



Fixed Wireless Solutions

> What is Fixed Wireless Access

- + CPE equipment mounted on or near home and aimed at tower
 - + NOT mobile
 - + May be portable
 - + May use the same technologies as mobile (i.e. 4G/5G)
 - + Increasing overlap with IOT and 5G

- + Point to Multipoint

> Wireless Network Performance

- + Signal Strength
 - + Conversations in a crowded room
- + Communication (Spectral) Efficiency
 - + Conversations at a distance
- + Channel width
 - + Lanes on a highway

Grossly simplified: 75 Mbps using a single 20 MHz channel



> Spectrum Bands and Performance

> 900 MHz ISM - Unlicensed

- + Range: 1-3 miles NLOS; 5-10 miles under ideal conditions
- + LOS/NLOS: NLOS
- + Speeds: 10/1
- + Latency: OK
- + Applications: Shifting to SCADA or other low bandwidth applications
Heavy Interference: precision farming GPS correction, phones, baby monitors, toys
Fixed wireless for small cells with NLOS coverage needs

> 2.4 GHz ISM - Unlicensed

- + Range 5-7 miles under ideal conditions
- + LOS/NLOS Line of sight only
- + Speeds 50-100 Mbps / 10-20 Mbps
- + Latency Good - 10-15 ms
- + Applications Traditional band largely replaced by 5 GHz U-NII
WiFi interference
Less available spectrum

> CBRS - Complex Shared License

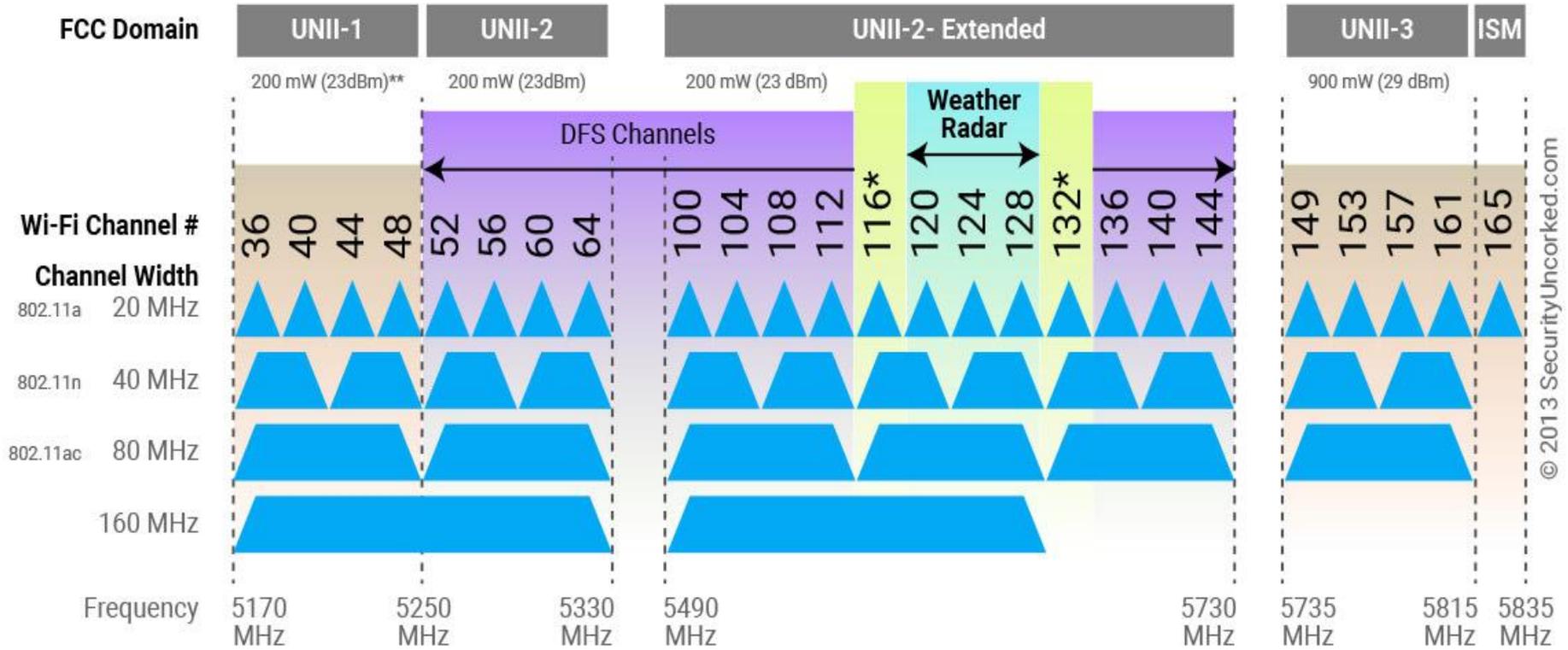
- + Range 3-5 miles typical; 10-15 miles possible under ideal conditions
- + LOS/NLOS NLOS
- + Speeds 25-50 Mbps typical
100/20 possible with additional channels or multiple streams
- + Latency OK - 4G/LTE 30-40 ms -- other versions less
- + Applications FCC regulation changes just taking effect
Tremendous interest and development
Integration w/ spectrum coordination service (SAS) required
Fits into 4G/5G ecosystem and equipment
Private LTE



> 5 GHz U-NII - Unlicensed

- + Range 1-3 miles for 100/20 Mbps; 5-7 miles under ideal conditions
- + LOS/NLOS Line of sight only
- + Speeds 500/50 Mbps+ under ideal conditions
50-100 Mbps / 10-20 Mbps typical
- + Latency Good - 10-15 ms
- + Applications Excellent option for high bandwidth applications
Readily available equipment - proprietary and WiFi based
Very common for fixed wireless applications

802.11ac Channel Allocation (N America)



*Channels 116-144 used for Doppler radar. Channel 132-144 not yet available in USA

**Allowed Power for UNII-1 band increased by FCC from 40 mW to 200 mW in 2014

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> mmWave Unlicensed/Lightly Licensed

- + Range Very short - 250 meters
- + LOS/NLOS LOS only
- + Speeds 500 Mbps+ symmetrical
- + Latency Excellent - <5 ms
- + Applications Fiber alternative in urban and suburban deployments
Heavy rain will impair connections / Oxygen in V-Band
Fiber, wireless PTP, or mesh for backbone

