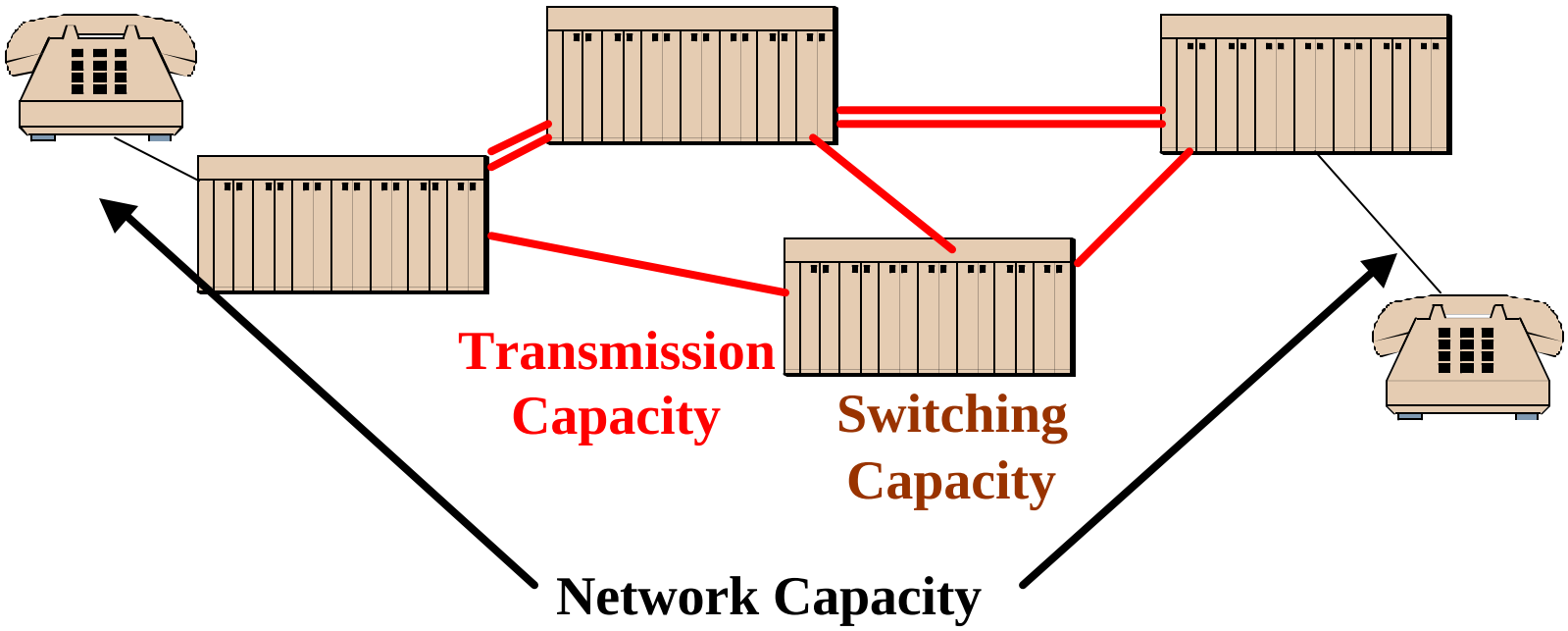
CISC452-00W
Telecommunications Systems

Lesson 4
Traffic Engineering

Why Worry About Traffic Engineering?

- **Telephone systems are multipoint-to-multipoint networks**
- **There can be many more users than transmission paths**
- **Traffic demand can exceed capacity, causing overflow and delay**
- **When demand > capacity, performance deteriorates exponentially**

Telecom Network Capacity

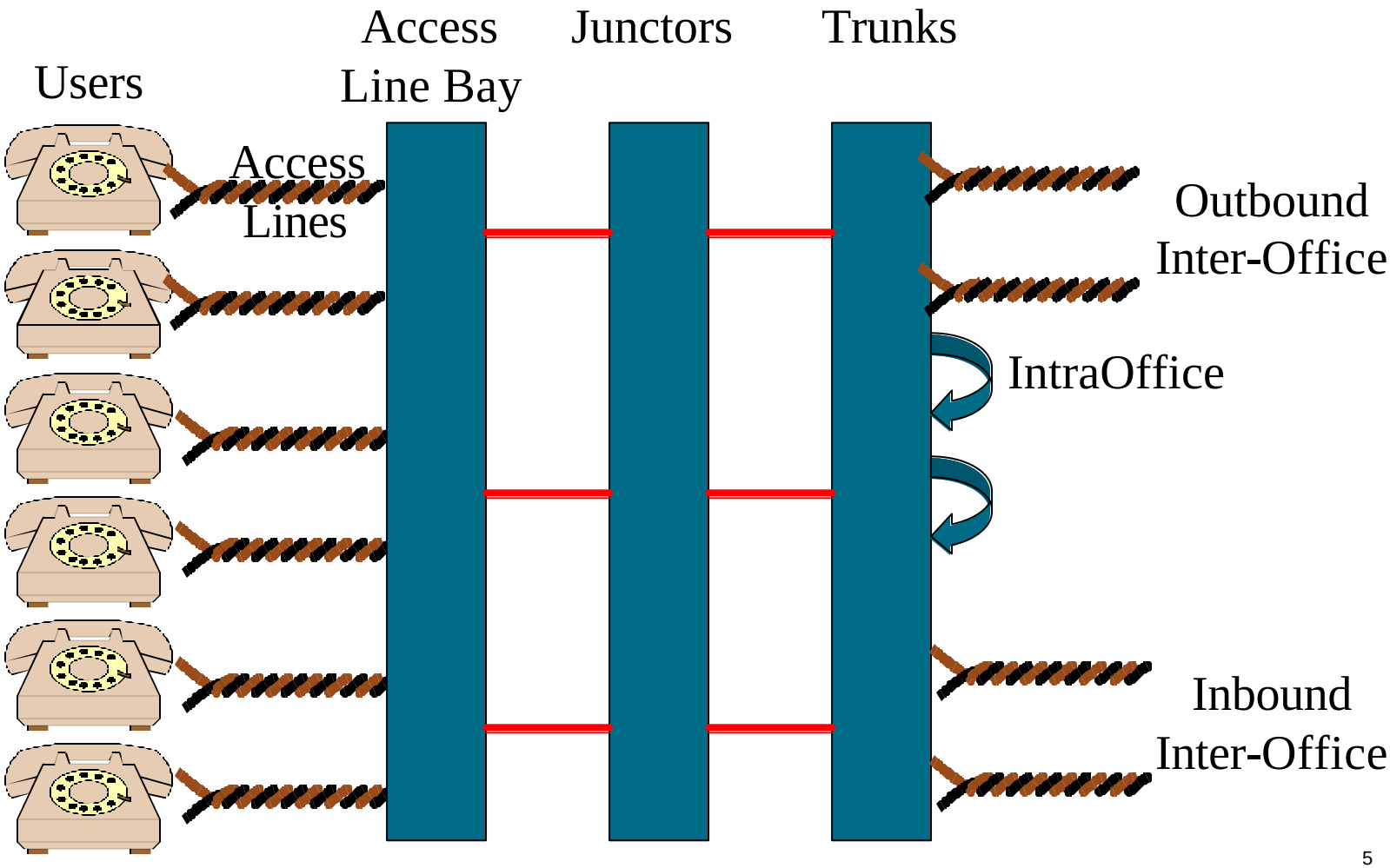


Basic Terminology

- Attempt - **Any action that initiates the process of establishing a connection**
- Call - **Attempt that is processed and makes a bid for service**
- Messages - **Calls that are successfully completed to the receiving user**
- Holding time - **The amount of time an attempt is in the system, regardless of its final disposition**
- Minutes of use - **The length of time that a connection is actually established between users**

Physical Aspect of Load

Line Concentration/Expansion



Traffic Density

? Erlang

All of the attempts and associated holding time in one hour expressed as a percentage of an hour

? CCS

All of the attempts and associated holding time in an hour expressed as hundreds of call seconds

One Erlang = 36 CCS

Erlangs = Average Arrival Rate × Average Holding Time

Traffic Measurement Concepts

- Usage measures are interchangeable (Erlang and CCS)
- Both can be used to express demand density as well as capacity density
- The hourly base is related to a statistically significant time period, not necessarily on hourly boundaries

Significant Measurement Intervals

- **Busy Hour - Busiest hour (not wall-clock hour) during which the system has the highest average business day load per access line**

