Solutions for Assignment #5

KJC (10/22/04)

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

```
1 customers --- thruput = 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 --- thruput = 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):

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

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 packt length. So, awking 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 autocorrection. 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.
