Quality of Service

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What is QoS

- Quality of Service
  - *» the ability of a network to provide better service to selected network traffic over various technologies including Ethernet, Wireless networks, IP-routed networks, ATM, and FR that may use any or all of these underlying technologies*
  - *» method to provide preferential treatment to some arbitrary amount of network traffic, as opposed to all traffic being treated as "best effort".*

Factors affecting QoS

- Delay – end-to-end
- Jitter (Delay Variation) – causes signal to be distorted
- Packet Loss and Out of Order Packets
- Bandwidth Available

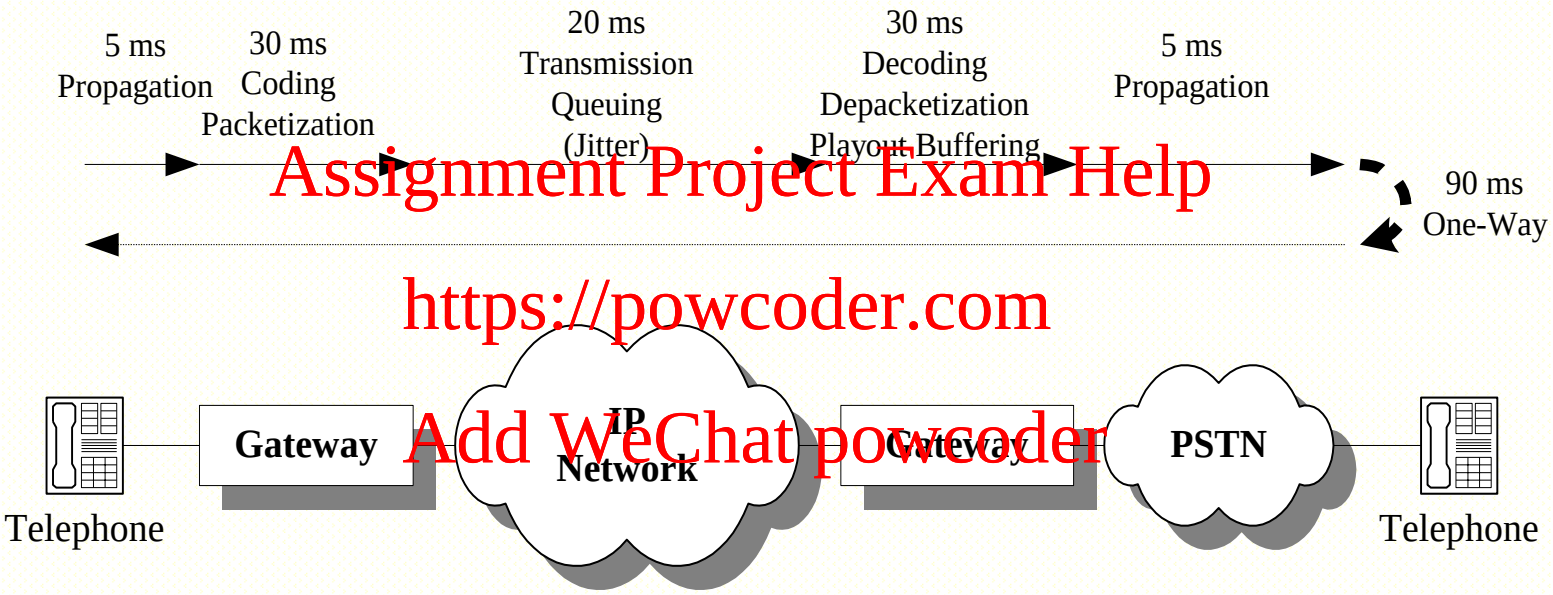
Factors affecting QoS

Delay

- Accumulation (speech samples to frame and frames to form packets)
- Processing (gateways and routers time to process the packets)
- Queuing (packets wait for their turn)
- Emission (minimal for small packets and/or high bandwidth links
- Propagation

Factors affecting QoS

Delay (cont.)



Delay results in echo and talker overlap

» *echo if round trip delay > 50ms*

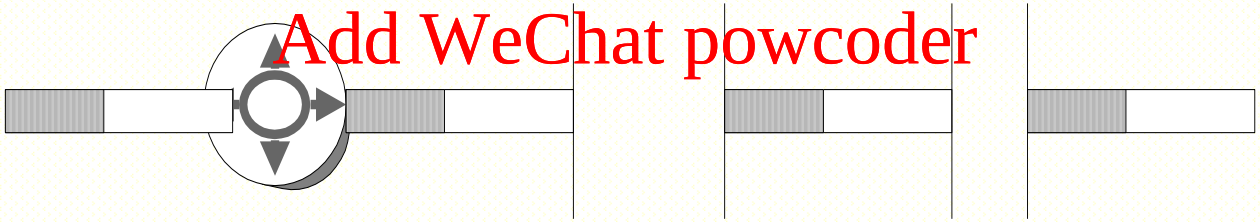
– echo cancellers (ITU recommendation G.168)

