RESEARCH REPORT

How to Make Twitter Available in North Korea

BY DEVABHAKTUNI SRIKRISHNA and RAJEEV KRISHNAMOORTHY

INTRODUCTION

Since Hiroshima's destruction in 1945, the march of nuclear proliferation throughout the world has shown no signs of halting. Nuclear proliferation is fueled, in part, by a fundamental disagreement between governments about whether their citizens have freedom of speech, expression, and thought – North Korea being one example. There are some nation-states that differ on the role of fundamental human rights versus NATO countries and their allies. As former Secretary of State William Perry explained recently,

> *"A world without nuclear weapons will not simply be today's world minus nuclear weapons.... The world we are looking to has to have some international way of dealing with conflict, that focuses on preventing the conflict in the first place, dealing with the causes of conflict. We are very far from that world today."*[1]

Freedom of expression would bring additional economic and social benefits with the free flow of ideas and commerce across the globe. North Korea imposes almost total Internet censorship on its citizens. Similarly, Iran controls internal access to external websites and media through packet-filtering technology. Egypt shut down all Internet access in a crisis. Technically the only way to overcome these filters is to physically bypass the infrastructure points that contribute to censorship.

Citizens with securely designed wireless mesh-enabled smartphones (SocialMesh) can overcome the Internet censorship imposed by national governments. These devices enable basic uncensored social applications such as Twitter, Facebook, and Google. Wireless data networks, which are formed virally from handheld radio-routers and adapted to changing RF propagation and interference — without relying on managed cellular infrastructure — can be designed to bypass packet filters and other countermeasures often relied on by nation-states that impose censorship.

Using low-cost hardware, self-organizing routing software, and code division multiple access (CDMA), wireless data networks can retain enough system capacity even under heavy load from users or interference from jammers to overcome Internet censorship anywhere in the world. A peer-to-peer viral distribution strategy could include bootstrapping incentives for end-users to help build the network, such as the more new users that sign up, the more bandwidth you receive.

The investment for developing, manufacturing, and deploying SocialMesh through viral distribution is estimated to be in the range of $10 million, which is less than one percent of the annual expenditure for maintaining U.S. troops along the Korean Demilitarized Zone (DMZ). If successful in reducing the tensions between North and South Korea, a SocialMesh can diminish the need for deployment of troops and of nuclear weapons in the Korean peninsula.

Eliminating state censorship through freedom of speech for Internet users anywhere in the world can neutralize and dissolve the differences that create conflict. Needless to say, a world free of nuclear proliferation would lead to a much more secure and peaceful world.

National governments cannot escape the mathematics of game theory and the prisoners' dilemma – often locking them in a balance of power with their adversaries. The Korean border is a case in point. North Korea has tested nuclear weapons and is believed to have several, while South Korea is protected by U.S. nuclear security assurances – placing populations of both Koreas and the United States at a constant state of risk for nuclear war. In addition to nuclear weapons, the security balance on the Korean border is maintained by a massive conventional military presence by both sides.

The widespread availability of mobile and social media has catalyzed social revolutions[3] including texting in the Philippines[4] and most recently the uprisings[5] known collectively as the Arab Spring.[6] Where Internet censorship is in place, the Obama administration has recently expressed interest in virally expanding wireless networks to enable citizens to bypass censors,[7] and is actively considering them for use all over the world. Such networks of devices in the hands of citizens promise to create universal access to mainstream applications of the web such as search (Google, Bing, etc), social networks (Facebook/Twitter), and personal communications (Skype, Google Chat, and Apple's Facetime) that enable people to communicate. How do they work in practice?

CIVILIAN AND MILITARY WIRELESS ARCHITECTURE

Mesh networks were first described by Paul Baran in the 1960s as a way to eliminate central points of failure and reduce the vulnerability of communication networks to a first nuclear strike by the Russians during the Cold War — when the telephone network architecture was based entirely on centralized switching.[8]

The idea of a survivable, mesh network consisting of wireless links inspired what became known as the Internet. Vint Cerf and Bob Kahn first envisioned this solution for "ad-hoc" battlefield communications for soldiers. DARPA funded an experimental "packet radio" network based on spread-spectrum techniques first built across the San Francisco Bay Area in the 1970s. Subsequently, wireless mesh networks have found application in several different domains.

