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Fixed Wireless Access in Fiber Operator Context: A performance and spend analysis

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Presentation outline

There are many misconceptions on what can Fixed Wireless Access (FWA) do and what they cannot. Our goal is to provide an unbiased technical and financial analysis on FWA using mmWave technology for Cable operators

- Millimeter wave fixed wireless access technical analysis
- How can cable operators work with fixed wireless?
- Total cost of ownership analysis
- Rural morphologies considerations
- Conclusions and observations

Millimeter Wave propagation impairments

Fixed Wireless Access (FWA) applications at 28 GHz

Material penetration

mmWave cannot penetrate well through material, especially **concrete ~(117 dB)** and **IRR glass (~31 dB)**. Standard glass and wood offers lower penetration losses: 7.6 and 8.2 dB, respectively.

Foliage attenuation

Attenuation due to foliage varies depending on the type and depth of vegetation. **17 dB loss for 10 m tree thickness**. This is 8 dB higher than loss at 3.5 GHz.

Rain fades

Small impact in heavy rain conditions due to short coverage range: ~0.5 dB/100 m attenuation for rainfall rate of 50 mm/hour (heavy rain).

Atmospheric absorption

Negligible losses due to oxygen and water vapor in FWA applications at 28 GHz especially since distance between transmitter and receiver is short (tens or hundreds of meters).

Propagation impairments

Signals undergo specular reflection, diffraction and diffusion scattering. These behavior depend on the type and size of surface. mmWave signals have rich diffusion scattering behavior that scatters power in different directions; they are also more prone to diffraction loss than reflection due to their short wavelength. To overcome path loss impairments, beamforming is used to concentrate power in horizontal and vertical planes. This would leverage any LOS component, but limited number of multipath components as may fall within the beam range.

Deployment considerations

Deployment model
Outdoor vs. indoor CPE, user self install vs. truck roll

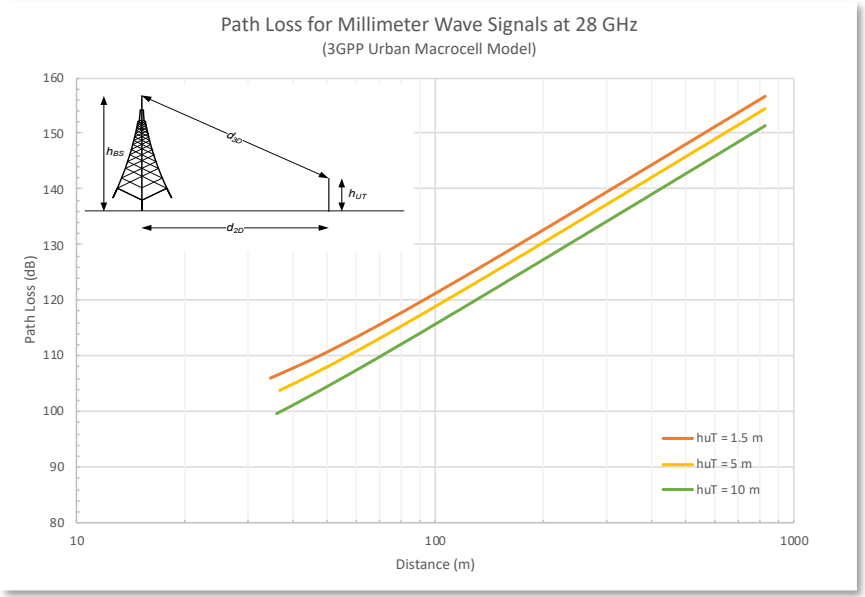
Outdoor CPE provide best chance of good service connectivity

Equipment design
Beamforming, MIMO layers, modulation, size, power consumption, cost

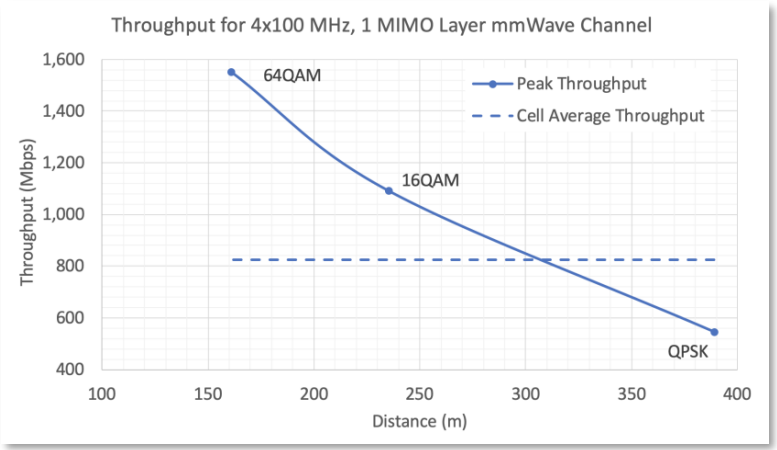
Performance of mmWave FWA highly depends on the deployment scenario and terrain clutter

