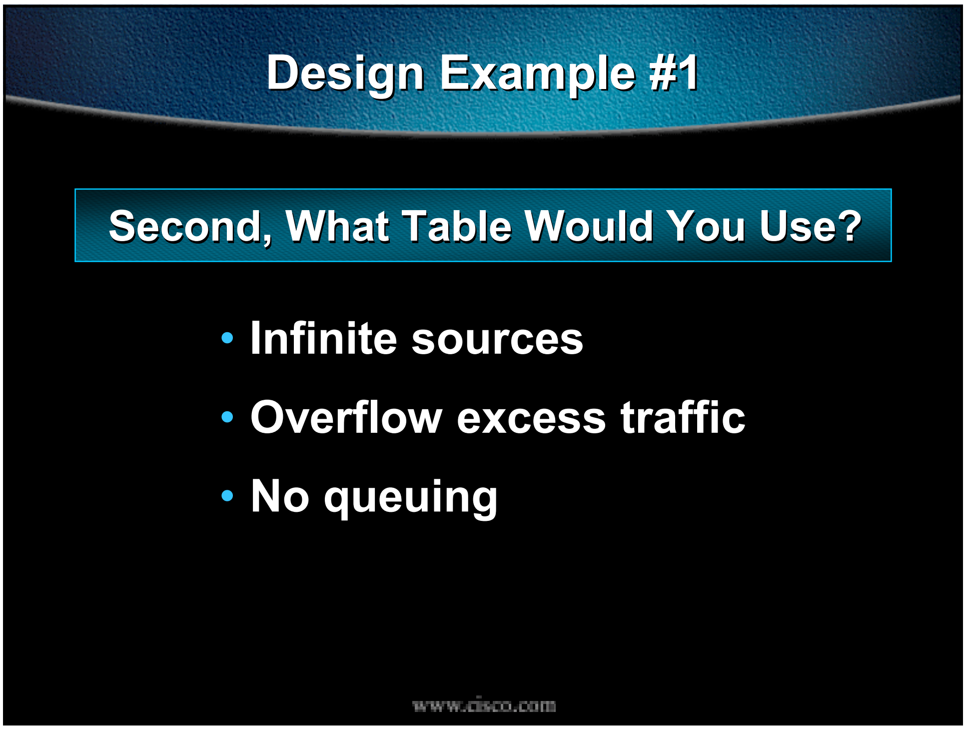

Design Example #1
First, What Is the Busy Hour?
BH = 352 hr ÷ 22 d/m x 0.15% Busy Hour x 1.10 Call Processing
= 2.64 E
www.cisco.com


Design Example #1
Second, What Table Would You Use?
• Infinite sources
• Overflow excess traffic
• No queuing
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Design Example #1

Second, What Table Would You Use?

Erlang B

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Design Example #1

Finally, Calculate the Number of Trunks Required?

N	P					
	.003	.005	.01	.02	.03	.05
1	.003	.005	.011	.021	.031	.053
2	.081	.106	.153	.224	.282	.382
3	.289	.349	.456	.603	.716	.9
4	.602	.702	.87	1.093	1.259	1.525
5	.995	1.132	1.361	1.658	1.876	2.219
6	1.447	1.622	1.909	2.276	2.543	2.961
7	1.947	2.158	2.501	2.936	3.25	3.738
8	2.484	2.73	3.128	3.627	3.987	4.543
9	3.053	3.333	3.783	4.345	4.748	5.371
10	3.648	3.961	4.462	5.084	5.53	6.216
11	4.267	4.611	5.16	5.842	6.328	7.077
12	4.904	5.279	5.876	6.615	7.141	7.95
13	5.559	5.964	6.608	7.402	7.967	8.835
14	6.229	6.664	7.352	8.201	8.804	9.73
15	6.913	7.376	8.108	9.01	9.65	10.63

Table Extracted from T. Frankel's “ABC of the Telephone

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Design Example #1

Finally, Calculate the Number of Trunks Required?

N			P			
	.003	.005	.01	.02	.03	.05
1	.003	.005	.011	.021	.031	.053
2	.081	.106	.153	.224	.282	.382
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14	6.229	6.664	7.352	8.201	8.804	9.73
15	6.913	7.376	8.108	9.01	9.65	10.63

Table Extracted from T. Frankel's "ABC of the Telephone

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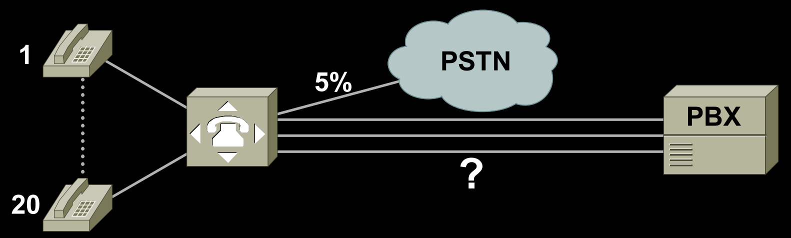
Design Example #2



How Many Tie Lines Are Required to Support a Remote Office Key System if the following Conditions Exist:

- There are 20 subscribers
- Average five calls per hour per user
- Average duration of 100 seconds per call
- 5% of the traffic will overflow to PSTN

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Design Example #2

- A = C * T
- A = $\frac{20 * 5 * 100}{3600}$ = 2.78 Erlang
- L = 20 users
- P = .05

A = Traffic Flow
C = Number of Calls Originated in 1 Hour
T = Average Holding Timer of One Call
L = Number of Callers
P = Probability of a Call being Blocked

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Design Example #2

Using Engset

N	P							
	0.001	0.002	0.003	0.005	0.01	0.02	0.03	0.05
	L = 20							
5	0.88	1.03	1.13	1.28	1.53	1.84	2.07	2.43
6	1.34	1.54	1.68	1.87	2.17	2.56	2.83	3.26
7	1.88	2.13	2.29	2.52	2.88	3.33	3.65	4.14
8	2.49	2.77	2.96	3.23	3.65	4.16	4.51	5.06
9	3.15	3.48	3.7	3.99	4.46	5.02	5.42	6.02

Six Trunks Satisfy the Requirements

Table Extracted from T. Frankel's "ABC of the Telephone"

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Design Example #3: Mixed–Model

- Call center design
  - Uses 1–800 number to sales, service, etc.
  - Some call centers provide function to several companies
  - Every minute can equate to $10,000s
- Real-time issues
  - Peaked traffic
  - Agent breaks, sickness, etc.

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Call Center Design

- Call centers use a device called an Automatic Call Distributor (ACD) to queue and distribute calls to agents
  - May be part of a PBX or a separate device
- Holding time of a trunk

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Call Center Traffic Models

- Erlang C is used to design number of agent positions
  - Queuing
  - No overflow

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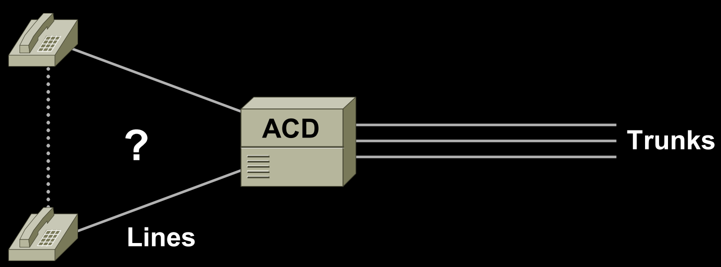
Design Example #3



How Many Lines Are Required to Support a Call Center that has:

- 230 calls per hour with an average delay not longer than 30 sec
- No more than 20 percent of the calls delayed over one minute
- Average hold time is 120 seconds
- Queuing is first in first out

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Design Example #3

- A = C * T
- A = $\frac{230 * 120}{3600}$ = 7.67 Erlangs
- D1 = $\frac{30 \text{ sec}}{120 \text{ sec}}$ = .25 holding time
- t = $\frac{60 \text{ sec}}{120 \text{ sec}}$ = .5 holding time
- P(t) (for t = .5) must be less than 20%

A = Traffic Flow
C = Number of Calls Originated in 1 Hour
T = Average Holding Timer of One Call
D1 = Average Delay on all Calls as a Percentage of the Holding Time
t = Time of no Greater than Delay as a Percentage of the Holding Time
P(t)= Probability of Delay Greater than t

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Design Example #3

Using Erlang C

					P(t) for t=						
A	N	P(0)	D1	D2	0.1	0.2	0.3	0.4	0.5	0.75	1
7.7	8	0.889	2.94	3.33	0.856	0.831	0.806	0.782	0.759	0.704	0.653
	9	0.564	0.434	0.769	0.496	0.435	0.382	0.336	0.295	0.213	0.154
	10	0.346	0.15	0.435	0.274	0.218	0.173	0.138	0.109	0.062	0.035
	11	0.202	0.061	0.303	0.145	0.104	0.075	0.054	0.039	0.017	0.007

