In [1]:
```
! wget --header="Host: archive.ics.uci.edu" --header="User-Agent: Mozilla/5.0
 (Windows NT 10.0; Win64; x64) AppleWebKit/537.36 (KHTML, like Gecko) Chrome/7
 .0.3626.81 Safari/537.36" --header="Accept: text/html,application/xhtml+xml,a
 plication/xml;q=0.9,image/webp,image/apng,*/*;q=0.8" "https://archive.ics.uc
 .edu/ml/machine-learning-databases/00463/XOR_Arbiter_PUFs.zip" -O "XOR_Arbite
 _PUFs.zip" -c
```

```
--2019-02-06 06:42:37--  https://archive.ics.uci.edu/ml/machine-learning-data
 ases/00463/XOR_Arbiter_PUFs.zip
 esolving archive.ics.uci.edu (archive.ics.uci.edu)... 128.195.10.249
 onnecting to archive.ics.uci.edu (archive.ics.uci.edu)|128.195.10.249|:44
 ... connected.
 TTP request sent, awaiting response... 200 OK
 ength: 159800482 (152M) [application/zip]
 aving to: ‘XOR_Arbiter_PUFs.zip’

 OR_Arbiter_PUFs.zi 100%[===================>] 152.40M  40.6MB/s    in 6.5s

 019-02-06 06:42:49 (23.3 MB/s) - ‘XOR_Arbiter_PUFs.zip’ saved [159800482/159
 00482]
```

In [2]:
```
!unzip 'XOR_Arbiter_PUFs.zip'
```

```
 rchive:  XOR_Arbiter_PUFs.zip
   creating: XOR_Arbiter_PUFs/
  inflating: XOR_Arbiter_PUFs/.DS_Store
   creating: XOR_Arbiter_PUFs/5xor_128bit/
  inflating: XOR_Arbiter_PUFs/5xor_128bit/.DS_Store
  inflating: XOR_Arbiter_PUFs/5xor_128bit/README.txt
  inflating: XOR_Arbiter_PUFs/5xor_128bit/test_5xor_128dim.csv
  inflating: XOR_Arbiter_PUFs/5xor_128bit/train_5xor_128dim.csv
   creating: XOR_Arbiter_PUFs/6xor_64bit/
  inflating: XOR_Arbiter_PUFs/6xor_64bit/.DS_Store
  inflating: XOR_Arbiter_PUFs/6xor_64bit/README.txt
  inflating: XOR_Arbiter_PUFs/6xor_64bit/test_6xor_64dim.csv
  inflating: XOR_Arbiter_PUFs/6xor_64bit/train_6xor_64dim.csv
   creating: __MACOSX/
   creating: __MACOSX/XOR_Arbiter_PUFs/
  inflating: __MACOSX/XOR_Arbiter_PUFs/._.DS_Store
   creating: __MACOSX/XOR_Arbiter_PUFs/5xor_128bit/
  inflating: __MACOSX/XOR_Arbiter_PUFs/5xor_128bit/._.DS_Store
  inflating: __MACOSX/XOR_Arbiter_PUFs/5xor_128bit/._README.txt
  inflating: __MACOSX/XOR_Arbiter_PUFs/5xor_128bit/._test_5xor_128dim.csv
   creating: __MACOSX/XOR_Arbiter_PUFs/6xor_64bit/
  inflating: __MACOSX/XOR_Arbiter_PUFs/6xor_64bit/._.DS_Store
  inflating: __MACOSX/XOR_Arbiter_PUFs/6xor_64bit/._README.txt
```

In [66]:
```
mport pandas as pd
_train = pd.read_csv(r'./XOR_Arbiter_PUFs/6xor_64bit/train_6xor_64dim.csv',he
der = None)
_train.head()
```

Out[66]:

	0	1	2	3	4	5	6	7	8	9	...	55	56	57	58	59	60	61	62	63	64
0	1	1	-1	1	-1	-1	-1	1	1	-1	...	1	1	1	1	1	1	1	1	-1	1
1	-1	1	1	1	1	1	1	1	-1	-1	...	-1	1	-1	1	-1	1	1	-1	1	-1
2	-1	-1	1	1	-1	1	1	1	1	-1	...	1	-1	1	-1	1	-1	-1	-1	1	1
3	1	-1	-1	1	-1	1	1	1	-1	1	...	1	-1	1	-1	1	-1	-1	1	-1	-1
4	1	1	1	-1	-1	-1	-1	1	1	-1	...	-1	1	-1	1	-1	1	-1	-1	1	1

5 rows × 65 columns

In [0]:
```
rom keras.utils import np_utils
rom keras.initializers import he_normal
mport seaborn as sns
rom keras.models import Sequential
rom keras.layers import Dense , Activation
rom keras import optimizers
```

In [0]:
```
 X_train = X_train.replace([-1],0)
```

In [69]:
```
_train.describe()
```

Out[69]:

	0	1	2	3	4	
count	2.000000e+06	2.000000e+06	2.000000e+06	2.000000e+06	2.000000e+06	2.000
mean	1.158000e-03	9.120000e-04	4.270000e-04	-1.580000e-04	-1.760000e-04	-3.02
std	9.999996e-01	9.999998e-01	1.000000e+00	1.000000e+00	1.000000e+00	1.000
min	-1.000000e+00	-1.000000e+00	-1.000000e+00	-1.000000e+00	-1.000000e+00	-1.00
25%	-1.000000e+00	-1.000000e+00	-1.000000e+00	-1.000000e+00	-1.000000e+00	-1.00
50%	1.000000e+00	1.000000e+00	1.000000e+00	-1.000000e+00	-1.000000e+00	-1.00
75%	1.000000e+00	1.000000e+00	1.000000e+00	1.000000e+00	1.000000e+00	1.000
max	1.000000e+00	1.000000e+00	1.000000e+00	1.000000e+00	1.000000e+00	1.000

8 rows × 65 columns

In [70]:
```
_train.shape
```

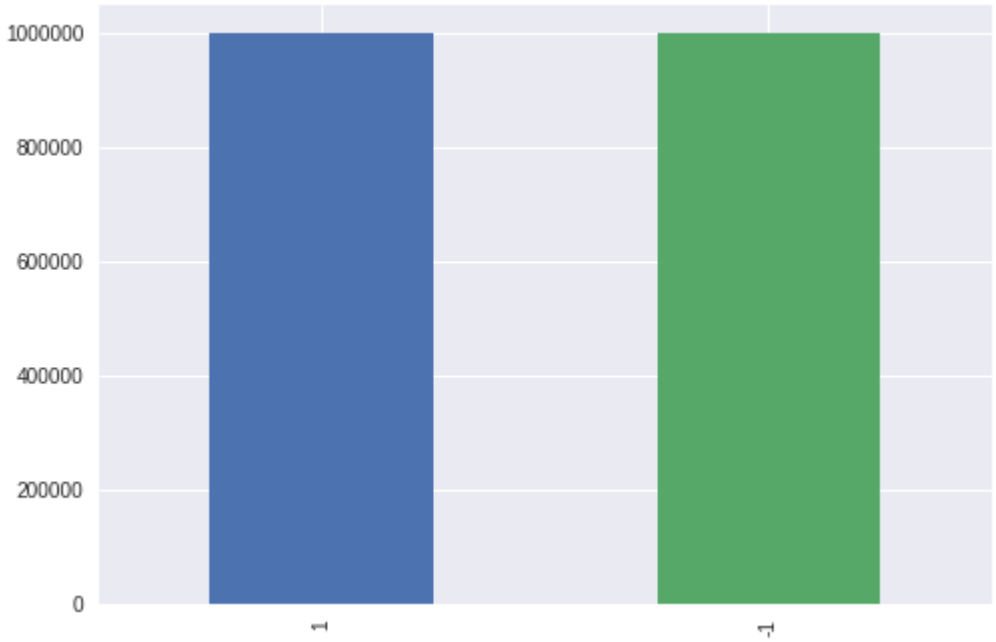
Out[70]: (2000000, 65)

