In [ ]:

```python
import pandas as pd
from sklearn.preprocessing import StandardScaler
from sklearn.model_selection import train_test_split, GridSearchCV, RandomizedSearchCV, cross_val_score
from sklearn.linear_model import LogisticRegression
from sklearn.ensemble import RandomForestClassifier, GradientBoostingClassifier
from sklearn.svm import SVC
from sklearn.metrics import accuracy_score, precision_score, recall_score, f1_score, roc_auc_score, confusion_matrix
from sklearn.neighbors import KNeighborsClassifier
from imblearn.over_sampling import SMOTE
import seaborn as sns
import matplotlib.pyplot as plt
import xgboost as xgb


# Combine datasets
df = pd.read_csv('data/ALLFLOWMETER_HIKARI2021.csv')
```

In [ ]:

```python
# Display the first few rows
df.head()
```

Out[ ]:

	Unnamed: 0.1	Unnamed: 0	uid	originh	originp	responh	responp	flow_duration	fwd_pkts_tot	bwd_pkts_tot	...	idle.min	idle.max	idle.tot	idle.a
0	0	0	Cg61Jch3vdz9DBptj	103.255.15.23	13316	128.199.242.104	443	2.207588	15	14	...	0.000000e+00	0.000000e+00	0.000000e+00	0.000000e+
1	1	1	CdRIlqLWdj35Y9vW9	103.255.15.23	13318	128.199.242.104	443	15.624266	15	14	...	1.534300e+07	1.534300e+07	1.534300e+07	1.534300e+
2	2	2	CLzp9Khd0Y09Qkgrg	103.255.15.23	13320	128.199.242.104	443	12.203357	14	13	...	1.196814e+07	1.196814e+07	1.196814e+07	1.196814e+
3	3	3	Cnf1YA4iLB4CSNWB88	103.255.15.23	13322	128.199.242.104	443	9.992448	14	13	...	9.759205e+06	9.759205e+06	9.759205e+06	9.759205e+
4	4	4	C4ZKvv3fpO72EAOsJ6	103.255.15.23	13324	128.199.242.104	443	7.780611	14	14	...	7.545305e+06	7.545305e+06	7.545305e+06	7.545305e+

5 rows × 88 columns

In [ ]:

```python
df.describe()
```

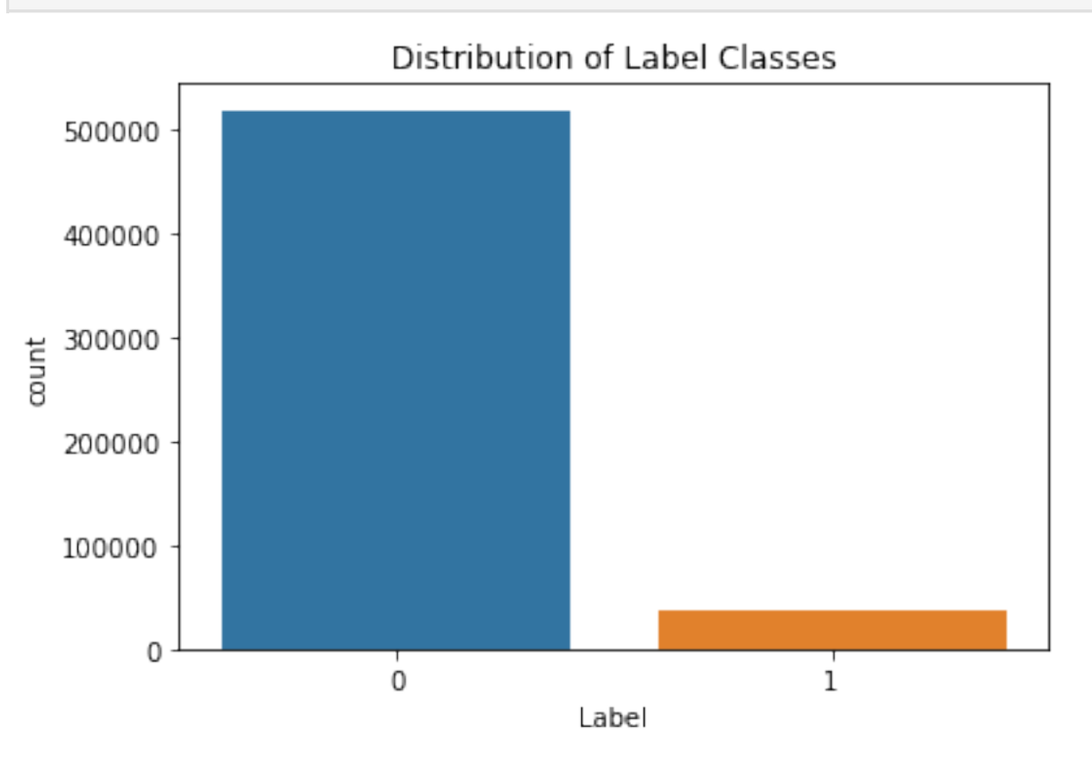
Out[ ]:

