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Selecting the correct PTP product for your application

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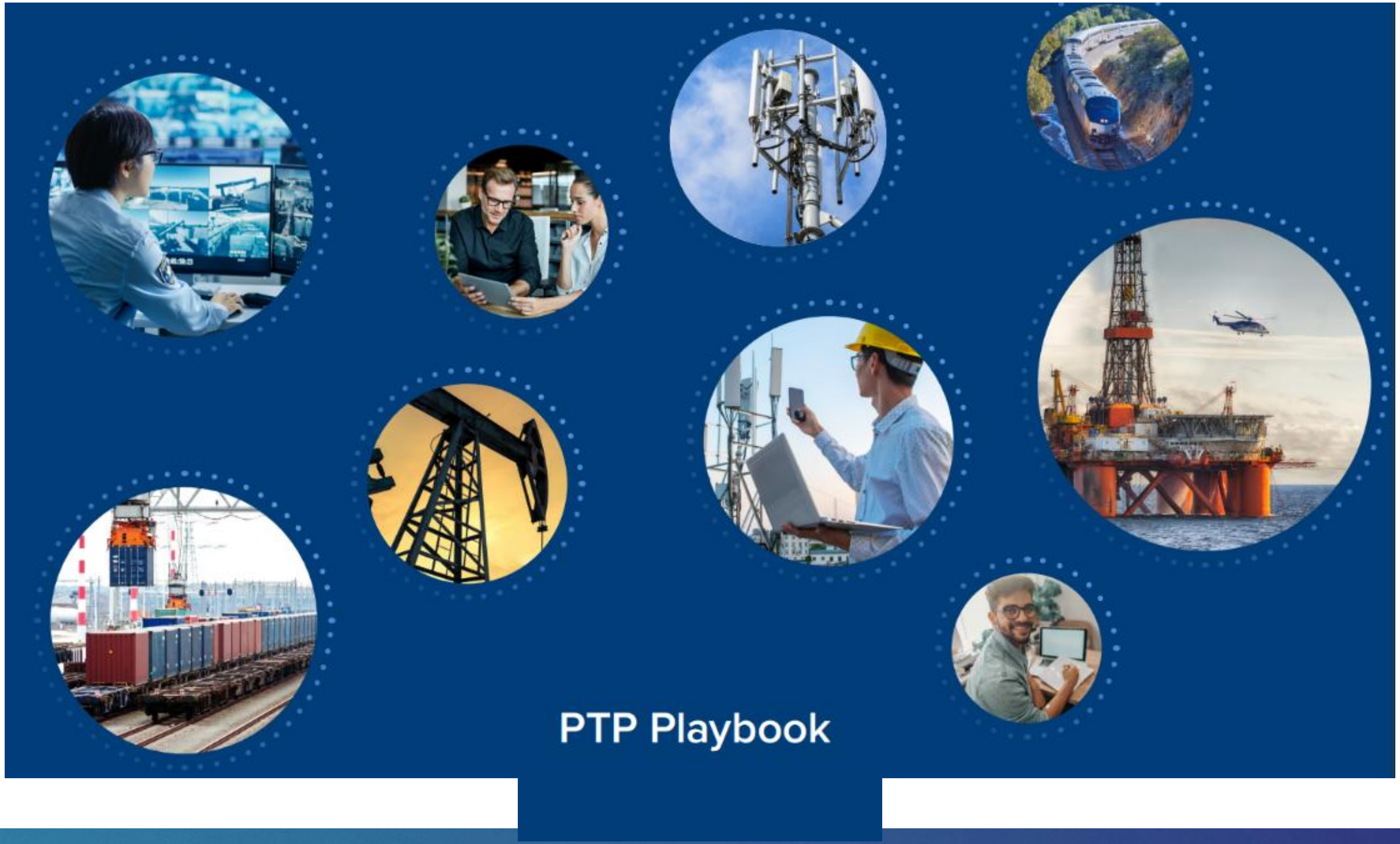
How Far, How Fast, How Critical



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Agenda

- Propagation & impairments
- Availability & fade margin
- Path engineering principles
- Design
- Q&A - Ask us anything!