Typical Switch Measurements

- **Peg count - Calls offered**
- **Usage - Traffic carried in Erlangs or CCS**
- **Overflow - Calls encountering all trunks busy (blocked)**

Call Blocking

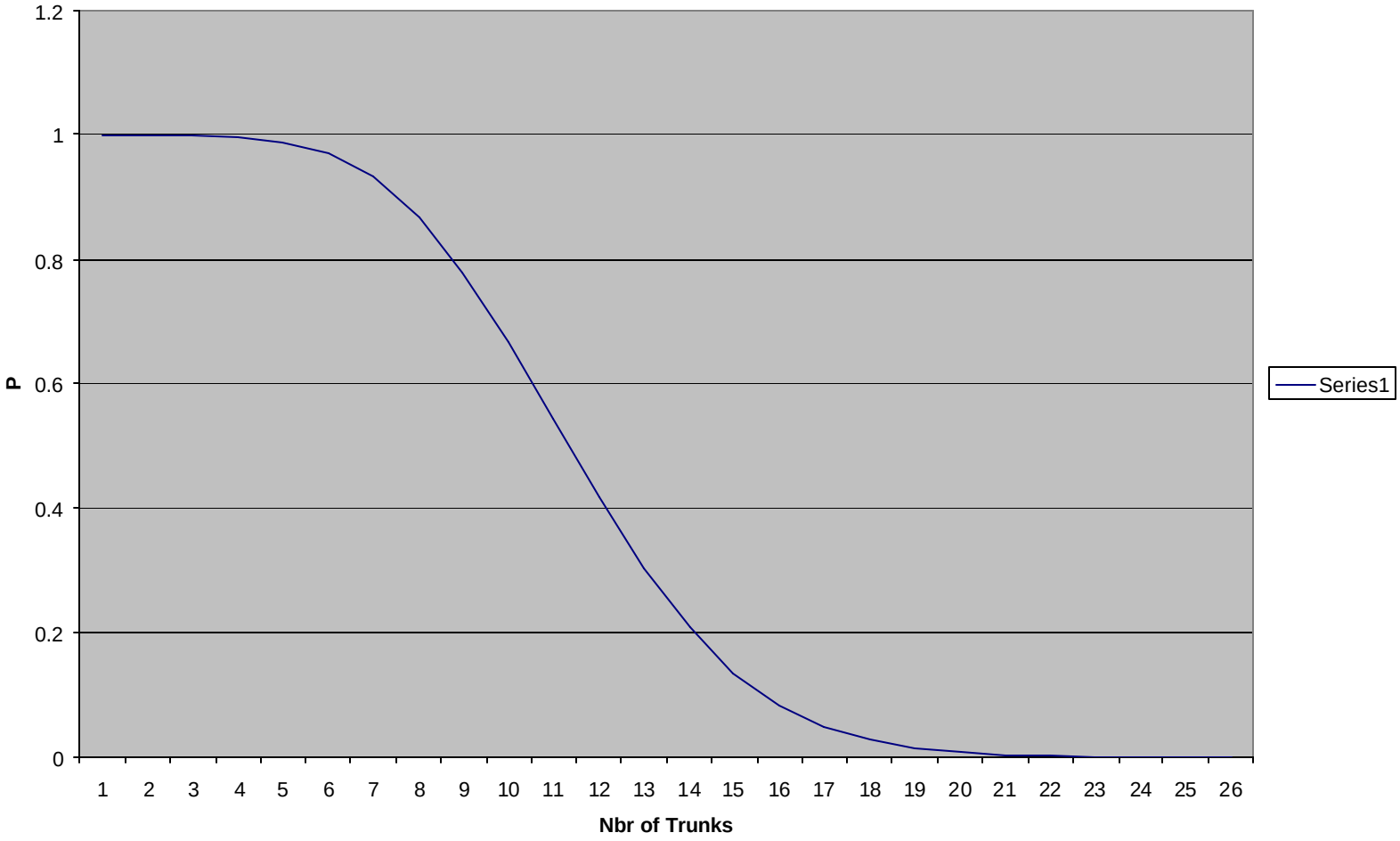
- *Grade of service* **- Probability of a call being blocked (*p*)**
- **Grade of service is effected by:**
  - **Call distribution in time**
  - **Duration of calls**
  - **Number of traffic sources**
  - **Number of paths available to service calls**
  - **Manner in which blockages are treated**

Statistical Assumptions

- In the US, Poisson distributions have been found to be a fairly accurate model of call arrivals
- Designs are done on the basis of Busy Hour
- Assumes calls originate from a large number of independent sources with a limited number of trunks or servicing channels, call attempts are random

Is Poisson Modeling Reasonable?

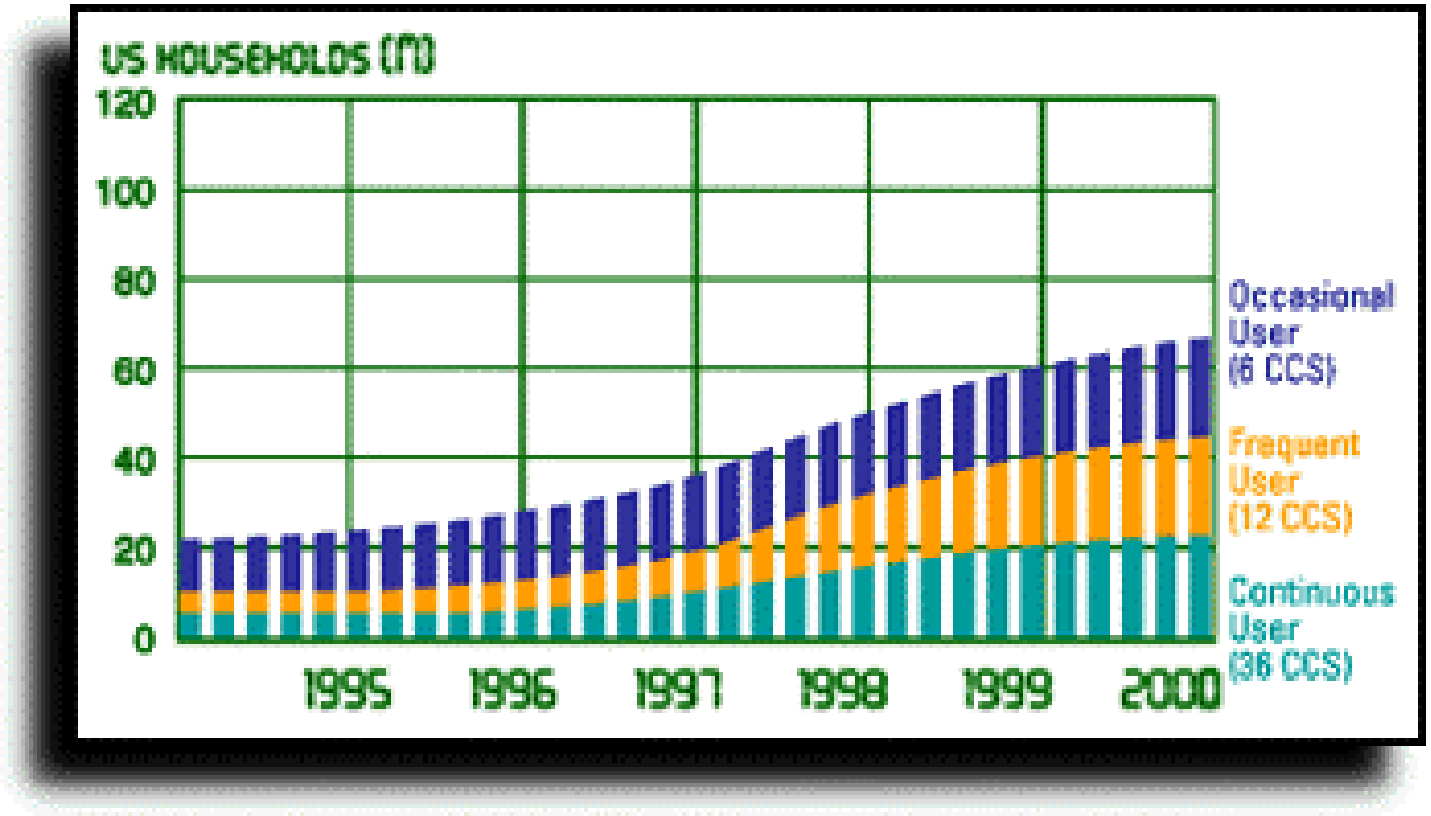
- **Primary advantage is simplicity; based upon mean offered load**
- **In actual practice, has been found to be a reasonable estimate**
- **DOES NOT recognize non-random peaks and variability of load WITHIN an hour**


