A panoramic view of the Seattle skyline at dusk or dawn. The Space Needle is the central focus, surrounded by various skyscrapers. In the background, snow-capped mountains are visible under a soft, hazy sky. The overall tone is warm and atmospheric.

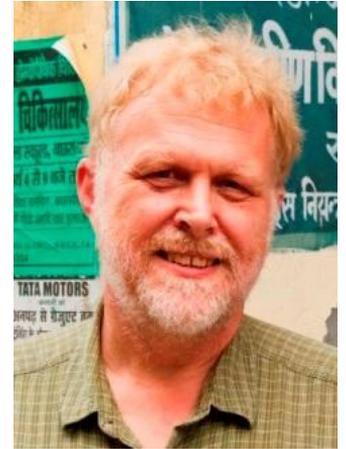
Technologies for decentralized urban community cellular networks

or

*Industry doesn't use wifi for city-scale
networks, why should we?*

ICTD Lab @ W

- <http://ictd.cs.washington.edu>
- Established research group focusing on technology and poverty (ICTD)
- Professor Richard Anderson
 - ~6 Students
 - Focus on health and financial services
- Professor Kurtis Heimerl (<https://kurti.sh>)
 - ~3 Students
 - Focused on Internet access and conservation



Brief Intro to Community Networking

- Networks built, owned, and operated by citizens and users in a participatory and open manner
- Many examples throughout the world:
 - Guifi.net > 35,000 nodes
 - Freifunk, Altermundi, NYC Mesh, etc
- Largely built on 802.11 “mesh” protocols
 - Operate primarily in unlicensed spectrum (with some licensed backhaul)
 - Technology is understood by “networking professionals”



Background on Community Cellular

- Built off of software implementations of cellular protocols - OpenBTS, Osmocom, OAI
- Example deployments:
 - Rhizomatica - Oaxaca, Mexico
 - AirWave Missions - Papua, Indonesia
- Long-term Evolution (LTE/4G)
 - CommunityLTE (CoLTE) deployed in Indonesia and Oaxaca. More deployments planned.
- “Traditional” rural-focused installations
 - Limited backhaul
 - Local Services



An aerial photograph of a residential community, possibly a housing project or a planned development. The scene is dominated by a large, multi-story building with a prominent red roof in the center. Surrounding this central structure are numerous smaller, single-story houses and trailers, many with light-colored roofs. A large, calm body of water, likely a lake or a wide river, stretches across the middle ground. In the background, a dense residential area is visible, extending to a distant shoreline. The overall atmosphere is somewhat hazy, suggesting an overcast day or a light mist. The text "Question: Is community cellular appropriate for *cities* as well?" is overlaid in the center of the image in a bold, black, sans-serif font.

Question: Is community cellular
appropriate for *cities* as well?

