Group 43 - ML System optimization Project - Part 1 CPU Based Methods

Contributions

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Imports

In [3]:
```
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import seaborn as sns
import time
import tensorflow as tf
from joblib import Parallel, delayed
from sklearn.model_selection import train_test_split
from sklearn.preprocessing import StandardScaler
from sklearn.ensemble import RandomForestClassifier, AdaBoostClassifier, GradientBoostingClassifier
from sklearn.metrics import accuracy_score, classification_report, confusion_matrix
from sklearn.utils import shuffle
from concurrent.futures import ThreadPoolExecutor
```

Section 1: Load and Inspect Dataset

Data Preprocessing (Using Dask)

In [5]:
```
# Load dataset from uploaded file
from google.colab import files
uploaded = files.upload()
filename = list(uploaded.keys())[0]

# Read CSV file
df = pd.read_csv(filename)
print(df.head())

print("### Dataset loaded successfully.")

# Convert column names to lowercase for consistency
df.columns = df.columns.str.lower()

# Print column names to verify structure
print("\n### Column Names:\n", df.columns)

# Display dataset information
print("\n### Dataset Info:\n")
print(df.info())
print("\n### Missing Values:\n")
print(df.isnull().sum())
```

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Upload widget is only available when the cell has been executed in the current browser session.

Please rerun this cell to enable.

```
Saving creditcard.csv to creditcard.csv
   Time        V1        V2        V3        V4        V5        V6        V7  \
0   0.0 -1.359807 -0.072781  2.536347  1.378155 -0.338321  0.462388  0.239599
1   0.0  1.191857  0.266151  0.166480  0.448154  0.060018 -0.082361 -0.078803
2   1.0 -1.358354 -1.340163  1.773209  0.379780 -0.503198  1.800499  0.791461
3   1.0 -0.966272 -0.185226  1.792993 -0.863291 -0.010309  1.247203  0.237609
4   2.0 -1.158233  0.877737  1.548718  0.403034 -0.407193  0.095921  0.592941

         V8        V9  ...       V21       V22       V23       V24       V25  \
0  0.098698  0.363787  ... -0.018307  0.277838 -0.110474  0.066928  0.128539
1  0.085102 -0.255425  ... -0.225775 -0.638672  0.101288 -0.339846  0.167170
2  0.247676 -1.514654  ...  0.247998  0.771679  0.909412 -0.689281 -0.327642
3  0.377436 -1.387024  ... -0.108300  0.005274 -0.190321 -1.175575  0.647376
4 -0.270533  0.817739  ... -0.009431  0.798278 -0.137458  0.141267 -0.206010

        V26       V27       V28  Amount  class
0 -0.189115  0.133558 -0.021053  149.62      0
1  0.125895 -0.008983  0.014724    2.69      0
2 -0.139097 -0.055353 -0.059752  378.66      0
3 -0.221929  0.062723  0.061458  123.50      0
4  0.502292  0.219422  0.215153   69.99      0

[5 rows x 31 columns]
### Dataset loaded successfully.

### Column Names:
 Index(['time', 'v1', 'v2', 'v3', 'v4', 'v5', 'v6', 'v7', 'v8', 'v9', 'v10',
       'v11', 'v12', 'v13', 'v14', 'v15', 'v16', 'v17', 'v18', 'v19', 'v20',
       'v21', 'v22', 'v23', 'v24', 'v25', 'v26', 'v27', 'v28', 'amount',
       'class'],
      dtype='object')

### Dataset Info:

<class 'pandas.core.frame.DataFrame'>
RangeIndex: 284807 entries, 0 to 284806
Data columns (total 31 columns):
 #   Column  Non-Null Count   Dtype
---  ------  --------------   -----
 0   time    284807 non-null  float64
 1   v1      284807 non-null  float64
 2   v2      284807 non-null  float64
 3   v3      284807 non-null  float64
 4   v4      284807 non-null  float64
 5   v5      284807 non-null  float64
 6   v6      284807 non-null  float64
 7   v7      284807 non-null  float64
 8   v8      284807 non-null  float64
 9   v9      284807 non-null  float64
 10  v10     284807 non-null  float64
 11  v11     284807 non-null  float64
 12  v12     284807 non-null  float64
 13  v13     284807 non-null  float64
 14  v14     284807 non-null  float64
 15  v15     284807 non-null  float64
 16  v16     284807 non-null  float64
 17  v17     284807 non-null  float64
 18  v18     284807 non-null  float64
 19  v19     284807 non-null  float64
 20  v20     284807 non-null  float64
 21  v21     284807 non-null  float64
 22  v22     284807 non-null  float64
 23  v23     284807 non-null  float64
 24  v24     284807 non-null  float64
 25  v25     284807 non-null  float64
 26  v26     284807 non-null  float64
 27  v27     284807 non-null  float64
 28  v28     284807 non-null  float64
 29  amount  284807 non-null  float64
 30  class   284807 non-null  int64
dtypes: float64(30), int64(1)
memory usage: 67.4 MB
None

### Missing Values:

time      0
v1        0
v2        0
v3        0
v4        0
v5        0
v6        0
v7        0
v8        0
v9        0
v10       0
```

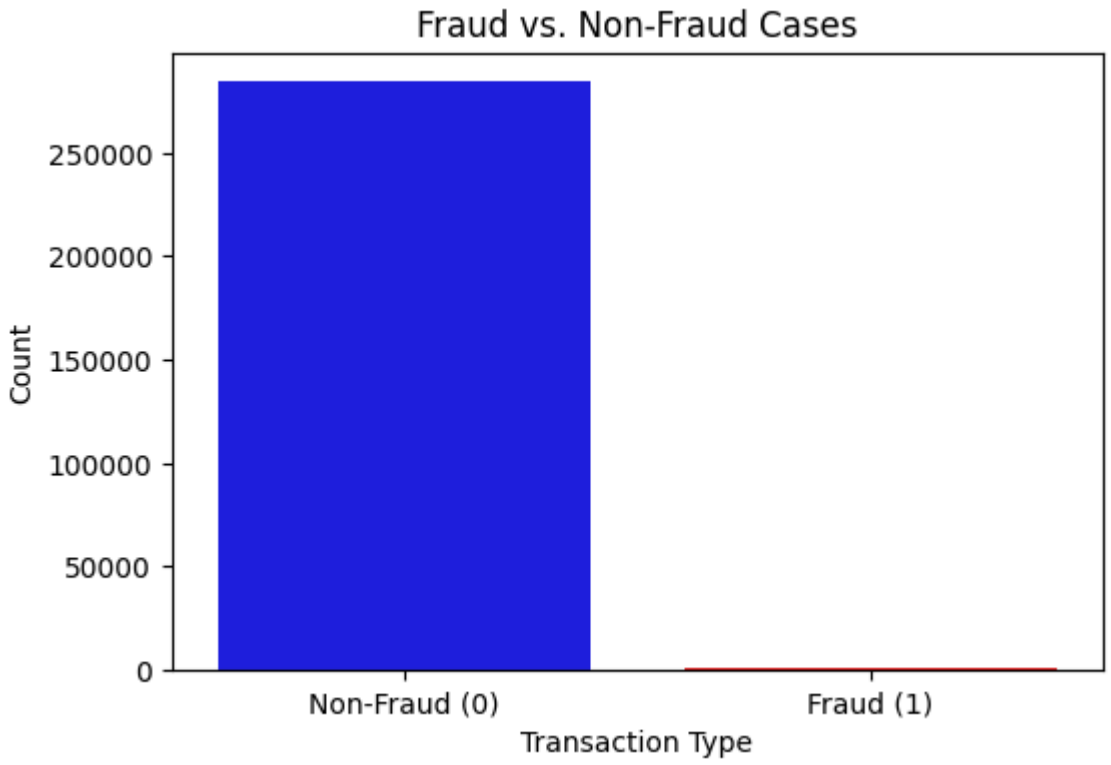
```
v11       0
v12       0
v13       0
v14       0
v15       0
v16       0
v17       0
v18       0
v19       0
v20       0
v21       0
v22       0
v23       0
v24       0
v25       0
v26       0
v27       0
v28       0
amount    0
class     0
dtype: int64
```

