Analysis of Smartphone Adoption and Usage in a Rural Community Cellular Network

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ABSTRACT

The smartphone has been touted as the technology of the 21st century. Global smartphone adoption rates are growing rapidly, up to over 24% in 2014, with usage increasing 25% in the last year. However, rural areas are often the last places to benefit from these technological trends. Utilizing cellular network registration logs, we explore the adoption and usage of smartphones in an extremely remote community in Indonesia. We found that 16% of the phones in the area were smartphones (compared to between 14-24% in Indonesia). This shows that smartphone adoption in rural Indonesia is similar to the rest of the country. We also explored usage in the network, and found that smartphone users were more likely to text, especially to other smartphone users.

Categories and Subject Descriptors

Human-centered computing [**Human computer interaction**]: Empirical studies in HCI

General Terms

Information and Communications Technology and Development

1. INTRODUCTION

The smartphone is poised to become the ubiquitous technology of the 21st century, with penetration growing globally from 15% in 2012 to 24% in 2014 [6]. However, technology adoption is often uneven; rural or developing regions may be some of the last areas to gain the benefits of recent innovations. A lack of infrastructure to support these power and network-hungry devices can limit their usefulness in rural environments and potentially reduce adoption.

At the same time, there has been a rise in community-owned cellular networks (CCNs) servicing rural areas. These networks generally utilize older technology, such as 2G [1, 10, 11], and support only basic featurephone services such as voice and SMS under the expectation that there will be less demand for smartphone services. During 2012, we were involved in a project installing one of these community-owned and operated cellular networks in a remote part of Papua, Indonesia [10]. This region lacks most community infrastructure, including power, internet and cellular (before the deployment of the CCN). The CCN provides a platform for investigating technology adoption within the community as our access allows us to log both the communications of, and devices used by, the local community. In particular, we were able to record the International Mobile Station Equipment Identity (IMEI) of every phone that attempted to log onto the network. This code describes the specific model of phone used, including manufacturer and operating system. As no other networks are around, this provides a comprehensive view of *all* powered-on phones in the area. We recorded this information over a period of fourteen weeks.

In the context of the growth of smartphones and community cellular networks, we decided to explore the presence and use of smartphones in the remote community we were working in. We utilized IMEI logs and call records to ask the following questions:

- How common are smartphones in the community?
- Are the CCN subscribers more likely to be smartphone users than the wider community?
- Are smartphone users in the CCN more likely to call or text other users based on the receiver's phone?
- What are the implications of the smartphone demographics?

We found that the smartphone adoption rate in the area was approximately 16%, very similar to the broader Indonesian rate which varies between 14%-24% depending on the study. The CCN users were no more likely to be smartphone users than the wider community, as both showed around 16% penetration (16.7% vs 16.3%). However, the specific devices used did have an impact on user communication behavior; smartphone users were more likely to text other smartphone users than featurephone users, with 92.7% of all smartphone-to-smartphone communications being text versus 88.3% for smartphone to featurephone. Featurephone users were much more likely to call in general, with just 62.0% of their communications to other featurephone users being texts and 82.8% of their communications to smartphone users being text. These results indicate that smartphones are being adopted just as quickly in even the most remote regions of Indonesia. CCN developers, and anyone with an interest in rural access, can expect to be able to use these platforms for their interventions in the future. The results also

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show that CCNs draw users from the community without a large technological bias, supporting their use as a platform for broader community services.

2. RELATED WORK

2.1 Community Cellular Networks

Due to advances in inexpensive cellular systems, researchers and practitioners have begun exploring and implementing community owned and operated cellular networks. Heimerl et al. [9] and Anand et al. [1] both proposed building custom OpenBTS-based networks for rural areas. Zheleva et al. [12] implemented one such system, deploying it in rural Zambia and supporting local communications. Heimerl et al. [10] implemented another, showing it to be sustainable and valuable to the community. Rhizomatica [11] is another example of a network in Oaxaca, Mexico. We utilize one of these deployments as a platform to explore emerging patterns of smartphone usage in the remote areas outside of traditional network coverage.