- + Facebook Terragraph initiative driving development



> mmWave Deployment

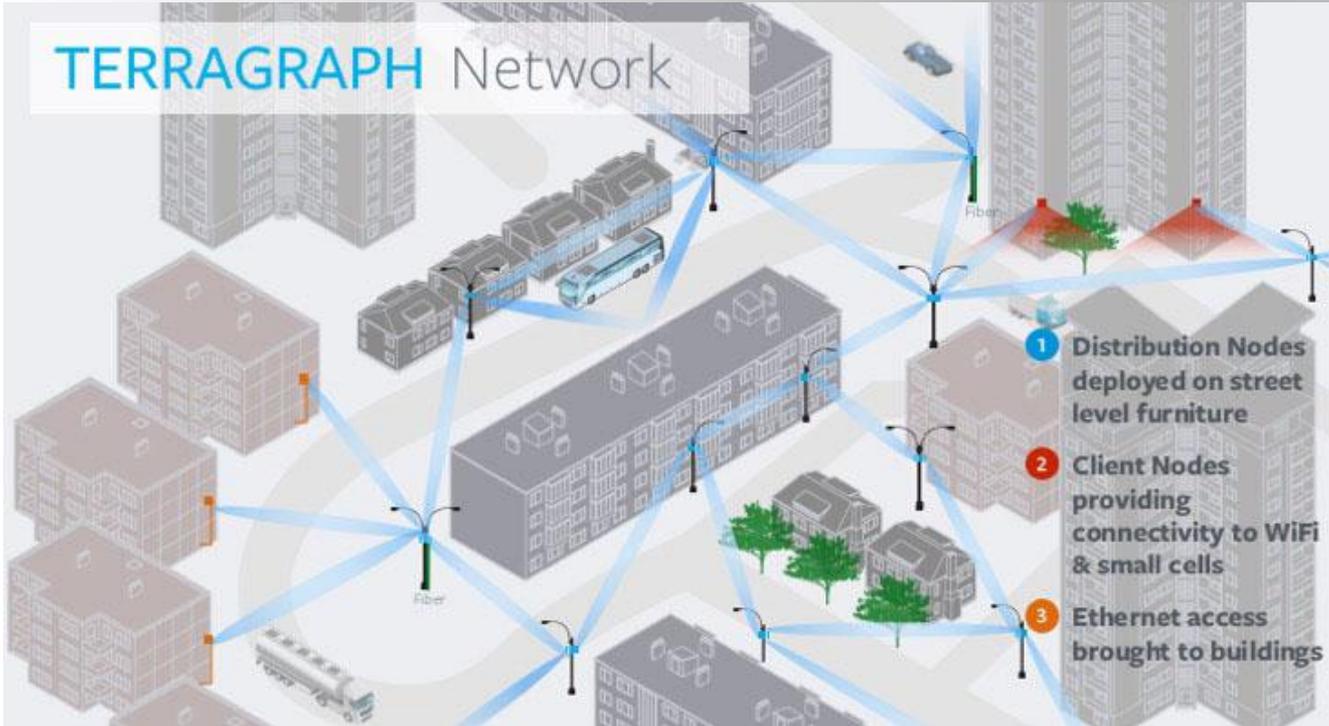
Fiber backbone



Image Source: Siklu

> mmWave Deployment

TERRAGRAPH Network

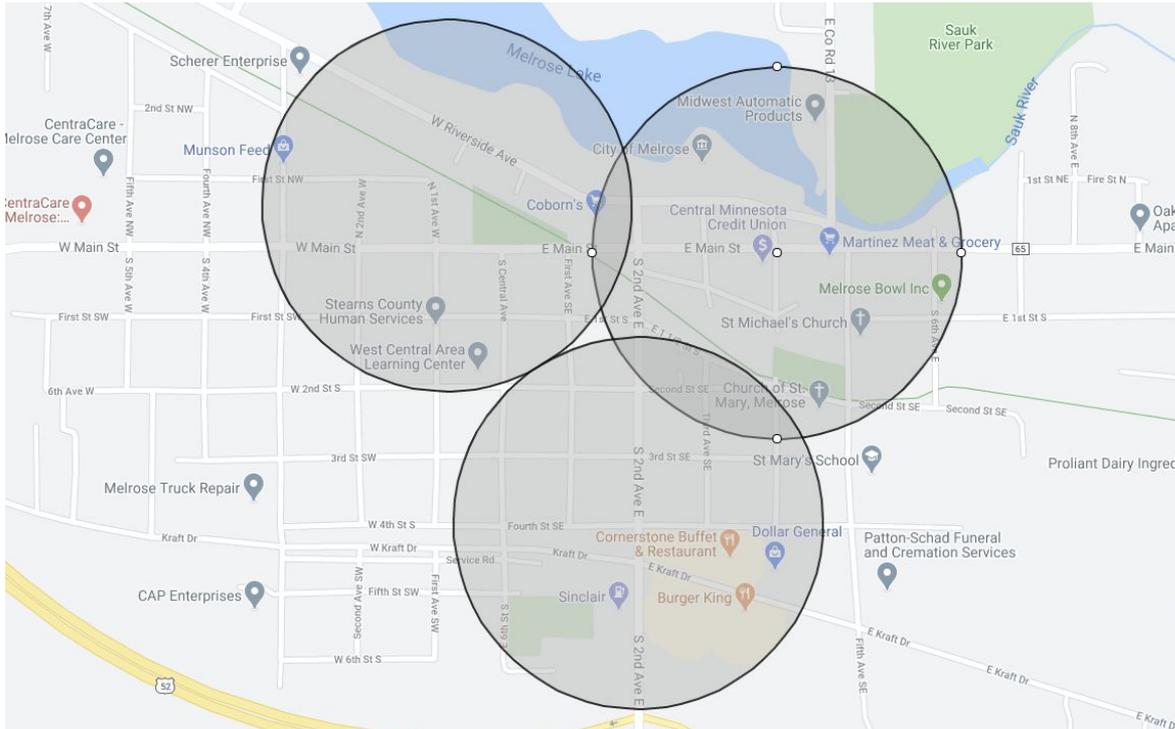


Self healing mesh

- 1 Distribution Nodes deployed on street level furniture
- 2 Client Nodes providing connectivity to WiFi & small cells
- 3 Ethernet access brought to buildings