Section 2: Data Visualization

Class Distribution

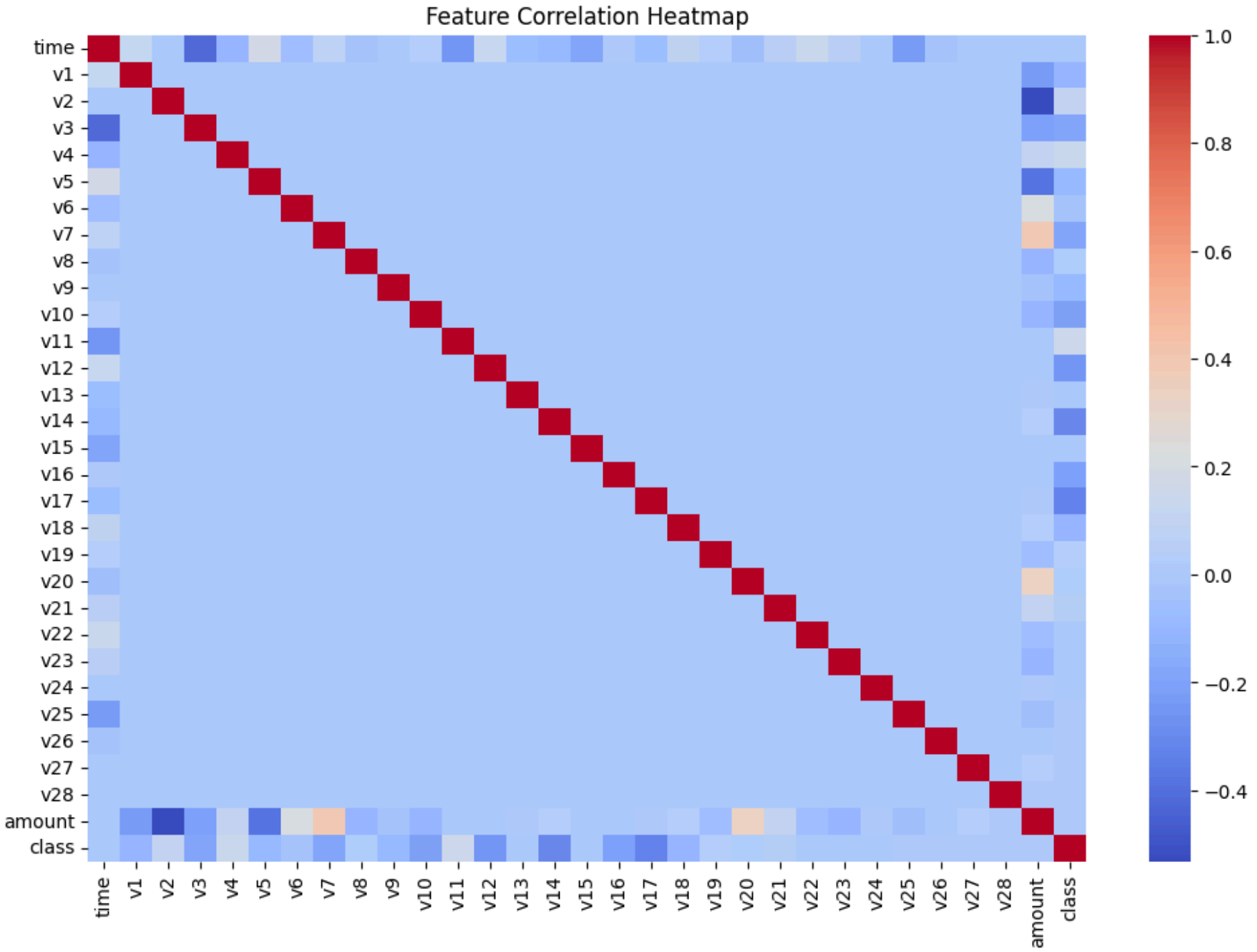
In [13]:
```
if 'class' in df.columns:
    print("\n### Class Distribution:\n")
    print(df['class'].value_counts())

    plt.figure(figsize=(6, 4))
    sns.countplot(x=df['class'], hue=df['class'], palette={0: "blue", 1: "red"}, legend=False)
    plt.title("Fraud vs. Non-Fraud Cases")
    plt.xlabel("Transaction Type")
    plt.ylabel("Count")
    plt.xticks(ticks=[0, 1], labels=["Non-Fraud (0)", "Fraud (1)"])
    plt.show()
else:
    print("Error: 'class' column not found in dataset.")
```

```
### Class Distribution:

class
0    284315
1       492
Name: count, dtype: int64
```



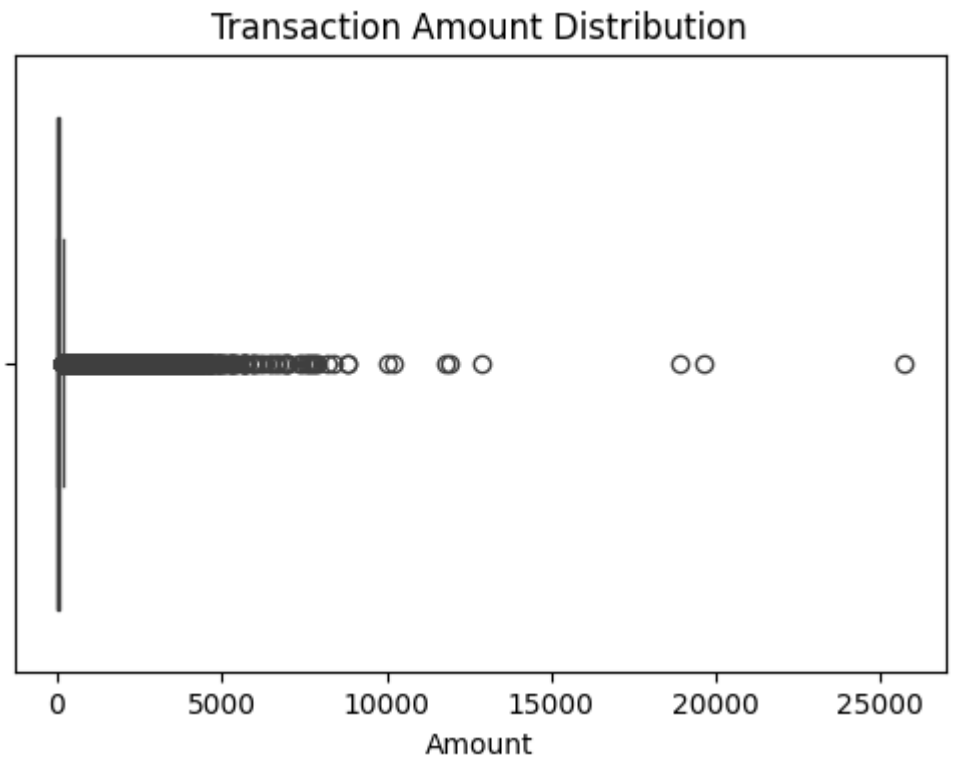
Correlation Heatmap

In [14]:
```
plt.figure(figsize=(12, 8))
sns.heatmap(df.corr(), cmap='coolwarm', annot=False)
plt.title("Feature Correlation Heatmap")
plt.show()
```