1. Found the Entry for Erlangs = 7.7
2. Found the Entry for d1 < .25
3. Looking at t = 0.5 Find p(t) < 0.20
4. 10 Agent Lines Will Meet My Requirements

Table Extracted from T. Frankel's "ABC of the Telephone"

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Agenda

- Basic Voice Traffic Engineering
- How Costs Impact Trunk Groups
- How to Apply Voice Traffic Engineering to a Packet-Based Data Network

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Step 4: Least-Cost Trunking

- Calculate the number of trunks required to carry the busy hour traffic
- Account for traffic overflowing to alternate paths, i.e. lost calls cleared
- Primary and alternate routes (overflow) are dictated by economics, e.g. carrier pricing
- Packet based networks can serve as either primary or alternate routes, given we understand the cost associated with their use

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Cost of Service

- Cost per minute often-quoted parameter
  - Unique to each organization
  - Varies with each organization
- In reality, costs should include transmission, equipment, administration and maintenance

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Cost—Optimization Rule

- Use average usage figures instead of busy hour calculations
- Use the least costly circuits until the cost per hour becomes more expensive than the next best route

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Back to Our First Example

- 2.64 Erlangs in the busy hour requires eight trunks for a p of .01
- 352 hours of first-attempt traffic in the month
- 22 business days per month
- 10% call processing
- Average hourly usage is equal to:

  352 hours/month—22 days/month—8 hours/day * 1.10 processing = 2.2 Erlangs per hour

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Example

- XYZ carrier has offered our company three choices for carrying voice traffic between its head office, and its sales office

  1. DDD $25 per hour
  2. Plan A $60 fixed charge plus $18 per hour
  3. Tie trunk $500

Which Option Is Best?

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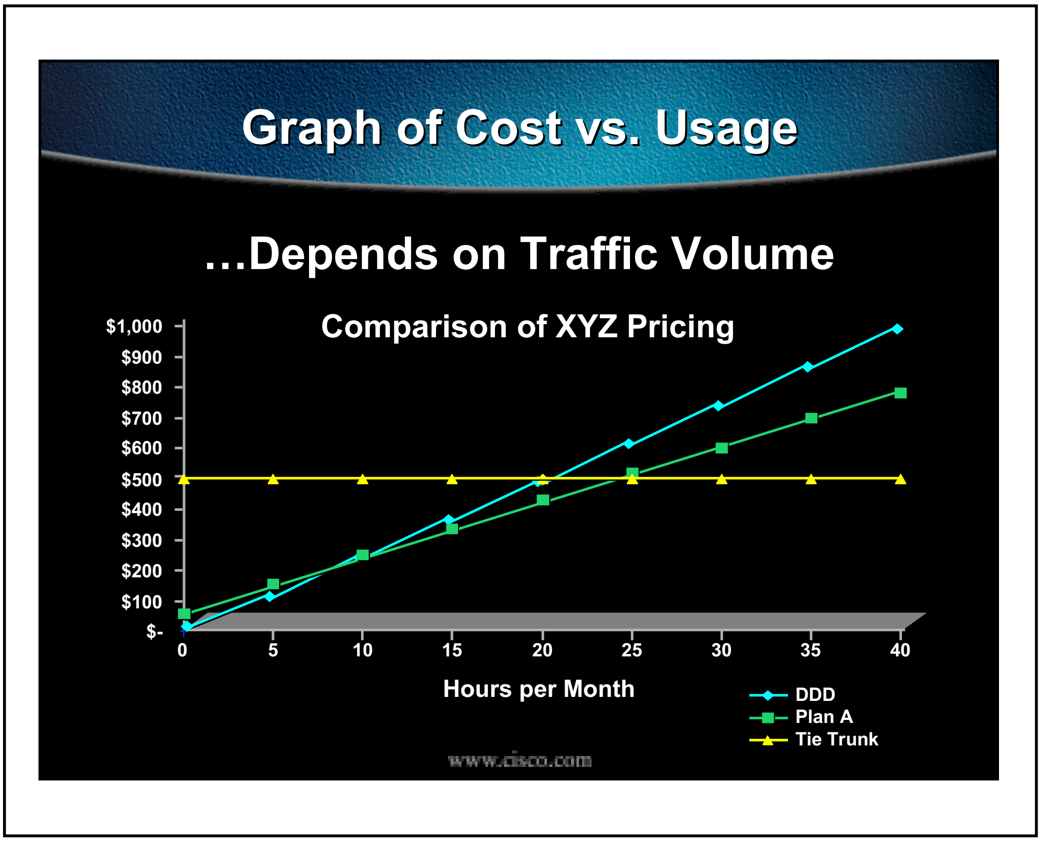
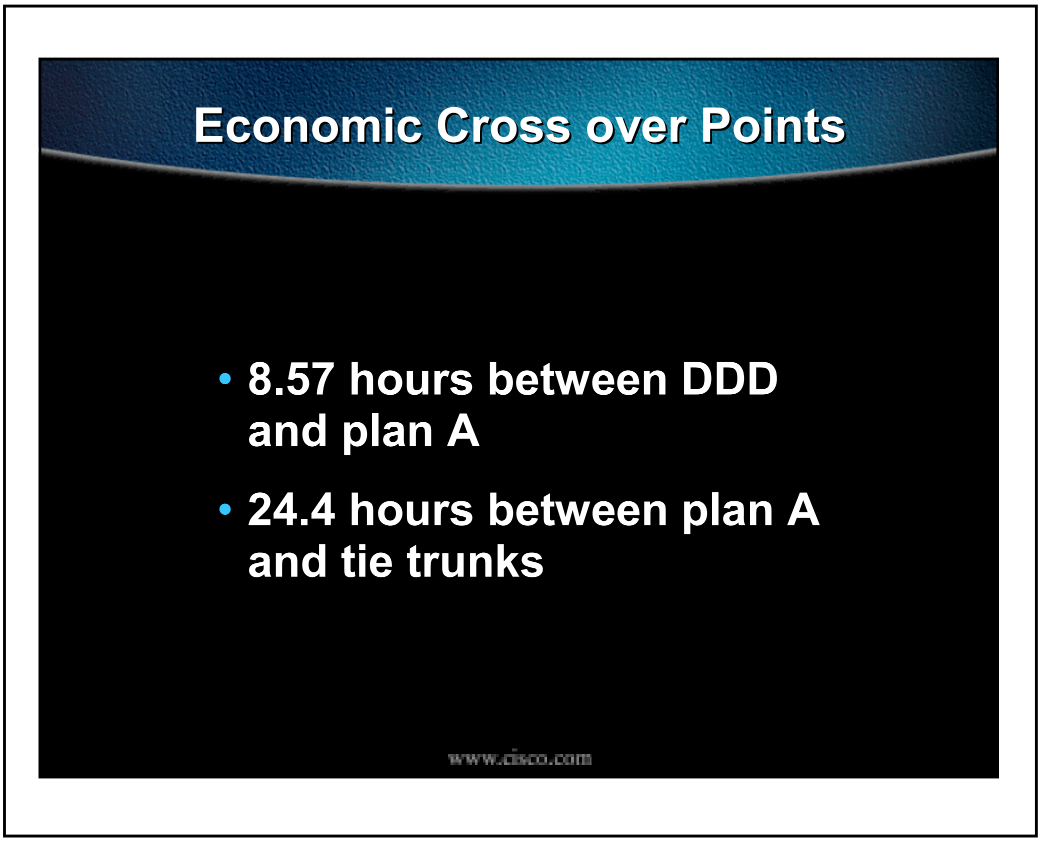


Graph of Cost vs. Usage
…Depends on Traffic Volume
Comparison of XYZ Pricing
$1,000
$900
$800
$700
$600
$500
$400
$300
$200
$100
$-
0
5
10
15
20
25
30
35
40
Hours per Month
DDD
Plan A
Tie Trunk
www.cisco.com



Economic Cross over Points
• 8.57 hours between DDD and plan A
• 24.4 hours between plan A and tie trunks
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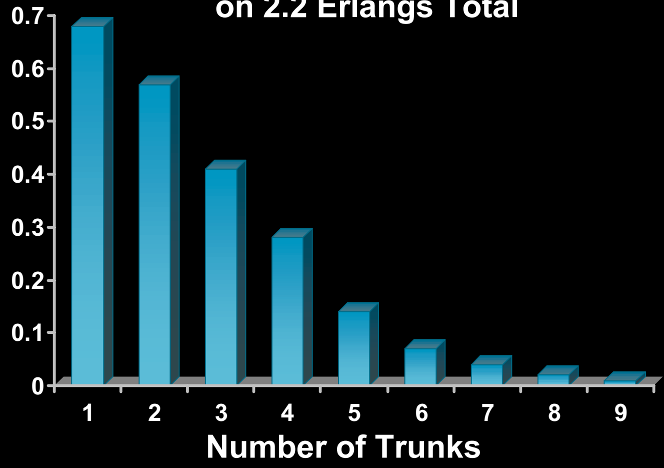
Traffic Distribution Based on Average Usage