»*Talker overlap if one way delay > 250ms*

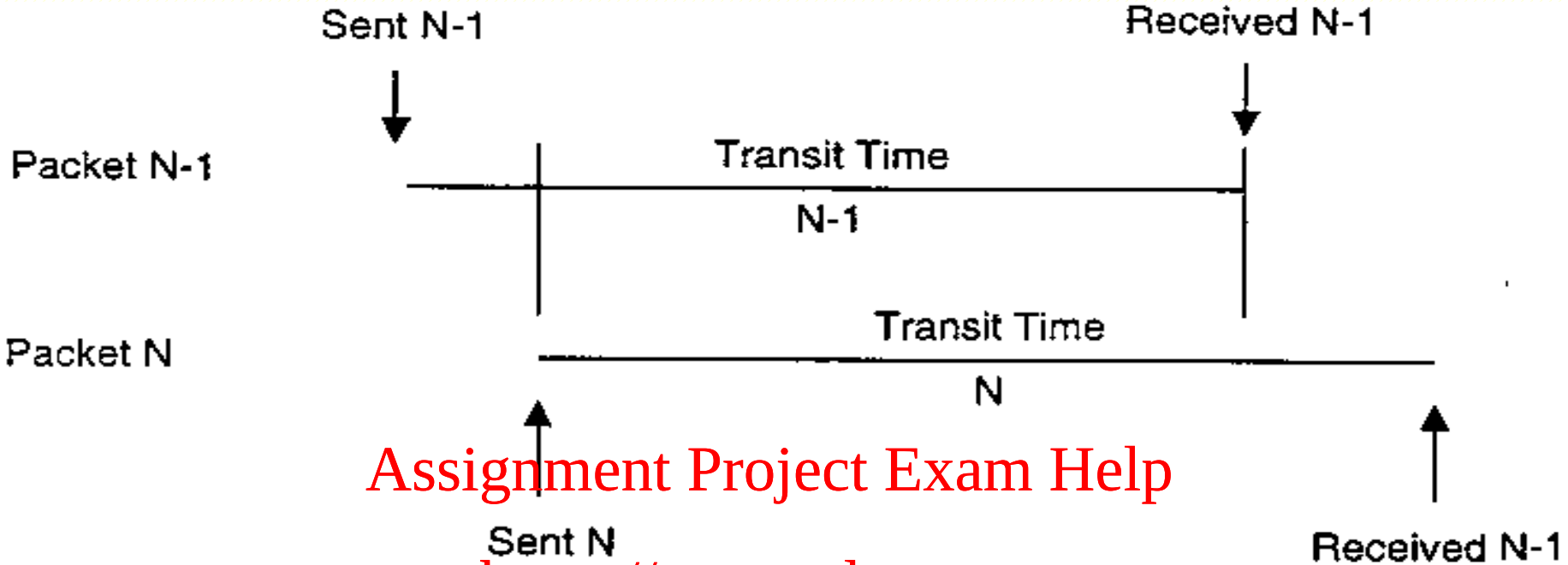
Factors affecting QoS

Network Problems

- Voice packets are continuous
  - no gap between packets
- Due to variations in inter-packet arrival time, gaps known as ***jitter*** occur between packets



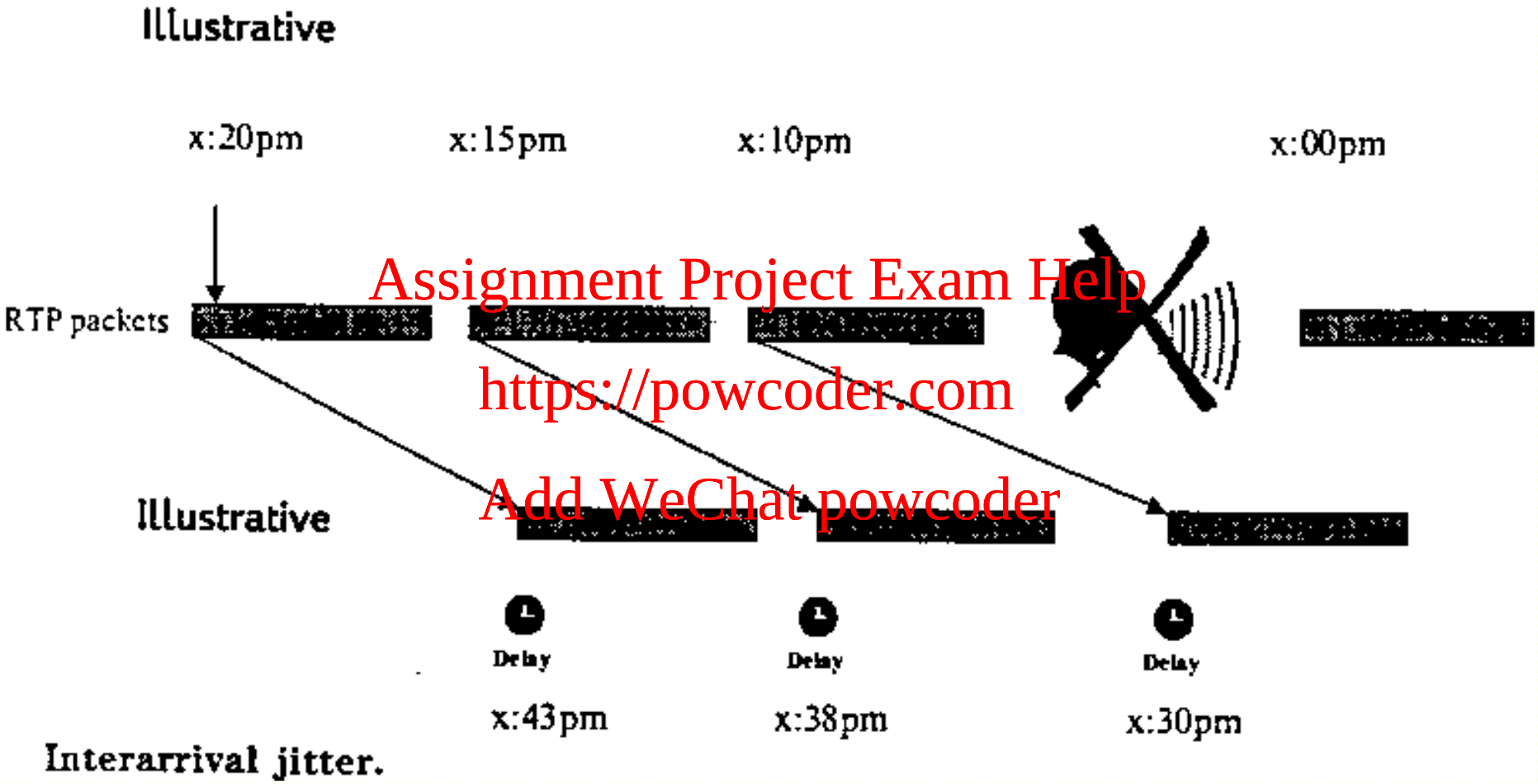
  - must be removed by receiving gateway by collecting packets in buffers



