How Users Understand Cellular Infrastructure

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Abstract

Billions of users across income levels, geographical locations, and cultural backgrounds routinely use wireless cellular communication. In this work, we investigate, through semi-structured interviews, how different users throughout the world (gathered through snowball sampling) experience and utilize these networks, including their strategies for dealing with network failures, understanding wireless propagation, and coping with intermittent coverage. We found that all subjects frequently encountered a lack of wireless coverage, finding work-arounds optimized to their network environments. Rural participants generally had a better knowledge about wireless infrastructure; including the location and propagation characteristics of nearby cellular towers.

1 Introduction

Cellular usage has skyrocketed throughout the world. The International Telecommunications Union estimates there are currently five billion cellular subscribers [1]. Wireless networks have a number of intrinsic properties, such as propagation, shadowing, and cancellation, that are not easy for even experts to predict or understand. Even the location of towers is not widely known, as network operators seek to obfuscate this information to limit legal liability and general headache.

In this study, we investigated how users throughout the world understand and make use of their cellular networks. We conducted semi-structured interviews with 17 users in 3 countries, including respondents from the rural US, urban US, urban India and urban Uganda, gathered through snowball sampling. We discovered that network failures were frequent, with almost all participants recently experiencing some form of intermittent coverage. We also found various strategies for dealing with failures. We learned that the users from rural areas seemed to have a better understanding of the location of wireless towers, the properties of wireless properties and as a result had better mechanisms for dealing with network failures.

The rest of this paper is organized as follows: [] We begin with a discussion of related work and the design of our study. We follow with the broad concepts that seemed to cross all boundaries, primarily the ubiquity of network failures and the use of social networks to investigate them. We then discuss the differences discovered between urban and rural users. Lastly, we evaluate the differences between developing and developed areas. We then discuss the implications of our findings and conclude.

2 Related Work

A number of technical innovations motivate our interest in how users understand their cellular networks. Companies now provide small programmable GSM base stations. These include Vanu [2], and Range Network's [3] OpenBTS [4] system. These systems are affordable enough that they are within the budget of small community groups in developing regions. As wireless technologies become more affordable, we expect users with less technical training to begin to deploy and manage these systems.

Fischer [5] looked at the adoption of traditional land-line phones in the US. Horst and Miller [6] investigated the use of cell phones among low-income users in Jamaica, finding that the cell phone use impacted many aspects of life. Burrell [7] investigated cell phone adoption and use in rural Uganda, discovering a number of different communication paradigms unique to the rural context. Donner [8] found that users were communicating by "beeping" users when they wanted to receive a call. Donner also argued that [9], "... pricing, network features, and even signal availability have a huge impact on how mobiles are actually used." Heimerl

et. al. [10] investigated asynchronous communication schemes in rural Uganda, showing that users often needed and used asynchrony to deal with network failures. Similarly, Surana et. al. [11, 12] looked at the sustainability of these locally managed wireless deployments. This work focused on expert users and technical administrators, rather than the common users referenced in our work.

3 Study Design

To investigate how users around the world understand and utilize wireless networks, we selected seventeen participants from different populations using a snowball sampling methodology. We then conducted semi-structured interviews with each individual, either over the phone or in person, to determine how they view, understand, and make use of cellular networks.

3.1 Target Populations

We began identifying interview targets in the Summer of 2010 starting by contacting a number of our friends and colleagues in three different countries: the United States, India, and Uganda. Earlier research had provided several contacts in each of these countries. Starting with these contacts, we then used a snowball sampling methodology acquire study participants. We had two requirements for participation: no direct personal connection with the researchers; and no specialized training or knowledge about wireless communications (both self-reported). In total, we acquired 17 participants: 9 in the developed world (United States) and 8 in the developing (Uganda and India). Of the nine in the United States, four were from rural areas and 5 were from cities. All of the Indian and Ugandan respondents were based in large metropolitan areas.

3.1.1 United States - Urban

Our urban United States population was selected from friends of friends in the California bay area, primarily San Francisco and Berkeley. Of the 5 urban US participants, 3 were students at UC Berkeley (2 undergraduate and 1 graduate), and two were working professionals in San Francisco. None had any prior training or specialized knowledge in wireless networks. Three of the users had only voice and text services on their phone. The remaining two had data connections. 4 of the participants were female, with one male. The participants were young, with the youngest being 21, the oldest being 38, and the average age being 27. All either had completed, or were pursuing, a bachelor's degree in a non-technical field.

