Home Wi-Fi Optimization
Application Front-end Design

YUQING GU
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Yuqing Gu

Master thesis
Examiner: Anders Västberg
Supervisor: Kiwon Sung

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Abstract

In this information society, wireless network is an indispensable technology supporting the daily information communication and various interaction services. With the motivation to improve the user experience of Wi-Fi service, this thesis presents the front-end development process of a visualization application for home Wi-Fi testing and optimization. To provide the desired service to the users, it is important to understand what they need. With prompt feedback, the development process can have much more customized schedule and specific aim. In this thesis, different methods are adopted to get the valuable feedbacks from potential users. Brainstorming and originality interview support the basic designing of application, which is presented by the wireframe prototype. The prototype were used for a test-run and get feedbacks in order to develop a web application front-end assimilating the ideas and suggestions from real users. As more detailed functionality are designed, the feasibility and practicability should be investigated. Questionnaires are used to do larger scale ranges of user investigation. The front-end is designed using HTML, CSS and JavaScript with Bootstrap framework. The elements within all the pages could be able to interact with each other to give the customers a visualized experienced of service. The web application provides the users with the functions to test the real-time Wi-Fi performance, check the performance trend of data history from a specific time period and get useful optimization solutions. The designing is aiming to synthesize enough accessible information and provide the users with self-helpful testing and optimization of home Wi-Fi, which can increase the efficiency of technical support and reduce the workload of customer service.
**Abstrakt**

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1 Introduction

1.1 Background Introduction

As the rapid development of Wi-Fi technology, how to improve the quality of service (QoS) for Wi-Fi has became the hot topic for Information and communication Technology (ICT) industry to support sufficiently large stream. Telenor Sverige is one of the largest operator companies which holds about 20% market share of the fixed-line broadband subscription [1]. The company is making contributions to develop a better solution product for home Wi-Fi optimization. This thesis project is to develop a web front-end for testing home Wi-Fi performance. The application should also be able to provide multiple optimization suggestions for different network problems.

1.2 Motivation

As the increasing requirement of network communication in today’s all-digital world, users care not only about if the network service is provided, but also about the efficiency and quality. Wi-Fi is one of the most popular network technology for wireless local access network (WLAN) based on IEEE 802.11 standards [2] which can support various devices for different useful online services. The services include both traditional and advanced ones such as video streaming, Internet Protocol television (IPTV), internet of Things (IoT) and so on. People are more and more relying on Wi-Fi for daily life, especially within the indoor area.

It is important for an operator who provides Wi-Fi services to have a proper solution for the maintenance. With the motivation to improve the user experience, Telenor Bredbandsbolaget team wants to start deeper learning about what parameters determine the performance of their Wi-Fi. The relevant data is extracted from the router gateway by Ubus script[3]. Ubus is a command line system based on OpenWRT platform[4]. Ubus can collect the status of Wi-Fi performance parameters from wireless router gateway and present the collected data in JSON format, which is human readable and fast[5]. This project, on one of the main routers Telenor provides to their customers, TG799, which is a product from Techincolor [6] The project is also expected to provide optimization solution for home Wi-Fi implementation and configuration. To show the analysis result and optimization solutions in a acceptable way to both users and Telenor engineers, a visualization tool needs to be developed with proper classifying of the presented data. The Graphical User Interface (GUI) is supposed to be clear and concise showing the useful information of home Wi-Fi network and the optimization solutions to the users.

1.3 Goals

This thesis project mainly requires Wi-Fi performance analysis and visualization tool development. The goals are listed below:

1. Provide the users with useful information of their home Wi-Fi performance.
2. Provide convenient and self-help services of Wi-Fi optimization.
3. Increase the user experience and hopefully reduce the workload of customer services.
4. Develop a clear and concise GUI showing the results of analysis and evaluation.

1.4 Problem

Based on the designing goals, the research questions below are proposed.

1. What data do the users want to see from the application?
2. How to present the data in suitable forms for different users?
3. How does this application help the customers to improve the home Wi-Fi?

1.5 Contribution

This thesis proposes the designing and implementation of a Wi-Fi performance testing and optimization web front-end. The self-helpful service provided by the application can hopefully reduce the workload of maintenance and customer service, and improve the working efficiency as well. The visualization tool can provide information to both customers and engineers regarding to the parameters influencing the user experience of wireless network. In this thesis, the designing is based on Wi-Fi usage investigation of Wi-Fi real users. The developing is improved
step by step integrating several user feedback rounds. The research of real user usage and suggestions contribute for the further improvement of related product.

1.6 Ethics and Sustainability

For ethics aspect, all the interviews, investigation and testings in this thesis are anonymous. The interviews are done in Stockholm Lappis student neighborhood and in KTH school. The interviewees are asked about what they need for the application and their requirement of Wi-Fi performance. During all the interviews, they have not been asked much about their personal information and it is promised not be leaked to others. The investigation is a online questionnaire. The respondents are chose randomly since it has been put to social network Facebook. The questionnaire did not require any log-in or registration step in order to protect the security of user’s account information.

In the future, this front-end might be linked to Telenor server, which will be described more in Section 7 Future Work. When using the application, the users will log in with their personal account which contains their registration information such as email or phone number. The application should be able to protect the information of customers. The application is aiming to help customers solve and optimize their home Wi-Fi performance. Timely feedback is an essential way to keep the customers satisfied, which gives them the impression that they can get technique supports as soon as possible. The Telenor engineers can access the related data of customers in the future only for helping them solve problems but not profit-making activities. The functions provided by this application have no harmful influence on society or daily life.

For sustainability aspect, this application can possibly reduce the workload of customer service and technique support, which could save companies’ expense. Customers can try to solve the problems first with the help of this application. It can save their time and money during waiting in the customer service calling line or door-to-door service charges if the problems can be fixed by themselves. The developing of this application can be reused inside the company for more improvement or additional function. The investigation can give some inspiration to the society as well for the developers to know more about what the users’ suggestions for Wi-Fi service.
2 Related Work

The reviewing and evaluation of previous related work not only inspires the designing in the thesis project but also introduce the challenges of developing additional functions during the developing process. The following sections 2.1 to 2.4 present the brief summary of related work researching. Since this thesis is an application developing thesis, the related work mostly introduced the information using in the contents of the website. The designing of contents and layout is presented more in details in section 4 to 6.