Calculating Interarrival Jitter in RTP

$$\text{Delay}_{(n-1)} = \text{Received}_{(n-1)} - \text{Sent}_{(n-1)},$$

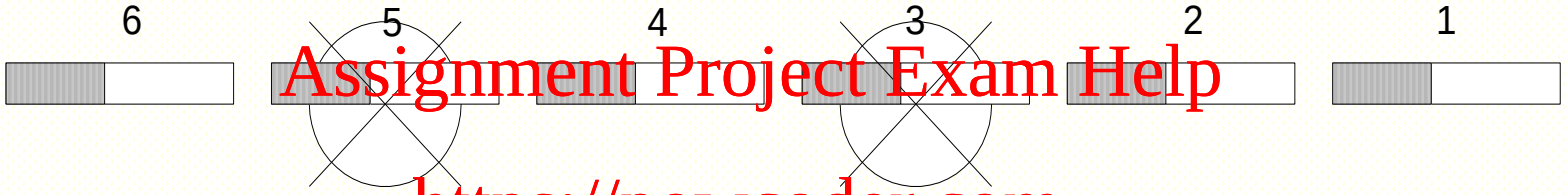
$$D_{(n-1,\,n)} = [\text{Received}_{(n)} - \text{Received}_{(n-1)}] - [\text{Sent}_{(n)} - \text{Sent}_{(n-1)}]$$



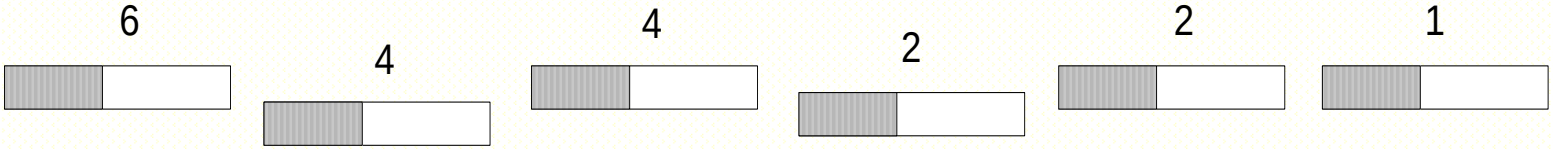
Factors affecting QoS

Network Problems (cont.)

Packet Loss: Congestion may drop some packets



- Missing packets are detected
- the last received packet re-played at a decreased volume

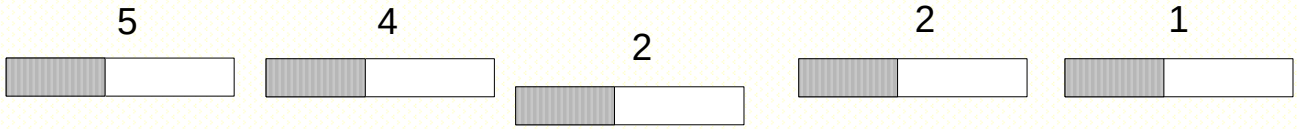


Factors affecting QoS

Network Problems (cont.)

Out of Order Packets: due to different routes

- Missing packet replaced by its last received packet as if it is lost



Factors affecting QoS

Bandwidth

Maximal data transfer rate that can be sustained between two endpoints – dictated by

- physical infrastructure of traffic path
- number of other flows which share this path

Voice Quality

- fidelity of the reproduced speech
- intelligibility (ability to extract the information)

Factors influencing delivery of high voice quality

- **clarity**
- **packet loss**

- **speech codecs**
- **silence suppression**
- **comfort noise generation**
- **end-to-end delay**
- **echo**

Factors influencing delivery of high voice quality

1. Clarity

- telephone devices through the quality of loudspeaker and microphone
  - echo generated between speaker and microphone
- Gateways that attach to PSTN
  - type of transcoding, speech codecs
  - possible silence suppression
  - comfort noise generator
- IP network
  - excessive jitter and packet loss
- Generic Media Gateways
  - speech codecs
  - voice activity detection mechanism

Factors influencing delivery of high voice quality

2. Packet Loss

- routers discard packets when experiencing congestion
- late arriving packets equivalent to lost packet
- information must arrive in certain time window
- retransmissions add an extensive delay

- Flow control and traffic prioritization algorithms necessary to avoid packet loss
- Modern routers must be designed to implement such schemes

