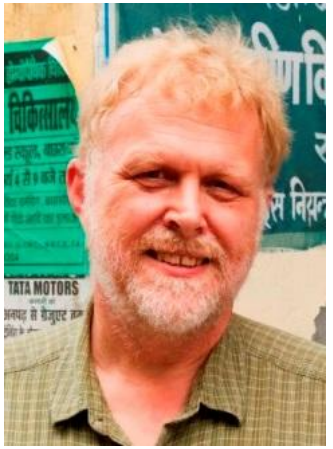
ICTDLab @ W

- ***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***)
  - ~4 Students
  - Focused on Internet access and conservation





My Work: 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
- We've built community-owned networks lots of places
  - Hawaii, Mexico, Philippines, Indonesia, etc
- Building a community-owned LTE network here in the Puget Sound
  - First installation in *Hilltop* neighborhood of Tacoma with *Tacoma Cooperative Network*
  - Other installations on the way with funding from City of Seattle



Why Small Wireless Facilties?

Shannon Limit of a Channel

- Developed by Claude Shannon **well before** the advent of modern systems
- Basically indicates the **maximum theoretical data rate possible**

$$C = B \log_2(1 + S/N) \text{ bits/sec}$$

C = Capacity (LTE = 300Mbps)

B = Bandwidth (LTE = 20MHz)

S = Signal Power (LTE = -20 dBm)

N = Noise (LTE = -110 dBM)

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C = Capa

B = Bandv

S = Signa

N = Noise (LTE = -110 dBM)

Key Points:

1. Increasing power (S) has diminishing returns
2. Increasing bandwidth (frequencies) increases capacity linearly





Options for increasing *bandwidth*

1. Open up new frequencies
2. Use frequencies more efficiently

Both lead to small cells/wireless facilities

UNITED STATES FREQUENCY ALLOCATIONS

THE RADIO SPECTRUM

RADIO SERVICES COLOR LEGEND

- AERONAUTICAL MOBILE
- AERONAUTICAL MOBILE SATELLITE
- AERONAUTICAL RADIONAVIGATION
- AMATEUR
- AMATEUR SATELLITE
- BROADCASTING
- BROADCASTING SATELLITE
- EARTH EXPLORATION SATELLITE
- FIXED
- FIXED SATELLITE
- INTER-SATELLITE
- LAND MOBILE
- LAND MOBILE SATELLITE
- MARITIME MOBILE
- MARITIME MOBILE SATELLITE
- MARITIME RADIONAVIGATION
- METEOROLOGICAL
- METEOROLOGICAL SATELLITE
- MOBILE
- MOBILE SATELLITE
- RADIO ASTRONOMY
- RADIODETERMINATION SATELLITE
- RADIOLOCATION
- RADIOLOCATION SATELLITE
- RADIONAVIGATION
- RADIONAVIGATION SATELLITE
- SPACE OPERATION
- SPACE RESEARCH
- STANDARD FREQUENCY AND TIME SIGNAL
- STANDARD FREQUENCY AND TIME SIGNAL SATELLITE

ACTIVITY CODE

- FEDERAL EXCLUSIVE
- FEDERAL/NON-FEDERAL SHARED
- NON-FEDERAL EXCLUSIVE

ALLOCATION USAGE DESIGNATION

SERVICE	EXAMPLE	DESCRIPTION
Primary	FIXED	Capital Letters
Secondary	Mobile	1st Capital with lower case letters

This chart is a graphic single-point-in-time portrayal of the Table of Frequency Allocations used by the FCC and NTIA. As such, it may not completely reflect all aspects, i.e. footnotes and recent changes made to the Table of Frequency Allocations. Therefore, for complete information, users should consult the Table to determine the current status of U.S. allocations.