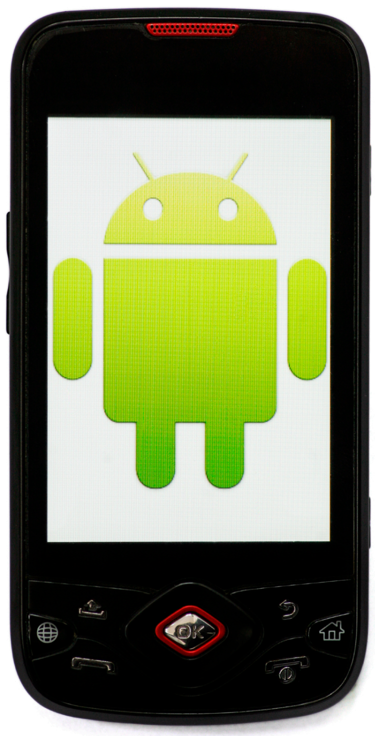
The first city-scale wireless mesh network was operated by Metricom Corporation in the 1990s using unlicensed spectrum (900MHz and 2.4GHz) radio-routers hung on lamp posts across multiple major metropolitan areas in the United States. These were based on proprietary, expensive frequency-hopping spread-spectrum radio technology and while technically successful, it ended up being a commercial failure.

Table 1: Comparison of North Korean and South Korean military capabilities

Military capability[2]	North Korea	South Korea
Annual budget	$1.5 billion	$13 billion
Troops (active)	1.1 million	0.69 million
Special Forces	88000	
Tunnels near (DMZ)	20	
Underground bunkers (DMZ)	4000	
Tanks	3500	2300
Artillery	10000	4500
Combat aircraft	605	538
Combat boats	305	111
Submarines	91	20
Mortars	7500	6000
Air-defense guns	11000	600
Surface-to-air missiles	10000	1000

At the same time in the 1990s, one of the authors took part in a standardization effort for low-power spread-spectrum radios used in local area networks called IEEE 802.11 (later known popularly as Wi-Fi or wireless Ethernet). After a decade, Wi-Fi was ubiquitously available and affordable throughout the world. At the time it was believed that public-access wireless networks had to be operated by regional telephone companies and cellular operators. Next-generation wireless routing technology built by Tropos Networks applied to Wi-Fi radios enabled city-scale wireless mesh networks that were similar in concept to the Metricom architecture, but more cost-effective and easy to operate.

Individual municipalities and small service providers were able to offer Wi-Fi based broadband service. Hundreds of municipal Wi-Fi mesh networks that used Tropos routers[10] (as well as those from vendors such as Belair Networks) are in operation today spanning thousands of square miles of contiguous broadband coverage including Oklahoma City, OK and Mountain View, CA.[11]



The freedom to experiment, learn, and innovate in unlicensed spectrum resulted in architectural and performance innovations for Wi-Fi mesh networks that are not seen in traditional cellular networks —enabling their rapid and resilient construction. These innovations demonstrate that it is possible to overcome multiple interference, propagation, and transmit power handicaps imposed by unlicensed spectrum regulations compared with licensed spectrum.

Aside from their use in local area networks indoors, the limitations of the spectrum allocation have thus far kept unlicensed radios from being used outdoors by a majority of the end-user population in favor of 3G and 4G networks operated by cellular carriers in licensed spectrum. In licensed cellular systems, high amounts of power can be transmitted to end-users by base stations leading to considerably strong performance on the downlink. However the amount of power transmitted by the handset is still limited by battery life and portability considerations to approximately 100 milliwatts (mW), resulting in performance limits on the uplink very similar to unlicensed spectrum.

In principle the idea of a network owned and operated entirely by citizens is promising, as adoption can grow virally until everyone can participate in the network. The software and hardware required can piggyback on advances in the large-scale production, development, and cost-reduction made possible by the open-source Android ecosystem based on Linux using Wi-Fi. The form factor for such a device can be similar to any modern Android-based smartphone commonly available today from manufacturers such as HTC, Motorola, or Samsung. Each device can participate in a self-organizing Wi-Fi or cellular (GSM) mesh network that can span multiple hops to external backhaul links and create connectivity in virtually any terrestrial environment.[12]

The applicability of citizen mesh networks based on unlicensed or licensed commercial radios is also severely limited both by the Wi-Fi or cellular radio interface as well as by how effectively they can bypass efforts by a censorship state to deploy a filter or block.

