KHARKIV NATIONAL UNIVERSITY OF RADIO ELECTRONICS

MSGCS PRACTICE #1

QOS METRICS EVALUATION

PROBLEMS AND SOLUTIONS

1. Assume:
$\lambda = 5.4 \times 10^5 \ packets/sec;$
$\mu = 6 \times 10^5 \ packets/sec;$
$B = 50 \ packets.$
Determine the packet loss ratio due to the buffer overflow.

Solution

Packet loss probability

Poisson's "law of large numbers" allows the **packet loss probability** to be **interpreted as a long term value of the ratio of the number of lost packets to the total number of packets transmitted**, and the packet loss probability is often referred to as the packet loss ratio as follows. As $n \to \infty$, the packet loss ratio:

$$\frac{k}{n} \to p,$$

where k – number of packet losses;
        n – total number of packets;
        $p =$ constant – packet loss probability.

For real time signals, e.g., voice and video, packet loss manifests itself as noise in the decoded signal, which results in voice clippings and skips, reduced speech intelligibility, and video quality degradation. The following are some of the main sources of packet loss:
- Bit errors due to transmission line impairments, e.g., "fading," circuit noise;
- Link layer packet collisions;
- Network layer processing errors;
- Network layer buffer overflows;
- Network layer random packet discarding.

Considering that at least k customers will be in the queue and, setting k to the buffer size B, the following equation is obtained for the <u>packet loss ratio</u> due to the buffer overflow in a steady state operation over a long period of time:

$$P(N \geq B) = \rho^B, B = 0, 1, 2, 3, \ldots$$

Observe that, as the buffer size B increases, the packet loss probability decreases; as the utilization factor (ρ) increases, the packet loss probability increases.

Utilization factor is a measure of how fully the resource is used to meet the customer need. It is defined as the ratio of arrival rate to service rate. Its mathematical symbol is ρ, and ρ is dimensionless.

$$\rho = \frac{\lambda}{\mu}.$$

Finally we have

$$\rho = \frac{\lambda}{\mu} = \frac{5.4 \times 10^5}{6 \times 10^5} = 0.9.$$

From the packet loss ratio equation

$$P(N \geq B) = \rho^B = 0.9^{50} = p = 0.005.$$

2. Responses from **200 subjects** on a VoIP quality are as follows:

Rating	Number of Subjects
Excellent	20
Good	40
Fair	80
Poor	40
Unsatisfactory	20

Determine the MOS, %GoB and %PoW.

Solution

Subjective testing. Mean Opinion Score (MOS).

End-user perception of QoS is determined by **subjective testing** as a function of network impairments. The test conditions representative of the factors that the end-users are concerned about are presented to a sample of test subjects. **For each test condition, the subjects are asked to rate it on a five-point rating scale of "excellent," "good," "fair," "poor," and "unsatisfactory."** Numerical scores are then assigned to the subjects' responses as follows:

Verbal Rating	Numerical Score
Excellent	5
Good	4
Fair	3
Poor	2
Unsatisfactory	1

MOS is the mean of the numerical scores given by the subjects and is calculated as follows:

$$MOS = \frac{(N_E \times 5) + (N_G \times 4) + (N_F \times 3) + (N_P \times 2) + (N_U \times 1)}{N},$$

where N_E, N_G, N_F, N_P, N_U are the numbers of the subjects who have rated the test conditions excellent, good, fair, poor and unsatisfactory, respectively; and N is the total number of subjects:

$$N = N_E + N_G + N_F + N_P + N_U.$$

%GoB, which reads "**Percent Good or Better**," **is the percentage of the subjects who rate the test conditions either good or excellent, that is, better than "good," and is calculated as follows**:

$$\%GoB = \frac{N_E + N_G}{N} \times 100.$$

%PoW, which reads "**Percent Poor or Worse**," **is the percentage of the subjects who rate the test conditions either poor or unsatisfactory, that is, worse than poor, and is calculated as follows**:

$$\%PoW = \frac{N_P + N_U}{N} \times 100.$$

For given problem we have

$$MOS = \frac{(20 \times 5) + (40 \times 4) + (80 \times 3) + (40 \times 2) + (20 \times 1)}{200} = \frac{600}{200} = 3;$$

