In [1]:

```
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import scipy.stats as sts
%matplotlib inline
```

Считывание данных

In [2]:

```
file_obj = open('6.csv', 'r')

# массив данных
date = np.array([])

# значение лямбда
lam_true = file_obj.readline().split(' ')
lam_true = 1/float(lam_true[-1])

# t0
t0 = file_obj.readline().split(' ')
t0 = float(t0[-1])

# t
t = file_obj.readline().split(' ')
t = float(t[-1])

# приведение данных к float
for line in file_obj:
    line = line[:-1]
    date = np.append(date, float(line))
file_obj.close()

# сортировка данных по возрастанию
date.sort()
```

In [3]:

```
print lam_true
```

```
0.00952380952381
```

Вывод формулы $E(N_t|N_s)$

$E(N_t|N_s) = E(N_t - N_s|N_s) + E(N_s|N_s) =$ по св-ву условного матожидания |
$= E(N_t - N_s|N_s) + E(N_s) =$ из независимости $|(N_t - N_s)$ и N_s и т.к. рассматривается ситуация в момент времени s | $= E(N_t - N_s) + N_s$

$$E(N_t - N_s) = \lambda * (t - s)$$

Таким образом:

$$E(N_t | N_s) = \lambda * (t - s) + N_s$$

Построение прогноза

In [4]:

```
def bayesian_estimation(sample, alpha, beta):
    sum_sample = sample[-1] - sample[0]
    conditional_expectation = (sample.size + alpha)/(sum_sample + beta)
    return conditional_expectation
```

In [5]:

```
def get_forecast_with_est(t, t0, date, alpha, beta):
    # прогноз количества серверов, которые сломаются в момент времени t
    # в i-ой ячейке хранится предсказание, данное в i*t0 момент времени
    break_servers = np.zeros(int(t/t0))

    lam = 0

    # количество серверов, сломавшихся к данному моменту
    cur_broke_servers = 0

    for time in np.arange(t0, t, t0):
        # обновляем количество сломавшихся серверов к моменту времени time
        while cur_broke_servers < date.size and date[cur_broke_servers] <= tim
            cur_broke_servers += 1

        # обновляем значение lam
        lam = bayesian_estimation(date[:cur_broke_servers], alpha, beta)

        # прогноз, полученный в момент времени time
        break_servers[int(time/t0)] = lam*(t - time) + cur_broke_servers

    return break_servers
```

In [6]:

```
def get_forecast_with_true_lambda(t, t0, date, lam):
    # прогноз количества серверов, которые сломаются в момент времени t
    # в i-ой ячейке хранится предсказание, данное в i*t0 момент времени
    break_servers = np.zeros(int(t/t0))

    # количество серверов, сломавшихся к данному моменту
    cur_broke_servers = 0

    for time in np.arange(0, t, t0):
        # обновляем количество сломавшихся серверов к моменту времени time
        while cur_broke_servers < date.size and date[cur_broke_servers] <= tim
            cur_broke_servers += 1

        # прогноз, полученный в момент времени time
        break_servers[int(time/t0)] = lam*(t - time) + cur_broke_servers

    return break_servers
```

$\alpha = 1$, потому что мы не знаем ничего о распределении λ, а при $\alpha > 1$ появляется горб в окрестности какого-то числа. $\beta = 1$ - чтобы график плотности был достаточно плавный.