NORTH KOREA: A CASE STUDY

Consider North Korea as an illustrative example. Pyongyang, North Korea's capital, is located only 20 miles from international waters and 150-200 miles from the South Korean border and Seoul. In theory, a wireless mesh (SocialMesh) spanning such distances and feeding off of external network links (backhaul) in South Korea, from a ship in international waters or by satellite, is sufficient to end Internet censorship there through viral adoption by the resident population. The 40km span from international waters to Pyongyang is shown in Illustration 1, where several hypothetical wireless mesh links carry data back and forth. The Internet gateways (backhaul) are shown in red and relay mesh nodes in light blue, with white lines illustrating the network connections established automatically by SocialMesh.

North Korea is well known to have very active RF jamming and countermeasures for radios, cell phones, and other wireless communication.[13] According to South Korea's defense minister, North Korea has an active RF jamming program for GPS, while South Korea is preparing to offer broadcast radios to North Korean citizens for deployment in case of a war.[14] Limited internal cellular communications exist inside North Korea,[15] and Internet access to external sites is blocked by state censorship. Chinese cellular signals penetrate the border to a small extent,[16] although North Korea is actively confiscating cell phones that operate on these frequencies.[17]

SOCIAL MESH

Is it possible to enable a virally expanding network with a ~100 mW mass-market smartphone (e.g., Android-based) if we assume the RF and radio layer is not constrained by legacy assumptions