	Unnamed: 0.1	Unnamed: 0	originp	responp	flow_duration	fwd_pkts_tot	bwd_pkts_tot	fwd_data_pkts_tot	bwd_data_pkts_tot	fwd_pkts_per_sec	...	active.std	
count	555278.000000	555278.000000	555278.000000	555278.000000	555278.000000	555278.000000	555278.000000	555278.000000	555278.000000	555278.000000	...	5.552780e+05	5.5
mean	277638.500000	137369.392132	38673.198034	5082.161647	9.306544	18.264091	18.892578	7.956928	15.803417	1720.704202	...	1.335883e+05	3.4
std	160295.095724	99946.804651	18071.825216	12915.812900	101.802730	463.901484	469.078877	73.441224	467.349374	4994.579973	...	8.289045e+06	1.8
min	0.000000	0.000000	21.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	...	0.000000e+00	0.0
25%	138819.250000	52201.000000	28581.000000	53.000000	0.000311	1.000000	1.000000	1.000000	0.000000	4.430152	...	0.000000e+00	0.0
50%	277638.500000	121610.500000	42693.500000	443.000000	0.026218	2.000000	2.000000	2.000000	2.000000	39.760205	...	0.000000e+00	0.0
75%	416457.750000	211889.750000	53120.000000	443.000000	0.347231	10.000000	12.000000	3.000000	5.000000	80.376058	...	0.000000e+00	0.0
max	555277.000000	350709.000000	65535.000000	65522.000000	17393.030600	326292.000000	326827.000000	3953.000000	326822.000000	223696.213333	...	5.438463e+09	2.9

8 rows × 84 columns

In [ ]:

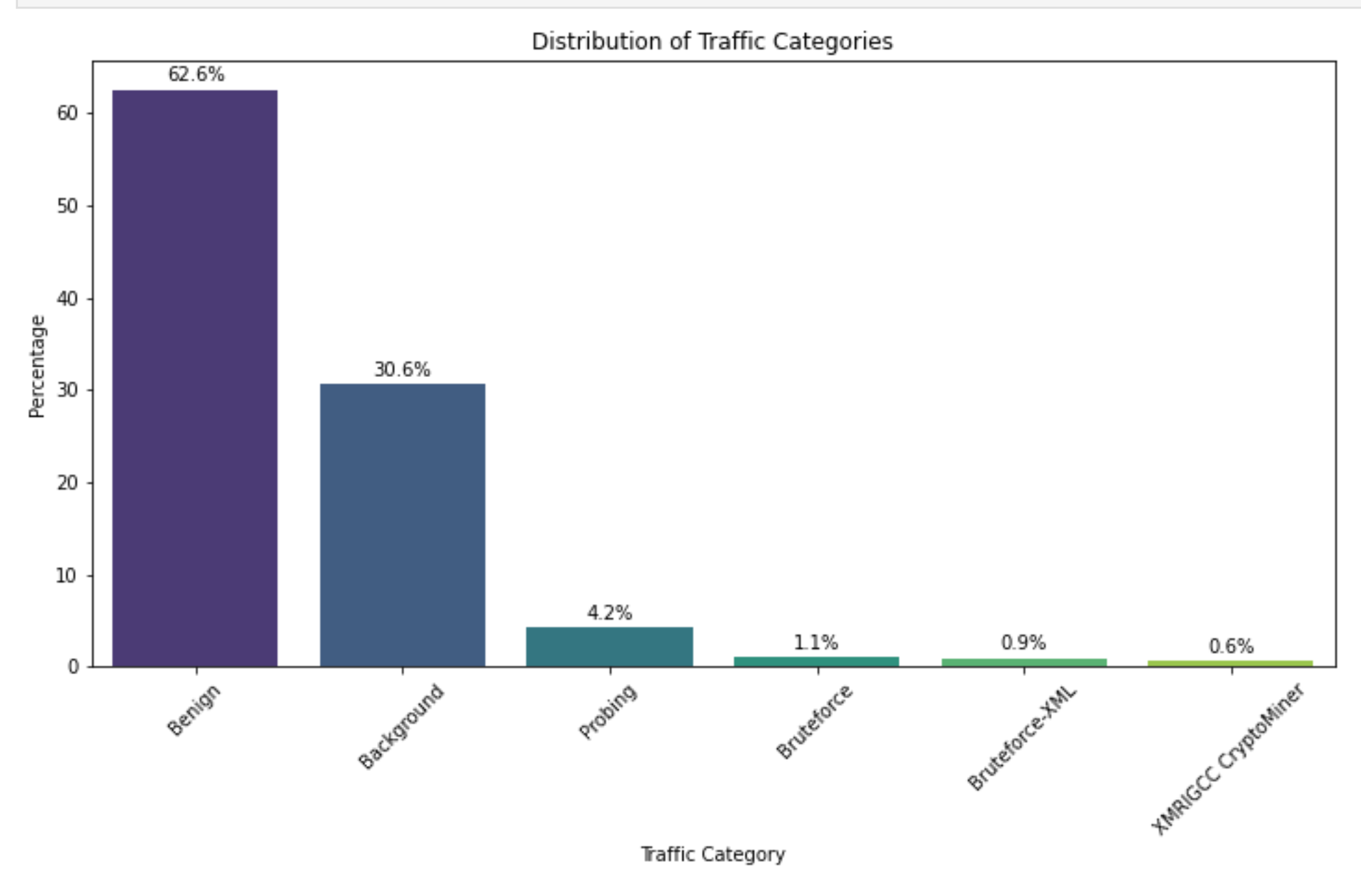
```python
# Plot the distribution of the label
sns.countplot(x='Label', data=df)
plt.title('Distribution of Label Classes')
plt.show()
```



