Title: Enabling Rural Internet Service in the Developing World

Keywords: Network management, challenged networks, software-defined networking

Background: Internet connectivity yields immense economic and societal benefits. Consider that a 10 percent increase in broadband penetration correlates with a 1.3 percent increase in GDP, almost twice that correlated with the same increase in mobile phone penetration [1]. Nevertheless, over 70% of the world, including 30% of the U.S. population, lives without Internet, primarily in rural areas [2]. The goal of my research is to overcome one of the most significant obstacles to Internet penetration in rural areas: the high degree of technical expertise required to run a network.

There exists little economic incentive for incumbent ISPs to deploy networks in rural areas; rural populations have slight buying power, and there are more profits to be made in higher margin markets. Local entrepreneurs would be ideal deployers of networks, as they have vested interest in obtaining connectivity and the trust of their community. Yet managing networks is a highly technical task, requiring at the least knowledge of router configuration languages, traffic engineering practices, and monitoring infrastructure. Such skills are scarce in rural areas. Moreover, education is not a viable solution, because there are strong financial incentives for skilled workers to move to large cities. Thus, a significant impediment to network deployment is the high degree of *technical expertise* required to run network.

Research Question: My research will answer the following question: to what extent can rural network management be outsourced? If successful, my proposed research will enable a new deployment model: local entrepreneurs could simply install and point antennas, while the more complex management tasks are handled by a third-party for a small fee.

Related Work: Network management outsourcing exists in limited forms on the Internet today. For example, Meraki offers enterprise customers a cloud-based network management product which ships with their wireless mesh network hardware [3]. In this model, IT staff at the enterprise express the desired behavior for their network through a simple GUI running in Meraki's datacenter, while the details of network device configuration are pushed down transparently.

The existing solutions do not suffice in our setting for two reasons. First, they assume *physical access* to the network so that technicians can be sent to make repairs when something breaks. This assumption will certainly not hold for many rural areas. Second, the paths between the control server and the customer's site are assumed to be reliable and relatively low latency. Rural networks by contrast, especially those in developing regions, are typically resource-constrained and prone to intermittent outages. The contribution of my work will be technical advances that push the notion of outsourcing to its extreme, removing the assumptions of physical access and reliable control channels.

Research Plan: Given the deployment constraints, I argue that software-defined networking (SDN) is a promising platform for deploying this research. Like Miraki, SDN executes control decisions on centralized servers rather than network devices. For the purposes of outsourcing, SDN provides a mechanism to control the behavior of networks devices from a remote server.

The SDN platform alone does not suffice for our goals; removing the assumptions of physical access and reliable control channels still presents significant challenges for the outsourcing model. I will address these issues in turn.

Without physical access, third-party operators will need the ability to remotely detect, isolate, diagnose, and provide straightforward repair instructions to faults in the network. Fault diagnosis for SDNs is currently an open problem, primarily because of the semantic distance between the view seen by control software and actual network device behavior.

My initial plan to address this first challenge is to analyze fault data from rural networks. The CEO of AirJaldi, a rural network in Dharamsala, India, has already given me access to several years of network traces [4]. I will use these data to identify a detailed set of failure modes seen in this typical rural wifi network. I will then design a system to pull diagnostic metrics from network devices and process them to attribute causes to fault behaviors. Finally, I will deploy my system on AirJaldi and measure how often it is able to provide effective repair instructions.

Without reliable control channels, SDN control servers will not be able to communicate with network devices. Consequently, the network may cease to function properly. This problem is a direct consequence of separating servers from the network. Until now, all SDN deployments have been in datacenter or WAN environments with reliable paths between controllers and switches.

My initial idea for solving this second challenge is to deploy 'backup control logic' in network devices or endhosts within the network. These devices will maintain an eventually consistent copy of the control server's state. When they detect that the controller has lost connection with the network, they will assume control until connectivity is restored. I will evaluate and iterate on this design by emulating unreliable paths between SDN controllers and switches for a number of different control applications, link properties, and workloads.

Qualification: My extensive previous research in network troubleshooting has given me a deep understanding of the complexities involved in network management. At UC Berkeley, under the mentorship of Scott Shenker, one of the inventors of SDN, and Eric Brewer, a leader in the field of ICTD, I have ample access to the resources and guidance needed to pursue my proposed research.

Intellectual Merit: Pushing SDN to its limits by deploying it in a resource-challenged environment will provide the networking community with valuable insights into the limits of the SDN architecture. Indeed, there is essentially no prior work on deploying SDN in challenged networks. Similarly, taking the notion of network management outsourcing to the extreme case of no physical access will yield beneficial knowledge of fault diagnosis techniques.

Broader Impact: By simplifying network management, my work will enable local entrepreneurs to deploy networks where they were not previously able, thereby catalyzing Internet coverage and the economic and educational benefits that come with it. This is especially important for rural areas, where some of the most underserved populations of the world reside.

References

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