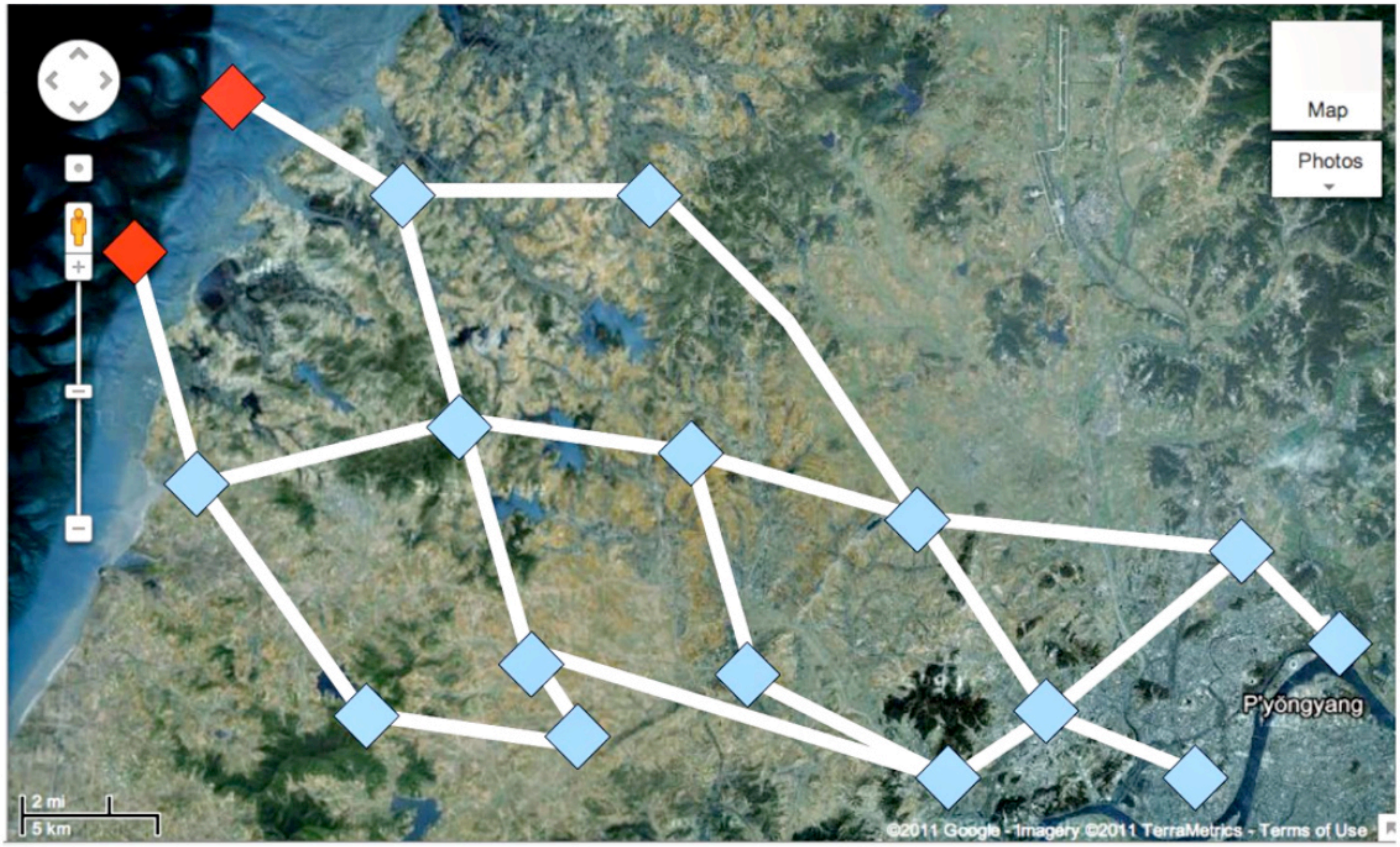


Illustration 1: A peaceful road to Pyongyang.

on spectrum allocation?

Android-based smart-phones are available in large quantities at low cost with an open-source operating system. Resembling its unlicensed spectrum counterparts, the SocialMesh would be a peer-to-peer, self-organizing mesh network of user-friendly smartphones with access to the uncensored Internet. A SocialMesh would also have to be resistant to countermeasures that could be employed by the censorship nation, including physical disruption, jamming, and protocol-based attacks.

In a companion paper,[18] network discovery and operation can be made resilient to physical disruption using wireless mesh routing to RF jamming through uncoordinated direct sequence spread spectrum (UDSSS) or alternatives, and protocol-based attacks through use of public-key cryptography during link-establishment. The following countermeasures may be overcome through design of the SocialMesh:

1. physical disruption of SocialMesh nodes
2. impersonation of SocialMesh nodes
3. RF jamming of SocialMesh nodes
4. Before the mesh reaches ubiquitous penetration with end-users, the censoring nation can hunt down a small number of users deterring further end-user adoption.

A smartphone radio operating in prime spectrum (250-750MHz) at 100 mW transmit power will be sufficient to create a SocialMesh network spanning the land from international waters to Pyongyang, providing secured broadband access to the Internet for end-users. For an estimated cost in the tens of millions of dollars, the U.S. can adopt policies to standardize, manufacture, and distribute SocialMesh nodes that permanently end government censorship across the world through viral expansion and adoption by the residents of these nations.

DATA RATE AND RELIABILITY OF LINKS IN THE NETWORK

In Figure 1, the link budget is used to calculate the expected single-link performance and reliability of this system as a function of transmitter and (equivalent) interferer/jammer distance under a variety of conditions, which is intended to approximate the equivalent of many neighboring interferers and jammers. The Mathematica notebook used to generate them is linked from Appendix A. Actual mileage will vary depending on the circumstances, but these can serve as a rough guide. In the plot below, the x-y axes are the distance of the transmitter and interferer to the receiver. The z-axis is the data rate achievable at transmit power of 200 milliwatts.

In Figure 1, unobstructed propagation is modeled by using a path loss exponent of 2.5 where the interferer and transmitter distance range from 0-10 km. The far end of the graph where distance to the interferer is 10km shows a near-ideal situation where interference is minimized and communication rate is noise-limited. Multi-megabit communication is possible for several kilometers and the communication rate rises into the tens and hundreds of megabits as the distance to the transmitter gets below one km. The plot shown is cutoff at 100 Mbps, which is why the plot appears flat as the distance to the transmitter approaches zero. The effect of increasing interference is modeled as the distance to the interferer is reduced from 10km to below 4km where we start to see significant effects.

MODEL SPECS FOR SOCIALMESH NODE

We propose a SocialMesh network consisting of access nodes, routers, and communication links that would shift power of choice into the hands of end-users who want access to information, and away from repressive state censors.

New developments need to be made to the communication radio for operation in 250-750MHz (or other wideband) and software for medium-access control, network routing (meshing), and secure design. The functional requirements for a SocialMesh include:

1. Broadband: The network will supply broadband to support essential apps such as email, video, voice to anyone who wants it, as much as allowed by physical constraints even with arbitrary countermeasures by state censors.

2. Environmental Propagation: The nodes would need to work well in a variety of environments, including wooded areas, plains, and a variety of temperature ranges.