Boxplot for Transaction Amounts

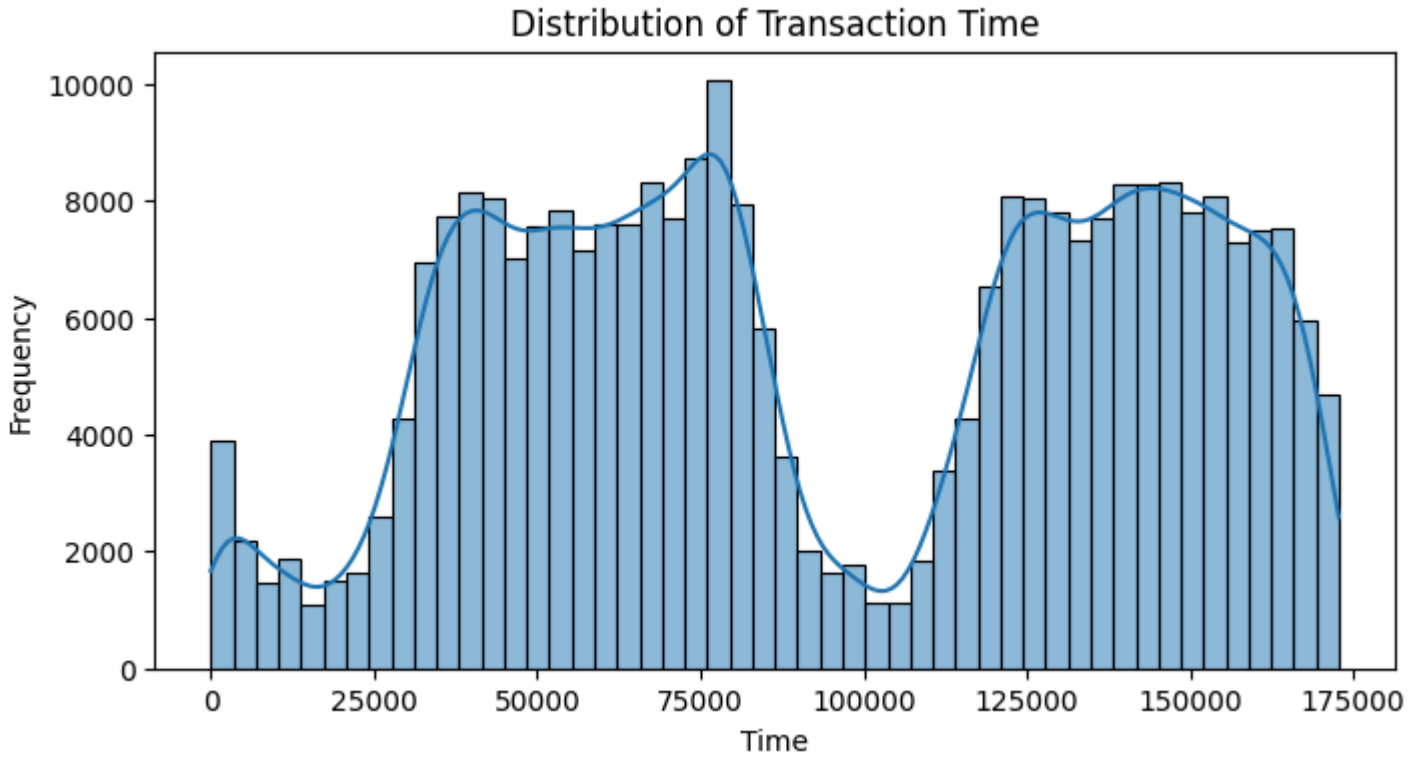
In [15]:
```
if 'amount' in df.columns:
    plt.figure(figsize=(6, 4))
    sns.boxplot(x=df['amount'])
    plt.title("Transaction Amount Distribution")
    plt.xlabel("Amount")
    plt.show()
else:
    print("Error: 'amount' column not found in dataset.")
```



Distribution of Time Feature

In [16]:
```
if 'time' in df.columns:
    plt.figure(figsize=(8, 4))
    sns.histplot(df['time'], bins=50, kde=True)
    plt.title("Distribution of Transaction Time")
    plt.xlabel("Time")
    plt.ylabel("Frequency")
```

```
    plt.show()
else:
    print("Error: 'time' column not found in dataset.")
```



Section 3: Data Preprocessing

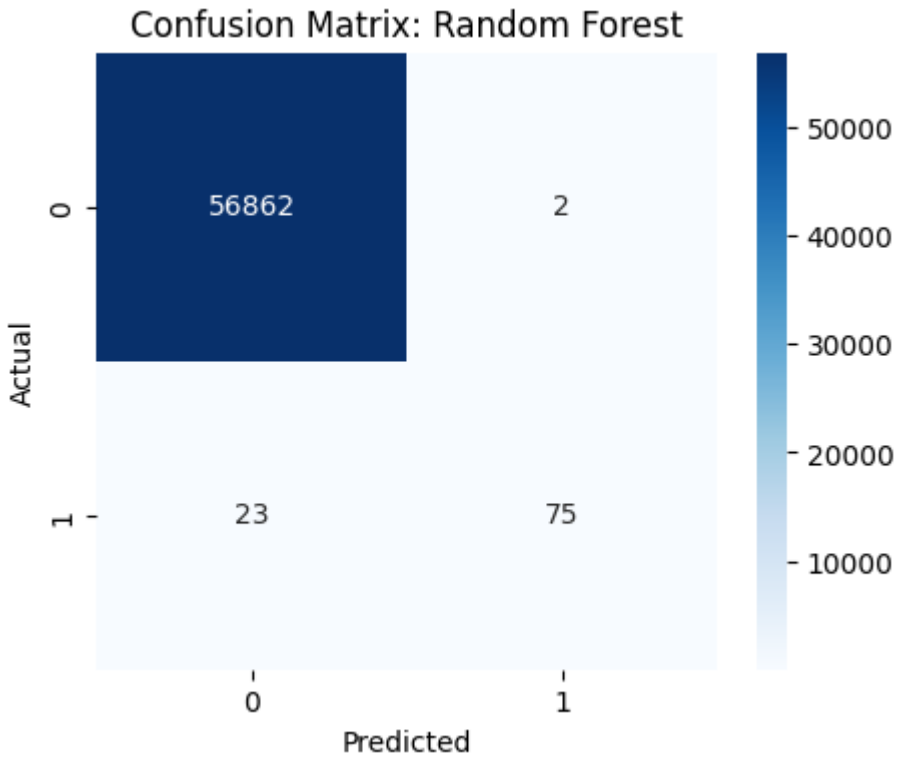
In [17]:
```
# Selecting Features and Target
features = df.drop(columns=['class'])
target = df['class']

# Scaling numerical features
scaler = StandardScaler()
features = scaler.fit_transform(features)

# Splitting dataset
X_train, X_test, y_train, y_test = train_test_split(features, target, test_size=0.2, random_state=42)
print("### Data Preprocessing Completed: Features scaled and dataset split.")
```

```
### Data Preprocessing Completed: Features scaled and dataset split.
```

