

NetView: A User-Centric Network Coverage Application

Colin Brennan and Petros Spachos

School of Engineering, University of Guelph, Guelph, ON, N1G 2W1, Canada

E-mail: cbrennan@mail.uoguelph.ca, petros@uoguelph.ca

Abstract—In accommodation of the expanding amount of WiFi-enabled products and services, the availability of Wi-Fi connectivity is rising. As available networks increase in quantity and overlapping coverage, a user's selection for connection becomes increasingly influential in the quality of their experience. In order for users to make effective decisions for their needs, they must be provided with information on these networks. In this work, we present NetView, a mobile application to acquire and present users with information based on their own usage context to make these informed decisions. Deployment of NetView in a university campus setting is used to demonstrate how user location and historical readings may be used with current network strength readings to shape policies for network selection.

I. INTRODUCTION

According to the Cisco Virtual Network Index, the number of Wi-Fi hotspots is expected to grow globally from the existing 94 million devices in 2016 to 541.6 million in 2021 [1]. This growth will result in an increased density of available Wi-Fi connections for users in the personal, public and commercial networks they encounter. Network operators address the resulting overlapping coverage through policies for efficient handover between access points in order to ensure a quality experience for their users. With the growing density of public hotspots providing users with more network selection to choose from, the conditions for an optimal user experience is moving outside an operator's control. As the number of devices per capita is also predicted to increase up to 1.5 by 2021 [1], the user's role in managing their experience continues to increase.

Public environments like shopping centers, university campuses, and smart cities already present users with multiple network selections [2], [3]. Without prior networking knowledge, it is not intuitive for the common user to make an optimal choice based on their needs and preferences in such circumstances. As such, users must be supported in their growing responsibility through the presentation of the network information needed to make this decision, and the means with which to evaluate their options. Knowing which networks have the best coverage over a user's frequented locations as well as which networks are most consistently available as the user moves throughout the day, could aid in their evaluation.

These metrics help to represent the network concepts of coverage, quality of service, and handoffs from a user's perspective.

In this work, we present an application for Android smartphones known as NetView, to provide users with the means of making informed decisions on their public network selections. The use of the wireless scans already conducted by the phone, along with the user location, allows NetView to provide network context to the user. These results are stored in a database on the device to analyze trends and to improve the accuracy of policies in frequented locations. We deployed NetView in a university campus setting to show the significance of the user location feature, and the decisions a user might make based on the newly available information.

The rest of this paper is organized as follows: Section II details the related works and tools. The system implementation of NetView is described in Section III followed by the experimental set up in Section IV. Section V has a discussion on the experimental results. The concluding remarks and the future work are in Section VI.

II. RELATED WORKS

User context has been previously demonstrated as an important feature for a variety of applications. Position information in particular, has been used in activity recognition in smart homes [4], wireless network service prediction [5], and content recommendation [6]. Useful directly or as an indirect feature for activity context, a user's position information is key for understanding the complete set of operating conditions. NetView has been designed around this principle to better assess internetwork transitions.

Within the 802.11 standards for Wi-Fi, horizontal handoff between access points is achieved by the end device disconnecting when signal degrades below a predefined threshold and then rescanning for available connections [7]. There is a breadth of work regarding improvements to this native mechanism for better control and experience quality. In [8], a software-defined network is proposed that uses traffic across access points as context for controlling load balancing within the network. For the content-centric network in [9], a user's location is utilized to route the requested traffic. These

works demonstrate the use of improved features allows for more advanced policies and better accommodation of unique circumstances. This will continue to be important as users manage their own experience. In the LeapFrog scheme [7], the end user devices make handover decisions using signal strength values obtained from all available access points. In this way, the user device may select the highest signal strength connection as soon as it is available instead of after the existing connection degrades. This work also details how an end user device may obtain information on the available network state using existing communications.

