Survey of Home Networks

by

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Abstract

Previous studies looking to understand user experiences around Home Network (HN) management, comfort levels and required skills have had minimal coverage up to this point. We are interested in understanding HN user experiences, including their perceived skill and comfort levels with managing devices and services that reside within their HN. In this paper we look to understand the perceived value of information from a recent survey we completed around the project How’s My Network (HMN), as focused on a user-centric approach to understanding the user experience when managing and using a HN. We also examine device types, Internet Connectivity, management options, interest, and preferred method of management of user HNs.

We believe that the landscape has changed and that users are now interested in an in-depth view of HN information. An in-depth review of these areas has not been completed before, and the information from this review and survey, we believe points toward characteristics that users versus researchers are keen on today. In this paper we show the results from this survey and discuss how they fit into potential future work.
1 Introduction

Since the advent of the Internet Home Networks (HNs) have leveraged service providers for Internet network connectivity to their homes. HN users have options to connect to the Internet via a variety of ISPs types including A/DSL, Cable, FIOS/Fiber, and dedicated telephony services. With these offerings, and changes in technology, HNs access to the Internet is no longer a luxury, but rather an expectation. Understanding that the landscape has changed it is now important to understand what is happening inside of HNs.

A study done by the United States Census \[27\] on Internet usage found that 75% of census respondents had an Internet connection, 43% leveraging cable as their connection the Internet. An interesting aspect the researchers found is that 5% used a satellite connection as their primary connection. They also found that 84% of respondents reported owning a computer (or devices), which is significantly less than what we found (99.9%) in the survey we ran.

There has been a shift to faster connectivity, along with a device explosion within the HN, which is clear from a report done by \[10\] and a recent study we did around Peering into the Home Network \[22\]. This study showed that the typical Home Network (HN) includes devices, such as hardware that allow for browsing, and connectivity to commodity Internet traffic. These Devices include routers, modems, PCs, tablets and smart-phones, and specialized hardware devices. This work also delved into the complexity of these devices and how they impact HN users in terms of types, and hardware, and created a new taxonomy to classify HNs. This study also looked to understand interests, and comfort levels of HN users as related to configuration, setup, and experiences with HNs, devices, and Applications. In the remainder of this paper we will continue to refer to ‘comfort’ as a user’s ability to manage, configure, setup, operate devices and customized hardware, software/tools, and home networking hardware; where these areas also include Security and Privacy.

In this work, we have designed a survey to take a focused examination of understanding HN user preferences, comfort levels and areas of interests in and around HNs. In addition we seek to understand user interests in wireless networks, mobile and networking devices, security, and privacy. This study and survey provides several contributions in understanding the user experience and comfort levels in using HNs.

In particular, this study provides:

1. an examination of user comfort levels, interest, and actions regarding, routers, mobile devices and Web-related tools,

2. an understanding of what type of information is important to HN users to operate their environment,

3. how security, privacy, configuration, and general operation health, are of interest to users, and,

4. insight on how HN users would like to see data collected within their HN.

The rest of this paper is organized as follows: Section \[2\] outlines background and similar work; Section \[3\] show research questions we are looking to answer ; Section \[4\] describes the methodology used ; Section \[5\] provides a review of survey questions and justification ; Section \[6\] provides details
on the survey; Section 7 is a comparison of survey types; and Sections 8, 9 and 10 conclude with a discussion, next steps, and summary respectively.

2 Related Work

In this section we provide background and related work in this area. A starting point is looking at work completed in commercial, research, and patents with an area of HN focus.

We start with work completed in the project How’s My Network, where the focus was using a Java via a browser to understand HNs [23]; this research focused on measurements of HNs targeted at researchers. A recent study on Home Networks (HNs) was completed with a focus on a review of device types, and classification of methodologies [22]. This work created a taxonomy of approaches used in HNs, along with specific areas referred to as data of interest, and tools (apps) used in HNs. Other studies focused on general information about HN Internet connections and demographics [27].

Studies such as [9] looked to understand digital competencies of university students, which would apply to how they leverage and manage HNs. This study found that educational readiness around digital competency is a key indicator to leveraging online tools. In addition a study by [24] looked at a variety of methodologies and research studies to determine skill levels in and around social and cultural boundaries. A study by [26] looked to understand Wifi connectivity in HNs using a hardware apparatus in the environment, for a period of time, with a focus on researchers versus HN users.

Bajpai, et. al. did a study [3] on legacy platforms which are all targeted toward throughput and provide researchers data versus HN users. A study focusing in on Wifi AP connection [19] looked to understand why APs are slow to connect, and provided some feedback to researchers as how to potentially improve a slow connect scenario. A study by [28] looked at user comfort level in and around specific background processing of Apps on mobile devices, and found that designers should be improving the mobile-privacy that systems allow.

A review of similar work done in and around surveys was also completed. These include papers by [11], [12], and [3], which used a service model and installed a fat-client onto a local system (PC in this case) to determine preferences via pop-ups and other techniques (in-app) via survey questions. The method used in this body of work required a ’administrator’ privileges and active techniques for monitoring and gathering information.

A recent study looked to understand Wifi congestion with neighbours, fitting nicely into HNs, and used heavily modified APs installed into test environments to measure overlap [18]. They found that their “metric” accuracy was confirmed when measuring congestion, and that it fits into an approach of remote management of Wifi connectivity.

A review of devices in HNs was also completed, an their impact in networking in-general. Cisco has predicted that by 2020 there will be 50 Billion IoT devices connected to the Internet, with a larger percentage of these devices residing in HNs [8]. Work done by [17] conceded that HN management is becoming increasingly challenging, and complex and argue for a vendor neutral API across all management tools, for configuration of Wifi networks. Various research and patents have been created around creating new low power and better efficiency of Wifi, connectivity, and IOT including [7], [13], [15], [14], and several others. While these approaches (and patents) target new technologies for commercial or research space, they provide little feedback for HN users.
Other work looked to provide approaches to models of security within the HN for IoT devices, using in-hub hardware approaches (physical hardware or modified routers) [25], [1]. Privacy work in and around HN Internet traffic shaping, by [], looked to leverage IoT and other devices, along with 802.3.ad (tunnelling, and VPNs) for privacy.

In this paper we are taking into account approaches used for privacy, security, and health as well as user comfort, interest, and skill level when managing their entire HN, and believe that users are interested in easy methods of data gathering around their areas of interests. This review is around HN users and their areas of interests, etc., versus that of solely researchers interest. We present our findings from our current HN research survey, in the next several sections.

3 Research Questions

In this section we layout the research questions we are looking to answer as part of this study. A focus of this work, and as part of the HMN study, include the following questions as part of this study:

1. What is the landscape of how users view the set up current HNs?
2. What is HN users skill level of setting up HNs, Devices, Tools and configurations of HNs?
3. What interests do users have in the areas of information, security, privacy, setup, and maintenance of HNs?
4. What types of services are users interested in monitoring as part of HNs?
5. What is the preferred method to collect data about a HN?

4 Methodology

In this section we provide the methodology used as part of this review. We start with the methodology that was used and review the survey we recently completed, and then turn to why this research matters and look to understand HN comfort levels of managing their HN, devices, services, as well as user interests in and around HNs. In this survey we exclusively requested feedback from respondents in and around their permanent HN environment. Survey responses were collected from September to November 2018.

The survey includes 12 questions, as recommended by the APA and PEW best practices [20], to minimize survey fatigue and keep users engaged without overwhelming with too many questions. The survey is requesting information from an HN users exclusively around their experiences of their home network (HN) and their comfort level managing and using their HN. At the completion of the survey respondents are provided a summary of results. In addition, respondents that provide an email address will be sent a copy of this report.