  - RSVP
  - MPLS
  - traffic classification with Differentiated Services

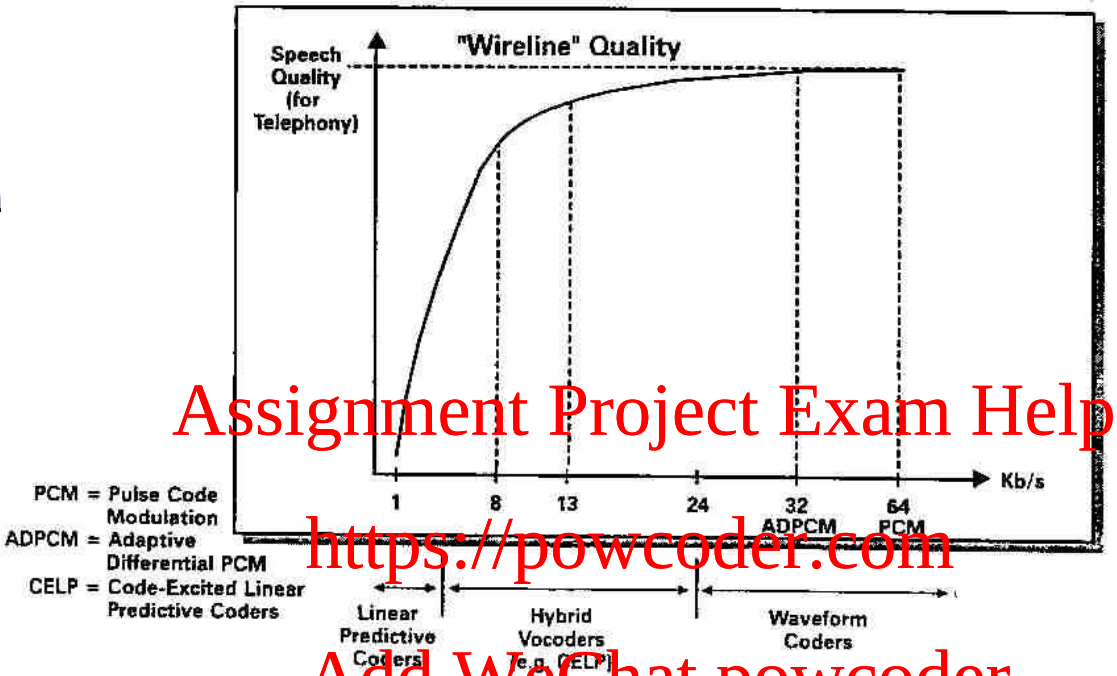
- PSTN does not suffer from this – bandwidth reserved for duration of the call

Factors influencing delivery of high voice quality

3. Speech Codecs

- transforms between analog voice and digital bit-streams
- may use compression techniques (removing redundant information)
  - compromise between
    - voice quality
    - computation power
    - delay
    - network bandwidth
- lost or severely damaged information has a more noticeable effect on lower bit-rate speech codecs than with G.711

DIGITAL SPEECH CODERS
THREE BROAD CATEGORIES



G.723.1 (5.3kbps, 6.3kbps)
G729 (8kbps)
G.726 (16kbps, 24kbps, 32kbps, 40kbps)
G.728 (16kbps)
G729A (7.9kbps) simplified version of G.729
G711 (64kbps)

Factors influencing delivery of high voice quality

4. Silence Suppression

(Voice Activity detection)

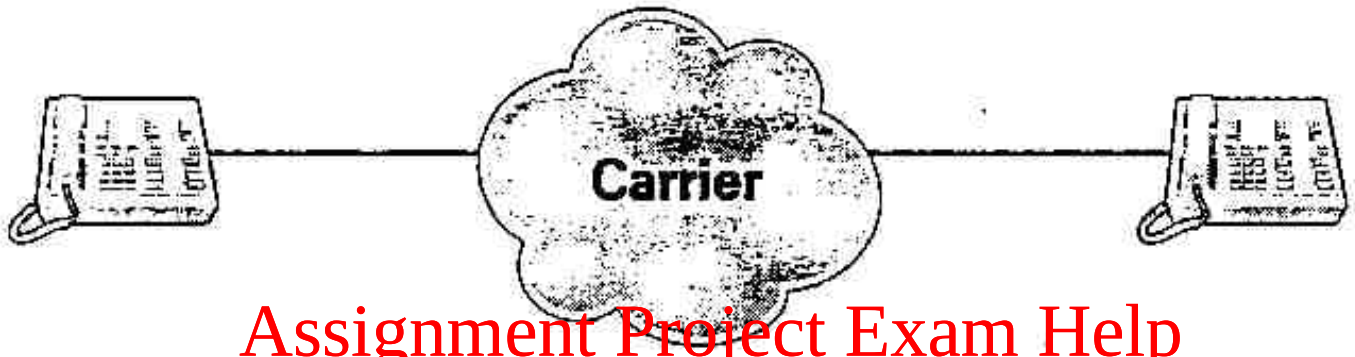
- no packets send when caller silent
- VAD can realize reduction in bandwidth requirement

5. Comfort Noise Generation

(complimentary of VAD)

- muting the channel gives impression that channel has gone dead
  - dead-air syndrome
- low-level noise signal generated at receiver

SILENCE DETECTION MODE
G.729B



- Studies show that speech conversations in English are silent in one direction over 60% of the time
- When one person speaks the other listens, providing 50% savings
- Pauses in between words and sentences add another 10%
- Gains from silence suppression may not be as great for other languages