U.S. DEPARTMENT OF COMMERCE
National Telecommunications and Information Administration
Office of Spectrum Management
JANUARY 2016

For sale by the Superintendent of Documents, U.S. Government Printing Office
Internet: bookstore.gpo.gov Phone: toll free (866) 512-1800; Washington, DC area (202) 512-1800
Fax: (202) 512-2250 Mail: Stop SSOP, Washington, DC 20402-0001



PLEASE NOTE: THE SPACING ALLOTTED THE SERVICES IN THE SPECTRUM DISPLAYED DOES NOT REFLECT PROPORTIONALLY THE TOTAL ACTUAL AMOUNT OF SPECTRUM OCCUPIED.

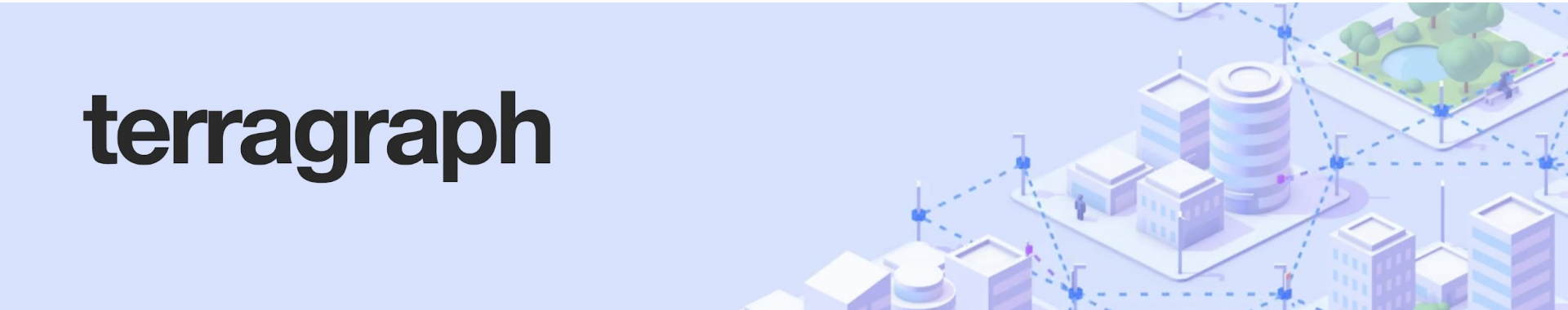
New Frequencies

- Vast majority of bands (specifically low ones) already taken
  - 850MHz, 1800MHz is traditional cellular
  - 600MHz, 900MHz, ~50 others are now LTE
  - 900MHz is ISM (cordless phones,microwaves mostly)
  - 2.4GHz/5GHz is ISM (Wifi)
- Higher bands (6GHz+) are largely fallow but have very poor characteristics
  - Low penetration (e.g., do not make it through walls)
  - High weather attenuation (e.g., rain makes them suck)

New Frequency Examples

- LTE Unlicensed/LAA - Cellular in Wifi Bands
- Wifi 6 - Wifi in new 6GHz ISM band
  - Some stuff around here remains licensed
- “Millimeter Wave” - ~60GHz bands
  - 5G Frequency Band 2 - 24.25 GHz to 52.6 GHz
    - Normal cellular models
  - 60GHz unlicensed (Terragraph)