As the availability of Wi-Fi has been growing and is projected to continue, other Radio Access Networks (RANs) such a WiMAX and 4G LTE have also been growing [1]. This is increasing the availability of heterogeneous networks and the need for vertical handoff policies between the different RANs. In [10] and [11], background processes observe the user’s activity and use it to learn policies. In the latter work, the policies are conditioned such that a user’s past behaviour and actions can be used to inform which actions they are most likely to do again. This is also an important consideration for a user’s daily schedule which is likely to include repeated events. The extended range of the WiMAX and cellular networks allows for the support of network connection in moving vehicles. To avoid unnecessary transitions between RANs, some policies consider position and velocity to anticipate when a transition will be viable [12], [13].

Several mobile applications exist with the aim of providing users more information about available networks. Two of the popular applications include Wifi Analyzer and WiFi Manager available from Google Play [14], [15]. Many of the existing applications are designed to be the user’s active application to perform their role. It is not common to find recommendation policies in these application that rely on any features beyond signal strength or that consider the history of the user. Other applications, like MobiDiag, instead centralize information from many users to create general policies for network troubleshooting [16].

III. SYSTEM DESCRIPTION

The proposed NetView system focuses on the integration of user location and a stored feature history for supporting user network decisions. Designed for Android smartphones, NetView makes use of the available Wi-Fi and Location services. Background processes allow these services to be measured for the necessary features while NetView is not the user’s active application. Impact on the device battery life is minimized by capturing the responses received from any Wi-Fi scan triggered on the device. This includes initial Wi-Fi discovery as well as requests made by any other user applications. For increased data collection, NetView can be configured to

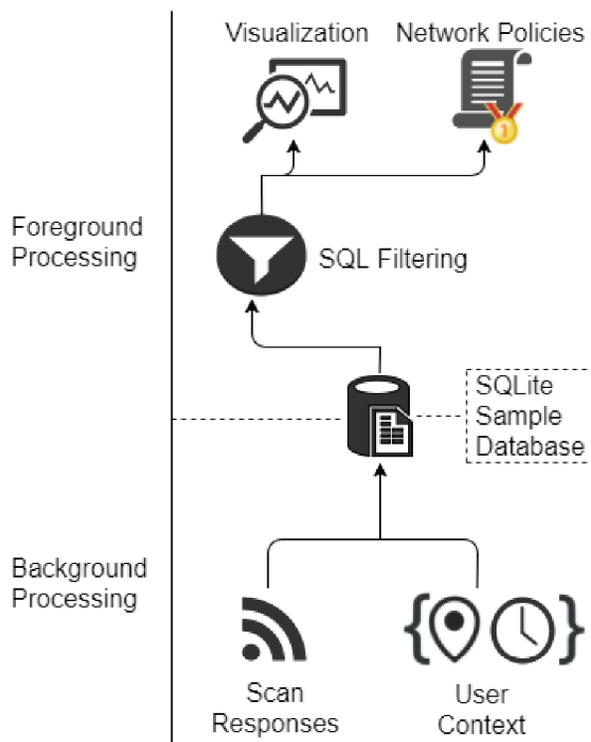


Fig. 1. The NetView processing architecture.

trigger scans if 30 seconds have elapsed from the last scan.

A. System architecture

The overall division of functionality and flow of information from hardware to the user can be seen in the architecture summary in Fig. 1.

To avoid disrupting the user’s normal activity and to avoid significant impact on battery performance, NetView collects information about the available networks using the responses received from the Android device’s native Wi-Fi scan. This scan occurs for any Wi-Fi discovery call and may also be triggered by user applications. For additional data, NetView can be configured to trigger a scan if one has not occurred within the last 30 seconds.

For every visible access point acknowledged by a scan, NetView’s background process records the following features:

- i) **SSID**: Unique network identifier.
- ii) **BSSID**: Access Point identifier.
- iii) **RSSI**: Current Signal Strength for the Access Point.
- iv) **Frequency**: 2.4GHz or 5GHz bands and channel.