Factors influencing delivery of high voice quality

6. End-to-End Delay

Packet delay primarily determined by the following

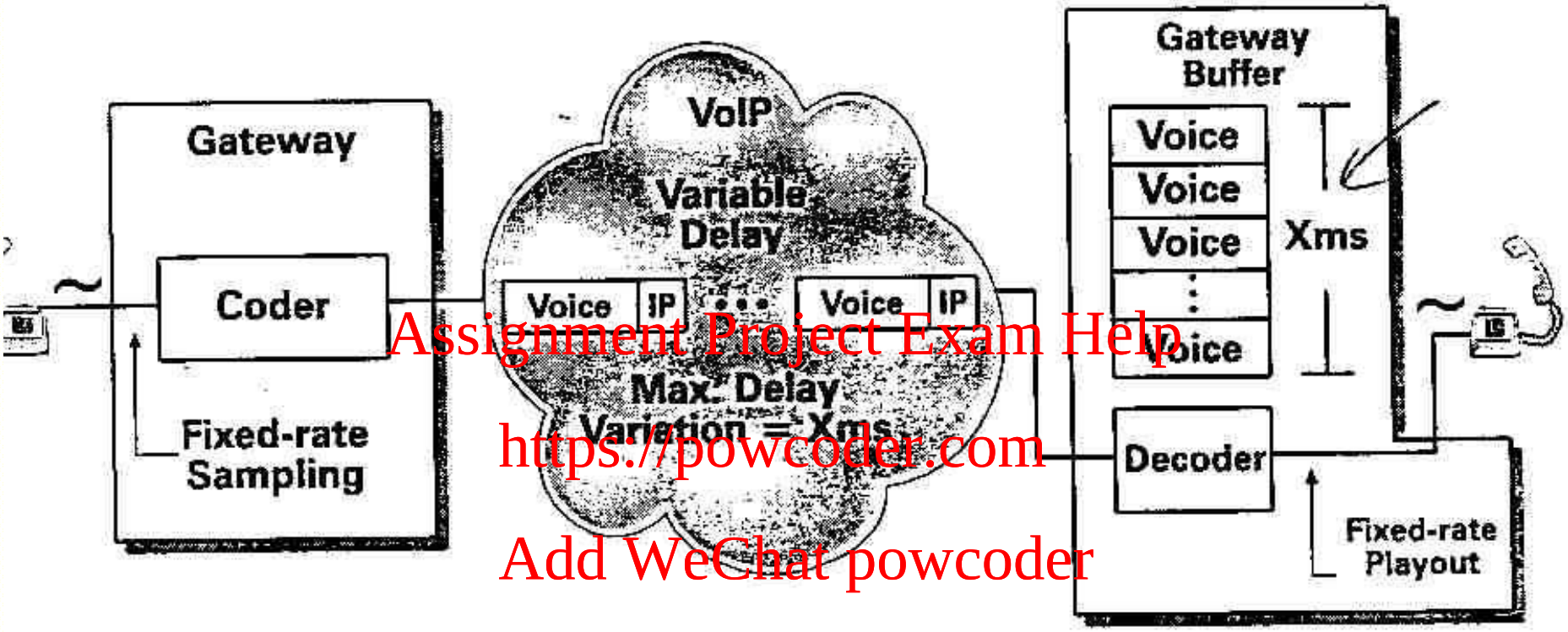
- Packet capture delay
- Switching or routing delay
- Queuing time

Gateways and Terminals

- Voice Signal processing at sending and receiving sides
- Delay due to packet variation at receiver side
- Packetization delay at the transmit side