In [7]:

```
# строим график прогноза от времени

# время
time = np.arange(0, t, t0)

# параметры априорного распределения
alpha = 1
beta = 1

# прогнозы
true_forecast = get_forecast_with_true_lambda(t, t0, date, lam_true)
est_forecast = get_forecast_with_est(t, t0, date, alpha, beta)

# построение графиков
plt.figure(figsize=(16, 18))

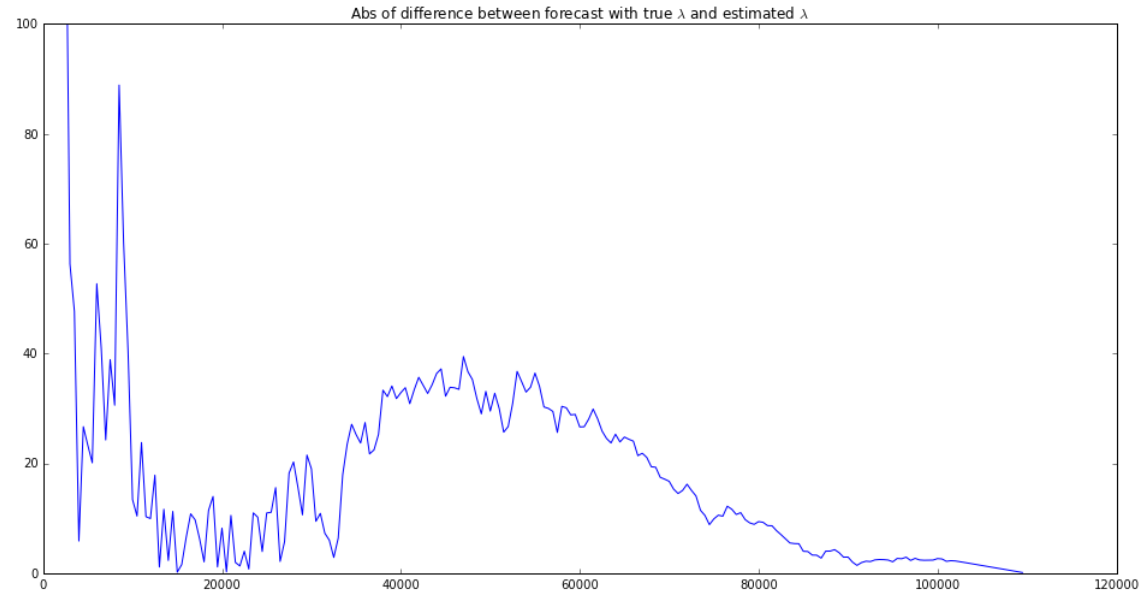
plt.subplot(2, 1, 1)

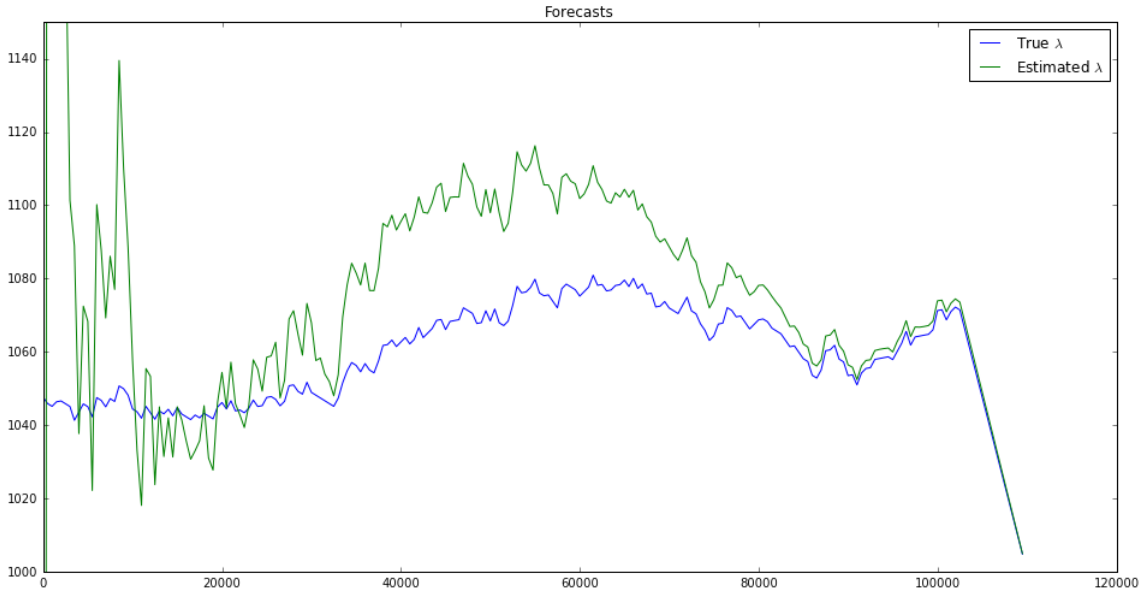
plt.plot(time, np.abs(true_forecast - est_forecast))
plt.ylim(0, 100)
plt.title('Abs of difference between forecast with true $\\lambda$ and estimat

plt.subplot(2, 1, 2)

plt.plot(time, true_forecast, label = 'True $\\lambda$')
plt.plot(time, est_forecast, label = 'Estimated $\\lambda$')
plt.ylim(1000, 1150)
plt.legend()
plt.title('Forecasts')

plt.show()
```


Abs of difference between forecast with true λ and estimated λ
100
80
60
40
20
0
0
20000
40000
60000
80000
100000
120000


Forecasts
True λ
Estimated λ
1140
1120
1100
1080
1060
1040
1020
1000
0
20000
40000
60000
80000
100000
120000