2.1 Similar Visualization Application

There are various application both for desktop and mobile devices to test the performance of Wi-Fi network. As an example, an application named “Wi-Fi Maximiser” developed by Telstra [8]. The main functions provided by this mobile application are:

1. Show the information of connected devices and APs.
2. Network performance testing including speed and service testing.
3. Overall wireless performance evaluation in different type of location.

The following Figure 1 presents the screen-shots of three example pages in this applications, which is adopted from Telstra Application.

![Figure 1: Telstra Wi-Fi Maximiser Screenshots](image_url)

Wi-Fi Maximiser can also show the password of connected Wi-Fi and device data usage such as device up-time and Wi-fi usage. Users can also contact the application development company to provide their feedbacks.

2.2 Home Wi-Fi Performance Analysis

To implement the optimization of indoor Wi-Fi performance, previous research and analysis are based on data collected from the application installed in terminals such as the similar application presented in Section 2.1. The testings it can implement includes throughput, coverage and transmit speeds, etc. The investigations mostly are done for the small-scale network deployments which provide multiple presentation and solutions for poor performance. [9]
The experiments are set up within different environments with several types of room in different size and building materials to test the wireless network performance using different IEEE 802.11 technologies. The identification of the parameters presenting or influencing the wireless network performances in this thesis was done by the whole thesis group by gathering the results of previous related researching and the data that can be extracted from the wireless router by Ubus script.

The parameters we used in the presenting of Wi-Fi performance are:

1. Received Signal Strength Indicator (RSSI): RSSI reflects Wi-Fi signal at a location. If the value of RSSI change with a tremendous reduction, it represents that the wireless network signal strength around this position is at a poor level.

2. Data rate: The value of data rate is influenced by the network surfing activities that the connected end-terminals operate. If the terminals are using higher flow capacity online service, the data rate per client will show higher value.

3. Information of neighbor Wi-Fi: For one router, the number and RSSI of neighbor Wi-Fi can influence the performance of the wireless network provided by the local router. The interference from the neighbor Wi-Fi might reduce the data rate.

4. Noise level: From the following formula, we can see that the higher noise value leads to the lower signal to interference and noise ratio (SINR) when the interference is assumed to be constant.

\[
\Gamma_{SINR} = \frac{Signal}{Interference + Noise}
\]

In non-interference environment, the noise from the background of the same location area of the local router can influence the performance of Wi-Fi such as the data rate. The noise can be produced by the microwave or Bluetooth. The utilization status of radio band can also introduce noise.

5. Traffic volume: Traffic volume is the amount of packets being sent or received by the wireless access point or router. If the network or the device is having a extremely poor performance or even not working, the traffic volume is concurrently showing an obviously low value or zero.

2.3 HCI Design

Human-Computer Interaction (HCI) is an inter-discipline which observe and research the interaction between human and computer. HCI is mostly about the behaviour and cognitive science of human. Besides psychological activities, HCI also focus on why people do something specific with the machine or application. In mobile application designing, HCI can be used to find the preference and reaction of real users during using the proposed application. It is not sufficient and objective enough for the process of designing to be driven only by the perspective of developers. The behaviour investigation of real users will benefit the designing with practical and timely feedbacks. In this thesis, several methodology have been used to get these feedbacks, which will be described in details in section 4 and 5.

2.4 Analysis of Wi-Fi performance data

This application utilizes the graphs of Wi-Fi parameter performance to show the result of network performance testing. The work of the visualization of performance data is carried out by another team member Dan Pan in the same thesis project group. The data presented to the users is extracted from the gateway of router TG799 and being presented as visual graphs.
3 Developing Tools

This section describes the development tools used in the whole web pages developing process. To achieve higher efficiency, these tools are used to manage different part of the front-end development.

3.1 HTML

HyperText Markup Language (HTML) is a language to describe the websites. Though it is used for website developing, HTML is not a programming language but a markup language containing a set of markup tags. HTML is the most important part of website developing which identifies the contents of the pages and an HTML document is a web page. An HTML file has a general structure as shown in Figure 2 below.

![HTML Document Structure](image)

Figure 2: HTML Document Structure

Technically, the contents, structure style and the action of pages can be described in one HTML file such as the font size, location and color of the texts and images. However, it is complicated to identify the style of contents for every paragraph. It will be easier to have a separate part to describe the presentation style of the web page.

3.2 CSS

Cascading Style Sheets (CSS) contains the presentation style identification of the HTML elements. The separation of contents and style description improves the efficiency of website developing. CSS makes it possible to modify the layout and appearance of all the websites. There are three different ways to insert CSS. The first way is to use external style sheet which are mostly adopted in the developing of this application as shown in figure 3 below.

![CSS: External Style Sheet](image)

Figure 3: CSS: External Style Sheet

The second way is internal style sheet, which is putting the layout definition in the head of the HTML file. Both two ways are efficient for modifying the layout uniformly. The CSS file or module is in the form as the example in Figure 4 below.
The third way is inline style which has been adopted in this thesis. Though it is not as efficient as the external style sheet, it can be used sometimes to adjust one specific element such as the layout defining for the image in figure 5 below.

![CSS Layout Definition Example](style.css)

### 3.3 JavaScript

JavaScript (JS) is one of the most famous script language which is applied in all the web pages no matter on PC, mobile phone or tablet computer. The interaction logic of almost all of the mobile applications based on HTML5 is driven by JavaScript. It is an interpreted programming language which is cross-platform and cross-browser. JS defines the action of the pages so a well organized development of it essentially effects the user experience. An HTML document can cite a local or online JS file. The cite location of JS inside the HTML file can also influence the speed of opening or refreshing websites. The speed is faster if it is cited at the end of HTML body than in the head. Another way to improve the loading speed is to put the script module inside an empty `<div>` module. The cite of JavaScript is as the example in Figure 6 below.

