

Solutions for Assignment #5

KJC (10/22/04)

#1) The run from `mva.c` gives the answers:

```
1 customers --- thrupt = 0.352941 cust/sec and delay = 2.833333 sec
>>> n[1] = 0.352941 --- t[1] = 1.000000
>>> n[2] = 0.176471 --- t[2] = 0.500000
>>> n[3] = 0.117647 --- t[3] = 0.333333
>>> n[4] = 0.352941 --- t[4] = 1.000000
<SNIP SNIP>
10 customers --- thrupt = 0.894850 cust/sec and delay = 11.175059 sec
>>> n[1] = 4.394081 --- t[1] = 4.910412
>>> n[2] = 0.790627 --- t[2] = 0.883530
>>> n[3] = 0.421210 --- t[3] = 0.470705
>>> n[4] = 4.394081 --- t[4] = 4.910412
```

#2) For an M/G/1 queue we know that (the P-K formula):

$$W = \bar{x} + \frac{\overline{\lambda x^2}}{2(1-\rho)}$$

For deterministic service (M/D/1) the first moment is $1/\mu$ and the second moment is $1/\mu^2$. For exponential service (M/M/1) the first moment is $1/\mu$ and the second moment is $2/\mu^2$. For M/D/1 we have:

$$W := \frac{1}{\mu} + \frac{\frac{\lambda}{\mu^2}}{2 \cdot \left(1 - \frac{\lambda}{\mu}\right)} \quad \text{which simplifies to} \quad W := \frac{1}{2 \cdot \mu} \cdot \frac{(\lambda - 2\mu)}{(\lambda - \mu)}$$

For M/M/1 we have:

$$W := \frac{1}{\mu} + \frac{\frac{2\lambda}{\mu^2}}{2 \cdot \left(1 - \frac{\lambda}{\mu}\right)} \quad \text{which simplifies to} \quad W := \frac{1}{(\mu - \lambda)} \quad (\text{as expected for M/M/1})$$

The ratio of W for M/D/1 divided by W for M/M/1 is:

$$\frac{1}{2} \cdot \frac{(-\lambda + 2 \cdot \mu)}{\mu} \quad \text{which simplifies to} \quad \frac{1}{2} \cdot (2 - \rho)$$

Thus, as ρ approaches 1.0 the difference in delay is one-half (M/D/1 has one-half the delay of M/M/1. For $\rho = 0$, the delay is the same (as would be expected).

#3) We state with the file trace.txt unzipped from trace.zip. The file trace.txt looks like this...

```
#StartTime srcIP dstIP srcPort dstPort bytes protocol
1018632325.243815 92.12.241.108 112.130.48.109 2674 1214 40 6
1018632325.243932 79.240.13.140 112.130.49.50 2049 4662 81 6
1018632325.244422 29.168.56.12 112.130.191.129 53005 6346 666 6
1018632325.244458 81.5.247.37 119.223.140.178 6701 49175 1420 6
1018632325.244739 92.12.241.108 112.130.48.109 2674 1214 40 6
1018632325.244982 85.24.242.225 112.130.68.89 3676 6346 367 6
1018632325.245022 145.188.97.170 112.130.113.244 1408 1214 40 6
<snip snip>
```

The sixth column is the packet length. So, awk'ing this out of the file we get a file named pkt_len.txt that looks like

```
40
81
666
1420
40
367
40
<snip snip>
```

The file pkt_len.txt has the following summary statistics and autocorrelation (computed using summary1.c, summary2.c, and autoc.c):

```
----- summary1.c -----
Total of 500000 values
  Minimum = 28.000000 (position = 264255)
  Maximum = 4470.000000 (position = 160161)
  Sum      = 362646682.000000
  Mean     = 725.293364
  Variance = 440843.384368
  Std Dev  = 663.960379
  CoV      = 0.915437
-----

----- summary2.c -----
Total of 500000 values
  Median    = 500.000000
  1% value  = 40.000000
  2% value  = 40.000000
  5% value  = 40.000000
  95% value = 1500.000000
  98% value = 1500.000000
  99% value = 1500.000000
-----

----- autoc.c -----
Autocorrelation for lag 1 = 0.084812
Autocorrelation for lag 2 = 0.092408
Autocorrelation for lag 3 = 0.085887
Autocorrelation for lag 4 = 0.075166
Autocorrelation for lag 5 = 0.065986
Autocorrelation for lag 6 = 0.059871
Autocorrelation for lag 7 = 0.050641
Autocorrelation for lag 8 = 0.045257
Autocorrelation for lag 9 = 0.038823
```

```

Autocorrelation for lag 10 = 0.034337
Autocorrelation for lag 11 = 0.030092
Autocorrelation for lag 12 = 0.024128
Autocorrelation for lag 13 = 0.020001
Autocorrelation for lag 14 = 0.015782
Autocorrelation for lag 15 = 0.012563
Autocorrelation for lag 16 = 0.008535
Autocorrelation for lag 17 = 0.008406
Autocorrelation for lag 18 = 0.005126
Autocorrelation for lag 19 = 0.001950
Autocorrelation for lag 20 = 0.000716
Autocorrelation for lag 21 = 0.000476
Autocorrelation for lag 22 = -0.001030
Autocorrelation for lag 23 = -0.003024
Autocorrelation for lag 24 = -0.003889
Autocorrelation for lag 25 = -0.003893
<snip snip>