Probability of Blocking; 10 Erlangs
1.2
1
0.8
0.6
0.4
0.2
0
P
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26
Nbr of Trunks
Series1

Traffic Engineers' Nightmare

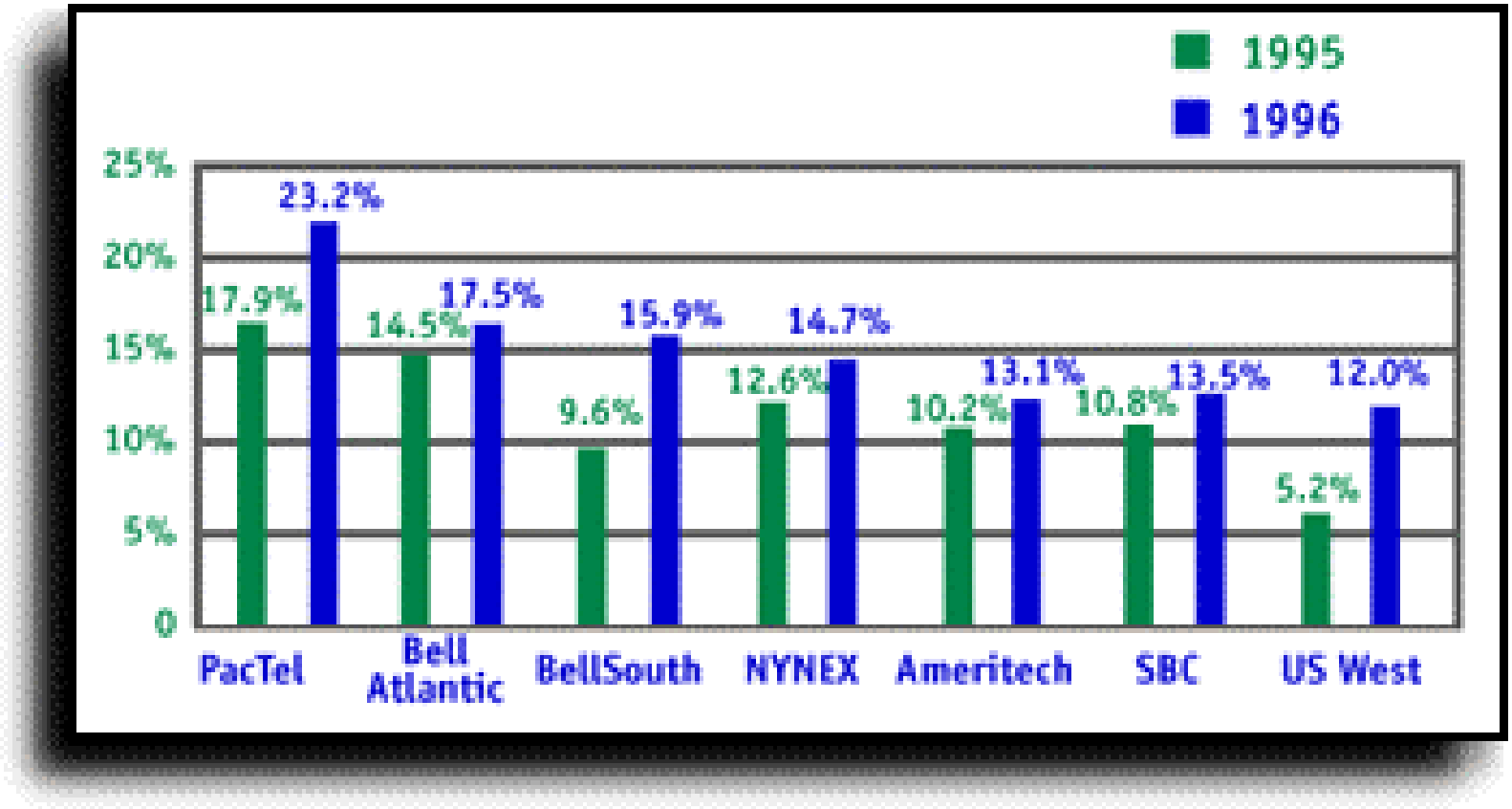
- Standard telco design - 5 minutes per subscriber per hour
- Internet and other data calls exhibit much longer holding times
- Effect on inter-exchange trunking is especially acute!