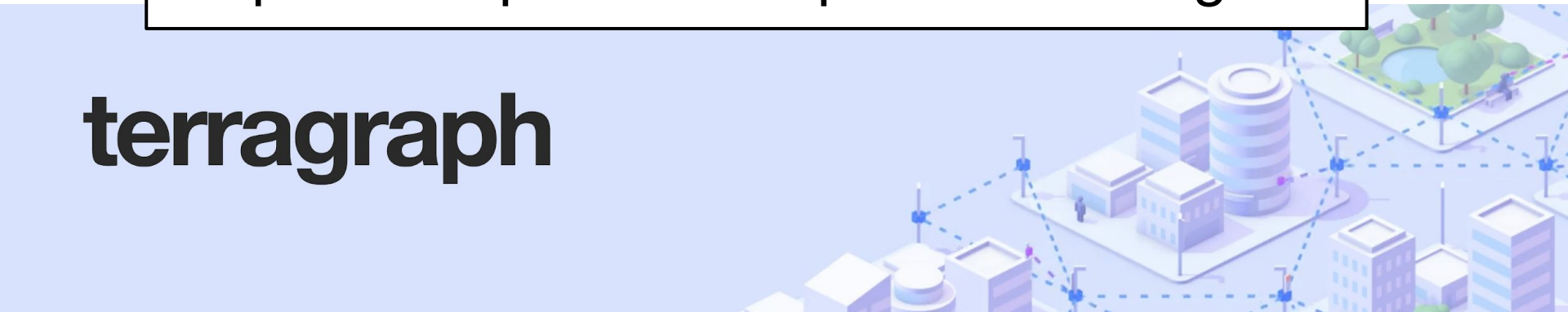
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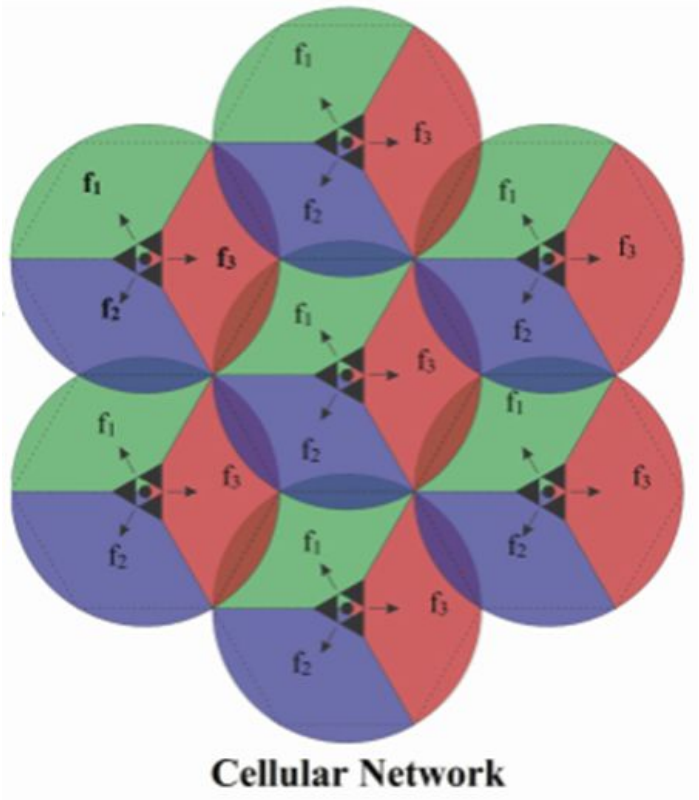
New Frequency Examples

- Wifi 6 - Wifi in new 6GHz ISM band
- **Conclusion:**
  New frequencies are all high, meaning they have limited range and need lots of access points to provide ubiquitous coverage