![JavaScript Citing Example](JavaScript example)
3.4 Bootstrap

Bootstrap is a HTML, CSS, and JS framework for developing web application. Bootstrap makes it possible to have visualized designing of the website layout, which can increase the efficiency of the development. Bootstrap provides separate module such as button or drop-down menu. An example is shown in Figure 7 below, which is a search menu.

![Figure 7: Bootstrap: Button and Text Bar](image)

The developer can drag the modules to the template page and modify them according to the appearance and effect. After managing the page, the code can be reused to the HTML file. Bootstrap is helpful but still needs additional modifying of the layout inside the HTML document. The designing of this Wi-Fi Optimization is using Bootstrap, HTML, CSS and JS, which will be presented in the session of Designing Implement.

Bootstrap has another advantage in application development. This framework is perfect for self-adaption which can zoom perfectly according to the size of browser window. If the web application is used on a mobile phone, it can also adapt the size of mobile browser. This advantage makes it easy to transfer the web application to mobile application, which saves the time period of related development.
4 Methods

In order to answer the questions of problems mentioned in section 1.4 and to evaluate the performance of the application, interviewing, Telenor customer service calls record, prototyping and online questionnaire are used to investigate the requirement and feedbacks from potential users.

In the processing of software developing, it is essential to understand the needing and feedback from real users so that the developers can avoid prejudice and obsession. The developing needs to concentrate on what users expect but not just what developers want. These investigations and testings make sure the whole processing of development is influenced and guided by user demands. On the other hands, not all the requirements from users can be achieved due to the limitation of time and technique. The choice of accepting or rejecting the proposed functions needs to be considered seriously by analyzing the feasibility and sustainability. Moreover, some of the ideas might not be able to realized at the moment but they could be added later as the simultaneously increasing back-end supporting of the application such us more stable and expanding database and server. In a word, most of the feedbacks from the real users are significant guidance and reference of the whole developing process. Figure 8 below is an illustration summarizing the steps of methodologies.

Figure 8: Methodology Summarize

From Section 4.1 to 4.4, the adopted methodologies are described and motivated. The detailed procedures of the methods is explained more in Section 5.

4.1 Interview of the Basic Designing

As mentioned above, it is essential to keep aware about the requirements from real users and the company. Interview has been proved to be an useful and trustful approaching for the software developing engineer to have a clear picture of what the users are expecting from the application and to detect the unpredictable actions of the users during the application testing. [24] The interviewing contains 4 questions and the interviewees can provide their suggestions and ideas freely.

Since this visualization application is designed for different user types, the investigation of user requirements need to be pertinent. Starting with the purpose of comprehending the services users expect in the visualization tool, several interviews are implemented by letting the users brainstorm for the contents and layout designing of the GUI. The detailed procedure and results of interviewing are presented in Section 5.1.
4.2 Customer Service Calls Record

In order to have a better understanding of what type of performance the users care about or always have problems with, the data recording of complains or consulting could provide objective and useful information. Telenor customer service office keeps a recording of the most asked questions or problems about the Wi-Fi performance. The results of interviewing are presented in Section 5.2. This report contains the type of questions being asked most often by Telenor wireless network customers. The results of this calling report are used in the designing to provide relatively accurate service for users.

4.3 Home Wi-Fi Usage Investigation

Questionnaire is chosen to know more about the suggestion and demands about the application this thesis propose. Through anonymous questionnaire, the respondents can provide valuable feedbacks. Online questionnaire is chosen because it makes it possible to get feedback from larger amount of respondents than one to one interview within the equal time.[25] The results can be collected synchronously when multiple respondents are answering the questionnaire, which is efficient and convenient. The collected results of questionnaire is presented in Section 5.3.

4.4 Prototyping

Before the real developing of front-end GUI, prototype and framework need to be proposed first to the real users to save the time of coding and problem discovery.[26] Based on the information gathered from the interview and usage investigation, a wireframe prototype is designed using Balsamiq[27], which can provide intuition testing. After gathering a new round of feedback, the processing of web page can finally start. The prototype designing process is presented in the section 6.1.
5 Evaluation Procedure and Results

Using the methods mentioned in section 4, the following evaluation results are achieved to inspire and improve the designing. Most of the respondents in the interview and questionnaire investigation are chosen from Campus Lappis neighborhood in Stockholm, which Telenor provides the network connection service in 2017. The respondents are all Telenor real users so their feedbacks are useful and practical. The other parts of the respondents in the online questionnaire are randomly chosen from internet and KTH student group, who can provide various suggestions and also can be potential tester and user for the application if they are interested in the quality of service. The detailed number of respondents is mentioned in Section 5.1 and 5.3.

5.1 Interview Result

There are 30 interviews being done in this interview section, in which 25 of the interviewees are chosen from Lappis neighborhood. The interviewees are invited to join the interview on the street in front of different 5 buildings. The other 5 interviewees are chosen from KTH main campus who are not Telenor users. All of the interviewees are willing to join the interview after being proposed the purpose of the interview and being guaranteed of the confidentiality and anonymity. After being introduced that there is an application for Wi-Fi performance testing and optimization, they have all been asked the following questions:

1. What functionality do you need in this application?
2. What suggestion do you have for the layout of the application?
3. What do you think are the key performance indicators of Wi-Fi service?
4. What other suggestions do you have for the application?

With the considering of practicability and rationality, the suggestions below are summarized from the interview results, which inspire the basic designing of this visualization tool.

1. The web application needs to be simple and easy to use.
   As an application providing self-helpful services, it is important to be user-friendly. The interface should give a good first impression to the new user that they can easily manage the application. Especially for the users who are not familiar with network and information technology, the descriptions of various functions and optimization suggestions should be clear and understandable.