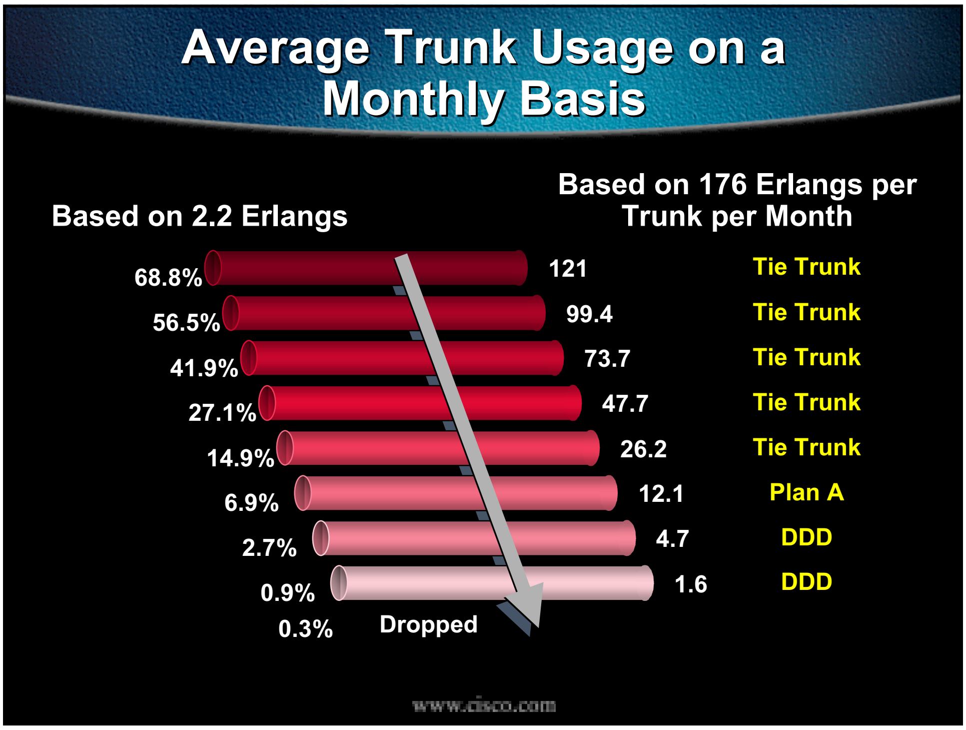
Number Trunks	Offerred Hours	Carried per Trunk	Cumulative Carried	Grade of Service
1	2.2	0.688	0.688	0.688
2	1.513	0.565	1.253	0.431
3	0.947	0.419	1.672	0.24
4	0.528	0.271	1.943	0.117
5	0.257	0.149	2.093	0.049
6	0.107	0.069	2.161	0.018
7	0.039	0.027	2.188	0.005
8	0.012	0.009	2.197	0.002
9	0.003	0.003	2.199	0

Traffic on Each Trunk Based on 2.2 Erlangs

Traffic Distribution Based on Average Usage (Cont.)

Erlangs Carried on Each Trunk Based on 2.2 Erlangs Total





Agenda

- Basic Voice Traffic Engineering
- How Costs Impact Trunk Groups
- How to Apply Voice Traffic Engineering to a Packet-Based Data Network

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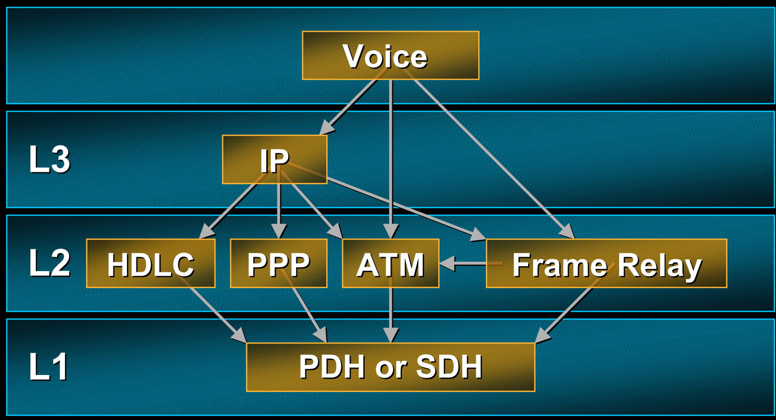
Voice Transport Choices



Each Layer Adds a Bandwidth Requirement which Must Be Accounted for in Proper Network Traffic Engineering

Erlang to Packet Conversion

- 1 Erlang = 60 minutes = 64Kbps * 3600 seconds /8bits/byte = 28.8 Mbytes
- IP
  - 1 Erlang = 450K packets (64 byte packets) or 125 pps
- Frame Relay
  - 1 Erlang = 1.44M frames (20 byte frames) or 400 fps
- ATM
  - 1 Erlang = (AAL1) 655K cells or 182 cells/second
  - = (AAL5) 600K cells or 167 cells/second

Voice Compression Bandwidth Requirements

Encoding/ Compression	Result Bit Rate
G.711 PCM	64 kbps (DS0)
G.726 ADPCM	16, 24, 32, 40 kbps
G.727 E-ADPCM	16, 24, 32, 40 kbps
G.729 CA-CELP	8 kbps
G.728 LD-CELP	16 kbps
G.723.1	6.3/5.3 kbps Variable

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G.729 Voice Compression

- Will reduce the bandwidth required to 1/8 th, 1 Erlang = 3.6Mbytes
- G.729 coder will output voice frames in 10 msec segments; 1–10msec frame = 10 bytes
- Bandwidth may or may not fit perfectly into a packet; for example, a 48 byte ATM cell will have at least 8 bytes of padding

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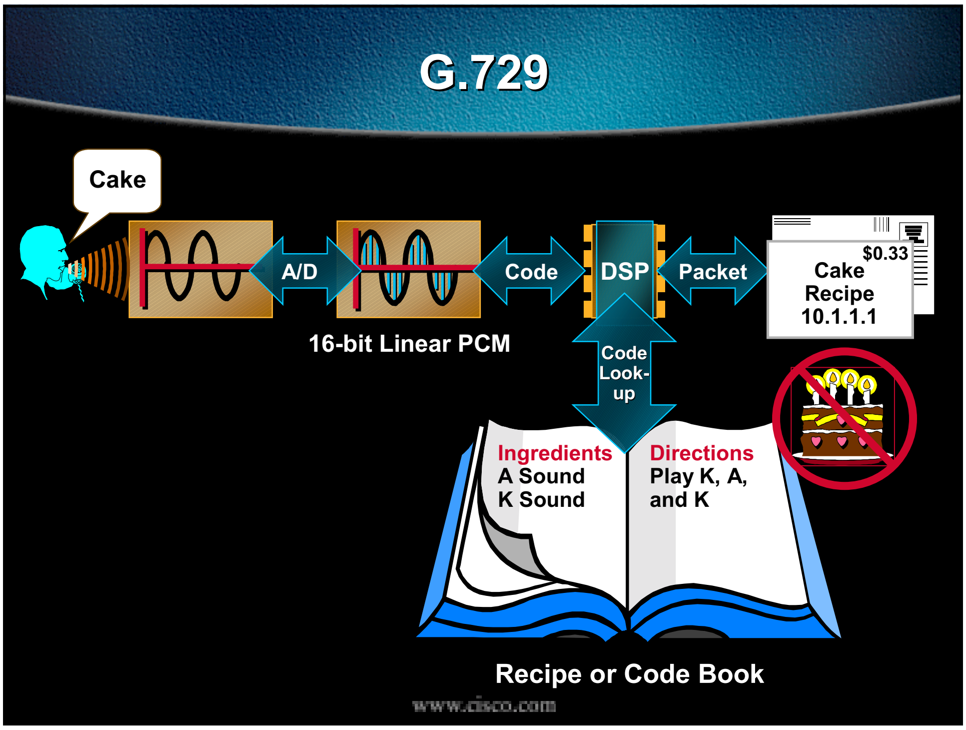
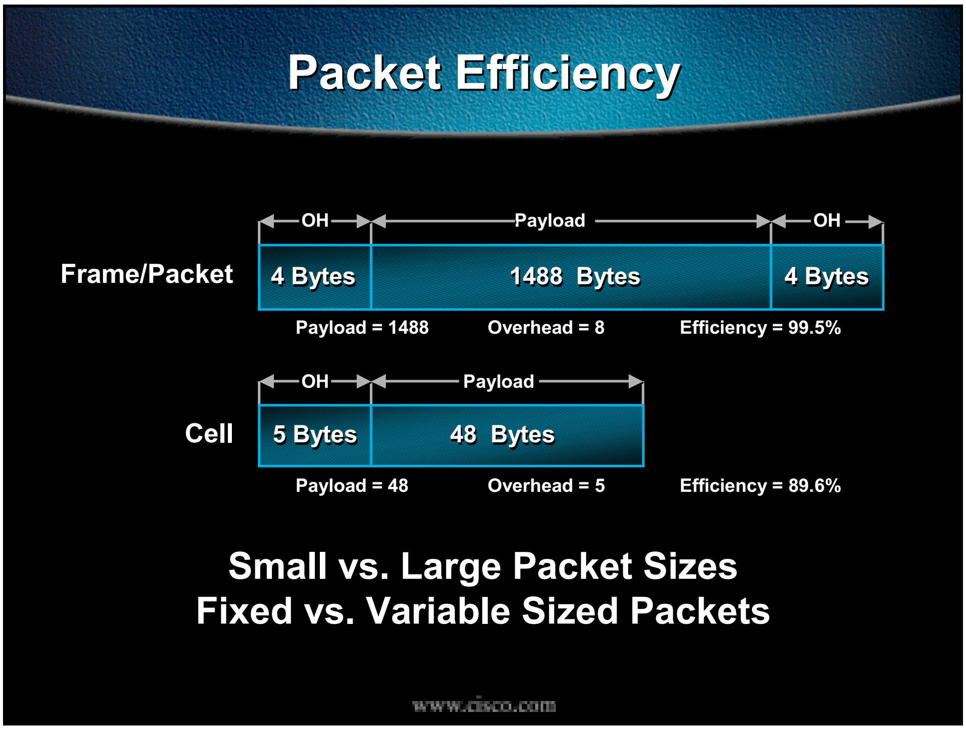