Residential Usage



Courtesy: Nortel

Residential Internet Usage

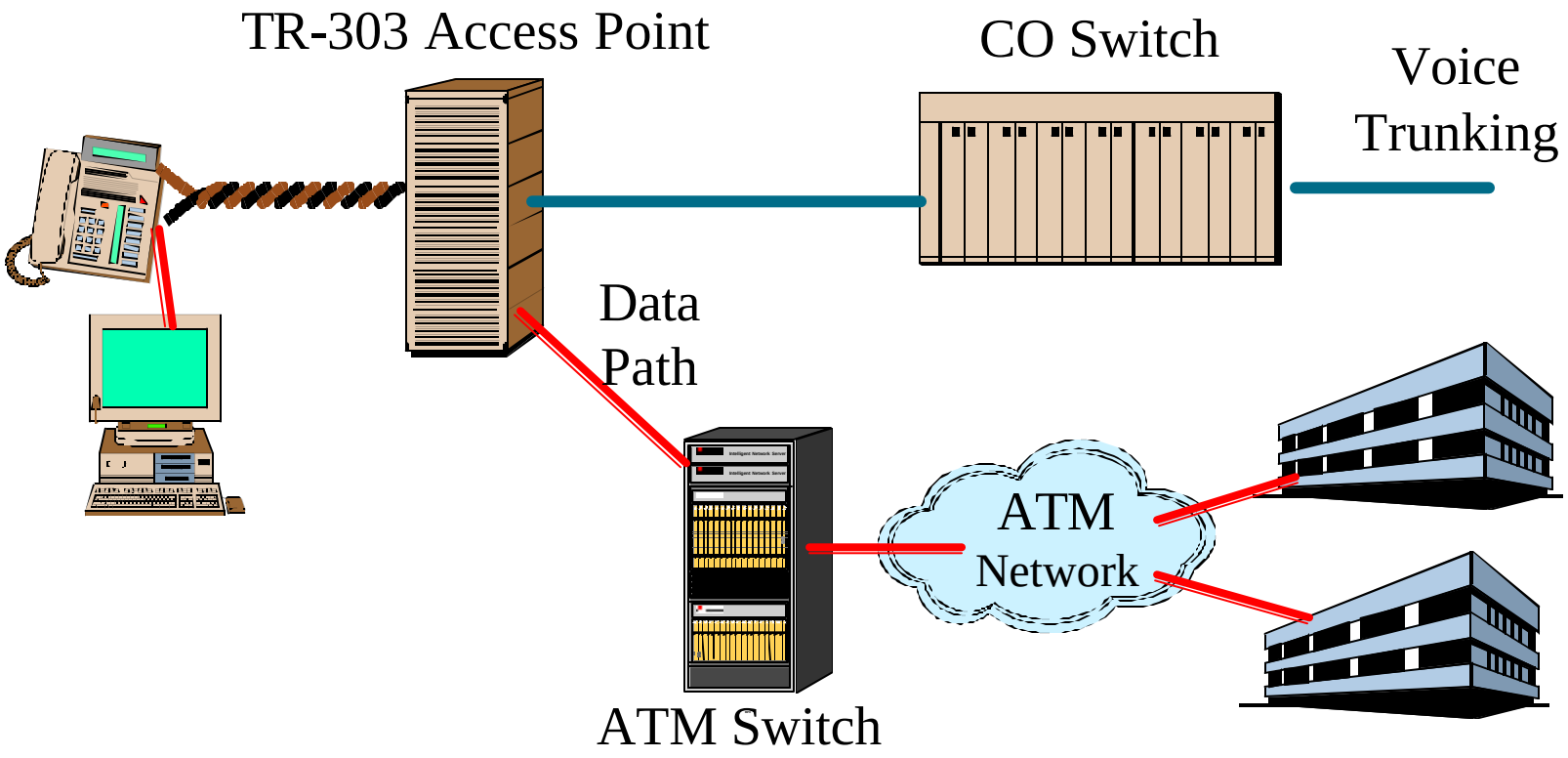


Courtesy: Nortel

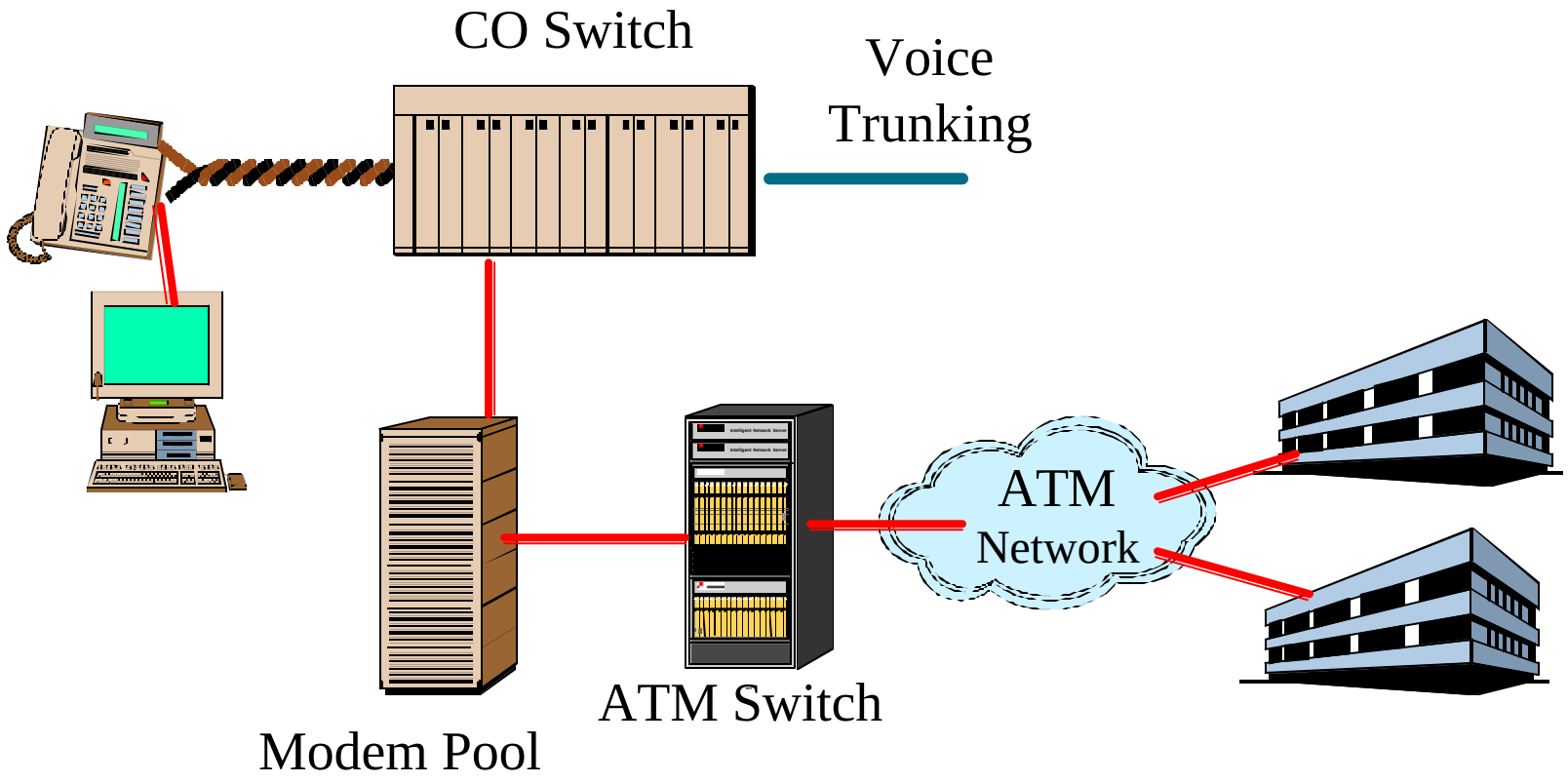
Solutions to Blockages

- Groom data calls before they get to the switch
- Groom data calls in the switch before they tie-up trunks
- Move Internet users to an alternate access technology

Grooming Calls at the Access Point



Grooming in the CO Switch



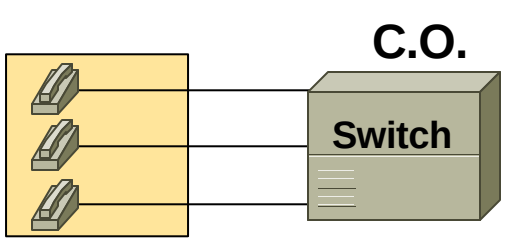
Alternate Access Technologies

- Cable modems
- Data-over-voice
- ISDN Digital Subscriber Loop (IDSL)
- *x*DSL (ADSL, HDSL, SDSL, XDSL …)