3.1.2 United States - Rural

The rural US respondents were contacted through personal connections of the authors. They came from three different towns: Kodiak, Alaska (population estimate 6,228 [13]), Palmer, Alaska (population estimate 8,201 [13], and the Hematite Township in Michigan (population estimated to be 352) located in a county with a total population of 11,633 [14]). All four participants were women; the two in Kodiak being 25 and 28, and the two others being 55. Three had master's degrees, and one had an associates degree in Art.

3.1.3 India - Urban

Our three participants in India were all located in the city of Bangalore, Karnataka, India. They were identified through professional contacts gathered through prior research projects. The participants were middle-aged (31, 33, 40) and included 2 computer scientists and 1 lawyer. Two of the three had graduate degrees (LLB and M.Sc.). All three were Male.

3.1.4 Uganda - Urban

The 5 study participants from Uganda were also identified from professional contacts gathered during prior research engagements. All were located in the capital of Uganda, Kampala. Of them, five were male and one female. The ages ranged from 23 to 53 with most being in their late 20s. The average age was 32. All 5 participants had completed undergraduate degrees in computer science (but without a focus on wireless) and were in the process of acquiring higher-level degrees.

4 Shared Experiences

Several experiences seemed to be common to everyone in our participant pool; crossing boundaries of income, culture and geography. These included the ubiquity of network failures and the use of "trial-and-error" to determine wireless network properties and coverage. Lastly, users from every area made use of text messages to communicate through network failures.

4.1 Ubiquity of Network Failures

One constant theme we observed in our interviews was the pervasiveness of network failures. Though significantly more common in rural areas, even in two of the supposed technology capitals of the world (San Francisco and Bangalore), network failures were an accepted fact of life.

According to rural users, most of their problems were based on the general lack of towers.

Interviewer: *So why do you think the service is bad out there?*

Rural US User 3: *I'm not sure, I think it's just the towers. There's not a whole lot of towers here. I think it's where the towers are that you just don't get service from your areas.*

Failures were less commonly mentioned by urban users, but still common enough to have impacted their lives on several occasions. These users were more concerned with congestion and the load on the towers than their physical location during a failure.

Interviewer: *So how often is Airtel failing for you?*

Urban India User 1: *Often. I don't know if it's because of the load because they've grown too fast, or if it's because their coverage is poor in certain routes.*

Interviewer: *When is the network congested?*

Urban Ugandan User 4: *Normally during the day around midday. Right after lunch. In fact sometimes, the mobile phone, I just can't use it. So I think around midday and right after lunch. That's when it is most congested.*

Urban US User 4: *When I switched back to AT&T, after not liking the Droid, I definitely noticed a big difference. I don't know if it's because it's iPhone 4, versus my old I-Phone, or the network, but it definitely drops a lot more calls. I personally don't like AT&T right now.*

4.2 Trial and Error

Many subjects mentioned using "trial-and-error" to discover facts about wireless networks. Users generated hypotheses about coverage patterns and mitigation behaviors available to them; evaluating them based on their own experiences.

Interviewer: *How do you know you can't get service there?*

Rural US User 1: *If you've tried in the past, you just know, automatically know. You can remember.*

Urban Indian User 1: *I figured by trial and error, not consciously, that if I stand in a certain direction the signal will be better.*

Interviewer: *So how do you guess that a location has coverage?*

Urban Ugandan User 5: *I guess keep using trial and error. You know that could get the coverage.*

For instance, one user didn't quite understand why being near a window improved his coverage, but had tested and verified that it helped.

Urban US User 1: *Maybe the satellite reads you better or something. If in fact that's what's actually giving you the feed is a satellite, I'm not even sure. I just tested it out and it seemed like standing close to the window worked, so I just kept doing it.*

Most information about cellular networks was either gained through first-hand experimentation or through social networks. This included contacting the providers themselves:

Interviewer: *So, how do you hear about the fiber optic cable getting cut?*

Rural US User 4: *All of a sudden you don't have service on your phone. And then somebody ends up calling AT&T and then you hear from someone else that they called AT&T and that's what they were told.*

Interviewer: *How do you know it's a cell phone tower?*

Rural US User 2: *Well, my coverage improved. I don't know who put it up, but my coverage improved after it got here. Before that tower came in we had no cell coverage out here. Then that tower showed up about a year or two ago. So I guess I'm assuming it was [a tower] and I think through conversations with neighbors, we all concluded it was a tower.*

We also encountered a number of rituals and superstitions that resulted from this kind of trial-and-error learning. One such ritual included "power-cycling" the phone, even though users had no idea why or if this helped.