Performance of mmWave fixed wireless access

Signal Strength Attenuation vs. Distance



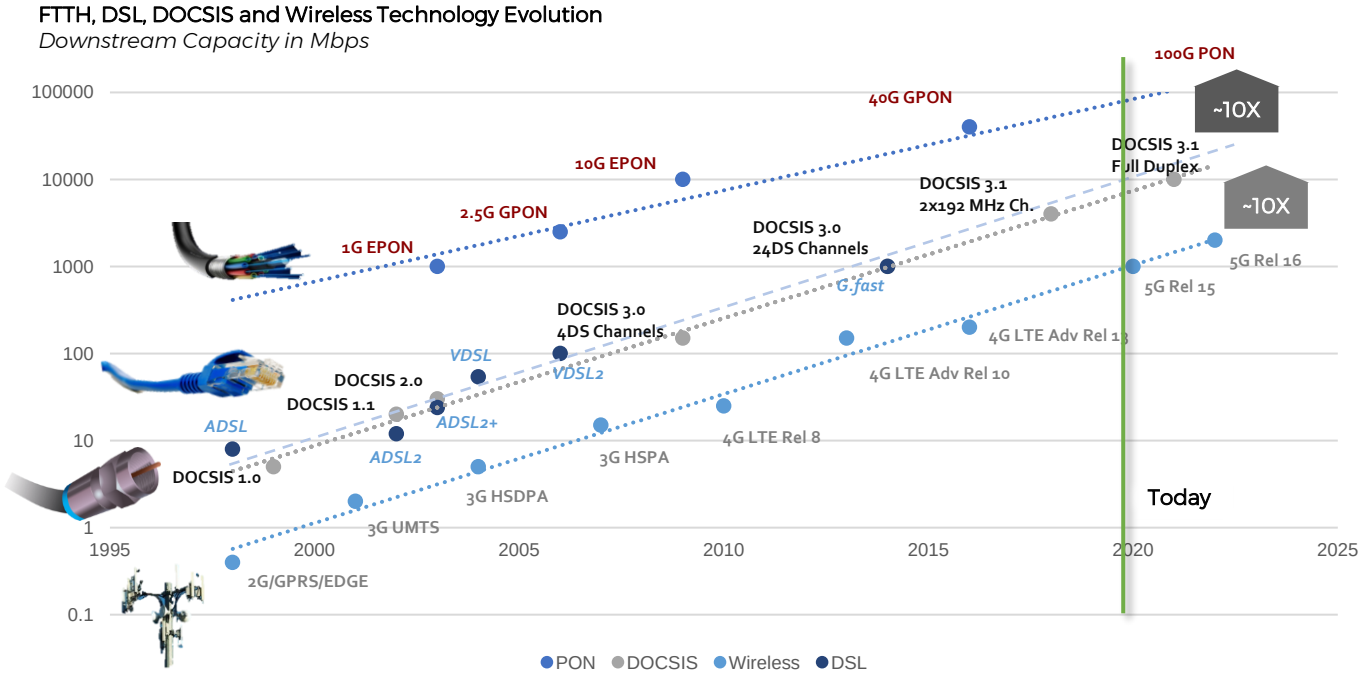
Throughput vs. Distance



- 141 dB MAPL leading to maximum 400 m cell range in outdoor FWA deployment with best of breed equipment parameters
  - Including fade and interference margins; excludes glass penetration losses (up to 36 dB) for outdoor deployment
- Peak 1.55 Gbps/825 Mbps average throughput per 400 MHz channel and 1-layer MIMO; Frame structure 31 (6:1 DL/UL ratio)
  - Average 1650 Mbps for 2 MIMO layer used in current deployments

Short range and high throughput for mmWave FWA lead to selective and targeted deployments

Different Wireline and Wireless access technology evolution



Downstream capacity wise, PON offers ~10x more than DSL or DOCSIS, and ~100x more than wireless

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Comparing capacity of different access technologies

Category	Fixed Wireless	DOCSIS	Fiber To The Home
Technology	mmWave	DOCSIS 3.1 with High split	XGSPON
Spectrum block (Downlink/Uplink)	400 MHz	3 x 192 MHz/ 200 MHz	NA
QAM (Downlink/Uplink)	64/16	256/64	NA
Peak capacity (Downlink/Uplink)	2.8 Gbps/0.34 Gbps	4.5 Gbps/1.3 Gbps	10 Gbps/10 Gbps
Non-Overhead	100%*	88%	90%
Oversubscription	20	20	20
Maximum subs (assuming 100% take rate)	200**	600	32
Avg. sellable bandwidth per sub*** (Downlink/Uplink)	142 Mbps/23 Mbps	132 Mbps/38 Mbps	5.6 Gbps/5.6 Gbps
Maximum distance to the customer	400 Meters	~5 Km	20 Km

