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Converged Networks and Mobility

Overlaying Mid-Band Spectrum Backhaul/Fronthaul onto HFC

A Symbiotic Convergence of Cable & Wireless

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Thanks to My Co-authors:

- Martin Zimmerman, CommScope
- Stuart Eastman, CommScope
- Zoran Maricevic, CommScope

Overlaying Mid-Band Spectrum Backhaul/Fronthaul onto HFC
A Symbiotic Convergence of Cable & Wireless

1. Wireless for (Cable) Dummies
   a. 5G Mid-band (CBRS, C-Band), Antenna 101, Small cell coverage, Back/Mid/Fronthaul

2. Network Capacity Planning for Midhaul or Fronthaul Small Cells
   a. Midhaul/Fronthaul Interface capacity requirements, CBRS RF Simulation study
   b. HFC Capacity Planning – DOCSIS 3.1 and 4.0

3. Mapping Mid-band Small Cells to HFC
   a. N+3 Case Study; Metro-Suburban area N+6 Case Study

4. Summary
   a. Lessons Learned, DAA Synergies, Business Opportunities, Conclusion

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Wireless for (Cable) Dummies

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Mid-Band Spectrum (3 – 6 GHz):

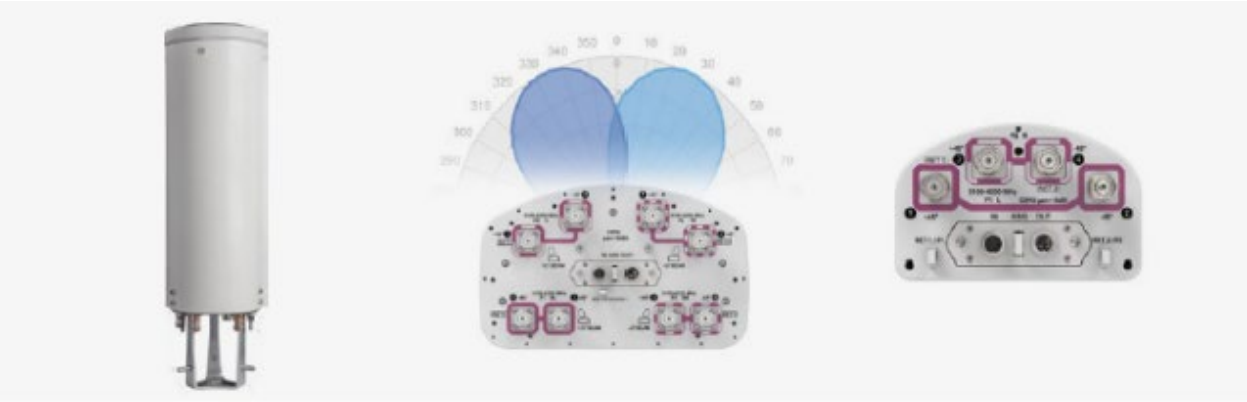
- Mid-Band will become the 5G workhorse
  - Excellent Capacity vs. Reach

- C-Band – MNO (Verizon/AT&T/T-Mobile)
  - Licensed, 3700-3980MHz
  - EIRP = 76dBm

- CBRS –
  - Tiered (Military/PAL/GAA), 3550-3700 MHz
    - PAL limited to 70 of 150 MHz
  - EIRP = 47dBm

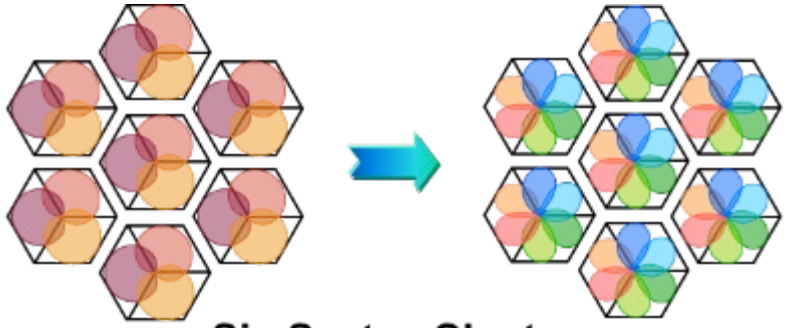
Antenna 101

Omni vs. Sectored Antenna



Omni antenna solutions | Twin beam antennas | Sector antennas

Increasing Sector Arrays



EIRP considerations (Effective Isotropic Radiated Power)

Link budget vs EIRP

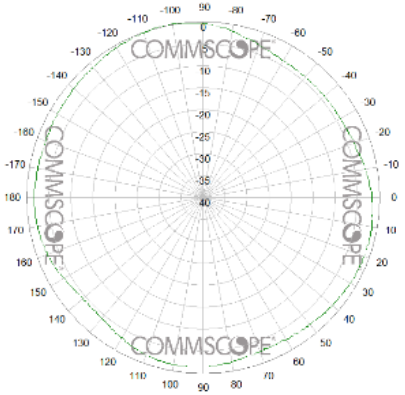
$$\text{Link Budget} = P_{TX} + G_{TX} + G_{RX} - L_{FS} - L_{other}$$

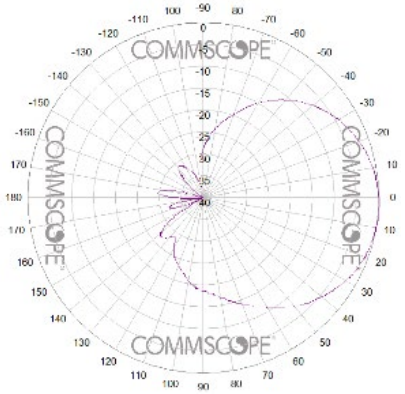
$$\text{EIRP} = P_{TX} + G_{TX}$$

If EIRP is limited, can focus on G_{RX}

Antenna Gain

Azimuth patterns





Low Gain Patterns

5 dBi

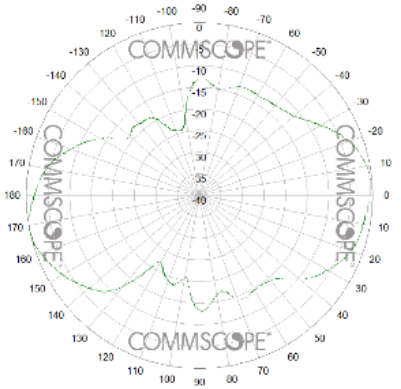
High Gain Patterns

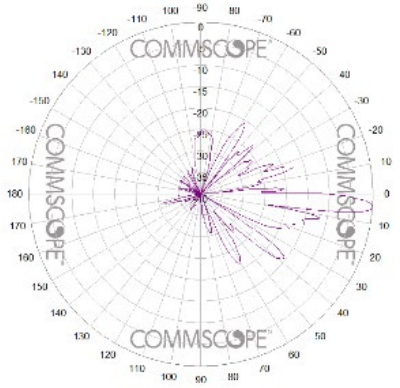
18 dBi

More gain in one place →

Less gain somewhere else!