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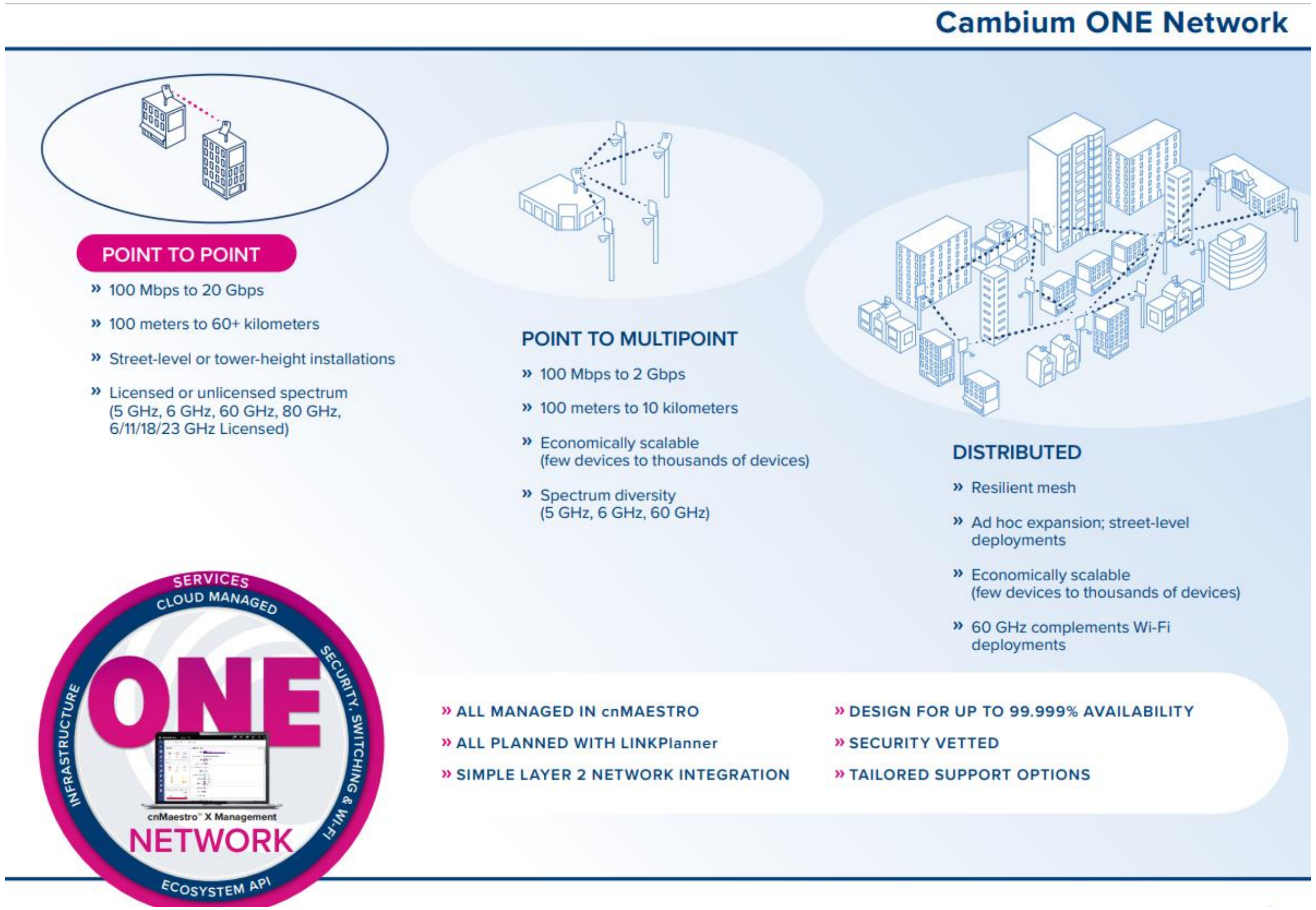
Strategic Solution Summary



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Getting Started: PTP Selection Criteria

CAPACITY, RANGE & AVAILABILITY

Between the three selection criteria of **capacity**, **range** and **availability**, there is always a tradeoff, so it's important to understand which parameters are of priority.

- **Range** is typically driven by the application, such as connecting one building to another. Relay nodes, distributed networks, or the choice of operating spectrum are driven by the range requirement. Range can also be increased by installing a larger antenna.

  Higher frequencies have lower range and typically require line of sight. Lower frequencies have longer range and improved non-line of sight but at lower capacities.

- Often **capacity** is the highest priority; if so, adding multiple shorter hops or reducing availability would be beneficial.

