Wireless Broadband Service Quality Prediction App

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T-Mobile

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Abstract

- 5G internet devices enable wireless internet access at an extremely high speed
- However, 5G waves have low wavelength and are hence blocked by obstacles. This creates outdoor-to-indoor propagation issues, which results in unreliable and inconsistent coverage.
- Customers might be unhappy with this coverage and companies face expensive churn
- Our solution is to build an app that predicts consumers' 5G service quality before they sign up for a 5G internet device.

Goals and Deliverables

Three stages to predict 5G service quality:

- **Radio Frequency (RF) Study**: Investigate outdoor-to-indoor propagation for low and mid band 5G to collect data
- **Machine Learning (ML) Model**:

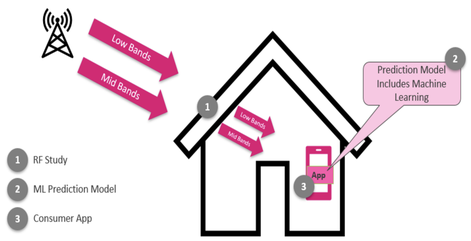


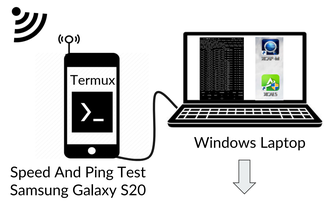
Figure 1. Project Stages Diagram

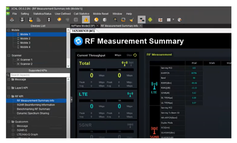
Train an ML model to predict service quality (throughput) of home internet

- **Consumer App**: Develop an app for consumers to predict service quality before signing up for T-Mobile Home Internet

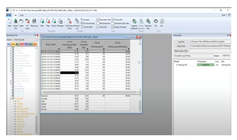
RF Study

- **Investigate outdoor-to-indoor RF propagation for low and mid frequency bands**
  - Collect outdoor/indoor RF metrics using state-of-the-art logging tools
    - Collect low and mid band, 4G and 5G data
    - Real-world data: team member homes, campus
    - Vary environmental factors: building height, near/no window, building/window material, elevation
  - Outdoor-to-indoor coverage data visualization
    - Indoor localization is challenging
    - Ideal CPE placement





XCAL: RF collection program



XCAP: RF extraction program

Figure 2. RF Data Collection Workflow

ML Engineering Model

- ML needs large amount of valid data to execute
- Here is the process we take to extract and predict values

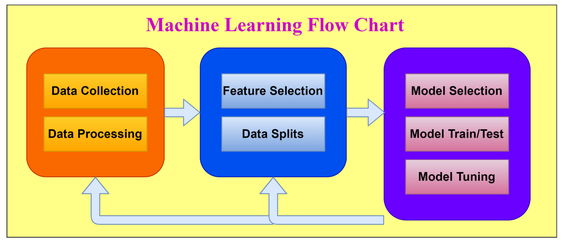


Figure 3. Machine Learning Flowchart

ML Processing

- **Data prepped for machine learning**
  - Raw data is first cleaned so that completed rows of datasets could be extracted
  - Clean data are then sieved to drop out the columns we do not need
- Features correlations are checked using a scatter matrix to verify the dependencies of the chosen columns (Figure 4)
- Then models will be chosen among the state-of-the-art machine learning models (Figure 5)
- Visualization of the different classes (greater or less than 80MBps) are observed (Figure 7)
- Hyperparameters are tuned by plotting the spectrum for neighbors of different sizes (Figure 8)

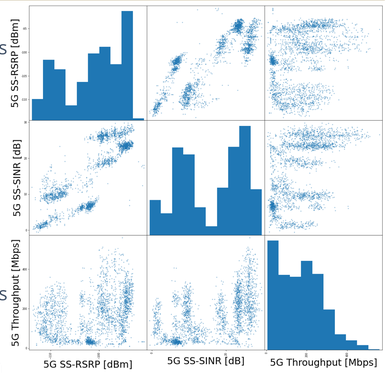


Figure 4. Scatter Matrix

	train accuacy	validation accuracy	validation f1 score
logistic regression	0.798	0.785	0.858
decision tree	0.837	0.86	0.911
random forest	0.837	0.835	0.895
k-nearest neighbors	0.903	0.897	0.933
KNN tuned	0.877	0.905	0.938

Figure 5. Model Selection

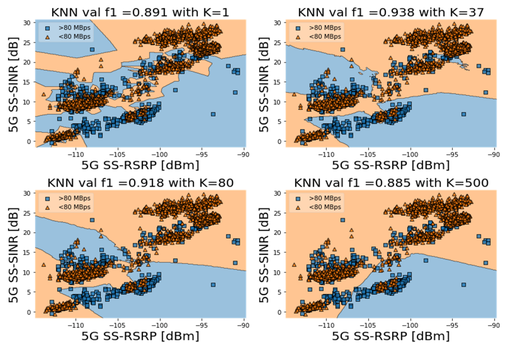


Figure 7. Boundary Visualization

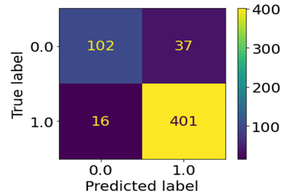


Figure 6. Confusion Matrix

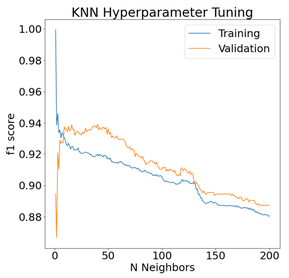


Figure 8. Hyperparameter tuning

Consumer App

- The android app (Figure 10) collects RF metrics available to the smartphone using the Android Telephony APIs.
- Out of all the collected RF metrics, 5GNR RSRP (dBm) and 5GNR SINR (dB) are taken and using POST request is sent to the backend server (Figure 9), where the ML model is hosted.
- Upon receiving the 5G-NR values the server feeds them as input to the ML model and the model spits out the prediction which is sent back to the app in JSON format as a response to the POST request (Figure 10).

Figure 9. Server QR code

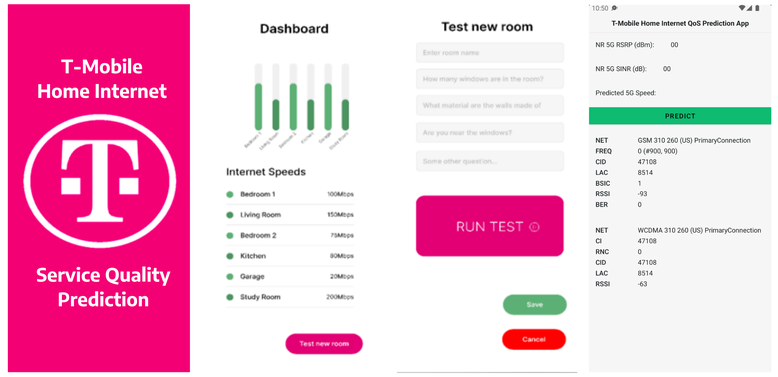


Figure 10. App Interfaces

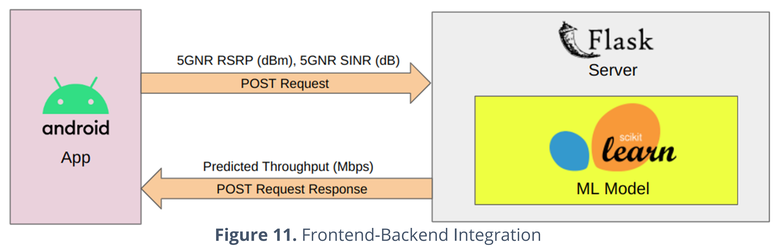


Figure 11. Frontend-Backend Integration

Result & References

- App predictions were validated using the T-Mobile Home Internet device.
- References
  - T-mobile slides
  - EE 505 slides

Figure 12. Home Internet Device

Future Work

- Create a 5G NR RF prediction model from 4G LTE RF data
- Implement behavior for 5G low band waves
- Create user authentication and allow them to store data
- Improve UI/UX and conduct user testing
- Integrate a feedback loop to collect large scale train data and verify model
- Expand dataset to more RF conditions

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