Example: City-scale Wifi

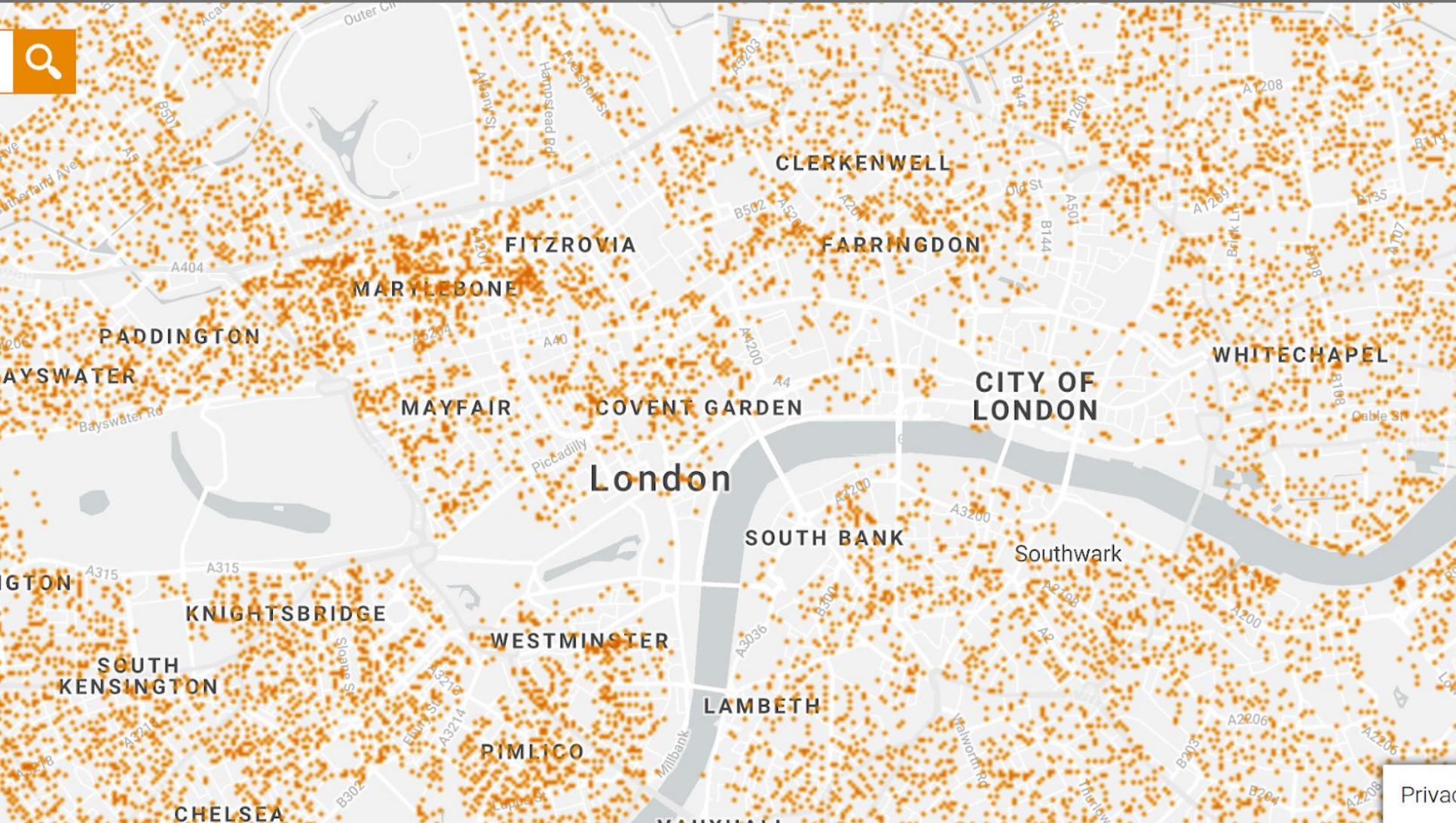


Join our global WiFi network by buying access or partnering with us.



Use our cutting-edge solutions to deliver WiFi services in a secure, scalable, and uniquely flexible way.





London

CLERKENWELL

FARRINGDON

FITZROVIA

MARYLEBONE

PADDINGTON

WHITECHAPEL

CITY OF LONDON

MAYFAIR

COVENT GARDEN

SOUTH BANK

Southwark

KNIGHTSBRIDGE

WESTMINSTER

LAMBETH

SOUTH KENSINGTON

PIMLICO

CHELSEA

Private

Why is city-scale wifi so hard?

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 - Operates at spectrum poorly suited for propagation
- Generally power-hungry

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3. Wifi is bad at spectrum coordination