G.729
Cake
A/D
Code
DSP
Packet
$0.33
Cake
Recipe
10.1.1.1
16-bit Linear PCM
Code
Look-
up
Ingredients
A Sound
K Sound
Directions
Play K, A,
and K
Recipe or Code Book
www.cisco.com


Packet Efficiency
OH
Payload
OH
Frame/Packet
4 Bytes
1488 Bytes
4 Bytes
Payload = 1488
Overhead = 8
Efficiency = 99.5%
OH
Payload
Cell
5 Bytes
48 Bytes
Payload = 48
Overhead = 5
Efficiency = 89.6%
Small vs. Large Packet Sizes
Fixed vs. Variable Sized Packets
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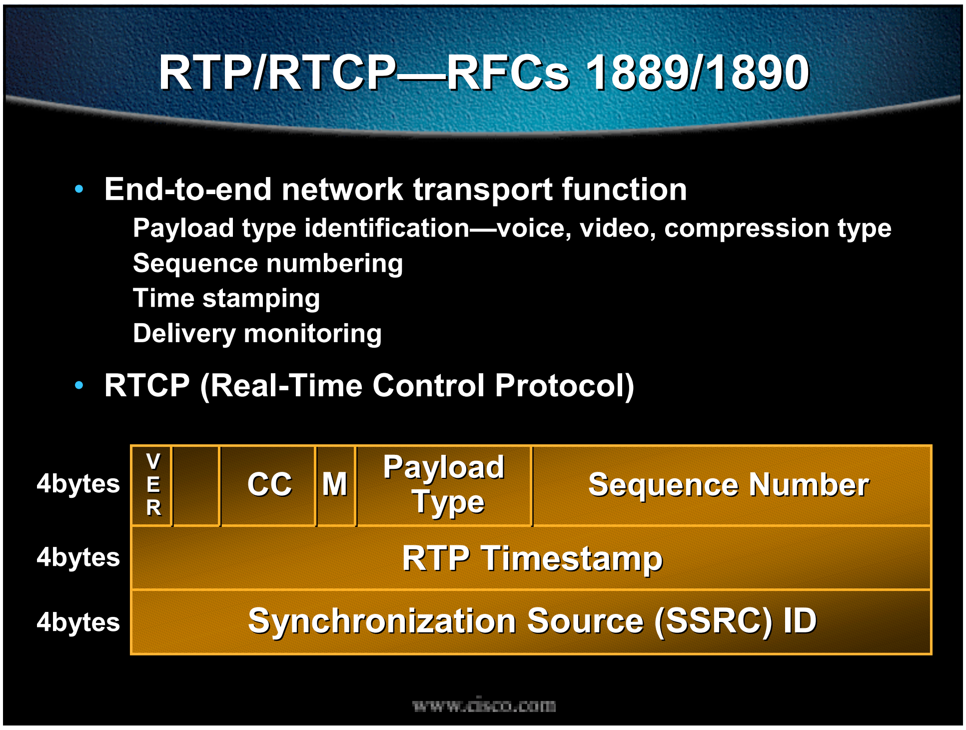
RTP/RTCP—RFCs 1889/1890
• End-to-end network transport function
Payload type identification—voice, video, compression type
Sequence numbering
Time stamping
Delivery monitoring
• RTCP (Real-Time Control Protocol)
4bytes
V E R
CC
M
Payload Type
Sequence Number
4bytes
RTP Timestamp
4bytes
Synchronization Source (SSRC) ID
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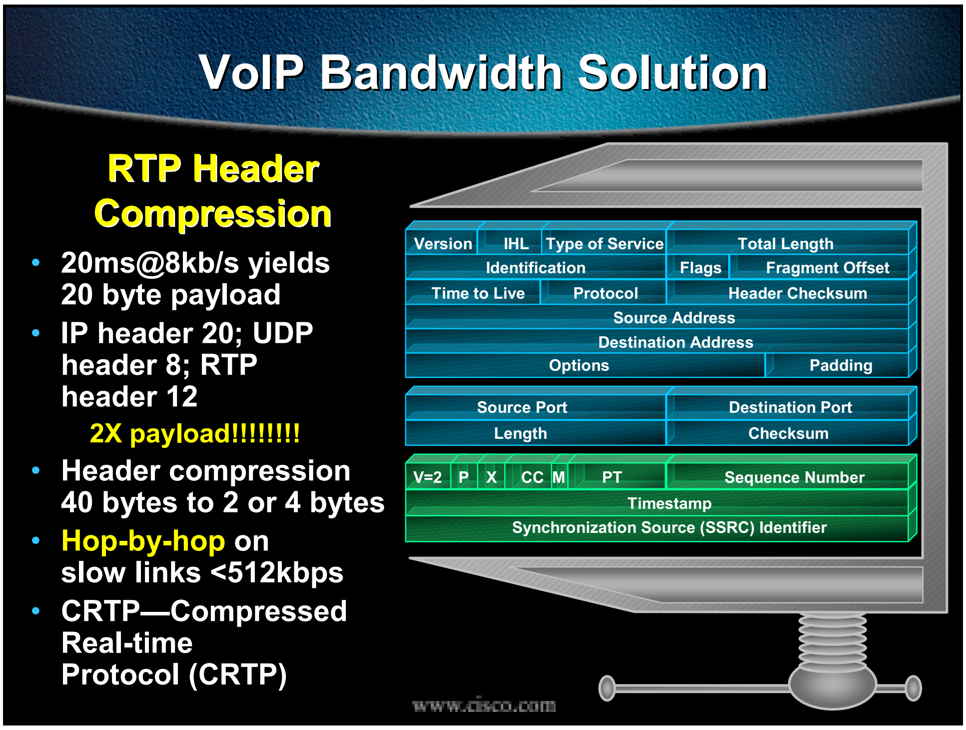
VoIP Bandwidth Solution
RTP Header Compression
• 20ms@8kb/s yields 20 byte payload
• IP header 20; UDP header 8; RTP header 12
2X payload!!!!!!!!
• Header compression 40 bytes to 2 or 4 bytes
• Hop-by-hop on slow links <512kbps
• CRTP—Compressed Real-time Protocol (CRTP)
Version
IHL
Type of Service
Total Length
Identification
Flags
Fragment Offset
Time to Live
Protocol
Header Checksum
Source Address
Destination Address
Options
Padding
Source Port
Destination Port
Length
Checksum
V=2
P
X
CC
M
PT
Sequence Number
Timestamp
Synchronization Source (SSRC) Identifier
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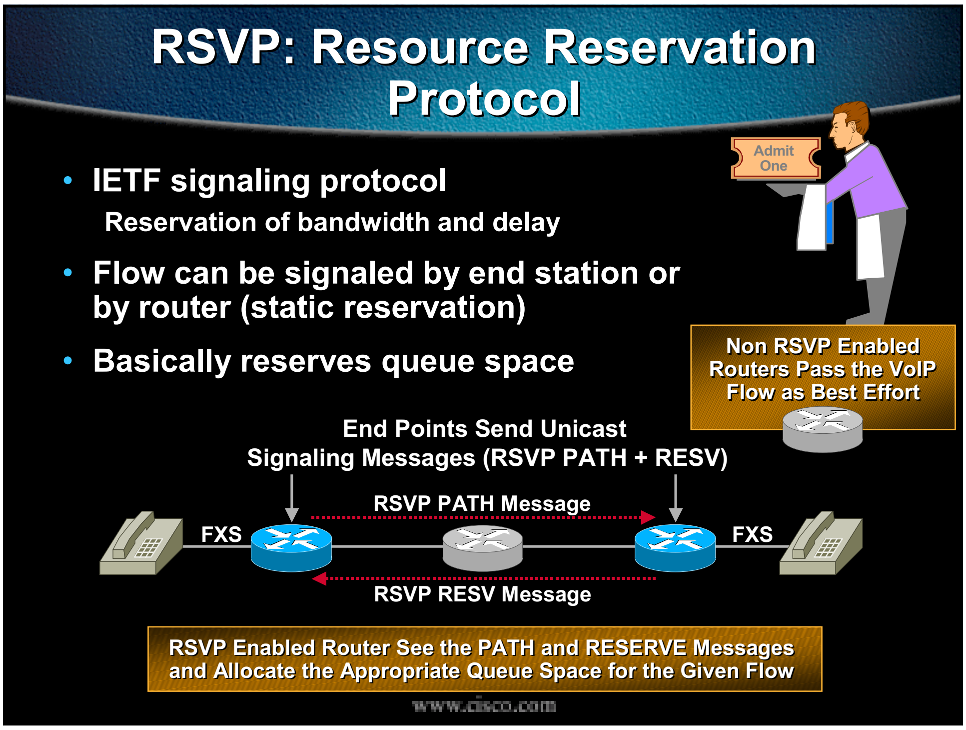
RSVP: Resource Reservation Protocol
• IETF signaling protocol
Reservation of bandwidth and delay
• Flow can be signaled by end station or by router (static reservation)
• Basically reserves queue space
Admit One
Non RSVP Enabled Routers Pass the VoIP Flow as Best Effort
End Points Send Unicast Signaling Messages (RSVP PATH + RESV)
RSVP PATH Message
FXS
FXS
RSVP RESV Message
RSVP Enabled Router See the PATH and RESERVE Messages and Allocate the Appropriate Queue Space for the Given Flow
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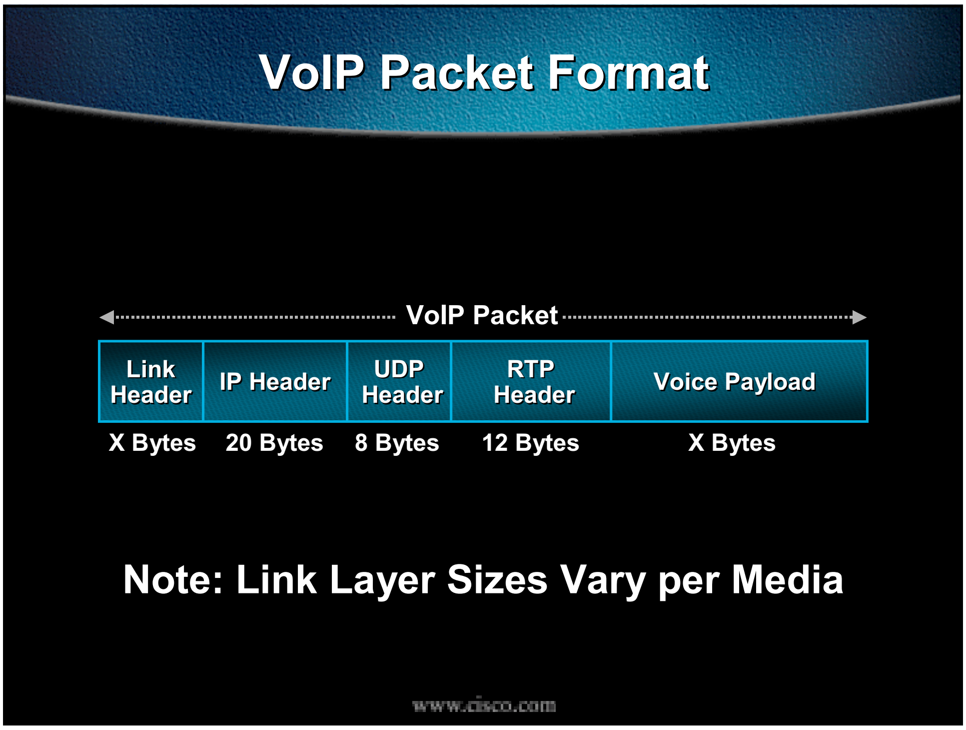
VoIP Packet Format
VoIP Packet
Link Header
IP Header
UDP Header
RTP Header
Voice Payload
X Bytes
20 Bytes
8 Bytes
12 Bytes
X Bytes
Note: Link Layer Sizes Vary per Media
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VoIP Bandwidth