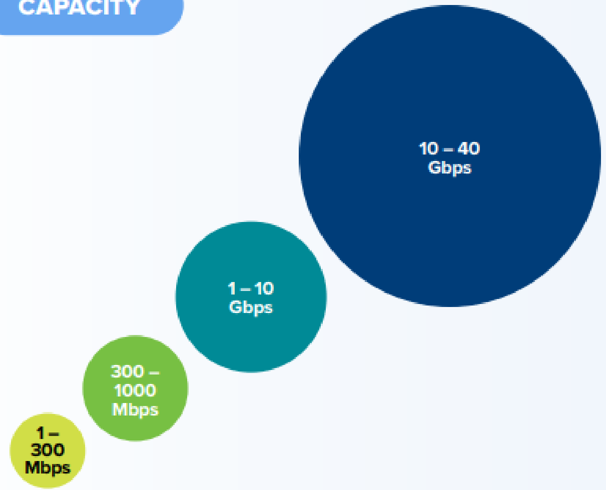
  Also consider whether the data demand is equal in both directions (symmetrical) or higher in one direction than the other (asymmetrical).

- Other times, **availability** is critical, for example, in public safety or defense. Here the customer may need to create additional links using hot standby or use shorter hops to improve availability.
  - The Availability Table (page 5) explains the amount of time a link is up and running; 99.95% availability means on average the link would be down for 4.38 hours per year.
  - Typically, enterprise customers set 99.9% availability, ISP customers set 99.95% availability, and carriers set 99.99% or 99.999% availability.

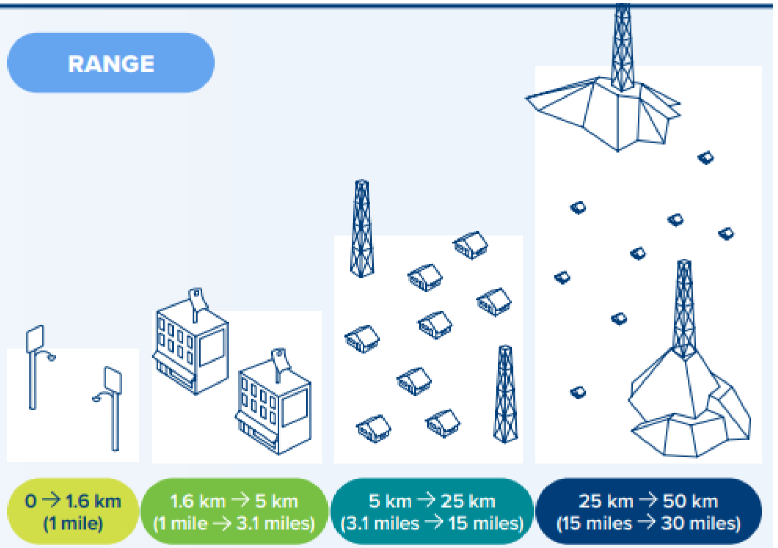
    Adaptive modulation and automatic transmit power control increase availability under a variety of conditions.

Selection Criteria Definitions

CAPACITY



RANGE



AVAILABILITY

Availability Level (Uptime)	Allowed Unavailability Window Per Year	Per Day	Application
99.90%	8.76 hours	1.44 minutes	Enterprise
99.95%	4.38 hours	43.2 seconds	ISP
99.99%	52.6 minutes	8.64 seconds	Critical Infrastructure
99.999%	5 minutes 13 seconds	0.86 seconds	Carrier

It’s not a Product Selection Problem

- PTP product selection is not a product decision. It’s a *propagation, availability, and constraints* problem.
  - Availability target (e.g. 99.99% vs 99.999%)
  - Distance
  - Spectrum constraints
  - Throughput requirement
  - Environment (multipath, rain, obstruction)

Propagation. The Primary Driver of Microwave Link Performance

- Most microwave outages are caused by **atmospheric effects**, not hardware
- Signal does not travel in ideal free space. It propagates through the **troposphere**
- Atmospheric conditions vary:
  - Time of day
  - Season
  - Weather patterns
- Link design is fundamentally about **predicting and managing outage probability**

The “Pencil Beam” Assumption is Wrong

- Microwave Signals Are Not Straight Lines
- Common misconception: microwave = narrow straight beam
- Reality:
  - Signal is a wavefront, **not** a ray
  - It is spatially distributed, not confined
- Different parts of the wave experience different atmospheric conditions
- **Propagation effects act across the entire wavefront, not a single path**

Refraction Bends the Microwave Path

- Air density decreases with altitude
- Top of wavefront travels faster than bottom
- Result:
  - Wavefront bends downward toward Earth
  - This is refraction, not reflection
- The Earth appears "flatter" to radio waves than it actually is.