- Network too dense? Spectrum congestion
- Network too sparse? Can't do handover

Example: City-scale Cellular

For the home

For business and public sector

For global business

Type keyword here to search



About BT

Investors

News & media

Digital impact & sustainability

Innovation

Careers



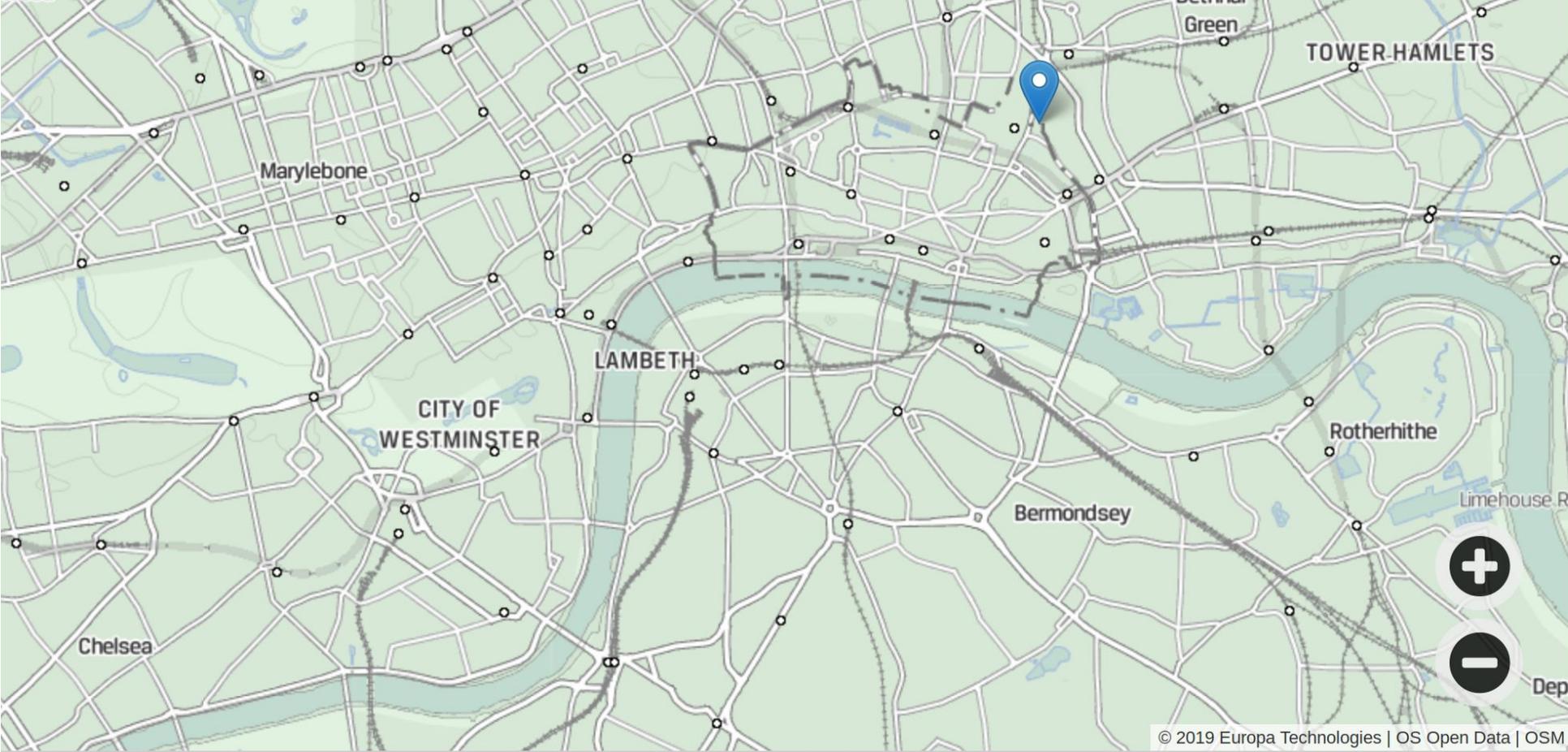
We use
commu
make a

Fi

2019 Annual report

Latest results

Share price: **187.02p** -1.96p (-1.04%)
2019



Likely to have good coverage

You may experience some problems

Reliable signal unlikely

You should not expect to receive a signal

Why is city-scale cellular so common?

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Lots of business reasons

We'll skip those for now

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- This is the whole point of “cellular”
- Variety of spectrum technologies such as self organizing networks (SONs)

Why is city-scale cellular so common?

