In [1]:
```
# Imports for this Notebook
import pandas as pd
from sklearn import preprocessing
from sklearn.model_selection import train_test_split
from sklearn import metrics
from keras.models import Sequential
from keras.layers.core import Dense, Activation
from keras.callbacks import EarlyStopping
```

```
Using TensorFlow backend.
```

In [2]:
```
from sklearn import preprocessing
import matplotlib.pyplot as plt
import numpy as np
import pandas as pd
import shutil
import os
import keras
import matplotlib
import matplotlib.pyplot as plt
%matplotlib inline
```

In [3]:
```

# Encode text values to dummy variables(i.e. [1,0,0],[0,1,0],[0,0,1] for
def encode_text_dummy(df, name):
    dummies = pd.get_dummies(df[name])
    for x in dummies.columns:
        dummy_name = "{}-{}".format(name, x)
        df[dummy_name] = dummies[x]
    df.drop(name, axis=1, inplace=True)


# Encode text values to a single dummy variable.  The new columns (which
# at every location where the original column (name) matches each of the
# each target value.
def encode_text_single_dummy(df, name, target_values):
    for tv in target_values:
        l = list(df[name].astype(str))
        l = [1 if str(x) == str(tv) else 0 for x in l]
        name2 = "{}-{}".format(name, tv)
        df[name2] = l


# Encode text values to indexes(i.e. [1],[2],[3] for red,green,blue).
def encode_text_index(df, name):
    le = preprocessing.LabelEncoder()
    df[name] = le.fit_transform(df[name])
    return le.classes
```

```
# Encode a numeric column as zscores
def encode_numeric_zscore(df, name, mean=None, sd=None):
    if mean is None:
        mean = df[name].mean()

    if sd is None:
        sd = df[name].std()

    df[name] = (df[name] - mean) / sd


# Convert all missing values in the specified column to the median
def missing_median(df, name):
    med = df[name].median()
    df[name] = df[name].fillna(med)


# Convert all missing values in the specified column to the default
def missing_default(df, name, default_value):
    df[name] = df[name].fillna(default_value)


# Convert a Pandas dataframe to the x,y inputs that TensorFlow needs
def to_xy(df, target):
    result = []
    for x in df.columns:
        if x != target:
            result.append(x)
    # find out the type of the target column.  Is it really this hard? :(
    target_type = df[target].dtypes
    target_type = target_type[0] if hasattr(target_type, '__iter__') else
    # Encode to int for classification, float otherwise. TensorFlow likes
    if target_type in (np.int64, np.int32):
        # Classification
        dummies = pd.get_dummies(df[target])
        return df.as_matrix(result).astype(np.float32), dummies.as_matrix
    else:
        # Regression
        return df.as_matrix(result).astype(np.float32), df.as_matrix([tar

# Nicely formatted time string
def hms_string(sec_elapsed):
    h = int(sec_elapsed / (60 * 60))
    m = int((sec_elapsed % (60 * 60)) / 60)
    s = sec_elapsed % 60
    return "{}:{:>02}:{:>05.2f}".format(h, m, s)
```

```
# Regression chart.
def chart_regression(pred,y,sort=True):
    t = pd.DataFrame({'pred' : pred, 'y' : y.flatten()})
    if sort:
        t.sort_values(by=['y'],inplace=True)
    a = plt.plot(t['y'].tolist(),label='expected')
    b = plt.plot(t['pred'].tolist(),label='prediction')
    plt.ylabel('output')
    plt.legend()
    plt.show()

# Remove all rows where the specified column is +/- sd standard deviation
def remove_outliers(df, name, sd):
    drop_rows = df.index[(np.abs(df[name] - df[name].mean()) >= (sd * df[
    df.drop(drop_rows, axis=0, inplace=True)


# Encode a column to a range between normalized_low and normalized_high.
def encode_numeric_range(df, name, normalized_low=-1, normalized_high=1,
                         data_low=None, data_high=None):
    if data_low is None:
        data_low = min(df[name])
        data_high = max(df[name])

    df[name] = ((df[name] - data_low) / (data_high - data_low)) \
               * (normalized_high - normalized_low) + normalized_low
```

