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Wireless Link Quality Estimation Using LSTM Model

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Abstract

In this paper, we propose a novel Wireless Link Quality Estimation (WLQE) model leveraging Long Short-Term Memory (LSTM) to a highly accurate estimation communication quality in wireless networks. Our LSTM-based approach outperforms conventional methods by 19.3% in accuracy and 9.5% in macro-F1, offering enhanced stability for outdoor communication on mobile devices.

Keywords

Link Quality Estimation, Deep Learning, LSTM, Wireless Network, Prediction, Wireless Quality of Service

I. Introduction

- Background
  - In recent years, mobile communication devices face fluctuating communication environments both indoors and outdoors and require stable and reliable network connectivity.
  - To address this, we aim to provide mobile devices with future communication quality estimates, enabling them to buffer and switch to optimal links before communication instability arises.
- Objective
  - Conventional methods for estimating communication quality does not utilize time-series information, and it is performed in a static environment and cannot flexibly respond to changes in the mobile environment.
  - Our objective is to utilize sequential information to provide a highly accurate estimate of future communication quality and a more adaptive model.

Urban areas　　Suburban areas

II. Proposed method

- LSTM-Based Wireless Link Quality Estimation (WLQE)
  - In this study, we proposed the LSTM-based WLQE shown in Fig. 1, focusing on time series data.
  - Long Short-Term Memory (LSTM) is a method that can learn long-term dependencies and is often used for time series data.
  - By focusing on time-series data of communication metrics information (RSRP, SINR), future link quality (RSRP) is estimated.
- Data Processing and Model Creation
  - Based on Table 1, a classification model was created by labelling the continuous values of RSRP into link quality grades (LQ grades).
  - Process communication metrics data into smoothed data and residual data and use LSTM to learn based on these time-series information.
  - We performed five preprocessing steps: missing value imputation, oversampling, residual separation, standardization, and binning.

Table 1. Mapping of RSRP values to link quality[1]

RSRP[dBm]	Link Quality	LQ grades(class)
$-84 \leq RSRP$	Very Good	4
$-84 < RSRP < -95$	Good	3
$-95 < RSRP < -105$	Intermediate	2
$-105 < RSRP < -115$	Bad	1
$RSRP \leq -115$	Very Bad	0

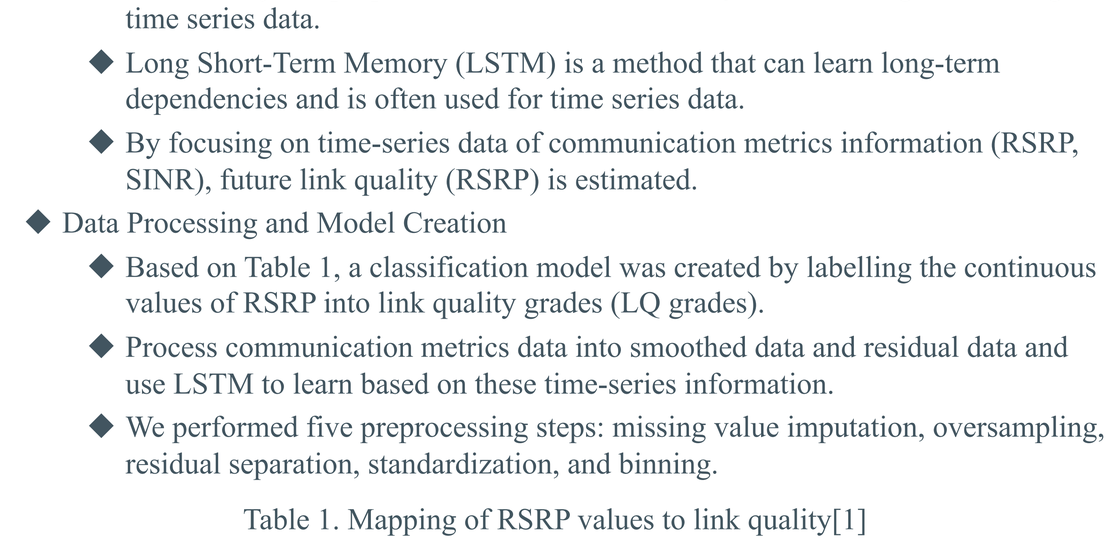

Fig. 1. The architecture of LSTM-based WLQE model.