(*) Overhead is already considered in the capacity calculation for 2 MIMO layers
(**) A maximum of 200 homes covered per sector is considered in this analysis
(***) Average sellable bandwidth per sub = Capacity * Non-Overhead * Over subscription / Maximum subs

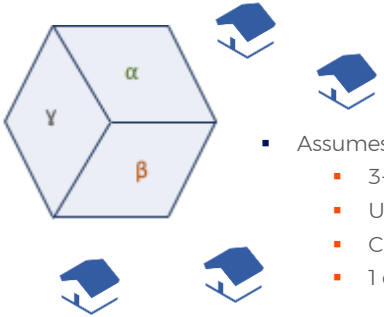
XGSPON based FTTH solution offers the highest per sub bandwidth and the longest distance from to the end of line

FWA and FTTH deployments for a suburban topology

We used a Greenfield suburban topology for this analysis

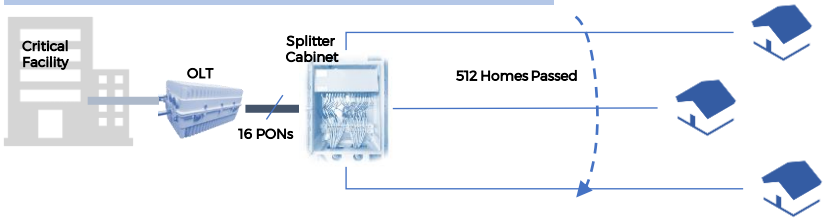
- Suburban greenfield area
- Primarily single-family residential community
- 600 home community
- North America cost and price structure

Fixed wireless access deployment



- Assumes:
  - 3-sectored cells; 25 m tower
  - User terminal at 5 m (50% self-install)
  - Cell area 0.136 sq. km (*r* = 390 m)
  - 1 cell site covers ~600 houses (50x100' lots)

Fiber To The Home access deployment



- Assumes:
  - XGSPON as the deployment technology
  - Hardened outside plant deployment
  - 1:32 split per PON with 16 PON port OLT

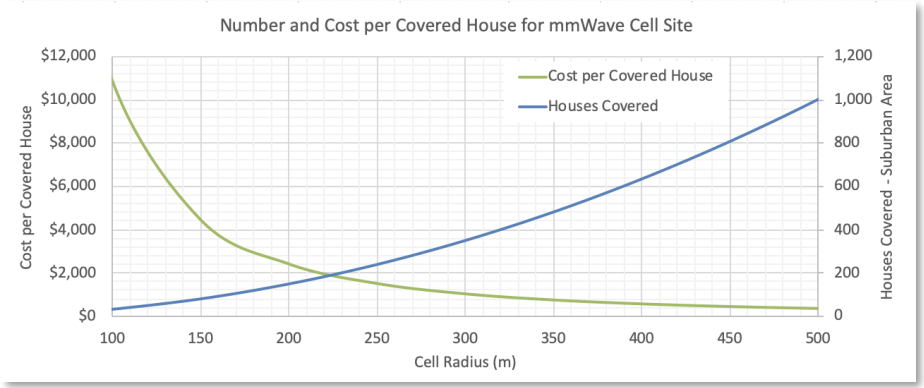
Fixed wireless access technology TCO analysis

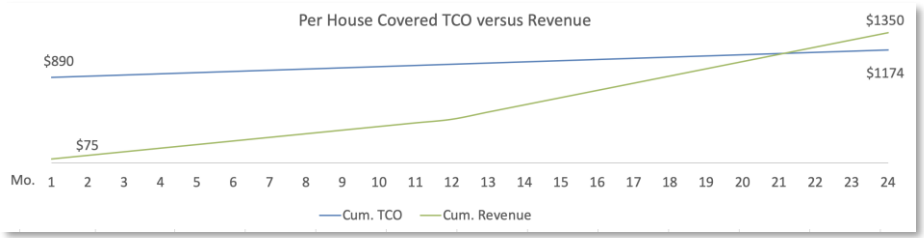
FWA TCO scenario parameters and results

- Revenue per subscriber: $75
- Leased infrastructure (site, backhaul)
- 284/46 Mbps; 20 oversubscription* (residential subscriber)
- 400 m cell radius
- Does not include spectrum acquisition costs
- 3-Sectors / site; 5 Gbps backhaul
- 50% market penetration
- 50% self-install CPEs