In [4]:

```

# This file is a CSV, just no CSV extension or headers
# Download from: http://kdd.ics.uci.edu/databases/kddcup99/kddcup99.html
df = pd.read_csv("/Users/tsaiflow/Downloads/kddcup.data_10_percent_correc

print("Read {} rows.".format(len(df)))
#print("Read {} rows.".format(len(df1)))
# df = df.sample(frac=0.1, replace=False) # Uncomment this line to sample
df.dropna(inplace=True,axis=1) # For now, just drop NA's (rows with missi
# df1.dropna(inplace=True,axis=1)

# The CSV file has no column heads, so add them
df.columns = [
    'duration',
    'protocol_type',
    'service',
    'flag',
    'src_bytes',
    'dst_bytes',
    'land',
    'wrong_fragment',
    'urgent',
    'hot',
    'num_failed_logins',
    'logged_in',
    'num_compromised',
    'root_shell',
    'su_attempted',
    'num_root',
    'num_file_creations',
    'num_shells',
    'num_access_files',
    'num_outbound_cmds',
    'is_host_login',
    'is_guest_login',

    'count',
    'srv_count',
    'serror_rate',
    'srv_serror_rate',
    'rerror_rate',
    'srv_rerror_rate',
    'same_srv_rate',
    'diff_srv_rate',
    'srv_diff_host_rate',
    'dst_host_count',
    'dst_host_srv_count',
    'dst_host_same_srv_rate',
    'dst_host_diff_srv_rate',
    'dst_host_same_src_port_rate',
    'dst_host_srv_diff_host_rate',
    'dst_host_serror_rate',
    'dst_host_srv_serror_rate',
    'dst_host_rerror_rate',
    'dst_host_srv_rerror_rate',


    'outcome'
]
```

```
Read 494021 rows.
```

In [5]:

```
df.head(5)
```

Out[5]:

	duration	protocol_type	service	flag	src_bytes	dst_bytes	land	wrong_fragment	urgent	ho
0	0	tcp	http	SF	181	5450	0	0	0	(
1	0	tcp	http	SF	239	486	0	0	0	(
2	0	tcp	http	SF	235	1337	0	0	0	(
3	0	tcp	http	SF	219	1337	0	0	0	(
4	0	tcp	http	SF	217	2032	0	0	0	(

5 rows × 42 columns

In [6]:

```
# Now encode the feature vector

encode_numeric_zscore(df, 'duration')
encode_text_dummy(df, 'protocol_type')
encode_text_dummy(df, 'service')
encode_text_dummy(df, 'flag')
encode_numeric_zscore(df, 'src_bytes')
encode_numeric_zscore(df, 'dst_bytes')
encode_text_dummy(df, 'land')
encode_numeric_zscore(df, 'wrong_fragment')
encode_numeric_zscore(df, 'urgent')
encode_numeric_zscore(df, 'hot')
encode_numeric_zscore(df, 'num_failed_logins')
encode_text_dummy(df, 'logged_in')
encode_numeric_zscore(df, 'num_compromised')
encode_numeric_zscore(df, 'root_shell')
encode_numeric_zscore(df, 'su_attempted')
encode_numeric_zscore(df, 'num_root')
encode_numeric_zscore(df, 'num_file_creations')
encode_numeric_zscore(df, 'num_shells')
encode_numeric_zscore(df, 'num_access_files')
encode_numeric_zscore(df, 'num_outbound_cmds')
encode_text_dummy(df, 'is_host_login')
encode_text_dummy(df, 'is_guest_login')
encode_numeric_zscore(df, 'count')
encode_numeric_zscore(df, 'srv_count')
encode_numeric_zscore(df, 'serror_rate')
encode_numeric_zscore(df, 'srv_serror_rate')
encode_numeric_zscore(df, 'rerror_rate')
encode_numeric_zscore(df, 'srv_rerror_rate')
encode_numeric_zscore(df, 'same_srv_rate')
encode_numeric_zscore(df, 'diff_srv_rate')
encode_numeric_zscore(df, 'srv_diff_host_rate')
encode_numeric_zscore(df, 'dst_host_count')
encode_numeric_zscore(df, 'dst_host_srv_count')
encode_numeric_zscore(df, 'dst_host_same_srv_rate')
encode_numeric_zscore(df, 'dst_host_diff_srv_rate')
encode_numeric_zscore(df, 'dst_host_same_src_port_rate')
encode_numeric_zscore(df, 'dst_host_srv_diff_host_rate')
encode_numeric_zscore(df, 'dst_host_serror_rate')
encode_numeric_zscore(df, 'dst_host_srv_serror_rate')
encode_numeric_zscore(df, 'dst_host_rerror_rate')
encode_numeric_zscore(df, 'dst_host_srv_rerror_rate')
outcomes = encode_text_index(df, 'outcome')
num_classes = len(outcomes)

# display 5 rows

df.dropna(inplace=True,axis=1)
df[0:5]
# This is the numeric feature vector, as it goes to the neural net
```