In [ ]:

```python
# Calculate the percentage distribution of traffic categories
category_counts = df['traffic_category'].value_counts()
category_percentages = (category_counts / category_counts.sum()) * 100

# Create a bar plot with percentages
plt.figure(figsize=(12, 6))
sns.barplot(x=category_percentages.index, y=category_percentages.values, palette='viridis')
plt.title('Distribution of Traffic Categories')
plt.xlabel('Traffic Category')
plt.ylabel('Percentage')
plt.xticks(rotation=45)
for i in range(len(category_percentages)):
    plt.text(i, category_percentages[i] + 0.5, f'{category_percentages[i]:.1f}%', ha='center', va='bottom')
plt.show()
```



In [ ]:

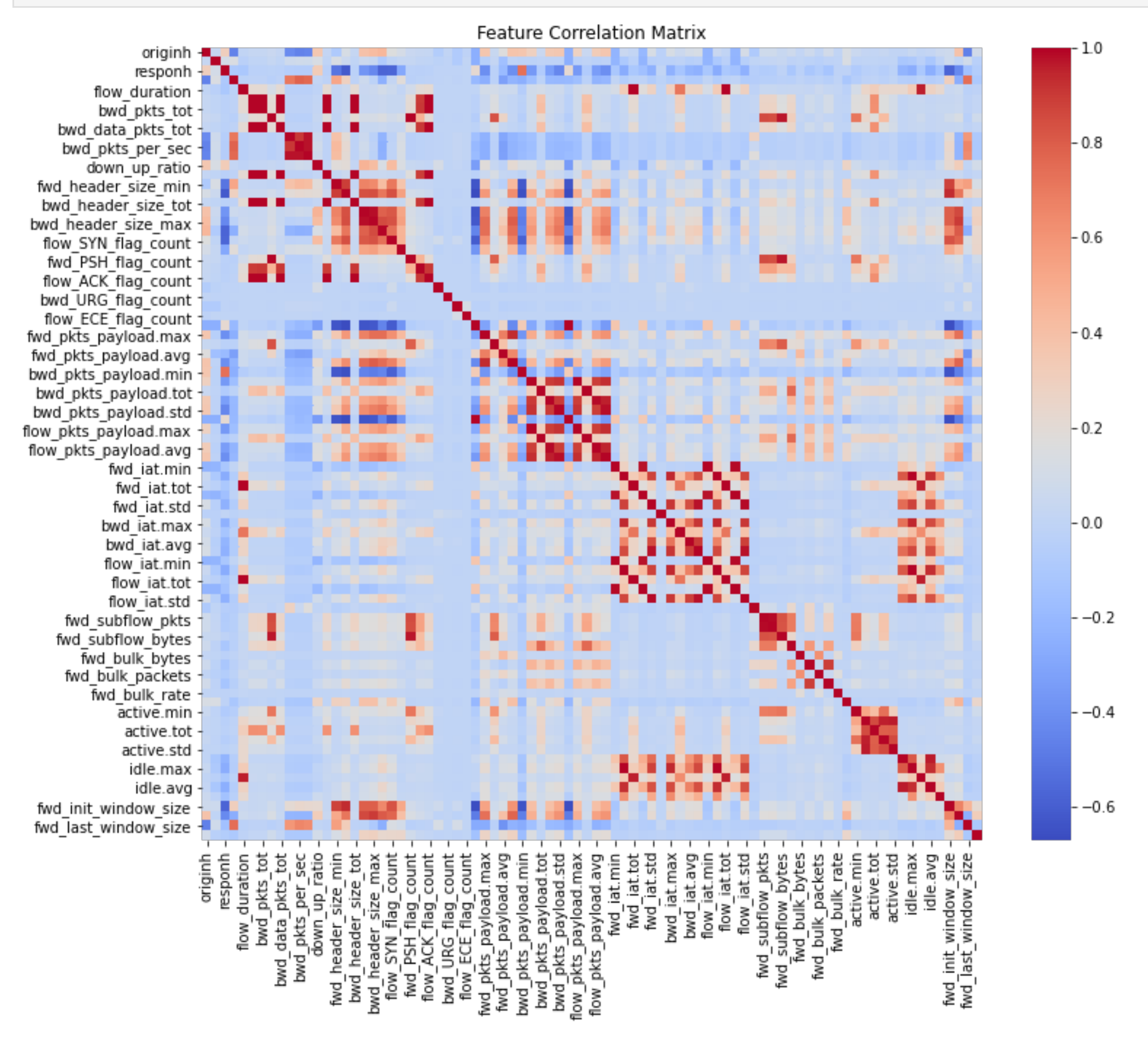
```python
# Drop unnecessary columns
columns_to_drop = ['Unnamed: 0.1', 'Unnamed: 0', 'uid','traffic_category']
data_cleaned = df.drop(columns=columns_to_drop)

# Encode categorical variables
# Frequency Encoding for high-cardinality categorical features
freq_encode_features = ['originh', 'responh']
for col in freq_encode_features:
    freq_encoding = data_cleaned[col].value_counts().to_dict()
    data_cleaned[col] = data_cleaned[col].map(freq_encoding)
```

In [ ]:

```python
# Compute the correlation matrix
correlation_matrix = data_cleaned.corr()

# Plot the heatmap
plt.figure(figsize=(12, 10))
sns.heatmap(correlation_matrix, annot=False, cmap='coolwarm')
plt.title('Feature Correlation Matrix')
plt.show()
```



In [ ]:

```python
# Normalise/scale features
features = data_cleaned.drop(columns=['Label'])