7. Echo

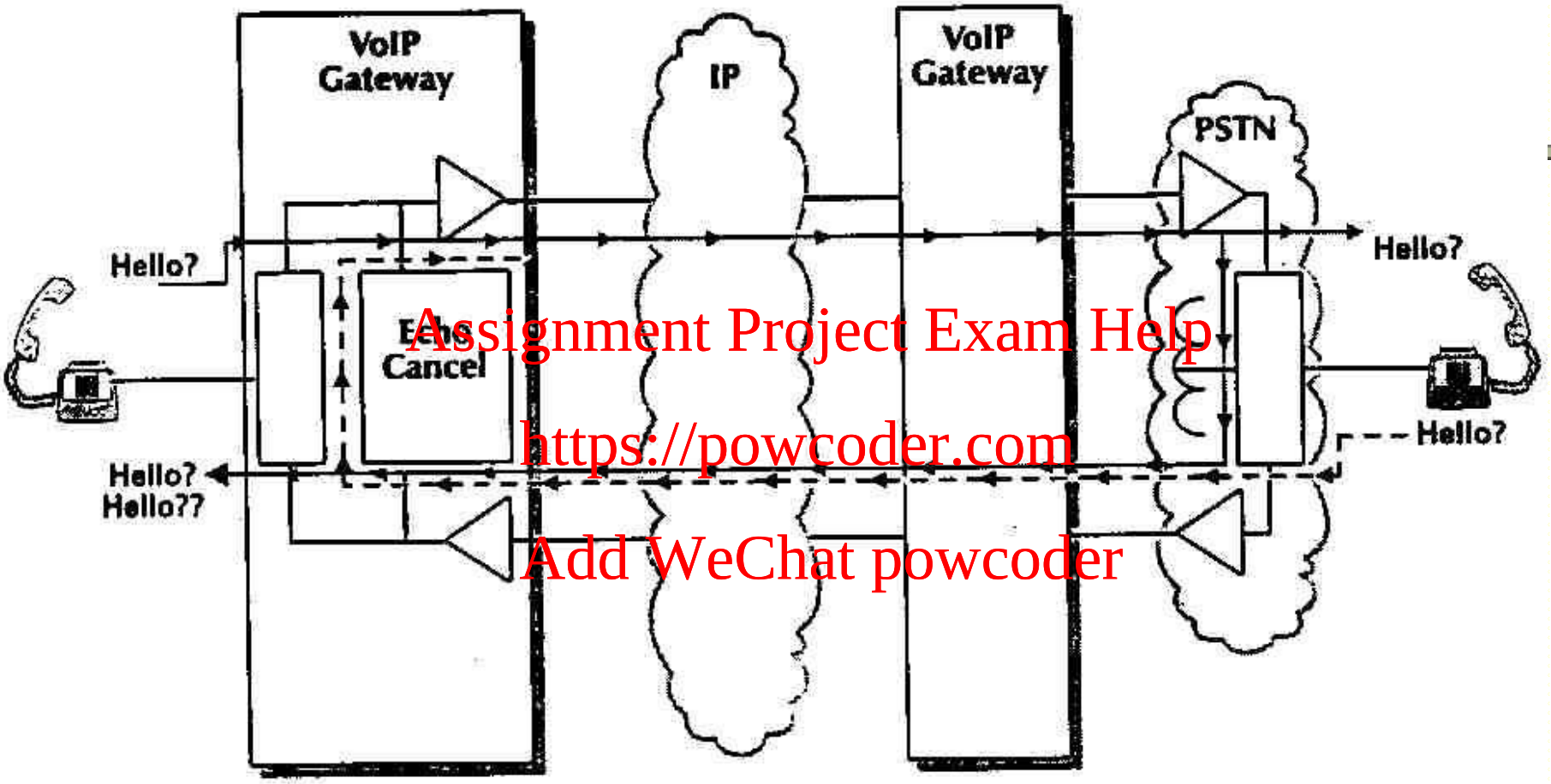
DEALING WITH DELAY VARIATION



Delay Variation

- Caused when voice packets suffer different transit delays, causing variation in arrival times at the receiver
- Minimized by buffering voice at the receiver for a period longer than expected delay variation

ECHO CANCELLERS CAN SOLVE THE ECHO PROBLEM



Service Levels

- refers to the actual QoS capabilities of a specific network application from end-to-end, with some level of control over bandwidth, jitter, delay, and loss, provided by the network

Different Service Levels

» *Best-Effort Service*

» *Differentiated Services*

» *Guaranteed Services*

Different Service Levels

- Best-Effort: lack of QoS
  - » *no priorities or guarantees*
  - » *basic queuing with FIFO packet delivery*
  - » *e-mails and general file transfers*
- Differentiated Service: qualitative QoS / Soft QoS
  - » *treats some traffic better than the rest*
    - – faster handling, more bandwidth on average, lower loss rate on average
    - – no hard and fast guarantee
  - » *course level of packet classification*
    - – each class receiving a particular QoS
  - » *lower delay for mission-critical interactive applications, packet voice applications*

Different Service Levels

- Guaranteed Service: quantitative QoS / Hard QoS

  » *absolute reservation of network resources, typically bandwidth*

  – implies reservation of buffer space
  – appropriate queuing disciplines

  » *for applications requiring a fixed delay and for delay-sensitive traffic, such as voice and video*

QoS mechanisms

Divided into basic groups that align with OSI model

- Physical Layer
  - » *can provide for alternate physical path for redundancy*
    - – can provide differentiated services if paths have different characteristics (best-effort on lower, QoS traffic on higher speed)
- Data Link Layer
  - » *MAC to provide service differentiation*
  - » *ATM*
    - – CBR and VBR best suited for telephony and voice applications, and multimedia applications such as video
    - – ABR and UBR for best-effort delay-insensitive traffic such as file transfers and e-mail
    - – inherent complexity of ATM and its QoS mechanisms
    - – provides only part of the end-to-end path for mostly TCP/IP networks

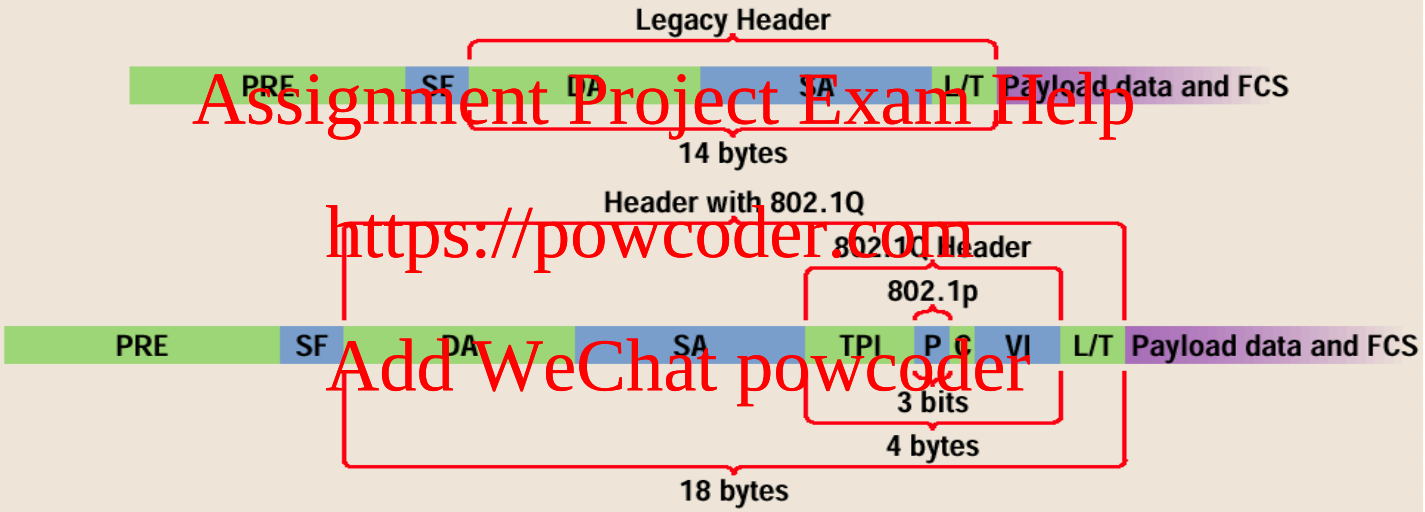
QoS mechanisms

(cont.)