Refractivity. The Real Control Parameter

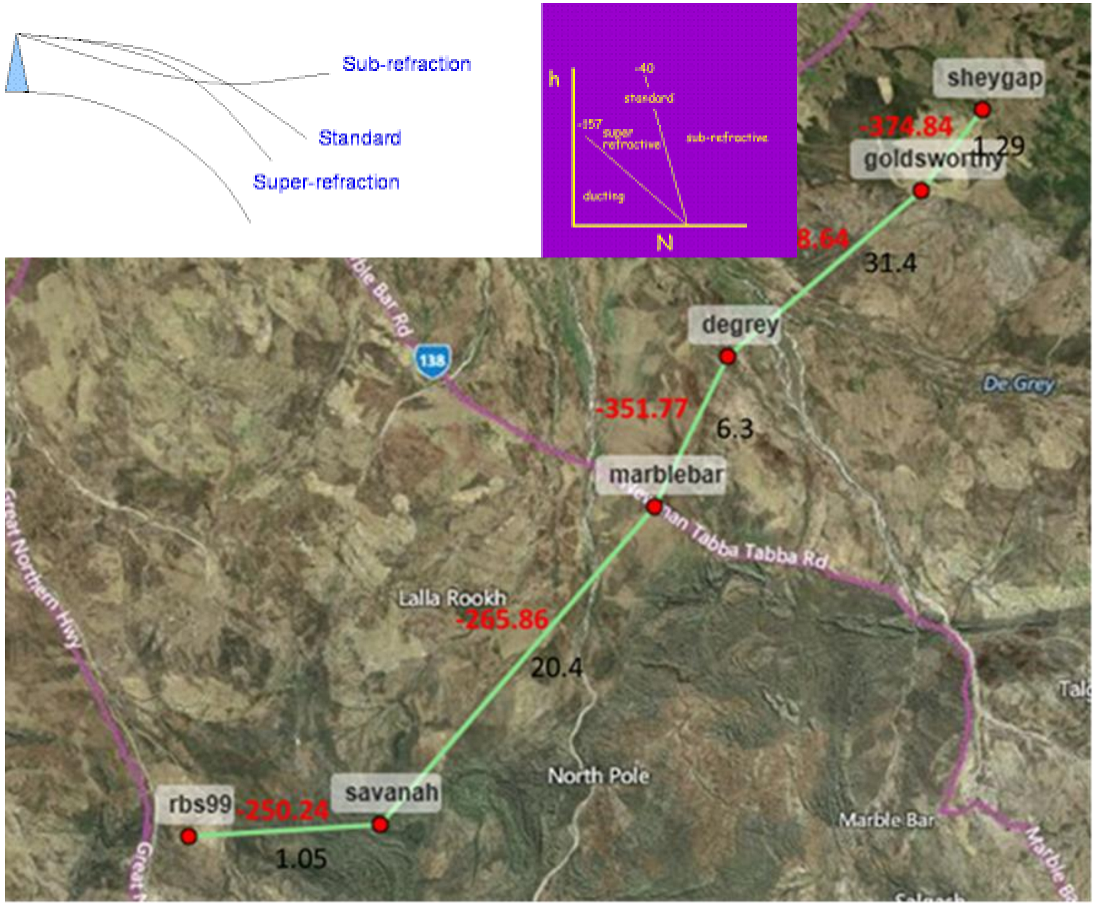
- Refractivity Defines Propagation Behaviour
- Refractivity (N) is driven by:
  - Pressure
  - Temperature
  - Humidity
- Typical ground value ≈ **315 N-units**
- Varies with altitude and environmental conditions
- Governs how strongly the path bends
- **Key takeaway:**
- Propagation is controlled by the atmosphere, not the radio.