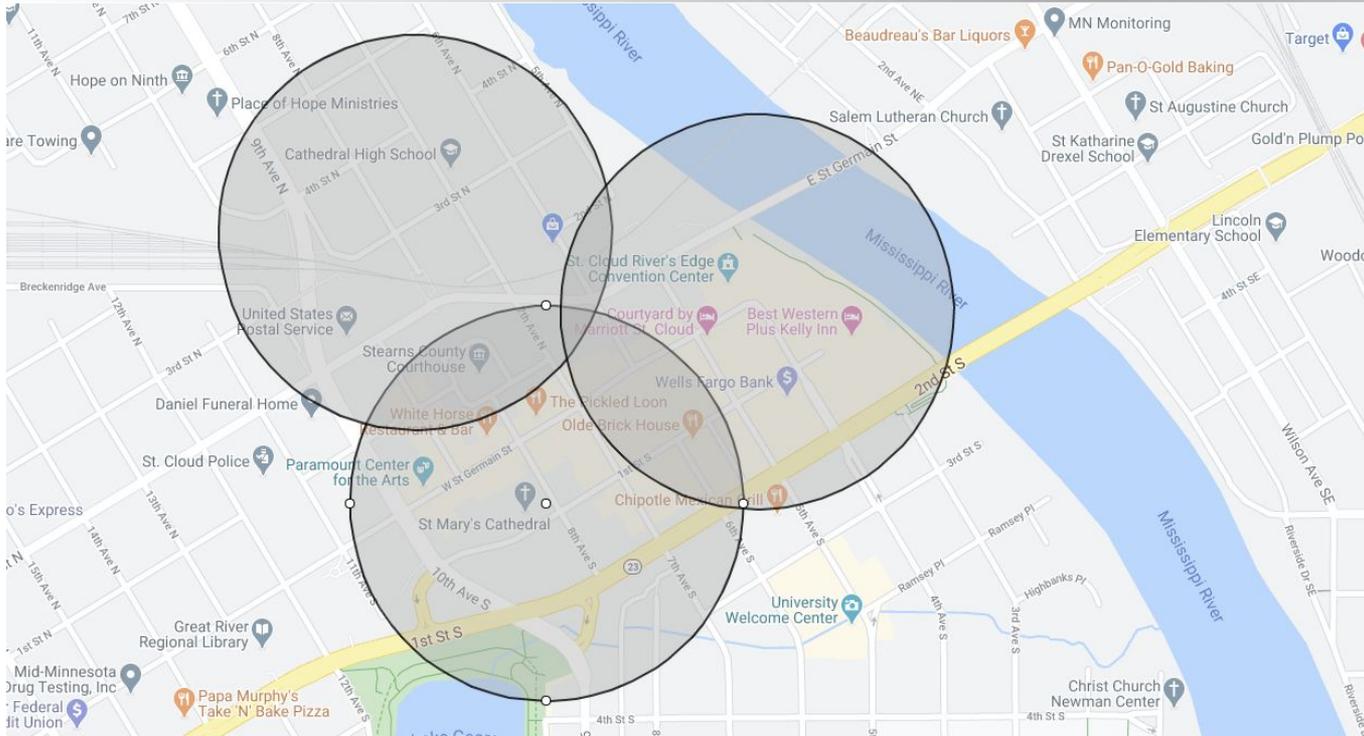
> mmWave Deployment



Small town -- Melrose, MN



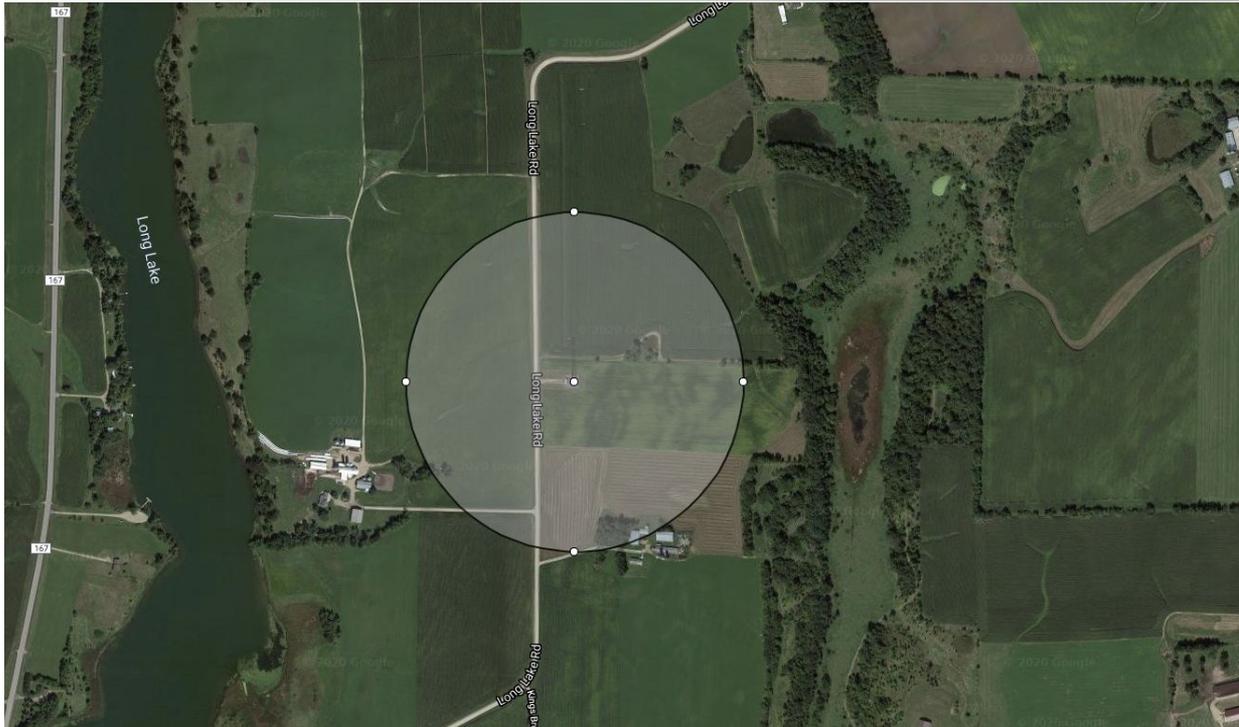
> mmWave Deployment



Downtown St. Cloud



> mmWave Deployment



Rural is not an ideal application

> TVWS - Unlicensed

- + Range 1-3 miles in NLOS conditions; 10-12 miles or more possible
- + LOS/NLOS NLOS
- + Speeds Typically <10/1 today
- + Latency Good - 10-15 ms
- + Applications Excellent potential to fill in coverage in hilly/wooded areas
Significant TV broadcast interference
Spectrum planning and analysis critical to success
NAB/Microsoft working to refine rules with FCC

More hype than reality at this point...



> Satellite

- + Traditional (Geostationary Orbit)
 - + Speeds of up to 25/3
 - + Latency: Very high - 500-700 ms -- not useful for interactive apps
- + Coming Soon? (Low Earth Orbit) -- Starlink, OneWeb, Project Kuiper
 - + Speeds reported of 500 Mbps+ in early Starlink tests
 - + Service offerings unclear
 - + Thousands of satellites -- Starlink initially deployment is 1584 satellites
 - + Latency 20 ms claimed - 25-35 ms potentially likely

> Other Bands

- + EBS/BRS (2.5 GHz) Whitespace - 4G/5G services
 - + Auction late 2020; Tribal Priority Window open now
 - + Spectrum originally allocated for educational use - many areas unused
 - + Two roughly 50 MHz channels, one 16.5 MHz channel
 - + Much available in Northern MN and other areas
 - + Build requirements (50% population at four years; 80% at eight years)

- + mmWave - 5G services
 - + 24 GHz Auction 101 completed 2019
 - + 28 GHz Auction 102 completed 2019
 - + 37/39/47 GHz Auction 103 winding down

> Ag Implications

- + Many IOT sensors likely to be 4G/5G
- + FarmBeats - Microsoft proposal tied to TVWS
 - + Challenges with connectivity to the farm and distribution on the farm
- + Excellent option for portable connectivity
 - + Wind farms, drilling rigs, mobile grain dryers, irrigation
- + Cost of wireline construction a barrier
- + CBRS and private LTE networks