1. Cellular is good at wide-area
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2. Cellular is good at mobility
 - C
 - L
3. Cellular is good at low-cost
 - T
 - V

What's stopping **us** from building these networks?

Issues with Community Cellular

1. **Spectrum - Cellular uses licensed spectrum.**

Issues with Community Cellular

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- a. Yes but they've started creeping in on other unlicensed bands
- b. Citizen's Broadband Radio Service (CBRS) is a dual licensed regime going live in April
- c. LTE-U and LTE-LAA are both protocols for operating cellular gear in Wifi bands

Issues with Community Cellular

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- 1. Spectrum - Cellular uses licensed spectrum.**
- 2. Hardware - Cellular hardware is super expensive and only telecoms can afford it at scale.**
 - a. Not since LTE. A reasonable LTE access point (eNB) costs ~\$2500USD, about half of a 2G radio.
 - b. This will continue to shrink as more manufacturers enter the NR space as they're "small cells"

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- 3. Interconnect - Telecoms don't play ball.**
 - Still true, but as LTE is entirely IP-based, that's fine. We can peer at the IXP.
 - OTT services (e.g., WhatsApp, Messenger, etc) are dominant anyhow!

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 - a. This has shifted dramatically. One point is the Wireless ISP market, with many operating LTE networks from BaiCells or TelRad. So the hackers can do it.
 - b. “Private LTE” is rapidly gaining traction. These are small companies or building running their own.
 - c. “Carrier Aggregation” is another important shift. Building owners will install their own network and allow their users to “roam” onto *multiple* MNOs for a cut.

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There is a great opportunity for urban
community cellular networks



What's the plan?

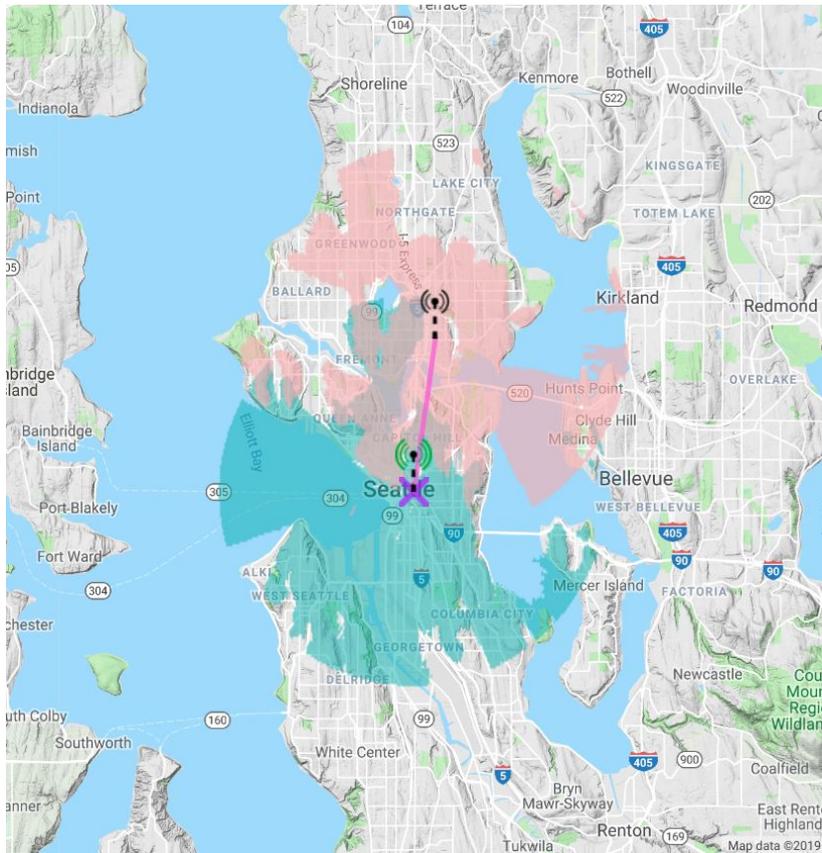
BURK

Technology agenda - Federated LTE/NR

- Use distributed ledger to allow for shared federated backbone
- Create a way for new network nodes (wide area transmitters) to dynamic join a single nation-scale telecom
- Need to distribute the following essential core network functions:
 - Authentication
 - Billing
 - Mobility
 - Network spectrum coordination (SON)
 - Sensed spectrum coordination (DSA)