Traffic Engineering - PBX Trunking Example

Overview/Review of PBX

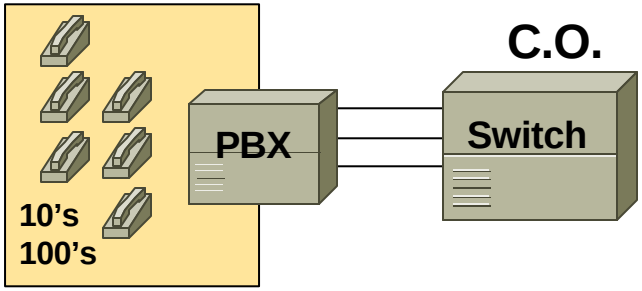
Traditional Telephone Service



# of Telephones
=
# of Lines

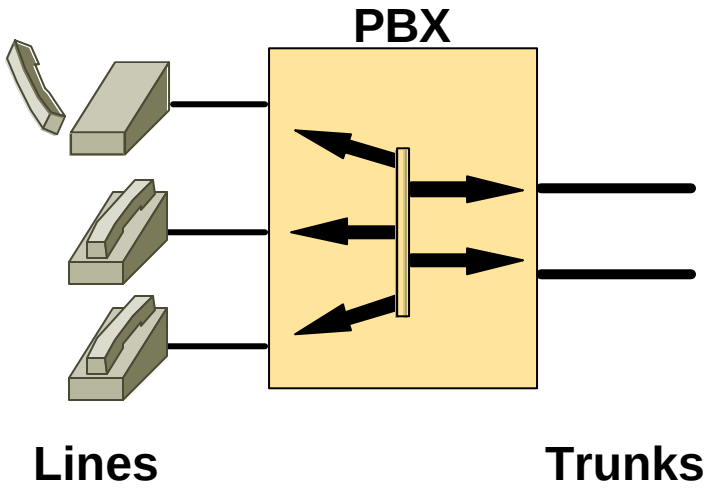
Growth
Cost
Features
Control

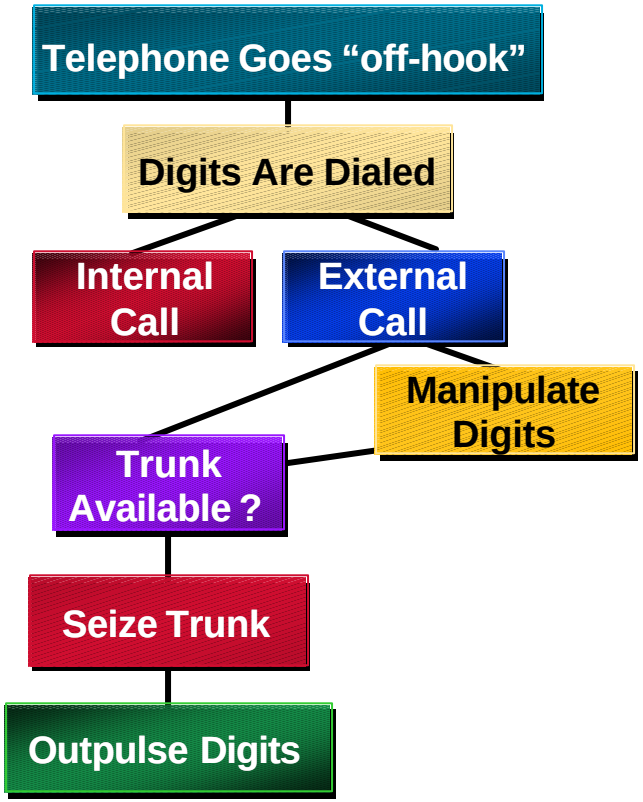
PBX Voice Service



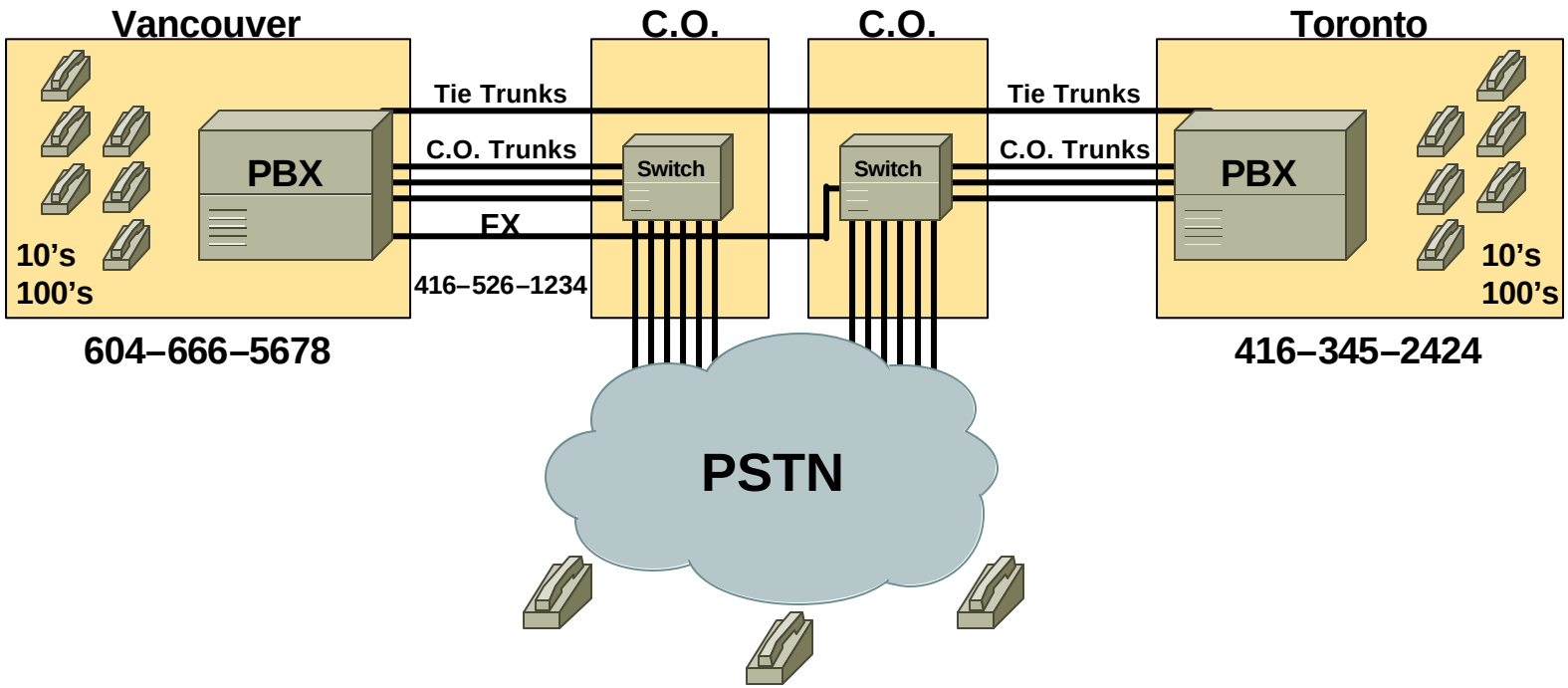
# of Telephones
>
# of Lines (trunks)

PBX Overview/Review



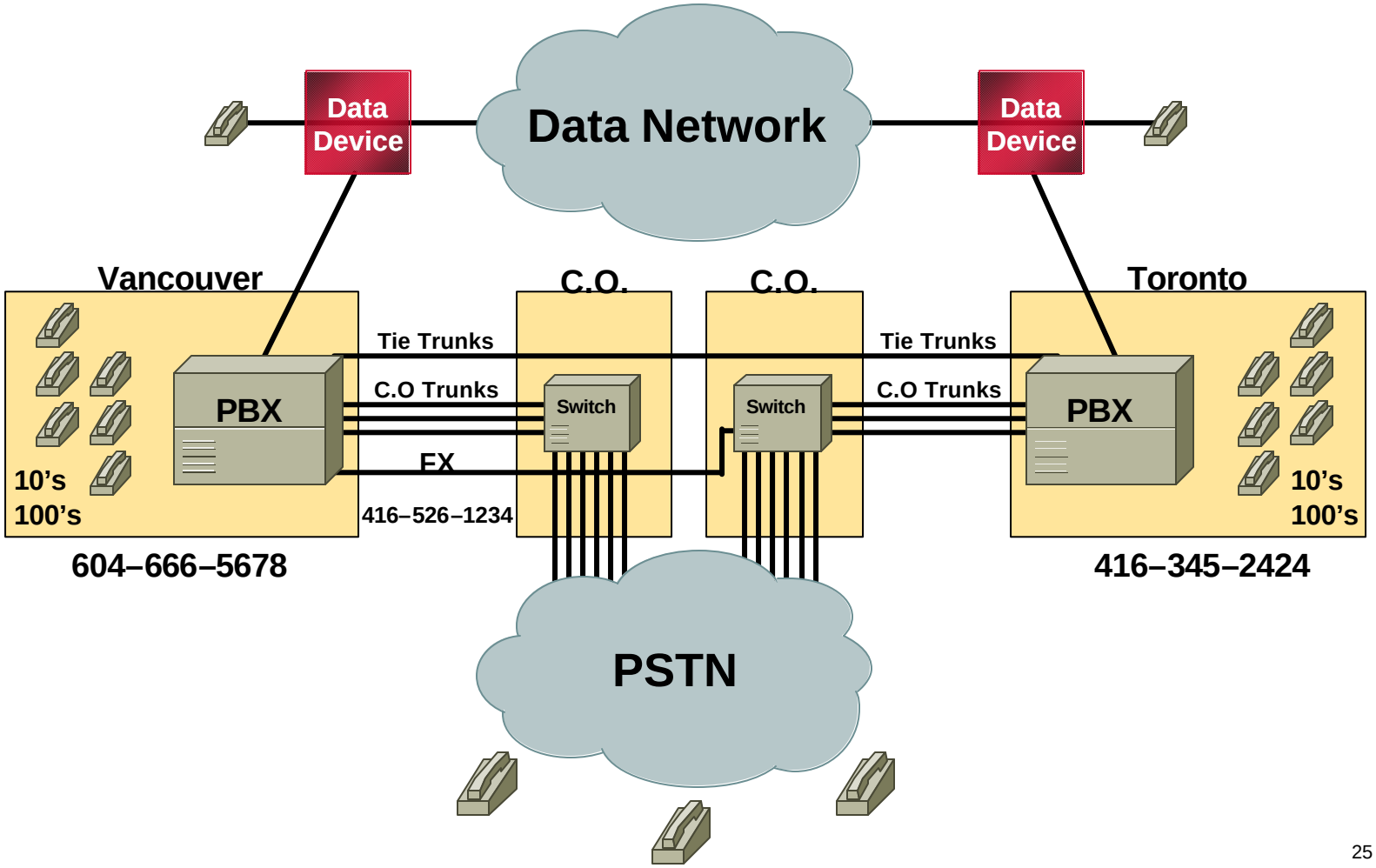


PBX Networking



? **Examples of services for long distance calls**

The New Voice Networking



Basic Voice Traffic Engineering: A Four-Step Process

- **Step 1: Obtain traffic data**
- **Step 2: Profile traffic**

  Determine the busy hour
- **Step 3: Determine number of physical trunks required too meet traffic**
- **Step 4: Determine the least-cost combination of trunks**

  Iterative comparison

Step 1: Obtain Traffic Data

- **Conceptually simple; difficult in practice**
- **Sources of traffic information**
  - **Carrier bills**
    - **Shows only chargeable calls**
  - **Carrier design studies or traffic reports**
  - **Traffic reports from PBX**
    - **CDR (Call Detail Report)**
    - **Reports specific to manufacturer**
  - **Third party software and hardware available for analysis**