Out[6]:

	duration	src_bytes	dst_bytes	wrong_fragment	urgent	hot	num_failed_logins	nun
0	-0.067792	-0.002879	0.138664	-0.04772	-0.002571	-0.044136	-0.009782	
1	-0.067792	-0.002820	-0.011578	-0.04772	-0.002571	-0.044136	-0.009782	
2	-0.067792	-0.002824	0.014179	-0.04772	-0.002571	-0.044136	-0.009782	
3	-0.067792	-0.002840	0.014179	-0.04772	-0.002571	-0.044136	-0.009782	
4	-0.067792	-0.002842	0.035214	-0.04772	-0.002571	-0.044136	-0.009782	

5 rows × 121 columns

In [7]:

```
df1 = pd.read_csv("/Users/tsaiflow/Downloads/kddcup.data.corrected", head
print("Read {} rows.".format(len(df1)))
#print("Read {} rows.".format(len(df1)))
# df = df.sample(frac=0.1, replace=False) # Uncomment this line to sample
df1.dropna(inplace=True,axis=1) # For now, just drop NA's (rows with miss
# df1.dropna(inplace=True,axis=1)

# The CSV file has no column heads, so add them
df1.columns = [
    'duration',
    'protocol_type',
    'service',
    'flag',
    'src_bytes',
    'dst_bytes',
    'land',
    'wrong_fragment',
    'urgent',
    'hot',
    'num_failed_logins',
    'logged_in',
    'num_compromised',
    'root_shell',
    'su_attempted',
    'num_root',
    'num_file_creations',
    'num_shells',
    'num_access_files',
    'num_outbound_cmds',
    'is_host_login',
    'is_guest_login',

    'count',
    'srv_count',
    'serror_rate',
    'srv_serror_rate',
    'rerror_rate',
    'srv_rerror_rate',
    'same_srv_rate',
    'diff_srv_rate',
    'srv_diff_host_rate',
    'dst_host_count',
    'dst_host_srv_count',
    'dst_host_same_srv_rate',
    'dst_host_diff_srv_rate',
    'dst_host_same_src_port_rate',
    'dst_host_srv_diff_host_rate',
    'dst_host_serror_rate',
    'dst_host_srv_serror_rate',
    'dst_host_rerror_rate',
    'dst_host_srv_rerror_rate',

    'outcome'
]

# Now encode the feature vector

encode_numeric_zscore(df1, 'duration')
encode_text_dummy(df1, 'protocol_type')
encode_text_dummy(df1, 'service')
encode_text_dummy(df1, 'flag')
encode_numeric_zscore(df1, 'src_bytes')
encode_numeric_zscore(df1, 'dst_bytes')
encode_text_dummy(df1, 'land')
encode_numeric_zscore(df1, 'wrong_fragment')
encode_numeric_zscore(df1, 'urgent')
encode_numeric_zscore(df1, 'hot')
encode_numeric_zscore(df1, 'num_failed_logins')
encode_numeric_zscore(df1, 'num_failed_logins')
encode_text_dummy(df1, 'logged_in')
encode_numeric_zscore(df1, 'num_compromised')
encode_numeric_zscore(df1, 'root_shell')
encode_numeric_zscore(df1, 'su_attempted')
encode_numeric_zscore(df1, 'num_root')
encode_numeric_zscore(df1, 'num_file_creations')
encode_numeric_zscore(df1, 'num_shells')
encode_numeric_zscore(df1, 'num_access_files')
encode_numeric_zscore(df1, 'num_outbound_cmds')
encode_text_dummy(df1, 'is_host_login')