Elevation patterns

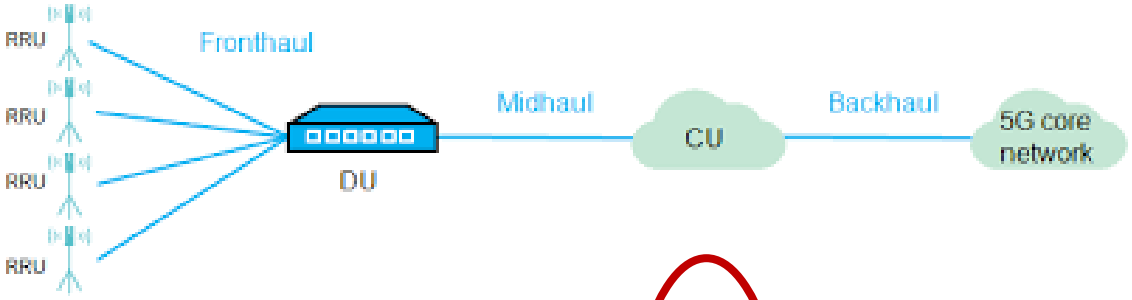


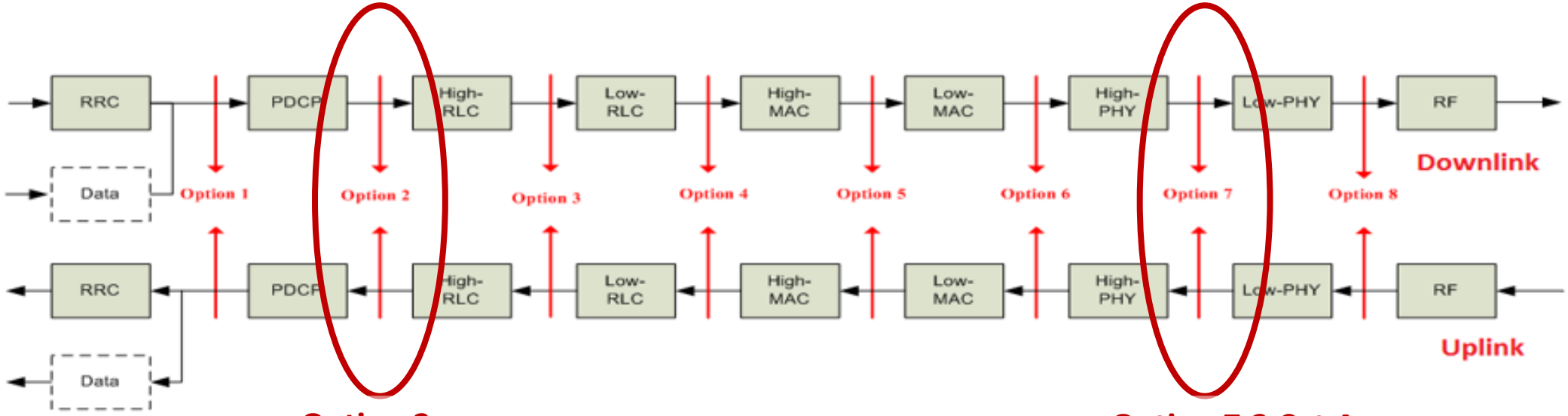


Small Cell Coverage

Mid-band Small Cell Ranges	EIRP	Mounting Location	Reasonable Range (more Urban)	Stretch Range (more Rural)
C-Band	52-58	Streetlight	600m (~2000')	900m (~3000')
		Strand	425m (~1400')	640m (~2100')
CBRS	47-53	Streetlight	340m (~1150')	500m (~1650')
		Strand	240m (~800')	360m (~1200')
Wi-Fi 6E 6 GHz	36	Streetlight	70m (~240')	100m (~325')
		Strand	50m (~175')	70m (~240')

RAN Interfaces – Back/Mid/Fronthaul





Option 2 – Midhaul

Option 7.2 Cat A – Fronthaul

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Capacity Planning for Mid/Fronthaul Small Cells

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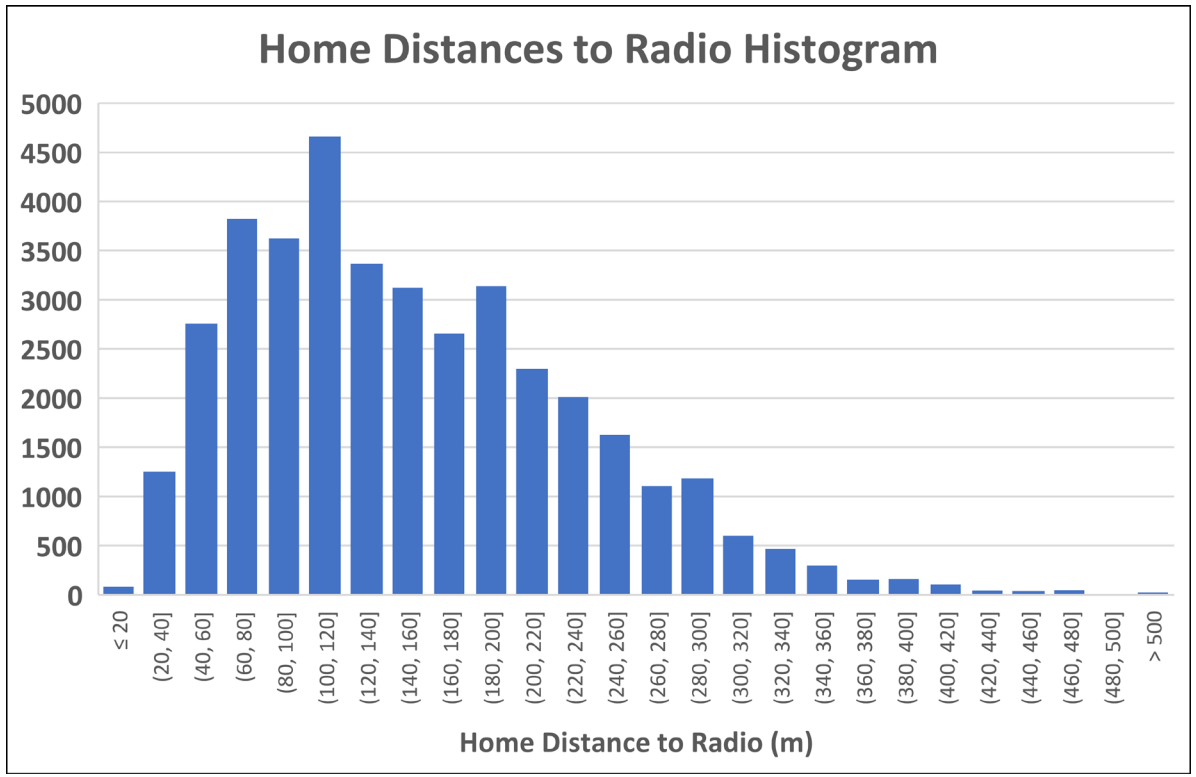
xHaul Capacity Estimates for various Antenna configurations

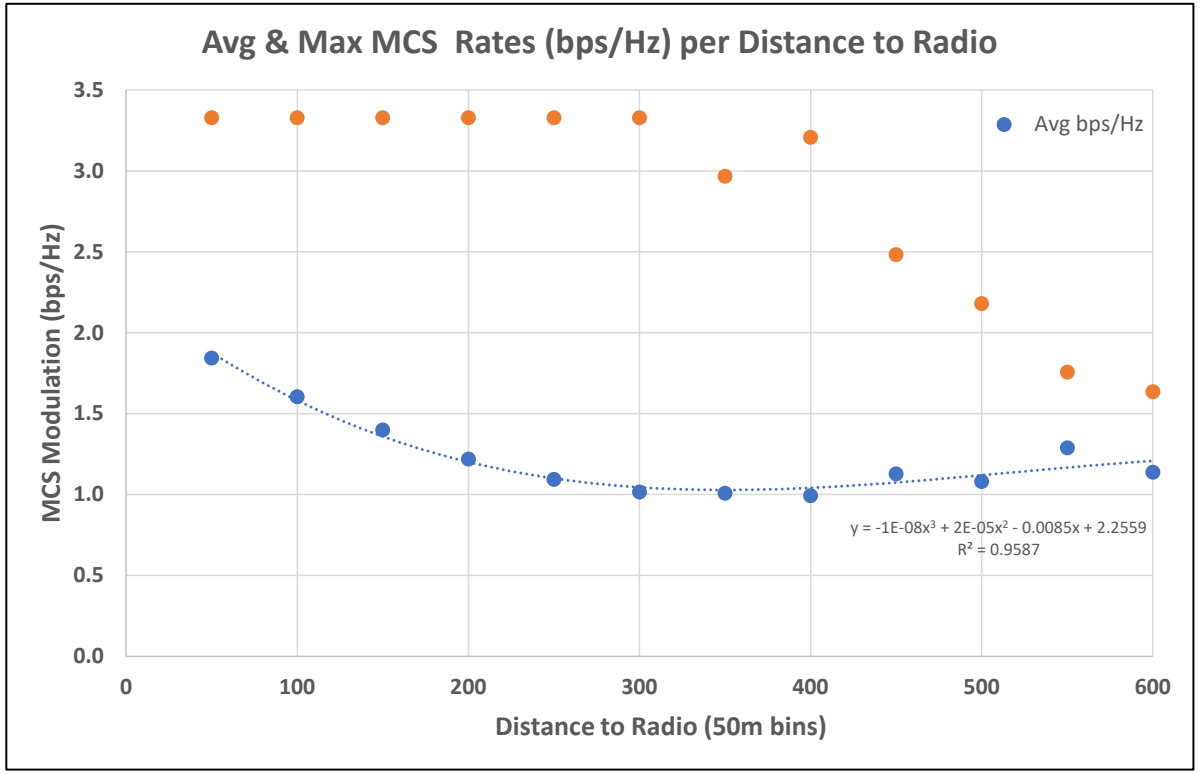
Antenna	MIMO	Location	Channel Bandwidth	Sectors per cell	Midhaul DL	Midhaul UL	Fronthaul DL	Fronthaul UL
2T2R	2x2	Strand or Streetlight	40MHz, DL only	1	525 Mbps	-	1.9 Gbps	-
			40MHz	1	420 Mbps	62 Mbps	1.9 Gbps	2.0 Gbps
4T4R	4x4	Strand or Streetlight	40MHz, DL only	1	1050 Mbps	-	3.8 Gbps	-
			40MHz	1	840 Mbps	125 Mbps	3.8 Gbps	4.1 Gbps
			100MHz	1	2.2 Gbps	320 Mbps	9.7 Gbps	10.6 Gbps
8T8R	BF 2x2		40MHz	3	0.6 – 1.1 Gbps	90 – 165 Mbps	2.8 – 5.0 Gbps	3.1 – 5.5 Gbps
	4x4	Mini-Macro	40MHz	3	1.3 – 2.2 Gbps	180 – 333 Mbps	5.7 – 10 Gbps	6.2 – 11 Gbps
	4x4		100MHz	3	3.3 – 5.8 Gbps	500 – 850 Mbps	15 – 26 Gbps	16 – 28 Gbps
64T64R	8x4	Macro	100MHz	6	10 – 23 Gbps	0.7 – 1.7 Gbps	44 –104 Gbps	24 – 56 Gbps