Refractivity Gradient. The Critical Design Variable

- **Refractivity Gradient Drives Link Stability**
- What matters is not N. It is dN/dh (gradient) - how quickly refractivity changes as you go up in altitude
- Typical median value:~ –39 N-units/km
- Gradient changes over time → causes:
  - Refraction variability
  - Ducting
  - Multipath conditions

Design Implication. Why This Matters for Product Selection

- Propagation Directly Influences Product Choice
- Atmospheric behaviour determines:
  - Fade margin requirements
  - Need for diversity (space, frequency)
  - Suitable frequency band
- Higher variability → requires:
  - More robust radios
  - Lower modulation reliance
  - Better fade mitigation



Fade Margin. Your Only Protection

- Fade Margin Defines Link Survivability
- Fade margin = difference between Nominal receive level and Receiver threshold
- Directly determines:
  - Link availability
  - Outage probability
- Must be aligned to:
  - SLA (99.9 → 99.999%)
  - Application requirements

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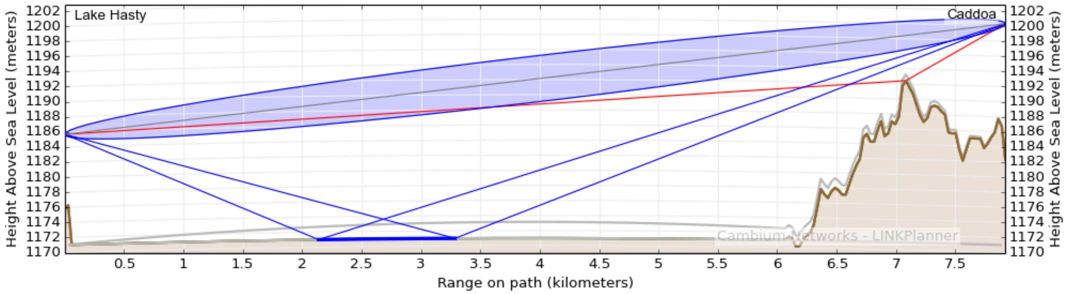
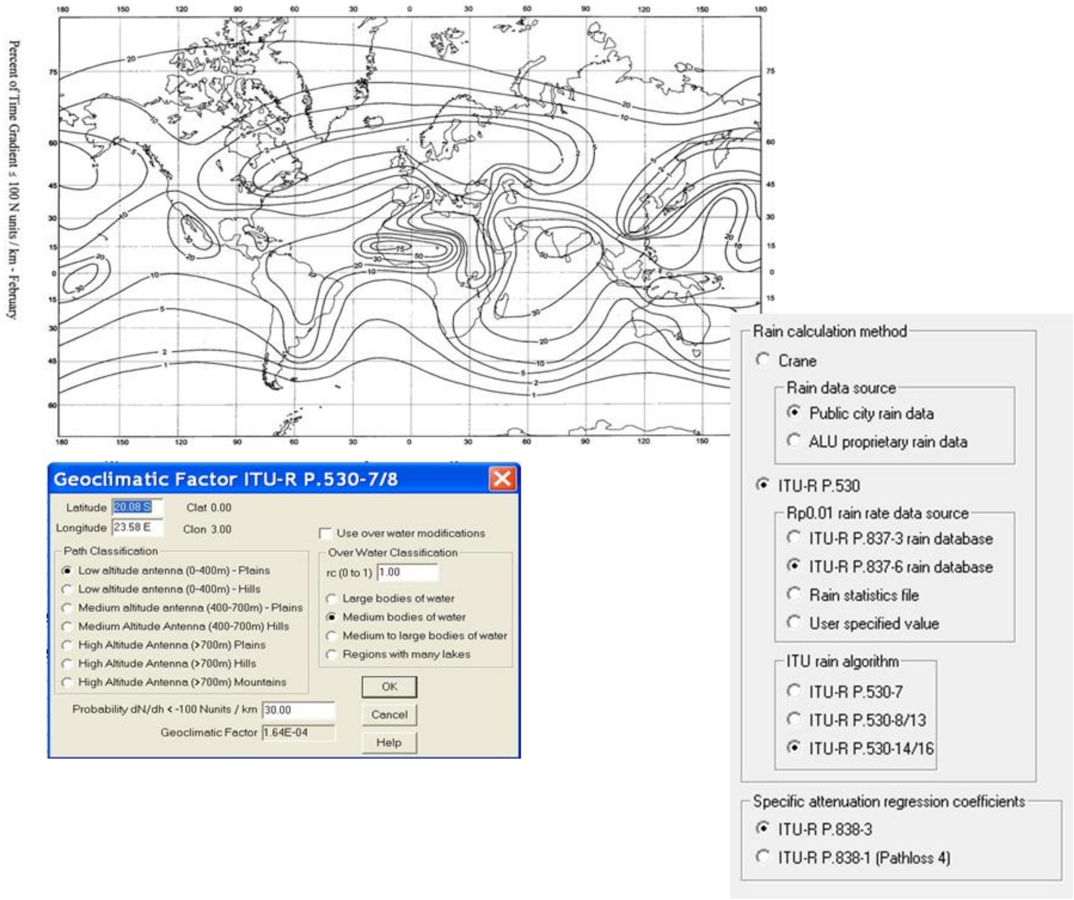
Multipath. The Primary Threat (Sub-11 GHz)