> Deployment Models

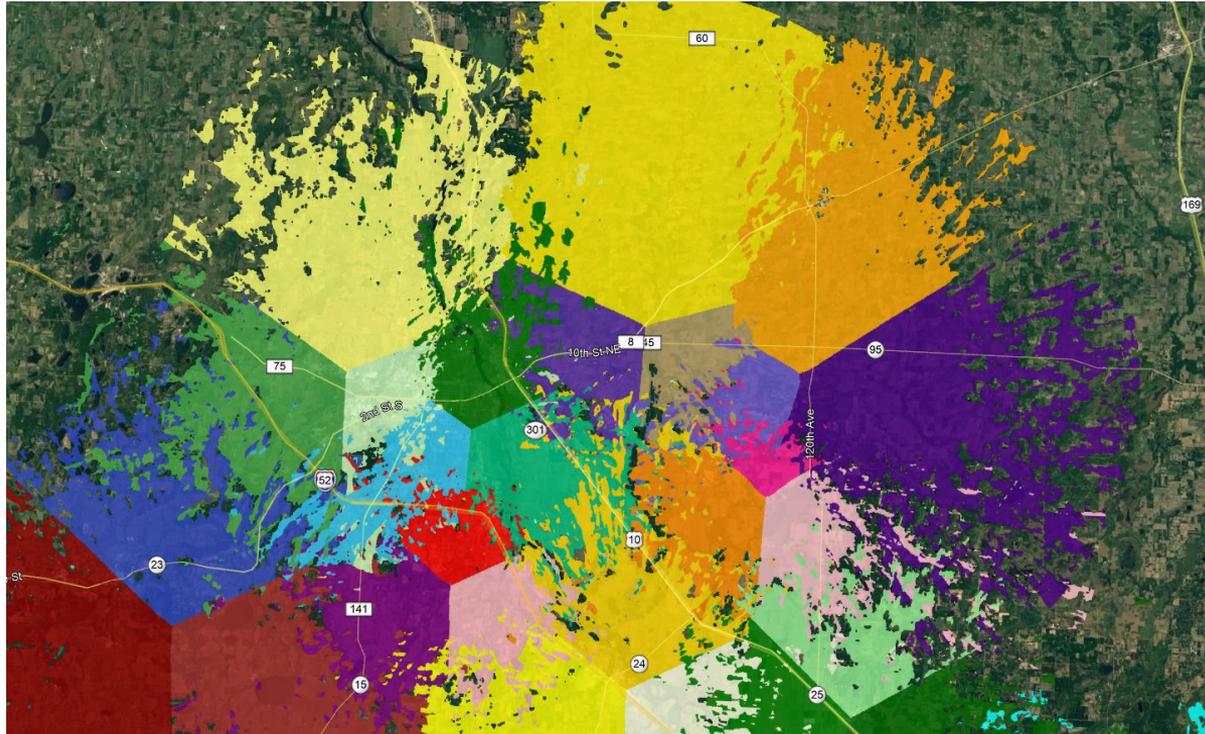
Macro Sites

- + 80% coverage or better
- + Coverage predictions with clutter data
- + Commercial towers provide stability but higher cost

Small Cells

- + Work around obstacles or interference
- + More sites to maintain and manage
- + Enlist customers to host sites
- + Reliability more challenging to ensure