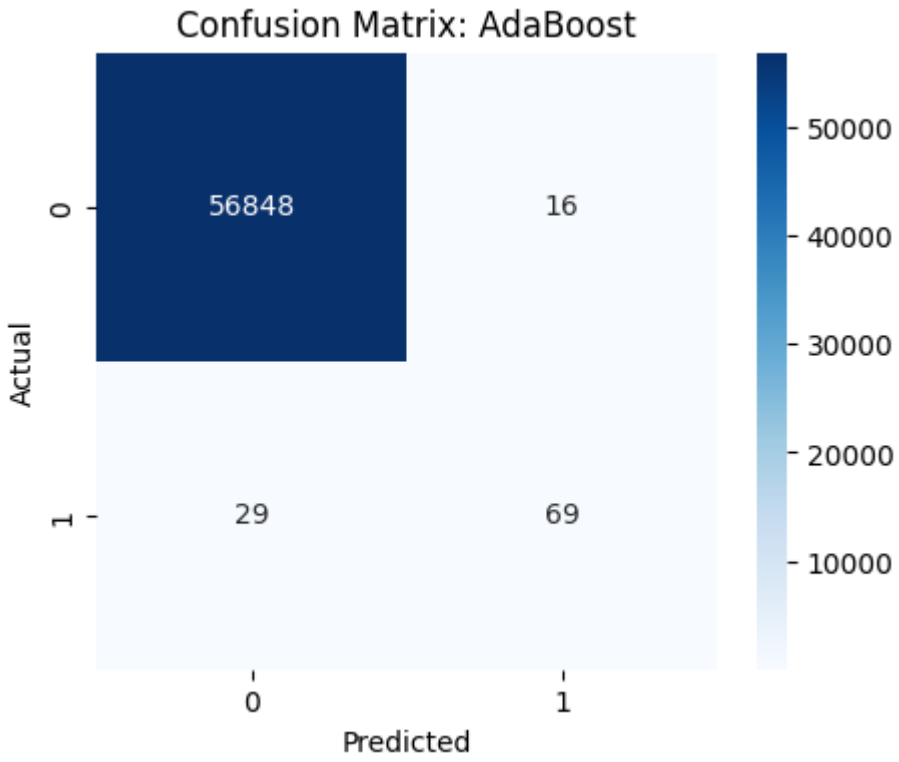
Section 4: Model Training and Evaluation

In [18]:
```
def train_and_evaluate(model, model_name):
    start_time = time.time()
    model.fit(X_train, y_train)
    end_time = time.time()

    y_pred = model.predict(X_test)
    accuracy = accuracy_score(y_test, y_pred)
    print(f"\n### {model_name} Model Results:")
    print(f"Training Time: {end_time - start_time:.2f} seconds")
    print(f"Accuracy: {accuracy:.4f}")
    print("Classification Report:")
    print(classification_report(y_test, y_pred))

    # Confusion Matrix
    plt.figure(figsize=(5, 4))
    sns.heatmap(confusion_matrix(y_test, y_pred), annot=True, fmt='d', cmap='Blues')
    plt.title(f"Confusion Matrix: {model_name}")
    plt.xlabel("Predicted")
    plt.ylabel("Actual")
    plt.show()

    # Fraud Detection Rate (FDR)
    tp = np.sum((y_test == 1) & (y_pred == 1))  # True Positives
    fn = np.sum((y_test == 1) & (y_pred == 0))  # False Negatives
    fdr = tp / (tp + fn) if (tp + fn) > 0 else 0  # Avoid division by zero
    print(f"Fraud Detection Rate (FDR): {fdr:.4f}")

# Train and evaluate models
rf_model = RandomForestClassifier(n_estimators=100, random_state=42)
adaboost_model = AdaBoostClassifier(n_estimators=100, random_state=42)
gb_model = GradientBoostingClassifier(n_estimators=100, random_state=42)

train_and_evaluate(rf_model, "Random Forest")
train_and_evaluate(adaboost_model, "AdaBoost")
train_and_evaluate(gb_model, "Gradient Boosting")
```

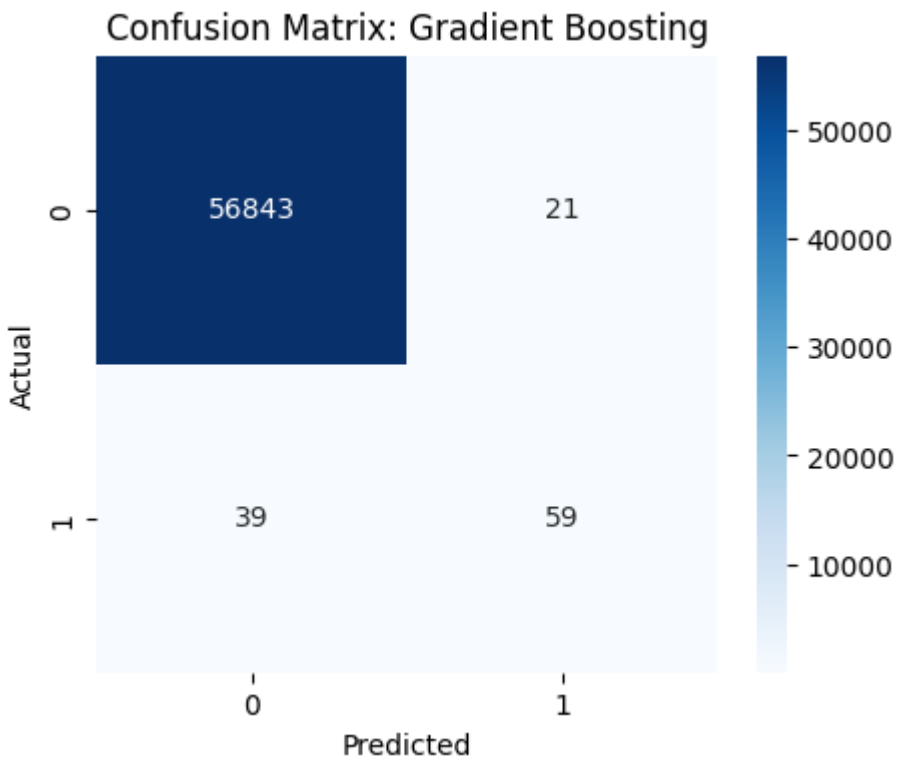
```
### Random Forest Model Results:
Training Time: 403.56 seconds
Accuracy: 0.9996
Classification Report:
              precision    recall  f1-score   support

           0       1.00      1.00      1.00     56864
           1       0.97      0.77      0.86        98

    accuracy                           1.00     56962
   macro avg       0.99      0.88      0.93     56962
weighted avg       1.00      1.00      1.00     56962
```




```
Fraud Detection Rate (FDR): 0.7653

### AdaBoost Model Results:
Training Time: 236.05 seconds
Accuracy: 0.9992
Classification Report:
              precision    recall  f1-score   support

           0       1.00      1.00      1.00     56864
           1       0.81      0.70      0.75        98

    accuracy                           1.00     56962
   macro avg       0.91      0.85      0.88     56962
weighted avg       1.00      1.00      1.00     56962
```



```
Fraud Detection Rate (FDR): 0.7041

### Gradient Boosting Model Results:
Training Time: 692.61 seconds
Accuracy: 0.9989
Classification Report:
              precision    recall  f1-score   support

           0       1.00      1.00      1.00     56864
           1       0.74      0.60      0.66        98

    accuracy                           1.00     56962
   macro avg       0.87      0.80      0.83     56962
weighted avg       1.00      1.00      1.00     56962
```