- Voice payload calculation

  20 msec voice sample * 8 kbps (for G.729) /
  8 bits/byte = 20 bytes

- Packet size calculations

  20 byte payload, uncompressed header (40 bytes) or
  RTP/CRTP (5 bytes)

- Bandwidth calculations

  Router using G.711 = 160 byte voice payload at 50 pps (80 kbps)

  Router using G.729 = 20 byte payload at 50 pps (24 kbps)

  IP Phone using G.711 = 240 byte payload at 33 pps (74.6 kbps)

  IP Phone using G.723.1 = 24 byte payload at 33 pps (17 kbps)

  (Not including link layer header or CRTP)

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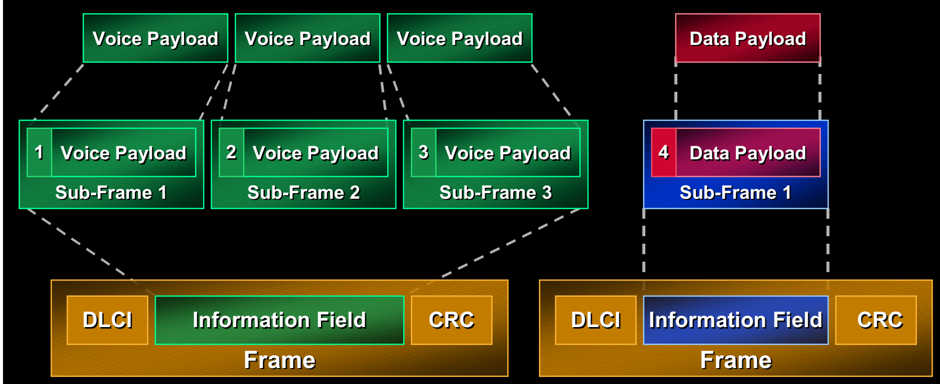
Multiple Sub-Channel Payloads in an FRF.11 Frame



Source: Frame Relay Forum

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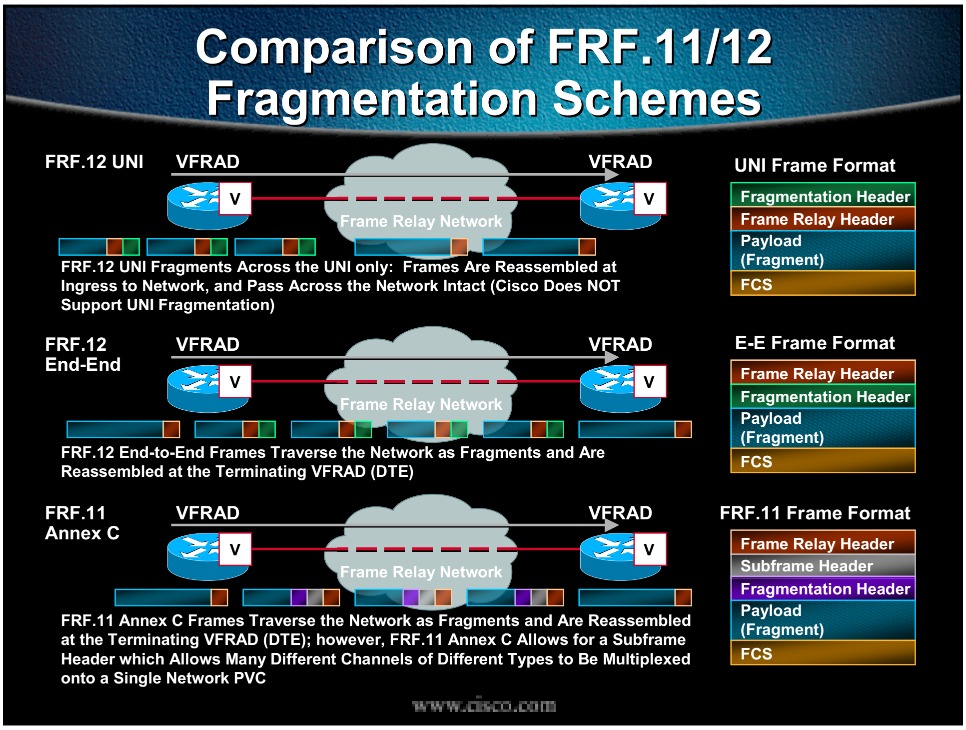