2.2 Smartphone Adoption and Use

There have been a variety of smartphone adoption studies, primarily by industrial research firms. Globally, the smartphone adoption rate is near 24% [6]. Studies disagree about smartphone adoption within countries. For instance, Google's Our Mobile Planet [8] found penetration of 14% in Indonesia in 2013. Nielson, however, reports smartphone adoption of 23% in Indonesia for the same year. eMarketer [5] estimates 17% smartphone adoption in country and Morgan Research reported 12% ownership in 2012 and 24% in 2014 [5]. These industrial studies generally utilize customer surveys rather than network data. One of the core goals of this work is to create an authoritative network-based analysis of smartphone adoption in rural Indonesia.

2.3 Cellular Network Usage and Analysis

Researchers have often used cellular network logs to investigate user behavior. Eagle et al. [4] investigated the differences between urban and rural usage in the developing world. Blumenstock used logs to measure the connections between different nations [2] and estimate user location between calls [3]. Frias-Martinez et al. explored urban land use analysis with similar cell network data [7]. Owing to our dual role as network operators, we were able to gather International Mobile Station Equipment Identity (IMEI) information as well as the basic call data records (CDRs) utilized in existing work. This allows us to analyze the adoption and use of smartphones in our target network at a deeper level.

3. CONTEXT

We utilize an existing community cellular network installed the village of Desa in Papua, Indonesia to explore the questions of smartphone adoption in rural areas. The installation, economics and use of this network are discussed in detail in earlier work [10], but in this section we provide background to inform this study.

3.1 Community

Desa is situated in the highlands of Papua, a mountainous region traversing the center of the island of Papua in Southeast Asia. It is an established community of approximately 1500 people (though there are no official census statistics) who are primarily indigenous Papuans. The region's main economic activity is subsistence agriculture, though there are a few stores and a large amount of political and governmental activity as the village transitions into a regional district.

Figure 1: The CCN installation in Papua

Desa has no core village infrastructure, including no traditional cellular coverage, and operates only on decentralized power and water solutions. There is an airstrip which is rarely used by the Missionary Air Force for emergencies and occasional resupplies. There is also a road running to Wamena, a major regional city with power and cellular connectivity.

3.2 Network

The Desa network is an instance of a *Community Cellular Network*, an autonomous cellular network owned and operated by members of the community. It was installed in late 2012 as part of a research agenda (Figure 1), went live in February 2013, and has been running ever since. It is owned by an ISP in Wamena and operated by a western missionary couple who have lived in the community for nearly ten years. The day-to-day operation is managed by Indonesian teachers at the missionary school which is also operated by the missionary couple. The network sits on the school campus, near the center of town. As of the time of this authoring (February 2015), the network has over 380 subscribers and generates nearly 2000USD per month in revenue for the missionary school and ISP. The network provides both local and global SMS and voice as well as well as a few support services like credit transfer. Users are given Indonesian phone numbers. There is no data service available. The subscribers are drawn from the wider Desa community and include individuals from all walks of life including Papuan teachers and church officials, non-Papuan store owners and military or police offers, and the missionaries themselves.

4. STUDY

To evaluate smartphone use in Desa, we gathered both registration and usage data from the community cellular network. We then analyzed this data in terms of both adoption and use.

4.1 Data

4.1.1 Data Collection

Our data was collected starting August 19th, 2014 to December 8th, 2014. There were two core sources of data: Location Update Requests (LURs) and usage logs.

LURs.

In GSM networks, when a phone wishes to connect to a tower, it sends a Location Update Request (LUR). When entering a new area, it first tries to send this to a tower associated with its SIM card (for instance, an AT&T tower if an AT&T SIM) but will try to associate to any tower if the SIM's network is not available. In the LUR it sends the International Mobile Subscriber Identity (IMSI, effectively the unique ID of the SIM) and the International Mobile Station Equipment Identity (IMEI, effectively the serial number of the phone). In the Desa network, we gathered the daily LUR logs, which include what phones (IMSI and IMEI) registered that day. A key thing to note is that, as the area has no other cellular towers, *every active phone in the village attempts to connect to the Desa network*. This allows us to poll not only network subscribers, but also phones of users outside of the network. This data is used to estimate the smartphone adoption of the entire community, rather than just Desa subscribers.

