Project Report

SDN-Based Multipath Data Offloading Scheme Using Link Quality Prediction for LTE and WiFi Networks

GROUP 6:

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Introduction and Motivation

The exponential growth of mobile data traffic, caused by apps like HD video streaming, cloud gaming, and multimedia services, has put a lot of pressure on cellular networks. Traditional **LTE networks** cannot handle this growth because spectrum availability is limited. **Wi-Fi networks** can add extra capacity, but using only Wi-Fi offloading is not enough because performance drops when many users connect.

Heterogeneous Networks (HetNet), where user devices can use both LTE and Wi-Fi together, are a cost-effective way to offload traffic. However, current methods have two main problems that must be solved:

1. **Dynamic link quality** – changes frequently due to user movement, interference, and network load.
2. **Packet reordering in multipath offloading** – causes delays and reduces throughput.

To solve these problems, our project reproduces and improves an **SDN-based multipath data offloading method**. We use **deep learning (LSTM and BLSTM)** to predict link quality and **flowlet-aware traffic splitting** to keep throughput stable, reduce delays, and make better offloading decisions.

Research Contributions

The research paper forms the foundation of our project, with the following major contributions:

1. **Channel Quality Prediction:**
    a. Introduced LSTM and BLSTM models to classify link quality into *Good*, *Intermediate*, and *Bad* classes.
    b. Used both hardware metrics (RSSI) and software metrics (Packet Delivery Ratio – PDR).
    c. Achieved up to **99.94% prediction accuracy**, outperforming traditional models.
2. **Multipath Data Offloading Scheme:**
    a. Designed an SDN-based LTE-WiFi integration where controllers monitor link conditions.
    b. Developed an offloading algorithm to dynamically decide whether to keep traffic on LTE or split between LTE and WiFi.

3. **Flowlet-Based Traffic Splitting:**
    a. Implemented flowlet detection to minimize packet reordering while leveraging multipath transmission.
4. **Performance Evaluation:**
    a. Built a testbed using Mininet-WiFi, Open vSwitch (OVS), and OpenDaylight SDN controllers.
    b. Demonstrated a **6.29% throughput improvement** over state-of-the-art SD-MTOP and MTCP schemes under high load.

Project Objectives

Our project aims to replicate and validate the above research while adapting it to our lab environment. Specifically, we set the following objectives:

- Implement link quality prediction using **LSTM and BLSTM models** with IoT-LAB dataset samples.
- Deploy an **SDN-enabled HetNet emulation** in Mininet-WiFi, with LTE and WiFi access points.
- Design and test a **Data Offloading (DO) module** to dynamically trigger LTE/WiFi offloading based on predicted link conditions.
- Integrate a **flowlet-aware multipath mechanism** into the controller to prevent packet reordering.
- Benchmark system performance against existing offloading schemes (SD-MTOP, MTCP).

Tools and Implementation

To achieve reproducibility in a controlled lab environment, the following tools and frameworks are used:

- **Mininet-WiFi** – to emulate LTE and WiFi nodes, mobility models, and heterogeneous access.
- **Open vSwitch (OVS)** – as the SDN-enabled data plane for forwarding and flow table updates.
- **Ryu or OpenDaylight SDN Controller** – to manage LTE and WiFi domains with communication between controllers.
- **Python (TensorFlow/Keras, scikit-learn)** – for implementing LSTM and BLSTM-based link quality prediction models.
- **Iperf** – to generate controlled traffic for throughput and delay measurements.
- **Flowlet-based Routing Module** – implemented in Python to detect flowlets and push group table rules via OpenFlow.

Implementation Steps:

1. Preprocess and train BLSTM models on RSSI and PDR data for link quality classification.
2. Deploy HetNet emulation in Mininet-WiFi with LTE and WiFi access points.
3. Integrate trained prediction model into the SDN controller for real-time quality assessment.
4. Implement Data Offloading algorithm with flowlet-aware splitting.
5. Run performance tests comparing LTE-only, SD-MTOP, MTCP, and our approach.

Future Work

While the current work successfully improves throughput and stability, several extensions are possible for further research:

1. **Reinforcement Learning for Offloading:**
    a. We plan to use deep reinforcement learning (DQN/PPO) for smarter offloading decisions in changing network conditions.
2. **QoE-Aware Offloading:**
    a. Extend the offloading module to incorporate user-level Quality of Experience (QoE) metrics such as video buffering time and latency, rather than throughput alone.
3. **Multi-Controller Coordination:**
    a. Investigate distributed controller architectures to ensure smooth service in large-scale HetNets during user mobility.

References

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