In [25]:

```
# Load CIFAR-10 data set
from keras.datasets import cifar10
(X_train, y_train), (X_test, y_test) = cifar10.load_data()
```

In [26]:

```
# Show examples from each class
import numpy as np
import matplotlib.pyplot as plt
import pandas as pd

num_classes = len(np.unique(y_train))
class_names = ['airplane','automobile','bird','cat','deer','dog','frog','horse','shi
fig = plt.figure(figsize=(8,3))
for i in range(num_classes):
    ax = fig.add_subplot(2, 5, 1 + i, xticks=[], yticks=[])
    ax.set_title(class_names[i])
    idx = np.where(y_train[:]==i)[0]
    features_idx = X_train[idx,::]
    rnd_img = np.random.randint(features_idx.shape[0])
    im = np.transpose(features_idx[rnd_img,::], (0, 1, 2))
    plt.imshow(im)
plt.show()
```

In [27]:

```
# Data pre-processing
X_train = X_train.astype('float32')
X_test = X_test.astype('float32')
X_train /= 255.0
X_test /= 255.0

from keras.utils import np_utils
Y_train = np_utils.to_categorical(y_train, num_classes)
Y_test = np_utils.to_categorical(y_test, num_classes)
```

In [28]:

```
def plot_model_history(model_history):
    fig, axs = plt.subplots(1,2,figsize=(15,5))
    # Summarize history for accuracy
    axs[0].plot(range(1,len(model_history.history['accuracy'])+1),model_history.hist
    axs[0].plot(range(1,len(model_history.history['val_accuracy'])+1),model_history.
    axs[0].set_ylim(0, 1)
    axs[0].set_title('Model Accuracy')
    axs[0].set_ylabel('Accuracy')
    axs[0].set_xlabel('Epoch')
    axs[0].set_xticks(np.arange(1,len(model_history.history['accuracy'])+1,step=len(
```

```
    axs[0].legend(['train', 'val'], loc='best')
    # summarize history for loss
    axs[1].plot(range(1,len(model_history.history['loss'])+1),model_history.history[
    axs[1].plot(range(1,len(model_history.history['val_loss'])+1),model_history.hist
    axs[1].set_title('Model Loss')
    axs[1].set_ylabel('Loss')
    axs[1].set_xlabel('Epoch')
    axs[1].set_xticks(np.arange(1,len(model_history.history['loss'])+1,step=len(mode
    axs[1].legend(['train', 'val'], loc='best')
    plt.show()
```

In [29]:

```
# Feed forward dense model
# Here it is not allowed to use convolutional layers
# You may use any regularizacion (see class slides)

from keras.models import Sequential
from keras.layers import Dense, Dropout, Activation, Flatten, BatchNormalization
from keras import optimizers
from keras.callbacks import EarlyStopping
from keras.regularizers import l2

learning_rate=0.001
epochs=1000
batch_size=512
es = EarlyStopping(monitor='val_loss', mode='min', verbose=1, patience=int(epochs*0.
p_dropout=0.2

# model.add(Dense(500, activation="relu", kernel_initializer="he_normal"))

model = Sequential()
model.add(Flatten(input_shape=(32, 32, 3)))
model.add(Dense(200, activation="relu"))
model.add(Dropout(rate=p_dropout))
model.add(BatchNormalization())
model.add(Dense(200, activation="relu"))
model.add(Dropout(rate=p_dropout))
model.add(BatchNormalization())
model.add(Dense(150, activation="relu"))
model.add(Dropout(rate=p_dropout))
model.add(BatchNormalization())
model.add(Dense(150, activation="relu"))
model.add(Dropout(rate=p_dropout))
model.add(BatchNormalization())
model.add(Dense(100, activation="relu"))
model.add(Dropout(rate=p_dropout))
model.add(BatchNormalization())
model.add(Dense(num_classes, activation='softmax'))

opt = optimizers.SGD(lr=learning_rate, momentum=0.9, nesterov=True)
# opt = optimizers.Adam(lr=learning_rate, beta_1=0.9, beta_2=0.999)


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

```
Model: "sequential_3"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
flatten_3 (Flatten)          (None, 3072)              0
```

```
dense_18 (Dense)             (None, 200)               614600
_________________________________________________________________
dropout_15 (Dropout)         (None, 200)               0
_________________________________________________________________
batch_normalization_15 (Batc (None, 200)               800
_________________________________________________________________
dense_19 (Dense)             (None, 200)               40200
_________________________________________________________________
dropout_16 (Dropout)         (None, 200)               0
_________________________________________________________________
batch_normalization_16 (Batc (None, 200)               800
_________________________________________________________________
dense_20 (Dense)             (None, 150)               30150
_________________________________________________________________
dropout_17 (Dropout)         (None, 150)               0
_________________________________________________________________
batch_normalization_17 (Batc (None, 150)               600
_________________________________________________________________
dense_21 (Dense)             (None, 150)               22650
_________________________________________________________________
dropout_18 (Dropout)         (None, 150)               0
_________________________________________________________________
batch_normalization_18 (Batc (None, 150)               600
_________________________________________________________________
dense_22 (Dense)             (None, 100)               15100
_________________________________________________________________
dropout_19 (Dropout)         (None, 100)               0
_________________________________________________________________
batch_normalization_19 (Batc (None, 100)               400
_________________________________________________________________
dense_23 (Dense)             (None, 10)                1010
=================================================================
Total params: 726,910
Trainable params: 725,310
Non-trainable params: 1,600
_________________________________________________________________
```

In [30]:

```
# Training
import time
start = time.time()
history = model.fit(X_train, Y_train, batch_size=batch_size, epochs=epochs, verbose=
end = time.time()
```

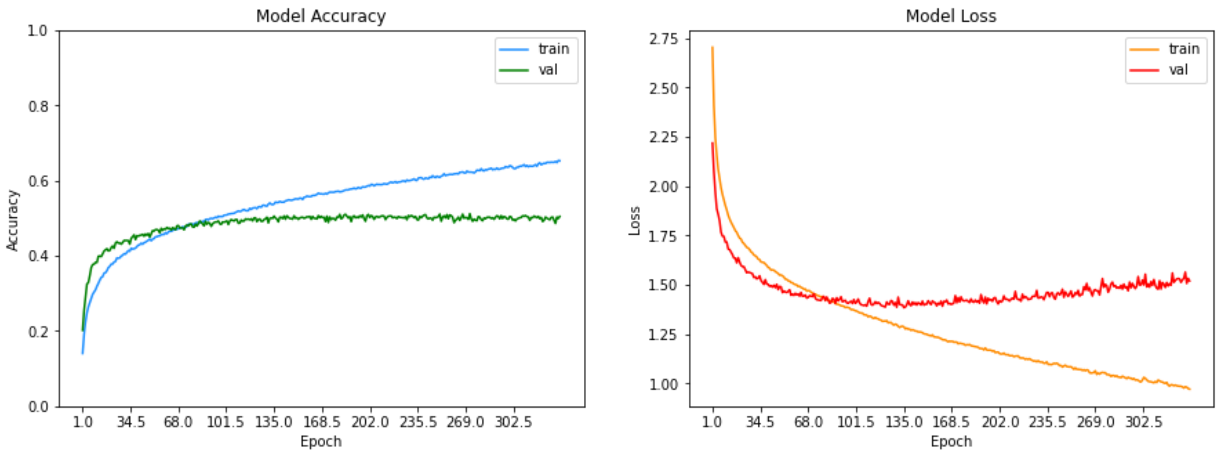
```
Epoch 1/1000
98/98 [==============================] - 2s 13ms/step - loss: 2.8288 - accuracy: 0.1
219 - val_loss: 2.2182 - val_accuracy: 0.2020
Epoch 2/1000
98/98 [==============================] - 1s 9ms/step - loss: 2.4514 - accuracy: 0.18
24 - val_loss: 2.0735 - val_accuracy: 0.2550
Epoch 3/1000
98/98 [==============================] - 1s 9ms/step - loss: 2.2851 - accuracy: 0.21
59 - val_loss: 1.9689 - val_accuracy: 0.2917
Epoch 4/1000
98/98 [==============================] - 1s 10ms/step - loss: 2.1777 - accuracy: 0.2
423 - val_loss: 1.8853 - val_accuracy: 0.3249
Epoch 5/1000
98/98 [==============================] - 1s 11ms/step - loss: 2.0893 - accuracy: 0.2
611 - val_loss: 1.8571 - val_accuracy: 0.3289
Epoch 6/1000
98/98 [==============================] - 1s 11ms/step - loss: 2.0402 - accuracy: 0.2
742 - val_loss: 1.8236 - val_accuracy: 0.3469
Epoch 7/1000
98/98 [==============================] - 1s 10ms/step - loss: 2.0037 - accuracy: 0.2
```

```
548 - val_loss: 1.5638 - val_accuracy: 0.4862
Epoch 333/1000
98/98 [==============================] - 1s 11ms/step - loss: 0.9789 - accuracy: 0.6
465 - val_loss: 1.5065 - val_accuracy: 0.5032
Epoch 334/1000
98/98 [==============================] - 1s 10ms/step - loss: 0.9628 - accuracy: 0.6
582 - val_loss: 1.5324 - val_accuracy: 0.4995
Epoch 335/1000
98/98 [==============================] - 1s 10ms/step - loss: 0.9667 - accuracy: 0.6
546 - val_loss: 1.5191 - val_accuracy: 0.5047
Epoch 00335: early stopping
```

Definición de una red convolucional multicapa

In [31]:

```
plot_model_history(history)
print("Training MLP took " + str(end - start) + " seconds")
```




```
Training MLP took 335.1605944633484 seconds
```

In [33]:

```
loss, acc = model.evaluate(X_test, Y_test, verbose=0)
print('Test loss:', loss)
print('Test accuracy:', acc)
```

```
Test loss: 1.503757273864746
Test accuracy: 0.5597000050544739
```