Urban US User 2: *I don't know if this is a problem with my phone or not, but when I go into places where there is no reception, and then I come back outside, sometimes the phone will not get reception. I'll turn it on and off. I don't know if it's this phone or what. I've dropped it so many times.*

Urban US User 1: *When I had cheaper phones I would turn my phone off then turn it on again. This is when i had really basic phones. This is probably three years ago and I think that did actually work at the time.*

Surprisingly, the users were very aware of the ritualistic nature of their fix, with some even suggesting that it may just be a superstition.

4.2.1 Texting

In general, texting was not mentioned by our respondents as a common form of communication. Most [] interviewees communicated primarily through voice. However, it was used to deal with network failures and users' busy schedules [10]. []

Interesting, one user in the US indicated that she communicated primarily through SMS. She lived in a shared house with thin walls, and used text messages to ensure a form of privacy.

Urban US User 2: *I don't really like to talk on the phone with other people around. I like having private phone conversations, so I guess that's the convenient of texting, you can do it anywhere.*

This strategy also shielded her from any transient

network failures, giving her a much different wireless experience than users of synchronous (e.g. voice) communication services. She reported few complaints [] about her network service. Surprisingly, this was not her justification for texting, the privacy and timing flexibility affordances were more important.

5 The Rural/Urban Divide

In rural areas, there are generally fewer towers, which are often operating at less than full capacity. As a result, coverage patterns tend to be more consistent and predictable but less pervasive. In urban areas, towers and networks are everywhere, but of highly varying quality. Propagation effects, such as shadowing and reflection, are more prevalent, such as when buildings and cars deflect signals. Loads on the tower are also highly dynamic, as it is difficult for providers to provision for unexpected loads (such as emergencies, rush hour or large events). As such, coverage is pervasive, covering most of the city, but also highly variable.

In our interviews, we sought to discover how the participants were affected by, and understood, these differences. We found three primary results. First, rural participants seemed to have more knowledge about the specifics of the wireless infrastructure that surrounded them. Secondly, urban participants gave the impression that they were unable to accurately predict many network failures. In contrast, rural users were able to much more accurately predict and diagnose wireless problems. Lastly, urban participants seemed to depend more heavily on the proper functioning of wireless networks, while rural users often had backup plans for dealing with network unavailability.

5.1 Understanding Wireless

Rural users seemed to have a more nuanced, deeper understanding of the wireless infrastructure around them. For example, they often knew where towers were (and were not) located.

Interviewer: *So how do you know they have a tower out there?*
Rural US User 4: *You can see all the towers around Kodiak. You know where they all are at.*
Interviewer: *So why do you think the service is bad out there?*
Rural US User 3: *I'm not sure, I think it's just the towers. There's not a whole lot of towers here. I think it's where the towers are that you just don't get service from your areas.*

In comparison, urban users often could not even tell us the location of a single tower:

Interviewer: *Okay, so but you have no idea off the top of your head, where you could say like "There's a cell phone tower here"?*
Urban US User 5: *No, unfortunately.*

Several urban users did not even know that cellular networks depend on wireless towers and antennae, instead referring to "satellites" when discussing network coverage:

Urban US User 1: *Maybe the satellite [sic] reads you better or something. If in fact that's what's actually giving you the feed is a satellite. I'm not even sure.*
Interviewer: *Do you have any idea why some random area would have bad reception?*
Urban US User 2: *I don't know, maybe they don't have enough satellites [sic] or something? I don't know if that even makes sense.*

Users in Uganda and India seemed to better understand the basics of GSM (towers send signals), though they were still generally under-informed about how these towers worked or where they were located.

Interviewer: *What does it mean to have a hole in the cellular coverage?*
Urban Indian User 1: *Well essentially one of the cell towers is probably not ... The idea is to have a set of cell towers that covers the whole geography right?*
Urban US User 5: *I assume theres some sort of physical barrier that is slowing down or some how interfering that transmission of information.*

5.2 Predicting and Knowing Coverage Areas

We found that rural subjects generally had a better understanding of where coverage was available and where it was not.

Rural US User 1: *Up here in Amasa, we might be able to get service outside, but here in our house we get absolutely no service at all. Golden Lake, which is on the other side of Iron River – halfway between Iron River and Watersmeet, there is no service over there.*
Rural US User 3: *It's on the way out of town, of the actual city of Kodiak, when you drive out. You drive out towards the Coast Guard base and then there's another area called Bell Flats. where where my family lives. We go out there quite a bit and that area always drops. And then also if you go to the other direction, out towards Menoshka, which is the opposite direction, there's a few areas out there that the service out there is not as good as in town.*

In comparison, urban users had less specific knowledge about coverage gaps, generally citing wider *regions* that had problems, rather than areas with no coverage.

