

ELG5901- EG00 Electrical Engineering Project

Network optimization and analysis using AI

Project Proposal



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Project Proposal

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Project Title: Network optimization and analysis using AI

Sponsor: Amazon Web Services (**AWS**)

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Problem Definition and Project Overview

Problem Definition

5G network is a bit more complex than the previous generations and in need of regular enhancement as it communicates with a much higher number of devices. There are two main features to work on when applying artificial intelligence, firstly, network optimization for better network establishments including lower cost and lower use of devices, nevertheless, higher provided quality of service for the users. Secondly, failure detection forecasting to provide lower maintenance cost and avoid unnecessary maintenance work. To settle these problems five aspects of 5G which are mobility, spectrum, user's peak data rate, user's experience data rate and network energy efficiency will need improvement through the following points:

- Optimization of every single 5G aspect.
- Network optimization "using spectrum efficiency".

Importance to sponsor

- AWS Private 5G is currently available in the following AWS Regions: US East (Ohio), US East (N. Virginia), and US West (Oregon) (AWS Private 5G Is Now Generally Available, 2022).
- AWS has a service category in augmented reality (AR) and virtual reality (VR) fields which require 5G technology so it's a point of interest.
- Optimization of beam selection efficiency using deep learning which will lead to the increase of spectrum efficiency which is mostly beneficial to the company.

General Approach

To achieve the mentioned aims, we will be working on 5G optimization, multi-input multi-output structures (MIMO), classical and deep machine learning techniques to detect the capabilities of the network to obtain a positive outcome, deep learning techniques.

Personal outcomes and accomplishments

- Beamforming selection using deep learning.
- Optimization for 5G network.
- Failure detection forecasting.

Background

5G is the 5th generation in mobile networks which is the second recent generation after the 6th generation which is still under development. It is designed to virtually connect everything including small devices and appliances which makes a tremendous improvement in networking and internet of things. To increase the dependency of the network, network optimization and failure detection forecasting should be handled through multiple aspects and techniques. In some articles autoencoders were used for cell outage detection by the supervision of a deep learning network. Network slicing was efficient in many approaches as it made it easier for the model to focus on a part of data. Various applications focused on handling different requirements including high peak values and user data rates, enhanced system capacity, reduced latency and improved energy efficiency. Different technologies have also been used like multiple-input multiple-output (MIMO) and millimeter wave (mm-wave) communications. In MIMO, each base station can transmit data streams of high-speed data to each device simultaneously. Nevertheless, in mm-wave, the base station can make use of high frequency spectrum to overcome the shortage of bandwidth and provide user's equipments with the availability of more bandwidth.

Project Guidance

	Project Sponsor (AWS)	Egypt Mentor (Dr. Anas Youssef)	uOttawa Supporter (Dr. Murat Simsek)
Summary of expertise and guidance	Knowledge and technical guidance and assistance with previous expertise in the field	Knowledge and technical guidance and paperwork recommendations	Knowledge and technical guidance and paperwork recommendations
Linkedin	https://www.linkedin.com/in/ahmed-elhamy-13270296/	https://www.linkedin.com/in/anas-youssef-62137370/	https://www.linkedin.com/in/murat-simsek-32a7b220/
Job title	Technical Manager at Psystems	Research Assistant & Application Developer at University of Calgary	Engineer in residence and Research Associate
Type of interaction	Physical meeting or online meeting	Online meeting	Online meeting
Frequency of interaction	<u>Every two weeks</u> or when technical or knowledge assistance needed	<u>Weekly</u> or when technical or knowledge assistance needed	<u>Every two weeks</u>

Team

	Student Name	Role	Responsibility
1	Abdelrhman Gaber Youssef Saad Rezkallah	Data Scientist	Responsible for detecting anomalies and time series forecasting.
2	Abdulrahman Muhammad AbdulSalam Ahmed	Full-stack developer	Responsible for creating web application for the end-user.
3	Ali Amin El-Sayed Mahmoud El-Sherif	Cloud Developer	Responsible for developing the system on AWS services.
4	Amir Safwat Halim Youssef	AI Engineer	Responsible for designing CNN architecture for optimization part.
5	Basma Reda Shaban Abd-El salam Abd-Elwahab	Cloud Developer	Responsible for developing the system on AWS services.
6	The whole team	Testing and validation	Testing the targeted task and validate its readiness

Project Context

In this project, Amazon web services and tools will be used. Possible services to be used are Amazon sagemaker, Amazon EC2 instances, Amazon EC2 auto-scaling, S3, Amazon Lambda, the following figure shows the flow of the project:

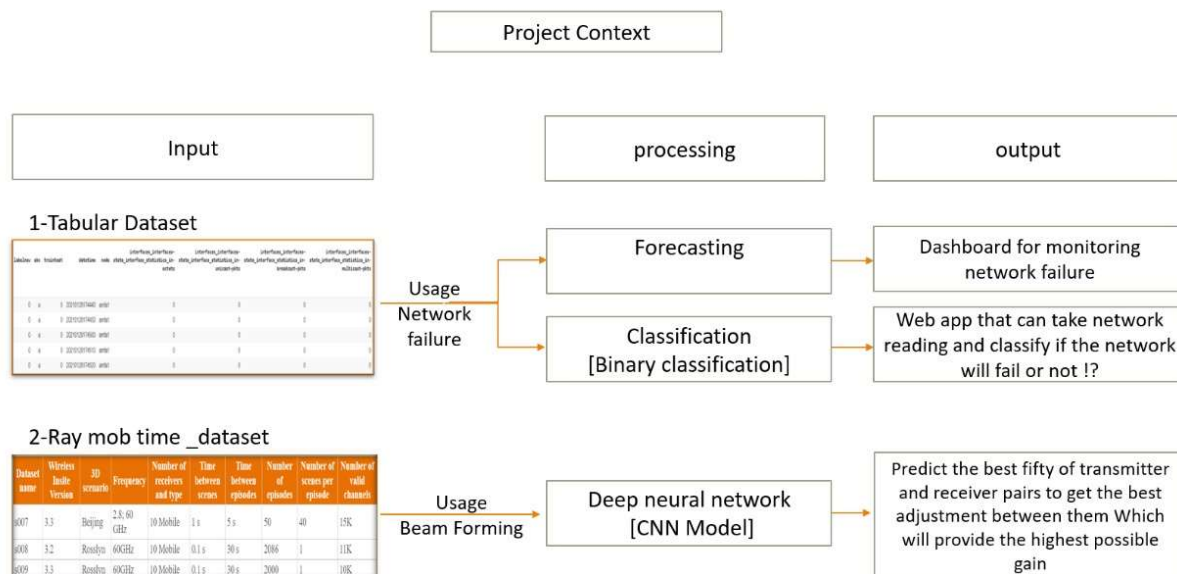


Figure 1 Project Context

Regarding the organizations and individuals who will be interacted with, first of all is amazon web services for technical and knowledge guidance and implementation (once every two weeks), Dr. Anas Youssef as the Egyptian mentor for technical and knowledge guidance(weekly), Dr. Murat Simsek as uOttawa support for technical and knowledge guidance as well (once every two weeks). Dr. Anas has already been contacted and agreed on the rate of meetings, negotiations with other supporters are still ongoing.

Data Testing Plan

The dataset is provided by Para-State university as a challenge that the university has posted based on a simulation made by its staff, any team around the globe can compete in this challenge (Baseline_data, 2022). The provided dataset will be split into three fragments which are training, validation and testing with the splitting percentage of 80%, 10% and 10% respectively.

We have two sub goals, figure 2 shows a sample of tabular data used to solve a binary classification problem, that contains essential network features that will be used in forecasting in failure detection, this dataset consists of (849994 rows × 108 columns), the next figure is a sample of the data:

labelnew	abc	traintest	datetime	node	interfaces_interfaces- state_interface_statistics_in- octets	interfaces_interfaces- state_interface_statistics_in- unicast-pkts	interfaces_interfaces- state_interface_statistics_in- broadcast-pkts	interfaces_interfaces- state_interface_statistics_in- multicast-pkts
0	0	a	0	2.021013e+13	amfa1	0.0	0.0	0.0
1	0	a	0	2.021013e+13	amfa1	0.0	0.0	0.0
2	0	a	0	2.021013e+13	amfa1	0.0	0.0	0.0
3	0	a	0	2.021013e+13	amfa1	0.0	0.0	0.0
4	0	a	0	2.021013e+13	amfa1	0.0	0.0	0.0

Figure 2 Tabular data sample

The second subgoal is network optimization, which is considered as a top-k classification problem. In this part the MMWave technology will improved using beamforming selection, this problem will be solved using Ray-Mob time dataset in figure 3 as follows:

Secondly, speaking of the second approach of the first goal by monitoring the network through a dashboard and forecast if the network will fail or not using time series algorithms such as LSTM model, PROPHET model, and AVR model, then connect with streamlit to have an interactive dashboard.

Thirdly, in figure 5, the results will be compared with AWS services results that are time series forecasting to build a time series model and Amazon QuickSight for the dashboard as the following architecture:

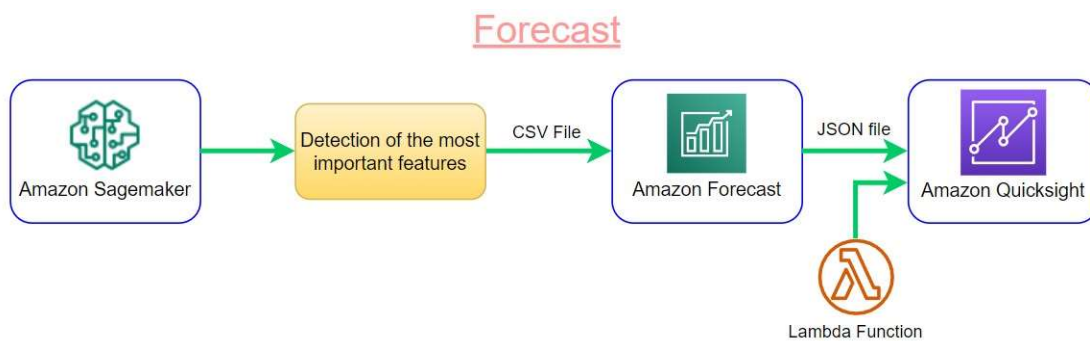


Figure 5 Forecast architecture using AWS

Finally, the second goal of the project is network optimization, in which deep learning approaches which will include deep neural networks using the CNN model (Asghar et al., 2019), to predict the top-k channels (receivers and transmitters pairs). The [baseline model](#) provided by the university will be used as a guide to build the architecture (ML5G_challenge, 2020).

Learning Outcomes

Knowledge

Learn 5G technology and deep learning techniques and use them to solve the beamforming selection.

Problem Analysis and Research

Collect data to determine needs and search for similar work done by others and compare the results with what has been obtained by others.

Design

Learn design approaches that can be useful in network failure and beamforming selection.

Verification and Validation Techniques

Test data will be used to detect whether the new model is robust or not.

Tools

AWS Cloud services, Jupyter notebook, python, anaconda and streamlet for web scrapping.

Project Management and Professional Skills

- Project tasks' distribution regarding personal skills.
- Peer review circulations in all the tasks to avoid minor and major slips.
- Consistently ongoing literature reviews in this field and the new approaches and failures.
- Regular meetings after finishing concurrent literature reviews or tasks for updates.

Society and Sustainable Development

5G network optimization and failure detection forecasting can increase user capacity while beamforming selection can save unnecessary equipment replacements and extra work with the right predictions and all these points can genuinely provide more precise and durable network in and city or company using a 5G network.