Usage Logs.

We also collected a log of all communications, voice and SMS, that happened in the Desa network during the study. These logs included the sender's IMSI, their type of communication (SMS or voice) and their dialed phone number. If the call is local (i.e., to a subscriber on the Desa network), we are able to associate the dialed number with the receiver's IMSI as well. All of the following analyses are for user-initiated communications; incoming calls and SMS, both local and out-of-network, are ignored.

4.1.2 Data Coding

In Google's *Our Mobile Planet*, a smartphone is defined as "a mobile phone offering advanced capabilities, often with PC-like functionality or ability to download apps" [8]. As the IMEI logs provide the specific operating system (rather than a set of supported features) used by each phone, we had to provide an alternative definition. In this work, a smartphone is defined as any phone running the Windows, Android, IOS, Blackberry, or Palm operating systems. The Symbian line of operating systems are debatable; they are present in both smartphones and more traditional featurephones. We do not include them in our definition of smartphone as our experience has shown that the S40 and S60 phones in Desa are most commonly featurephones.

4.1.3 Data Analysis

For any communication in the usage log, we map the sender to an IMEI though our daily LUR logs. Unfortunately, the usage logs are of IMSIs alone; we do not record the IMEI per communication. Though most of the users (86.3%) never switch their SIMs between phones (creating a one-to-one mapping between IMSIs and IMEIs) some users do. In this case, we do not know which phone (IMEI) was used to send the communication. To resolve these cases, we map the IMSI to the *most commonly used* IMEI for that particular IMSI. This effectively maps all of an individual's communications (IMSI) to their most commonly used phone (IMEI). As most users do not move their SIMs between phones, and these moves happen rarely, it has little impact on the results.

4.2 Results

4.2.1 Demographics

In fourteen weeks, we observed 3230 phones (IMEIs) attempting to register on the Desa network through LURs. We first sort all of the logged phones (417 accepted onto the CCN, 3003 rejected, with some switching) by the operating system type. Table 1 shows the results. Android was by far the most popular smartphone operating system, but generic embedded feature phones dominate the overall install base comprising over 77% of all phones in the area. Overall around 16% of the total cellular population is smartphones based on our earlier definition. This is comparable to national averages within Indonesia of between 14% [8] and 24% [5], showing that even in remote rural areas smartphone technology has taken root.

OS	Type	#	%
Android	Smartphone	296	9.2%
Blackberry	Smartphone	194	6.0%
Nokia S60	Featurephone	112	3.5%
Nokia S40	Featurephone	90	2.8%
IOS	Smartphone	27	0.8%
Windows	Smartphone	11	0.3%
Generic	Featurephone	2500	77.4%
Smartphone		528	16.3%
Featurephone		2702	83.7%
Total		3230	100.0%

Table 1: Operating System demographics detects in Desa. Note that S60 and S40 are not considered smartphones in the analyses.

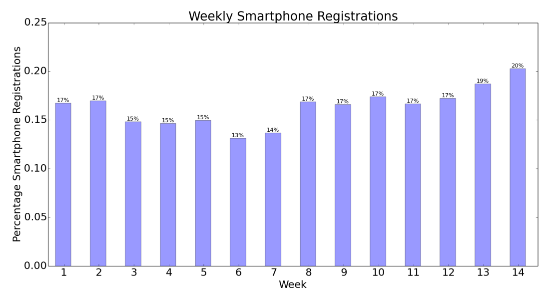

Figure 2: Weekly smartphone registrations. There is little variance over time.

This 16% number also maintained over time, with a weekly minimum of 13.1% of the smartphone registrations being smartphones in week 6 and a maximum of 20.0% in week 14 (Figure 2). The median of the 14 weeks of observation is 16.7%, very similar to the actual smartphone registration percentage of 16.3%. We conclude that there is was no systematic change in smartphone adoption during the duration of the trial.