encode_text_dummy(df1, 'is_guest_login')
encode_numeric_zscore(df1, 'count')
encode_numeric_zscore(df1, 'srv_count')
encode_numeric_zscore(df1, 'serror_rate')
encode_numeric_zscore(df1, 'srv_serror_rate')
encode_numeric_zscore(df1, 'rerror_rate')
encode_numeric_zscore(df1, 'srv_rerror_rate')
encode_numeric_zscore(df1, 'same_srv_rate')
encode_numeric_zscore(df1, 'diff_srv_rate')
encode_numeric_zscore(df1, 'srv_diff_host_rate')
encode_numeric_zscore(df1, 'dst_host_count')
encode_numeric_zscore(df1, 'dst_host_srv_count')
encode_numeric_zscore(df1, 'dst_host_same_srv_rate')
encode_numeric_zscore(df1, 'dst_host_diff_srv_rate')
encode_numeric_zscore(df1, 'dst_host_same_src_port_rate')
encode_numeric_zscore(df1, 'dst_host_srv_diff_host_rate')
encode_numeric_zscore(df1, 'dst_host_serror_rate')
encode_numeric_zscore(df1, 'dst_host_srv_serror_rate')
encode_numeric_zscore(df1, 'dst_host_rerror_rate')
encode_numeric_zscore(df1, 'dst_host_srv_rerror_rate')
outcomes = encode_text_index(df1, 'outcome')
num_classes = len(outcomes)

# display 5 rows

df1.dropna(inplace=True,axis=1)
del df1['service-aol']
del df1['service-harvest']
del df1['service-http_2784']
del df1['service-http_8001']
del df1['is_host_login-1']
df1[0:5]
# This is the numeric feature vector, as it goes to the neural net
```

```
Read 4898431 rows.
```

Out[7]:

	duration	src_bytes	dst_bytes	wrong_fragment	urgent	hot	num_failed_logins	nun
0	-0.066833	-0.001720	0.068188	-0.015139	-0.001103	-0.026521	-0.004391	

1	-0.066833	-0.001777	0.005325	-0.015139	-0.001103	-0.026521	-0.004391
2	-0.066833	-0.001698	0.000208	-0.015139	-0.001103	-0.026521	-0.004391
3	-0.066833	-0.001701	0.001455	-0.015139	-0.001103	-0.026521	-0.004391
4	-0.066833	-0.001695	-0.000942	-0.015139	-0.001103	-0.026521	-0.004391

5 rows × 121 columns

In [8]:

```
import numpy
from pandas import read_csv
from sklearn.decomposition import PCA
# load data

array_outcome_whole = df1[['outcome']].values
array_outcome_whole[array_outcome_whole!=11] = 1
array_outcome_whole[array_outcome_whole==11] = 0

del df1['outcome']

X_whole = df1.values
Y_whole = array_outcome_whole
```

In [9]:

```
array_outcome = df[['outcome']].values
array_outcome[array_outcome!=11] = 1
array_outcome[array_outcome==11] = 0

del df['outcome']

X = df.values
Y = array_outcome
print(np.shape(X),np.shape(Y))
```

```
(494021, 120) (494021, 1)
```

In [10]:

```
# ######################
# #########PCA##########
# ######################

# # feature extraction
# pca = PCA(n_components=20)
# fit = pca.fit(X.T)
# # summarize components
# print(("Explained Variance: %s") % fit.explained_variance_ratio_)
# print(np.shape(fit.components_.T))
# X = fit.components_.T
# # print(fit.components_)
```