scaler = StandardScaler()
features_scaled = scaler.fit_transform(features)

# Combine scaled features with the label
data_preprocessed = pd.DataFrame(features_scaled, columns=features.columns)
data_preprocessed['Label'] = data_cleaned['Label'].values
```

In [ ]:

```python
# Split the data
X = data_preprocessed.drop(columns=['Label'])
y = data_preprocessed['Label']
# Handle class imbalance
smote = SMOTE(random_state=42)
X_resampled, y_resampled = smote.fit_resample(X, y)

X_train, X_test, y_train, y_test = train_test_split(X_resampled, y_resampled, test_size=0.2, random_state=42)
```

In [ ]:

```python
# Define models
log_reg = LogisticRegression(max_iter=1000)
```

In [ ]:

```python
rf = RandomForestClassifier()
```

In [ ]:

```python
gbm = GradientBoostingClassifier()
```

In [ ]:

```python
xgb_model = xgb.XGBClassifier()
```

In [ ]:

```python
log_reg.fit(X_train, y_train)
y_pred_log_reg = log_reg.predict(X_test)
```

```
/Users/sako/opt/anaconda3/lib/python3.8/site-packages/sklearn/linear_model/_logistic.py:460: ConvergenceWarning: lbfgs failed to converge (status=1):
STOP: TOTAL NO. of ITERATIONS REACHED LIMIT.

Increase the number of iterations (max_iter) or scale the data as shown in:
    https://scikit-learn.org/stable/modules/preprocessing.html
Please also refer to the documentation for alternative solver options:
    https://scikit-learn.org/stable/modules/linear_model.html#logistic-regression
  n_iter_i = _check_optimize_result(
```