VoFR Bandwidth

- **Voice payload calculation**

  20 msec voice sample * 8 kbps (for G.729) / 8 bits/byte = 20 bytes

  Note: to derive the payload for G.711, substitute 64 kbps = 160 bytes

- **Packet size calculations**

  20 byte payload + 7 byte Header = 27 bytes (Header = DLCI/FRF.11/seqn/CRC)

- **Bandwidth calculations**

  27 b/voice packet * 8 bits/byte * 50 pps

  = 10.8 kbps per call

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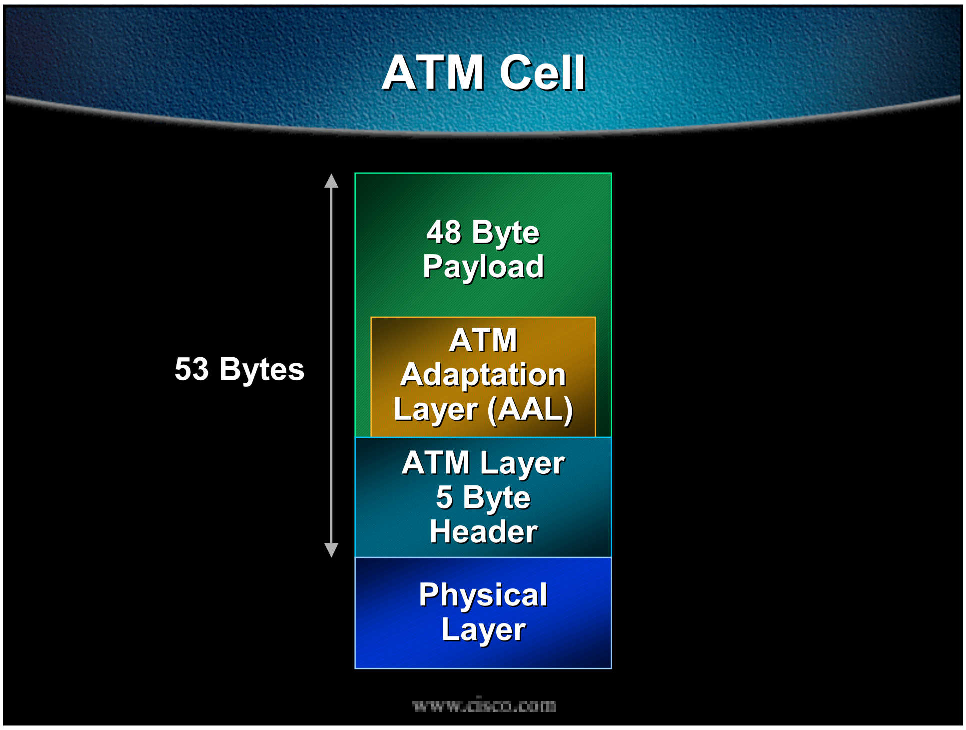
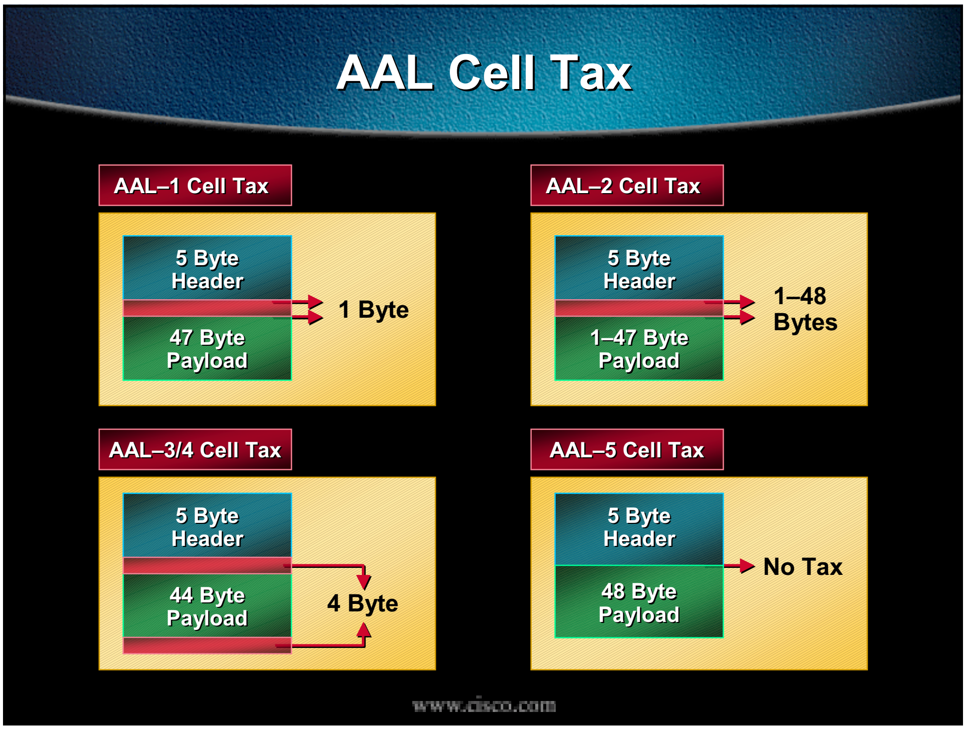

ATM Cell
48 Byte Payload
ATM Adaptation Layer (AAL)
53 Bytes
ATM Layer 5 Byte Header
Physical Layer
www.cisco.com