2. The application needs to be safe and stable.
   The raw data we use to analyze the Wi-Fi performance are collected from router gateway. As the user information and data processing results are also available to the customer service or network engineer from Telenor, it is important to keep all the information safe from leaking risk. The data of one user account should only be access for the user and the company.
   On the other hand, users might want to test the Wi-Fi performance whenever they want, such as when they think the wireless network is not working as well as they expect. The application should try to be available at the period of time when there are users using home Wi-Fi. The Telenor system testing or server maintenance for Wi-Fi service might need to be arranged during the slack hours of Wi-Fi usage.

3. The application needs to be available when the wireless network is not working.
   This suggestion proposes a requirement of offline technologies. This will be discussed in the part of future work due to the limitation of developing time.

4. The application could provide some Wi-Fi optimization suggestions.
   The suggestions could be about how to configure the router or at which location the router can provide the best network service. These information could help the users have a better understanding of Wi-Fi environment and try to optimize their network by themselves at the moment when the network is not working well, which will also reduce the workload of customer service.

5.2 Customer Feedbacks

The Figure 9 below presents the summary of calls from customers about Telenor Wi-Fi technical problems within the first month of 2017 which shows the relevant information we need in the research. Figure 9 is adopted from Telenor customer service report.
From the figure we can have a general picture about the key problems Wi-Fi users meet, which are:
1. Cannot connect wirelessly to the gateway/modem.
2. Poor wireless speed.
3. Flapping wireless connection.
4. Can connect to wireless network, but cannot surf.
5. About repeater and other technical questions.
Considering the results above, we can have general picture about the performance or function users care the most. The visualization tool is aiming to provide the self-helpful service which can show these information in a proper way which will be discussed more in the prototype designing part, which is mentioned in Section 4.3 and presented in Section 6.1.

5.3 Home Wi-Fi Usage Investigation Results

In order to have a deeper understanding of home Wi-Fi usage, a questionnaire was created to gather useful feedbacks from 350 user samples. The respondents are chose randomly since the questionnaire has been put to social network Facebook. 350 copies of answers are collected by the questionnaire. In this section, the important results will be described in detail. The full edition of the investigation questionnaire is presented in Appendix A. The questions containing in the questionnaire are designed according to the results from interviews and customer issues. Since each interview did not take more than 10 minutes to keep the interviewees patient, we cannot ask more about the details of Wi-Fi performance and usage during the interview. The results of calling report presented in section 5.2 only give the types of problems asked by customers but not the detail requirement about the performance. The questionnaire extends the investigation of important Wi-Fi performance indicators. The results of the questionnaire can benefit the detailed designing of application front-end.

5.3.1 Respondents Classification

Since we want to develop this visualization application for different type users who have different level of understanding about wireless network knowledge, we need to know the Wi-Fi knowledge level of the samples. Considering the sample diversity and the privacy of personal information [30], whether the respondent thinks she/he has the ability to help themselves with the network problems or not is what we concentrate on. Hence, instead of asking the respondents about gender, education level or age, we hide this question inside a bigger question: When there are some problems with your home Wi-Fi, what is the first option you choose to deal with? (When rebooting devices does not work) The choices given to the respondents are:

1. I have some knowledge about networking, I can try to fix it first by myself
2. Search for some relevant solutions, try to fix it according to the tips
(3) Contact the operator’s customer service

Figure 10 below shows the distribution result. We can have a general understanding on what behavior the users would like to choose at the moment when they find there is problem with their Wi-Fi. The first choice is for the users who have a certain degree of understanding and mastering of Wi-Fi configuration, who can possibly fix the problem without searching for solutions or asking for help. The second choice is that they can roughly identify the type of problems. When the wireless network is not working, they can search the solutions through mobile network or offline application which proposed in section 7 future work.

About 26.3% respondents would choose to contact the operators’ customers at once to get remote assistance, which requires the customer service to have access to the relevant data within the specific customer’s wireless network environment. However, there are 73.7% respondents choose to solve the problems first by themselves. Among them, 38.0% of the total 350 respondents would like to fix them with their own network knowledge and 35.7% of them would choose to search for some relevant solutions and try to fix it according to the tips. These results remind the importance of providing the tips or guidance of optimization in the visualization tool. If the tips are proper and helpful, the visualization tool can not only save the solution searching time of the real users but also reduce the workload of customer services. The increasing efficiency of trouble-shooting for home Wi-Fi will benefit the quality of service as well.

5.3.2 General Wi-Fi Usage

As mentioned several times in the background introduction section 1.1, from observation, people are relying on Wi-Fi more and more nowadays which makes Wi-Fi necessary in daily life. From the investigation results, the observation is proved to be true. As shown in the figure 11 below, 98.6% of the 350 respondents use home Wi-Fi almost everyday.

Figure 11: Frequency of Using Home Wi-Fi
With this common use of Wi-Fi, it is important to maintain and improve the quality of service and performance of home Wi-Fi service. The better service the company provides, the more customers will stay satisfied and loyal to the company. When there is upgrading or maintenance of network and application, the service might need to be stopped during the slack hours. In order to understand more about the using time and period, several questions are proposed to the respondents and the results are presented below.

The respondents were asked about the utilization duration and time period of Wi-Fi everyday. As shown in the figure 12 below, about 29.7% of the respondents use Wi-Fi over 7h everyday. The bound of 7h is according to the estimated time period when people are sleeping or on work but not at home. There are 18.3% of the respondents averagely using Wi-Fi 1h-3h everyday which is the least among the four proposed duration and 3h-5h is the most chosen duration which have 31.4% respondents choose it. The active time of users using home Wi-Fi shows the requirement of the stability of the network and visualization tool.

![Figure 12: Home Wi-Fi Using Duration](image)

Furthermore, the active time period is also needed to be investigated. From the collected results of the questionnaire shown in figure 13 below, the peak hours of using home Wi-Fi is 18:00-24:00 as 93.1% choose it in a multiple choice quiz. 00:00-06:00, which holds 9.7% share of the research, is the obviously the non-rush hours. This result reflects that the system testing or upgrading should better to happen in the midnight but not during the evening which is the busiest hours.