In [ ]:

```python
rf.fit(X_train, y_train)
y_pred_rf = rf.predict(X_test)
```

In [ ]:

```python
gbm.fit(X_train, y_train)
y_pred_gbm = gbm.predict(X_test)
```

In [ ]:

```python
xgb_model.fit(X_train, y_train)
y_pred_xgb = xgb_model.predict(X_test)
```

In [ ]:

```python
# Evaluation Metrics Function
def print_evaluation_metrics(model_name, y_test, y_pred):
    print(f"Evaluation Metrics for {model_name}:")
    print(f"Accuracy: {accuracy_score(y_test, y_pred):.4f}")
    print(f"Precision: {precision_score(y_test, y_pred):.4f}")
    print(f"Recall: {recall_score(y_test, y_pred):.4f}")
    print(f"F1-Score: {f1_score(y_test, y_pred):.4f}")
    print(f"ROC-AUC: {roc_auc_score(y_test, y_pred):.4f}")
    print("\n")
```

In [ ]:

```python
print_evaluation_metrics("Logistic Regression", y_test, y_pred_log_reg)
```

```
Evaluation Metrics for Logistic Regression:
Accuracy: 0.9221
Precision: 0.8679
Recall: 0.9957
F1-Score: 0.9274
ROC-AUC: 0.9221
```

In [ ]:

```python
print_evaluation_metrics("Random Forest", y_test, y_pred_rf)
```

```
Evaluation Metrics for Random Forest:
Accuracy: 0.9219
Precision: 0.9086
Recall: 0.9382
F1-Score: 0.9232
ROC-AUC: 0.9220
```

In [ ]:

```python
print_evaluation_metrics("Gradient Boosting Machine (GBM)", y_test, y_pred_gbm)
```

```
Evaluation Metrics for Gradient Boosting Machine (GBM):
Accuracy: 0.9281
Precision: 0.8747
Recall: 0.9994
F1-Score: 0.9329
ROC-AUC: 0.9282
```

In [ ]:

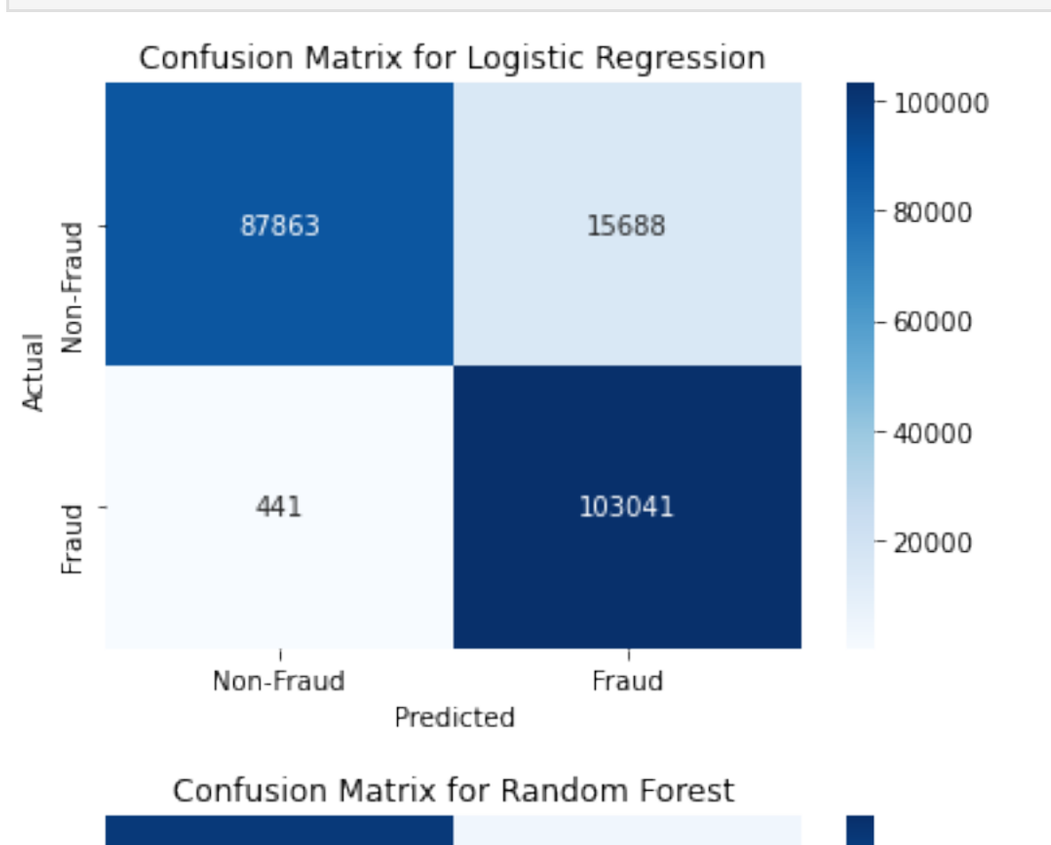
```python
print_evaluation_metrics("XGBoost", y_test, y_pred_xgb)
```