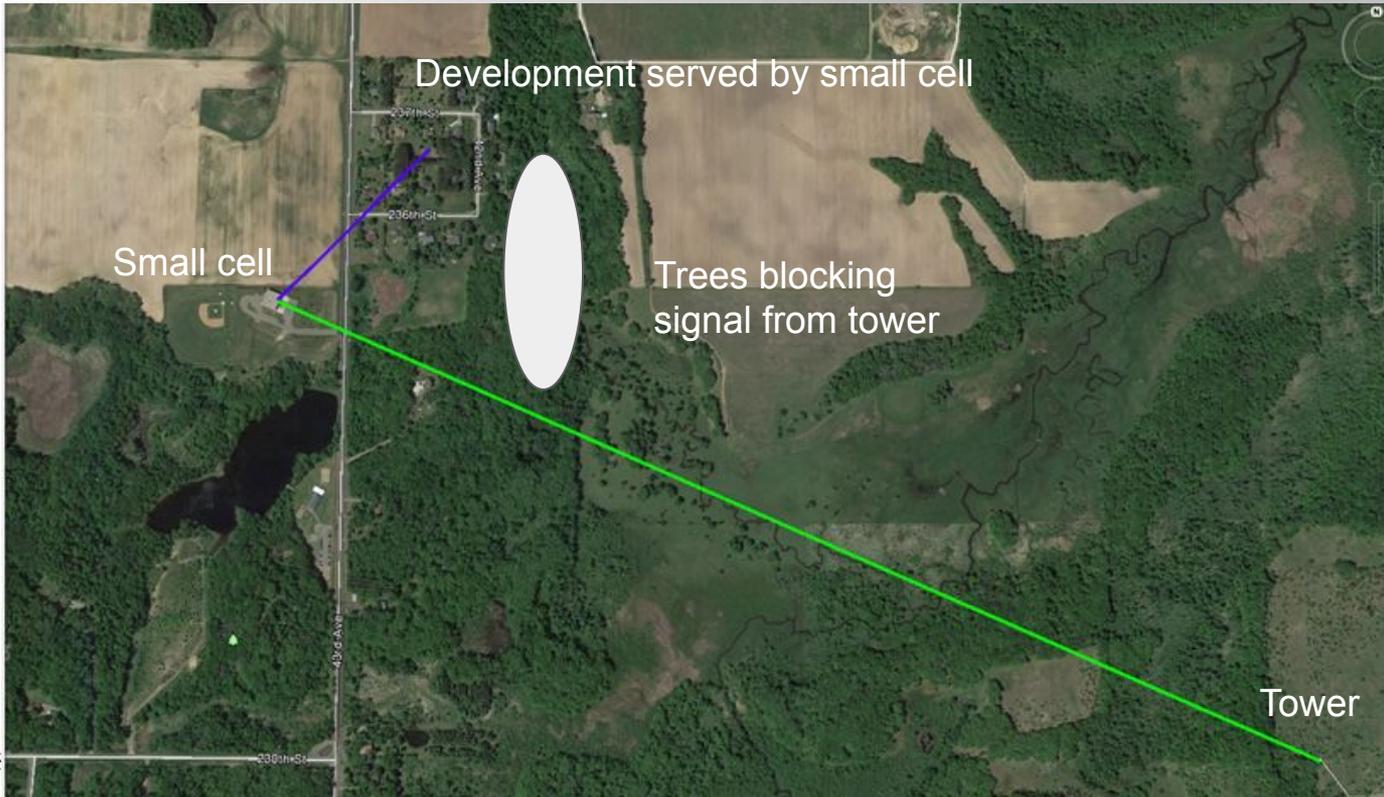
> Macro Site Coverage



Broad coverage predictions

Gaps still visible in some areas

> Small Cells



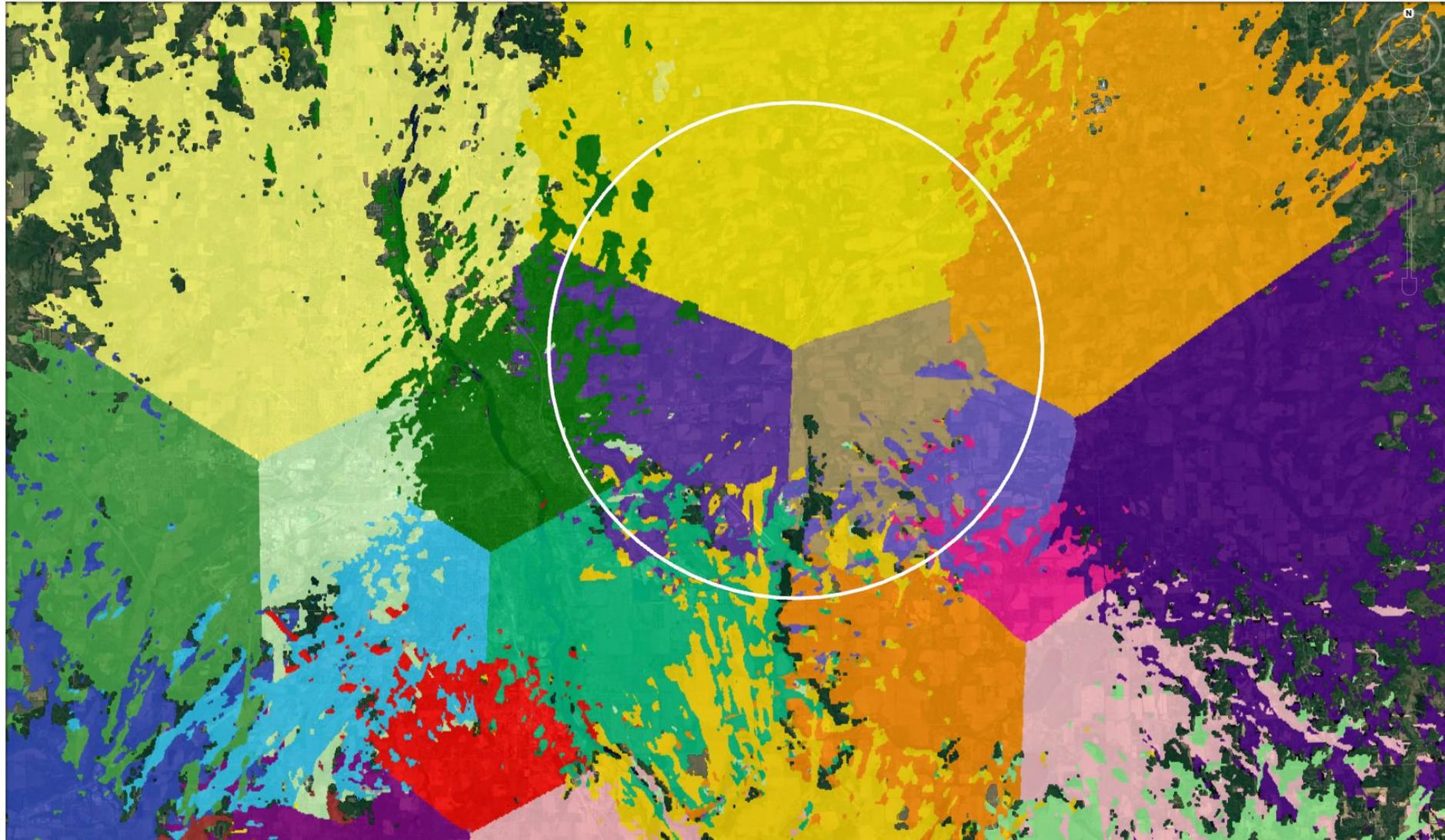
Small cells extend coverage into hard to reach areas