The background for several of the survey questions include [5], [19], [18], and work we completed on "Peering into the Home Network" [22]. The following are some of the definitions from this work, which were used as a starting point to create this survey. These include approaches:
hardware and software that provide a plethora of localized information by peering behind the HN router using several approaches, in an attempt to determine and characterize configurations.

We refer to the Software/applications running on these devices as 'Tools'. Approaches are classified to include: Routers, Apps, Hardware, Web/Scripting tools. Each of these areas may have a subsection, which includes customized groupings. Data of Interest: the gathering of desired data collection from the user perspective. We have included the attributes of each of these data of interest, which are the data points collected by the tools. The areas classified include: Throughput (upload/download, jitter, network flow, and performance), Networking Characteristics (discovery, Wi-Fi, and fingerprints), Health (including security and privacy), and Historical Norms (Local and Global norms).

4.1 Skill Level

The following are the questions and a review of how we are using the information from the survey in this paper. We start with classification of respondents. Respondents are classified by taking answers from the categories of classification and split into skill levels, which we have modified from the NIH [5] competency scale:

- **Novice**: An individual that has limited experience and rely upon help. They have some common knowledge or an understanding of basic techniques and concepts.

- **Intermediate**: An individual that is able to successfully complete tasks with minimal help, but may need assistance from time-to-time.

- **Advanced**: An individual who can perform actions associated with a given skill without assistance. This group is recognized within their group as a person to ask when difficult questions arise regarding this skill.

- **Expert**: An individual who can provide guidance, troubleshoot and answer questions. They are known as an expert in this area, and provide guidance, troubleshoot and answer questions related to this area of expertise and the field where the skill is used.

4.2 Assessment

Respondents have been split by their skill level, which they have self selected. The areas we are slicing these respondents into are ability and comfort, Ability (including management) and comfort (including preference), with the following categories: Self-assessment of skill level, Home router knowledge, Technology comfort, which includes mobile, PC, and hardware, Wifi literacy, and App literacy.

Home networks are broken down from the data collected, and the respondents information classifies their areas of ability and comfort level with HNs. The respondent is supplying information about their own home network which we previously classified. The data collected is used to classify HNs in specific areas as well, including: devices and connectivity.
5 Survey Questions

In this section we provide an overview of how we have used or plan to use these results as part of this work. We walk through each question, list possible answers after each question, and provide a short justification for each question.

Introduction to Survey
We start the survey with the following heading and basic information, and then move to each question. We start the survey with a brief description / heading:

How’s My Network (HMN) Home Networking (HN) survey. This survey is student thesis work, under the department of Computer Science at Worcester Polytechnic Institute (WPI), on the project 'How’s My Network'.

We are conducting a survey to learn about Home Networks, and help users fully access its functionality. As part of this survey we are exclusively looking for feedback on your Home Network environment, including: Wifi (wireless network), mobile and networking devices, security, and privacy. Your personal information and survey results will not be shared. This information will only be used in aggregate to better understand the current state of Home Networks.

The following is a review, Figure 5, of the current survey header description. The following URL is a link to the survey: https://wpi.qualtrics.com/jfe/form/SV_3VqE1eisY3RUYYd
5.1 To which gender do you identify?
Respondents have the option of selecting one of the following:

- Female
- Male
- Prefer Not to Say
- Other (open feedback)

We start by asking respondents to identify their gender. While we did not use this question to bucketize responses into classified genders, this information was used to help understand those responding to the survey. We have used the gender to help classify and slice data by selected categories.

5.2 How would you rate your Home Network skill level, this includes managing your Router/Mobile/PC devices and Apps/Software?
Respondents have the option of selecting one of the following:

- Novice (limited experience and rely upon help)
- Intermediate (you are able to successfully complete tasks with minimal help)
- Advanced (you can perform actions associated with this skill without assistance)
- Expert (you can provide guidance, troubleshoot, and answer questions).

Home Network skill level question is looking to have the user self-classify their abilities of managing their HN, devices, tools, and comfort level. The classification types have been aligned with the NHI’s Competencies Proficiency Scale [5]. This information is used as part of this study to classify users from what they have defined or selected along with how they answer questions related to their environment, comfort level, and abilities in this survey. We use this selection to compare level of devices, and management across a variety of areas.

5.3 Question What type of home Internet connection do you currently have?
Respondents have the option of selecting one of the following:

- DSL/ADSL
- Cable
- FIOS/Fiber
Dial up Via a Modem

I do not Know, or Other; option allows open feedback from the respondent.

Internet classification type is asking basic information around their home network. We start with the basics of the Internet technology type to get an understanding of the landscape of today's Home Network Internet types being used. This question allows for an open answer or to mark one oval. This information is being used to identify users by provider, and update of previous work done from [23] on HN Internet providers. This information is used to understand if HN users can identify their Internet provider.

5.4 Wifi and Mobile devices on my Home Network include:

Respondents have the option of selecting one or more of the following devices:

- I do not have any Mobile or Wifi Devices
- Android Phone
- Android Tablet
- Iphone
- Ipad
- Windows Laptop/Desktop
- Mac Laptop/Desktop
- Reading Devices (e.g. Kindle)
- Health and Wellness Devices (e.g. Fitbit)
- Game Console (E.g. PS, Xbox, Nintendo)
- Wifi Range Extender (e.g. Netgear)
- TV and Sound System (e.g. LG TV, Sonos Sound System)
- Streaming Devices (e.g. Roku)
- Smart Speakers Assistive Wifi Devices (e.g. Amazon Alexa, Google Home)
- Find Your Device (e.g. Tile)
- Thermostat (e.g. Nest)
- Home Security and Video Cameras (e.g. Ring, Nest, Lorex)
- Smart Lock (e.g. August Smart Lock)
- Smart Sprinkler or Home Control devices (e.g. Rachio)
In this question, we are looking for standard devices in the HN, (e.g., Wifi, etc.), as well as peering into IoT-based devices. The list of devices from this list is similar to those in the recent review of the most popular device list of 2018 [21]. These include Wifi, mobile, and other similar (IoT) devices the user has on their HN. Results from this question can be seen in Table 6.4. The question allows multiple selections and an open entry from the user. This information is being used to classify devices a user has on their HN, and compare against the mobile app collection data set. This is of interest as it points toward hardware commonality and global network and device norms. We have used this question to classify HNs using the device and connectivity classification we have created as part of this study. As an example in this question, we can see that the most popular devices across all networks are Windows PCs (81%) and mobile devices (>65%), which more than 50% of all respondents reported having in their HN.

5.5 Which of the following best describes your abilities to install and configure a home router?

Respondents have the option of selecting one of the following abilities:

☐ I am not comfortable with setting up my Home Router / Home Network

☐ I am not comfortable with setting up my Home Router / Home Network

☐ I have minimal experience, and rely on friends and my Internet provider to help manage my Home Router / Home Network

☐ I have set up my Home Router / Home Network, but still need help from time to time

☐ I am very comfortable with setting up a Home Router / Home Network

☐ Other; allows open feedback from the respondent.

In this question, we are looking to understand the abilities of the Home Network user when working with their HN router. This question is congruent with a series of future questions around HN experiences, and lines up with work done by [5], and the research from the paper peering into the home network [22]. This question allows the user to classify how they feel about their experiences with their HN. These classification of answers are similar to what Google Measurement labs [16] uses when looking for feedback. This question allows for an open answer or to mark one oval.