Scan responses are also labelled with the current device time and user latitude and longitude to incorporate the user context. Location measurements are obtained via GPS or Wi-Fi based indoor localization depending on availability. Sampling functionality does not require any

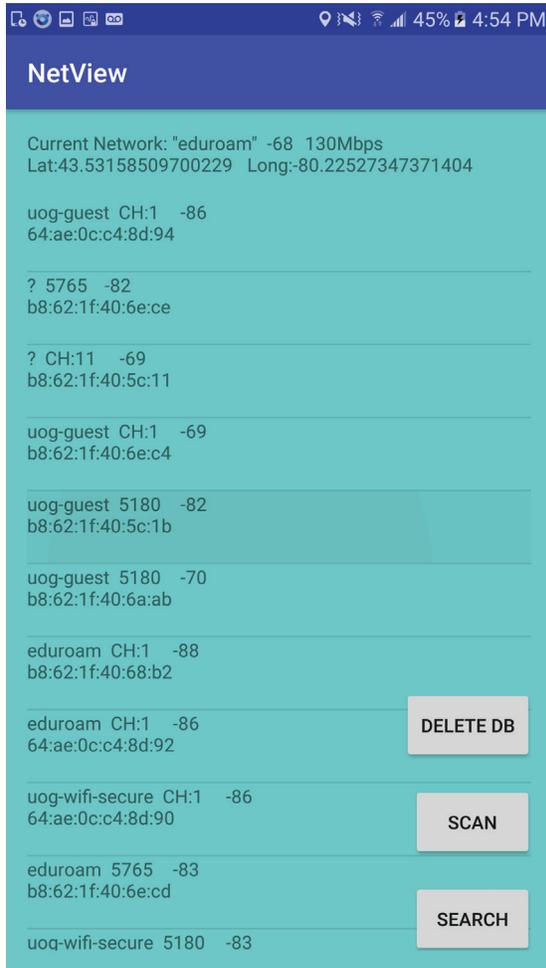


Fig. 2. Display of main screen and recent scan results.

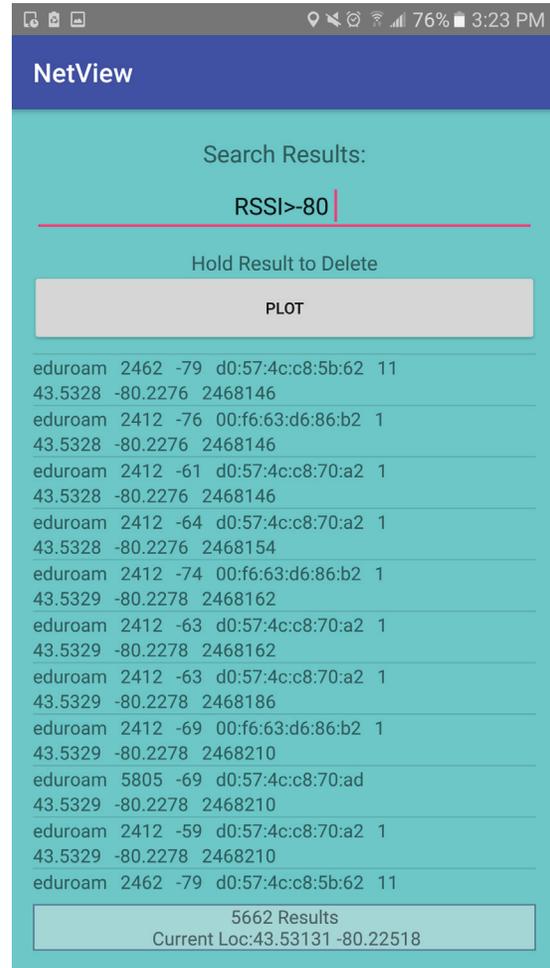


Fig. 3. Filtering samples database by RSSI values.

remote services or servers, so the user location is never communicated outside of the NetView Application.

Each context labelled scan result is treated as a sample for use in policy assessment and presentation. This application data is managed through a SQLite database which makes the aggregated samples accessible to standard SQL queries against any of the sample features. A database manager is used to protect write access to the database. The manager is equipped with its own background process to support sampling while NetView is minimized. Every sample received is saved and maintained on the device until removed by the user.