Urban US User 4: *In the Mission it might have like one bar. I always have to use my friend's Verizon phone to do anything. Yeah. I think the main problem area is the Mission.*

5.3 Mitigating Network Failures

Different subject pools had very different ways of mitigating network failures. Many rural subjects, for instance, tended to "climb" when needing better coverage.

Rural US User 1: *You try to go up high and get coverage, you know, and hopefully you'll get it.*

Other strategies adopted by rural participants included modifying their calling behavior. For instance, they batched-performed communication tasks before exiting network coverage.

Rural US User 3: *If I'm coming out to my parent's house, I'll call or I'll text them to make sure they're here, or if they need something from town, before I go through the spot that I lose [network coverage] at.*

Urban participants also commonly batch-performed communication tasks when exiting or entering an area with predictable network failures.

Urban US User 2: *When I go home I take [public transit] and I like to call my mom to come pick me up. I have to plan a few stops in advance, because reception really sucks [on the train].*

Some rural participants also carried alternate communication devices, using these in areas with limited coverage.

Rural US User 2: *So when I know I'm going to be in a dead spot, I may use the On-Star [a Verizon-based car communications system].*

Other urban users had very different solutions. Many reported that, when in a building, going outside would improve their network coverage.

Urban US User 3: *I would try that If I'm somewhere indoors and I don't get reception, I'll try to go outside.*

Urban Ugandan User 2: *If I try to make call [in a building] and it fails, normally I would move next to the window, or move out of the building a little bit and make a call. Normally that works.*

Another common urban strategy to improve coverage was to simply walk in circles.

Urban US User 1: *Just keep walking around until something happens, I don't know.*

Urban US User 5: *When I talk to people, I usually pace around the room. So when [the call quality drops] I usually try to go back to the last spot where I was, before it started [failing], to see if it's something on my end.*

Interviewer: *Why do you think that (walking around randomly) would work?*

Urban US User 3: *I don't know. Maybe I'm influenced by my understanding or perception of old radio.*

5.4 Network Dependence

Rural users were generally less dependent on the availability of wireless networks.

Rural US User 1: *If [the network] doesn't work, we deal with it. If it doesn't work we just don't use the phones.*

Rural US User 2: *I might wander around a little bit, but after a while I'm just going to say, "Well, it's not going to happen." The call is not that important. Unless it is that important, I guess I'd get in the car and find [coverage].*

On the other hand, urban subjects seemed to expect network coverage everywhere they went. Unfortunately, this meant that network failures often had a more dramatic impact on their lives. For example, one user was totally unable to find her friends at a large concert.

Urban US User 2: *It's this huge... there's like 185,000 people at the LA stadium. The texts were extremely delayed, so there were people that I was supposed to meet up with that I hadn't seen in years and the texts were so backed up that I was getting things like four hours late.*
Interviewer: *How did you eventually deal with it?*
Urban US User 2: *I didn't see any of these people that I was supposed to see, and it was really sad.*

Such conditions were often exacerbated during periods of crisis or volatility, when networks could be particularly congested, or even deliberately made unavailable.

Urban India User 2: *I remember once, there was a flood that happened in Bombay, a real flood, and everyone was trying to call. It was totally congested so I was not able to reach people. That kind of situation in India, the moment there's a festival or there's a disaster, then all the networks almost invariably collapse.*

Urban Ugandan User 6: *There was a period when the networks were intentionally shut down for political reasons and you couldn't call or SMS. It affected work and life a lot because we've come to depend quite a bit on those services and just kind of expect them to work. The fact that the government could just shut it down is something which I still find quite disturbing.*

6 The Urban Developed and Developing Divide

We saw fewer such widespread differences between participants in developed (United States) and developing (India and Uganda) regions. Subjects in developing areas tended to have more issues with network congestion and

battery life, and were more sensitive to pricing. They also developed novel solutions for dealing with network failure that are not seen in the developed world.

6.1 Network Congestion

Participants in both Bangalore and Kampala complained significantly more about wireless congestion than users in San Francisco.