![Figure 13: Home Wi-Fi Using Time Period](image)
5.3.3 Application Functions Investigation

To understand if the application is welcomed to the real users and the functions they want to have, several questions are proposed to them. As presented in Figure 14, there are 56.0% of the 350 respondents said they will use our proposed application. 32.9% of them said they maybe will choose to use it and 11.1% of them said they will not use it. This result shows the considerable feasibility of the visualization application.

![Pie chart showing the responses](image)

Figure 14: Application Feasibility Investigation

In the basic designing of this visualization tool, we want to provides the function that the users can see the performance trend and the devices connecting to the Wi-Fi. From the research, we can summarize that the users always have 2-5 devices connecting to the Wi-Fi. The way to show the information of devices need to be considered according to the result presented in the Figure 15 below.

![Bar chart showing the number of connected devices](image)

Figure 15: Connected Devices Number Investigation

The application is also designed to provide the function of checking the data history of Wi-Fi performance for a specific duration. The history is supposed to be shown in the form of pictures. The realization of user-defined time duration will require a fast process of images creating. A more efficient and easy way might be to let the users choose a desired duration. In the questionnaire, we get the summarized result about how long do the users want to check, which is shown in Figure 16 below.
Another important function of this application is provide the users with the performance test of the connected Wi-Fi. With the recording of router raw data, there are different indicators extracted from gateway that can be used to present or calculate the performance value. In order to know what performance indicators do the users care about, the respondents were asked to sort the Wi-Fi performance indicators below according to the importance principle: Network speed; Network stability (if there is flapping network); Signal strength; Connection Speed; Surrounding interference. The collected result is shown in the Figure 17. The numbers in the figure are the percentage of respondents who choose each option as No.1 to No.5.

<table>
<thead>
<tr>
<th>Options</th>
<th>Sort as No.1</th>
<th>Sort as No.2</th>
<th>Sort as No.3</th>
<th>Sort as No.4</th>
<th>Sort as No.5</th>
<th>Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Network speed</td>
<td>46.86%</td>
<td>36.86%</td>
<td>11.44%</td>
<td>2.29%</td>
<td>2.57%</td>
<td>1</td>
</tr>
<tr>
<td>Network stability (if there is flapping network)</td>
<td>42.29%</td>
<td>33.14%</td>
<td>17.15%</td>
<td>6.29%</td>
<td>1.14%</td>
<td>2</td>
</tr>
<tr>
<td>Signal Strength</td>
<td>7.71%</td>
<td>20.86%</td>
<td>50.27%</td>
<td>16.57%</td>
<td>4.57%</td>
<td>3</td>
</tr>
<tr>
<td>Connection Speed</td>
<td>2.85%</td>
<td>7.14%</td>
<td>16.00%</td>
<td>62.28%</td>
<td>11.72%</td>
<td>4</td>
</tr>
<tr>
<td>If there is interference from other routers or the environment</td>
<td>0.29%</td>
<td>2.00%</td>
<td>5.14%</td>
<td>12.57%</td>
<td>80.00%</td>
<td>5</td>
</tr>
</tbody>
</table>

Figure 17: Wi-Fi Performance Indicators Investigation
6 Designing and Implementation

6.1 Wireframe Prototype Development

The application is aiming to provide a user-friendly experience introducing the current home Wi-Fi environment and advisable optimization solutions. As mentioned in section 4.4, the wireframe is designed using Balsamiq. [27]

6.1.1 Site Map Design

Sitemaps show the logical relationship among web pages that can be used to describe the organization of the application. It is important for the developer to have a clear picture of the operating logic load. [33] The site map of the web application is designed as Figure 18 below.

![Site Map Design](image)

Figure 18: Wireframe Designing Site Map

6.1.2 Wireframe Prototype Design

The first proposed function of the application is the performance test of user’s connected Wi-Fi. This function should provide general performance evaluation. A marking mechanism showing how is the quality of the Wi-Fi services using different color for clear differentiation and visualization. Threshold needs to be decided, which is finding what level of experience is fair enough for the users to be desired/sustainable/unbearable of the service.

In the research of customer investigation, we get the result of Wi-Fi performance indicators that users care about. The result shows that the network speed is the most important indicator. Inspired from similar application, we have the prototype below. In this section we only show the main pages, all the prototype designing can be found in Appendix B. The whole designing of the visualization application needs to be simple and easy to learn, without much complicated operation. For example, the starting page shown in the figure 19 just contains 3 main functions, login and application information.
6.1.3 User Classification

This visualization application is designed for 2 different types of users. The differentiation of the users is planned to be done by the processing of registration and login process.

1. Common customers

Generally, most of the real users of Wi-Fi do not have enough background knowledge about information and communication technology or they do not want to investigate deeper about the detailed technique configuration. What information they mostly want is: Is my Wi-Fi working well? Why is it not working? Why there is delay? How to improve the performance? Etc. However, some of the customers might want to manage the optimization of Wi-Fi by themselves as we summarized from the questionnaire results.

2. Telenor bredbandsbolaget engineers

The Telenor engineers need detailed technique information to support the maintenance and development. They should be able to access the system with their staff ID and the system can lead them to the page for experts. The engineers can get access to user information database and help customers with their Wi-Fi problems.

6.1.4 Feedbacks on the Wireframe

With the prototype, feedbacks are taken from 30 real users. The respondents were asked to test the wireframe and propose the missing function or information. Here are several useful feedbacks from real user testing:

1. In the prototype, the slide menu of personal page is on the left. This is not convenient for zooming according to the window size, especially in mobile browsers. Several users suggest that the menu bar is better to be located at the top of contents.

2. The website is designed for commercial object, there should be space in the pages saved for notification and advertisements. The advertisement should be hid within some hyperlink after a brief introduction. If the users are interested in it, they can access the link. The notification such as the improvement of designing or urgent service unavailable should be presented at conspicuous location to remind users.

3. Customer service page should provide multiple ways for technique support. Several users suggest that the waiting time of human service combines interactive voice response might be long and not convenient. Online re-
quirement form or common problem Q&A would be useful for users to get feedbacks. The improvement suggestions above are only representative feedbacks, the other scattered suggestions are considered of accepting or rejecting and completed in the web application. There is one version of wireframe before the real developing of website using HTML language. This prototyping is for gathering intuitional feedbacks by showing the proposed application to the interviewees. As we can see in Figure 19, the detailed data used in the wireframe is fictive since this prototyping is more for gathering layout and function designing feedback. The real implementation has rather different painting style since Balsamiq only provides freehand style sketching wireframe. The purpose of wireframe prototyping is to simulate some but not all the feature of the interface. Due to the limitation of developing time, the prototyping of wireframe has only been created for one version since the useful feedbacks presented in section 6.1.4 is adopted directly in the development processing of website which is presented in section 6.2.

6.2 Web Application Implementation

Based on the feedbacks from last sections, the front-end is designed using HTML, CSS and JavaScript. The designing is presented in section 6.2.1 to section 6.2.7 below.

6.2.1 Register and Login Page

The layout of Register and Login pages are defined by a separate CSS file. The designing is aiming to be easy and simple to use and convert to mobile version. Telenor engineers who have access to the user database should use their Telenor email to register. Their email addresses need to be controlled through database about which staffs can access the engineer version application. Figure 20 below are register and login pages.

![Register and Login Page](image)

Figure 20: Register and Login Page

6.2.2 Main Home Page

After login to the application, the main page, as presented in Figure 21 below shows the guidance of functions. Without complicated introduction, three main functions are shown as clickable icons. The icons are also hyperlinks...
to the function pages. These icons are reused in the bottom of every pages to make sure the users can access the other functions anytime they want. The menu at the top of pages contains several accesses to different pages. The drop-down menu of "Functions" contains the same hyperlinks to 3 main functions: Test Wi-Fi environment, Wi-Fi performance trend and Wi-Fi optimization.

6.2.3 Wi-Fi Environment Testing Pages

The screen-shots in Figure 22 below show the first main function of this visualization application, which is testing the Wi-Fi performance.

![Figure 22: Wi-Fi Environment Testing Pages](image)

From the investigation and the feedback from wireframe, the designing is improved to be able to hide and show the detail information of every connected device. The trend of device performance can be checked in "view details". The test button allows the users to get the latest performance data and the shown data should be refreshed after
finishing the testing. As several real users suggested, the brief information of devices is shown in a form and the users can choose to check more technical details by using the accordion menu. The MAC addresses of connected devices can be extracted from the raw data, which shows in the figure 23 below.

Customers should be able to get the information of the speed or throughput of their home Wi-Fi. The received signal strength indicator (RSSI) shows the power level that a device received in a specific location and time point. The performance threshold of marking mechanism should also be decided in the future work.

### 6.2.4 Wi-Fi Performance Trend Pages

The second main function is to check the trend of Wi-Fi performance. The summarized results from raw data and Wi-Fi usage investigation questionnaire, several performance indicators are chosen to be presented to the users. The screenshots in Figure 24 below show the functionality.

First, users can check the channel status to see which channel are the connected devices occupying. The busier the channel is, the more chance to get bad performance for the devices connected to the same channel. Hence,
to optimize the performance of Wi-Fi for one specific device, the user can change to another available low-load channel. Second, users can check the RSSI and throughput trend of the specific frequency, 2.4GHz or 5GHz. This indicator shows the quality of wireless network communication. Third, the strength background noise can also be checked by every channel, which is in dBm unit. These indicators should be able to check by different time duration. As most of the respondents choose in the usage investigation, the default figures shown in the pages are better to present the data from last 24 hours. Connected devices monitoring is another proposed function in the Wi-Fi performance trend pages, which can also be checked in the environment testing page. This function has not been designed completely, which will be described more in detail in section 7, Future Work.

6.2.5 Wi-Fi Optimization Pages

The third main function of the application is Wi-Fi optimization. This page provides different ways of optimization. The pages of Wi-Fi optimization are shown as the screen-shots in Figure 25 below.

![Figure 25: Wi-Fi Optimization Pages](image)

The first one is to manage auto-optimization for home Wi-Fi. The users should click the optimize button and waiting for the better configuration to be done through an auto-algorithm. The algorithm could be able to change the device to another low-load channel or frequency. The waiting time of auto-optimization needs to be as short as possible so that the users can get efficient and satisfied service. The second optimization method is to provide the optimization tips to the users. From the home Wi-Fi usage investigation, we know that 38.0% of the total 350 respondents would like to fix them with their own network knowledge and 35.7% of them would choose to search for some relevant solutions and try to fix it according to the tips. It will be very useful for the application to provide the related optimization tips to the users, which not only saves the users from searching for the result by themselves but also provides a page for the company to add updating configuration advice for the router.

6.2.6 Wi-Fi Customer Service Pages

Customer service, as one of the most important ways to provide proper services and get valuable user feedback, should be efficient and well organized in the website. The quality of customer service is strongly associated with the evaluation of the product even the company from users. The balance between sufficient efficiency and reasonable workload for customer service office needs to be considered cautiously. The pages of customer service are shown as the screen-shots in Figure 26 below.

This application is designed to provide the users with much more self-helpful services and reduce the workload of customer service office. With the reference of bredbandsbolaget official website, several accesses of customer service are provided to the users, which is hot-line, online chatting, leaving message and Facebook page. The variety of customer service guarantees the users with prompt and effective technical supports. The customer service page is designed to be easy to learn and obvious to find the information. The complaint and suggestion online form is also provided to the users in order to get the feedback in time. The often asked questions and answers list can also be provided to the users to let them check if they have the similar problems, which might save their valuable time.
6.2.7 Personal Information Pages

After logging in, the data is shown for the specific user. The users should be able to change their registration information and update more related personal information. With more detailed information of users’ home environment, the more helpful and specific technical support can be provided to the users. For example in this thesis, we have implemented experiments monitoring several houses home Wi-Fi. The data are extracted from the routers in these houses which are different type of houses with different building materials and structure. The summary of testing environment is presented in Figure 27 below.

<table>
<thead>
<tr>
<th>Environment</th>
<th>Placement</th>
<th>Materials</th>
<th>Rooms</th>
<th>Storeys</th>
<th>Year built</th>
<th>Surrounding WiFi</th>
<th>Telenor IPTV-service</th>
<th>TV through TG234</th>
</tr>
</thead>
<tbody>
<tr>
<td>SDU</td>
<td>On the second floor, in the middle of the floor</td>
<td>Stonehouse with armed concrete between floors</td>
<td>5</td>
<td>2</td>
<td>1947</td>
<td>2 other 5GHz</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Small office</td>
<td>By the window in the middle of the office</td>
<td>Open area, drywalls, lots of neighboring Wi-Fi</td>
<td>6</td>
<td>1</td>
<td>1980</td>
<td>Crowded about 10 2GHz</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>MDU</td>
<td>Livingroom/attic/middle of apartment</td>
<td>Concrete walls / Drywall</td>
<td>4</td>
<td>1</td>
<td>1910</td>
<td>Busy/Crowded about 2 2GHz &amp; 1 MHz</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>SU</td>
<td>In the middle of the house in the hallway by the staircase</td>
<td>Wood/drywall 2 walls</td>
<td>2</td>
<td>1</td>
<td>1948</td>
<td>5 other SSDs visible</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>MDU</td>
<td>Hallway</td>
<td>Stonehouse with wooden beams and drywall</td>
<td>5</td>
<td>2</td>
<td>1978</td>
<td>Yes</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>SDU</td>
<td>Hallway/ lower floor</td>
<td>Drywall/brick building with 60 cm thick brick walls between the router and some rooms</td>
<td>2</td>
<td>2</td>
<td>1934</td>
<td>Fairly busy, about 7-10 other WiFi networks visible</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>MDU</td>
<td>Dining room on lower floor, against external wall</td>
<td>Mix of cement and wood beams between lower floor and upper floor</td>
<td>2</td>
<td>2</td>
<td>1914</td>
<td>Yes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SU/shadbnat</td>
<td>Living room on lower floor, against external wall, 40 cm up from the floor; Free sight</td>
<td>Outer walls; Wooden beams and double drywall</td>
<td>5</td>
<td>2</td>
<td>2012</td>
<td>5-7 other networks visible on 2.4 GHz, 3 other networks on 5 GHz</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>SU/pahus</td>
<td>Upper floor, corner of the house, against the wall of the neighboring pahus and the exterior</td>
<td>Wood house with just the side walls made of brick. Interior walls of wood and cast</td>
<td>5</td>
<td>2</td>
<td>1976</td>
<td>Home appliances (printer, music system) and few other SU neighbors</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>SU</td>
<td>Sleeping room in one corner of the house, please see picture</td>
<td>Wood house with internal walls of wood and cast (question, see closet door with mirror in the sleeping room will that effect the WiFi)</td>
<td>2</td>
<td>2</td>
<td>1980</td>
<td>Few weak signals mainly at 2.4 GHz from other houses (20m distance)</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

There are several types of house: Single house or villa; Single dwelling units (SDUs) with few neighboring Wi-Fis; Flat houses with multiple Wi-Fis APs per floor; multiple dwelling units (MDUs) with multiple neighboring Wi-Fis, small office and so on. As these information is not convenient to get from every user, during the communication between technical support and customers, it might take some time to achieve these information. If the users can update these information briefly, it might increase the efficiency of customer service supporting. Otherwise, if there is public database can be accessed to get these house information, it can also be adopted in the application. The screen-shots below present the functionality proposed above. The "Services Ordered" menu is saved for the bundled services package that users order along with Wi-Fi service such as IPTV. The pages of personal information are shown as the screen-shots in Figure 28 below.
Figure 28: Personal Information Pages
7 Future Work

In the future, the front-end could interact with Telenor server and database to make a completed application. The recommended API for web service is Representational State Transfer (REST), which is an efficient and concise.\textsuperscript{[11]} Offline service is also a great function to have for the application. When there are problems with network, the browsers might show no network connection and not be able to use the online application. If the application can be used when there is no network connection and still be able to get the data from router and test the environment, it will very helpful for the optimization and trouble-shooting.

If the front-end can interact with enough database resource, it can be much more helpful for the communication between users and the company. If there is any public database about the information of house type and material for the specific address, it will be more sufficient to support the optimization for different kinds of home environment. This front-end is designed with Bootstrap CSS framework, it can be used in any browser, including the browsers in mobile devices. If there is mobile application needed, the web application can be used to do the test-run. Bootstrap is also easy to transfer into mobile application in Android devices.\textsuperscript{[42]} The optimization suggestion used in the front-end now is adapted from Telenor official website. More optimization tips and the auto-optimization algorithm would be much more helpful for the users to achieve self-helpful service.

Since we can get the information from the router about the connected device MAC address, an additional proposed function is to monitor connected devices and see if there is someone else using the Wi-Fi. In the questionnaire, the respondents are asked if they want this function and the result is shown in Figure 29 below. 80.3\% respondents would like to have this function in the application, which can be considered in the future development.

![Figure 29: Additional Function: Monitor Connected Devices](image-url)
8 Conclusion

This thesis presents the whole development progress of an application front-end aiming to help users test and optimize their home Wi-Fi performance. In order to provide the desired service to the users, it is important to understand what they need. With prompt feedback, the development process can have much more customized schedule and specific aim. Brainstorming and originality interview support the basic designing of application, which is presented by the wireframe prototype. The prototype were used for a test-run and get feedbacks in order to develop a web application front-end assimilating the ideas and suggestions from real users. As more detailed functionality are designed, the feasibility and practicability should be investigated. Questionnaires are used to do larger scale ranges of user investigation. The front-end is designed using HTML, CSS and JavaScript with Bootstrap framework. The elements within all the pages could be able to interact with each other to give the customers a visualized experience of service.