- Multipath Is the Dominant Failure Mode at < ~11 GHz
- Caused by:
  - Reflections (ground, water)
  - Atmospheric ducting
- Creates:
  - Signal cancellation (deep fades)
  - Phase interference
- Results in:
  - Rayleigh fading (narrowband)
  - Selective fading (wideband)



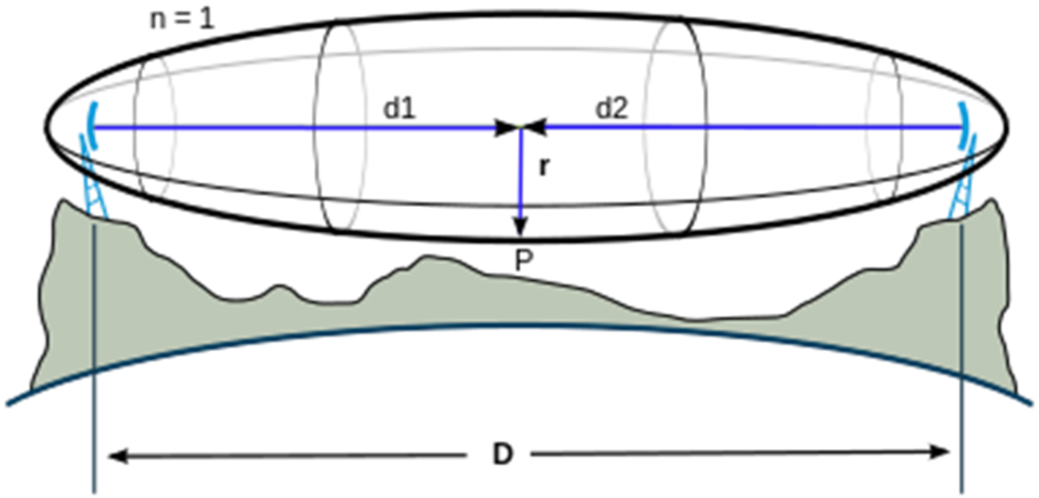
Rain vs Frequency. The Hard Trade-Off

- Rain Becomes Dominant Above ~10 GHz
- Below ~5 GHz:
  - Rain negligible
- 5–10 GHz:
  - Secondary effect
- 10 GHz:Major attenuation driver
- Higher frequency:
  - Higher attenuation
  - Shorter viable link distances



Fresnel Clearance. LOS Is Not Enough

- Line of Sight Does Not Guarantee Performance
- What is a Fresnel Zone? It represents a BOUNDARY condition where the net effect of a Huygens' energy source changes from enhancing the overall signal to depleting it
  - Nothing to do with antennas
  - Nothing to do with shape of radiowaves (b/c rays travel in straight lines)
  - Are not relevant until an OBSTACLE is introduced and therefore nothing to do with power density
  - Are three dimensional but normally refer to vertical obstruction (hill, tree, building, etc)



$$F_1 = \sqrt{\lambda \frac{d_1 . d_2}{d_1 + d_2}}$$

Diffraction Fading and Planning Criteria

Diffraction Fading

- Variations in atmospheric refractive conditions cause changes in the effective Earth's radius or k-factor from its median value of approximately 4/3 for a standard atmosphere
  - (see Recommendation ITU-R P.310).
- When the atmosphere is sufficiently sub-refractive (large positive values of the gradient of refractive index, low k-factor values), the ray paths will be bent in such a way that the Earth appears to obstruct the direct path between transmitter and receiver, giving rise to the kind of fading called diffraction fading.
- This fading is the factor that determines the antenna heights.