Urban Indian User 2: *There's just too many users in certain given spaces. For instance in Bombay and Delhi, Bombay particularly there's so many users crammed into one square kilometer that it's really hard [to provide coverage].*

Urban Ugandan User 1: *Usually on weekends, most times, and that is due to congestion. Everyone is communicating and wanting to get together with family and everything.*

6.2 Battery Issues

Subjects in developing areas reported significantly more battery issues, as well as more strategies for dealing with poor battery performance. For example, users would often travel with their chargers. [1]

Urban Indian User 1: *I try all kinds of tricks, I have a charger on the car, I have a charger at my desk, but something or other happens and I forget to charge it. At least once in 2 days I run into a situation where I'm off of my phone for 30-40 minutes because I haven't got a charger handy. I might be in a meeting and I don't have a charger with me so when I get back I plug my phone in. That's not uncommon.*

Urban Ugandan User 1: *I make sure I move with my charger. Another thing is to have an alternative battery so that you can substitute.*

6.3 Pricing

In the USA, most respondents had bulk plans (often paid by their parents), providing unlimited access to voice, data and SMS communications. In contrast, users abroad (particularly Ugandans) were much more price sensitive, using complex strategies (including using multiple SIMs or sending texts instead of calling) to reduce their overall expenditure.

Urban Ugandan User 5: *Yes, that is the important concession. Currently the biggest factor is the money, is the airtime.*

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[1]While we're certain this does happen in developed areas as well, it seems significantly less prevalent. Perhaps low-quality power harms the batteries, or their phones are of lower quality?

Urban Ugandan User 1: *The messages are cheaper than calling. You find most people opting to use messaging service than call.*

6.4 Network Failure Mitigation

A number [] of interviewees from Uganda used multi-SIM phones to handle network failures. These phones allows for multiple concurrent GSM connections across different, competing networks. The primary use case was saving money using in-network pricing, but effective coverage was also improved. Multi-SIM phone participants often adopted a "call forwarding" scheme which forwards a call from one network to the other in cases of failure. As one subject said:

Interviewer: *The [Uganda Telecom] one is generally good when the MTN one fails?*
Urban Uganda User 6: *Yes. They never fail at the same time.*

Users with multiple-SIM phones (or even multiple phones) had very few complaints about network coverage. One user even mentioned a phone capable of supporting 4 simultaneous GSM connections.

7 Discussion

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Attempts by mobile operators to intentionally obfuscate their installations (for example, by shaping base stations like trees) make it even more difficult for users to reason about and plan around wireless coverage. This is particularly problematic in rural areas, where there are relatively few towers and users could gain a lot of benefit from knowing their locations. On the other hand, citizens often object to tower deployments, fearing that wireless signals may have adverse health effects. There is also expensive equipment in these towers, leading to the threat of theft.

To address these concerns, mobile operators first need to do a better job of debunking rumors of adverse health effects of wireless signals [15]. Moreover, even if they are unwilling to publicize the location of their towers and coverage, operators need to realize that others are going to do it anyhow. Two current examples are Open Signal Maps [16], which aggregates user network coverage measurements, and Antennas [17], an app for discovering cellular towers in your area. Our research also shows that rural users already approximately know where towers are, and as such, providers likely gain little from hiding them. We suggest that providers make towers that are "hyper-visible", perhaps branded or lit, to improve users' ability to reason about and plan around wireless availability.

We also observed that rural users have a better understanding of the location and properties of wireless networks. This knowledge could even be leveraged when planning wireless deployments. Rural communities could be more likely to provide helpful, meaningful feedback into the deployment process than other groups. In the future, we hope to build tools for assisting rural community groups in deploying wireless networks, like the Village Base Station [18]. Finally, we observed that urban users probably depend on wireless availability more then they should. Encouraging users to think in advance about the potential for wireless failure, and providing tools for them to deal with such failures (for example, allowing them to batch asynchronous communications), could reduce users' frustration, and help them avoid unnecessary difficulties.

8 Conclusion

In this study, we investigated how users throughout the world understand and make use of their cellular networks. We conducted semi-structured interviews of 17 different people, both rural and urban, across three different countries; the United States, India, and Uganda.

We learned a great deal from these interviews. First, all of our interview subjects regularly deal with network failures. These users also primarily learned about their networks through trial-and-error, sometimes leading users to invent strange rituals or superstitions in response.

We discovered that the rural users we interviewed tended to have a better understanding of the location and properties of wireless networks than urban users. They were also generally better at predicting and knowing where coverage was not available. These two subject pools had very different ways to mitigate and deal with network failures. Rural subjects tended to go up, while urban participants either went outside or walked in circles.

Lastly, we noticed a few differences between the urban populations located in developed and developing parts of the world. Users in the developing world were more price-sensitive, had more battery issues, and dealt with network congestion more often. Fortunately they also had access to multi-SIM phones, which allowed them to mitigate network failures in ways not seen in the developed world.

To improve users' ability to reason about and plan around the availability wireless connectivity, we propose mechanisms to make wireless coverage more "visible", starting by making wireless towers easier (as opposed to more difficult) to find. We also encourage increased awareness and the development of better tools for urban users to deal with unpredictable network failures.

9 Acknowledgments

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