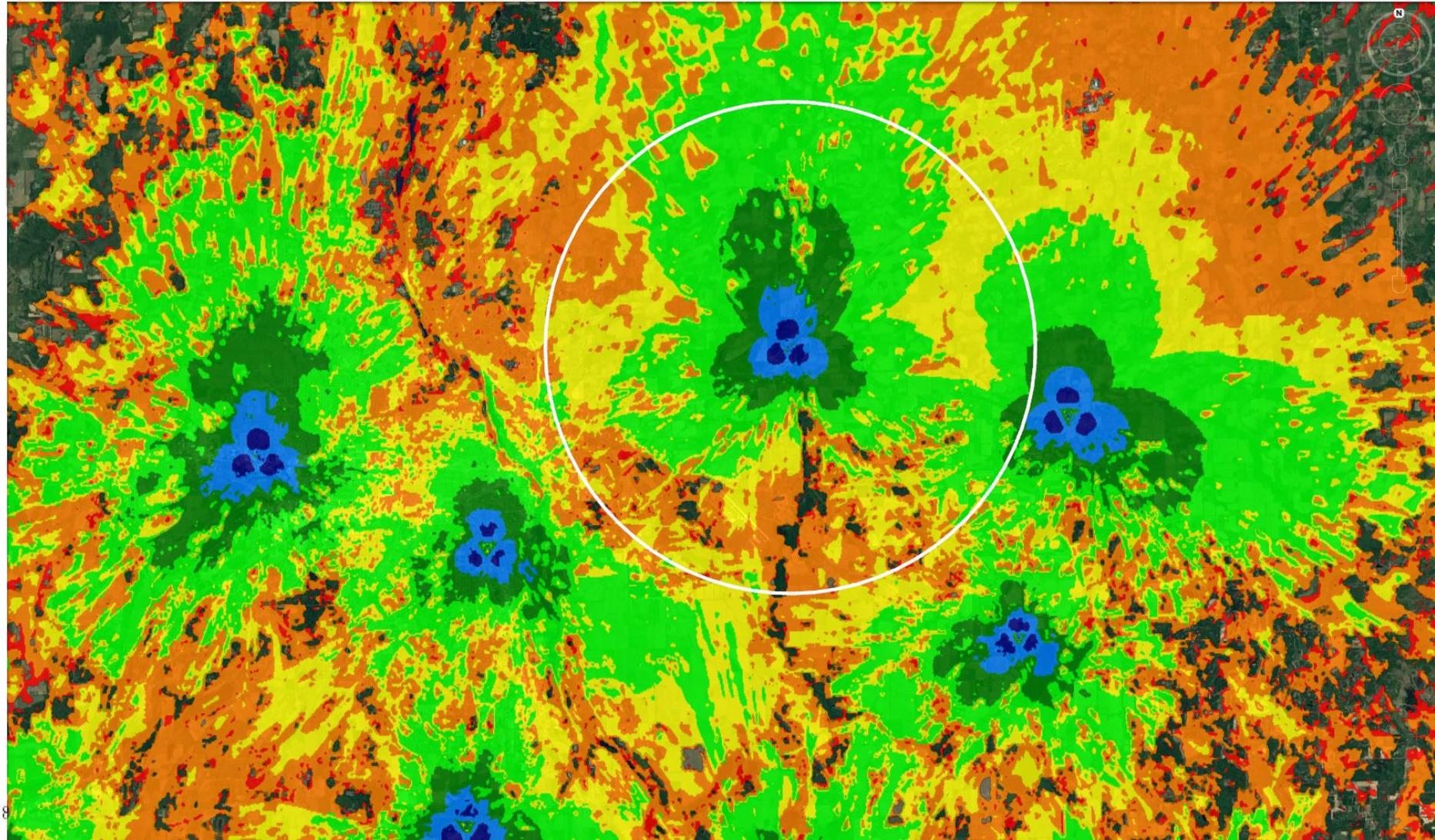
> Example Radio Network Plan

CBRS Band LTE based coverage example

- + 20 MHz channel
- + Downlink: 2x2 MIMO at 64 QAM
- + Uplink: SC-FDMA 16 QAM
- + 6m CPE height
- + Includes relevant clutter data
- + Terrain mixed rolling farmland and slightly hilly wooded areas in central MN

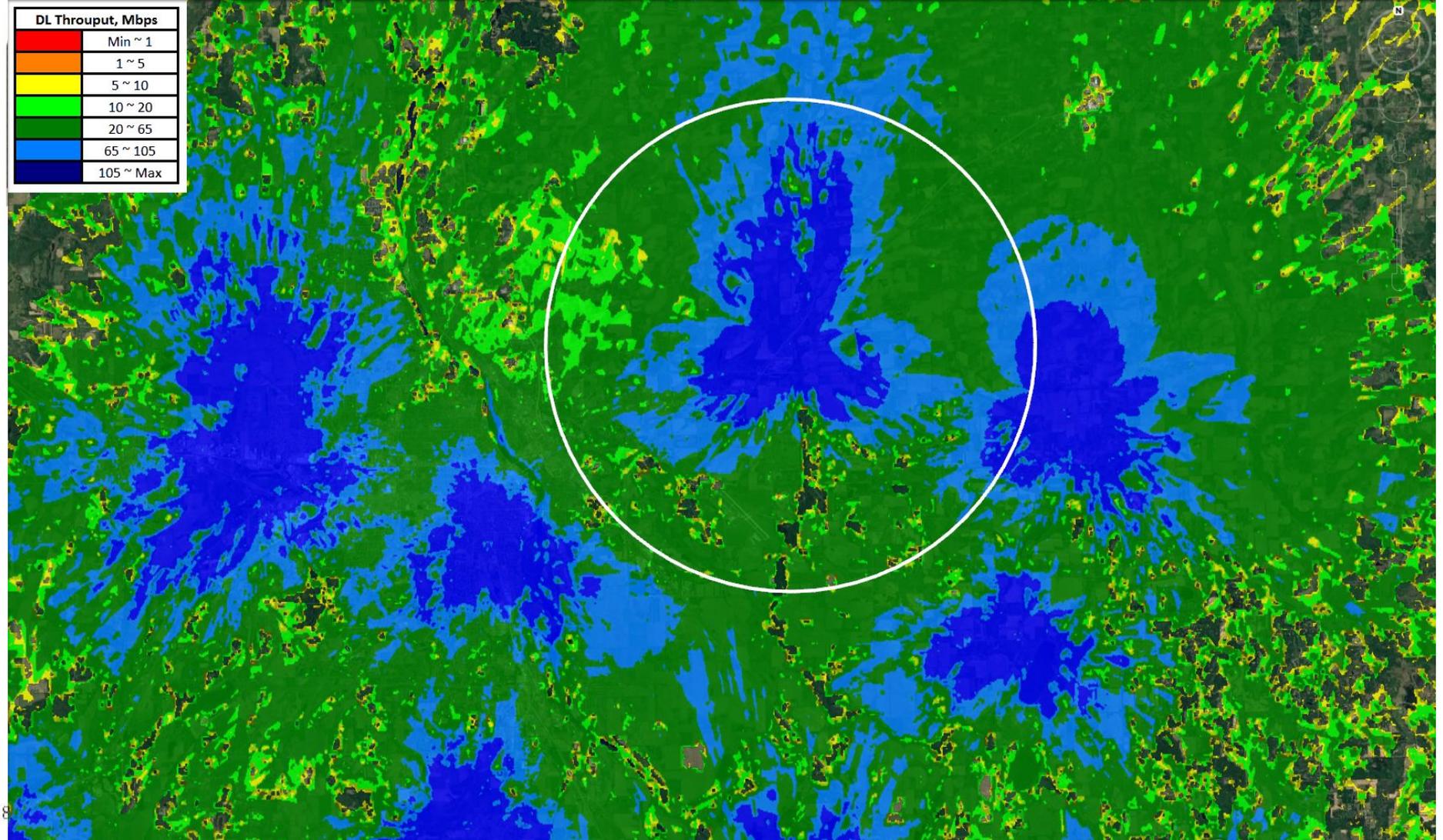
White circle at 5 mile radius for reference