Deployment agenda - Community LTE in Seattle

- Deploying first urban cooperative cellular network in the fall of 2019
- Two networks federated together:
 - Campus (north) network
 - Hospital (south) network
- Eventually high points will be used to provide backhaul
 - Instead of transmitting
- You can join too!
 - We have SIMs to share!





Thanks!

Kurtis Heimerl
kheimerl@cs.washington.edu

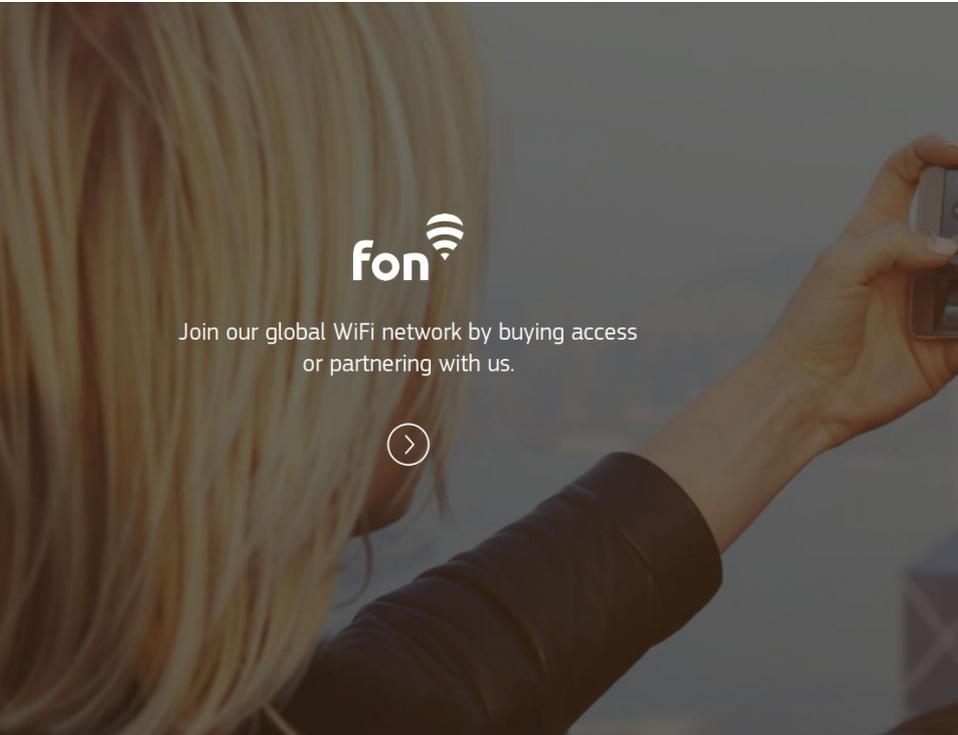
What's the largest single wifi network in the world?

- Assume at most single password or login

What's the largest single cell network in the world?

- Assume at most single SIM

What's the largest single wifi network in the world?



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What's the largest single wifi network in the world?

- **Fon (UK)**
 - Claims 23M hotspots
 - Partner with ISPs/Telecoms: installed on “base” provided routers to share network
- **Boingo Wireless (USA)**
 - Unknown number of hotspots, claims 1.4B airport travellers
 - Focuses on “premium networks”
- **Guifi.net (Catalonia)**
 - 35,000 nodes is crazy successful

What's the largest single cell network in the world?

- **China Mobile (China)**
 - 925M Subscribers
 - Leading NR drive
- **Vodafone Group (Spain)**
 - 500M Subscribers
- **Deutsche Telekom AG**
 - 160M Subscribers
 - 40 Countries
- These peer as well so a single SIM will cover *all* of them!