terragraph



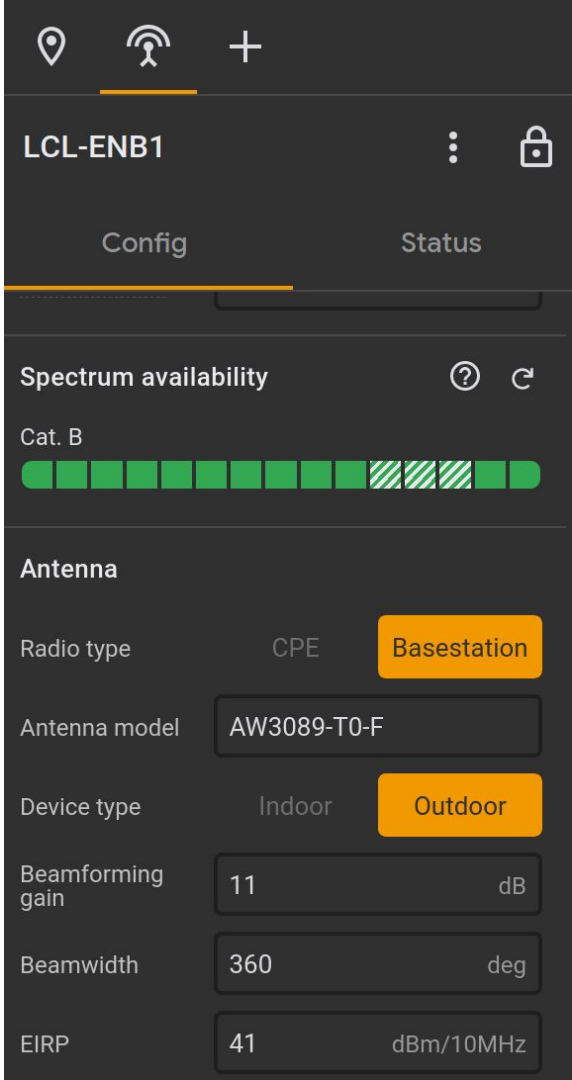
More efficient use of spectrum - Spatial Reuse