AAL Cell Tax
AAL–1 Cell Tax
5 Byte Header
47 Byte Payload
1 Byte
AAL–2 Cell Tax
5 Byte Header
1–47 Byte Payload
1–48 Bytes
AAL–3/4 Cell Tax
5 Byte Header
44 Byte Payload
4 Byte
AAL–5 Cell Tax
5 Byte Header
48 Byte Payload
No Tax
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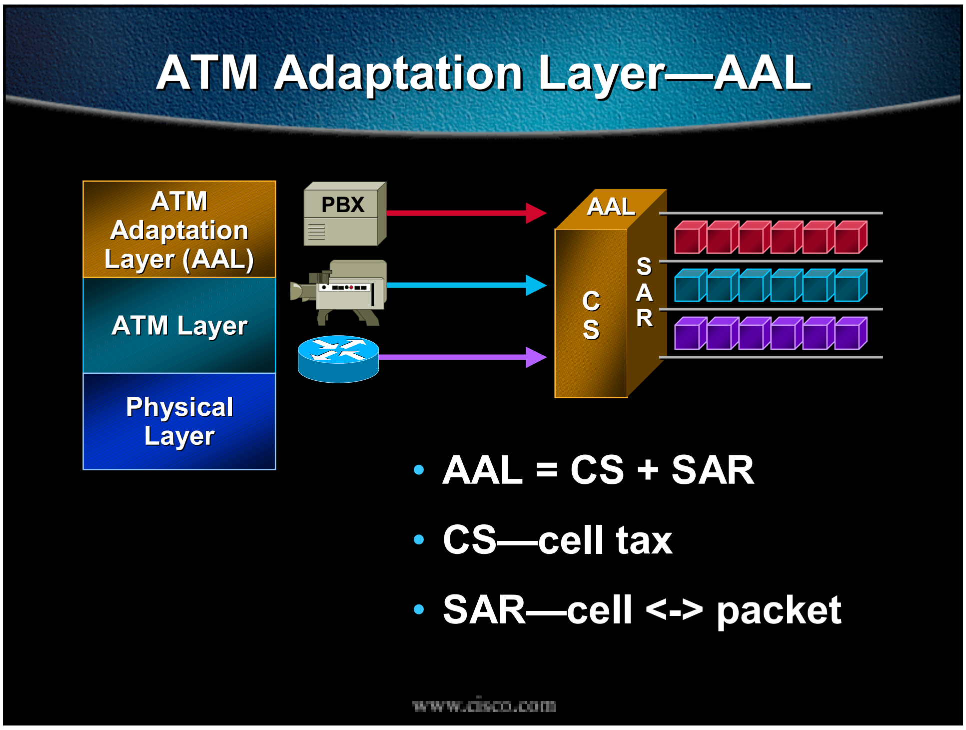
ATM Adaptation Layer—AAL
ATM Adaptation Layer (AAL)
ATM Layer
Physical Layer
PBX
AAL
C S
S A R
• AAL = CS + SAR
• CS—cell tax
• SAR—cell <-> packet
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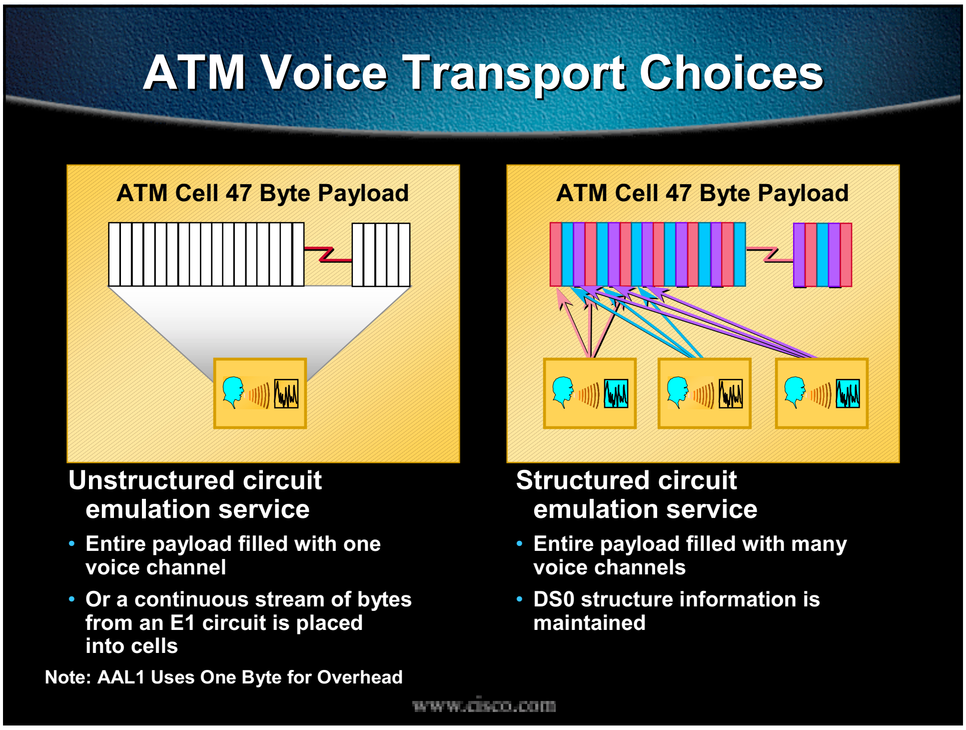
ATM Voice Transport Choices
ATM Cell 47 Byte Payload
ATM Cell 47 Byte Payload
Unstructured circuit emulation service
• Entire payload filled with one voice channel
• Or a continuous stream of bytes from an E1 circuit is placed into cells
Structured circuit emulation service
• Entire payload filled with many voice channels
• DS0 structure information is maintained
Note: AAL1 Uses One Byte for Overhead
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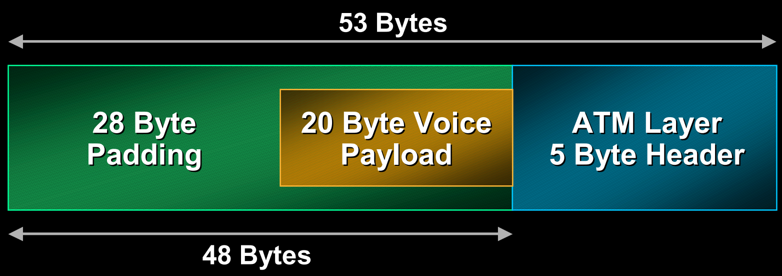
ATM AAL5 Voice Cells



- G.729 compression with 20 ms voice sample
- No AAL5 CS “Cell Tax”
- 28 Bytes “Overhead” due to padding

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VoATM Bandwidth

- **Voice payload calculation**

  20 msec voice sample * 8 kbps (for G.729) / 8 bits/byte = 20 bytes

  Note: to derive the payload for G.711, substitute 64 kbps = 160 bytes

- **Packet size calculations**

  20 byte payload + 28 byte pad +5 byte header = 53 bytes

- **Bandwidth calculations**

  53 b/voice packet * 8 bits/byte * 50 pps

  = 21.2 kbps per call

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Various Link Layer Header Sizes
"Varying Bit Rates per Media"

Example

G.729 with 60 byte packet (Voice and IP Header) at 50pps
(No RTP Header Compression)

Media	Link Layer Header Size	Bit Rate
Ethernet	14 Bytes	29.6 kbps
PPP	6 Bytes	26.4 kbps
Frame Relay	4 Bytes	25.6 kbps
ATM	5 Bytes per Cell	42.4 kbps

Note: For ATM a Single 60 Byte Packet Requires Two 53 Byte ATM Cells

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Traffic Distribution: How Do Voice Trunks Equate to Bandwidth?

- Still use 8 trunks to give us the required grade of service
- At any point in time we could be using 8 * 64 kbps (PCM) or 512 kbps of bandwidth
- During the busy hour we will be using 2.64 trunks x 64 kbps or 169 kbps (or 33% of 512 kbps)
- During the average hour we will be using 2.2 trunks x 64 kbps or 141 kbps (or 27.5% of 512 kbps)
- Over a period of a month we will be using 352 Erlangs out of a possible 1408 (8 trks *8 hrs/day *22 days) or 25%

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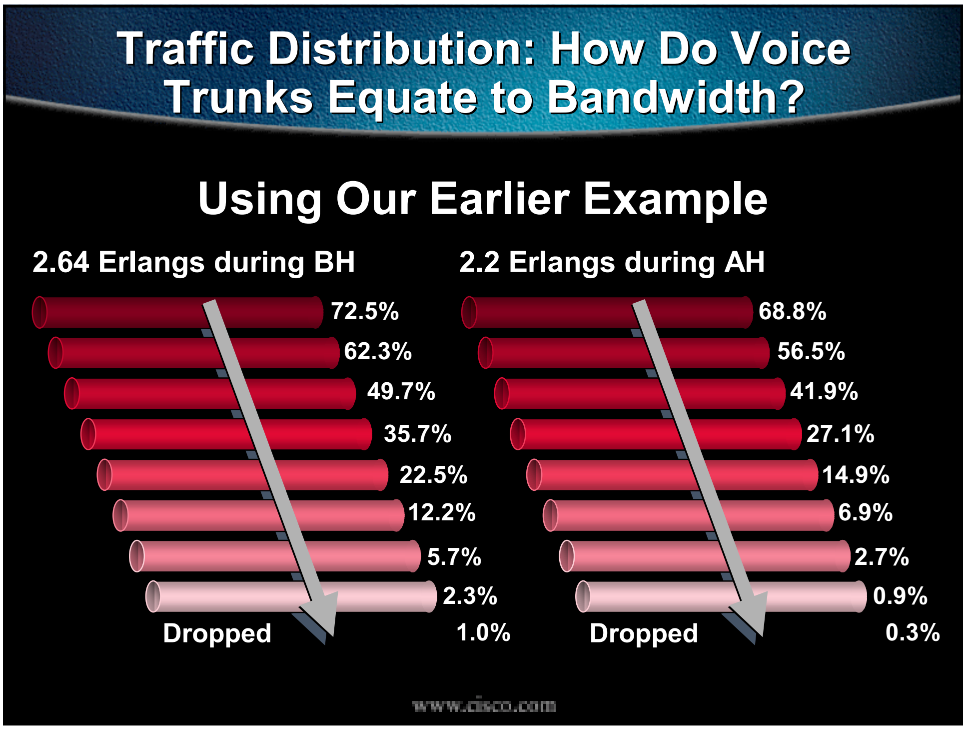
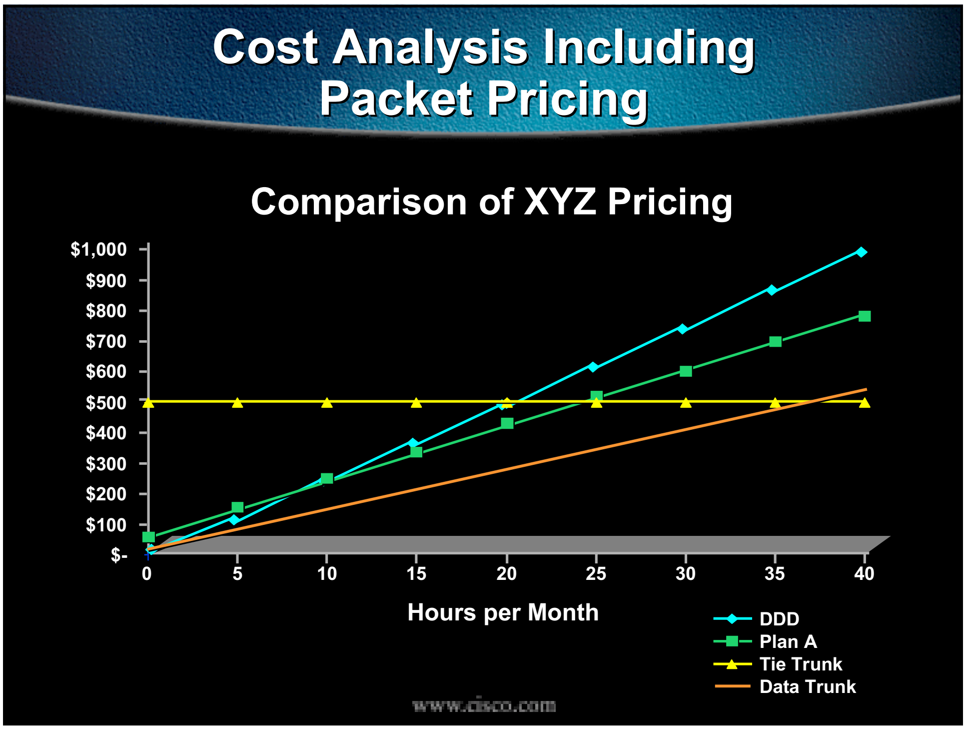