We are classifying the users home router knowledge, which is part of the abilities (including management) and comfort (including preference) classification we have created as part of this study. This question is used in conjunction with other questions to help classify areas related to skill level, and other functions in the HN. These answers are also quantifiable into novice, intermediate, advanced, and expert levels from the results, as they lineup with the scale we have defined. We use respondents results to compare skill level versus management abilities in the 7 section.
5.6 Please rank the following in terms of your comfort level with using each type of device or application (lowest comfort [1] to highest comfort [4])

Respondents have the option of selecting one of the following per each of the comfort areas related to device/application type. Please note that this question allows one answer per row.

- I have no idea how to use
- I have used before, but typically need help
- I have downloaded software/updates and or run Apps (applications) on it
- I am very comfortable using.

The following Device types were listed (one per line) to select versus comfort level, and included:

- Mobile Device (such as a smartphone or tablet)
- PC (Mac or Windows) applications (word, etc.)
- Web Browser
- Router
- Purchased home networking devices that monitor and manage security and privacy (e.g. Bitfender, Luma, Dojo, F-secure, Fing, etc.)
- Customized hardware (specialized router, Linux Machine, etc.).

In this question we are interested in comfort level using devices or applications, and approached this area with work done by [4] and the terminology created around approaches from the research paper [22] in an effort to understand comfort level of each area related to: Mobile devices, PCs, Web browsers, Router, and customized / purchased hardware. Included as part of this question is purchased home networking device, and example hardware that fit, where they are types that monitor and manage security and privacy (e.g. Bitfender, Luma, Dojo, F-secure, Fing). This information helps with understanding which approach type is desired for ease of management. We have used the responses to this question to classify the users technology comfort level of HN activities, which includes abilities (management) and comfort (including preference) to point to concrete areas of how users manage their HNs.

In addition, we used this question to classify the users technology comfort level of HN activities, which includes abilities (including management) and comfort (including preference) to help point to a concrete areas of how users manage their HNs.
5.7 Please select all actions you have made to your Wifi/Router or devices in the past)

Respondents have the option of selecting one or more of the following per each of the comfort areas related to device/application type

- □ Added a device to my Wifi
- □ Logged into my Router
- □ Updated my Router firmware
- □ Setup a new Router out of the box, including configuring Wifi and passwords
- □ Run an online speed test of my Internet connection (e.g. Google, Ookla)
- □ Logged into my router to review what devices have connected to my home network in the past
- □ Run a basic network scan to determine what devices are attached to my home network (e.g. NMAP, JNetMap, Network Scanner)
- □ Run advanced network diagnostics gathering: fingerprinting, topology, and Wifi layout. Using tools which typically require administrator or super-user privileges to execute (e.g. NMAP, Wifi Visual Analyzer, Internet Mapper Tool, Advanced IP Scanner).

This question is diving into the approach types, and data of interest as defined in [22]. This question continues on the same line as the previous question (comfort level), and looks to understand Wifi/Router or devices the users have managed within their HN. This question includes generic areas executing a task or managing an application within the approach types and data of interest areas. The scope of questions directly correlate to interest of study and approaches done to this point in research and commercial applications. This question allows for an open answer or to mark a series of ovals. This information is used to classify the respondents Wifi/router literacy into the areas of abilities (including management) and comfort (including preference), that we have created as part of this study.

5.8 Please select all actions you have made to your Mobile or PC device(s)

Respondents have the option of selecting one or more of the following per each of the comfort areas related to device/application type

- □ Installed a new App (application) on my mobile device (e.g. smartphone or tablet)
- □ Used a recommendation App to install Apps on my devices
- □ Run an App to review what applications are running on my device (Mobile or PC)
- □ Run an App to review what networks my device (PC/Mobile) has connected to in the past
Run an App to review the security or privacy of my Mobile/PC device (e.g. Verizon Security, Norton)

Run an app to review what devices have connected to my home network in the past

Run an App (Mobile or PC) to review the security of my home network (e.g. Home Network Security, Sophos, Check Point ZoneAlarm)

Run an App to review the health of my home network and internet connection including tools that examine configurations, normal operation, security and local device privacy (e.g. Bullguard, Sophos, Cryptguard, Textsecure, Orbit)

other ; option allowed for user open ended input.

This question is looking to understand the Actions HN users have performed on Mobile/PCs devices. This question also allows for an open answer or to mark a series of ovals. The information from this question is used to classify the respondents app literacy level, by the areas of abilities (including management) and comfort (including preference), that we have created as part of this study. This question has several check boxes that the user can select around Apps, and we following a similar rating as other questions we calculate the respondents App Literacy. These areas were reviewed as part of previous research done, and include either generic questions of executing a task or managing an application within an Approach type and data of interest. The scope of this question directly correlates to interest of study and approaches done to this point in research and commercial applications. Work done by [11], [12], and as shown in [22] was background for this questions. We have included examples to this survey to include software or tool types, e.g.: Google Speed test, NMAP software, etc.

5.9 Please select your interests around managing, or understanding in more detail your Home Network

Respondents have the option of selecting one of the following interest types; the selection allows for multiple options, these include:

- When changes happen to my Mobile (or similar) devices
- How to setup my home network correctly, Speed to the Internet
- Why my Wifi is slow, and how to fix it (connection to devices on your home network, e.g. printer, tv)
- How my network compares to others in terms of setup devices, and a Mobile Applications
- Is a networked device secure (e.g. is anyone trying to break into the device?)
- What devices have connected to my Home Network (my devices, and friends devices)
- Home network health (e.g. is my firmware up to date, are there open devices on my network)
☐ Device health (Is my device running at peak performance in terms of memory, apps, storage)

☐ How private are my network devices (e.g. are they leaking data that can be seen by the outside world?)

☐ Detecting unauthorized devices attaching to my network, and automatically disable them

☐ How to use my home network to control multiple devices from one location (e.g. Alexa Dot, tvs, audio, video, heat, kitchen, bathroom)

☐ How to control how much of my internet bandwidth can be used by each device

☐ other; allows for an open answer from the respondent.

This question is looking to understand HN users interests and management preferences. Management is centered around HN user interest in terms of (immediate and delayed) feedback of their HN or to manage their network. This question also allows for an open answer or to mark a series of check boxes. This question continues with the classification of the respondent’s interest are in terms of gathering information and around their HN, and which approach type lines up with their interests. The results show that Mobile phone and PC results are desired for data collection at this point.

The data of interest [22] as part of this question includes security and privacy, throughput, as well as management of functionality. The question includes examples in each of these areas, where it makes sense, to show what type of tool would potentially be used, or what it would provide. This question continues with the classification of the respondent’s interest are in terms of self management or details in and around their HN. We use this information as fodder for the Mobile HN app, and which features respondents are most interested in seeing; although, some features may not be possible to implement.

In addition, a review of what can and cannot be done from this question can be seen in the summary section of what can/cannot be done [10].

We use this question to classify users interests, along with each of the sub questions in this question are a result of the research from [22], [11], [12] and [21] and looks to understand how HN users have interest in retrieving and reviewing HN information. We are looking to understand where users have interest not only in areas of concern, but also how to gather and display this information. One approach is to leverage an App to provide this information versus using a Web browser. As an example, an App targeted at an Android specific Mobile HN App could gather and provide information to HN users, and fit into the mold of this question.

5.10 Which of the following would you prefer to use to gain access to information about your Home Network?

Respondents have the option of selecting one or more of the following per each the areas around preference of gaining access to HN information:
□ My Mobile Phone/Tablet
□ My PC/Mac
□ A Web Browser
□ My home network router
□ A modified Router that allows for advanced diagnostics, and functionality
□ A purchased unit of hardware specifically designed for Home Network data gathering (e.g. Cujo, Keezel, RaTTrap)
□ I am not interested in gathering any information,
□ Other; allows for an open ended answer.