Sample CDR Report

tran_date	duration	ckt	dialing_no	dialed_no	charge	extension	facility_nar	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	Sumı	ary					
–	--------	-----	----------					
Total Calls:	595							
Total Minutes:	2382.3							
Total Cost:	900.17							

Step 2: Profiling the Traffic—Group into Categories

- Inbound vs. outbound
- Call distance
  - Local calls
  - Intrastate long distance
  - Interstate long distance
  - International
- Type of call

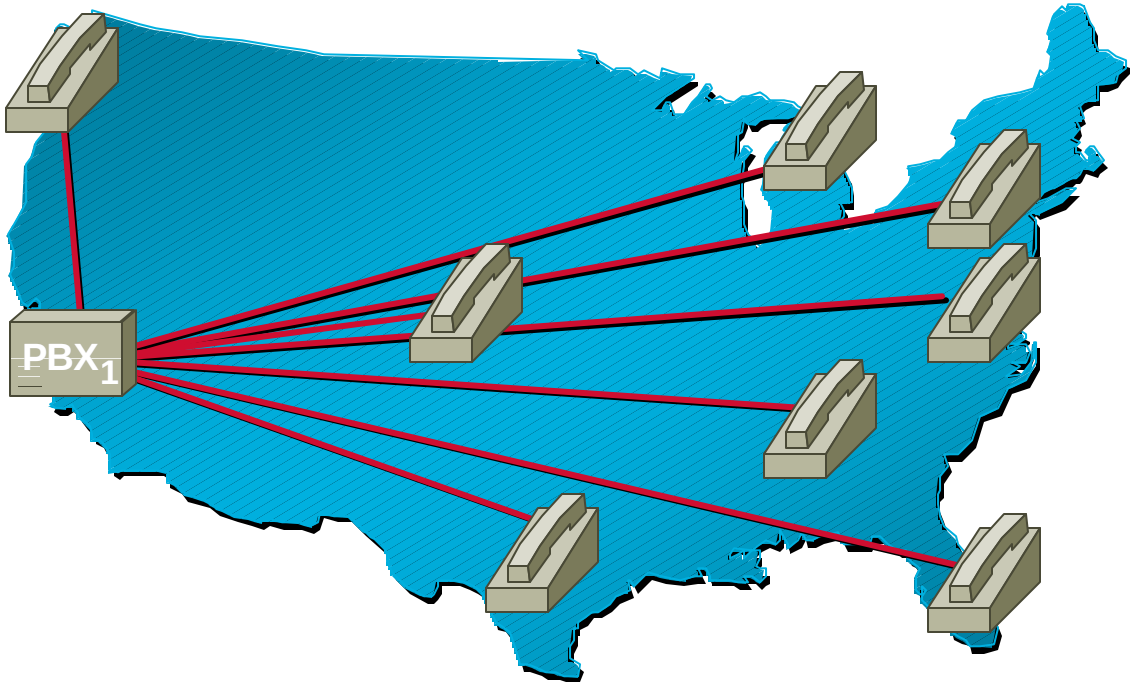
Defining the Traffic

$$A = C \times T$$

A, the Traffic Flow Is the Product of:

C the Number of Calls Originated During a Period of 1 Hour and T, the Average Holding Time of the Call

For Example



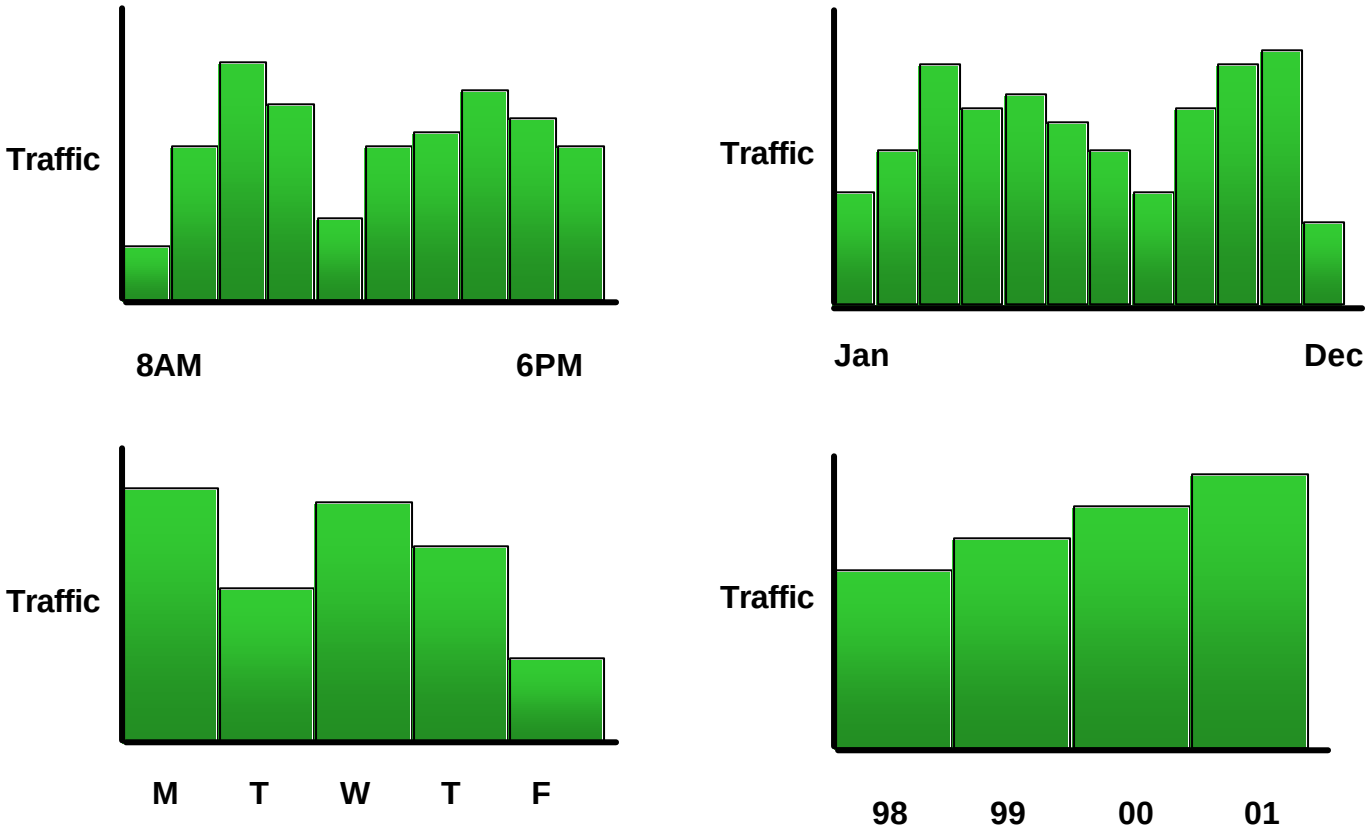
200 Calls of an Average Duration of Two Minutes Are Generated During a Period of One Hour. The Traffic Flow Is Equal to 400 Call-Minutes per Hour

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 or the continuous use of a circuit for one hour
- Another common measurement is CCS (Centum Call Seconds)

  1 erlang = 36 CCS

Traffic Variation



Traffic Varies by Hour, Day, Month and Year

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**

Adjusting the Holding Time

- **Holding time = total time trunk in use**
  - **Dialing + Call Setup + Ringing + Conversation + Release**
- **Factors affecting holding time**
  - **Call processing may or may not be included**
  - **Telephone bills only have conversation time**
  - **Call timing data “in” varies by PBX manufacturer**
  - **Other sources of trunk use: Ring-no-answer, busy signal, etc.**

Adjusting the Holding Time (Cont.)

- **If additional holding time is not included, the result is too few trunks**
  - **Add 10% to 16% to length of all calls**
- **Call billing**
  - **If billing is in 6 second increments**
    - **No adjustment is required**
  - **1-minute increments, on average, is 30 seconds too long**
    - **Using this information for trunking will result in too many trunks**
    - **Subtract 30 seconds from each call**

Example

A Bill Shows 404 Calls Totaled 1834 Minutes.
Billing Is in 1 Minute Increments.
What Is the Adjusted Traffic?