In [0]:
```
istrb = X_train.iloc[:,64].value_counts()
```

In [0]:
```
mport matplotlib.pyplot as plt
```

In [73]:
```
istrb.plot(kind = 'bar')
```

Out[73]: <matplotlib.axes._subplots.AxesSubplot at 0x7f93a549ef60>



In [74]:
```
mport numpy as np
_train.isnull().values.any()
```

Out[74]: False

In [0]:
```
_train = X_train[[64]]
```

In [0]:
```
_train.drop([64],axis = 1,inplace = True)
```

In [77]:
```
_train.shape
```

Out[77]: (2000000, 64)

In [78]:
```
mport pandas as pd
_test = pd.read_csv(r'./XOR_Arbiter_PUFs/6xor_64bit/test_6xor_64dim.csv',head
r = None)
_test.head()
```

Out[78]:

	0	1	2	3	4	5	6	7	8	9	...	55	56	57	58	59	60	61	62	63	64
0	-1	-1	1	1	-1	1	1	1	1	-1	...	-1	-1	-1	-1	-1	-1	-1	-1	1	-1
1	1	1	-1	1	-1	-1	1	1	-1	1	...	-1	-1	-1	-1	-1	-1	1	1	-1	1
2	1	1	1	-1	1	1	-1	1	-1	1	...	-1	-1	-1	-1	-1	-1	1	1	1	1
3	1	-1	1	-1	-1	-1	-1	-1	-1	1	...	1	1	1	1	1	1	1	1	1	1
4	1	-1	1	-1	1	-1	-1	1	1	1	...	1	1	1	1	1	1	1	1	1	-1

5 rows × 65 columns

In [0]:
```
 X_test = X_test.replace([-1],0)
```

In [80]:
```
mport numpy as np
_test.isnull().values.any()
```

Out[80]: False

In [0]:
```
_test = X_test[[64]]
```

In [0]:
```
_test.drop([64],axis = 1,inplace = True)
```

In [83]:
```
_test.shape
```

Out[83]: (400000, 64)

In [0]:
```
_train = np_utils.to_categorical(Y_train, 2)
_test = np_utils.to_categorical(Y_test, 2)
```

In [0]:
```
epoch = 30
utlayer = 2
atch_size = 10000
```

In [91]:
```
rom keras.layers.normalization import BatchNormalization
rom keras.layers import Dropout
rom keras.layers.merge import concatenate
rom keras.utils import plot_model
rom keras.layers import Input
rom keras.models import Model

nput_layer = Input(shape = (64,))

ut1 = Dense(64,activation = 'relu')(input_layer)
ut1 = Dropout(0.5)(out1)
ut1 = BatchNormalization()(out1)

ut2 = Dense(64,activation = 'relu')(input_layer)
ut2 = Dropout(0.5)(out2)
ut2 = BatchNormalization()(out2)

ut3 = Dense(64,activation = 'relu')(input_layer)
ut3 = Dropout(0.5)(out3)
ut3 = BatchNormalization()(out3)

erge = concatenate([out1,out2,out3])

utput = Dense(2,activation = 'sigmoid')(merge)

odel = Model(inputs=input_layer, outputs=output)
 summarize layers
rint(model.summary())

 plot graph
lot_model(model, to_file='MODEL.png')

dam = optimizers.Adam(lr = 0.001)
odel.compile(loss='binary_crossentropy', optimizer = adam, metrics=['accurac
']
```

```
_________________________________________________________________
_____________________
 ayer (type)                 Output Shape              Param #     Connected to
=================================================================
=====================
 nput_11 (InputLayer)        (None, 64)                0
_________________________________________________________________
_____________________
 ense_41 (Dense)             (None, 64)                4160        input_11[0]
 0]
_________________________________________________________________
_____________________
 ense_42 (Dense)             (None, 64)                4160        input_11[0]
 0]
_________________________________________________________________
_____________________
 ense_43 (Dense)             (None, 64)                4160        input_11[0]
 0]
_________________________________________________________________
_____________________
 ropout_9 (Dropout)          (None, 64)                0           dense_41[0]
 0]
_________________________________________________________________
_____________________
 ropout_10 (Dropout)         (None, 64)                0           dense_42[0]
 0]
_________________________________________________________________
_____________________
 ropout_11 (Dropout)         (None, 64)                0           dense_43[0]
 0]
_________________________________________________________________
_____________________
 atch_normalization_1 (BatchNor (None, 64)             256         dropout_9[0]
 0]
_________________________________________________________________
_____________________
 atch_normalization_2 (BatchNor (None, 64)             256         dropout_10
 0][0]
_________________________________________________________________
_____________________
 atch_normalization_3 (BatchNor (None, 64)             256         dropout_11
 0][0]
_________________________________________________________________
_____________________
 oncatenate_11 (Concatenate)    (None, 192)           0           batch_normal
 zation_1[0][0]
                                                                  batch_normal
 zation_2[0][0]
                                                                  batch_normal
 zation_3[0][0]
_________________________________________________________________
_____________________
 ense_44 (Dense)             (None, 2)                 386         concatenate_
 1[0][0]
=================================================================
=====================
 otal params: 13,634
```

```
rainable params: 13,250
on-trainable params: 384
_________________________________________________________________
_________________
one
```