This question continues with the classification of the respondent’s interest are in terms of gathering information and around their HN, and which approach type from the Tech Report lines up with their selection. We are looking for information to understand top approaches to gather information and how to most effectively continue our study in the HN.

5.11 What other information are you interested in understanding, in and around your Home Network? Let us know your thoughts.

Respondents have the option to enter an open ended thought in the provided box.

□ Other ; Open ended feedback

In this question we are looking for additional information from respondents on things not covered and provide open ended feedback. This is direct user feedback of information not asked or touched on as part of this survey. We are looking to understand what users are interested, whether it Could or not. From all of the research done in the Tech Report we are interested to see which areas have not had research or commercial experiences at this point. This question allows for an open answer over several paragraphs, if needed. This information is used to understand the classifications of the user and the HN. We are looking for this information to point toward functionality or prompts to be added to the Mobile app we plan to deploy as part of our work. This information is used to understand the classifications of the user and the HN. We are looking for this information to point toward functionality or prompts to be added to future research and how we can deploy these into our HMN study.

5.12 Email Address

Respondents are asked to enter an email address in the open ended text field provided.

□ Email Address ; Open text for email entry

We use respondents email address to update them on study results and future work, via web links and downloadable tools.
6 Results from Survey

In this section we delve into the survey, including introductions and results. We have created a Home Network survey as part of the Hows My Network (HMN) work, and the Peering into the Home Network Tech Report (WPI-CS-TR-18-02) [22], which was targeted at Home Network (HN) users.

We used the following methodology to distribute and conduct the survey. Hows My Network Home Network (HMN) Survey was released in September of 2018, and completed in Nov of 2018. The survey was sent out using email and social media links. The emails and social media included the following networking channels: an initial email to social and other connections asking them to forward to their social and other networks, survey Reddit posts, surveytandem utility (a shareable survey tool), and other social networks, the Worcester Polytechnic Institute (WPI) faculty and staff, and finally to a WPI Graduate and Undergraduate student email list. Of the 550 respondents we believe that roughly 12% where from the initial connections sent out, an additional 48% came in from the initial group forwarding to their social communities along with posts from Reddit and surveytandem, with a final 40% of responses coming in from the WPI community. Figure 1 shows a timeline over the 60 days of the survey (29 date data points), with lower values removed for logical plotting purposes. A small percentage (<2%) of respondents did not fill out each question, and sub-questions, of survey. Those respondents who did not fill out a specific question where removed from that question, and not included in the results.

As a bi-product of the survey collection tool we were able to determine devices and browsers used by respondents to take the survey. The variety of devices include the following: 48% used a Windows system, 18% Iphone, 15% Mac, 14% Android, and 5% Linux or other OS (including Chrome OS). 60% of all respondents used the Chrome browser, 23% used Safari (60% of all Mac/Iphone users), 11% used Firefox, and 7% used Microsoft IE/Edge. A data point of interest is the types of Operating Systems (OS) used by Mobile users, specifically Android users. The majority of users taking the survey (45%) were running version 8.0 (Oreo), which is currently one version behind the latest version of Android PIE (9.0). 19% running PIE (9.0), and 17% running Nougat (7.0-7.1), two versions behind. Almost 20% of respondents are running older versions of Android, Marshmallow (6.0x) or Lollipop (5.0x), which are deprecated or no longer supported.

The following shows results for each of the question.

6.1 To which gender do you identify?

<table>
<thead>
<tr>
<th>Respondents (%)</th>
<th>Gender</th>
</tr>
</thead>
<tbody>
<tr>
<td>240 (44%)</td>
<td>Female</td>
</tr>
<tr>
<td>296 (53%)</td>
<td>Male</td>
</tr>
<tr>
<td>14 (3%)</td>
<td>Other</td>
</tr>
</tbody>
</table>

We can see from these results that there were more Male survey respondents versus that of Female or Other classifications from the selection.
6.2 How would you rate your Home Network skill level, this includes managing your Router/Mobile/PC devices and Apps/Software?

<table>
<thead>
<tr>
<th>Respondents (%)</th>
<th>Skill Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>90 (16%)</td>
<td>Novice</td>
</tr>
<tr>
<td>230 (43%)</td>
<td>Intermediate</td>
</tr>
<tr>
<td>143 (26%)</td>
<td>Advanced</td>
</tr>
<tr>
<td>81 (15%)</td>
<td>Expert</td>
</tr>
</tbody>
</table>

The largest cross section of users were classified as 'Intermediate', with the lowest classification area of 'Expert'. We saw 50% of all female respondents classified as Intermediate versus 35% of males. In contrast 25% of Males where classified as Expert versus 1% of females.

6.3 What type of home Internet connection do you currently have?

<table>
<thead>
<tr>
<th>Respondents (%)</th>
<th>Internet Media</th>
</tr>
</thead>
<tbody>
<tr>
<td>68 (12%)</td>
<td>ADSL/DSL</td>
</tr>
<tr>
<td>273 (50%)</td>
<td>Cable</td>
</tr>
<tr>
<td>102 (19%)</td>
<td>FIOS/Fiber</td>
</tr>
<tr>
<td>8 (2%)</td>
<td>Dial Up via Modem</td>
</tr>
<tr>
<td>81 (15%)</td>
<td>I do not Know</td>
</tr>
<tr>
<td>8 2%</td>
<td>Other (fill in)</td>
</tr>
</tbody>
</table>
We saw that 85% of respondents reported that they had a home Internet connection, with an additional 15% reporting that they were unclear of connection type; although 5% percent of these reported they do have Internet connection but could not identify it. We estimate that >90% of all respondents have a home Internet connection. This number is an increase from a 2013 US Census (American Community Survey) on Internet and other areas of research, where 73% of households reported an Internet connection[27] and type.