B. Graphical User Interface

In order to communicate the information within the scan results to the user, NetView uses a simple and direct interface. Upon launching NetView, users are met with the main screen shown in Fig. 2. This screen presents the user with a summary of the most recent scan responses. Whereas the native Wi-Fi discovery in Android presents users with the unique networks available,

NetView presents the user with all visible access points. The main screen also provides the user with access to three core functions: deleting the accumulated database, triggering a manual Wi-Fi scan, and investigating the available data.

The investigation activity allows users to filter the database to view a subset of the results. This filtering can be applied through any of the scan result features as string comparisons for the ID fields or as expressions for the numerical fields. An example of a suitable expression for signal strength is shown in Fig. 3 which returns only the entries with RSSI field greater than $-80dBm$. Scans results may also be filtered by those received within a chosen radius of the current position, and by a recent scan time window. Multiple filters across features can be combined in a single user search.

All samples returned by user filters can be combined into a visualization to improve understanding of the contained information. These results are plotted as a probability distribution over signal strength based on the frequency of occurrence in the user's accumulated data.

TABLE I
DEPLOYMENT STATISTICS AND NETWORK RECOMMENDATIONS.

Building	User State	Duration (min.)	Total Scan Results	Results per SSID E : G : S	Moderate RSSI E : G : S	Best by Scans	Best by PDF
1 - Food Court	Stationary	20	699	231:230:238	96:94:106	S	G,S
2 - Study Atrium	Walking	5	352	125:117:110	86:80:81	E	S
2 - Study Atrium	Stationary	20	2017	669:649:699	479:471:485	S	S
3 - Classroom	Walking	5	772	261:260:251	86:99:100	G,S	E
3 - Classroom	Stationary	20	996	344:321:331	166:127:130	E	E

This allows users to see an expectation of the quality of the signals under the specified conditions. These distributions are lower bounded by the user defined *moderate* signal strength threshold e.g. greater than $-80dBm$. Users also define a *good* signal strength threshold for use in best network evaluations.

IV. EXPERIMENTAL SET UP

The campus of the University of Guelph was selected for the trial deployment of NetView as a real environment where users are exposed to overlapping network selections. The campus is serviced by three primary Wi-Fi networks: ‘Eduroam’, ‘uog-guest’, and ‘uog-wifi-secure’. These networks will herein be labelled as ‘E’, ‘G’, and ‘S’ respectively. As much of the physical infrastructure for these networks is shared throughout the campus, it is reasonable to assume that for any campus location with wireless access, each of the networks are present.

A. Experimental environment

Tests were conducted at three major buildings on campus to capture situations students and faculty of the university would experience in their normal daily activities. Building 1 includes a major food court and student services, Building 2 has an open atrium used for work and study, and Building 3 consists of classrooms for seminars and lectures. For each building, a test was conducted with the user remaining stationary during the test duration. In Building 2 and Building 3, tests were also done with the user walking through the building in order to capture the transitions that occur in a user’s daily schedule.

B. Experimental procedure

The process for conducting each test is as follows. The user begins the test by launching NetView to enable the background processes. NetView is then minimized, and the user resumes their normal Internet activities. These activities include: accessing social media, streaming videos, reviewing online course material, and tending to emails. After the specified test duration, the user

ceases these activities and returns to NetView to review the records. The test durations were 20 minutes for a stationary user and 5 minutes for a walking user. The following values were documented for each test: building, user movement state, test duration, and the total scan responses received for each of the three major networks.

All tests were conducted on a Samsung Galaxy Note 5 smartphone running Android 6.0.1. The user settings were maintained throughout the deployment. For increased data collection, the maximum time between scans was constrained to be 30 seconds. The user defined thresholds for *moderate* and *good* signal strengths where assigned to $> -80dBm$ and $> -70dBm$ respectively.