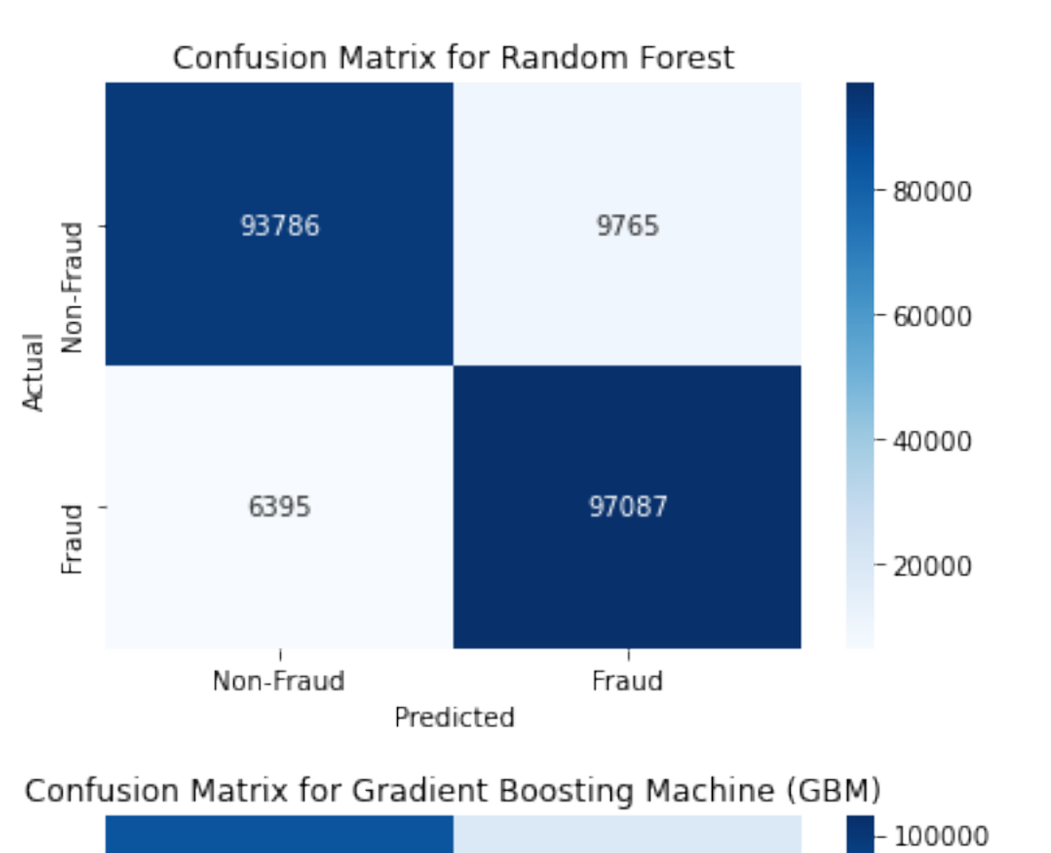
```
Evaluation Metrics for XGBoost:
Accuracy: 0.9573
Precision: 0.9529
Recall: 0.9620
F1-Score: 0.9574
ROC-AUC: 0.9573
```