III. Experiments

- Dataset
  - Proposed model and conventional models trained on SRFG dataset..
  - Dataset is split 7:2:1 for training, validation, and testing.
- Learning Methods for the Proposed Model
  - The proposed model is first trained with LSTM, and the best model is prepared before the loss of validation increases using Early Stopping.
  - The output values estimated by the LSTM model are input to the binning component and discretized.
  - Finally, the trained LSTM model is used to evaluate the test dataset.

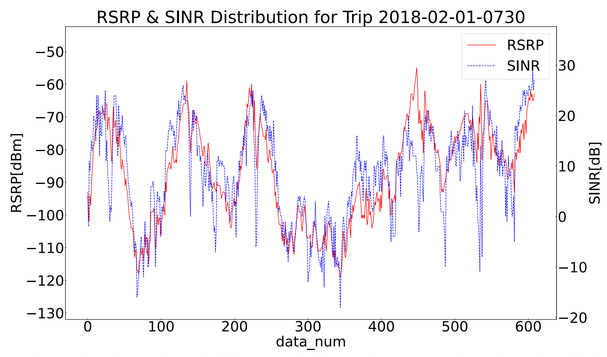

Fig. 2. Temporal variation in RSSI and SINR samples in the SRFG dataset.

IV. Results

- Table 2 shows the results of the evaluation of the proposed method against the conventional method ”Stacked AutoEncoder-based Link Quality Estimator (LQE-SAE)”[2] in terms of accuracy and macro-F1 metrics.
- The LSTM-based WLQE performs the best, with 19.3% higher accuracy and 9.5% higher macro-F1 than LQE-SAE.

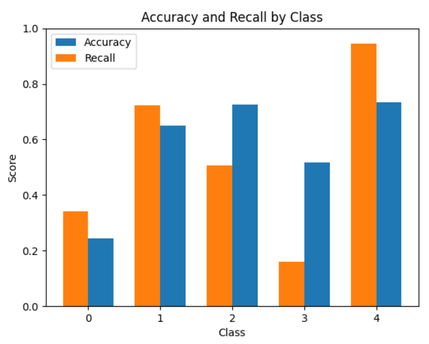

Fig.3 LQE-SAE

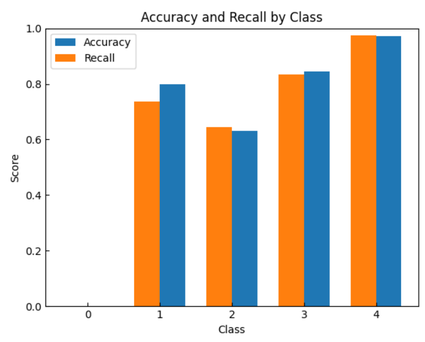

Fig.4 LSTM-based WLQE

Table 2. Model Performance

Model	Accuracy	macro-F1
LQE-SAE	0.694	0.527
LSTM-based WLQE	**0.887**	**0.622**

V. Conclusion

- Model Performance
  - In this study, we have developed an LSTM-based WLQE model that can effectively use sequential information.
  - The proposed method outperforms the conventional methods in terms of average accuracy and macro-F1.
  - The results of this study show that the proposed method, which utilizes sequential information using LSTM, is effective in estimating link quality with high accuracy.
- Future Outlook
  - In the future, we will search for optimal hyperparameters and propose new methods (e.g., regression models) that utilize other features.

References
[1] “MiFi Signal Strength Bar Meaning (RSRP,SNR,RSSI)”. https://insg.my.site.com/insgtechsupport/s/article/MiFi-Signal-Strength-Bars- vs-RSRP-etc
[2] X. Luo, L. Liu, J. Shu, and M. Al-Kali, ”Link quality estimation method for wireless sensor networks based on stacked autoencoder”, IEEE Access, vol. 7, 2019, pp. 21572–21583,

Acknowledgment
• This work was partly supported by JSPS KAKENHI Grant Number JP23H03379.