6.4 Wifi and Mobile devices on my Home Network include: (All Device Types)

<table>
<thead>
<tr>
<th>Respondents (%)</th>
<th>Device Types</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 (1%)</td>
<td>I do not have any Mobile or Wifi devices</td>
</tr>
<tr>
<td>292 (53%)</td>
<td>Android-Phone</td>
</tr>
<tr>
<td>123 (22%)</td>
<td>Android-Tablet</td>
</tr>
<tr>
<td>377 (67%)</td>
<td>Iphone</td>
</tr>
<tr>
<td>262 (48%)</td>
<td>Ipad-similar</td>
</tr>
<tr>
<td>446 (81%)</td>
<td>Windows Laptop/Desktop</td>
</tr>
<tr>
<td>230 (42%)</td>
<td>Mac Laptop/Desktop</td>
</tr>
<tr>
<td>193 (35%)</td>
<td>Reading Devices (e.g. Kindle)</td>
</tr>
<tr>
<td>127 (23%)</td>
<td>Health and Wellness Devices (e.g. Fitbit)</td>
</tr>
<tr>
<td>300 (54%)</td>
<td>Game Console (e.g. PS, Xbox, Nintendo)</td>
</tr>
<tr>
<td>110 (20%)</td>
<td>Wifi Range Extender (e.g. Netgear)</td>
</tr>
<tr>
<td>296 (54%)</td>
<td>TV &amp; Sound Systems (e.g. LG TV, Sonos Sound system)</td>
</tr>
<tr>
<td>278 (51%)</td>
<td>Streaming Devices (e.g. Roku, Chrome)</td>
</tr>
<tr>
<td>28 (5%)</td>
<td>Digital Photo Frames</td>
</tr>
<tr>
<td>147 (27%)</td>
<td>Smart Speakers Assistive Wifi Devices (e.g. Amazon Alexa, Google Home)</td>
</tr>
<tr>
<td>31 (5%)</td>
<td>Find your device (e.g. Tile)</td>
</tr>
<tr>
<td>52 (9%)</td>
<td>Thermostat (e.g. Nest)</td>
</tr>
<tr>
<td>84 (15%)</td>
<td>Home Security &amp; Video Cameras (e.g. Ring, Nest, Lorex)</td>
</tr>
<tr>
<td>9 (2%)</td>
<td>Smart Lock (e.g. August Smart Lock)</td>
</tr>
<tr>
<td>5 (1%)</td>
<td>Smart Sprinkler or home control devices (e.g. Rachio)</td>
</tr>
<tr>
<td>2 (1%)</td>
<td>Other Open Ended</td>
</tr>
<tr>
<td>Number of Homes (%)</td>
<td>Device Types</td>
</tr>
<tr>
<td>---------------------</td>
<td>--------------</td>
</tr>
<tr>
<td>11 (2%)</td>
<td>1</td>
</tr>
<tr>
<td>34 (6%)</td>
<td>2</td>
</tr>
<tr>
<td>48 (9%)</td>
<td>3</td>
</tr>
<tr>
<td>72 (13%)</td>
<td>4</td>
</tr>
<tr>
<td>67 (12%)</td>
<td>5</td>
</tr>
<tr>
<td>75 (14%)</td>
<td>6</td>
</tr>
<tr>
<td>64 (12%)</td>
<td>7</td>
</tr>
<tr>
<td>65 (12%)</td>
<td>8</td>
</tr>
<tr>
<td>49 (9%)</td>
<td>9</td>
</tr>
<tr>
<td>23 (4%)</td>
<td>10</td>
</tr>
<tr>
<td>22 (4%)</td>
<td>11</td>
</tr>
<tr>
<td>1 (&lt;1%)</td>
<td>12</td>
</tr>
<tr>
<td>8 (1%)</td>
<td>13</td>
</tr>
<tr>
<td>4 (1%)</td>
<td>14</td>
</tr>
<tr>
<td>2 (&lt;1%)</td>
<td>15</td>
</tr>
<tr>
<td>1 (&lt;1%)</td>
<td>16</td>
</tr>
</tbody>
</table>

This summary includes device types within the HN, where the respondents selected they have one or more of that type. We can see that Less than 1% of all respondents reported not having any devices on their network, and 95% of all respondents reported having between 2-11 devices in their HN. An additional 20% of respondents reported having more than eight devices. Overall respondents reported a total of 3395 devices, where the highest devices (on average) per household was six or 14% of households reported.

6.5 Which of the following best describes your abilities to install and configure a home router?

<table>
<thead>
<tr>
<th>Respondents (%)</th>
<th>Ability to Install Router</th>
</tr>
</thead>
<tbody>
<tr>
<td>74 (14%)</td>
<td>I am not comfortable with setting up my Home Router / Home Network</td>
</tr>
<tr>
<td>126 (23%)</td>
<td>I have minimal experience, and rely on friends and my Internet provider to help manage my Home Router / Home Network</td>
</tr>
<tr>
<td>156 (29%)</td>
<td>I have set up my Home Router / Home Network, but still need help from time to time</td>
</tr>
<tr>
<td>188 (34%)</td>
<td>I am very comfortable with setting up a Home Router / Home Network</td>
</tr>
<tr>
<td>3 (&lt;1%)</td>
<td>Other Open ended</td>
</tr>
</tbody>
</table>

Novice users make up the largest percentage of respondents who are Not Comfortable with installing and configuring their HN router versus that of expert users who are very comfortable with these tasks.

6.6 Please rank the following in terms of your comfort level with using each type of device or application (lowest comfort [1] to highest comfort [4])
This table provides important feedback into users' ability and comfort when working with their devices, or approach types, in the HN network. A high level of confidence working with a Mobile Device, PC or Web browser was found with 88%, 86%, and 89% respectively. A sharp drop off in comfort was found when working with a HN Router, purchased and customized hardware. The skill areas of expert and advanced had the most comfort for these two approach types, these include: Router 63% and 95%, Purchased Hardware at 21% and 49%, and Customized hardware at 28% and 66% respectively.

### 6.7 Please select all actions you have made to your Wifi/Router or devices in the past

<table>
<thead>
<tr>
<th>Respondents (%)</th>
<th>Actions Wifi / Router</th>
</tr>
</thead>
<tbody>
<tr>
<td>489 (89%)</td>
<td>Added a device to my Wifi</td>
</tr>
<tr>
<td>370 (67%)</td>
<td>Logged into my Router</td>
</tr>
<tr>
<td>239 (43%)</td>
<td>Updated my Router firmware</td>
</tr>
<tr>
<td>307 (56%)</td>
<td>Setup a new Router out of the box, including configuring Wifi and passwords</td>
</tr>
<tr>
<td>367 (67%)</td>
<td>Run an online speed test of my Internet connection (e.g. Google, Ookla)</td>
</tr>
<tr>
<td>240 (44%)</td>
<td>Logged into my router to review what devices have connected to my home network in the past</td>
</tr>
<tr>
<td>171 (31%)</td>
<td>Run a basic network scan to determine what devices are attached to my home network (e.g. NMAP, JNetMap, Network Scanner)</td>
</tr>
<tr>
<td>92 (16%)</td>
<td>Run advanced network diagnostics gathering: fingerprinting, topology, and Wifi layout. Using tools which typically require administrator or super-user privileges to execute (e.g. NMAP, Wifi Visual Analyzer, Internet Mapper Tool, Advanced IP Scanner)</td>
</tr>
</tbody>
</table>
While most users felt comfortable with adding a device to their HN Router, few ran a basic scan or network diagnostics. We found that 27% of novice HN users, 59% Intermediate, 81% of Advanced, and 91% of Expert logged into their HN router and also updated their firmware. We saw that 1% of Novice, 14% Intermediate, 42% Advanced, and 72% Expert HN users had a comfort with running a network scan, and reviewing their HN router for devices. While only 2% of Intermediate, 17% of Advanced, and 44% of Expert users where comfortable with all skills listed.

6.8 Please select all actions you have made to your Mobile or PC device(s)

<table>
<thead>
<tr>
<th>Respondents (%)</th>
<th>Actions App / PC</th>
</tr>
</thead>
<tbody>
<tr>
<td>526 (96%)</td>
<td>Installed a new App (application) on my mobile device (e.g. smartphone or tablet)</td>
</tr>
<tr>
<td>220 (40%)</td>
<td>Used a recommendation App to install Apps on my devices</td>
</tr>
<tr>
<td>287 (52%)</td>
<td>Run an App to review what applications are running on my device (Mobile or PC)</td>
</tr>
<tr>
<td>199 (36%)</td>
<td>Run an App to review what networks my device (PC/Mobile) has connected to in the past</td>
</tr>
<tr>
<td>250 (45%)</td>
<td>Run an App to review the security or privacy of my Mobile/PC device (e.g. Verizon Security, Norton)</td>
</tr>
<tr>
<td>138 (25%)</td>
<td>Run an app to review what devices have connected to my home network in the past</td>
</tr>
<tr>
<td>107 (19%)</td>
<td>Run an App (Mobile or PC) to review the security of my home network (e.g. Home Network Security, Sophos, Check Point ZoneAlarm)</td>
</tr>
<tr>
<td>97 (18%)</td>
<td>Run an App to review the health of my home network and internet connection including tools that examine configurations, normal operation, security and local device privacy (e.g. Bullguard, Sophos, Cryptguard, Textsecure, Orbit)</td>
</tr>
<tr>
<td>12 (&lt;2%)</td>
<td>Other (Open ended)</td>
</tr>
</tbody>
</table>

A majority of respondents reported installing apps on their PC/Mobile devices, while only a small percentage reported running an App to review Health (normal operations) of their HN in the past. Novice, Intermediate, Advanced, and Expert respondents reported 9%, 17%, 27% and 32% of interest respectively regarding review of application, network, and security/privacy of their Mobile device.