- Data Link Layer (cont.)
  - » *Frame Relay*
    - – Committed Information Rate (CIR) confirms network delivery
  - » *IEEE 802.1p* (bright future for Ethernet technology)
    - – allows preferential queuing on the basis of "priority" value
    - – provides consistent method for Ethernet, Token Ring, etc.
    - – 3-bit priority field (0 assigned as lowest priority and 7 as the highest priority)

QoS mechanisms

IEEE 802.1p



Code	Name	Bits	Description
PRE	Preamble	56	Used to synchronize traffic between nodes
SF	Start Frame Delimiter	8	Marks the beginning of the header
DA	Destination Address	48	The MAC address of the final destination
SA	Source Address	48	The MAC address of the original sender
TPI	Tag Protocol Identifier	16	Indicates that this frame contains 802.1Q data (x8100)
P	Priority	3	Indicates the user priority values provided by 802.1p
C	Canonical Format Indicator	1	Indicates whether the embedded MAC addresses are in canonical format
VI	VLAN Identifier	12	Indicates which specific VLAN this frame belongs to
L/T	Length or Protocol Type	8	Indicates the 802.3 frame length or the Ethernet II protocol (such as IP or IPX)

QoS mechanisms

IEEE 802.1p

Proposed IEEE 802.1p Priority Values and Associated Traffic Types

Priority	Binary	Traffic Types
7	111	Network Control
6	110	Interactive Voice
5	101	Interactive Multimedia
4	100	Controlled Load Applications (Streaming Multimeia)
3	011	Excellent Effort
0	000	Best Effort (Default)
2	010	Spare
1	001	Background

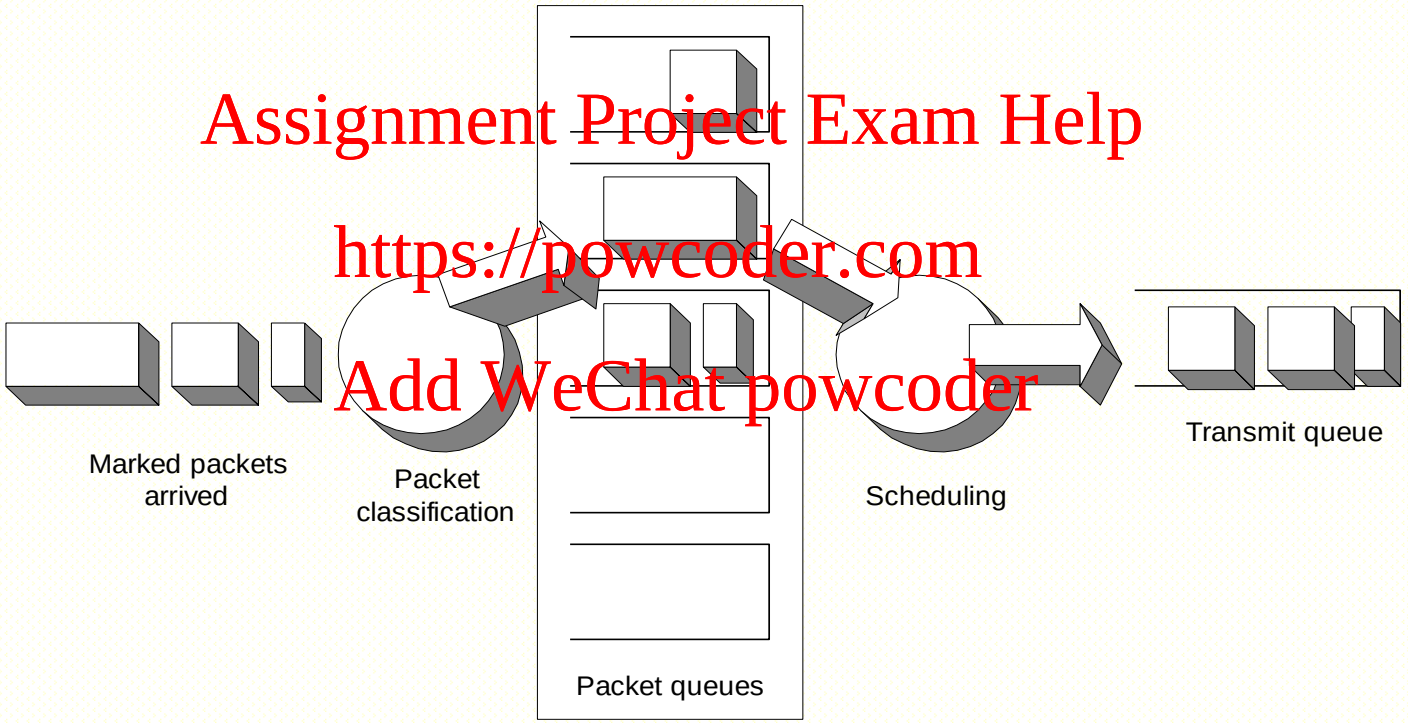
QoS mechanisms

(cont.)

- Network Layer
  - » IP precedence: the three precedence bits in the IPv4 header's Type of Service (ToS) field utilized to specify class of service for each packet.
  - » **Packet marking:** The ingress router must mark the packets as they enter the network with appropriate values so that interior routers can handle packets differentially.
  - » **Packet classification:** Routers must check all received packets to determine if the packets should receive differential treatment.
  - » **Packet queuing:** The routers may employ multiple queues along with some scheduling disciplines such that delay-sensitive traffic will be serviced sooner.

QoS mechanisms

(cont.)



Packet classification and queuing

QoS mechanisms

(cont.)