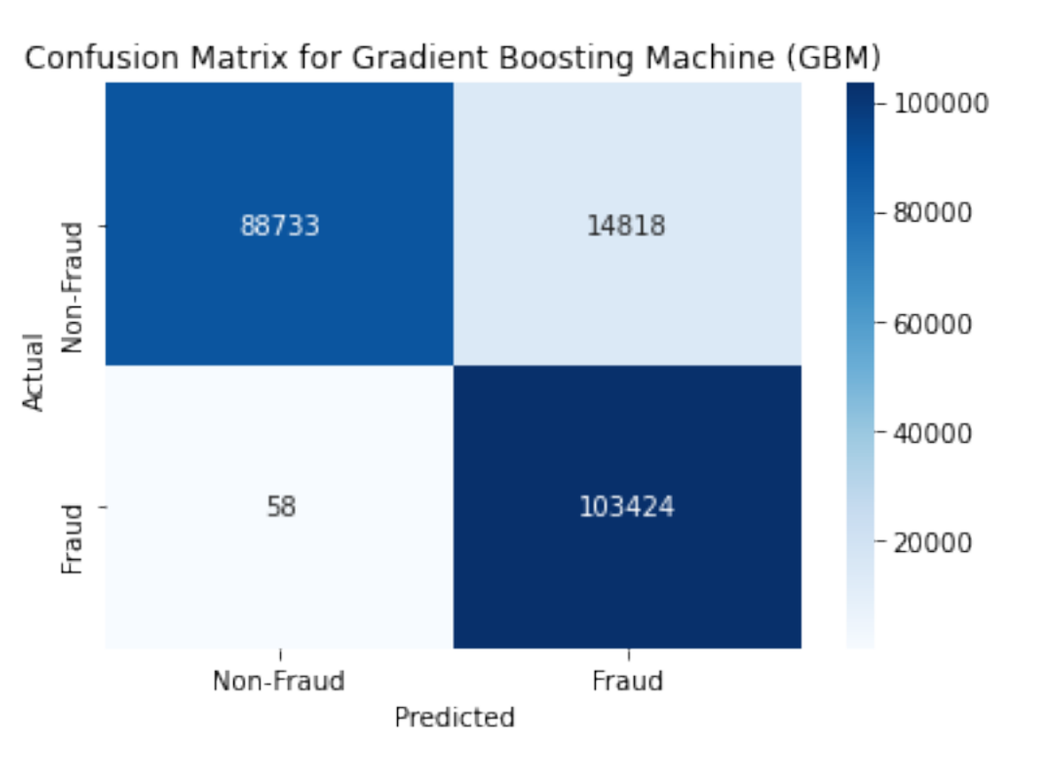
In [ ]:

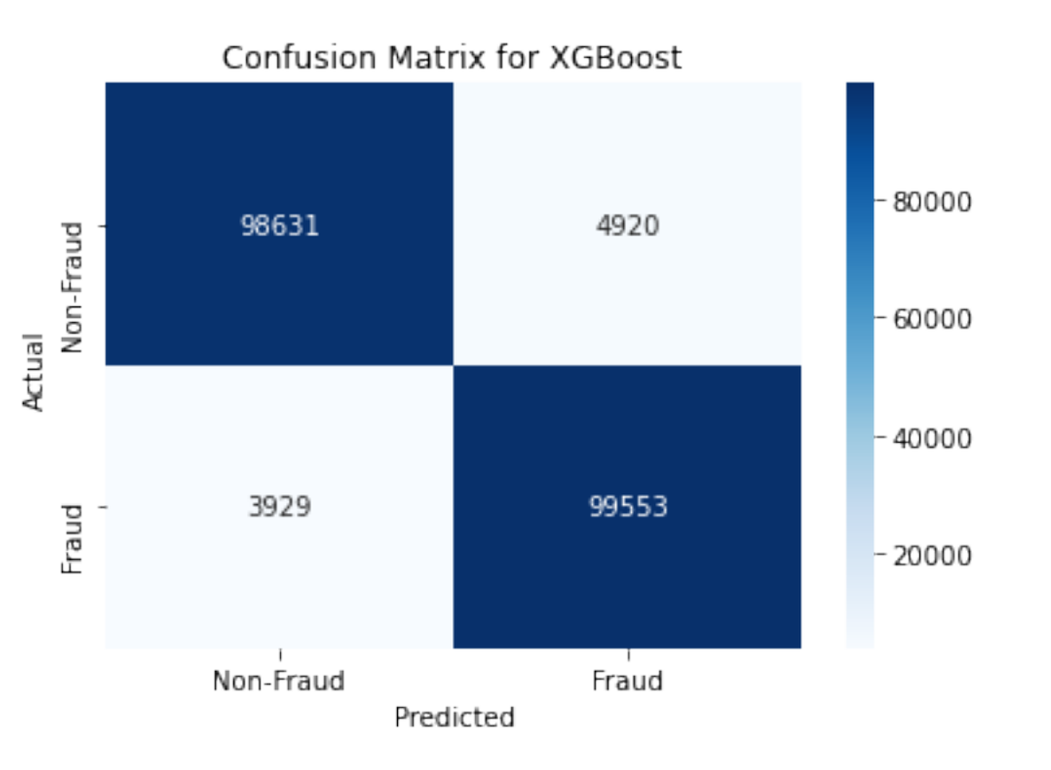
```python
from sklearn.metrics import confusion_matrix
# Plot confusion matrices
def plot_confusion_matrix(y_test, y_pred, model_name):
    cm = confusion_matrix(y_test, y_pred)
    sns.heatmap(cm, annot=True, fmt='d', cmap='Blues', xticklabels=['Non-Fraud', 'Fraud'], yticklabels=['Non-Fraud', 'Fraud'])
    plt.xlabel('Predicted')
    plt.ylabel('Actual')
    plt.title(f'Confusion Matrix for {model_name}')
    plt.show()

plot_confusion_matrix(y_test, y_pred_log_reg, "Logistic Regression")
plot_confusion_matrix(y_test, y_pred_rf, "Random Forest")
plot_confusion_matrix(y_test, y_pred_gbm, "Gradient Boosting Machine (GBM)")
plot_confusion_matrix(y_test, y_pred_xgb, "XGBoost")
```