7-Year TCO Analysis Results	
Subscribers per site	300
Houses covered	600
Market penetration rate	50%
Cost/house covered	$ 607
Cost/sub/mo	$ 23
Profit (Loss) / sub / mo	$ 47
Months to breakeven	22

Houses covered per cell size and cost per covered house for typical North American suburban area





High sensitivity to cell radius and cell loading (no. of subs): FWA susceptible to competition from wireline service providers**

(*) Business subscriber requires lower oversubscription – e.g. 1-5 – leading to different parameters and results
(**) Cost of CPE, % of self-install, cost of backhaul and cost of site lease are other important factors for positive business case

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Fiber To The Home access technology TCO analysis

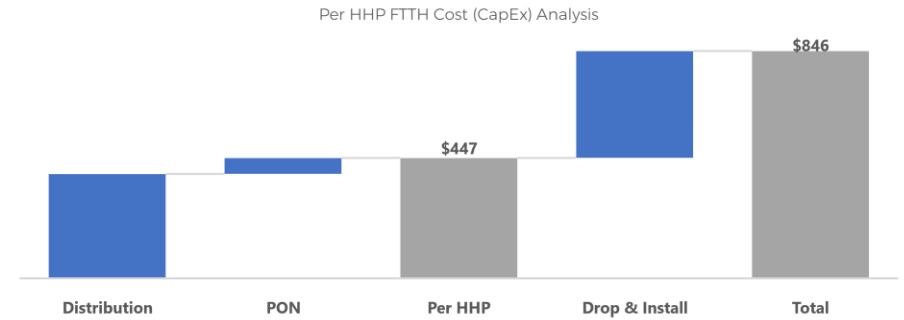
Parameters that influence the FTTH financial analysis

- Cost and revenue related
  - Revenue per subscriber: $75 per month
  - Assumes 1 mile of aerial and 3 miles of underground construction
  - Assumes $53/year/homes passed* operational expense
  - Deployment considerations
    - No RFOG (All IP solution), centralized splitter
    - 100 feet drops
    - 50% take rate

- Difference between FWA and FTTH deployments
  - All homes are connected due to franchise agreements
  - Leasing equipment or fiber is not considered (not applicable)
  - Conduit sharing (join trenching) is not considered in this analysis

Note: XGSPON offers significantly higher capacity per sub leading to longer lifetime from product offering capability point of view

FTTH cost and revenue analysis



A typical greenfield FTTH deployment costs ~$850/HHP with a $53/year/HP OpEx cost, leading to a one year breakeven

(*) Refer to "Operational Expense Comparison in Access Networks," Fiber Broadband Association

Comparing mmWave FWA and FTTH TCO analysis

Category	mmWave Fixed Wireless		Fiber To The Home	
	Pros	Cons	Pros	Cons
Deployment	Quick access to market Could be deployed quickly	Propagation characteristics (foliage, material, clutter) impact on range	Can be deployed in any terrain	Requires advanced planning, permitting
Quality of Experience		Variable depending on location	Constant & predictable	
Throughput		Decreases proportionally to distance, varies depending on obstructions in signal path	Constant & predictable; ~100x more capability than FWA	
Availability		Depends on distance and location of user terminal; foliage and IRR glass reduce availability	Constant & predictable	
Number of users	Cell densification to increase capacity; Roadmap to support greater throughput/# of users	Variable depending on deployment scenario in addition to other factors	Linearly scalable	
Financial Structure	Lower CapEx (scenario specific), quick access to market	High OpEx (scenario specific)	Low OpEx	Initial CapEx investment heavy
TCO	22 Months to breakeven (case dependent)	1. Small coverage range or low sub penetration lead to poor biz case 2. Actual breakeven is longer when factoring cost of core network and spectrum	~ 12 mo. breakeven; Better product offers	

Fixed wireless access could be considered more tactical and complementary to fiber which is more strategic

Access networks for rural morphologies

Rural morphologies have certain twists

Density	Low population density leading to longer construction distribution/drops and lower subs per sector
Terrain	Different cost/mile, permitting etc. that change the economics for wireline Open terrain helps extend wireless coverage
Vegetation	Foliage and seasonality significantly impact wireless performance
Product Offers	Product needs and hence the offers in the rural locations are different than that in the urban morphologies
Revenue	Different revenue opportunities from urban areas leading to potentially longer breakeven

Impact of rural on the access deployments

Fixed Wireless Access

- mmWave offers shorter range especially in areas of high foliage
- Lower density drives negative business case
- Sub 6 GHz 5G solutions (e.g. 3.5 GHz) offer a better option
  - When spectrum available use 100 MHz carrier with option for carrier agg.
  - Low spectrum price $0.01 - $0.4 / MHz-PoP depending on market (CBRS offers 80 MHz of unlicensed spectrum with potential to use up to 150 MHz)
  - 64T64R massive MIMO antennas with multiple MIMO layers to reach gigabit throughput