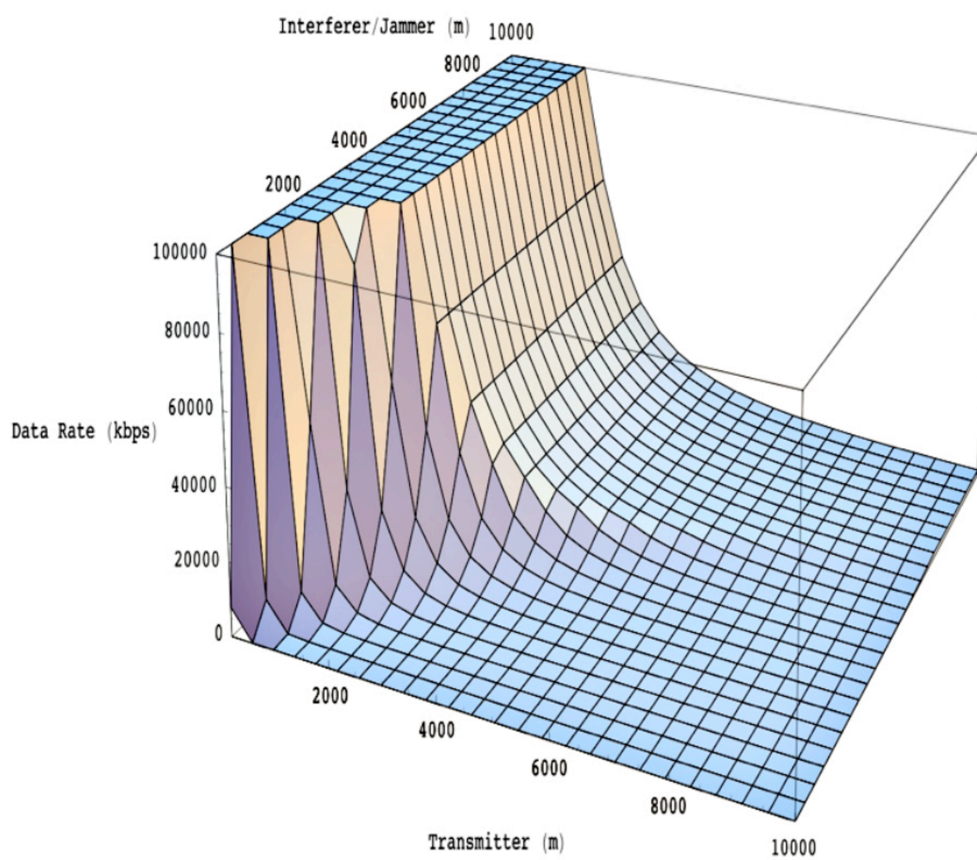


Figure 1: Path Loss Exponent = 2.5 (0-100 Mbps, 0-10 km)

3. Power Consumption: Battery, solar, recharging stations.

4. Plug-and-Play: The need to involve end-users in network configuration or setup ought to be minimal or zero.

5. Geographically Restricted Operation: Since the SocialMesh's radio will not be compliant with local regulations in "censorship-free" countries like South Korea, the nodes will have to include a GPS receiver to be non-operational except in areas of interest such as North Korea. Using location, the node can be programmed by software to operate only within the borders of the area of interest and not transmit if located outside this area.

Viral Deployment Strategy and Bootstrapping Incentives

The bootstrapping of a SocialMesh may begin with a small number of network nodes bridging across key areas, driven by individuals who are brave enough to take a risk. Islands of connectivity may form and eventually coalesce into a single unified network. These are the three stages of network deployment based on the framework of Malcom Gladwell's *The Tipping Point*:[20]

1. Connectors: The SocialMesh nodes are first offered to curious, early adopters who are connecters at heart and wish to circumvent the communications censors. This is known as the "seed" of the network that establishes its footprint early on.

2. Mavens: Next, the nodes are supplied to a broader population who want to grow the network and use it in a limited fashion, experiment with its capabilities, and learn how to use it effectively. They will start to make information available via Twitter and other sources. This will comprise about 15 percent of the population.

3. Salesmen: These individuals will convince others to adopt the SocialMesh in a viral manner, creating large-scale growth in the network. Since SocialMesh network capacity is limited, network access may be scarce at times. This fact can be used to motivate the salesmen through referral incentives. Through controls built into SocialMesh software, salesmen can be granted preferential access to the network over other users based on the number of additional SocialMesh users (nodes) they enable. Essentially the more users you sign up, the more bandwidth you have access to.