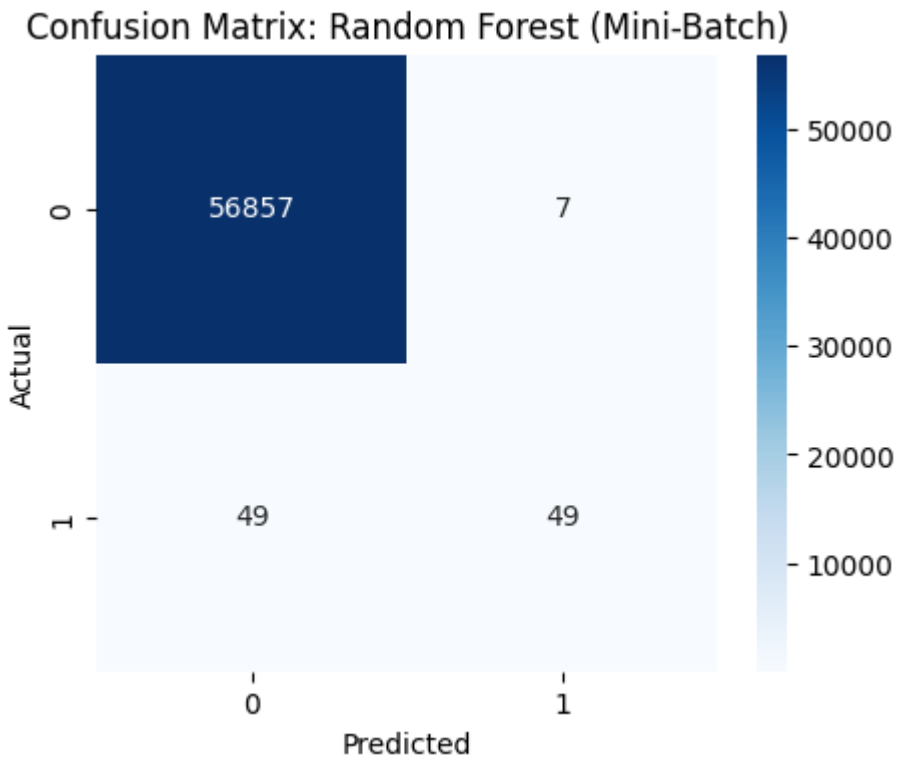



```
Fraud Detection Rate (FDR): 0.6020
```

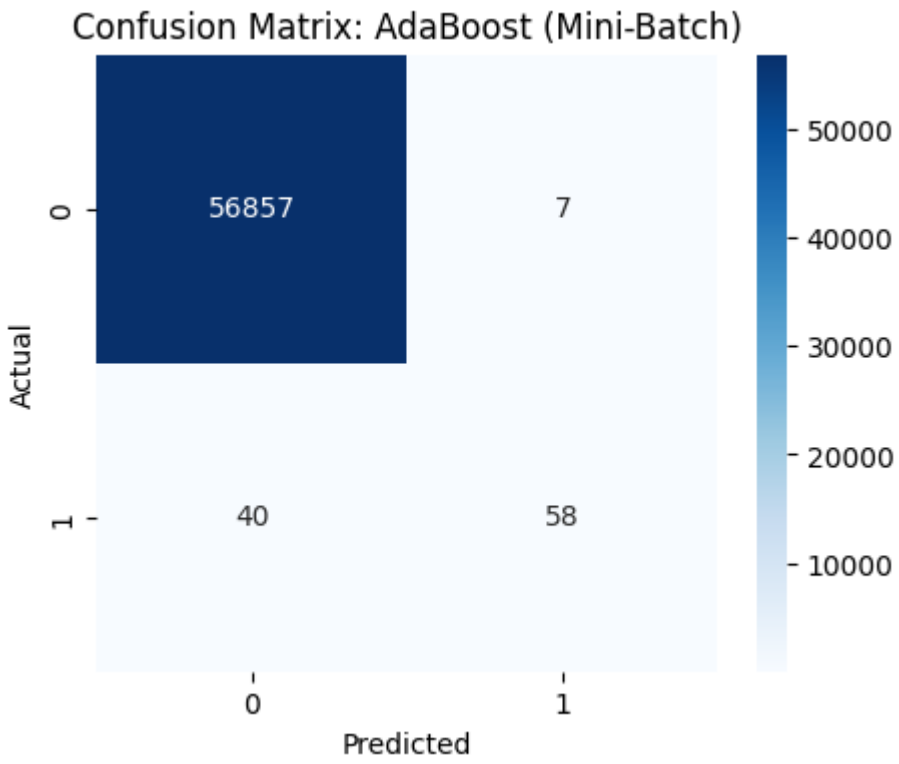
Section 5: Mini-Batch Parallel Training

In [19]:
```python
def mini_batch_train(model, model_name, batch_size=10000):
    X_train_shuffled, y_train_shuffled = shuffle(X_train, y_train, random_state=42)
    num_batches = len(X_train) // batch_size
    start_time = time.time()

    for i in range(num_batches + 1):
        start_idx = i * batch_size
        end_idx = start_idx + batch_size
        X_batch = X_train_shuffled[start_idx:end_idx]
        y_batch = y_train_shuffled[start_idx:end_idx]

        if len(X_batch) > 0:
            model.fit(X_batch, y_batch)

    end_time = time.time()
    y_pred = model.predict(X_test)
    accuracy = accuracy_score(y_test, y_pred)

    print(f"\n### {model_name} Mini-Batch Training Results:")
    print(f"Training Time: {end_time - start_time:.2f} seconds")
    print(f"Accuracy: {accuracy:.4f}")
    print("Classification Report:")
    print(classification_report(y_test, y_pred))

    # Confusion Matrix
    plt.figure(figsize=(5, 4))
    sns.heatmap(confusion_matrix(y_test, y_pred), annot=True, fmt='d', cmap='Blues')
    plt.title(f"Confusion Matrix: {model_name} (Mini-Batch)")
    plt.xlabel("Predicted")
    plt.ylabel("Actual")
    plt.show()

    # Fraud Detection Rate (FDR)
    tp = np.sum((y_test == 1) & (y_pred == 1))  # True Positives
    fn = np.sum((y_test == 1) & (y_pred == 0))  # False Negatives
    fdr = tp / (tp + fn) if (tp + fn) > 0 else 0  # Avoid division by zero
    print(f"Fraud Detection Rate (FDR): {fdr:.4f}")

# Mini-Batch Training
mini_batch_train(RandomForestClassifier(n_estimators=100, random_state=42), "Random Forest")
mini_batch_train(AdaBoostClassifier(n_estimators=100, random_state=42), "AdaBoost")
mini_batch_train(GradientBoostingClassifier(n_estimators=100, random_state=42), "Gradient Boosting")
```