6.9 Please select your interests around managing, or understanding in more detail your Home Network
Respondents (%) | Interests around managing or understanding HN
---|---
271 (49%) | When changes happen to my Mobile (or similar) devices
290 (53%) | How to setup my home network correctly
338 (61%) | Speed to the Internet
380 (69%) | Why my Wifi is slow, and how to fix it (connection to devices on your home network, (e.g. printer, tv)
170 (31%) | How my network compares to others in terms of setup, devices, and a Mobile Applications
330 (60%) | Is a networked device secure (e.g. is anyone trying to break into the device?)
230 (42%) | What devices have connected to my Home Network (my devices, and friends devices)
279 (51%) | Home network health (e.g. is my firmware up to date, are there open devices on my network)
296 (54%) | Device health (Is my device running at peak performance in terms of memory, apps, storage)
325 (59%) | How private are my network devices (e.g. are they leaking data that can be seen by the outside world?)
322 (59%) | Detecting unauthorized devices attaching to my network, and automatically disable them
163 (30%) | How to use my home network to control multiple devices from one location (e.g. Alexa Dot, tvs, audio, video, heat, kitchen, bathroom)
160 (29%) | How to control how much of my internet bandwidth can be used by each device
8 (1%) | Other (Open ended)

A majority of respondents expressed an interest in Mobile changes when they happen, how to setup their HN, Throughput, how to report and fix Wifi issues, security/privacy and health of their devices and network. We also saw more than half of all respondents, across all skill levels, had an interest in the following areas specifically:

- Mobile device Changes
- HN Setup
- Speed of their Wifi and Internet connections
- Information about their Wifi Setup
- Devices within their HN, and when they change
- How to Control devices and Bandwidth
6.10 Which of the following would you prefer to use to gain access to information about your Home Network?

<table>
<thead>
<tr>
<th>Respondents (%)</th>
<th>Preferred Access to HN information</th>
</tr>
</thead>
<tbody>
<tr>
<td>293 (53%)</td>
<td>My Mobile Phone/Tablet</td>
</tr>
<tr>
<td>364 (66%)</td>
<td>My PC/Mac</td>
</tr>
<tr>
<td>204 (37%)</td>
<td>A Web Browser</td>
</tr>
<tr>
<td>84 (15%)</td>
<td>My home network router</td>
</tr>
<tr>
<td>60 (11%)</td>
<td>A modified Router that allows for advanced diagnostics, and functionality</td>
</tr>
<tr>
<td>20 (4%)</td>
<td>A purchased unit of hardware specifically designed for Home Network data gathering (e.g. Cujo, Keezel, RaTTrap)</td>
</tr>
<tr>
<td>30 (5%)</td>
<td>I am not interested in gathering any information</td>
</tr>
<tr>
<td>5 (1%)</td>
<td>Other</td>
</tr>
</tbody>
</table>

Respondents across the board felt most comfortable with requesting to gather information from a Mobile or PC device.

6.11 What other information are you interested in understanding, in and around your Home Network? Let us know your thoughts.

<table>
<thead>
<tr>
<th>Respondents (%)</th>
<th>Open end Other Interests</th>
</tr>
</thead>
<tbody>
<tr>
<td>117 (21%)</td>
<td>Respondents provided feedback of some sort, ranging from requesting more information related to network security, to wireless setup.</td>
</tr>
</tbody>
</table>

We saw a strong set of feedback. With more than 20% of users providing feedback. The feedback ranged from generic information to outlier requests in managing and servicing HNs. This information lined up with areas of interest using a Mobile or PC device to understand more information about HNs, along with areas of interests around throughput, optimization, security/privacy and health, comparison to other HNs, summary of information via an easily discernible App.

6.12 Email Address

<table>
<thead>
<tr>
<th>Respondents (%)</th>
<th>Email Address</th>
</tr>
</thead>
<tbody>
<tr>
<td>278 (51%)</td>
<td>Respondents provided an email address to contact them.</td>
</tr>
</tbody>
</table>

6.13 Devices and Browsers used to take Survey

Tables 1 and 2 are the device types, Operating System (OS), and browser type used by respondents to take the survey. Table 3 and Figure 2 represent percentage and device count respectively of devices compared to Skill type, grouped from devices ranging between 1-3, 4-7, 7-9, and 10-16.

Table 1: Device Types Used to Take Survey (%)
Operating System Percentage

<table>
<thead>
<tr>
<th>Operating System</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Windows</td>
<td>48%</td>
</tr>
<tr>
<td>Iphone</td>
<td>18%</td>
</tr>
<tr>
<td>Mac</td>
<td>15%</td>
</tr>
<tr>
<td>Android</td>
<td>14%</td>
</tr>
<tr>
<td>Linux/other</td>
<td>5%</td>
</tr>
</tbody>
</table>

Table 2: Browser Type Used to Take Survey (%)

<table>
<thead>
<tr>
<th>Browser</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chrome</td>
<td>60%</td>
</tr>
<tr>
<td>Safari</td>
<td>23%</td>
</tr>
<tr>
<td>Firefox</td>
<td>11%</td>
</tr>
<tr>
<td>IE/Edge</td>
<td>7%</td>
</tr>
</tbody>
</table>

Table 3: Device Count Range Percentage vs. Skill Level

<table>
<thead>
<tr>
<th>Skill</th>
<th>1..3</th>
<th>4..6</th>
<th>7..9</th>
<th>10..16</th>
</tr>
</thead>
<tbody>
<tr>
<td>Novice</td>
<td>34%</td>
<td>43%</td>
<td>20%</td>
<td>2%</td>
</tr>
<tr>
<td>Intermediate</td>
<td>16%</td>
<td>45%</td>
<td>33%</td>
<td>6%</td>
</tr>
<tr>
<td>Advanced</td>
<td>11%</td>
<td>36%</td>
<td>39%</td>
<td>13%</td>
</tr>
<tr>
<td>Expert</td>
<td>12%</td>
<td>23%</td>
<td>35%</td>
<td>30%</td>
</tr>
</tbody>
</table>

Figure 2: Device Count Range by Skill Type

7 Comparisons

In this section we provide results from the survey as related to comparisons of Skill level versus each of the questions. Results from this area are compiled by classifying the skill levels: novice,
intermediate, advanced, expert. We calculate these comparisons juxtaposed by varying areas of these questions. We provide a short summary at the end of each question, where applicable, as a short review.

### 7.1 Gender Vs Skill

A comparison of Gender vs. Skill shown in Fig 3. In this area of summary Women respondents categorized themselves at a higher level in both novice and intermediate, and lower in advanced and expert skill level as compared to their male counterpart respondents. Table 4 shows the distribution as related to Female versus Male respondents across all skill levels.