404 x (0.5) = 202

1834 - 202 = 1632 “Real Traffic”

Traffic Probability

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

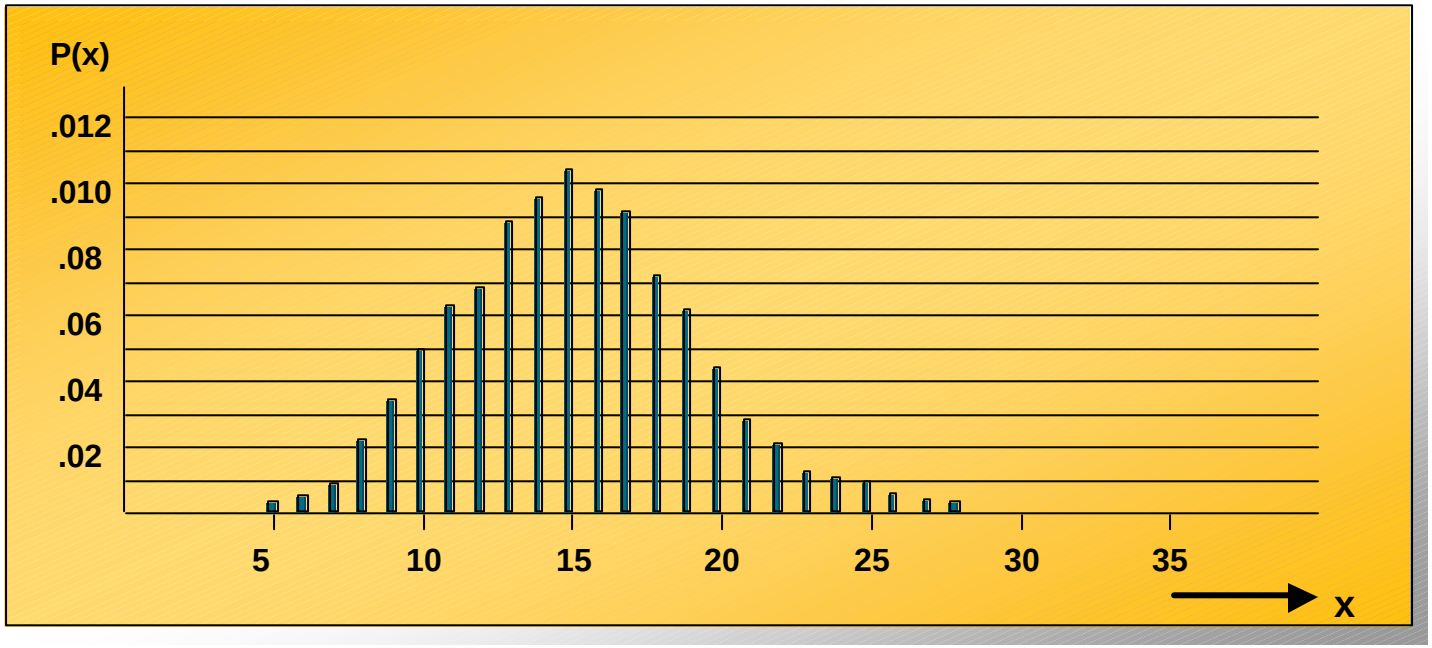
Number of Originating Sources

- Infinite—Probability of call arrival is constant and does not depend upon the state of occupancy
- Finite—The number of sources is relatively small and the arrival rate is proportional to the number of sources not already engaged in a call

Poisson Distribution with 10 Trunks and a P of .01

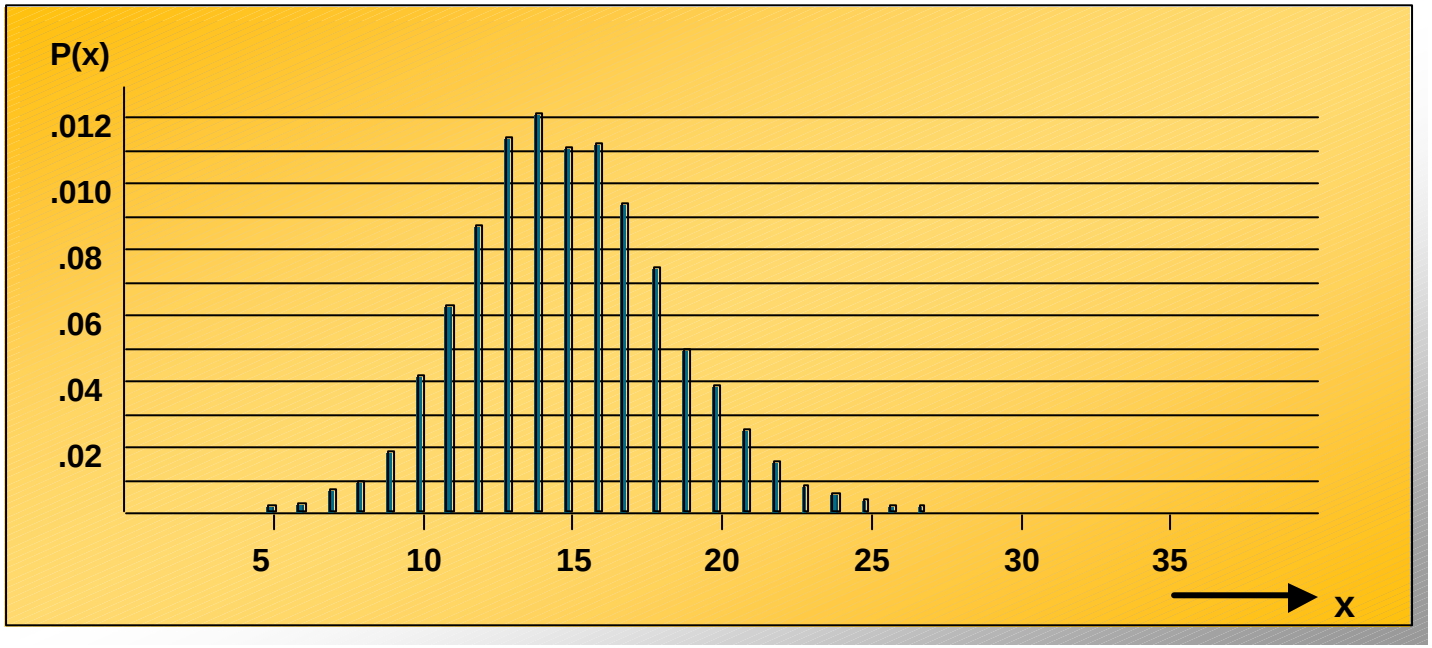
Number of Sources	Traffic Capacity (erlangs)
Infinite	4.13
100	4.26
75	4.35
50	4.51
25	4.84
20	5.08
15	5.64
13	6.03
11	6.95
10	10

Random Traffic



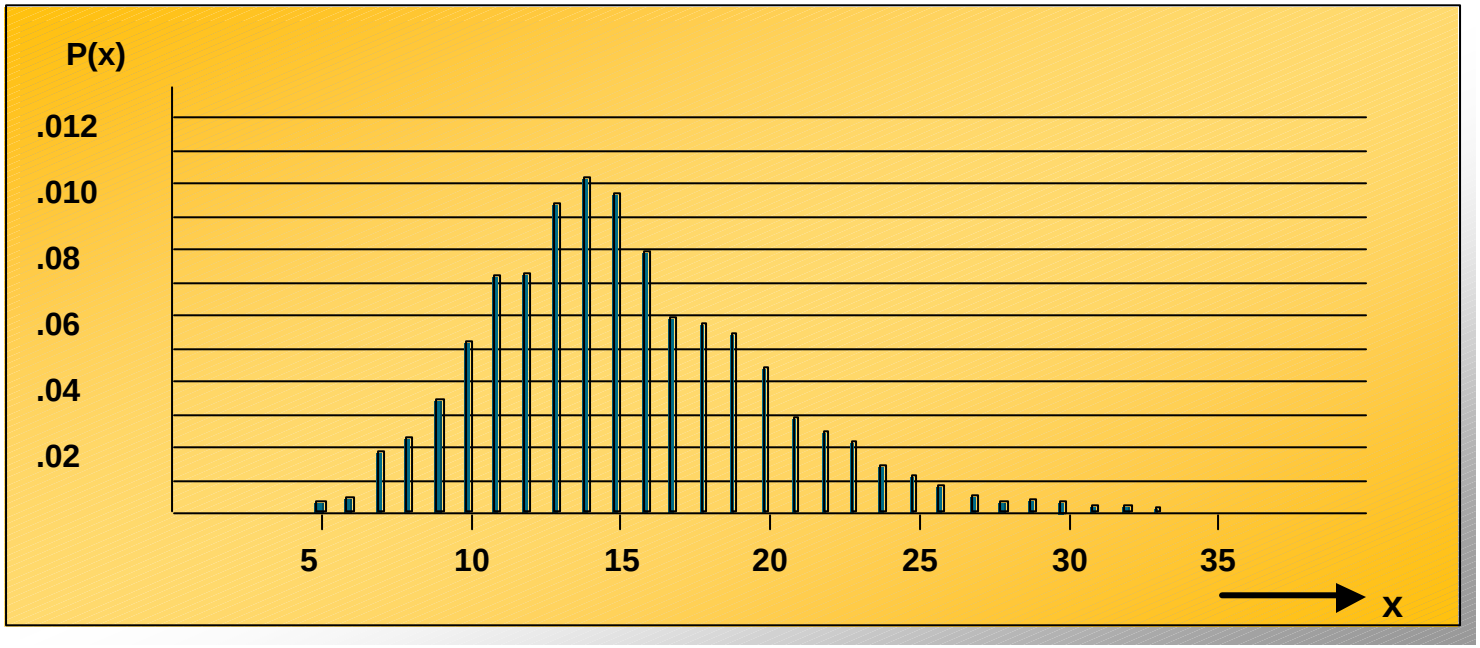
Mean, u = 15.02
Variance = 15.67
VMR = 1.04