In [11]:

```
import keras.backend as K
K.clear_session()
```

In [12]:

```
# Break into X (predictors) & y (prediction)
# Create a test/train split.  25% test
# Split into train/test

x_train, x_test, y_train, y_test = train_test_split(
    X, Y, test_size=0.25)
```

In [13]:

```
# Create neural net
model = Sequential()

# Used relu for activation function
model.add(Dense(10, input_dim=X.shape[1], kernel_initializer='normal', ac
model.add(Dense(50, input_dim=X.shape[1], kernel_initializer='normal', ac
model.add(Dense(10, input_dim=X.shape[1], kernel_initializer='normal', ac

# output layer
model.add(Dense(1, kernel_initializer='normal'))
# model.add(Dense(y.shape[1],activation='softmax'))
model.add(Dense(1,activation = 'sigmoid'))
```

In [14]:

```
# TODO:  Print the model summary
model.summary()
```

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #   
=================================================================
dense_1 (Dense)              (None, 10)                1210      
_________________________________________________________________
dense_2 (Dense)              (None, 50)                550       
_________________________________________________________________
dense_3 (Dense)              (None, 10)                510       
_________________________________________________________________
dense_4 (Dense)              (None, 1)                 11        
_________________________________________________________________
dense_5 (Dense)              (None, 1)                 2         
=================================================================
Total params: 2,283
Trainable params: 2,283
Non-trainable params: 0
_________________________________________________________________
```

In [15]:

```
class LossHistory(keras.callbacks.Callback):
    def on_train_begin(self, logs={}):
        # TODO:  Create two empty lists, self.loss and self.val_acc
        self.losses = []
        self.accs = []
        self.val_acc = []
        self.val_loss = []
    def on_batch_end(self, batch, logs={}):
        # TODO:  This is called at the end of each batch.
        # Add the loss in logs.get('loss') to the loss list
        loss = logs.get('loss')
        acc = logs.get('acc')
        self.losses.append(loss)
        self.accs.append(acc)
    def on_epoch_end(self, epoch, logs):
        # TODO:  This is called at the end of each epoch.
        # Add the test accuracy in logs.get('loss') to the val_acc list
        val_acc = logs.get('val_acc')
        val_loss = logs.get('val_loss')
        self.val_acc.append(val_acc)
        self.val_loss.append(val_loss)

# Create an instance of the history callback
history_cb = LossHistory()
```

In [16]:

```
from keras import optimizers

# optimizer defined
opt = optimizers.Adam(lr=0.001, beta_1=0.9, beta_2=0.999, epsilon=1e-08,
```

In [17]:

```
## compile model
model.compile(optimizer=opt,
              loss='binary_crossentropy',
              metrics=['accuracy'])
```

In [18]:

```
batch_size = 100
epochs = 5
model.fit(x_train,y_train,callbacks=[history_cb],validation_data=(x_test,
```

```
Train on 370515 samples, validate on 123506 samples
Epoch 1/5
370515/370515 [==============================] - 13s - loss: 0.0206 -
acc: 0.9951 - val_loss: 0.0048 - val_acc: 0.9982
Epoch 2/5
370515/370515 [==============================] - 16s - loss: 0.0039 -
acc: 0.9987 - val_loss: 0.0034 - val_acc: 0.9990
Epoch 3/5
370515/370515 [==============================] - 18s - loss: 0.0032 -
acc: 0.9992 - val_loss: 0.0033 - val_acc: 0.9990
Epoch 4/5
370515/370515 [==============================] - 22s - loss: 0.0027 -
acc: 0.9993 - val_loss: 0.0030 - val_acc: 0.9992
Epoch 5/5
370515/370515 [==============================] - 21s - loss: 0.0026 -
acc: 0.9993 - val_loss: 0.0027 - val_acc: 0.9993
```

Out[18]:

```
<keras.callbacks.History at 0x1277d7c50>
```

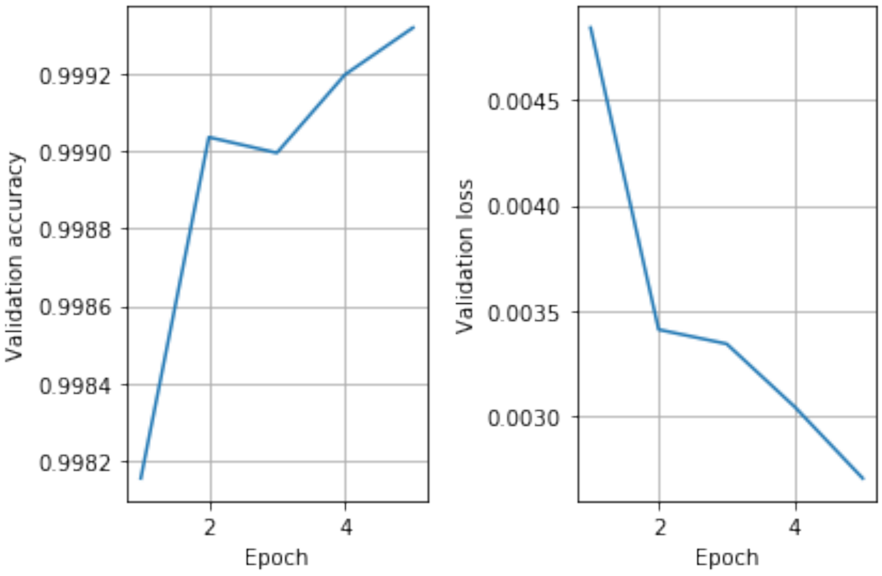
In [19]:

```
yhat = model.predict(x_test)
yhat[yhat>0.5] = 1
yhat[yhat<=0.5] = 0
count = 0
yhat_size = np.shape(yhat)[0]

for i in range (yhat_size):
    if yhat[i] != y_test[i]:
        count = count + 1
print("Accuracy is: %s" %(1-count/yhat_size))
print("# of wrongly classified: %s" %(count))
```

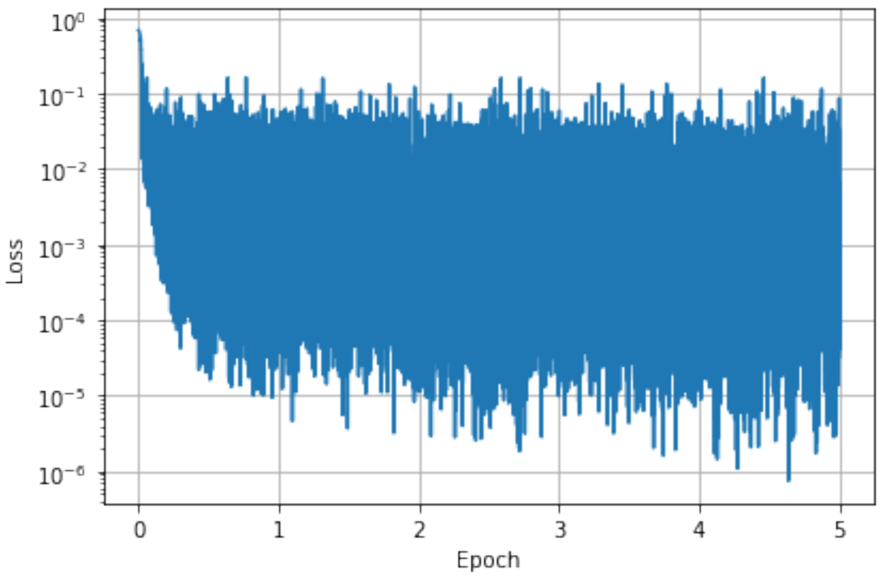
```
Accuracy is: 0.9993198710993798
# of wrongly classified: 84
```

In [20]:
```
valAcc = history_cb.val_acc
valLoss = history_cb.val_loss
epoch_it = np.arange(1,6)
plt.subplot(121)
plt.plot(epoch_it, valAcc)
plt.grid()
plt.xlabel('Epoch')
plt.ylabel('Validation accuracy')
plt.tight_layout()
plt.subplot(122)
plt.plot(epoch_it, valLoss)
plt.grid()
plt.xlabel('Epoch')
plt.ylabel('Validation loss')
plt.tight_layout()
plt.show()
```

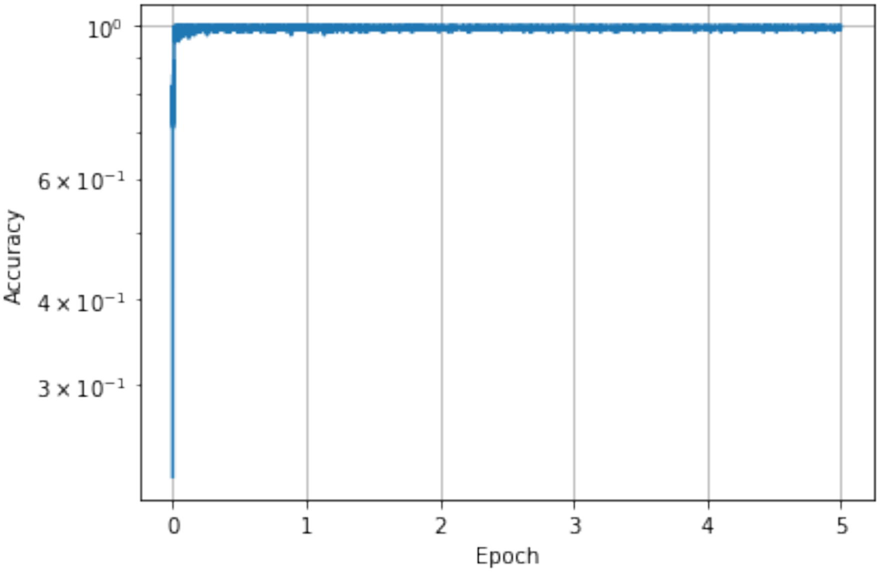


In [21]:
```
Ls = history_cb.losses
Acc = history_cb.accs
ntr = np.shape(x_train)[0]
epochNum = []
for i in range(18530):
    epochNum.append(i*100/ntr)