In [8]:

```
# на всякий случай печать прогноза с данным лямбда
print true_forecast
```

```
[ 1047.61904762  1045.85714286  1045.0952381   1046.33333333  1
046.57142857
  1045.80952381  1045.04761905  1041.28571429  1043.52380952  1
045.76190476
  1045.          1042.23809524  1047.47619048  1046.71428571  1
044.95238095
  1047.19047619  1046.42857143  1050.66666667  1049.9047619   1
048.14285714
  1044.38095238  1043.61904762  1041.85714286  1045.0952381   1
043.33333333
  1041.57142857  1043.80952381  1043.04761905  1044.28571429  1
042.52380952
  1044.76190476  1043.          1042.23809524  1041.47619048  1
042.71428571
  1041.95238095  1043.19047619  1042.42857143  1041.66666667  1
044.9047619
  1046.14285714  1044.38095238  1046.61904762  1043.85714286  1
044.0952381
  1043.33333333  1044.57142857  1046.80952381  1045.04761905  1
045.28571429
  1047.52380952  1047.76190476  1047.          1045.23809524  1
046.47619048
  1050.71428571  1050.95238095  1049.19047619  1048.42857143  1
051.66666667
  1048.9047619   1048.14285714  1047.38095238  1046.61904762  1
045.85714286
  1045.0952381   1047.33333333  1051.57142857  1054.80952381  1
057.04761905
  1056.28571429  1054.52380952  1056.76190476  1055.          1
054.23809524
  1057.47619048  1061.71428571  1061.95238095  1063.19047619  1
061.42857143
  1062.66666667  1063.9047619   1062.14285714  1063.38095238  1
066.61904762
  1063.85714286  1065.0952381   1066.33333333  1068.57142857  1
068.80952381
  1066.04761905  1068.28571429  1068.52380952  1068.76190476  1
072.
  1071.23809524  1070.47619048  1067.71428571  1067.95238095  1
071.19047619
  1068.42857143  1071.66666667  1067.9047619   1067.14285714  1
068.38095238
  1072.61904762  1077.85714286  1076.0952381   1076.33333333  1
077.57142857
  1079.80952381  1076.04761905  1075.28571429  1075.52380952  1
073.76190476
  1072.          1077.23809524  1078.47619048  1077.71428571  1
076.95238095
  1075.19047619  1076.42857143  1077.66666667  1080.9047619   1
078.14285714
  1078.38095238  1076.61904762  1076.85714286  1078.0952381   1
078.33333333
  1079.57142857  1077.80952381  1080.04761905  1077.28571429  1
078.52380952
  1075.76190476  1076.          1072.23809524  1072.47619048  1
073.71428571
  1071.95238095  1071.19047619  1070.42857143  1072.66666667  1
```

```
074.9047619
  1071.14285714  1070.38095238  1067.61904762  1065.85714286  1
063.0952381
  1064.33333333  1067.57142857  1067.80952381  1072.04761905  1
071.28571429
  1069.52380952  1069.76190476  1068.          1066.23809524  1
067.47619048
  1068.71428571  1068.95238095  1068.19047619  1066.42857143  1
065.66666667
  1064.9047619   1063.14285714  1061.38095238  1061.61904762  1
059.85714286
  1058.0952381   1057.33333333  1053.57142857  1052.80952381  1
055.04761905
  1060.28571429  1060.52380952  1061.76190476  1058.          1
057.23809524
  1053.47619048  1053.71428571  1050.95238095  1054.19047619  1
055.42857143
  1055.66666667  1057.9047619   1058.14285714  1058.38095238  1
058.61904762
  1057.85714286  1060.0952381   1062.33333333  1065.57142857  1
061.80952381
  1064.04761905  1064.28571429  1064.52380952  1064.76190476  1
066.
  1071.23809524  1071.47619048  1068.71428571  1070.95238095  1
072.19047619
  1071.42857143  1066.66666667  1061.9047619   1057.14285714  1
052.38095238
  1047.61904762  1042.85714286  1038.0952381   1033.33333333  1
028.57142857
  1023.80952381  1019.04761905  1014.28571429  1009.52380952  1
004.76190476]
```