Planning Criteria

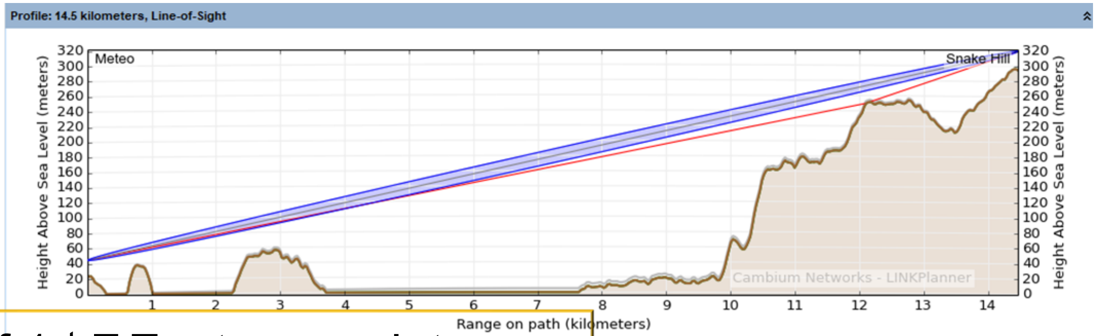
- Diffraction theory indicates that the direct path between the transmitter and the receiver needs a clearance above ground of at least 60% of the radius of the first Fresnel zone to achieve free-space propagation conditions.

Clearance Rules for Main Antenna			
	Rule 1	Rule 2 (Temperate)	Rule 2 (Tropical)
Traditional	100% F1 at k = 4/3	60% F1 at k = 2/3	60% F1 at k = 2/3
ITU-R P.530-12	100% F1 at k = 4/3	0% at k_{min}	60% F1 at k_{min}
		(isolated obstacle)	
		30% at k_{min}	
		(extended obstacle)	

Recommendation ITU-R P.530-18

k factor & Clearance Real-world Advice

- Short Hops (< 20km)
- Longer hops (>20km)
- First Criteria - One for normal atmospheric conditions (K=4/3)
  - Should meet 100% first Fresnel zone radius over K=4/3.
- Second Criteria - Substandard atmosphere that uses a minimum value of K.
  - Should meet 60% first Fresnel zone radius over a minimum value of K



Radius of 1st F.Z. at any point along the path (in **meters**):

$$\mathbf{R} = 17.3 \times \sqrt{\frac{d1d2}{f[GHz] \times (d1+d2)}}$$

$$\mathbf{Rmax} = 8.66 \times \sqrt{\frac{D[Km]}{f[GHz]}}$$

Set Clearance Criteria

OK Cancel Help

	Main	Diversity
1st Criteria - K	1.333	1.333
1st Criteria - %F1	100.00	60.00
1st Criteria - Fixed Height (ft)		
2nd Criteria - K	0.667	
2nd Criteria - %F1	30.00	
2nd Criteria - Fixed Height (ft)		
Frequency (MHz)	11200.00	

Diversity 2nd Criteria - %F1 :

One major deduction to be made from the theory of Fresnel zones is that, in theory, provided at least **60% of the first zone is clear of any obstruction**, the effect of the Earth can be ignored and the path loss approximated by the **free-space loss**. There will be no diffraction loss.

Design Implication. Product Selection Framework

Condition	Dominant Issue	Product Strategy
<10 GHz, long paths	Multipath	Diversity, robust modulation
>10 GHz	Rain	Short hops, high fade margin
Obstructed paths	Diffraction	Lower freq, higher antennas
High reflection paths	Multipath	Space diversity

- The Core Trade-Off Triangle - You Cannot Optimise Everything
- Three competing factors:
  - Availability
  - Capacity
  - Cost
- Improving one - Degrades at least one other

Link Design Is About Availability. Not Just Connectivity

Microwave Link Design = Availability Engineering

- Objective is not "make the link work"
- Objective is:
  - Meet availability targets (e.g. 99.99%, 99.999%)
- Requires:
  - Quantifying outage probability
  - Designing against worst-case conditions

The Design Process Is Iterative

- No single-pass solution
- Design requires iteration between:
  - Path profile
  - Frequency selection
  - Equipment choice
  - Fade margin
- Trade-offs are unavoidable