Fiber To The Home Access

- Expensive & rocky terrains make the fiber construction not viable
- Operator may have a different price structure for rural customers
- Low density ➔ Longer distribution and drop ➔ higher costs leading to worse than wireless business case
  - Recommend to use targeted deployments and cost sharing with customer

Rural morphologies presents different set of problems for FWA and wireline access – navigate them accordingly

 |

Our observations and conclusions

1

FWA - Quick to deploy but limited QoE

FWA could be deployed quickly and selectively but offers limited QoE depending on location and deployment scenario

2

FTTH 100x Better

FTTH technologies have been offering constantly 100x better throughput than FWA and offers product headroom

4

High ROI variability

Several FWA and FTTH service models are possible: own vs. lease; wholesale vs. retail; residential vs. business, greenfield vs. brownfield, hybrid wireless/fiber, shared vs. dedicated, etc.

3

CapEx or OpEx

The scenario analyzed in this paper shows FTTH is CapEx intensive compared to FWA's OpEx intensive nature

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Thank You!

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Link budget and expected range performance

General parameters	Downlink	Uplink	
Bandwidth per carrier	100	100	MHz
Occupied channel BW	95.04	95.04	MHz
Carriers	4	4	
Total BW	400	400	MHz
PRB per carrier	66	66	
Transmitter parameters			
Tx Power (all carriers)	32	20	dBm
Tx antenna gain	28	19	dB
EiRP	60	39	dBm
EiRP per carrier	54	33	dBm
Receiver parameters			
Thermal noise density	-174	-174	dBm/Hz
Receiver noise figure	7	6	dB
Effective noise power	-87.2	-88.2	dBm
MCS	QPSK	QPSK	
SNR	-0.9	-0.9	dB
Receiver sensitivity	-88.1	-89.1	dBm
Rx antenna gain	19	28	dB
Rx power	-107	-117	dBm
Path loss	167.1	156.1	dB
Margins			
Implementation margin	2	2	dB
Interference margin	6	2.5	dB
Lognormal fading	10	10	dB
MAPL - Outdoor	149.1	141.6	dB

- Link budget maximizes the equipment performance
  - 60 dBm gNB EiRP; 28 dB antenna gain including beamforming
    - Typically 55 – 60 dBm EiRP
  - 39 dBm CPE EiRP including 19 dB antenna gain
  - 400 MHz bandwidth (4x100 MHz carriers)
    - Up to 8x100 MHz carriers is possible
- For window-mounted CPE, up to 36 dB additional loss may be incurred (IRR glass)
- **Expected range: 390 m**
  - Uplink limited 141 dB path loss
  - **Range for glass mounted CPE: 42 m**
    - 36 dB glass penetration loss

Throughput and capacity performance

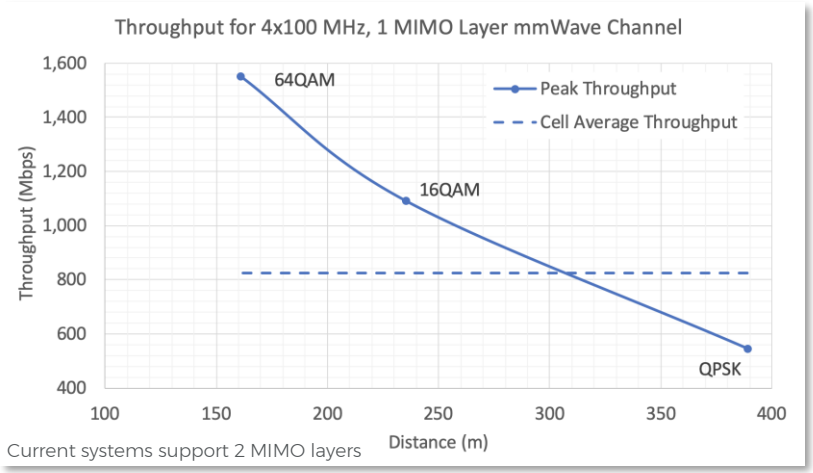
- 5GNR has a flexible TDD frame structure which could be fine-tuned to different downlink and uplink ratios
  - Slot format information can be sent to UE on every frame (dynamic scheduling, via DCI), or can be semi-static or static (through RRC)

Throughput for 4x100 MHz carriers; 1 MIMO layer

Modulation	Downlink Mbps	Uplink Mbps
QPSK	462	84
16QAM	924	169
64QAM	1,385	253*
Average (Mbps)	825	

Frame structure 31: 6:1 DL/UL ratio

Format #	Symbol number in a slot													
	0	1	2	3	4	5	6	7	8	9	10	11	12	13
31	D	D	D	D	D	D	D	D	D	D	D	F	U	U



Current systems support 2 MIMO layers

* 64QAM in UL and 256 QAM in DL are challenging to achieve in practice because of high SINR requirements and high propagation losses

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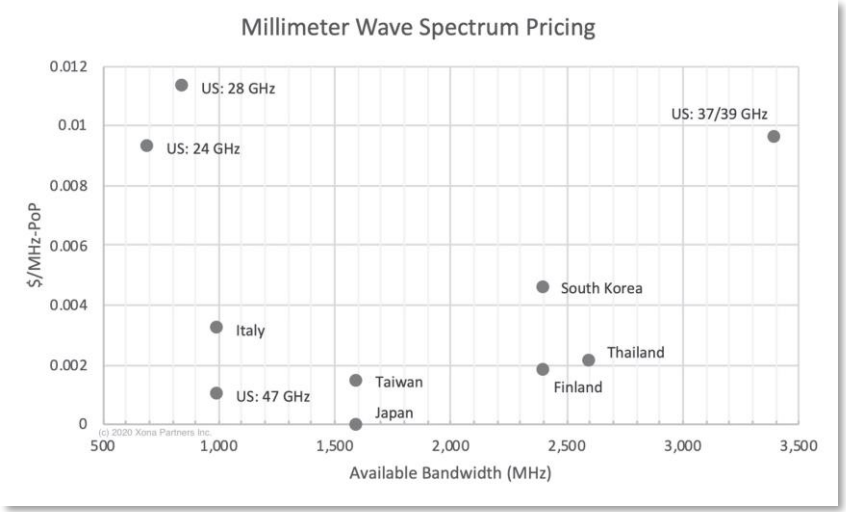
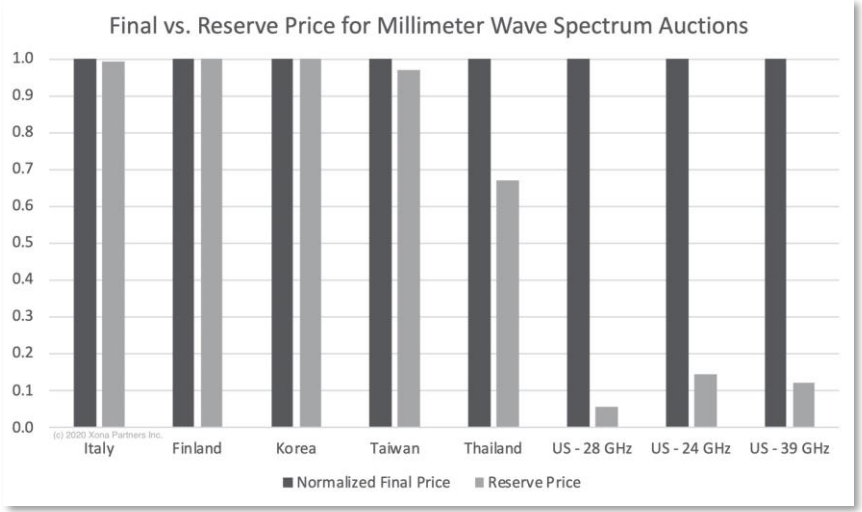
Spectrum allocations and pricing





- Low demand for mmWave spectrum expect in the US
- Valuation at fraction of a cent/MHz-PoP
  - US price increased by ~3x since 1998 LMDS auction: $0.00262/MHz-PoP [$0.004112 in 2019 dollars]
  - 3.5 GHz CBRS auction national average price $0.21/MHz-PoP: ~20x higher than mmWave

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Different equipment used for the Fixed Wireless Access

Equipment

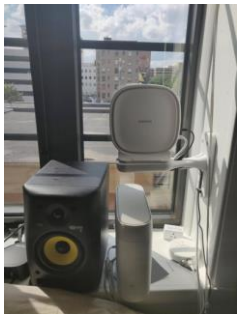
- 3 sector gNB @25m
  - 2 or 4 sectors also used in actual deployments
- CPE height = 5 m
  - Outdoor typically
  - Indoor: glass mounted

Samsung 28 GHz gNB (AT1K01)

50 dBm EiRP
33 lbs
19.41x9.57x6.89”
8 CC x 100 MHz
4x256 antenna elements
525 W (10.9 A; -48 VDC)

Nokia Airscale 28 GHz radio (AEUB)

60 dBm EiRP
44 lbs
23.6x12x4.7”
2x2 MIMO
2x256 antenna elements
420 W



Samsung 310 5G CPE

39 dBm EiRP
2.6 lbs
7.8x7.4x1.5”
8 CC x 100 MHz
2x2 MIMO
2x32 antenna elements
20 W

Wistron 4G/5G CPE

5G: 37 – 40 GHz / 27.50 – 28.35 GHz
4G B2/B4/B5/B13/B66
6x3x3”
2x2 MIMO
5G 1x4 antenna elements (3x modules)
60 W (PoE)

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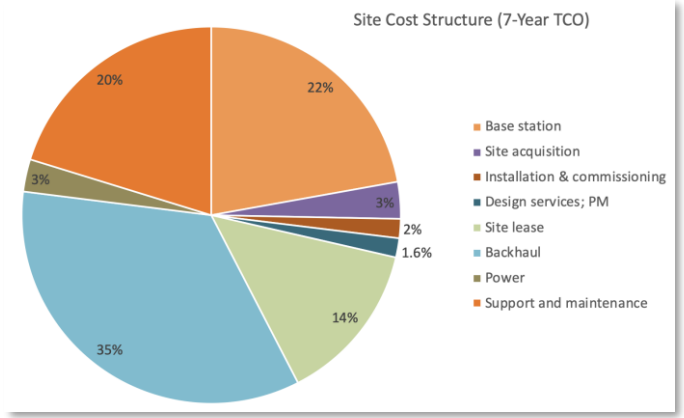
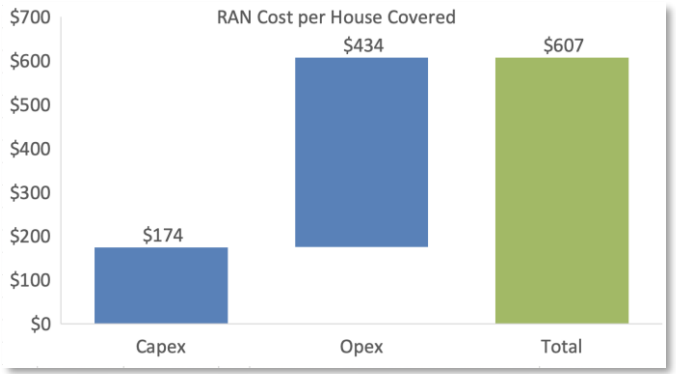
Key parameters of the mmWave Fixed Access TCO

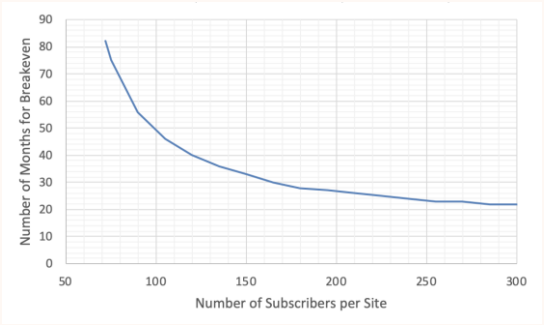
Parameters that have high impact on the mmWave TCO model:

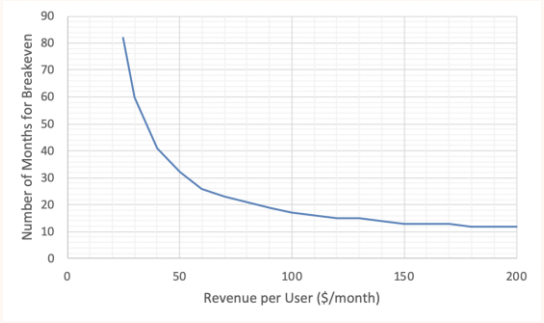
- Revenues
  - Subscribers per cell site: Range
    - Up to 400 m (200 m encountered often in practice)
      - Up to 600 houses in suburban area
      - Up to 300 subscriber: 50% penetration
  - Revenue per subscriber
    - $50-$90 / subscriber
- Costs
  - Backhaul for 5 Gbps/site
  - Site lease: 3 sectors typical (2 or 4 also common)
  - CPE & CPE installation: 50% of total
    - Leverage LTE ecosystem to reduce cost
    - Minimize truck roll: e.g. window mount CPEs
- 7-Year TCO RAN Scenario Outline
  - 3 sectors per cell site
  - Leased site; backhaul leased from 3rd party
  - Core network; OSS/BSS; spectrum costs not included