In [92]:
```
ist = model.fit(X_train, y_train, epochs=nepoch, batch_size=batch_size,valida
ion_data = (X_test,y_test))
 Final evaluation of the model
cores = model.evaluate(X_test, y_test, verbose=0)
rint("Accuracy: %.2f%%" % (scores[1]*100))
```

```
rain on 2000000 samples, validate on 400000 samples
poch 1/30
000000/2000000 [==============================] - 30s 15us/step - loss: 0.29
1 - acc: 0.8695 - val_loss: 0.0094 - val_acc: 1.0000
poch 2/30
000000/2000000 [==============================] - 28s 14us/step - loss: 0.01
6 - acc: 0.9998 - val_loss: 0.0012 - val_acc: 1.0000
poch 3/30
000000/2000000 [==============================] - 28s 14us/step - loss: 0.00
9 - acc: 1.0000 - val_loss: 4.4878e-04 - val_acc: 1.0000
poch 4/30
000000/2000000 [==============================] - 28s 14us/step - loss: 0.00
4 - acc: 1.0000 - val_loss: 2.2683e-04 - val_acc: 1.0000
poch 5/30
000000/2000000 [==============================] - 29s 15us/step - loss: 7.89
8e-04 - acc: 1.0000 - val_loss: 1.3536e-04 - val_acc: 1.0000
poch 6/30
000000/2000000 [==============================] - 28s 14us/step - loss: 5.15
6e-04 - acc: 1.0000 - val_loss: 8.9262e-05 - val_acc: 1.0000
poch 7/30
000000/2000000 [==============================] - 28s 14us/step - loss: 3.62
0e-04 - acc: 1.0000 - val_loss: 6.2621e-05 - val_acc: 1.0000
poch 8/30
000000/2000000 [==============================] - 28s 14us/step - loss: 2.64
7e-04 - acc: 1.0000 - val_loss: 4.6066e-05 - val_acc: 1.0000
poch 9/30
000000/2000000 [==============================] - 27s 14us/step - loss: 2.02
0e-04 - acc: 1.0000 - val_loss: 3.5049e-05 - val_acc: 1.0000
poch 10/30
000000/2000000 [==============================] - 28s 14us/step - loss: 1.59
5e-04 - acc: 1.0000 - val_loss: 2.7222e-05 - val_acc: 1.0000
poch 11/30
000000/2000000 [==============================] - 28s 14us/step - loss: 1.26
9e-04 - acc: 1.0000 - val_loss: 2.1630e-05 - val_acc: 1.0000
poch 12/30
000000/2000000 [==============================] - 28s 14us/step - loss: 1.02
6e-04 - acc: 1.0000 - val_loss: 1.7446e-05 - val_acc: 1.0000
poch 13/30
000000/2000000 [==============================] - 28s 14us/step - loss: 8.36
0e-05 - acc: 1.0000 - val_loss: 1.4305e-05 - val_acc: 1.0000
poch 14/30
000000/2000000 [==============================] - 28s 14us/step - loss: 7.01
9e-05 - acc: 1.0000 - val_loss: 1.1810e-05 - val_acc: 1.0000
poch 15/30
000000/2000000 [==============================] - 28s 14us/step - loss: 5.87
9e-05 - acc: 1.0000 - val_loss: 9.8847e-06 - val_acc: 1.0000
poch 16/30
000000/2000000 [==============================] - 29s 14us/step - loss: 4.96