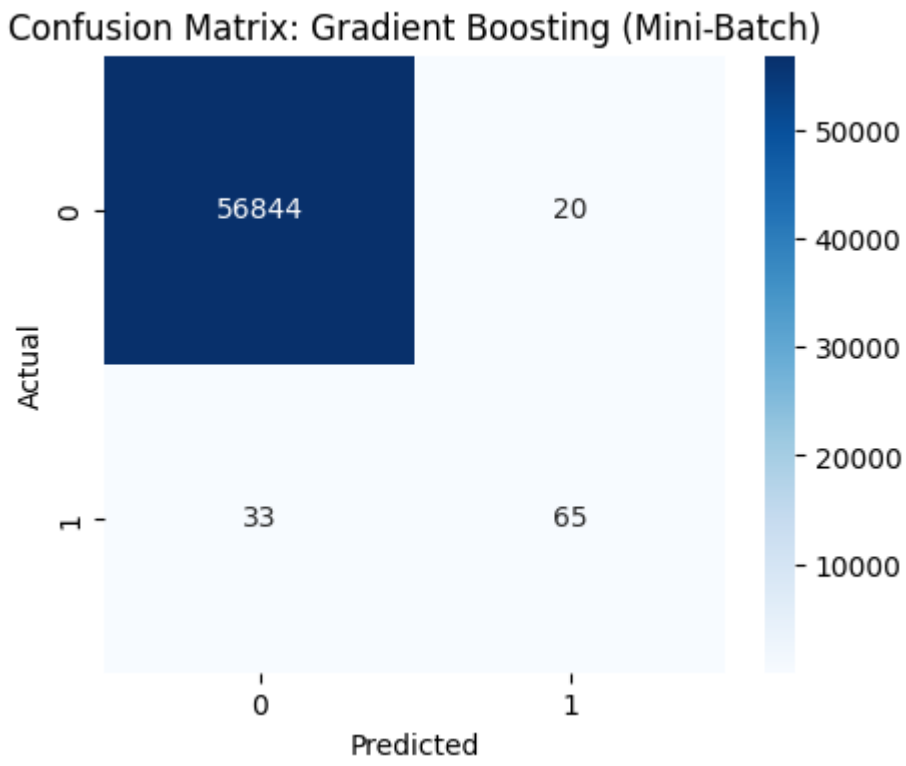
```
### Random Forest Mini-Batch Training Results:
Training Time: 68.74 seconds
Accuracy: 0.9990
Classification Report:
              precision    recall  f1-score   support

           0       1.00      1.00      1.00     56864
           1       0.88      0.50      0.64        98

    accuracy                           1.00     56962
   macro avg       0.94      0.75      0.82     56962
weighted avg       1.00      1.00      1.00     56962
```




```
Fraud Detection Rate (FDR): 0.5000

### AdaBoost Mini-Batch Training Results:
Training Time: 153.88 seconds
Accuracy: 0.9992
Classification Report:
              precision    recall  f1-score   support

           0       1.00      1.00      1.00     56864
           1       0.89      0.59      0.71        98

    accuracy                           1.00     56962
   macro avg       0.95      0.80      0.86     56962
weighted avg       1.00      1.00      1.00     56962
```



```
Fraud Detection Rate (FDR): 0.5918

### Gradient Boosting Mini-Batch Training Results:
Training Time: 336.48 seconds
Accuracy: 0.9991
Classification Report:
              precision    recall  f1-score   support

           0       1.00      1.00      1.00     56864
           1       0.76      0.66      0.71        98

    accuracy                           1.00     56962
   macro avg       0.88      0.83      0.85     56962
weighted avg       1.00      1.00      1.00     56962
```




```
Fraud Detection Rate (FDR): 0.6633
```

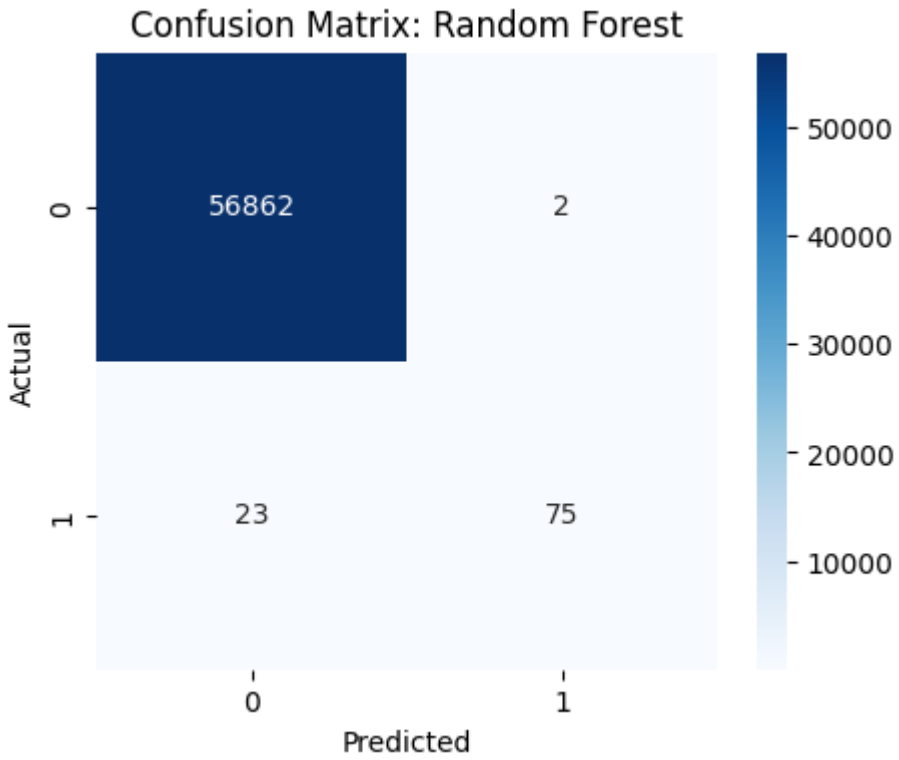
Section 6: Parallel Training with CPU Multithreading Optimization (18 Min vs 15 Min)

In [20]:

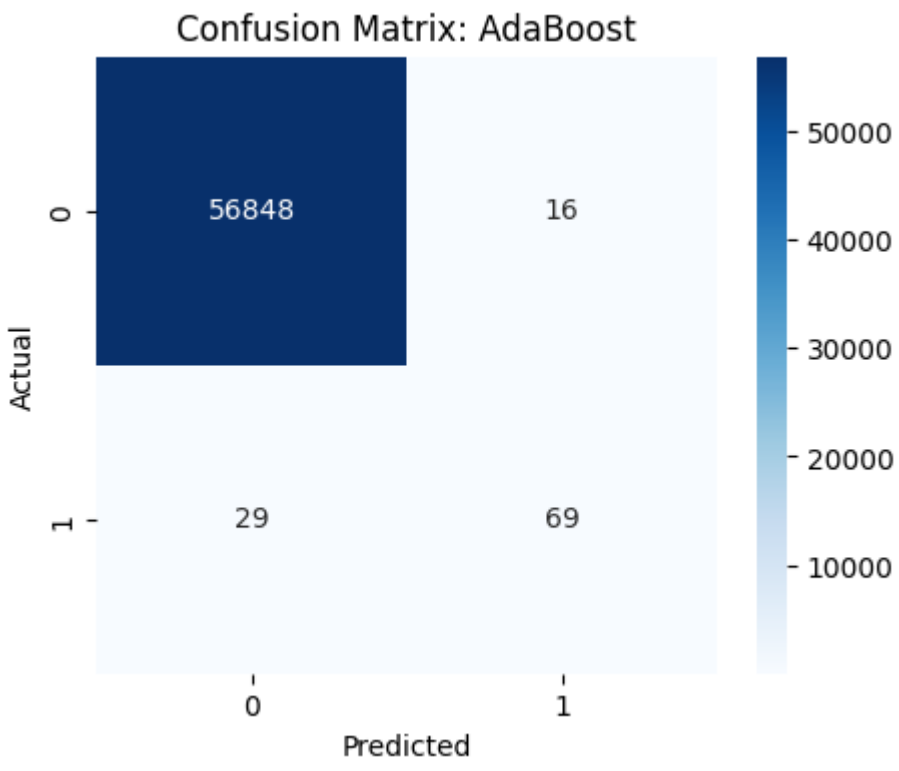
```python
# Load dataset
file_name = "creditcard.csv"
df = pd.read_csv(file_name)
df.columns = df.columns.str.lower()

# Selecting Features and Target
features = df.drop(columns=['class'])
target = df['class']

# Scaling numerical features
scaler = StandardScaler()
features = scaler.fit_transform(features)

# Splitting dataset
X_train, X_test, y_train, y_test = train_test_split(features, target, test_size=0.2, random_state=42)

# Function to train and evaluate models
def train_and_evaluate(model, model_name):
    start_time = time.time()
    model.fit(X_train, y_train)
    end_time = time.time()

    y_pred = model.predict(X_test)
    accuracy = accuracy_score(y_test, y_pred)
    print(f"\n### {model_name} Model Results:")
    print(f"Training Time: {end_time - start_time:.2f} seconds")
    print(f"Accuracy: {accuracy:.4f}")

    # Confusion Matrix
    plt.figure(figsize=(5, 4))
    sns.heatmap(confusion_matrix(y_test, y_pred), annot=True, fmt='d', cmap='Blues')
    plt.title(f"Confusion Matrix: {model_name}")
    plt.xlabel("Predicted")
    plt.ylabel("Actual")
    plt.show()

    # Fraud Detection Rate (FDR)
    tp = np.sum((y_test == 1) & (y_pred == 1))  # True Positives
    fn = np.sum((y_test == 1) & (y_pred == 0))  # False Negatives
    fdr = tp / (tp + fn) if (tp + fn) > 0 else 0  # Avoid division by zero
    print(f"Fraud Detection Rate (FDR): {fdr:.4f}")
```

```
# Train models sequentially using multithreading for faster training
def parallel_training():
    models = [
        (RandomForestClassifier(n_estimators=100, random_state=42, n_jobs=-1), "Random Forest"),
        (AdaBoostClassifier(n_estimators=100, random_state=42), "AdaBoost"),
        (GradientBoostingClassifier(n_estimators=100, random_state=42), "Gradient Boosting")
    ]

    with ThreadPoolExecutor(max_workers=3) as executor:
        futures = [executor.submit(train_and_evaluate, model, name) for model, name in models]
        for future in futures:
            future.result()

# Run training in parallel
parallel_training()
```

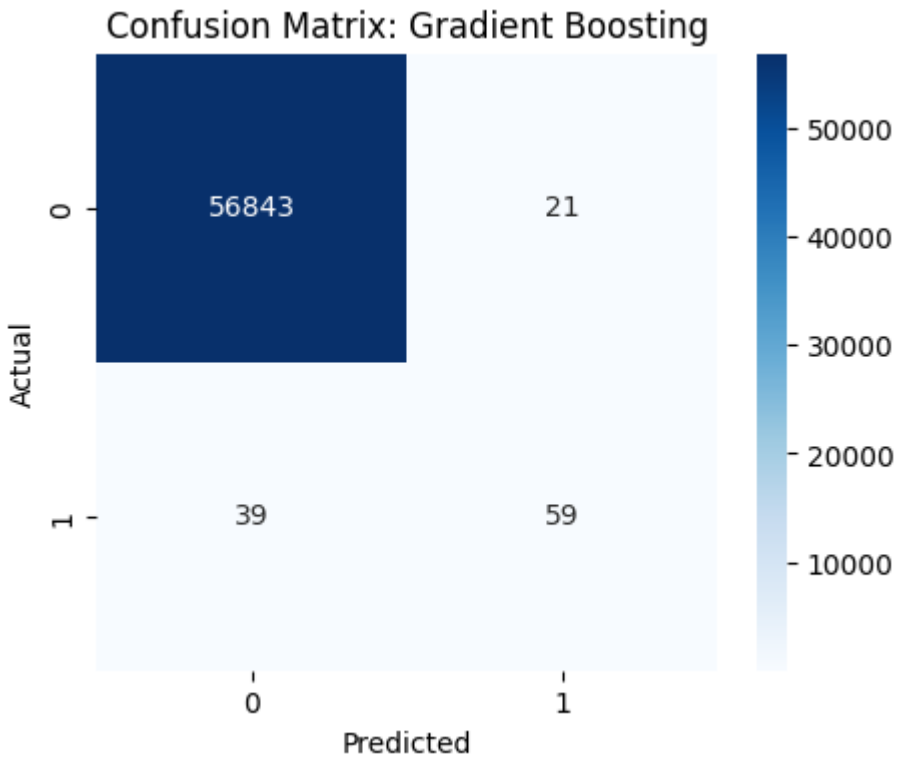
```
### Random Forest Model Results:
Training Time: 657.61 seconds
Accuracy: 0.9996
```




```
Fraud Detection Rate (FDR): 0.7653

### AdaBoost Model Results:
Training Time: 707.11 seconds
Accuracy: 0.9992
```




```
Fraud Detection Rate (FDR): 0.7041

### Gradient Boosting Model Results:
Training Time: 1135.56 seconds
Accuracy: 0.9989
```




```
Fraud Detection Rate (FDR): 0.6020
```

Section 7 : Using DASK vs Spark For Model Training

In [2]:
```python
import dask
from dask import delayed, compute
from pyspark.sql import SparkSession
from pyspark.ml.classification import RandomForestClassifier as SparkRF, GBTClassifier as SparkGBT
from pyspark.ml.feature import VectorAssembler
from pyspark.ml.evaluation import MulticlassClassificationEvaluator
```