CBRS RF Simulation Case Study

CBRS Metro area Study – Home Distances to Radio histogram

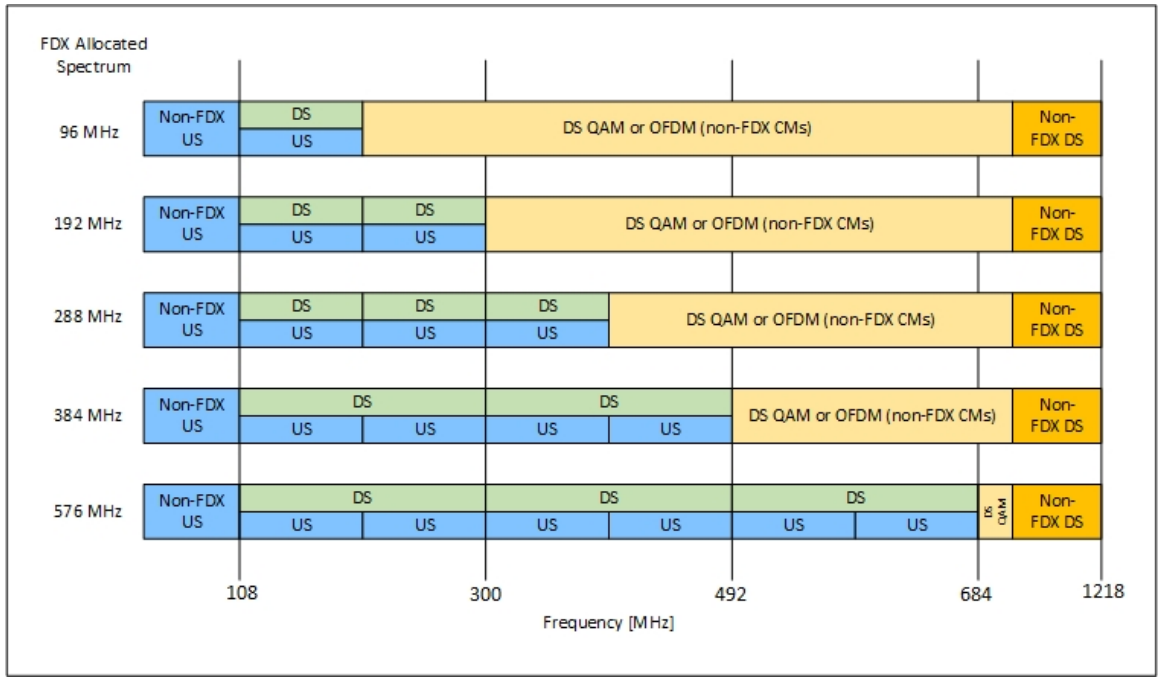


Avg & Max MCS Rates per Distance to Radio

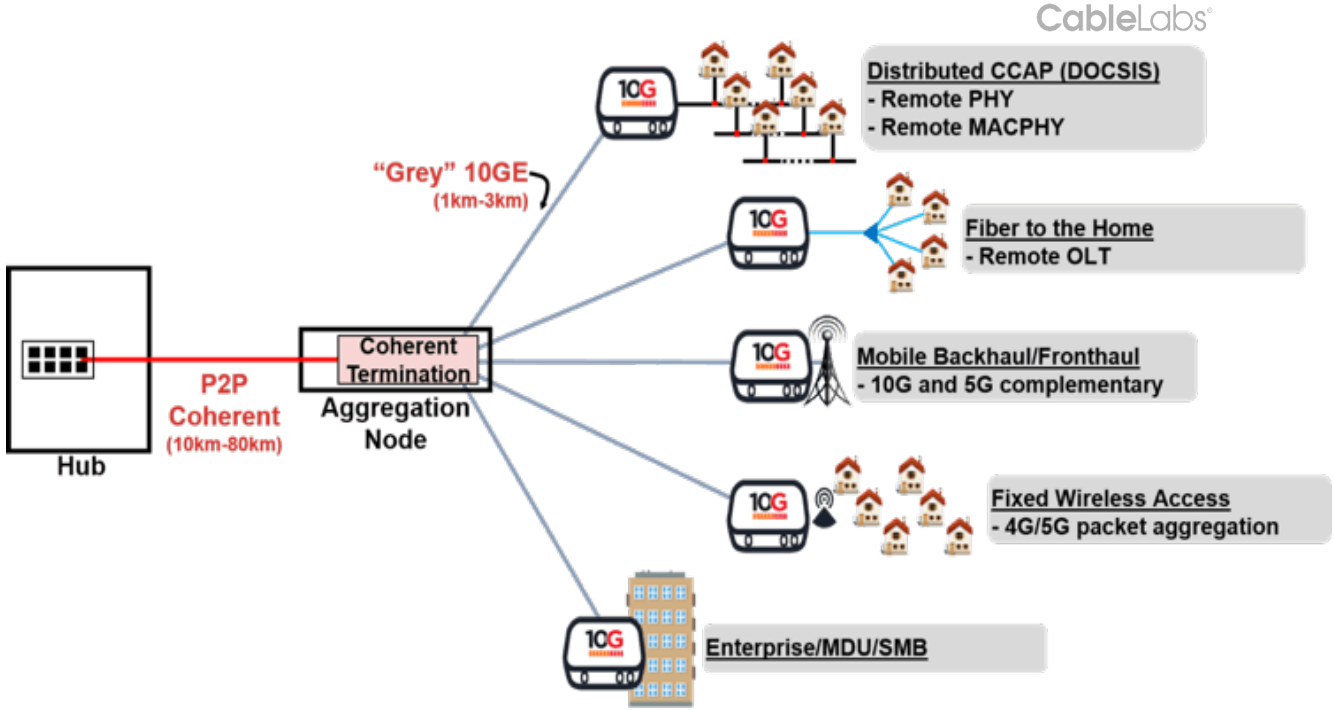


HFC Capacity Planning – DOCSIS 3.1/4.0, 10G

DOCSIS 4.0 Upstream Spectrum Options



10G™ Converged Optical Network – Distributed Access Architecture vision



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HFC Case Study for N+3 nodes of varying Homes Passed densities

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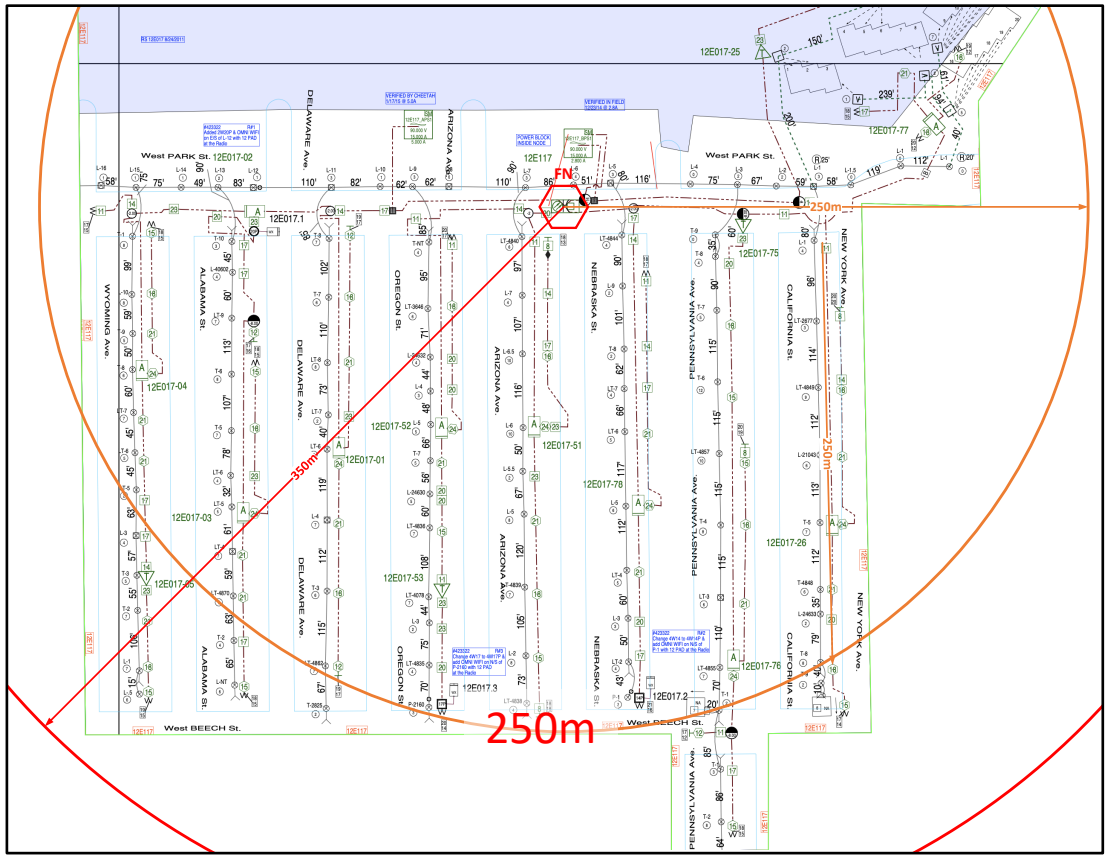
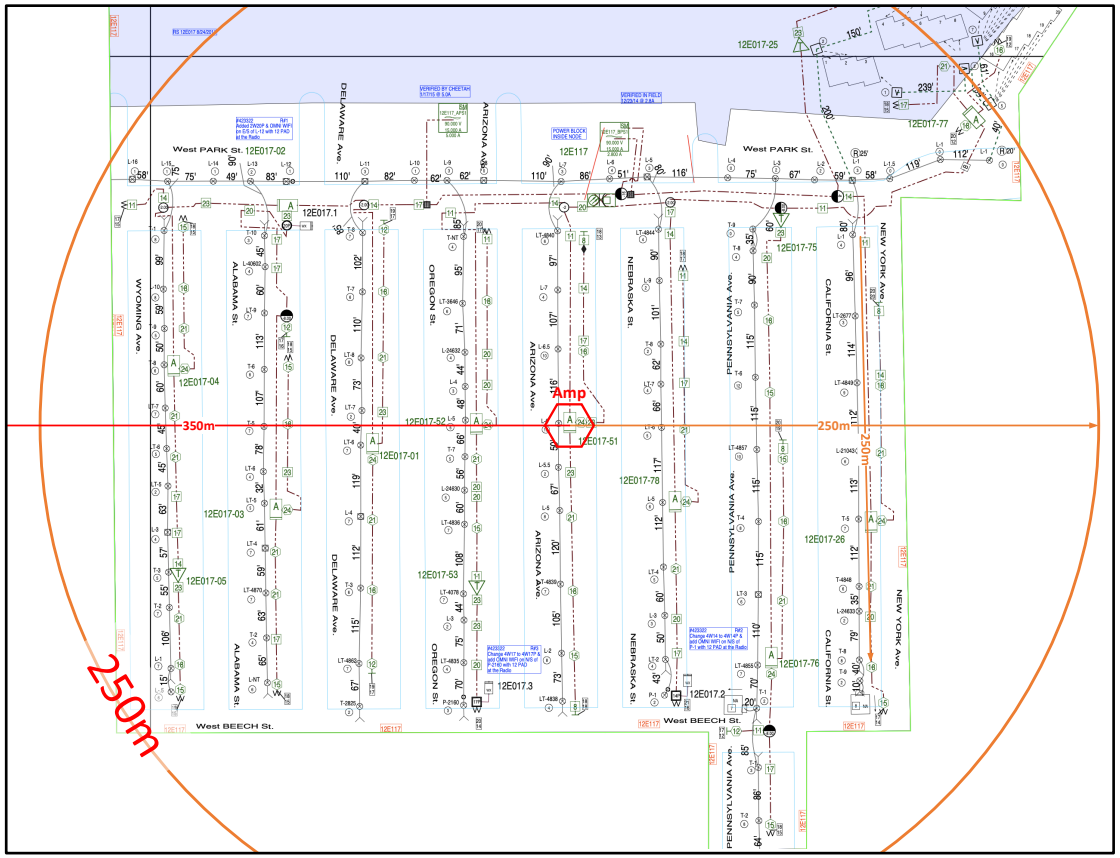
High-Density N+2 – 274 HP/mile

Small Cell adjacent to Fiber Node

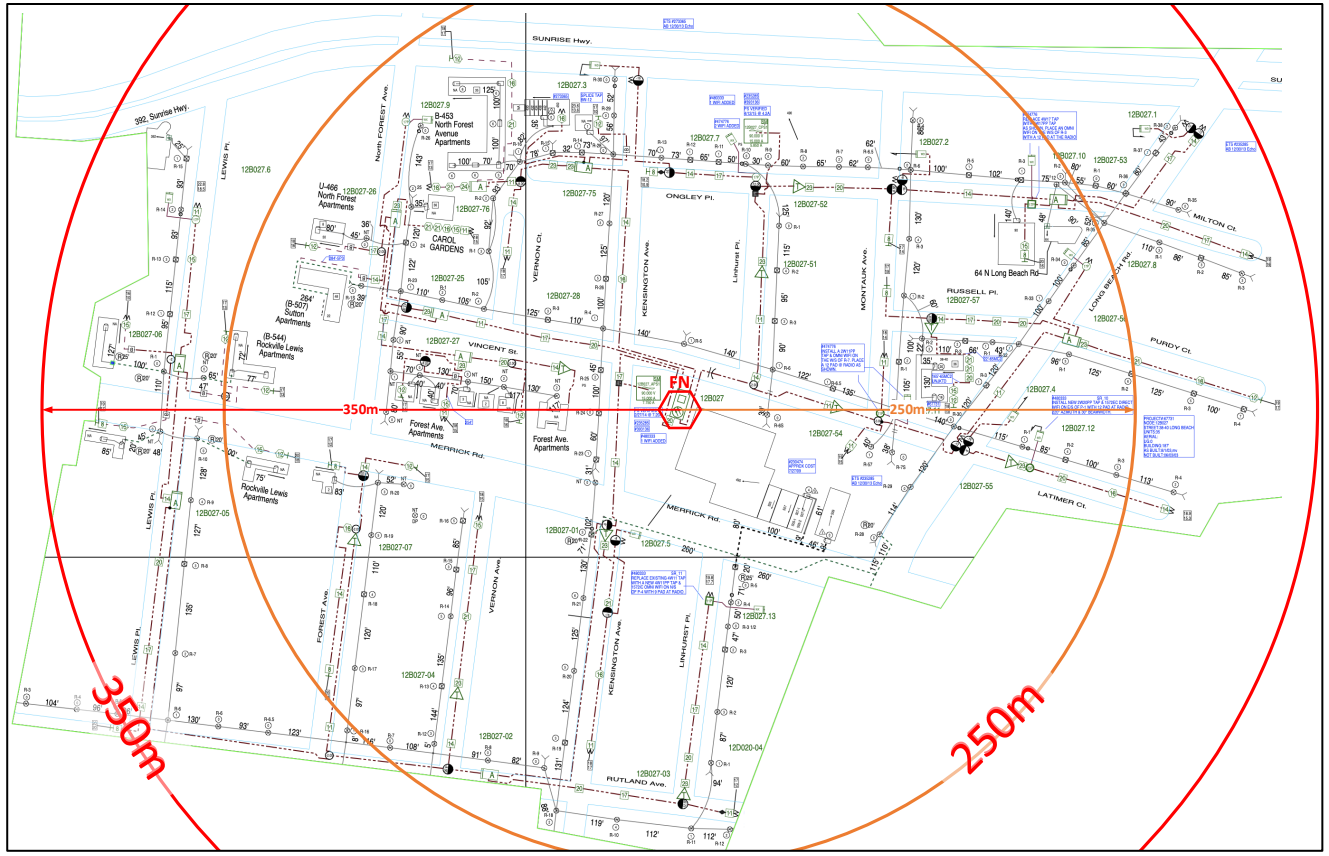


Small Cell on HFC Coax



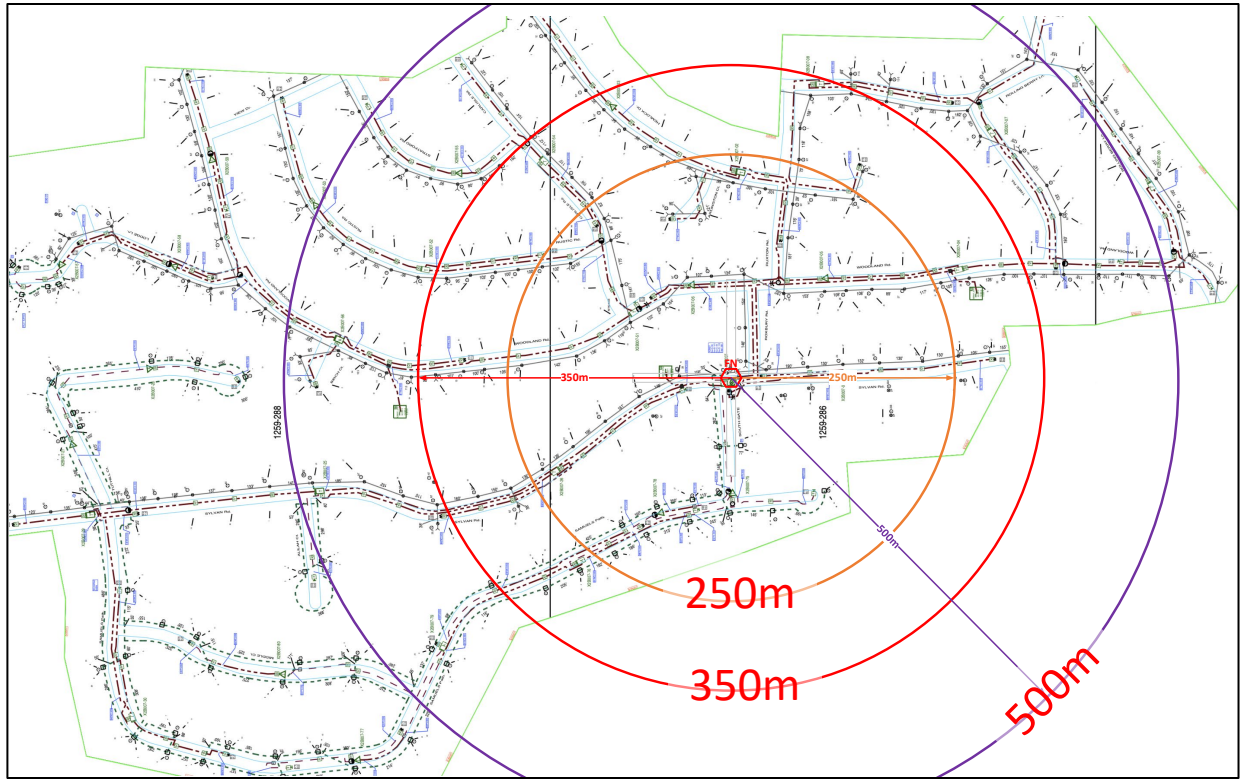
Med-High Density N+3 – 187 HP/mile

Small Cell adjacent to Fiber Node

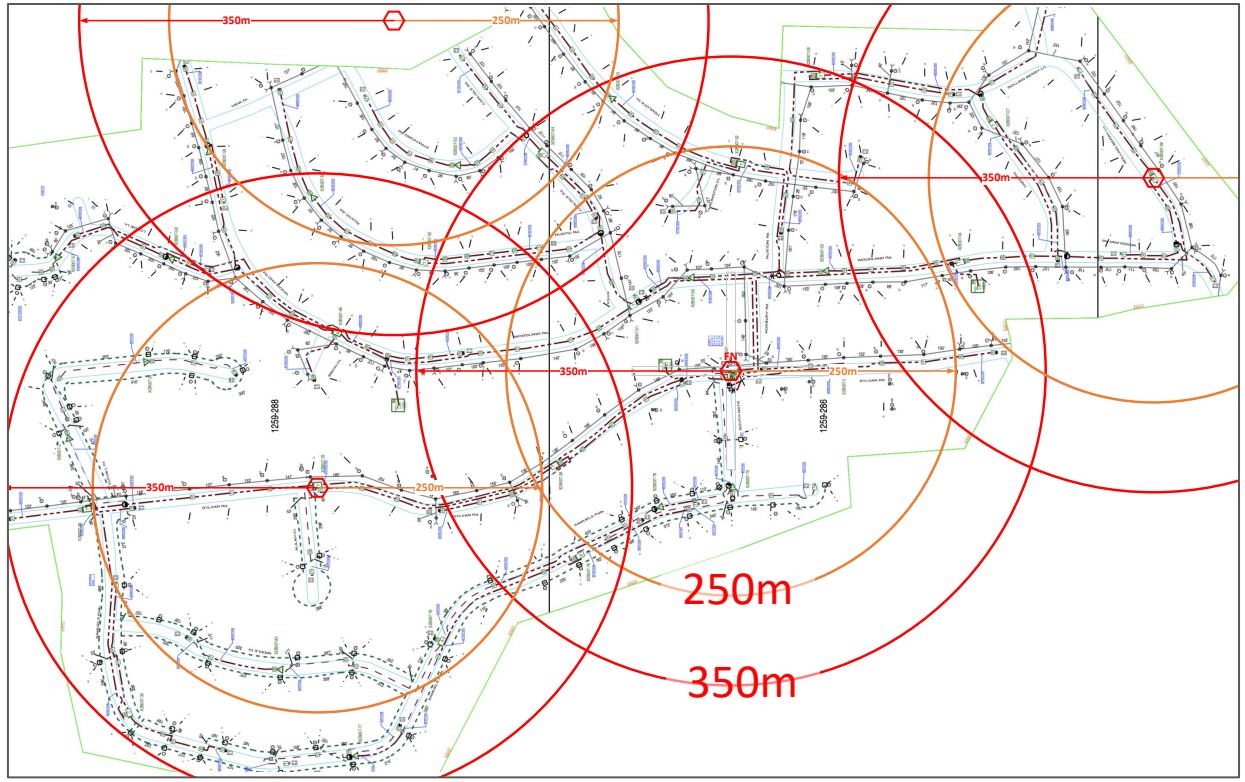


Med-Low Density N+3 – 57 HP/mile

Small Cell adjacent to Fiber Node

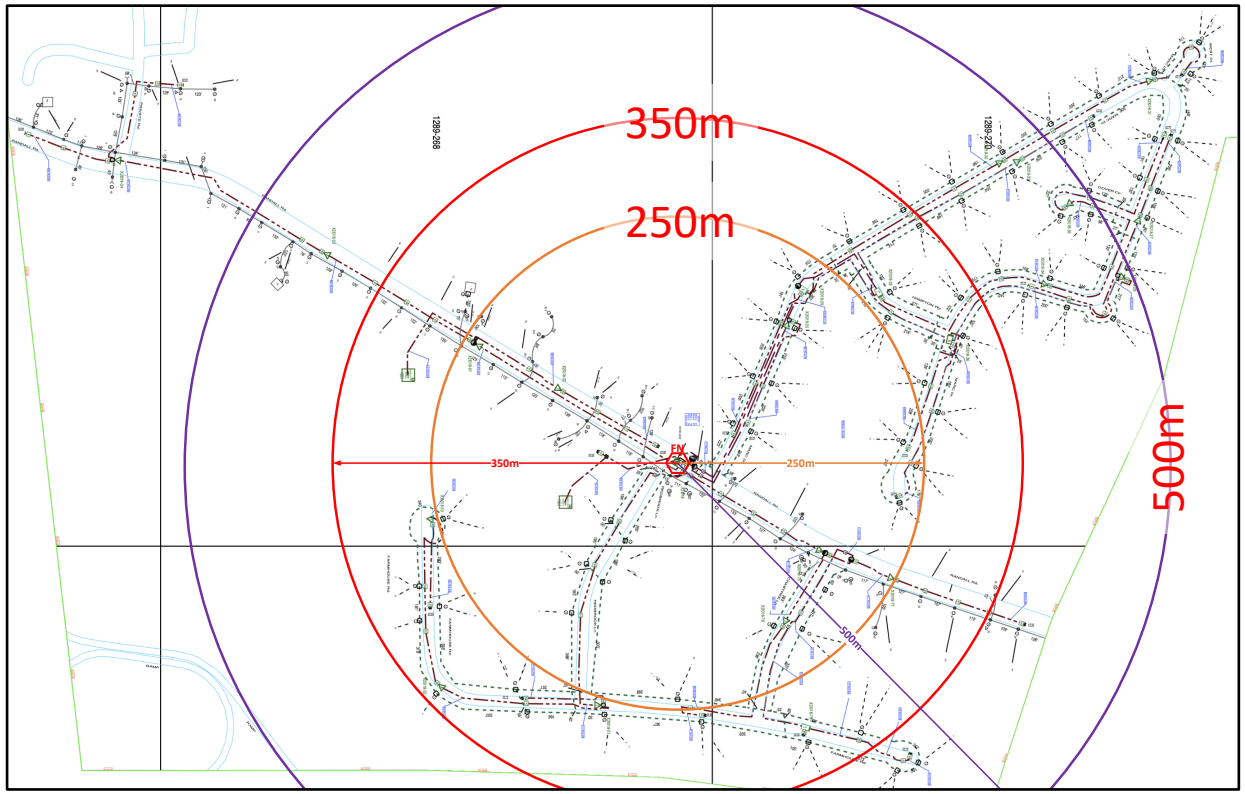


With additional Small Cells on Coax

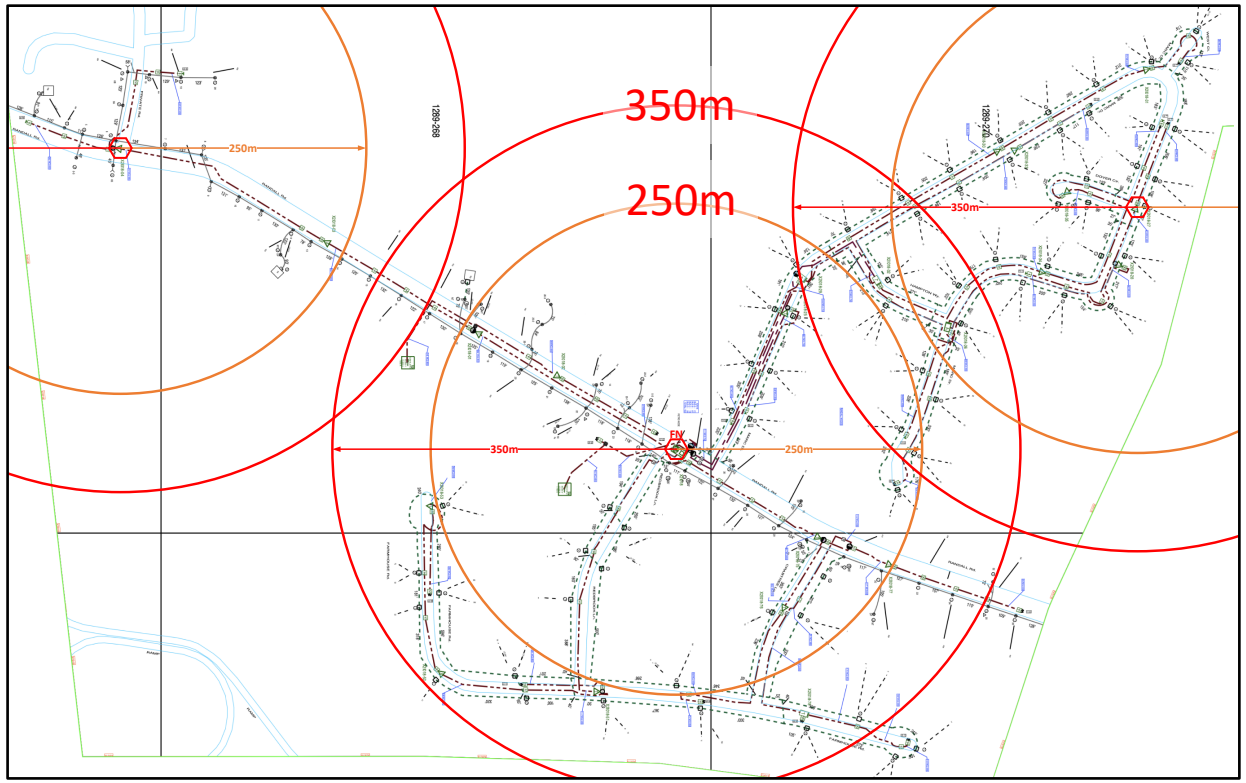


Low Density N+3 – 37 HP/mile

Small Cell adjacent to Fiber Node



With additional Small Cells on Coax



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HFC Case Study for a Metro-Suburban area (N+6, 9 nodes, 3.5 sq mi)

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Statistics of Metro-suburban HFC N+6 nodes of various densities

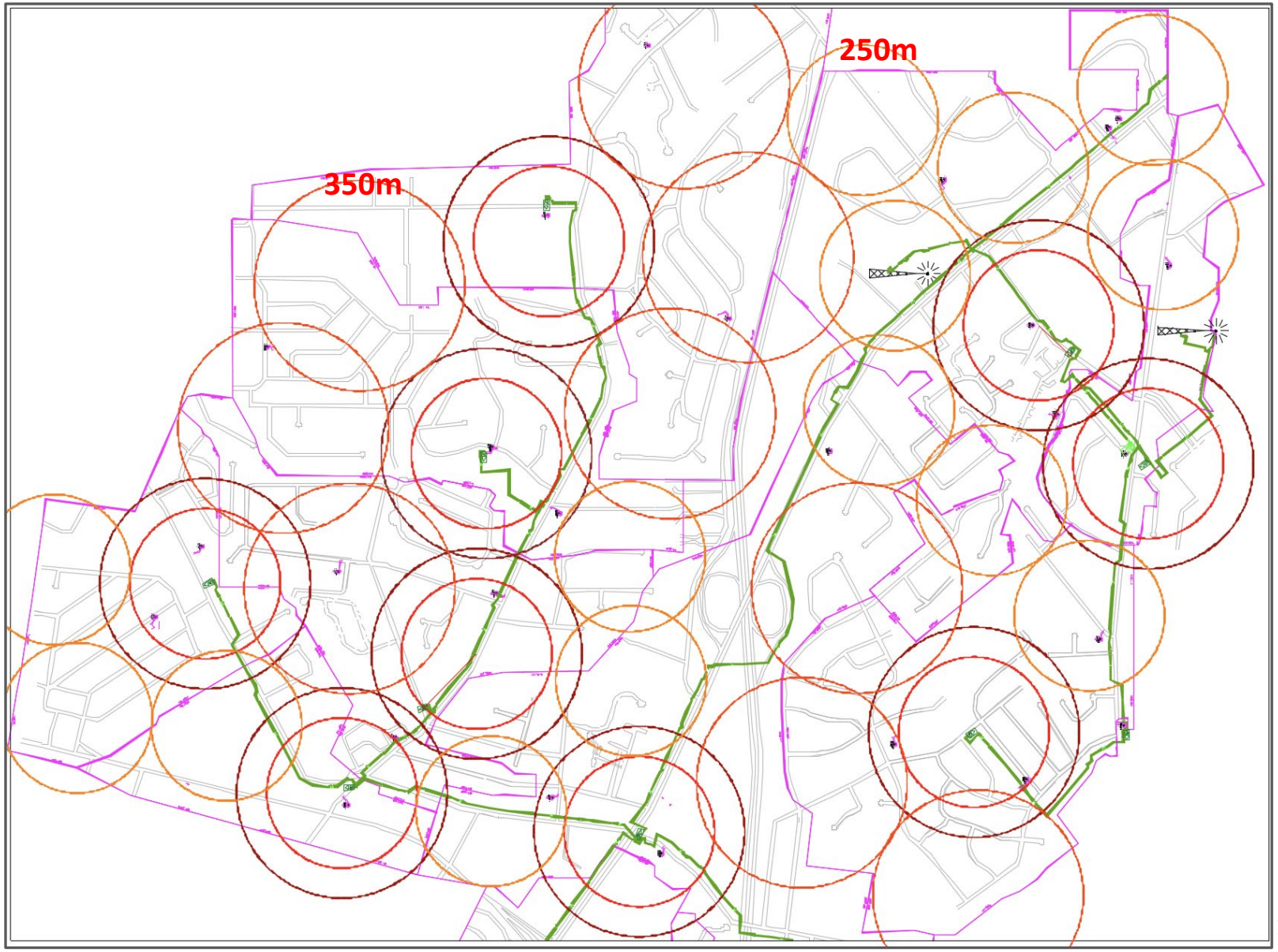
N+6 Case Study:	Overall Area (9 nodes)		Node #1 Low Density	Node #2 Low Density	Node #3 High Density	Node #4 High Density
Coax Plant Mileage	59.6		9.56	6.58	4.3	2.24
Aerial	36.1		3.87	5.39	3.34	1.59
Underground	23.5		5.69	1.19	0.96	0.65
Total Actives	381		61	45	32	13
Actives/Mile	6.4		6.4	6.8	7.4	5.8
Cascade	N+3 – N+6		N+6	N+5	N+4	N+3
Total Passings	5,740		724	502	628	370
HP/Mile	96		76	76	146	165

Small Cells at Fiber Nodes

- **Green Lines** = Fiber
- Access to Fiber enables either Option 2 Midhaul or Option 7.2x Fronthaul
- Two cells overlapped and were moved 500'-860' from node
- Overall coverage is spotty, but may be okay for mobile off-load

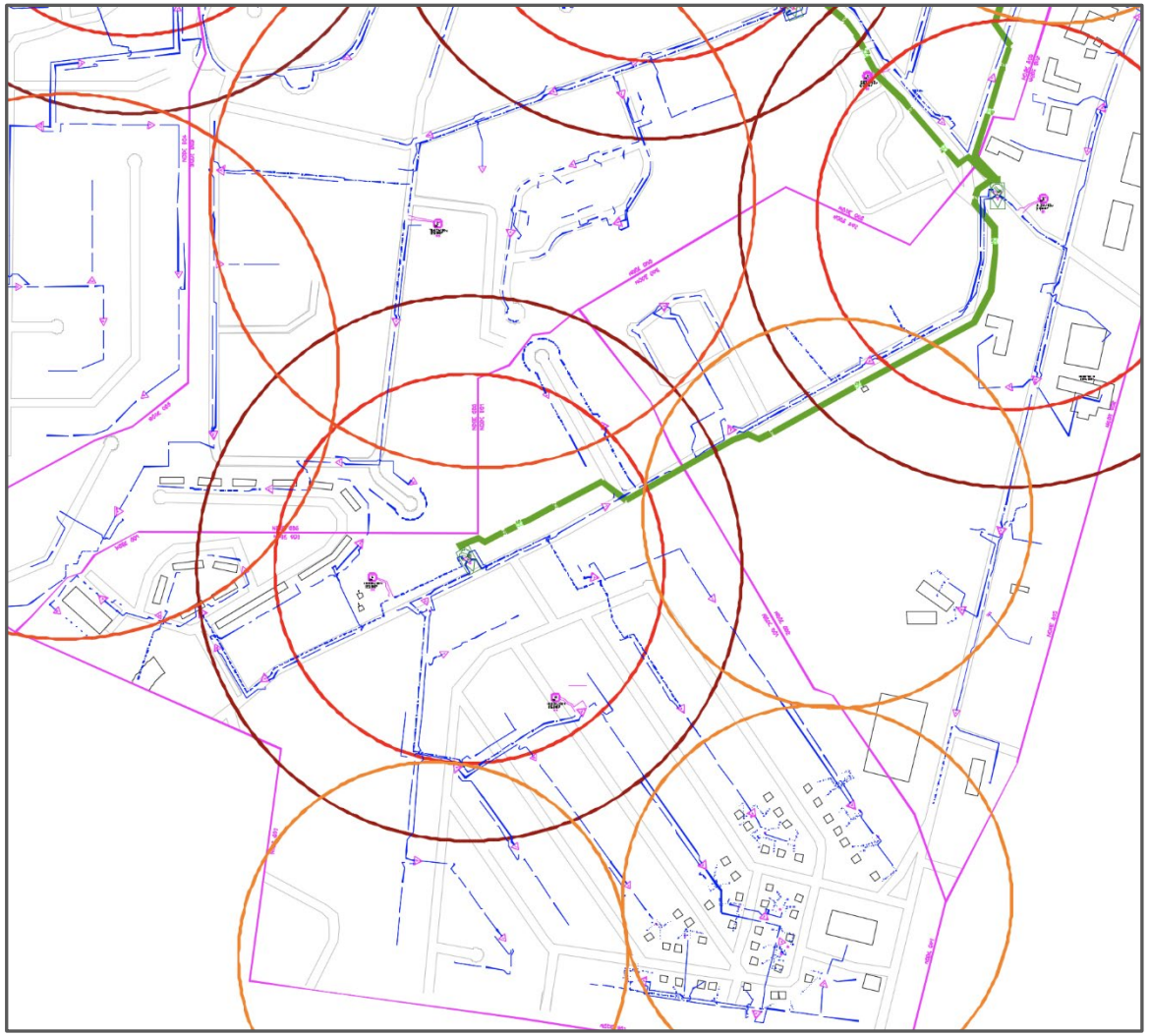
Small Cells at Nodes + Coax

- **Green Lines** = Fiber
- High density areas have 250m range
- Low density areas have 350m range
- 9 Small cells @ nodes
- 23 Small cells on coax
- 2-5 small cells per node