C. Data collection

The data obtained from these tests was then assessed by two policies to determine the best network for the user in each situation. The first policy, *Best by Scans* chooses the network that has the most scan responses above the *moderate* signal threshold. For mobile users, connecting to the network that was most consistently available on their route is most likely to reduce occurrence of a dropped connection, thus reducing the number of network transitions required. The second policy, *Best by PDF* chooses the network that has the best probability of having a *good* signal given all the responses that were at least *moderate* through assessment of the probability distributions for each network. This policy is most beneficial for stationary users exposed to overlapping coverage. Since RSSI is a time varying metric, it is useful to select the network with the highest expected signal strength to increase the chances of having the highest quality connection for the duration of the stay.

V. EXPERIMENTAL RESULTS AND DISCUSSION

The results for each test and the corresponding network recommendations from both policies are seen in Table I. NetView records all scan responses in its database but the results presented here are those exclusive to the location and time of each respective test.



Fig. 4. Building 2, stationary user response distributions.



Fig. 5. Building 3, stationary user response distributions.

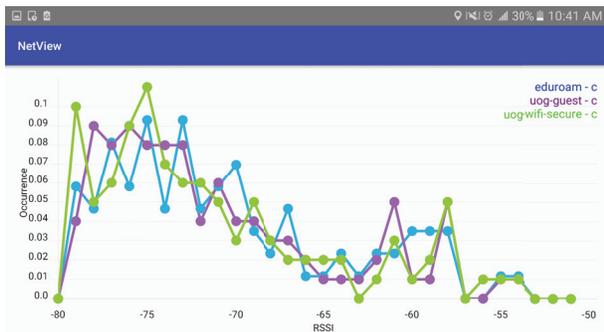


Fig. 6. Building 3, mobile user response distributions.

The proportion of total scans attributed to each of the networks is observed to be a 4.3% deviation from uniform across locations, supporting the assumption of no significant coverage gaps between networks. Reviewing the stationary user tests it is revealed that the open study atrium in Building 2 is a denser wireless environment, returning more than double the scan results of the other buildings for the same duration test. It is also the only building to observe *moderate* signal strength for more than half of the received responses. In contrast, the tests with mobile users indicate that the halls of Building 2 are less densely covered than those of Building 3.

The variation amongst the proposed best networks across the different tests illustrates the importance of user

position context on network selection. For Building 2, a user passing through would be more inclined to select the *Best by Scans* network, network ‘E’, but based on the scan response distribution shown in Fig. 4, the user should switch to network ‘S’ for extended stays. Had the *good* signal strength threshold been decreased to $-72dBm$, thus include the occurrence spike for network ‘G’ seen in the Figure, the selection would instead be ‘G’. This example indicates the potential sensitivity to the user defined thresholds in these evaluations when limited data is available. As user’s continue to expose NetView to their environments these distributions will become more established, and these observations between networks will become more significant.

For two of the conducted tests, contrasting sets of recommendations are made. Stationary users in Building 3 should connect to network ‘E’ but choose either network ‘G’ or network ‘S’ for passing through. The distributions for the Building 3 tests are shown in Fig. 5 and Fig. 6. In Building 2, there is likewise disagreement between the *Best by Scans* and *Best by PDF* policies, and these recommendations are mirrored to those of Building 3. This outcome illustrates the importance of position and action context in network selection.

Applications which rely on a fixed scanning interval to perform recommendation updates would effectively be sampling from the observed scan response distributions, potentiality leading to changes at each interval. Maintaining a history of scan results enables policies which are smoothed and capable of making recommendations for longer periods without requiring frequent network transitions.

VI. CONCLUSION AND FUTURE WORK

In this paper, we presented the application NetView, to aid users in optimizing network selection in public environments. Two proposed selection policies, *Best by Scans* and *Best by PDF* allow users of NetView to make decisions based on their preferred metric of quality. Deployment on a university campus setting demonstrated that the use of user location and the aggregation of results allows for recommendations tailored to the user’s past and present situations. As such, these recommendations can be targeted for the expected network performance over longer durations, reducing the need for frequent transitions.