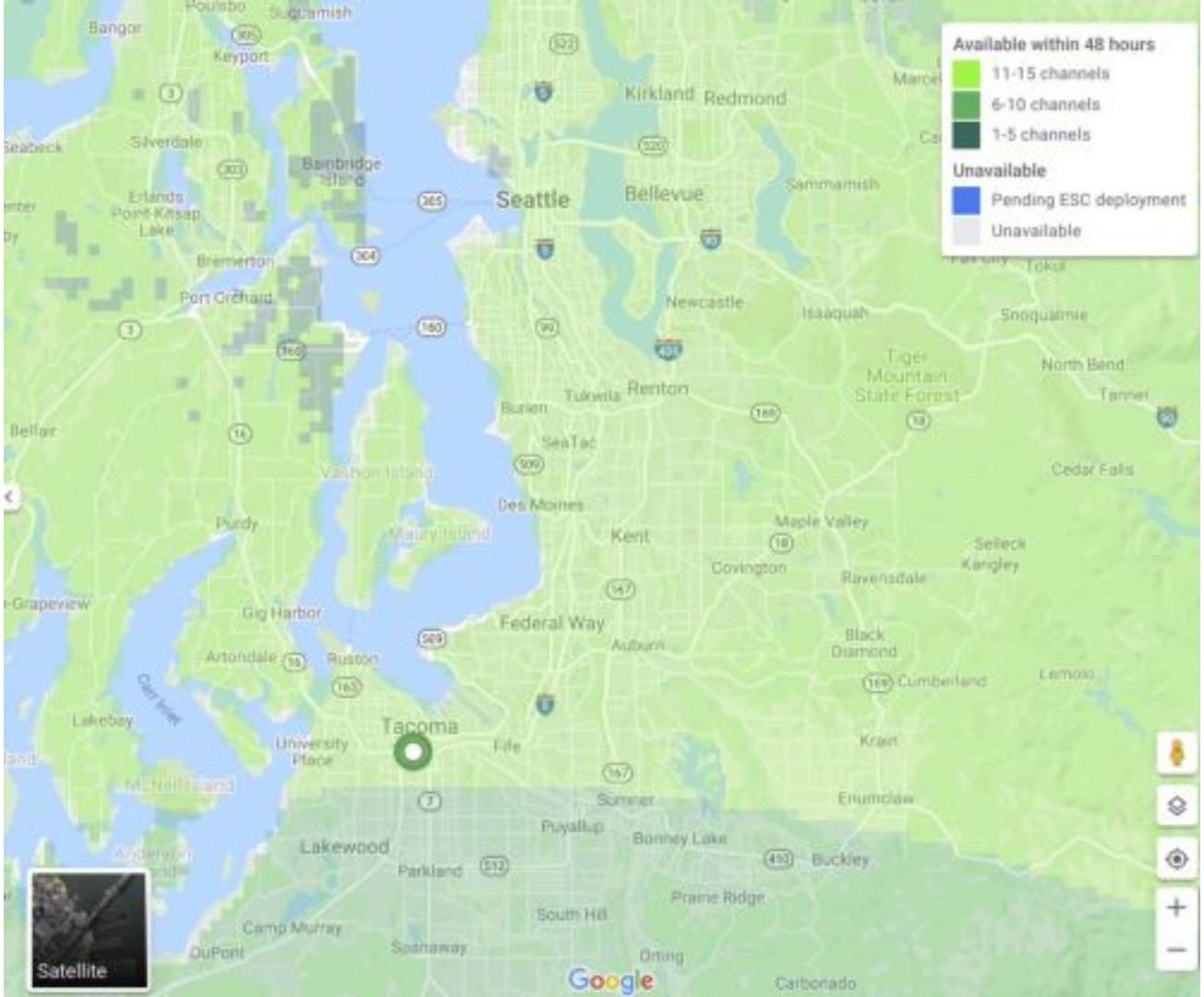




Spectrum Access: CBRS

- Bands opened in April 2020
- Provides 150mhz of “open” access
  - Can be bought by incumbents but if not actively used it is available
- 50mhz of “unlicensed” access
  - GAA only: no incumbents allowed
- Coordinates spectrum through third-party SAS
  - Google has graciously given us access

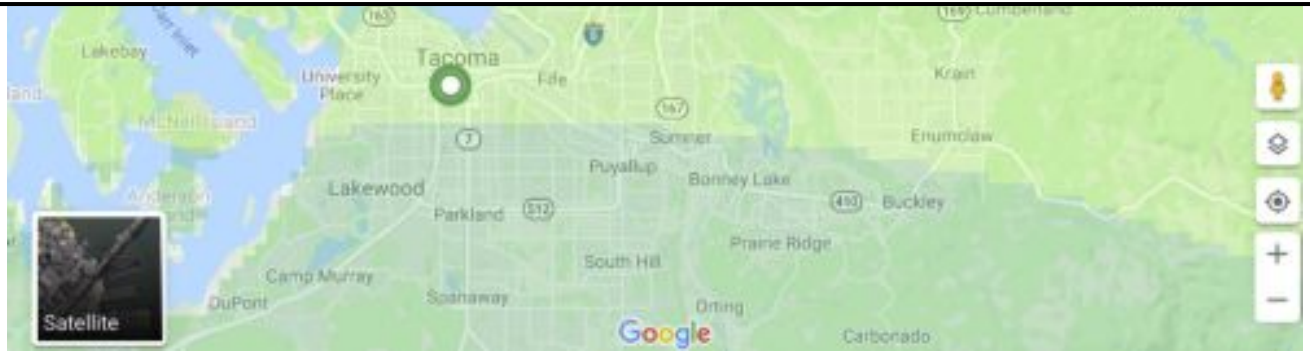



Available within 48 hours
11-15 channels
6-10 channels
1-5 channels
Unavailable
Pending ESC deployment
Unavailable
Seattle
Bellevue
Kirkland
Redmond
Bainbridge Island
Bremerton
Port Orchard
Renton
Tacoma
Federal Way
Kent
Auburn
Lakewood
Puyallup
Gig Harbor
Vashon Island
Maury Island
Des Moines
SeaTac
Burien
Tukwila
Newcastle
Issaquah
Snoqualmie
North Bend
Maple Valley
Covington
Ravensdale
Black Diamond
Enumclaw
Buckley
Sumner
Bonney Lake
Parkland
Prairie Ridge
South Hill
Orting
Carbonado
Lakebay
University Place
Fife
Milton
Edgewood
Fife
Kraut
Cedar Falls
Tiger Mountain State Forest
Satellite
Google



Conclusion:

Small cells maximize frequency reuse, allowing for more frequency to be available to operators





Thanks!

kheimerl@cs.washington.edu
https://kurti.sh