Traffic Distribution: How Do Voice Trunks Equate to Bandwidth?
Using Our Earlier Example
2.64 Erlangs during BH
72.5%
62.3%
49.7%
35.7%
22.5%
12.2%
5.7%
2.3%
Dropped
1.0%
2.2 Erlangs during AH
68.8%
56.5%
41.9%
27.1%
14.9%
6.9%
2.7%
0.9%
Dropped
0.3%
www.cisco.com


Cost Analysis Including Packet Pricing
Comparison of XYZ Pricing
$1,000
$900
$800
$700
$600
$500
$400
$300
$200
$100
$-
0
5
10
15
20
25
30
35
40
Hours per Month
DDD
Plan A
Tie Trunk
Data Trunk
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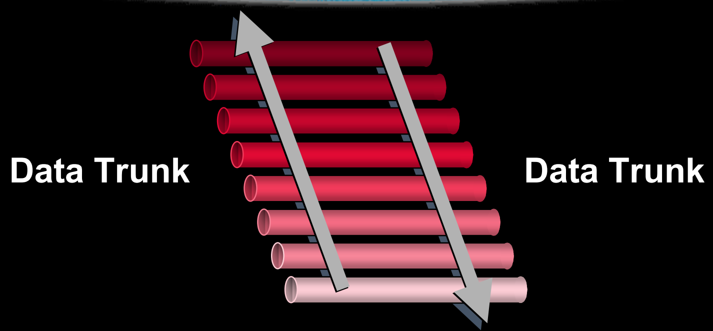
Other Trunk Selection Criteria



- Do we take the most busy trunks and move them on to the data network, or do we take the least busy trunks?
- The decision will be based on desired voice quality and costs, but will have an impact on the traffic load delivered to the data network

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Agenda

- Basic Voice Traffic Engineering
- How Costs Impact Trunk Groups
- How to Apply Voice Traffic Engineering to a Packet-Based Data Network

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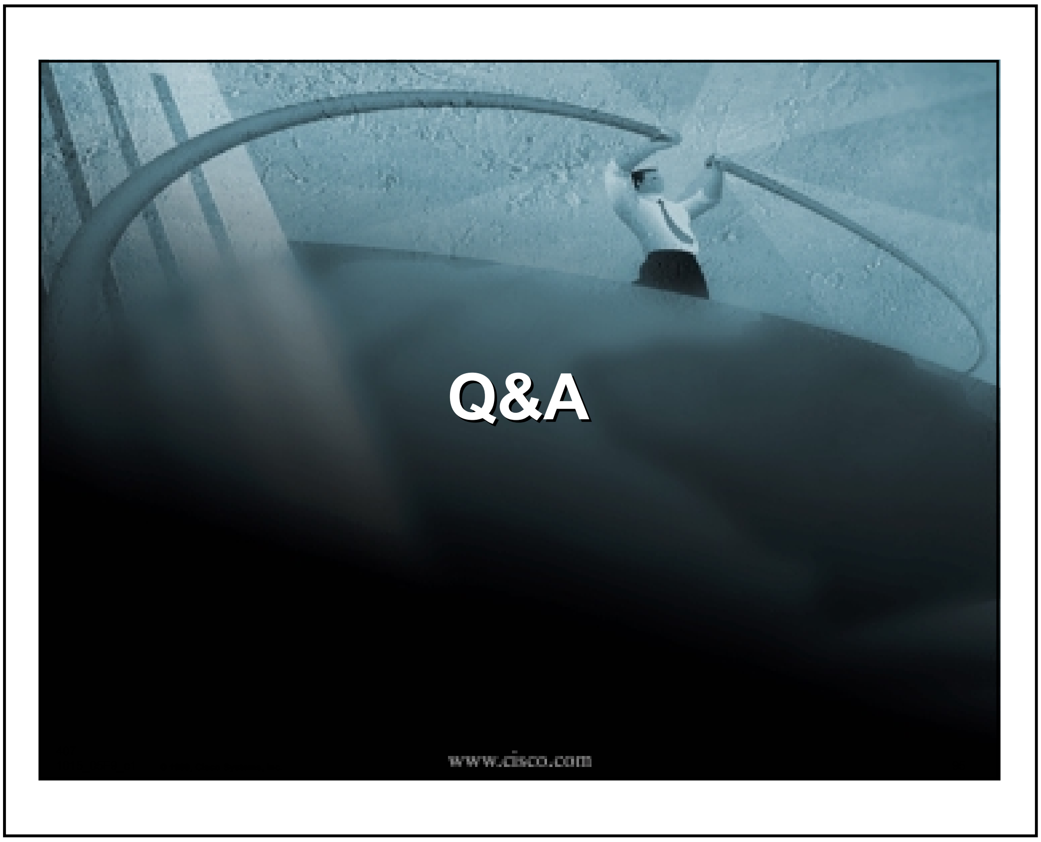
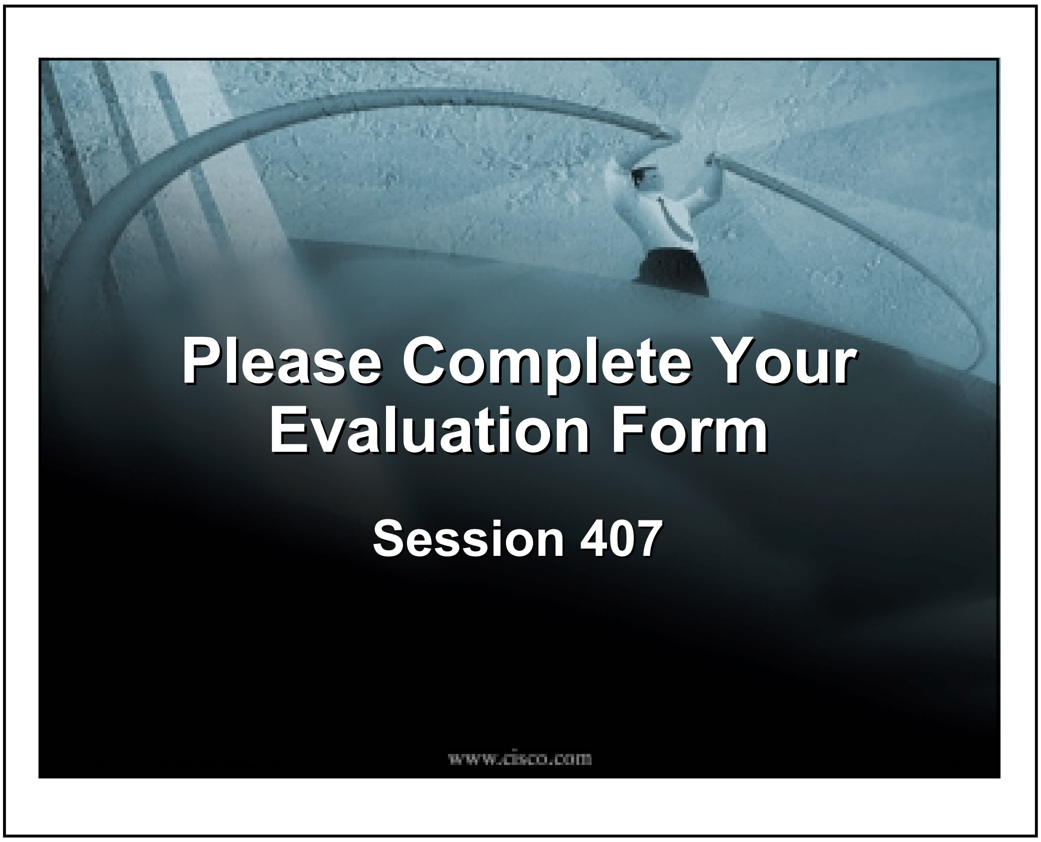

Q&A
www.cisco.com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