In [22]:
```python
# Load dataset
file_name = "creditcard.csv"
df = pd.read_csv(file_name)
df.columns = df.columns.str.lower()

# Selecting Features and Target
features = df.drop(columns=['class'])
target = df['class']

# Scaling numerical features
scaler = StandardScaler()
features = scaler.fit_transform(features)

# Splitting dataset
X_train, X_test, y_train, y_test = train_test_split(features, target, test_size=0.2, random_state=42)

# Function to train and evaluate models using Dask with Fraud Detection Rate (FDR)
def dask_train_and_evaluate(model, model_name, X_train, y_train, X_test, y_test):
    start_time = time.time()
    model.fit(X_train, y_train)
    end_time = time.time()

    y_pred = model.predict(X_test)
    accuracy = accuracy_score(y_test, y_pred)

    # Fraud Detection Rate (FDR)
    tp = np.sum((y_test == 1) & (y_pred == 1))  # True Positives
    fn = np.sum((y_test == 1) & (y_pred == 0))  # False Negatives
    fdr = tp / (tp + fn) if (tp + fn) > 0 else 0  # Avoid division by zero

    print(f"\n### {model_name} Model Results (Dask):")
    print(f"Training Time: {end_time - start_time:.2f} seconds")
    print(f"Accuracy: {accuracy:.4f}")
    print(f"Fraud Detection Rate (FDR): {fdr:.4f}")
    print("Classification Report:")
    print(classification_report(y_test, y_pred))

    # Confusion Matrix
    print("Confusion Matrix:")
    print(confusion_matrix(y_test, y_pred))

    return model_name, end_time - start_time, accuracy, fdr

# Wrap models in Dask delayed
dask_models = [
    delayed(dask_train_and_evaluate)(RandomForestClassifier(n_estimators=100, random_state=42, n_jobs=-1), "Random
    delayed(dask_train_and_evaluate)(AdaBoostClassifier(n_estimators=100, random_state=42), "AdaBoost (Dask)", X_tr
    delayed(dask_train_and_evaluate)(GradientBoostingClassifier(n_estimators=100, random_state=42), "Gradient Boost
]

# Execute training in parallel using Dask
```

```
results = compute(*dask_models)
for model_name, train_time, accuracy, fdr in results:
    print(f"{model_name}: {train_time:.2f}s, Accuracy: {accuracy:.4f}, Fraud Detection Rate (FDR): {fdr:.4f}")
```

```
### Random Forest (Dask) Model Results (Dask):
Training Time: 460.74 seconds
Accuracy: 0.9996
Fraud Detection Rate (FDR): 0.7653
Classification Report:
              precision    recall  f1-score   support

           0       1.00      1.00      1.00     56864
           1       0.97      0.77      0.86        98

    accuracy                           1.00     56962
   macro avg       0.99      0.88      0.93     56962
weighted avg       1.00      1.00      1.00     56962

Confusion Matrix:
[[56862     2]
 [   23    75]]

### AdaBoost (Dask) Model Results (Dask):
Training Time: 497.30 seconds
Accuracy: 0.9992
Fraud Detection Rate (FDR): 0.7041
Classification Report:
              precision    recall  f1-score   support

           0       1.00      1.00      1.00     56864
           1       0.81      0.70      0.75        98

    accuracy                           1.00     56962
   macro avg       0.91      0.85      0.88     56962
weighted avg       1.00      1.00      1.00     56962

Confusion Matrix:
[[56848    16]
 [   29    69]]

### Gradient Boosting (Dask) Model Results (Dask):
Training Time: 679.91 seconds
Accuracy: 0.9989
Fraud Detection Rate (FDR): 0.6020
Classification Report:
              precision    recall  f1-score   support

           0       1.00      1.00      1.00     56864
           1       0.74      0.60      0.66        98

    accuracy                           1.00     56962
   macro avg       0.87      0.80      0.83     56962
weighted avg       1.00      1.00      1.00     56962

Confusion Matrix:
[[56843    21]
 [   39    59]]
Random Forest (Dask): 460.74s, Accuracy: 0.9996, Fraud Detection Rate (FDR): 0.7653
AdaBoost (Dask): 497.30s, Accuracy: 0.9992, Fraud Detection Rate (FDR): 0.7041
Gradient Boosting (Dask): 679.91s, Accuracy: 0.9989, Fraud Detection Rate (FDR): 0.6020
```

In [9]:

```
# Load dataset
file_name = "creditcard.csv"
df = pd.read_csv(file_name)
df.columns = df.columns.str.lower()

# Selecting Features and Target
features = df.drop(columns=['class'])
target = df['class']

# Scaling numerical features
scaler = StandardScaler()
features = scaler.fit_transform(features)

# Splitting dataset
X_train, X_test, y_train, y_test = train_test_split(features, target, test_size=0.2, random_state=42)

# Stop any existing Spark session
try:
    spark.stop()
except:
    pass

# Initialize Spark Session
spark = SparkSession.builder.appName("FraudDetectionML").getOrCreate()

# Convert Pandas to Spark DataFrame
spark_df = spark.createDataFrame(pd.concat([pd.DataFrame(features), target], axis=1))
```

```
# Rename class to "label" as class is reserved word
spark_df = spark_df.withColumnRenamed("class", "label")

# Assemble features
feature_cols = [str(i) for i in range(features.shape[1])]
assembler = VectorAssembler(inputCols=feature_cols, outputCol="features")
spark_df = assembler.transform(spark_df).select("features", "label")

# Split into training and test sets
train_df, test_df = spark_df.randomSplit([0.8, 0.2], seed=42)

# Function to train and evaluate models using Spark ML with Fraud Detection Rate (FDR)
def spark_train_and_evaluate(model, model_name, train_df, test_df):
    start_time = time.time()
    model_trained = model.fit(train_df)
    end_time = time.time()

    predictions = model_trained.transform(test_df)
    evaluator = MulticlassClassificationEvaluator(labelCol="label", predictionCol="prediction", metricName="accurac
    accuracy = evaluator.evaluate(predictions)

    # Extract predictions and labels
    y_pred = [row.prediction for row in predictions.select("prediction").collect()]
    y_true = [row["label"] for row in predictions.select("label").collect()]

    # Fraud Detection Rate (FDR)
    tp = np.sum((np.array(y_true) == 1) & (np.array(y_pred) == 1))  # True Positives
    fn = np.sum((np.array(y_true) == 1) & (np.array(y_pred) == 0))  # False Negatives
    fdr = tp / (tp + fn) if (tp + fn) > 0 else 0  # Avoid division by zero

    print(f"\n### {model_name} Model Results (Spark):")
    print(f"Training Time: {end_time - start_time:.2f} seconds")
    print(f"Accuracy: {accuracy:.4f}")
    print(f"Fraud Detection Rate (FDR): {fdr:.4f}")

    return model_name, end_time - start_time, accuracy, fdr

# Train and evaluate models using Spark ML
spark_rf = SparkRF(labelCol="label", featuresCol="features", numTrees=100)
spark_gbt = SparkGBT(labelCol="label", featuresCol="features", maxIter=100)

rf_results = spark_train_and_evaluate(spark_rf, "Random Forest (Spark)", train_df, test_df)
gbt_results = spark_train_and_evaluate(spark_gbt, "Gradient Boosting (Spark)", train_df, test_df)

# Stop Spark session
spark.stop()

# Print final results
for model_name, train_time, accuracy, fdr in [rf_results, gbt_results]:
    print(f"{model_name}: {train_time:.2f}s, Accuracy: {accuracy:.4f}, Fraud Detection Rate (FDR): {fdr:.4f}")
```

```
### Random Forest (Spark) Model Results (Spark):
Training Time: 59.83 seconds
Accuracy: 0.9994
Fraud Detection Rate (FDR): 0.7396

### Gradient Boosting (Spark) Model Results (Spark):
Training Time: 413.97 seconds
Accuracy: 0.9995
Fraud Detection Rate (FDR): 0.7188
Random Forest (Spark): 59.83s, Accuracy: 0.9994, Fraud Detection Rate (FDR): 0.7396
Gradient Boosting (Spark): 413.97s, Accuracy: 0.9995, Fraud Detection Rate (FDR): 0.7188
```

Summary of Tools and Libraries Used

Component	Tool/Library Used	Purpose
Data Processing	**Pandas**	Data handling & preprocessing
	Dask	Parallel data processing
Feature Scaling	**sklearn.preprocessing (StandardScaler)**	Normalizing feature values
Train-Test Split	**sklearn.model_selection (train_test_split)**	Splitting dataset into training & testing
Model Training (CPU)	**sklearn.ensemble (RF, AdaBoost, GB)**	Standard ML model training
Mini-Batch Training	**sklearn.utils (shuffle)**	Splitting data into smaller batches
Multi-threading	**ThreadPoolExecutor**	Parallel execution on CPU
Distributed Computing	**Dask**	Parallel training using multiple CPU cores
	Apache Spark MLlib	Distributed training across multiple nodes
GPU Acceleration	**RAPIDS cuML**	GPU-accelerated Random Forest & Gradient Boosting
Evaluation Metrics	**sklearn.metrics (accuracy_score, confusion_matrix)**	Measuring model performance

Component	Tool/Library Used	Purpose
Visualization	**Matplotlib, Seaborn**	Graphical representation of results

In [ ]: