Assignment 6.2a

In [43]:
```
#Import required libraries
import keras
from keras.datasets import cifar10
from keras.models import Sequential
from keras import layers,  models,  optimizers
from keras.layers import Conv2D, Activation, MaxPooling2D, Dropout, Dense, Flatten

from matplotlib import pyplot
import matplotlib.pyplot as plt

import numpy as np

import tensorflow as tf
tf.config.run_functions_eagerly
from tensorflow.keras.preprocessing.image import ImageDataGenerator
from tensorflow.keras.utils import to_categorical
```

In [44]:
```
#splitting into training and test sets
# load dataset
(x_train, y_train),(x_test,y_test) = cifar10.load_data()
```

In [45]:
```
x_train = x_train.astype('float32')
x_train /= 255
x_test = x_test.astype('float32')
x_test /= 255
x_val_train = x_train[:10000]
x_train = x_train[10000:]

#Convert target data to single array of shape (50000,) and (10000,)
y_train = y_train.reshape(y_train.shape[0])
y_test = y_test.reshape(y_test.shape[0])
y_val_train = y_train[:10000]
y_train = y_train[10000:]
```

In [46]:
```
#Build the model without dropout or data-augmentation
from keras.layers import Conv2D, Activation, MaxPooling2D, Dropout, Dense, Flatten

model = Sequential()
model.add(Conv2D(32, (3, 3),
                 padding='same',
                 input_shape=x_train.shape[1:]))
model.add(MaxPooling2D((2, 2)))
model.add(Conv2D(64, (3, 3), activation='relu'))
model.add(MaxPooling2D((2, 2)))
model.add(Conv2D(128, (3, 3), activation='relu'))
model.add(MaxPooling2D((2, 2)))
model.add(Flatten())
model.add(Dense(512, activation='relu'))
model.add(Dense(10, activation='sigmoid'))

model.summary()
```

```
Model: "sequential_2"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv2d_7 (Conv2D)           (None, 32, 32, 32)        896

 max_pooling2d_5 (MaxPooling  (None, 16, 16, 32)       0
```

```
2D)

conv2d_8 (Conv2D)            (None, 14, 14, 64)        18496

max_pooling2d_6 (MaxPooling  (None, 7, 7, 64)          0
2D)

conv2d_9 (Conv2D)            (None, 5, 5, 128)         73856

max_pooling2d_7 (MaxPooling  (None, 2, 2, 128)         0
2D)

flatten_2 (Flatten)          (None, 512)               0

dense_4 (Dense)              (None, 512)               262656

dense_5 (Dense)              (None, 10)                5130

=================================================================
Total params: 361,034
Trainable params: 361,034
Non-trainable params: 0
_________________________________________________________________
```

In [51]:
```
#Configure the model for training
model.compile(loss='sparse_categorical_crossentropy',
              optimizer=keras.optimizers.RMSprop(learning_rate=0.0001, decay=1e-6),
              metrics=['acc'])
```

In [52]:
```
#Fit the model
history = model.fit(
      x_train,y_train,
      epochs=30,
      batch_size=64,
      validation_data=(x_val_train,y_val_train),
      validation_steps=50)
```

```
Epoch 1/30
625/625 [==============================] - 34s 52ms/step - loss: 1.9091 - acc: 0.3082 -
val_loss: 1.7230 - val_acc: 0.3700
Epoch 2/30
625/625 [==============================] - 42s 67ms/step - loss: 1.6238 - acc: 0.4171 -
val_loss: 1.5416 - val_acc: 0.4531
Epoch 3/30
625/625 [==============================] - 41s 66ms/step - loss: 1.5026 - acc: 0.4589 -
val_loss: 1.4667 - val_acc: 0.4681
Epoch 4/30
625/625 [==============================] - 34s 54ms/step - loss: 1.4249 - acc: 0.4881 -
val_loss: 1.3969 - val_acc: 0.4934
Epoch 5/30
625/625 [==============================] - 35s 55ms/step - loss: 1.3649 - acc: 0.5163 -
val_loss: 1.3238 - val_acc: 0.5266
Epoch 6/30
625/625 [==============================] - 44s 70ms/step - loss: 1.3132 - acc: 0.5348 -
val_loss: 1.2730 - val_acc: 0.5581
Epoch 7/30
625/625 [==============================] - 32s 51ms/step - loss: 1.2657 - acc: 0.5550 -
val_loss: 1.2511 - val_acc: 0.5525
Epoch 8/30
625/625 [==============================] - 29s 47ms/step - loss: 1.2233 - acc: 0.5696 -
val_loss: 1.2196 - val_acc: 0.5741
Epoch 9/30
625/625 [==============================] - 29s 47ms/step - loss: 1.1861 - acc: 0.5843 -
val_loss: 1.1689 - val_acc: 0.5791
Epoch 10/30
```

```
625/625 [==============================] - 29s 47ms/step - loss: 1.1503 - acc: 0.5967 -
val_loss: 1.1477 - val_acc: 0.5900
Epoch 11/30
625/625 [==============================] - 34s 54ms/step - loss: 1.1187 - acc: 0.6105 -
val_loss: 1.1145 - val_acc: 0.6081
Epoch 12/30
625/625 [==============================] - 29s 47ms/step - loss: 1.0881 - acc: 0.6221 -
val_loss: 1.0825 - val_acc: 0.6197
Epoch 13/30
625/625 [==============================] - 35s 56ms/step - loss: 1.0612 - acc: 0.6313 -
val_loss: 1.0898 - val_acc: 0.6106
Epoch 14/30
625/625 [==============================] - 43s 69ms/step - loss: 1.0359 - acc: 0.6401 -
val_loss: 1.0915 - val_acc: 0.6206
Epoch 15/30
625/625 [==============================] - 43s 70ms/step - loss: 1.0098 - acc: 0.6475 -
val_loss: 1.0331 - val_acc: 0.6341
Epoch 16/30
625/625 [==============================] - 39s 63ms/step - loss: 0.9891 - acc: 0.6589 -
val_loss: 1.0174 - val_acc: 0.6419
Epoch 17/30
625/625 [==============================] - 32s 52ms/step - loss: 0.9670 - acc: 0.6636 -
val_loss: 1.0107 - val_acc: 0.6488
Epoch 18/30
625/625 [==============================] - 31s 49ms/step - loss: 0.9457 - acc: 0.6743 -
val_loss: 0.9807 - val_acc: 0.6541
Epoch 19/30
625/625 [==============================] - 33s 52ms/step - loss: 0.9260 - acc: 0.6798 -
val_loss: 0.9800 - val_acc: 0.6463
Epoch 20/30
625/625 [==============================] - 44s 70ms/step - loss: 0.9055 - acc: 0.6878 -
val_loss: 0.9768 - val_acc: 0.6606
Epoch 21/30
625/625 [==============================] - 43s 70ms/step - loss: 0.8885 - acc: 0.6947 -
val_loss: 0.9570 - val_acc: 0.6637
Epoch 22/30
625/625 [==============================] - 43s 69ms/step - loss: 0.8697 - acc: 0.7014 -
val_loss: 0.9568 - val_acc: 0.6681
Epoch 23/30
625/625 [==============================] - 40s 63ms/step - loss: 0.8523 - acc: 0.7085 -
val_loss: 0.9608 - val_acc: 0.6675
Epoch 24/30
625/625 [==============================] - 43s 69ms/step - loss: 0.8343 - acc: 0.7120 -
val_loss: 0.9539 - val_acc: 0.6697
Epoch 25/30
625/625 [==============================] - 45s 71ms/step - loss: 0.8173 - acc: 0.7178 -
val_loss: 0.9255 - val_acc: 0.6709
Epoch 26/30
625/625 [==============================] - 41s 65ms/step - loss: 0.8038 - acc: 0.7237 -
val_loss: 0.9307 - val_acc: 0.6787
Epoch 27/30
625/625 [==============================] - 29s 47ms/step - loss: 0.7868 - acc: 0.7284 -
val_loss: 0.9243 - val_acc: 0.6775
Epoch 28/30
625/625 [==============================] - 41s 66ms/step - loss: 0.7675 - acc: 0.7350 -
val_loss: 0.9503 - val_acc: 0.6750
Epoch 29/30
625/625 [==============================] - 47s 75ms/step - loss: 0.7560 - acc: 0.7393 -
val_loss: 0.8935 - val_acc: 0.6894
Epoch 30/30
625/625 [==============================] - 36s 58ms/step - loss: 0.7381 - acc: 0.7466 -
val_loss: 0.9086 - val_acc: 0.6844
```

In [53]:

```
# Evaluate the model
results = model.evaluate(x_test, y_test)
```

```
print(results)
```

```
313/313 [==============================] - 6s 18ms/step - loss: 0.9508 - acc: 0.6800
[0.950763463973999, 0.6800000071525574]
```

In [54]:
```
history_dict = history.history

acc = history_dict['acc']
val_acc = history_dict['val_acc']
loss_values = history_dict['loss']
val_loss_values = history_dict['val_loss']
epochs = range(1,len(acc) + 1)
```

In [55]:
```
# Saving Model files to results folder
model.save('results/Assignment_6-2a_model.h5')
print('Saved 6.2a trained model to results folder')
```

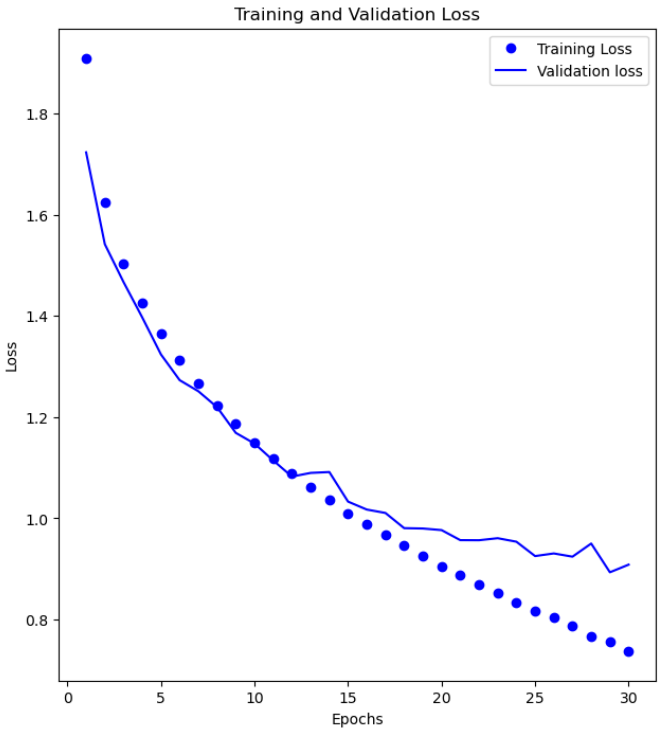
```
Saved 6.2a trained model to results folder
```

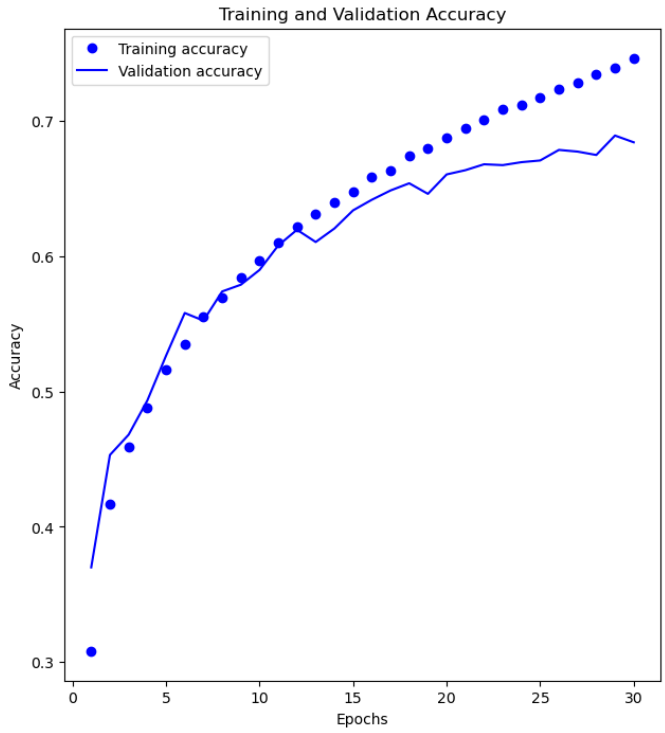
In [56]:
```
# Plotting metrics

fig, [ax1, ax2] = plt.subplots(1,2, figsize=(16,8))

ax1.plot(epochs, loss_values,  'bo', label = 'Training Loss')
ax1.plot(epochs, val_loss_values, 'b', label = 'Validation loss')
ax1.set_title('Training and Validation Loss')
ax1.set_xlabel("Epochs")
ax1.set_ylabel("Loss")
ax1.legend()
plt.savefig('results/Assignment_6-2a_Loss.png')

ax2.plot(epochs, acc,  'bo', label = 'Training accuracy')
ax2.plot(epochs, val_acc, 'b', label = 'Validation accuracy')
ax2.set_title('Training and Validation Accuracy')
ax2.set_xlabel("Epochs")
ax2.set_ylabel("Accuracy")
ax2.legend()
plt.savefig('results/Assignment_6.2a_Accuracy.png')
plt.show()
```





In [57]:
```
import pandas as pd
```

```
with open('results/Assignment_6-2a_metrics.txt', 'w') as f:
    f.write('Training Loss: {}'.format(str(history.history['loss'])))
    f.write('\nTraining Accuracy: {}'.format(str(history.history['acc'])))
    f.write('\nTest Loss: {}'.format(results[0]))
    f.write('\nTest Accuracy: {}'.format(results[1]))
predictions = pd.DataFrame(pred_res)
predictions.to_csv('results/Assignment_6-2a_predictions.csv', index=False)
```

Assignment 6.2b

In [73]:
```
from keras.preprocessing.image import ImageDataGenerator
```

In [74]:
```
# Includes dropout
model = Sequential()
model.add(Conv2D(32, (3, 3), padding='same',
                 input_shape=x_train.shape[1:]))
model.add(Activation('relu'))
model.add(Conv2D(32, (3, 3)))
model.add(Activation('relu'))
model.add(MaxPooling2D(pool_size=(2, 2)))
model.add(Dropout(0.25))
model.add(Conv2D(64, (3, 3), padding='same'))
model.add(Activation('relu'))
model.add(Conv2D(64, (3, 3)))
model.add(Activation('relu'))
model.add(MaxPooling2D(pool_size=(2, 2)))
model.add(Dropout(0.25))
model.add(Flatten())
model.add(Dense(512))
model.add(Activation('relu'))
model.add(Dropout(0.5))
model.add(Dense(10))
model.add(Activation('softmax'))
```

In [75]:
```
model.summary()
```

```
Model: "sequential_5"
_________________________________________________________________
 Layer (type)                 Output Shape              Param #
=================================================================
 conv2d_18 (Conv2D)           (None, 32, 32, 32)        896

 activation_12 (Activation)   (None, 32, 32, 32)        0

 conv2d_19 (Conv2D)           (None, 30, 30, 32)        9248

 activation_13 (Activation)   (None, 30, 30, 32)        0

 max_pooling2d_14 (MaxPoolin  (None, 15, 15, 32)        0
 g2D)

 dropout_7 (Dropout)          (None, 15, 15, 32)        0

 conv2d_20 (Conv2D)           (None, 15, 15, 64)        18496

 activation_14 (Activation)   (None, 15, 15, 64)        0

 conv2d_21 (Conv2D)           (None, 13, 13, 64)        36928

 activation_15 (Activation)   (None, 13, 13, 64)        0

 max_pooling2d_15 (MaxPoolin  (None, 6, 6, 64)          0
 g2D)
```

```
 dropout_8 (Dropout)          (None, 6, 6, 64)          0

 flatten_5 (Flatten)          (None, 2304)              0

 dense_10 (Dense)             (None, 512)               1180160

 activation_16 (Activation)   (None, 512)               0

 dropout_9 (Dropout)          (None, 512)               0

 dense_11 (Dense)             (None, 10)                5130

 activation_17 (Activation)   (None, 10)                0

=================================================================
Total params: 1,250,858
Trainable params: 1,250,858
Non-trainable params: 0
_________________________________________________________________
```

In [76]:
```
# Configure the model
model.compile(loss='sparse_categorical_crossentropy',
              optimizer=keras.optimizers.RMSprop(learning_rate=0.0001, decay=1e-6),
              metrics=['acc'])
```

In [77]:
```
# Includes data-augumentation - rotation, width shift, height shift, etc.

datagen = ImageDataGenerator(
    rotation_range=40,
    width_shift_range=0.2,
    height_shift_range=0.2,
    shear_range=0.2,
    zoom_range=0.2,
    horizontal_flip=True)

datagen.fit(x_train)
```

In [78]:
```
#Fit the model
history = model.fit(datagen.flow(x_train,
                                 y_train,
                                 batch_size=64),
                    epochs=30,
                    validation_data=(x_val_train, y_val_train),
                    workers=4,
                    verbose=False)
```

In [79]:
```
results = model.evaluate(x_test, y_test)
print(results)
```

```
313/313 [==============================] - 8s 26ms/step - loss: 1.2053 - acc: 0.5789
[1.2052512168884277, 0.5788999795913696]
```

In [80]:
```
history_dict = history.history

acc = history_dict['acc']
val_acc = history_dict['val_acc']
loss_values = history_dict['loss']
val_loss_values = history_dict['val_loss']
epochs = range(1,len(acc) + 1)
```