In [ ]:

```python
# Perform cross-validation
cv_scores_log_reg = cross_val_score(log_reg, X, y, cv=5, scoring='accuracy')
cv_scores_rf = cross_val_score(rf, X, y, cv=5, scoring='accuracy')
cv_scores_gbm = cross_val_score(gbm, X, y, cv=5, scoring='accuracy')
cv_scores_xgb = cross_val_score(xgb_model, X, y, cv=5, scoring='accuracy')

# Print cross-validation scores
print("Cross-Validation Scores:")
print(f"Logistic Regression: {cv_scores_log_reg.mean():.4f} ± {cv_scores_log_reg.std():.4f}")
print(f"Random Forest: {cv_scores_rf.mean():.4f} ± {cv_scores_rf.std():.4f}")
print(f"Gradient Boosting Machine (GBM): {cv_scores_gbm.mean():.4f} ± {cv_scores_gbm.std():.4f}")
print(f"XGBoost): {cv_scores_xgb.mean():.4f} ± {cv_scores_xgb.std():.4f}")
```

```
/Users/sako/opt/anaconda3/lib/python3.8/site-packages/sklearn/linear_model/_logistic.py:460: ConvergenceWarning: lbfgs failed to converge (status=1):
STOP: TOTAL NO. of ITERATIONS REACHED LIMIT.

Increase the number of iterations (max_iter) or scale the data as shown in:
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Please also refer to the documentation for alternative solver options:
    https://scikit-learn.org/stable/modules/linear_model.html#logistic-regression
  n_iter_i = _check_optimize_result(
/Users/sako/opt/anaconda3/lib/python3.8/site-packages/sklearn/linear_model/_logistic.py:460: ConvergenceWarning: lbfgs failed to converge (status=1):
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/Users/sako/opt/anaconda3/lib/python3.8/site-packages/sklearn/linear_model/_logistic.py:460: ConvergenceWarning: lbfgs failed to converge (status=1):
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Please also refer to the documentation for alternative solver options:
    https://scikit-learn.org/stable/modules/linear_model.html#logistic-regression
  n_iter_i = _check_optimize_result(
Cross-Validation Scores:
Logistic Regression: 0.9017 ± 0.0180
Random Forest: 0.8659 ± 0.0740
Gradient Boosting Machine (GBM): 0.8900 ± 0.0341
XGBoost): 0.8761 ± 0.0574
```

In [ ]:

```python
# Feature importance for Random Forest
rf_feature_importances = pd.DataFrame(rf.feature_importances_, index=X.columns, columns=['Importance']).sort_values(by='Importance', ascending=False)
rf_feature_importances.head(10).plot(kind='bar', title='Top 10 Feature Importances from Random Forest')
plt.show()

# Feature importance for GBM
gbm_feature_importances = pd.DataFrame(gbm.feature_importances_, index=X.columns, columns=['Importance']).sort_values(by='Importance', ascending=False)
gbm_feature_importances.head(10).plot(kind='bar', title='Top 10 Feature Importances from GBM')
plt.show()
```