![Figure 3: Gender vs Skill](image)

<table>
<thead>
<tr>
<th>Gender</th>
<th>Novice</th>
<th>Intermediate</th>
<th>Advanced</th>
<th>Expert</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>23%</td>
<td>51%</td>
<td>22%</td>
<td>4%</td>
</tr>
<tr>
<td>Male</td>
<td>10%</td>
<td>35%</td>
<td>30%</td>
<td>25%</td>
</tr>
</tbody>
</table>

### 7.2 Internet vs Skill

A comparison of Internet type vs Skill is shown in Fig 4. 40% of novice users reported they did not know their Internet type vs that of 5% Advanced and Expert users. In all skills levels Cable was the dominate Internet connectivity media type. Table 5 provides some additional views into the differences between skill types and management; we have removed comments from this and rounded the percentages to the nearest digit. This
Figure 4: Internet type vs Skill

The figure follows the flow of the percentages shown from this question in terms of skill level across groupings. Table 5 also provides some additional views into the differences between skill types and management; we have removed comments from this and rounded the percentages to the nearest digit. This figure follows the flow of the percentages shown from this question in terms of skill level across groupings.

Table 5: Comfort level versus Skill managing HN Router

<table>
<thead>
<tr>
<th></th>
<th>Novice</th>
<th>Intermediate</th>
<th>Advanced</th>
<th>Expert</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not Comfortable</td>
<td>48%</td>
<td>12%</td>
<td>3%</td>
<td>0%</td>
</tr>
<tr>
<td>Rely on Friends</td>
<td>42%</td>
<td>31%</td>
<td>8%</td>
<td>4%</td>
</tr>
<tr>
<td>Need Help time-to-time</td>
<td>10%</td>
<td>45%</td>
<td>27%</td>
<td>2%</td>
</tr>
<tr>
<td>Very Comfortable</td>
<td>0%</td>
<td>11%</td>
<td>61%</td>
<td>93%</td>
</tr>
</tbody>
</table>

7.3 Devices vs. Skill

We next compare results between Devices in the HN and Skill level, which can be seen in Fig 5. Figure 5 show little change between Advanced and Export users in terms of device types in a network, save security and smart devices. Overall their is little difference between devices and skill level. In this figure Reading/Kindle device is one that is used for Ebooks or similar in users HNs. We removed outliers from this figure as the areas were too low in terms of values received.

7.4 Abilities vs Skills

A review of Abilities to install/configure a Home Network or Home Router vs Skill level can be seen in Fig 6. We can see that Novice users had the least comfort in terms of installing/configuring
a HN router, and was almost 4x less comfortable than their Intermediate counterparts. Intermediate users were 5x more likely to rely on friends vs. their Advanced cohorts, and almost 2x more likely to need help from time to time. Advanced respondents are also ~2x as their Expert counterparts to rely on friends, and ~11x to need help from time to time. Expert users are 9x and 30x that of intermediate and advanced users in terms of being very comfortable managing their router.
7.5 Comfort level versus Skill level

In this area we are looking at comfort level with managing several types of devices or software/tools vs that of skill level. The areas we reviewed include: Mobile Devices, PCs (Mac or Windows), Web Browser comfort, Router Comfort, Purchased hardware with specific tasks (e.g. Nest, etc.), and Customized Hardware/software solutions (e.g. Linux). We have created a graph for each of these comparisons against the skill level counterparts. These plots include the following: Mobile Fig 7, PC (Mac/Windows) Fig 8, Web Browser Fig 9, Router Fig 10, Purchased Hardware Fig 11, Customized Hardware Fig 12.

Starting with the Mobile vs. Skill level we can see from Fig 7 that most users are fairly comfortable using their Mobile device. Only a small percentage of Novice respondents reported they no idea how to use a mobile device. Similarly we can see that PC users, Fig 8, have a high level of comfort using their Windows/Mac system. ~35% of Novice users reported that they need help in some capacity when using a PC vs that of only ~10% of Intermediate cohorts.

A review of Web Browser comfort vs Skill level, Fig 9, shows that there is a high level of confidence overall when using. ~25% of Novice users reported that they need help to use their web browser in some capacity vs that of only ~12% of Intermediate, and ~2% of Advanced users. An interesting fact in this case is that 100% of Expert users reported being very comfortable with using a Web Browser.

We next move to the review of Router Comfort vs. Skill level, Fig 10, and find that almost 7x more Novice users had no idea to use their router vs. that of Intermediate group, while there was there was only a ~30% difference for this group in terms of needed help from friends, and an ~10x difference in being comfortable with their router. Intermediate respondents reported at a ~3x less being comfortable versus their Advanced counterpart, and ~5x less than the Expert grouping. The grouping reported a 40% increase over Intermediate in being very comfortable using their router. We can see a sharp increase of comfort as the skill level increases across each of these levels for the Router category.

A review of purchase hardware (e.g. Nest, etc.) vs Skill level, Fig 11, shows a geometric drop in need for help across all areas for the skill levels. There is a 5x increase between comfort level of Intermediate and Expert, vs that of 2.5x between Intermediate and Advance. A 2x+ increase is seen between Advanced and Expert respondents being very comfortable with these devices.

As a final comparison in this subgroup we reviewed Customized hardware/software (e.g. Linux, etc.), Fig 12, and Skill level. We can see similarities in terms of Novice, Intermediate, and Advanced users needed help using from friends. With Intermediate users ~3x more likely needing help than their Advanced counterparts, and ~10x more likely then Expert users. Expert respondents are 2x more confident vs. the Advanced group when using these tools/hardware.

In summary, the overwhelming majority of comfort, for each of the device types listed, grew at at a minimum of a linear rate (in some cases exponential) in terms of user classification and comfort; save the exception are of Web and Intermediate users.

7.6 Actions WiFi/Router Vs. Skill level

We next move to a review of actions respondents have successfully accomplished using their WiFi/Router vs Skill level, Fig 13, was completed. We break this area apart by Skill level and compare each of the sub categories. Each skill level reported adding a device to their network via
Figure 7: Comfort Mobile vs Skill

Figure 8: Comfort PC vs Skill
How’s My Network Survey – Web Comfort vs Skill Level

% of Respondents

% of Respondents

How’s My Network Survey – Router Comfort vs Skill Level

% of Respondents

Figure 9: Comfort Web Browser vs Skills

Figure 10: Comfort Router vs Skill
Figure 11: Comfort Purchased HW vs Skill

Figure 12: Comfort Customized HW vs Skill
their Router at similar levels. Novice users were 50% less likely to have logged into their router vs. Intermediate, and 2+χ less likely vs advanced and Expert. <5% of Novice respondents reported to updating firmware, which was 5χ less likely than intermediate, 12χ less than Advances, and 18χ vs that of Expert users. Intermediate users were 2χ and 3χ less likely to have run a device scan or logged into their router vs that of their Advanced and Expert cohorts respectively. More than 50% of all Expert respondents ran simple or advanced network or device diagnostics in past. Intermediate respondents were 3χ less likely to have run an advanced network diagnostic, and 50% to run a basic network scan versus the Advanced grouping.

In summary, users across all areas, of ascending difficulty levels, increased their interactions on their Wifi/Routers according to their skill level. This showed that expert users would have experience with running advanced skills versus that of novice users who did minimal actions across these device types, and rely heavily on assistance.

### 7.7 Actions Mobile/PC vs. Skill Level

Similar to the Wifi vs. Skill we compared respondents Actions completed on a PC/Mobile devices vs. Skill level, Fig [14]. An interesting item to note is that users across all skill levels downloaded, installed, and used a tool or app in each of the categories listed. The most popular areas across all skill levels were recommendation tools, tools that reviewed apps on the device, Device Security/privacy, and network device discovery. ~50% of all respondents found interest in tools that reviewed apps running on their device/system, and overall 20% of all respondents had interest in reviewing device health. ~50% of Intermediate and Advanced respondents had run a tool to determine which SSIDs their device had attached to in the past, while ~20% and ~40% respectively had used a tool to determine network security.
7.8 Interests Managing vs Skill Level

We next move to examining respondents' interest in managing or understanding their HN vs skill level, Fig [15]. The following are some interesting data points from this review. Approximately 50% of all respondents, across all skill levels, had interest in the following areas: Network Device Scanning (e.g., when a device was added to their network), how to setup a HN, throughput of their local and Internet connection, why Wifi is slow (this had the highest overall rating across all skill levels), Device privacy, and detection of unauthorized devices. Approximately 40+% of Intermediate and Advanced respondents had an interest in how their HN compares to other.