At the end of this thesis, the research questions mentioned in section 1.4 could be answered by using different research methodologies. To understand what data the real users want to check from the application, all the adopted methodologies could provide useful feedbacks along with the whole development processing.

The first research question is: What data do the users want to see from the application? The answers will be described below as three main functions we provide in the application.

First, the users would like to check the real-time Wi-Fi performance and have a general evaluation and intuition of the performance. By gathering the feedbacks and considering the available indicators we can get or calculate from the router raw data, the information we can provide for the performance testing is: network speed, network basic information, connected devices information and an evaluation mechanism with the determined threshold of different wireless network performance quality level.

Second, the performance trend, which are presented as figures created using the performance indicators data histories from a specific time period chosen by the users. The users would be able to check the channel status in order to see which channel is busy or available. For the connected devices, the users could access the performance trend of specific devices in a chosen time period. Furthermore, for more detailed technical indicators, we can provide the information about RSSI, throughput and background noise. The desired default time period is 24 hours and the users can choose another duration if they want.

Third, the application is designed to provide multiple methods for the wireless network performance optimization. From the results of investigation survey, there are an impressive amount of users choose to solve the problems by themselves first when they meet problems with their home Wi-Fi performance. Among them, most of the respondents choose to search for the optimization tips. This web application can manage to provide multiple proper solutions for the often asked questions from customers in order to save the searching time. Another optimization method provided to the users for optimization technical supporting is different customer service accessing. To provide more specific optimization solutions for different user environment and problem type, there is a data collection form for gathering the information of house type, building materials and necessary user personal information.

The second research question is: How to present the data in suitable forms for different users?

This application is designed for both customers and Telenor engineers. Customers can choose to check different type of performance indicators within different time period as answered in the first question above. The engineers can choose to login the application with their staff ID and check the performance of specific users by entering the customers’ personal number or address.

The third research question is: How does this application help the customers to improve the home Wi-Fi?

The application is aiming to synthesize enough accessible information and provide the users with self-helpful testing and optimization of home Wi-Fi, which can increase the efficiency of technical support and reduce the workload of customer service.
References


Appendix

A

Home Wi-Fi Usage Investigation Questionnaires

Dear friends, we are so appreciated for the time and effort you contribute for this questionnaire. In order to understand better about the problems and needings of the service, this questionnaire is created for gathering your valuable feedback. It might take a few minutes to finish this anonymous questionnaire, thanks for your patience.

Wish you a wonderful day!

1. How often do you use your home Wi-Fi?
   (1) Almost every day
   (2) Several times a week
   (3) Several times a month
   (4) Rarely use

2. How long are you using your home Wi-Fi everyday
   (1) 1h - 3h
   (2) 3h - 5h
   (3) 5h - 7h
   (4) ≥ 7h

3. Which time period are you usually using your home Wi-Fi service?
   (1) 00:00 - 06:00
   (2) 06:00 - 12:00
   (3) 12:00 - 18:00
   (4) 18:00 - 24:00
   (5) I do not use home Wi-Fi.

4. How many devices are connected to your home Wi-Fi at the same time usually? (e.g. Smartphone, tablet PC, PC, TV or game console)
   (1) 1
   (2) 2
   (3) 3
   (4) 4
   (5) 5
   (6) 6
   (7) 7
   (8) 8
   (9) 9
   (10) 10
   (11) >10

5. When there are some problems with your home Wi-Fi, what is the first option you choose to deal with? (When rebooting devices does not work)
   (1) I have some knowledge about networking, I can try to fix it first by myself
   (2) Search for some relevant solutions, try to fix it according to the tips
   (3) Contact the operator’s customer service

6. When there are some problems with your home Wi-Fi, if the operator provides a web/mobile application which can manage auto-optimization for the Wi-Fi configuration, will you choose to use it?
   (1) Yes, I will use it
   (2) Maybe
   (3) No, I will not use it
7. Please sort the Wi-Fi performance indicators below according to the importance principle
   (1) network speed
   (2) network stability if there is flapping network
   (3) Signal Strength
   (4) Connection Speed
   (5) if there is interference from other routers or the environment

8. Do you want to check the performance of your Wi-Fi whenever you want?
   (1) Yes
   (2) No

9. Do you want to know if someone else is using your home Wi-Fi?
   (1) Yes
   (2) No

10. Do you want to check the data history of your home Wi-Fi performance during a period of time?
    (1) Yes
    (2) No

11. If it is possible to check the data history of your home Wi-Fi performance, how long do you want to check?
    (1) last 1 hour
    (2) last 12 hours
    (3) last 24 hours
    (4) No, I do not want to check

12. We are developing a web application providing our customers with the services of real-time testing and optimization of Wi-Fi performance. Please share your suggestions with us if you want. The advice from you is very important, thanks a lot!
B

Prototype Designing

Figure 30: Wireframe Prototype - Main Page

Figure 31: Wireframe Prototype - Forget Password
Figure 32: Wireframe Prototype - Wi-Fi Performance Testing

Figure 33: Wireframe Prototype - Wi-Fi Performance Trends
Figure 34: Wireframe Prototype - Personal Information

Figure 35: Wireframe Prototype - House Information

C
Web Page Screenshots
Figure 36: Wi-Fi Environment Testing Page1

Figure 37: Wi-Fi Environment Testing Page2
Figure 38: Wi-Fi Performance Trend Page 1

Figure 39: Wi-Fi Performance Trend Page 2
Figure 40: Wi-Fi Performance Trend Page 3

Figure 41: Wi-Fi Performance Trend Page 4
Figure 42: Wi-Fi Optimization Page 1

Figure 43: Wi-Fi Optimization Page 2
Figure 44: Customer Service Page 1

Figure 45: Customer Service Page 2
Figure 46: Personal information

Figure 47: House information