In [9]:

```
# на всякий случай печать прогноза с оцениваемым лямбда
print est_forecast
```

```
[    0.          1479.10628774  1211.2096518   1210.26440453  1
170.31757064
  1178.84865163  1101.36295454  1088.98037259  1037.64854652  1
072.4509195
  1068.30417418  1022.12261205  1100.18361654  1087.70656246  1
069.22802656
  1086.08604931  1077.02851314  1139.5331691   1110.0660757   1
088.46302841
  1057.80007434  1033.19729409  1018.04617081  1055.40379353  1
053.29429447
  1023.71008331  1044.95173182  1031.39922629  1041.94967117  1
031.25766651
  1044.96254911  1041.40624396  1035.69756708  1030.65366156  1
032.9926001
  1035.68724459  1045.27389222  1030.97312936  1027.68482266  1
046.06698077
  1054.35995963  1044.65205492  1057.15290725  1045.8331163   1
042.76059052
  1039.31199554  1045.34183017  1057.80270055  1055.25622063  1
049.24521497
  1058.49952657  1058.86209064  1062.59648815  1047.39520433  1
052.25862444
  1068.95295885  1071.21160848  1064.79110299  1059.07190833  1
073.18524457
  1067.92021829  1057.60044889  1058.28722911  1053.90975756  1
051.89004812
  1047.97940304  1053.74465722  1069.52129165  1078.31831212  1
084.17649595
  1081.518681    1078.23593928  1084.20263106  1076.7299886   1
076.70048568
  1082.75191729  1095.04655381  1094.11926555  1097.27922761  1
093.22563941
  1095.54675009  1097.69315206  1093.01518803  1096.82255093  1
102.29374919
  1098.0786652   1097.83467193  1100.66966948  1104.93906029  1
106.01576367
  1098.28123738  1102.14085354  1102.29147495  1102.24702616  1
111.46070349
  1107.92841144  1105.74566828  1099.5071211   1096.98016065  1
104.30151638
  1097.954029    1104.43615093  1097.88722951  1092.83642792  1
095.08150169
  1103.53158557  1114.60686374  1110.99998015  1109.32242354  1
111.45059176
  1116.25280435  1110.10706772  1105.56352665  1105.53901038  1
103.22499806
  1097.6408516   1107.62601597  1108.60105661  1106.54891699  1
105.87586173
  1101.83372785  1103.10653676  1105.72157012  1110.80222525  1
106.27116125
  1104.26453762  1101.15770375  1100.58297275  1103.41002836  1
102.24507402
  1104.37308112  1102.20021454  1104.09789888  1098.69999535  1
100.37068034
  1096.85248697  1095.40264116  1091.53312076  1089.94899967  1
090.84646756
  1088.69547769  1086.51126059  1084.9496623   1087.74748818  1
```

```
091.11769569
  1086.22151993  1084.45839823  1079.09112613  1076.38905959  1
071.95322006
  1074.2375548   1078.14873156  1078.20629345  1084.25518039  1
082.95246336
  1080.23231315  1080.79568344  1077.77442767  1075.42107411  1
076.38409995
  1078.11986479  1078.23175491  1076.87174248  1075.0766411   1
073.4312389
  1071.95012451  1069.40970334  1066.90110214  1067.02884664  1
065.24304731
  1062.1024103   1061.29404056  1056.8878258   1056.10563149  1
057.80968762
  1064.31129078  1064.56176232  1066.06676821  1061.75504198  1
060.17021687
  1056.42707985  1055.75034369  1052.39099468  1056.13558671  1
057.62973192
  1057.80517169  1060.33520659  1060.64738889  1060.8621798   1
061.02355389
  1059.94872997  1062.79873729  1064.98104498  1068.5018951   1
064.14342056
  1066.76865481  1066.71060511  1066.89505194  1067.15844202  1
068.39805504
  1073.91237272  1074.08645994  1070.89092881  1073.24308102  1
074.43250599
  1073.54304361  1068.64017404  1063.73730446  1058.83443489  1
053.93156532
  1049.02869574  1044.12582617  1039.22295659  1034.32008702  1
029.41721744
  1024.51434787  1019.6114783   1014.70860872  1009.80573915  1
004.90286957]
```