Project Plan

Milestone Deliverables	Hours per Student
<p align="center">Project Proposal Presentation – August 28th</p> <p align="center">Project Proposal Final Draft – September 14th</p>	
<ul style="list-style-type: none"> • Finalizing project's proposal • Description of problem domain • Literature review completion • Development Environment (Amazon Web Services) setup • Datasets and Test Environment setup • Completion of defining the Methodology, Algorithms, Models • Detailed Project Plan • Project Proposal Presentation 	24
<p align="center">Minimum Viable Prototype Présentation – Octobre 30th</p>	
<ul style="list-style-type: none"> • Establish the project architecture based on the MVP pattern • Collect the data • Data understanding • Cleaning and form exploratory data analysis on the dataset • Building classical machine learning models to predict the failure in the network • Compare between the classical models and select the best among them • Examine test results • Sponsor and mentor reviewing and feedback • Make a presentation regarding the project architecture based on the MVP pattern and the previously done work in this section 	72

Beta Release Presentation – December 18th	
<ul style="list-style-type: none"> • Build a time series model that can forecast whether the network will fail or not based on the readings using amazon deepAR, ARIMA and SARIMA • Compare between different time series techniques to select the best model • Examine test results • Sponsor and mentor reviewing and feedback • Make beta presentation 	84
Final Report, Internship Evaluation, (Team Peer Review) – January 15th	
<ul style="list-style-type: none"> • Building deep learning model to help with beamforming selection • Examine test results • Sponsor and mentor reviewing and feedback • Final deployment of Technology • Final report finalizing and Handing off the Documentation • Evaluation Forms 	60
Total Hours	240

Detailed Project Plan

Iteration	Tasks	Hours
1	<ul style="list-style-type: none"> a. Discuss project with mentor b. Research approaches, relevant technologies c. Plan project schedule and deliverables d. Literature review 	6
<p align="center">Project Proposal Presentation – August 28th</p> <p align="center">Project Proposal Final Version for Marks – September 14th</p>		
2	<ul style="list-style-type: none"> a. Problem understanding b. Finalizing project's proposal c. Description of problem domain d. Literature review completion e. Development Environment (Amazon Web Services) setup f. Datasets and Test Environment setup g. Completion of defining the Methodology, Algorithms, Models h. Detailed Project Plan i. Project Proposal Presentation 	10
3	<ul style="list-style-type: none"> a. Demonstrate progress in terms of minimum viable prototype to project mentor b. Complete requirements analysis and finalize evaluation criteria with project mentor c. Create presentation (Screen shots of current status, Requirements, Criteria) 	8

Minimum Viable Prototype Presentation – October 30th

4	<ul style="list-style-type: none"> a. Establish the project architecture based on the MVP pattern b. Collect the data c. Data understanding d. Data cleaning and preprocessing e. Form exploratory data analysis on the dataset 	17
5	<ul style="list-style-type: none"> a. Building classical machine learning models to predict the failure in the network b. Compare between the classical models and select the best among them c. Examine test results d. Make a presentation regarding the project architecture based on the MVP pattern and the previously done work in this section e. Validate project results with project mentor. 	30
6	<ul style="list-style-type: none"> a. Demonstrate project in terms of completion but not finalized release to project mentor b. Finalize design. Finalize TODO list. c. Finalizing the presentation based on the feedbacks and the possible edits before submission (Screen shots of current status, Results, Design) 	25

Beta Release Presentation – December 18 th		
8	<ul style="list-style-type: none"> a. Final demonstration and delivery of results to project mentor b. Build a time series model that can forecast whether the network will fail or not based on the readings using amazon deepAR, ARIMA and SARIMA c. Compare between different time series techniques to select the best model d. Examine test results e. Sponsor and mentor reviewing and feedback f. Complete Project Mentor Evaluation Form, and Team Peer Review. g. Draft report to project mentor and projects coordinator. Submit final report. h. Make beta presentation 	84
Final Report, Internship Evaluation, (Team Peer Review) – January 15 th		
9	<ul style="list-style-type: none"> a. Building deep learning model to help with beamforming selection b. Examine test results c. Sponsor and mentor reviewing and feedback d. Final deployment of Technology e. Final report finalizing and Handing off the Documentation f. Evaluation Forms 	60
Total Hours		240

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