matplotlib.pyplot.semilogy(epochNum, Ls)
plt.grid()
plt.xlabel('Epoch')
plt.ylabel('Loss')
plt.tight_layout()
plt.show()
```



In [22]:
```
matplotlib.pyplot.semilogy(epochNum, Acc)
# plt.plot(epochNum, Acc)
plt.grid()
plt.xlabel('Epoch')
plt.ylabel('Accuracy')
plt.tight_layout()
# plt.axis([0.3,3,0.96,1])
plt.show()
```



In [23]:
```
##################
#####details######
##################
```

In [24]:
```
from sklearn.metrics import classification_report,confusion_matrix
```

In [25]:
```
y_pred_whole = model.predict_classes(x_test,verbose=1)
#print(y_pred_whole[:5])
```

```
4898431/4898431 [==============================] - 232s
```

In [26]:

```
# yhat[yhat>0.5] = 1
# yhat[yhat<=0.5] = 0
count = 0
yhat_size = np.shape(y_pred_whole)[0]

for i in range (yhat_size):
    if y_pred_whole[i] != y_test[i]:
        count = count + 1
print("Accuracy is: %s" %(1-count/yhat_size))
print("# of wrongly classified: %s" %(count))
```

```
Accuracy is: 0.9994051156380482
# of wrongly classified: 2914
```

In [27]:

```
print(classification_report(Y_whole, y_pred_whole))
```

```
             precision    recall  f1-score   support

          0       1.00      1.00      1.00    972781
          1       1.00      1.00      1.00   3925650

avg / total       1.00      1.00      1.00   4898431
```

In [28]:

```
Cm = confusion_matrix(Y_whole,y_pred_whole)
C = np.sum(Cm)
Cm = Cm/C
print('Confusion Matrix:')
print(np.array_str(Cm, precision=4, suppress_small=True))
```

```
Confusion Matrix:
[[ 0.1982  0.0004]
 [ 0.0002  0.8012]]
```