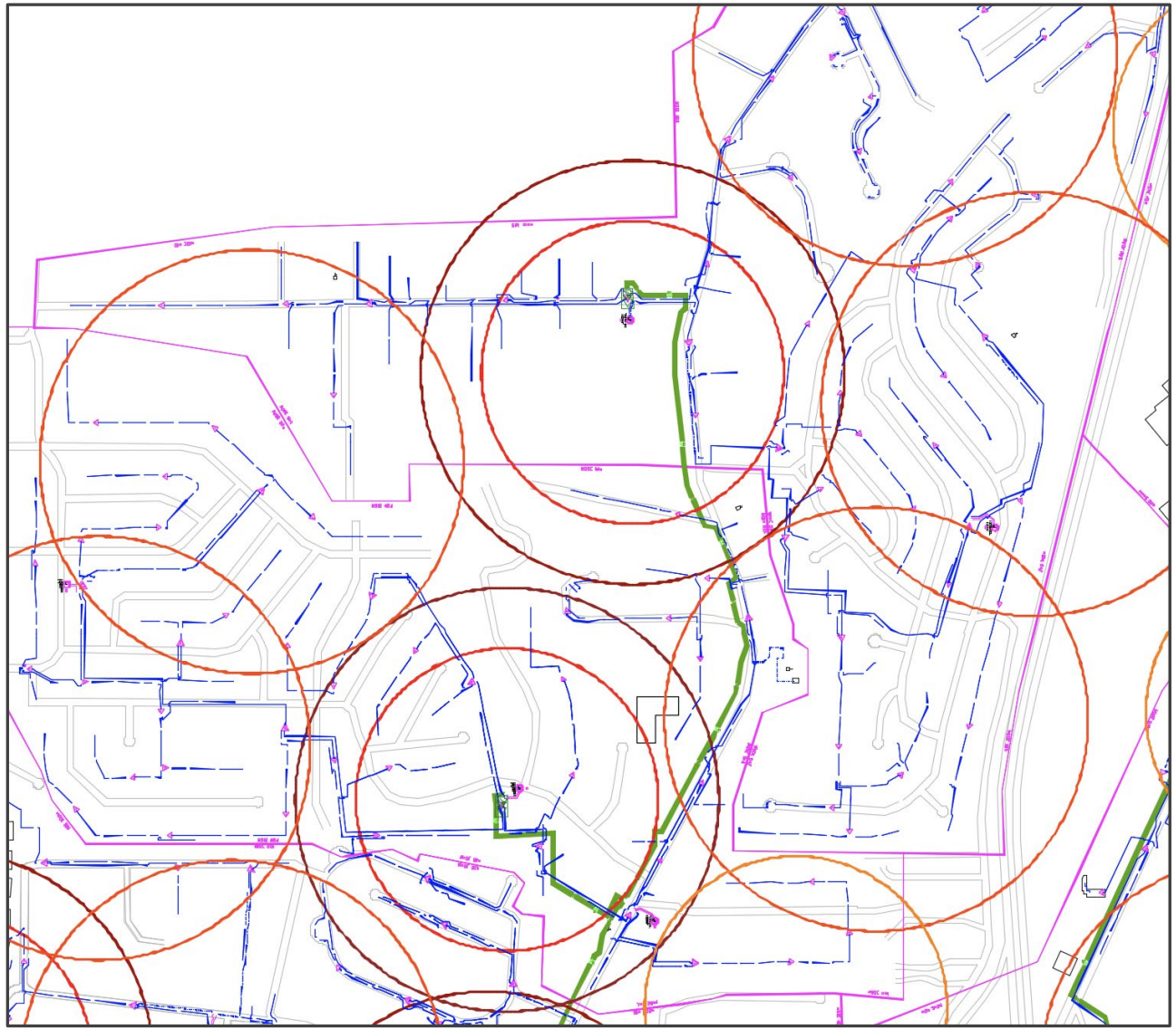


HFC Case Study for Metro-Suburban Area

Zoom into High Density area

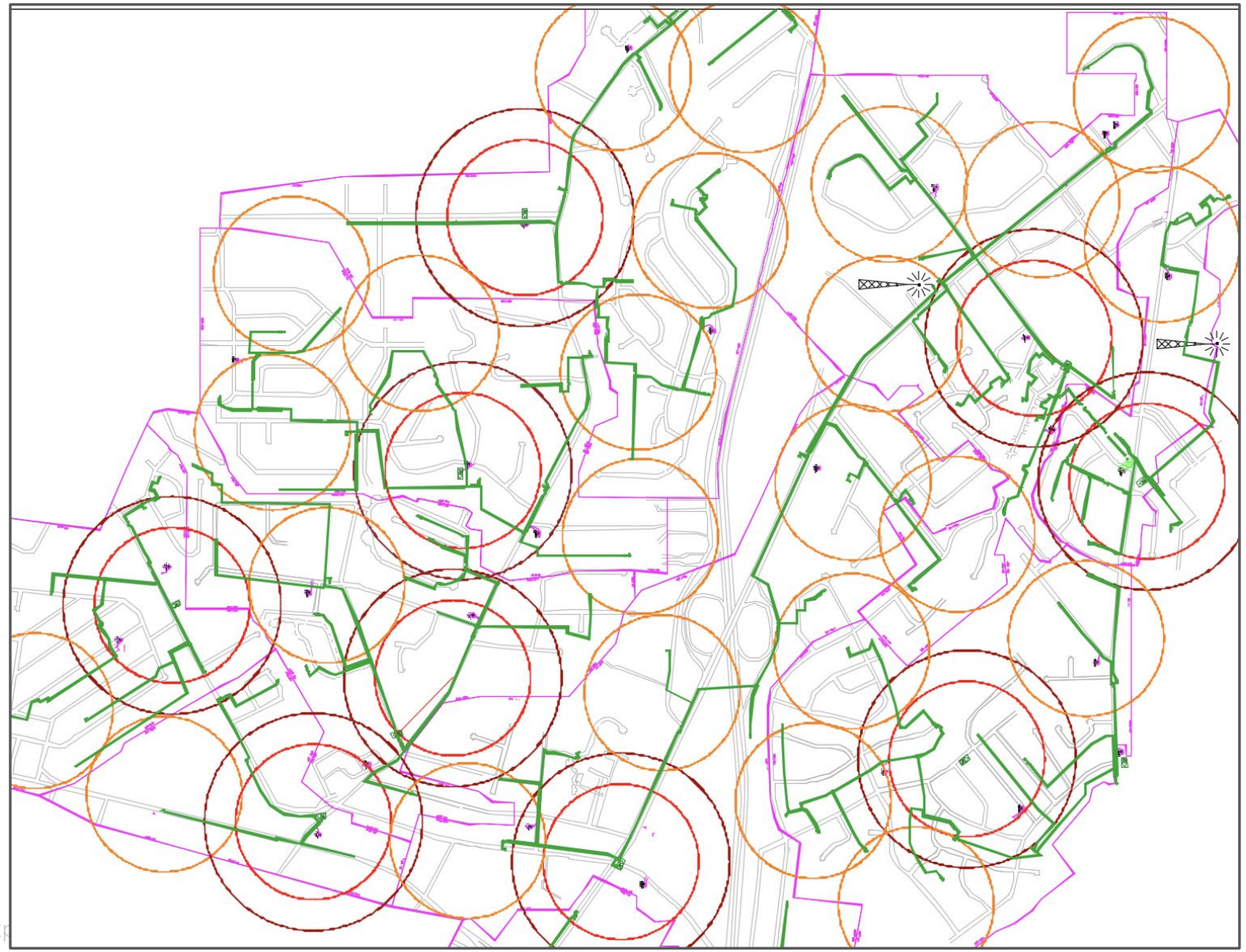


Zoom into Low Density area



Small Cells after N+0 Upgrade

- **Green Lines** = Fiber
- Fiber increased from 8.55 to 24.8 miles
- 110 fiber nodes vs. 32 small cells
- 26 of 32 cells @ nodes
- 6 coax cells, within 100m-150m of nodes



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Summary – Overlaying Mid-Band Spectrum Backhaul/Fronthaul onto HFC

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Lessons Learned – Key Takeaways

Mid-band Small Cell coverage range

- Strand-mount or streetlight small cells: 2T2R/4T4R Omni antennas likely
- CBRS strand-mount small cells might have ~240m urban reach; ~360m rural reach
- CBRS streetlight cells: ~340m urban reach; ~500m rural reach
- C-Band small cells have 50% further reach then CBRS cells thanks to its higher EIRP
- Some 5G might be DL only, using more robust Low-Band frequencies for UL signals
- Wi-Fi 6E range limited to <100m; but still expected to rule inside the home

Mid/Fronthaul capacity requirements

- Option 2 Midhaul interface substantially reduces BW capacity requirements versus Option 7.2 Cat A Fronthaul interface
- D3.1 capacity easily handles Mid-Band small cells with Option 2 Midhaul interface
  - Midhaul interface for 100 MHz of Mid-Band spectrum might need 1218/204 MHz HFC
- In general, Option 7.2 Cat A Fronthaul interface would need a direct fiber connection
  - DOCSIS 4.0 needs further investigation

Lessons Learned – Key Takeaways

How to map Mid-band Cells to HFC

- Place first small cell at or near fiber node leverages both power & fiber backhaul
  - Enables Option 7.2x if needed or desired
- Add Option 2 Midhaul interface cells as needed along HFC to access power + DOCSIS
  - Over time, pull fiber to any small cells whose capacity outgrows DOCSIS
- *N+2 HFC* appears to align nicely with CBRS small cells at fiber node location
- Higher density areas require fewer coax-based small cells; Lower density areas require several more, but cells are also lighter capacity load too

DAA Synergies

- Small cells near fiber node can share 10G Ethernet connection with RMD/RPD
- RMD works best for distributed DU in the field
  - RPD would require DOCSIS MAC core to be located near DU, not in the cloud
- DU in the field aggregating 6-12 small cells with Option 7.2x interfaces fits nicely into the CableLabs 10G DAA architecture
- DU in the field greatly reduces long range backhaul BW capacity requirements
  - E.g. from 100's of Gbps down to 10's of Gbps
- Aggregation node with CL coherent optics has lots of BW capacity for wireless networks

Potential 5G Mid-Band Business Opportunities for MSOs

Rural Areas with Sparse Macro-Towers

- Provide site/power/backhaul for C-Band small cells *across entire MSO footprint* for MNOs
  - C-Band range higher than CBRS, need fewer small cells for coverage
- Deploy CBRS small cell network across MSO footprint
  - Small cells at fiber nodes + HFC DOCSIS
  - *Use GAA*, access up to 100MHz for 2Gx300M
- *If vMNO,* deploy limited CBRS small cells to off-load traffic as needed

Urban Areas with dense Macro-Towers

- Provide site/power/backhaul for C-Band small cells *in congested or low coverage areas* for MNOs
  - C-Band range higher than CBRS, need fewer small cells for coverage
- Deploy CBRS small cell network across MSO footprint
  - Small cells at fiber nodes + HFC DOCSIS
  - *May need PAL* in addition to GAA due to spectrum competition
- If vMNO, deploy limited CBRS small cells to off-load traffic as needed

Conclusions – A Symbiotic Convergence of Cable & Wireless

- HFC is ideally suited to support this Mid-band xHaul infrastructure

- Strategy – D3.1 midhaul can be leveraged extensively in the early days to get wide 5G Mid-band coverage quickly for HFC of varying densities
  - Pull fiber to small cells as capacity demand requires

- HFC N+2 appears to align nicely with CBRS small cells co-located with Fiber Nodes
  - Enables Option 7.2x Fronthaul and evolution to denser antenna arrays
    - E.g. multi-sector 8T8R or higher

Cable and Mid-band wireless (C-Band, CBRS, Wi-Fi 6E) are much stronger together and are at the core of a next gen converged network evolution

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Thank You!

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