$$\%GoB = \frac{60}{200} = 30\%;$$
$$\%PoW = \frac{60}{200} = 30\%.$$

3. Using the **delay budget table** for **G.729** modem, determine the end to end delay of connection via an airplane six km above ground. See **Figure 1**.
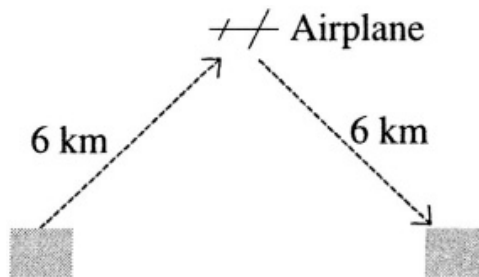
Figure 1 Exercise 3

Solution

Codec performance

The performance of codec is measured by subjective testing. For waveform codecs, one of the main factors that affect the codec performance is the quantization noise.

Examples of delay budget associated with a typical **ITU-T G.729** codec are shown below:

Delay Source	Delay Budget
Device sample capture	0.1
Encoding delay (algorithmic+processing)	17.5
Packetization/depacketization delay	20
Move to output queue/queue delay	0.5
Access (up) Link transmission delay	10
Backbone network transmission delay	variable
Access (down) Link transmission delay	10
Input queue to application	0.5
Jitter buffer	60
Decoder processing delay	2
Device play out delay	0.5

QoS of non-real time services such as file transfer and email is determined by user requirements.

For given problem we have next:

$$Propagation\ delay = \frac{6 \times 10^3 \times 2\ m}{3 \times 10^8\ m/sec} = 4 \times 10^{-5}\ sec = 4 \times 10^{-2}\ ms = 0.04\ ms.$$

$$End-to-end\ delay = Codec\ delay + Propagation\ delay = 121.1 + 0.04 = 121.14\ ms.$$

4. ***Erlang B System – Finding N***
Assume:
Number of user hosts, $M = 500$;
Number of virtual connection requests per host during busy hour, $\lambda = 4$;
Virtual connection holding time, $H = 18\ seconds$.

What is the number of virtual connections required to keep the busy hour virtual connection blocking probability P_B at 1% (i.e., 0.01)?

Solution

Blocking Probability

For connection-oriented packet services, **the blocking probability is a key QoS measure**. We discuss general mathematical models for determining blocking probabilities: **Erlang B** and **Erlang C systems**.

"Trunked Channel" systems

Figure 2 shows a "trunked channel" system. Connection requests (i.e., call setup requests or virtual channel requests) come to the system for a resource, i.e., communications channel to be assigned to the request. "Trunks" are shared by multiple users. Each trunk is occupied during the duration of a connection and is reassigned to another connection request when the current call is finished ("loop").
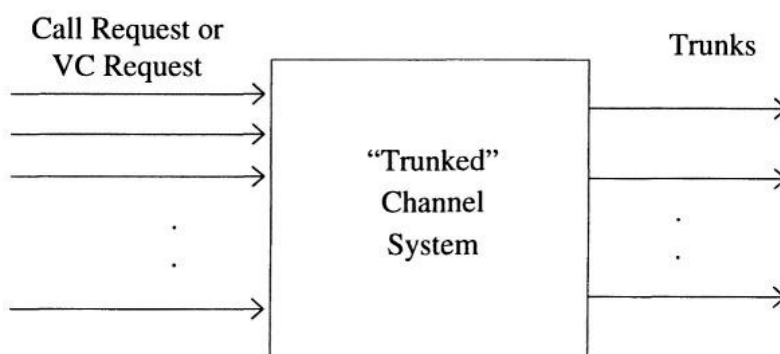
Figure 2 A general model of a trunked channel system

Offered traffic load

The amount of traffic load offered to a trunked channel system is given by the following equations:

$$L_u = \lambda H, \quad L = L_u M,$$

where

L_u – Traffic load generated by a single user;

L – Total offered traffic load;

λ – Arrival rate of connection requests per user (i.e., number of connection requests placed by a user per unit time);

H – Average call duration per call, i.e., "call holding time";

M – Number of users served by the system.