7.9 Preferred Device to Review HN Info vs Skill Level

In the final comparison, we reviewed respondents' preferred method to gain access to information about HN (e.g., using Mobile, etc.) vs skill, Fig [16]. Across all categories of skill level respondents reported preference using Mobile or a PC to view HN information. Web was the third (3rd) preferred method to view HN information across all respondents and skill levels, and was 2x less of a preference to Mobile for Novice, Intermediate, and Advance users. Respondents also showed an interest in understanding comparisons across networks and mobile devices, with 43% of Intermediate and 40% of Advanced HN users.

8 Discussion

In this section, we provide a discussion of the study, and changes that have occurred from previous studies that have done work in and around the HN areas.

Work in this space from the past 5-10 years focused on researchers' interests, and had little to provide to the average HN users. As an example, previous work done by [11], [26], [23], [6], and
Figure 15: Interests Managing HN Vs Skill

Figure 16: Preferred Method Gain Access vs Skill
others, used restricted methodologies using tools that ranged from fat client software (manually downloaded and configured executable files), web browsing techniques, and customized hardware. It is clear from this survey that users no longer are interested in these approach types, and would prefer to gather data in an open and generic manner using ubiquitously available approaches.

As part of this work, and the takeaways from this survey include the following:

1. HN users have an interest in understanding more information about HNs and prefer to leverage a tool running on a Mobile App.

2. Expert users are the only set of users who do not need help and felt completely comfortable with using and managing their HN, devices, or advanced tools.

3. HN users have an interest in understanding when changes occur in their HNs, such as devices, mobile security and privacy changes, and Wifi health.

4. HN users are more interested in gathering information using their Mobile device versus using a Web browser.

Next, we show the changes that are reflected from the review of this survey and how it relates to changes to the current HN landscape. We look at the results from the last two questions of the survey, which asked about user interest in managing or understanding HN and their preferences to gaining access to HN information. Comparing these questions with skill level, and examining the landscape as a whole via the survey we can see that users have a keen interest in a variety of information in and around their HN, including: network discovery, throughput (e.g. why is my wifi slow, etc), and other areas of HNs. The interests in this area is a key indicator that HN users are indeed looking for information to help optimize their environments. Users have shown an overwhelming interest in the gathering of data from their HN. In addition, respondents pointed toward using a mobile device as a data collection point when collecting data. This indicates the desire for a Mobile app in this space as it was highly desired by respondents.

The following are takeaways from this work based off of the comparisons and summary, where we find the following:

☆ Until users reach an expert level they still feel they need help with basic functions, such as setting up a home router.

☆ Novice users need the most support managing and configuring their HNs. This includes basic setup of routers, devices, Apps/software, Web, customized hardware, and also includes areas such as security, privacy, and health of their devices and HNs.

☆ Intermediate users fall into a similar category as their Novice counterparts in terms of support required across these range of services.

☆ Advanced users claimed they had experience with specific areas, similar to their expert counterparts, but where 3x less likely to have these skills as compared to the expert groups (in some cases).

☆ Expert users are willing to support other HN users
Expert users are the most likely (~2x more than their closest counterpart) to use customized tools, such as a modified router, Linux, or have leveraged tools to scan their network.

A majority of users across all skills levels are interested in understanding HN specifics such as the following approaches: Wifi Speed, Internet Throughput, Device Security/Privacy, Device detection, Device and HN Health, and Mobile changes (Apps, permissions and similar). This also includes changes, and norms around these changes and a comparison of their HN to others.

All users across all skills levels showed a high level of interest in understanding how to make changes to their devices, or HN to optimize their experience.

A majority of users across all skill areas preferred using a Mobile device to determine characteristics within their HN.

In addition to the takeaway points shown, a deeper dive into the desired preferences, along with approaches, as classified in work [22], include the following desired areas:

- Wifi Speed: Identify health of connectivity, and attributes related to operation.
- Internet Throughput: upload and download, including comparisons to others.
- Device Security/Privacy: When changes happen to devices, and where to review these changes.
- Device detection: When new devices appear on the network.
- Device health: A fingerprint of how the device is operating, including a comparison to others.
- and HN Health: A fingerprint of how the HN is operating including throughput, devices, Wifi, etc. along with comparison to others.
- Mobile changes: A review and notification when Apps or permissions change on the device.
- HN Norms: A review of how a HN and Mobile device compares at the local and global levels.

9 Next Steps

In this section we discuss next steps and future work as related to this survey and the work related to this research. The information collected and collated from this survey and study have several directions for next steps and future work. We start with the summary of the survey to understand how the landscape of HNs have changed over the past 10 years. This is a crucial step to allow for the adaption and adoption of changes in both technology and comfort levels of HN users. We first look to understand these changes in terms of technology within the HN, and how users comfort with these devices, and experience are driving privacy, security, and overall perception of health within their HNs.
HN technology has changed in the past few short years in terms of devices available, and approaches used for data collection. This includes an array of option changes for HN users. We can see from this study that users have expressed interest in understanding specifics of their HNs; these details include such things as when changes occur in and around their HNs (e.g. devices added, networking, and Apps).

As an example, future work includes providing details to HN users around “norms” of devices, apps, permissions, and overall privacy and security of HNs. These details extend to providing feedback when new devices are found in a user’s HN, an App is installed or there are mobile device changes in terms of security/privacy or permissions. Norms included as part of this work look to include comparisons to other HNs, e.g. device count, throughput, apps installed, permissions, and health (security and privacy of devices and HN, as well as Wifi and Internet connection), as well as creating a ranking and allowing for user feedback will be crucial for future work in this space.

The next area of focus is in and around data collection of these data of interest. It is clear that the need for data collection has moved from traditional Web browsing, and PC based to interests using Mobile devices as a data collection point. The survey points clearly in a trending direction of Mobile ubiquity of usage. In addition, we can see that HN users are now interested in leveraging their Mobile Devices to gather this information, where more than 53% of respondents had an interest in this methodology as a collection method. With more than 5 Billion people world-wide owning a phone world wide, along with the fact that there are more than 4 Billion Internet users, bolsters and adds additional fodder toward HN discovery via a Mobile device. The device and Internet count are included within the ever growing population of HNs available today, and it is clear that an approach using an App for a mobile device is a direction for continued discovery and user research.

Additional work using a mobile App approach would include the features presented above and provide a clear taxonomy of permissions acceptable levels of Apps, permissions, and health within the user’s HN. Leveraging well know HCI (Human Computer Interaction) for a clear and discernible results, along with options for providing potential improvements of general health of Apps, Wifi, Internet, and the overall HN.

10 Summary

In this survey, and study we have shown that the interests of HN users in wide variety of areas, which point toward the creation and extension of HN studies targeted at HNs versus that of researchers exclusively. This work should provide options for security, privacy, information discovery, norms of changes, as well as health of the environment being reviewed.

As a summary, our next steps are to look toward moving this study to understanding data collection points level directly from the HNs, using targeted preference points for data collection and dissemination to HN users.
References


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