4.2.2 Adoption

We now explore the uptake of smartphones in our network. As shown in Table 2, there is no significant difference between the subscribers on the Endaga CCN and the wider community. Both populations have adoption of around 16%. This indicates that the CCN subscriber base is not a more technologically advanced subgroup of the main population.

4.2.3 Usage

We also explored how smartphones were used inside of the CCN. For each call or SMS in the network (outbound calls/sms were ignored), we queried the IMEI of both the sender and receiver, determining if they were a smartphone user. Figure 3 shows the results. Generally, smartphone users were more likely to text than featurephone users. The receive side mattered as well; smartphone users were also more likely to receive texts than featurephone users. Without any qualitative analysis, we can't be sure why. Our guess is that it's simply input modality; smartphones generally have better interfaces for text input. It could also be economic; smartphone users may be more educated and literate.

4.3 Implications

These results show that smartphone penetration in one of the

CCN			Out of Network		
Smartphone	38	16.7%	Smartphone	490	16.3%
Featurephone	189	83.3%	Featurephone	2513	83.7%
Total	227	100.0%	Total	3003	100.0%

Table 2: Smartphone adoption in and out of network. There is no significant difference between the CCN subscribers and the village population in terms of smartphone adoption.

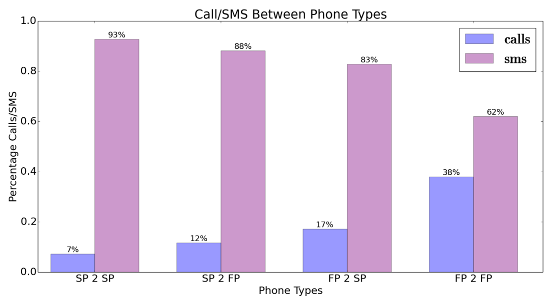

Figure 3: Usage between groups. SP is Smartphone and FP is Featurephone.

most remote parts of Indonesia is comparable to urban areas. This supports the idea that smartphone-based services, such as applications that run on the devices, will become more and more important in these regions. We also saw that smartphone users texted more often, meaning that SMS-based services may similarly be more useful in the future. Lastly, we saw that CCNs draw subscribers uniformally from the population, at least in terms of smartphone adoption, supporting these platforms as a tool for interacting with the broader community.

5. DISCUSSION

5.1 Study Issues

There are a few potential issues with this analysis. The largest one is a selection bias; the Desa community has a relatively large western presence compared to other nearby communities. There is a westerner-run missionary school that often brings outsiders, including teachers from other Indonesian islands and even other westerners. This could bias the smartphone penetration towards a more urban-like distribution. At the same time, the military and police in Desa are generally non-Papuan Indonesians as well. Desa may be a representative community even with these migrants. It's hard to know without a comprehensive census of the highlands, which does not exist.

5.2 Future Work

We plan to explore a variety of other questions based on the call and IMEI logs. For instance, we can calculate the number of FM radios in the community to determine if that is a good platform for broadcast access. This network is mature, having run for almost two years. New networks may be different. We will explore if the installation of the network affects the smartphone penetration in the community. We are interested in network services that could encourage smartphone adoption. Lastly, we hope to conduct a broader qualitative analysis of smartphone adoption in the community to get at the deeper reasons why this technology is being adopted despite the various infrastructure issues.

6. CONCLUSION

In this work we explored the smartphone adoption rate in a community in rural Papua, Indonesia through the lens of a long-running community cellular network. Through the intricacies of the GSM protocol, we were able to poll *every* powered-on phone that entered the community through a 14 week period. We found that smartphone penetration was comparable to greater Indonesia (16% locally versus 14-24% nationally) despite the rural environment. We also explored the intra-network communication and found that smartphone users broadly texted more often than featurephone users. These results inform future CCN deployments as well as future phone-based interventions in rural areas.

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