9e-05 - acc: 1.0000 - val_loss: 8.3016e-06 - val_acc: 1.0000
poch 17/30
000000/2000000 [==============================] - 28s 14us/step - loss: 4.20
8e-05 - acc: 1.0000 - val_loss: 7.0298e-06 - val_acc: 1.0000
poch 18/30
000000/2000000 [==============================] - 28s 14us/step - loss: 3.61
6e-05 - acc: 1.0000 - val_loss: 5.9908e-06 - val_acc: 1.0000
poch 19/30
000000/2000000 [==============================] - 28s 14us/step - loss: 3.10
```

```
9e-05 - acc: 1.0000 - val_loss: 5.1543e-06 - val_acc: 1.0000
poch 20/30
000000/2000000 [==============================] - 28s 14us/step - loss: 2.68
8e-05 - acc: 1.0000 - val_loss: 4.4315e-06 - val_acc: 1.0000
poch 21/30
000000/2000000 [==============================] - 28s 14us/step - loss: 2.33
4e-05 - acc: 1.0000 - val_loss: 3.8321e-06 - val_acc: 1.0000
poch 22/30
000000/2000000 [==============================] - 28s 14us/step - loss: 2.02
6e-05 - acc: 1.0000 - val_loss: 3.3260e-06 - val_acc: 1.0000
poch 23/30
000000/2000000 [==============================] - 28s 14us/step - loss: 1.76
5e-05 - acc: 1.0000 - val_loss: 2.8841e-06 - val_acc: 1.0000
poch 24/30
000000/2000000 [==============================] - 28s 14us/step - loss: 1.54
5e-05 - acc: 1.0000 - val_loss: 2.5205e-06 - val_acc: 1.0000
poch 25/30
000000/2000000 [==============================] - 28s 14us/step - loss: 1.35
1e-05 - acc: 1.0000 - val_loss: 2.2010e-06 - val_acc: 1.0000
poch 26/30
000000/2000000 [==============================] - 28s 14us/step - loss: 1.19
0e-05 - acc: 1.0000 - val_loss: 1.9307e-06 - val_acc: 1.0000
poch 27/30
000000/2000000 [==============================] - 29s 14us/step - loss: 1.05
3e-05 - acc: 1.0000 - val_loss: 1.6964e-06 - val_acc: 1.0000
poch 28/30
000000/2000000 [==============================] - 28s 14us/step - loss: 9.25
6e-06 - acc: 1.0000 - val_loss: 1.4888e-06 - val_acc: 1.0000
poch 29/30
000000/2000000 [==============================] - 28s 14us/step - loss: 8.25
6e-06 - acc: 1.0000 - val_loss: 1.3121e-06 - val_acc: 1.0000
poch 30/30
000000/2000000 [==============================] - 28s 14us/step - loss: 7.25
4e-06 - acc: 1.0000 - val_loss: 1.1546e-06 - val_acc: 1.0000
ccuracy: 100.00%
```

In [0]:

```
def plt_dynamic(x, vy, ty):
 plt.figure(figsize=(10,5))
 plt.plot(x, vy, 'b', label="Validation Loss")
 plt.plot(x, ty, 'r', label="Train Loss")
 plt.xlabel('Epochs')
 plt.ylabel('Binary Crossentropy Loss')
 plt.title('\nBinary Crossentropy Loss VS Epochs')
 plt.legend()
 plt.grid()
 plt.show()
```

In [94]:
```
mport matplotlib.pyplot as plt
 = list(range(1,31))
y = hist.history['val_loss']
y = hist.history['loss']
lt_dynamic(x, vy, ty)
```