In [10]:

```
# на всякий случай печать исходных данных
print lam_true, '\n', t0, '\n', t, '\n', date
```

```
0.00952380952381
500.0
110000.0
[    198.4406     460.8092     494.1672     517.8483     560.4
633.9109
     921.567     1158.8588    1274.4149    1287.2666    1328.93
48
    1360.5433    1466.1662    1581.8253    1592.6818    1821.16
89
    1821.574     1978.1997    2041.0241    2080.241     2267.94
37
    2334.7124    2515.4969    2797.2978    2827.6293    2883.97
54
    3005.4021    3518.4422    3640.7351    3677.105     3701.69
48
    3836.6024    3874.7631    3893.9537    4061.5291    4198.89
96
    4226.5964    4266.4072    4331.3636    4419.0845    4493.33
09
    4632.8954    4841.545     4854.6571    4917.4448    5289.09
97
    5341.4091    5505.4492    5515.7956    5574.0126    5711.17
51
    5748.7882    5758.8604    5932.6071    5976.6869    5979.52
18
    5979.74      6273.6398    6336.2478    6429.7853    6447.52
24
    6589.2105    6626.7495    6857.621     7032.9753    7210.18
2
    7229.9956    7370.2266    7375.1584    7458.1236    7467.76
02
    7549.1966    7649.2758    7920.8578    7933.7474    8106.38
45
    8148.2834    8160.8184    8223.7964    8234.5101    8287.69
9
    8300.8639    8357.6157    8371.035     8507.08      8889.98
68
    8970.8845    8992.371     9136.5452    9285.1659    9466.95
71
    9826.7627   10019.8912   10330.1514   10424.8071   10495.69
91
   10595.1228   10621.3687   10969.4783   11065.6358   11089.59
21
   11104.2035   11144.2902   11183.8962   11184.6211   11193.14
91
   11414.1819   11587.5524   11691.6212   11729.3666   12033.92
03
   12082.042    12402.2028   12516.4022   12538.4642   12669.46
16
   12670.8646   12749.5149   12778.7654   12886.7514   13209.14
87
   13270.3539   13366.0482   13490.9278   13500.1439   13509.46
54
   13561.7326   13728.1727   13892.0573   13987.6753   14074.88
41
   14369.6151   14443.9096   14515.7884   14530.4876   14543.63
06
```

```
    14865.3176   14926.5647   14987.2605   14999.1581   15075.13
08
    15085.8427   15344.2632   15530.1176   15715.1789   15778.33
7    15851.81
    16013.0438   16138.4394   16141.6965   16353.7992   16581.11
38
    16581.8651   16596.8048   16661.92     16667.0497   16971.55
49
    17042.2722   17072.6697   17199.27     17329.2784   17518.24
63
    17567.6207   17591.4941   17766.7852   17785.8047   17795.59
55
    18104.9975   18327.9242   18419.3775   18498.0124   18697.64
69
    18825.6093   18951.0019   18980.4652   19079.3652   19083.91
84
    19090.7049   19149.5465   19195.708    19287.8536   19380.62
59
    19491.424    19545.6561   19588.2367   19614.8531   19617.87
25
    19778.9189   19958.0036   20139.5023   20448.3286   20455.99
73
    20618.9989   20619.1092   20666.9317   20751.6735   20897.06
05
    20918.2173   20939.6648   21235.2633   21357.8327   21575.92
41
    21650.8065   21855.5143   21878.9643   21967.1083   22005.64
9
    22056.3098   22390.1757   22459.8703   22507.1727   22644.37
6
    22725.7527   22804.4241   22935.5377   22961.2749   23040.11
5
    23112.6132   23154.0185   23178.7242   23245.2068   23363.50
39
    23407.7153   23589.6478   23707.3862   23739.0186   24100.78
17
    24140.4859   24159.0623   24414.5285   24439.5622   24506.03
88
    24595.3745   24634.2227   24780.2192   24790.3395   24849.47
1
    24956.748    25072.2256   25092.4643   25150.0499   25168.50
34
    25468.8685   25514.1468   25704.7445   25721.1483   25739.48
29
    26013.865    26244.7956   26481.1452   26554.2068   26577.54
67
    26687.3774   26887.9086   26954.3653   26986.4754   27040.75
1
    27118.6686   27126.602    27237.9219   27299.8843   27327.05
62
    27392.8404   27403.6314   27493.8138   27555.9628   27665.99
79
    27865.2897   27916.5605   27932.9349   28030.037    28096.44
15
    28400.5865   28605.5884   28771.4682   28840.6398   28990.18
94
    29087.5932   29136.9677   29207.811    29250.7742   29323.50
```

```
74
   29355.0333   29386.6032   29407.5789   29585.6795   29701.09
47
   30044.1611   30137.6325   30353.6023   30479.1865   30685.50
98
   30763.2704   30787.6534   30833.3521   31000.1177   31110.45
01
   31347.6677   31393.2223   31562.8646   31703.8797   31735.89
37
   31860.2996   32063.7306   32085.9182   32273.0142   32411.56
14
   32539.8796   32599.4339   32644.0284   32645.987    32829.89
32
   32971.0103   32985.7815   33036.9579   33084.0716   33226.61
61
   33226.6507   33273.9312   33312.4291   33351.1214   33397.70
1
   33399.4407   33609.9533   33672.5605   33748.4726   33765.70
1
   33842.3669   33863.2243   33887.6639   33960.8311   34053.16
29
   34098.1141   34117.6851   34273.4458   34398.1148   34455.07
69
   34498.3066   34785.3546   34892.9889   34896.866    34983.58
01
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