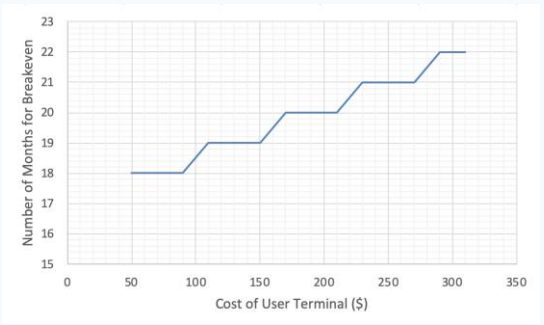


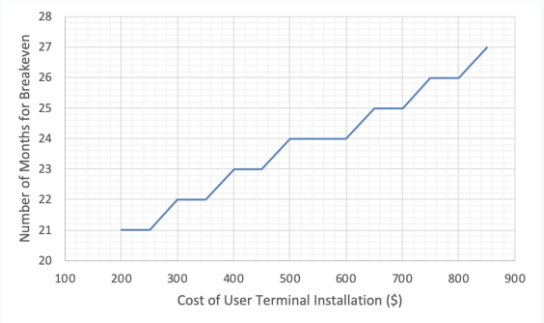
Sensitivity of mmWave FWA To Key Parameters





High sensitivity to subscriber penetration and revenue per subscriber





Low sensitivity to cost of CPE and installation services

- ~1 month impact on breakeven per $100

Scenario: Leased Site

- 300 subscribers / site
- $75/month RPU (revenue per user)
- $600/month site lease
- $1,500/month backhaul

Notes on the TCO analysis

- Cost of spectrum is not factored into the TCO analysis; it would be additive and amortized over the number of sites in a market
- The cost of core network, OSS and BSS are included. They would be additive amortized over the number of base stations and subscribers.

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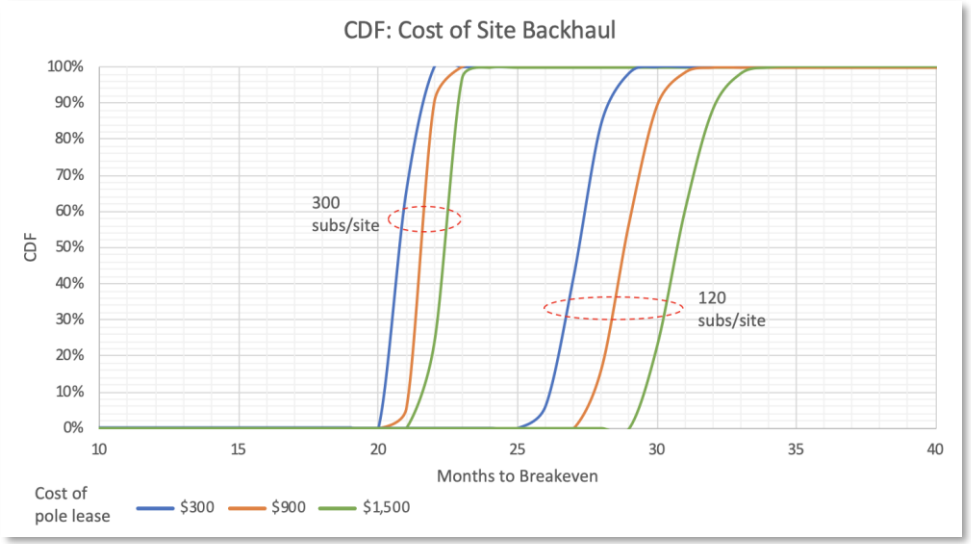
Sensitivity to Backhaul and Site Lease Costs

Critical paramters for business case success

- Coverage range
  - Careful analysis of service area
  - Selective market entry
    - Open areas more likely to be profitable
    - Wooded areas present a challenge
- Subscriber acquisition and retention
  - Quality of service to minimize subscriber churn
    - Today's FWA also leverage LTE networks
- Control infrastructure costs
  - Leverage existing assets to minimize new site construction
  - Leverage existing backhaul/fiber plant



Monte Carlo Analysis N = 5,000 for cost of backhaul

- Cost of backhaul with normal distribution; mean = $1,500/month; std. dev. = 300; $1,000 low bound
- $75/month revenue per user

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Site Type: Leased

	Leased Site		
	Low	Mid	High
Subs per site	180	240	300
Revenue ($/month/Sub)	50	70	90
Site lease per month ($/mo)	150	600	1,200
Backhaul per site ($/mo)	500	1,500	2,000
Throughput DL:UL (Mbps)	200:33	200:33	200:33
Oversubscription	9	12	15
Months to breakeven	**37**	**26**	**20**

Site Type: Owned [New Construction]

	Own Site		
	Low	Mid	High
Subs per site	180	240	300
Revenue ($/month/Sub)	50	70	90
Site lease per month ($/mo)	0	0	0
Backhaul per site ($/mo)	0	0	0
Throughput (Mbps)	200:33	200:33	200:33
Oversubscription	9	12	17
Months to breakeven	**48**	**29**	**22**

- Penetration and revenue is critical to overcome expenses and get a positive business case.
  - Low revenue and penetration cannot make business case valid even if costs are low.