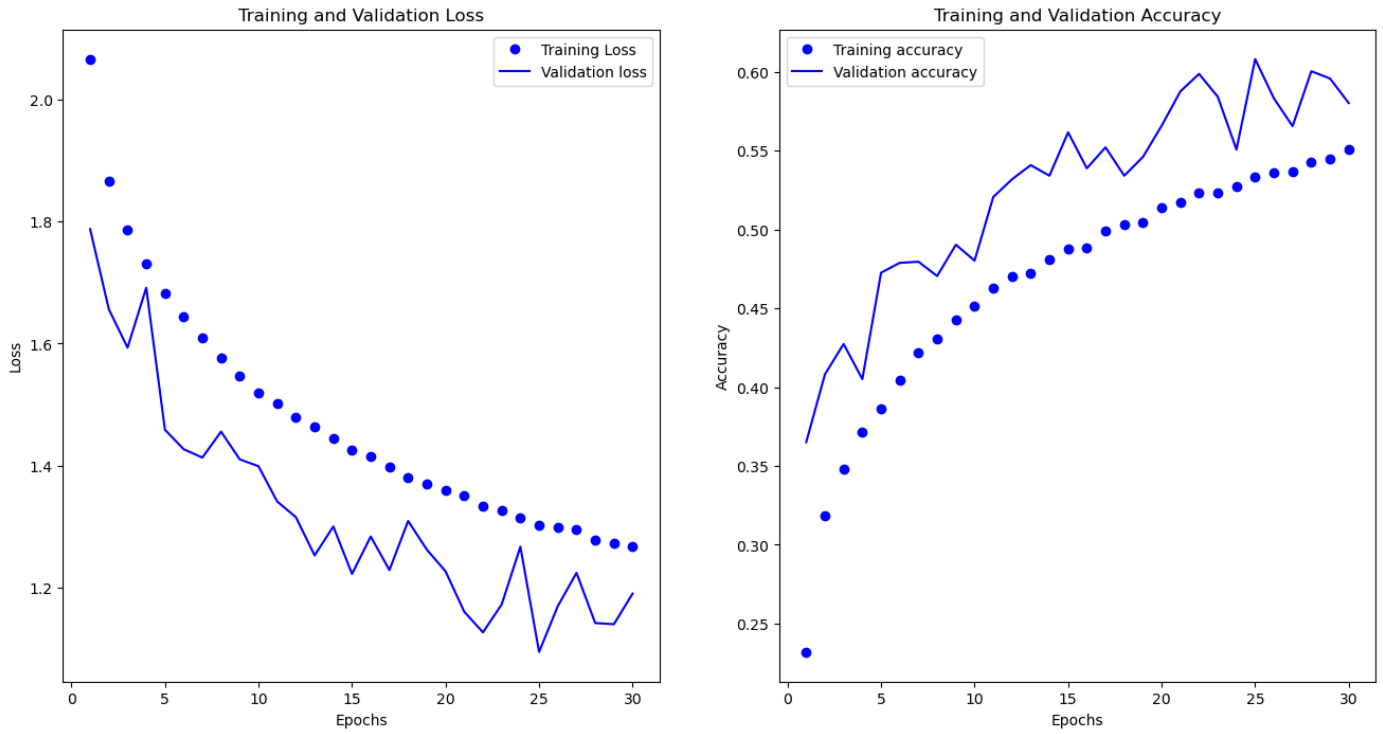
In [81]:
```
# Saving Model files to results folder
model.save('results/Assignment_6-2b_model.h5')
print('Saved 6.2b trained model to results folder')
```

```
Saved 6.2b trained model to results folder
```

In [82]:
```
# Plotting metrics
fig, [ax1, ax2] = plt.subplots(1,2, figsize=(16,8))

ax1.plot(epochs, loss_values,  'bo', label = 'Training Loss')
ax1.plot(epochs, val_loss_values, 'b', label = 'Validation loss')
ax1.set_title('Training and Validation Loss')
ax1.set_xlabel("Epochs")
ax1.set_ylabel("Loss")
ax1.legend()
plt.savefig('results/Assignment_6-2b_Loss.png')
ax2.plot(epochs, acc,  'bo', label = 'Training accuracy')
ax2.plot(epochs, val_acc, 'b', label = 'Validation accuracy')
ax2.set_title('Training and Validation Accuracy')
ax2.set_xlabel("Epochs")
ax2.set_ylabel("Accuracy")
ax2.legend()

plt.savefig('results/Assignment_6-2b_Accuracy.png')
plt.show()
```



In [83]:
```
with open('results/Assignment_6-2b_metrics.txt', 'w') as f:
    f.write('Training Loss: {}'.format(str(history.history['loss'])))
    f.write('\nTraining Accuracy: {}'.format(str(history.history['acc'])))
    f.write('\nTest Loss: {}'.format(results[0]))
    f.write('\nTest Accuracy: {}'.format(results[1]))
predictions = pd.DataFrame(pred_res)
predictions.to_csv('results/Assignment_6-2b_predictions.csv', index=False)
```