Units of traffic load

$$ccs = \frac{s}{100},$$

where

s – number of busy seconds in one hour;

ccs – "**Hundred Call Second**;" number of busy seconds during a one-hour period divided by 100;

$1\ erlang$ – amount of traffic load that makes one trunk circuit busy for one hour.

How many $ccs's$ is $1\ erlang$ equal to?

By definition, $1\ erlang$ is the amount of traffic load that makes one trunk circuit busy for $1\ hour$. Since there are $3600\ seconds$ in $1\ hour$,

$$1\ erlang = \frac{60 \times 60}{100} = 36\ ccs.$$

Trunk utilization factor

From the definition of utilization factor, the utilization factor of a trunked channel system, or trunk utilization factor, can be expressed as follows:

$$\rho = \frac{L}{N},$$

where L – offered load in $erlangs$ and N – number of trunks.

The following statistics provide typical busy-hour statistics:

- Loops
  - Residential 2 ccs (200 sec/hr, i.e., 5.6 % of time);
  - Business 5 ccs;
  - Average 3.5 ccs;
- Trunks 20 ccs (67 % utilization).

Erlang B

The **Erlang B** system is based on the following assumptions:
- **Call arrivals**, i.e., the random arrivals at the trunked channel system, **are assumed to be Poisson**. **This implies that the reservoir of arrivals is infinite, i.e., the number of end-users generating traffic is infinite.** The Erlang B formula provides a conservative estimate of probability of blocking because in reality the number of users is finite.
- **Call holding times are exponentially distributed**.
- There are a **finite number of channels** available in the trunking pool.
- "**Blocked calls cleared**" system. **If no channel is available** (i.e., "all trunks are busy") at the time of connection setup request, the connection attempt is blocked and cleared from the system, i.e., **there is no queue for the blocked calls**. Hence, **the Erlang B system may be thought of as a queuing system with zero buffer length**.

The QoS measure used for the Erlang B system is the **blocking probability**: **a call or connection request either gets accepted or blocked**. The blocking probability, P_B, of the Erlang B system is a function of **two variables – the offered traffic load** in $erlangs$, L, and **the number of trunks**, N – and is given by the following equation:

$$P_B = \frac{\frac{L^N}{N!}}{\sum_{k=0}^{N} \frac{L^k}{k!}}.$$

The above equation is tabulated in **the Erlang B Table** in terms of the following three parameters:
- Blocking probability (P_B);
- Number of channels (N);
- Offered load in erlangs (L).

Given two of the three parameters, the value of the third parameter can be found from the Erlang B table, i.e.,

Given P_B and L, N can be found.
Given P_B and N, L can be found.
Given L and N, P_B can be found.

For given problem we have:

$$L = 4 \times 18 \times 500 = \frac{36{,}000}{100} = 360 \; ccs = 10 \; erlangs.$$

From the **Erlang B table**, the required number of channels, $N = 18$.

Erlang C Mean Delay

Erlang C system

The same assumptions as those for the Erlang B system apply to the **Erlang C** system except that, in the Erlang C system, the blocked calls are queued instead of being cleared. **The Erlang C system is called the "Blocked Calls Delayed" system**. An example of the Erlang C system is the call attendant service, where a blocked call is put in a queue with a recorded message playing in the background, "your call is important to us ..." The initial blocking probability is given by the following equation, which is tabulated in mathematical tables:

$$P_B = P(delay > 0) = \frac{L^N}{L^N + N!\left(1 - \frac{L}{N}\right)\sum_{k=0}^{N-1}\frac{L^K}{k!}}.$$

In the **Erlang C** system, there is only delay and no blocking. The probability that delay will exceed a value t is given by the following equation, which is the product of the initial blocking probability of previous equation and the second term of the exponential function:

$$P(delay > t) = P(delay > 0)e^{-\frac{(N-L)t}{H}} \; for \; N > L,$$

where
L – total offered load in $erlangs$;
N – number of trunked channels;
t – time in $seconds$;
H – average holding time in $seconds$.

The mean delay is given by the following equation:

$$\eta_D = P(delay > 0)\frac{H}{N-L} \; for \; N > L.$$