Scheduling Algorithms:

- FIFO queuing – traditional IP router (basic store and forward)

- fair algorithm, same delay is imposed on all queued packets

- Priority queuing

- queue for each distinct priority levels

- serviced in order of priority with highest priority traffic receiving minimal delay

- lower priority may be prevented from being serviced

QoS mechanisms

(cont.)

Scheduling Algorithms (cont.):

- Weighted Round Robin: network is shared with minimal bandwidth or latency requirements

- bandwidth is guaranteed at a potential congestion point, however, no application achieves more than a predetermined proportion of overall capacity

- Queues serviced round-robin in proportion to a weight assigned for each queue

QoS mechanisms

(cont.)

Scheduling Algorithms (cont.):

- Weighted Fair Queuing:

- interactive traffic is scheduled in front of the queue to reduce response time

- the remaining bandwidth is fairly shared among high-bandwidth flows

- ensures queues do not starve for bandwidth

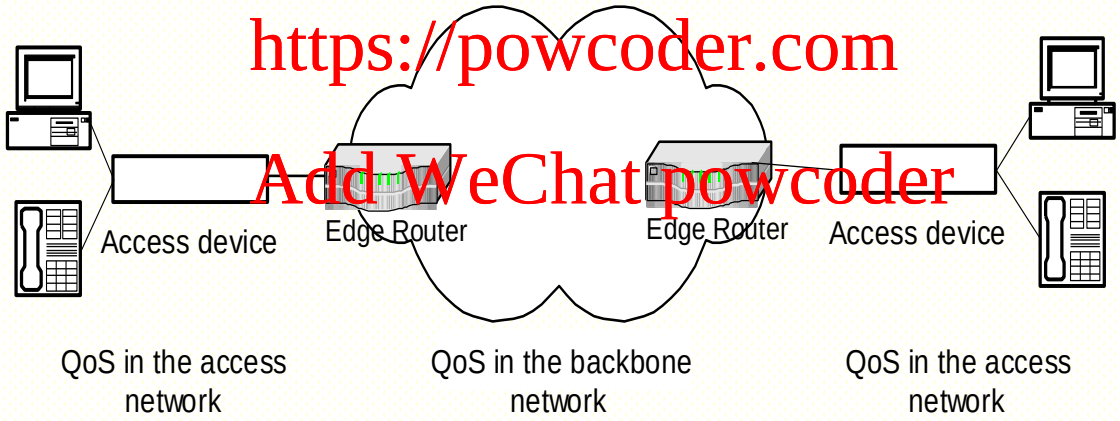
QoS mechanisms

(cont.)

- Transport and Application Layer
  - » packets may be marked and classified at these layers
  - » routers can use port numbers, however will have to locate transport-level header that might be behind optional IP header
  - » routers need to know many application-level protocols

End-to-End Implementation

- Every element in the network path should deliver its part of QoS



End-to-End Implementation

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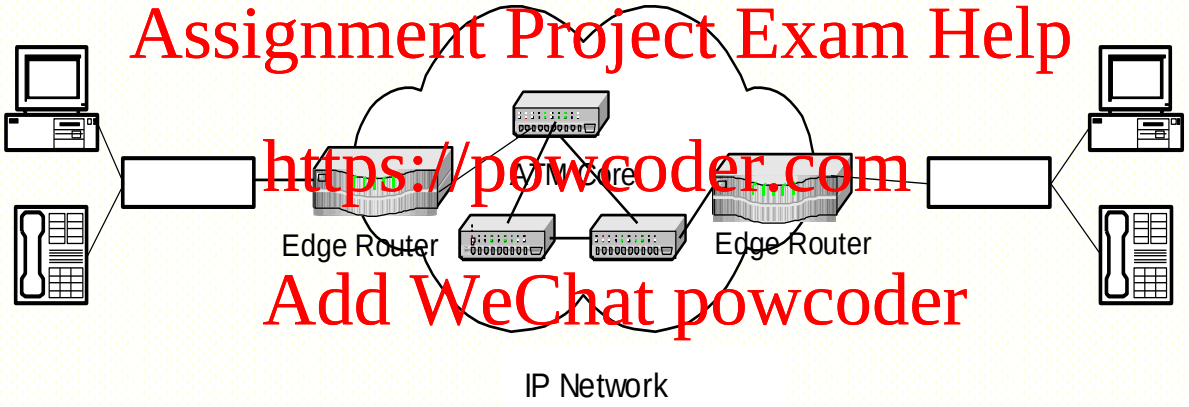

Delay-sensitive traffic channeled to ATM core

Service Level Agreements

- A service contract between a customer and a service provider
- specifies the service classes supported and the amount of traffic allowed in each class.
- *Static SLAs* - negotiated on a regular, e.g. monthly and yearly, basis.
- *Dynamic SLAs* must use a signaling protocol, to request for services on demand.
- The classification, policing and shaping rules used at the ingress routers are derived from the SLAs.
- The amount of buffering space needed for these operations is also derived from the SLAs.
- DS field may be re-marked, as determined by the SLA between the two domains.

Influencing Factors in Quality Perception

SERVICE QUALITY FACTORS	VOICE QUALITY FACTORS	
PSTN and VoIP Networks	Common to PSTN and VoIP Networks	Additional Parameters for IP Networks
Telephone Services—for example, Calling Card, 800/900 services, Call Forwarding, Voicemail, etc. *Availability*—down time, network busy indications *Reliability*—dropped calls, wrong numbers, calls not completed *Post-Dial Delay* *Price*	Loudness Delay Echo Clarity: *Intelligibility* *Noise* *Fading* *Cross talk*	Delay-Jitter Clarity: *Packet Loss* *Bandwidth* *Compression*