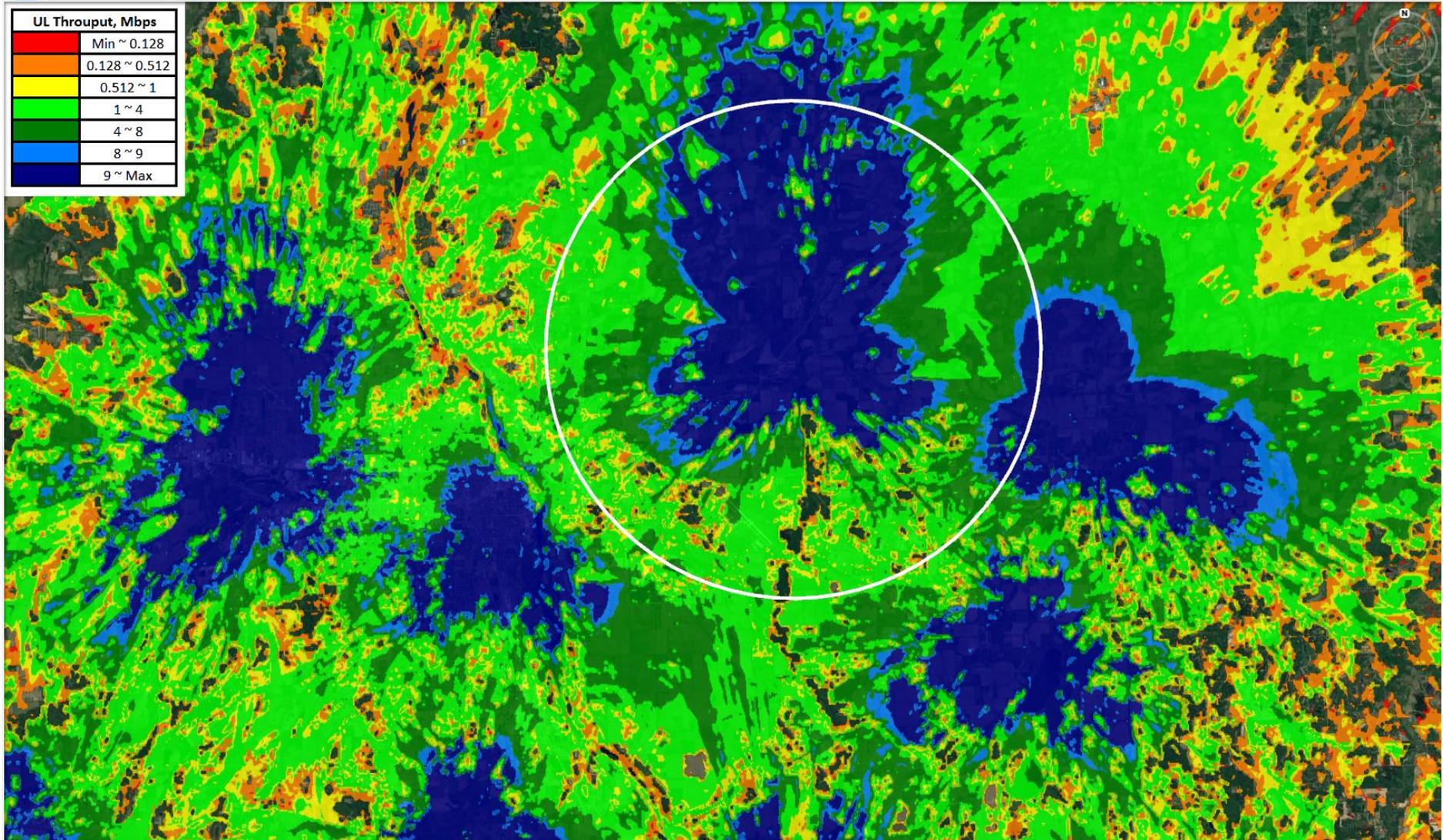


DL Throuput, Mbps

	Min ~ 1
	1 ~ 5
	5 ~ 10
	10 ~ 20
	20 ~ 65
	65 ~ 105
	105 ~ Max



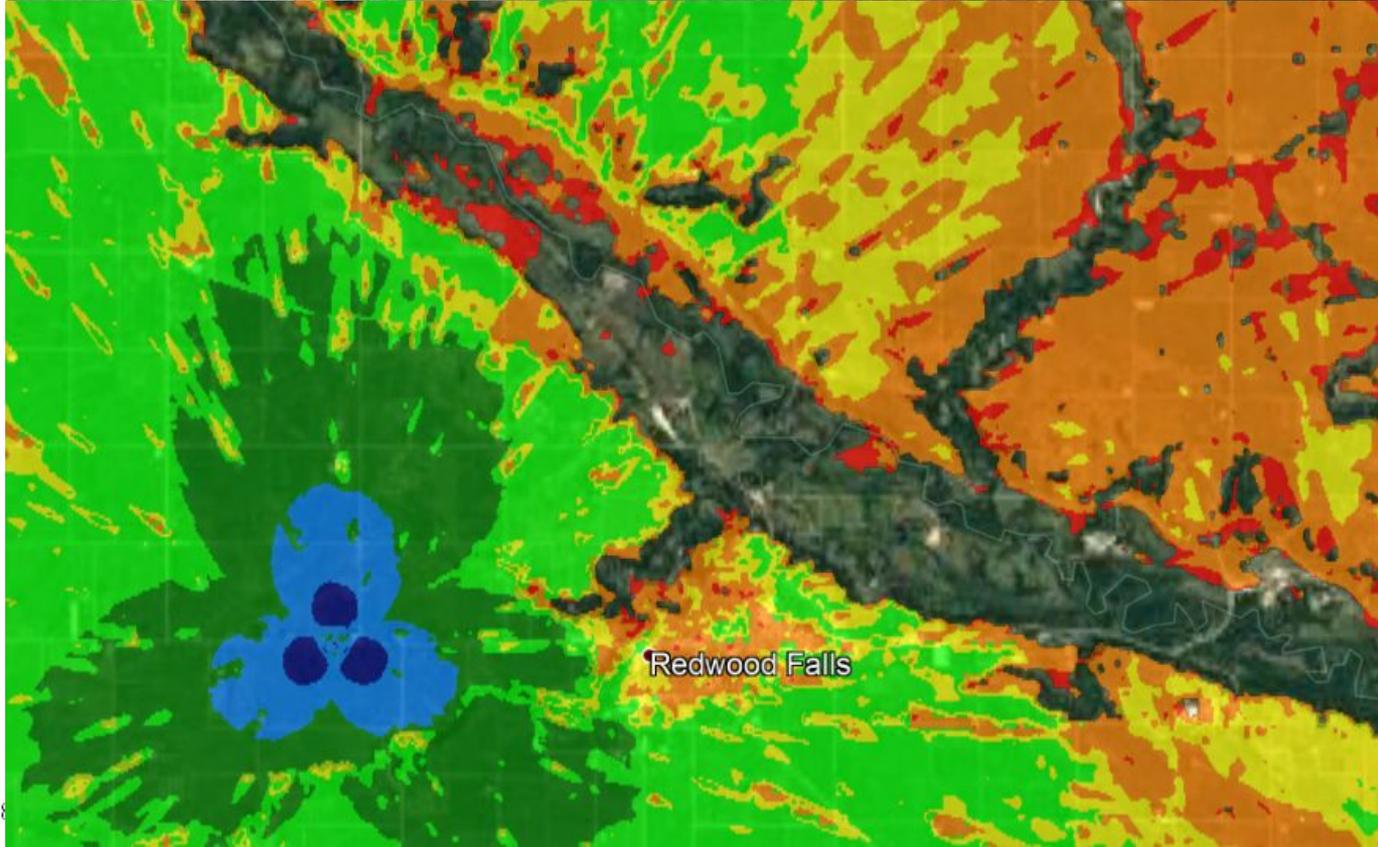
UL Throuput, Mbps	
Red	Min ~ 0.128
Orange	0.128 ~ 0.512
Yellow	0.512 ~ 1
Light Green	1 ~ 4
Dark Green	4 ~ 8
Blue	8 ~ 9
Dark Blue	9 ~ Max