In the near future, we will be running additional experiments to integrate user activity context from current applications and expected data requirements. These new data features will enable the integration of more advanced policies tailored to a wider range of user experience preferences. Using the available history to predict state such as user action or network demand, may further improve the application of automatic policies.

REFERENCES

- [1] Cisco Visual Network Index, "Global Mobile Data Traffic Forecast Update, 2016-2021;" in *White Paper*, 2017.
- [2] Z. Ning, F. Xia, X. Hu, Z. Chen, and M. S. Obaidat, "Social-oriented adaptive transmission in opportunistic internet of smartphones," *IEEE Transactions on Industrial Informatics*, vol. 13, no. 2, pp. 810–820, April 2017.
- [3] J. Kwak, O. Choi, S. Chong, and P. Mohapatra, "Processor-network speed scaling for energy-delay tradeoff in smartphone applications," *IEEE/ACM Transactions on Networking*, vol. 24, no. 3, pp. 1647–1660, June 2016.
- [4] L. Chen, C. D. Nugent, and H. Wang, "A knowledge-driven approach to activity recognition in smart homes," *IEEE Transactions on Knowledge and Data Engineering*, vol. 24, no. 6, pp. 961–974, June 2012.
- [5] M. Xin, H. Cao, and Z. Niu, "An approach to a location context awareness service prediction algorithm," in *2014 IEEE Workshop on Electronics, Computer and Applications*, May 2014, pp. 766–770.
- [6] A. Bouzeghoub, K. N. Do, and L. K. Wives, "Situation-aware adaptive recommendation to assist mobile users in a campus environment," in *2009 International Conference on Advanced Information Networking and Applications*, May 2009, pp. 503–509.
- [7] Y. Zhang, Y. Liu, Y. Xia, and Q. Huang, "Leapfrog: Fast, timely wifi handoff," in *IEEE GLOBECOM 2007 - IEEE Global Telecommunications Conference*, Nov 2007, pp. 5170–5174.
- [8] N. Kiran, Y. Changchuan, and Z. Akram, "Ap load balance based handover in software defined wifi systems," in *2016 IEEE International Conference on Network Infrastructure and Digital Content (IC-NIDC)*, Sept. 2016, pp. 6–11.
- [9] Z. Qin, D. Li, and M. Chuah, "Lehigh explorer: A real time video streaming application with mobility support for content centric networks," in *2013 IEEE 9th International Conference on Mobile Ad-hoc and Sensor Networks*, Dec. 2013, pp. 33–40.
- [10] J. Hyun, Y. Won, D. S. C. Nahm, and J. W. K. Hong, "Measuring auto switch between wi-fi and mobile data networks in an urban area," in *2016 12th International Conference on Network and Service Management (CNSM)*, Oct. 2016, pp. 287–291.
- [11] Q. Li, Q. Han, and L. Sun, "Context-aware handoff on smartphones," in *2013 IEEE 10th International Conference on Mobile Ad-Hoc and Sensor Systems*, Oct. 2013, pp. 470–478.
- [12] J. Guo, T. Tsuboi, and J. Zhang, in *Mitsubishi Electric Research Laboratories*, 2010.
- [13] N. Abbas, S. Taleb, H. Hajj, and Z. Dawy, "A learning-based approach for network selection in wlan/3g heterogeneous network," in *2013 Third International Conference on Communications and Information Technology (ICCIT)*, June 2013, pp. 309–313.
- [14] farproc, "Wifi Analyzer," in *Computer software. Google Play. Vers. 3.10.5.L*, 05 Feb. 2017.
- [15] Kostya Vasilyev, "Computer software. Google Play. Vers. 3.6.0.5," in *WiFi Manager*, 26 July 2017.
- [16] X. Ye, B. Yan, and G. Chen, "Providing diagnostic network feedback to end users on smartphones," in *2013 IEEE 32nd International Performance Computing and Communications Conference (IPCCC)*, Dec. 2013, pp. 1–9.