Smooth Traffic



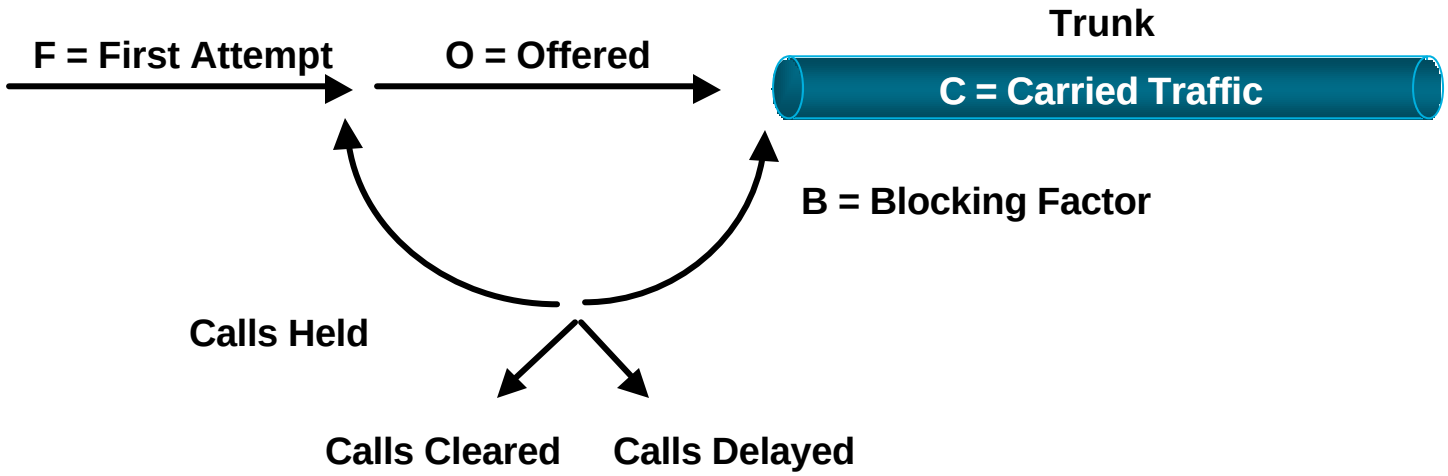
Mean, u = 14.97
Variance = 10.82
VMR = .72

Rough or Peaked Traffic



Mean, u = 15.21
Variance = 20.82
VMR = 1.37

Handling Lost Calls

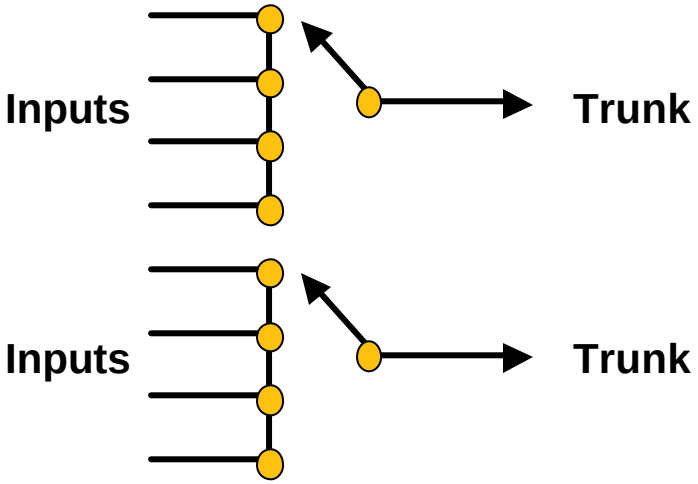


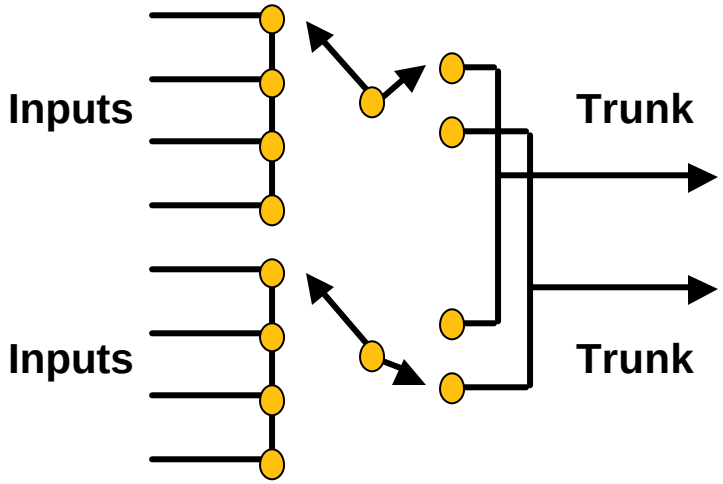
Lost Calls Cleared (LCC)—Give up on a Busy Signal

Lost Calls Held (LCH)—Redial on a Busy Signal

Lost Calls Delayed (LCD)—Sent Somewhere Else When Busy

Switch Trunk Availability





Limited Availability

Full Availability

Step 3: Trunk Group Provisioning

? **Theory of large trunk groups:**

The larger the trunk group, the more efficient they are

The benefit of adding another trunk gets smaller as the trunk group gets larger

Trunks	Erlangs	Avg/Trunk	Traffic Increase	Traffic Increase
2	0.15	0.08		
4	0.87	0.22	480%	480%
8	3.15	0.39	2000%	262%

Defining Grade of Service

- **Grade of Service**
  - **% of calls blocked, % of calls delayed**
  - **Average delay of all calls**
  - **Average delay of delayed calls**
- **Grade of Service is based on the busiest hour**
  - **BH is when the most traffic is offered**
  - **BH varies between days, weeks, and months**

Determining Grade of Service

- GoS dependent on strategic objectives
- Acceptable grade of service unique to each organization
- Too poor can be more expensive than too good

Traffic Tables

- **Eliminates the use of equations**
  - **Input: Given a volume of traffic and a GoS**
  - **Output: Number of trunks required**
- **Pick the model that best fits your application**
  - **Number of sources: Finite and infinite**
  - **Traffic characteristics: Random, smooth or rough**
  - **How blocked calls are handled**
  - **Switch availability**

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

- Used throughout the world as the standard

Poisson

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

  Outbound trunks with no overflow and queue, trunk group of last resort

- Overstates trunk requirements

  Not heavily used outside of the U.S.

Extended Erlang B

- % of lost calls return
- Infinite sources
- Constant or exponential holding time
- Random traffic
- Application
  - Inbound trunks, e.g. 1–800
  - Outbound trunks with no overflow and queue
- Most Accurate, but hard to identify returned calls

Erlang C

- Lost calls delayed
- Infinite sources
- Exponential holding time
- Random traffic
- Calls served in arrival order
- Application

  ACD agents, trunks with queuing but no overflow

Engset

- Lost calls cleared
- Finite sources
- Constant or exponential holding time
- Equal traffic distribution (smooth)
- Application

  Small PBX or Key System with tie lines to a central PBX and using overflow to the PSTN