> Terrain Challenges

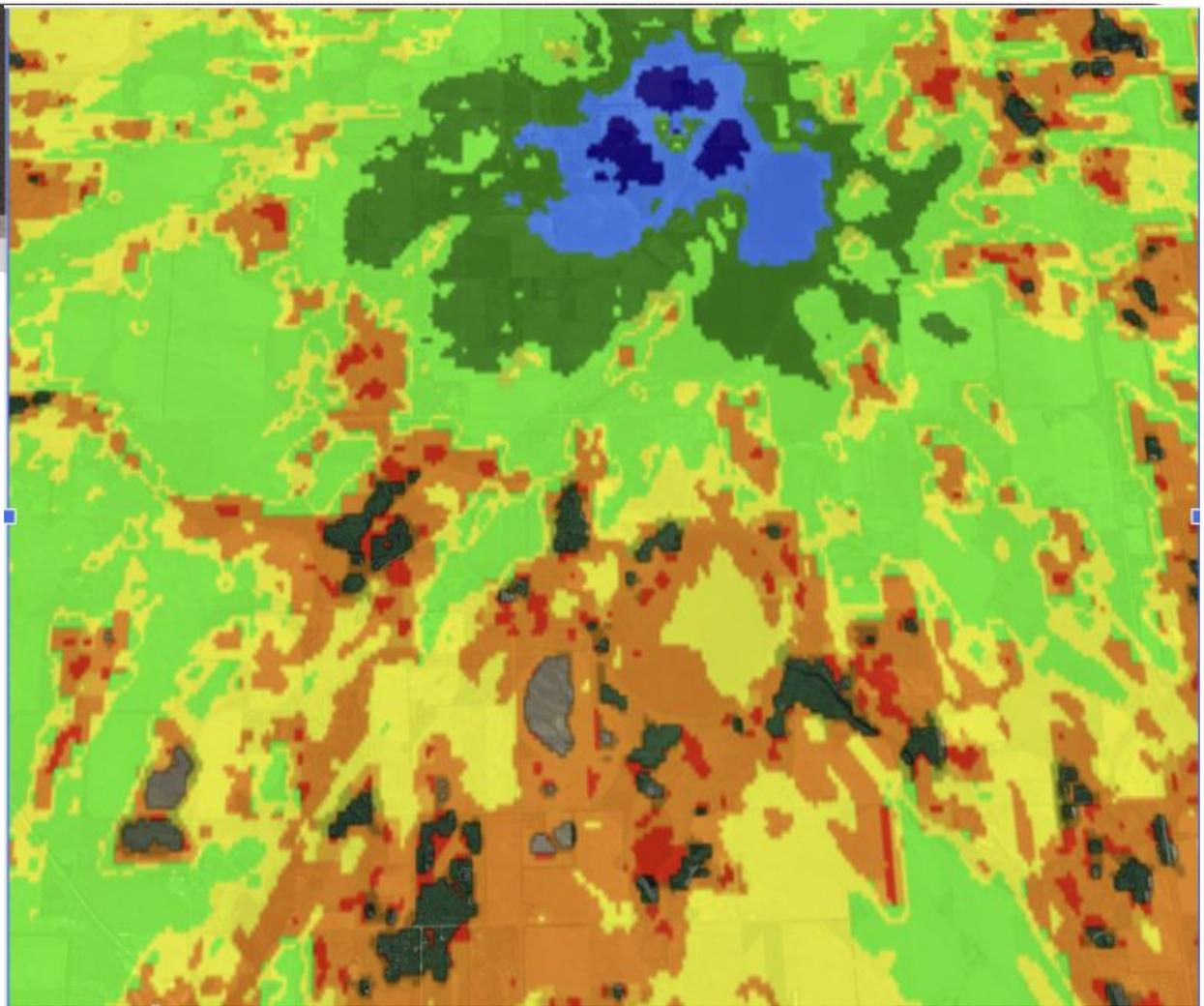
- + Rolling land with shelter belts
- + Urban
- + River valleys or depressions
- + Hills and mountains
- + Forests
- + Lakes
 - + Terrain is a bowl
 - + Typically wooded
 - + Small lot

> Terrain Challenges

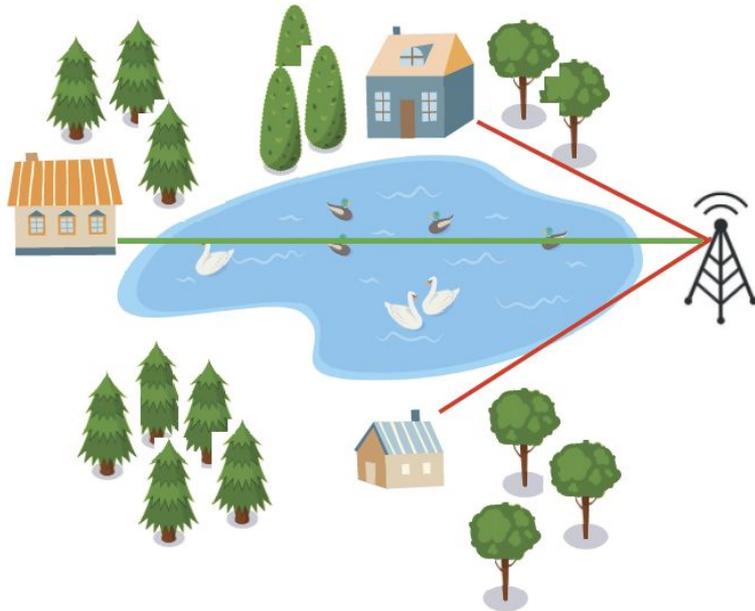


River valleys and depressions

Poor coverage due to forest
and depression



> Lakes



Terrain and foliage challenges

> Lakes



Locations on the near shore of lakes can be a challenge

> Evolving Technology

Traditional

- + Single radio, single antenna, one device at a time
- + Frequency hopping
- + Proprietary technology

Evolving

- + Beamforming - increase connection quality
- + MIMO (layers, chains, spatial streams) - more bandwidth
- + MU-MIMO/OFDMA - increase sector throughput and reduce latency
- + Channel aggregation and re-use - more bandwidth
- + Standards compliant - lower cost



> Technology Comparison

Fiber

- + Best long term solution for 1 Gbps+ capability
- + Most expensive and longest time to market
- + Future proof
- + No mobility

Copper/Coax with fiber to the node

- + Deployed by most legacy operators due to existing infrastructure
- + No mobility
- + Older plant with increasing maintenance
- + Speeds can approach fiber with correct technology: G.fast, DOCSIS 3.1

Wireless

- + Less initial infrastructure costs
- + Fastest time to market
- + Potentially the highest operational expense
- + Not future proof -- maybe
- + Mobile capable depending on technology
- + Capacity is variable with many uncontrollable influences

> Business Challenges

- + Proprietary equipment
 - Tech refresh requires replacing everything including all CPE
 - CPE costs high compared to other technologies
- + Commercial tower terms typically five years long
 - Limited economic or other early exit criteria
 - Escalator each year
 - Value of grain elevators, siloes, water towers increasing