```

The autocorrelation drops to approximately zero (less than 1/100) after lag 15.

We modify `hist.c` to generate a file `data dist.dat` for `genemp.c` to use to generate empirically distributed values of packet lengths. The program `hist.c` is used “as is” with the only modification being the line that outputs results. What was:

```

// Output the histogram
for (i=0; i<NUM_BUCKET; i++)
    printf(" %14.9f <= X < %14.9f = %6ld -- %f %% \n",
        (i * (double) BUCKET_SIZE), ((i + 1) * (double) BUCKET_SIZE),
        bucket[i], 100.0 * ((double) bucket[i] / num_values));

```

Was changed to:

```

// Output ration and bucket size
printf(" %14.9f %14.9f \n", ((double) count / N), (i * (double)
BUCKET_SIZE));

```

The values of `BUCKET_SIZE` and `NUM_BUCKET` were set as:

```

#define BUCKET_SIZE 1.0 // Bucket size
#define NUM_BUCKET 4500 // Number of buckets

```

We generate 500,000 synthetic packet lengths and the characterization with `summary1.c`, `summary2.c`, and `autoc.c` is:

```

----- summary1.c -----
Total of 500000 values
  Minimum = 28.000000 (position = 484991)
  Maximum = 4470.000000 (position = 407082)
  Sum      = 362544727.000000
  Mean     = 725.089454
  Variance = 440740.249295
  Std Dev  = 663.882707
  CoV      = 0.915587
-----

```

```
----- summary2.c -----
Total of 500000 values
  Median      = 501.000000
   1% value  = 40.000000
   2% value  = 40.000000
   5% value  = 40.000000
  95% value  = 1500.000000
  98% value  = 1500.000000
  99% value  = 1500.000000
```

```
----- autoc.c -----
Autocorrelation for lag 1 = -0.000880
Autocorrelation for lag 2 = -0.002227
Autocorrelation for lag 3 = -0.000101
Autocorrelation for lag 4 = -0.001942
Autocorrelation for lag 5 = -0.000272
Autocorrelation for lag 6 = -0.000454
Autocorrelation for lag 7 = -0.001022
Autocorrelation for lag 8 = -0.000879
Autocorrelation for lag 9 = -0.000839
Autocorrelation for lag 10 = 0.000112
Autocorrelation for lag 11 = -0.002152
Autocorrelation for lag 12 = 0.000736
Autocorrelation for lag 13 = 0.000095
Autocorrelation for lag 14 = 0.001198
Autocorrelation for lag 15 = 0.000397
Autocorrelation for lag 16 = -0.000586
Autocorrelation for lag 17 = -0.001475
Autocorrelation for lag 18 = 0.000865
Autocorrelation for lag 19 = 0.002005
Autocorrelation for lag 20 = 0.000411
Autocorrelation for lag 21 = 0.000501
Autocorrelation for lag 22 = -0.001766
Autocorrelation for lag 23 = -0.001037
Autocorrelation for lag 24 = 0.001701
Autocorrelation for lag 25 = 0.001722
<snip snip>
```

The summary statistics (mean, standard deviation, and percentiles) of the synthetic packet lengths are the same (with 1%) of the actual. The key difference is in autocorrelation. The actual packet length trace has an autocorrelation of about 0.1 for the first few lags (i.e., a measurable and non-zero autocorrelation). The empirically distributed packet lengths show no autocorrelation (this is the case since empirically generated values are done so using an independent (i.e., uncorrelated) random number generator).

#4) Graded individually.

#5) Graded individually.