Finally, a larger group of people (lurkers) will be compelled to join the communications network to "tune in" and watch the content being created by the previous two groups. They may operate their radios in "listen-only" mode to pay close attention to what is transpiring in order to make better decisions. They will comprise more than 50 percent of the population.

Handset cost estimates

For a representative bill of materials of a typical high-end smartphone see "iPhone 3Gs Carries $178.96 BOM and Manufacturing Cost, iSuppli Teardown Reveals"[21] which lists the cost of an iPhone less than $200. The additional cost for adding the new LTE standard to an existing phone is in the range of $50 according to "Teardown of HTC ThunderBolt Provides Insights on Rumored LTE iPhone."[22]

Multiple antennas to enable the obfuscation of transmitter location would be embedded in the smart phone case. An extra antenna adds only pennies to the overall increase in cost. The marginal cost increment is small — power amplifiers for handsets cost less than $1 currently.

The eventual cost of the handsets is going to be dominated by the supply chain, the volumes, and the maturity of the products (how long they are in production.) As an example, looking at the iPhone BOM, the multimode baseband IC is $13 and the RF transceiver for all the 3G standards is $2.80. The WAN communications electronics therefore account for less than 10 percent of the total BOM of the handset.

TOTAL COST

Outdoor mesh networks have been built for areas of several hundred square miles covering entire metropolitan areas (Oklahoma City and Philadelphia are examples). To setup a SocialMesh the size of 100 x 100 square kilometers at a density of 10 per square km would require on order of 100,000 SocialMesh nodes. In mass production, the hardware cost of each node may be on the order of $100 each, bringing the total cost to $10 million. Considerably reduced functionality phones can be designed in the range of $20.

The initial investment needed to develop SocialMesh technology is likely to be on the order of tens of millions or less, as comparable technology has been developed and marketed by companies in the United States (e.g. Tropos Networks, Qualcomm, TZero).

CONCLUSIONS

The U.S. Departments of State and Defense should take action to end state censorship worldwide. An official policy needs to be approved for eliminating censorship worldwide based on deployment of SocialMesh. Almost anyone can use and deploy SocialMesh nodes once the design is developed, tested, and standardized. The deployment of a SocialMesh in censorship states would permanently end censorship by enabling viral adoption among the resident population.

SocialMesh nodes can be designed to be resilient to jamming and disruption by censors based on user-friendly smartphone technology and operating in a wireless mesh architecture. By shedding legacy assumptions about spectrum allocation in censor-free nations, a smartphone radio operating in prime spectrum (250-750MHz) at 100 mW transmit power will be sufficient to create a SocialMesh over multiple mesh hops from international waters to provide secure broadband communications to citizens of these countries.

To maintain the balance of security with North Korea, South Korea maintains 12 brigades and the U.S. stations 18,000[23] troops between Seoul and the DMZ – costing taxpayers in both countries several billion dollars annually. The total investment in SocialMesh technology development, mass manufacturing, and network deployment is estimated in the tens of millions of dollars, or a fraction of one percent of the annual cost of maintaining the troop presence. The U.S. government should adopt policies and standardize the technology for SocialMesh to be deployed in censorship states through viral distribution by citizens – to eliminate the differences that fuel nuclear proliferation. ■

Appendix A: RF Calculations and 3-D plots

See both the linked spreadsheet[23] for the RF link budget and the Mathematica Notebook used to generate the 3-D plot. Reference materials are available online at www.FAS.org.

Devabhaktuni Srikrishna is founder and formerly Chief Technical Officer of Tropos Networks. Tropos manufactures wireless mesh network routers based on the 802.11 (Wi-Fi) standard and are operated by 850+ cities across the world including Oklahoma City, OK, and Mountain View, CA. He holds a Bachelor of Science in mathematics from the California Institute of Technology and a Master of Science in electrical engineering and computer science from the Massachusetts Institute of Technology.

Dr. Rajeev Krishnamoorthy was most-recently the founder of TZero Technologies, a pioneer in Ultrawide-band RF radios. While at Bell Labs, he was instrumental in the design and development of the early 802.11 and 802.11b systems and in the formation of the 802.11 (Wi-Fi standard). He holds a Bachelor of Science from the California Institute of Technology and a Master of Science and PhD from Cornell University.

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