Terminology

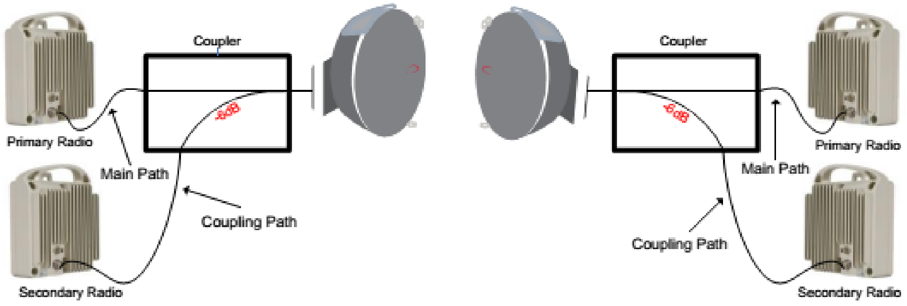
- FDD VS TDD:
  - FDD uses two frequencies for simultaneous send/receive.
  - TDD uses one frequency, alternating between send and receive.
- AGGREGATE CAPACITY VS ONE WAY CAPACITY:
  - Aggregate capacity indicates uplink (UL) capacity plus downlink (DL) capacity.
  - One-way capacity indicates either UL or DL capacity but not aggregate.
  - Most unlicensed PTP radios can be configured in 50:50 or 75:25 or other modes.
  - Typically, most licensed PTP radios are configured in 50:50 mode.
- LICENSED VS UNLICENSED FREQUENCY:
  - Government agencies regulate which frequency bands can be used without any license or charge, these are known as unlicensed frequency; for example: 5 GHz, 6 GHz, 60 GHz.
  - Licensed frequency such as 11/18/23/80 GHz require a government license for deployment.

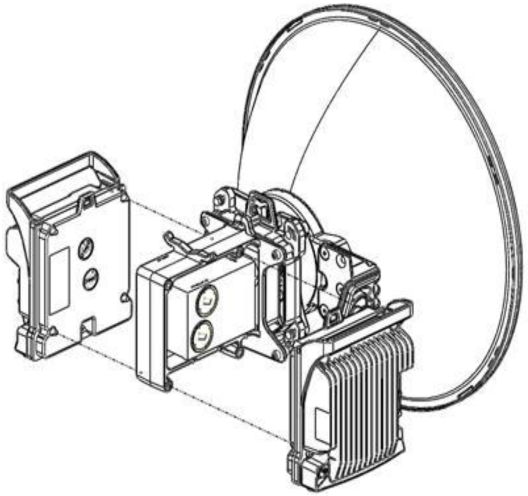
Terminology

- PTP RADIOS CAN BE SET UP IN MULTIPLE CONFIGURATIONS:
  - 1+0: Single radio, no redundancy built in
  - 1+1: Two radios; however, only single radio at any given time (aka hot standby)
  - 2+0: Two radios working simultaneously
  - 2+2: Four radios; however, only two radios are active at any point
  - 4+0: Four radios working simultaneously

- SPACE DIVERSITY:
  - Same signal sent through different antennas to improve reliability

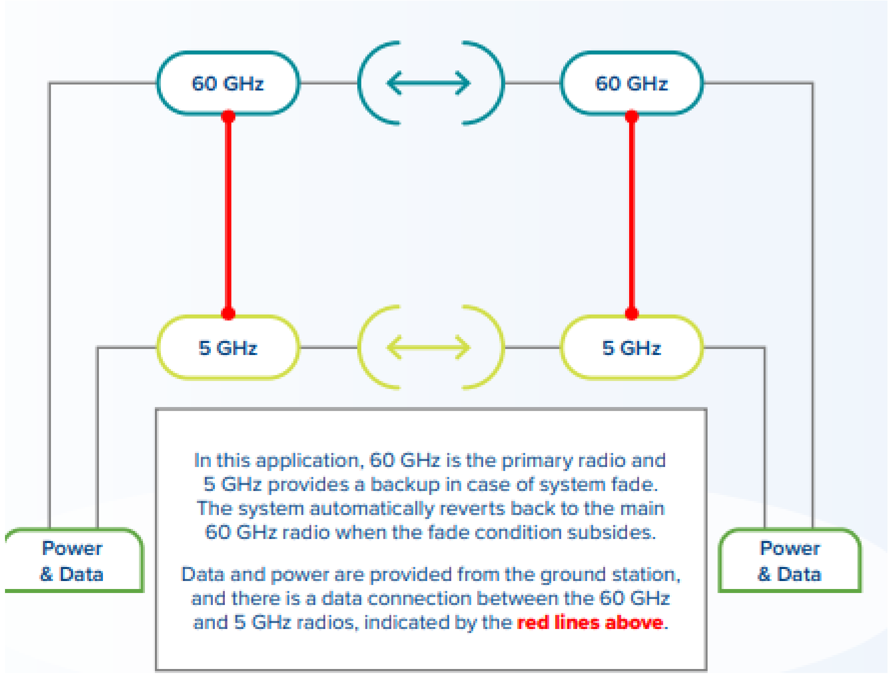
Configuration Types

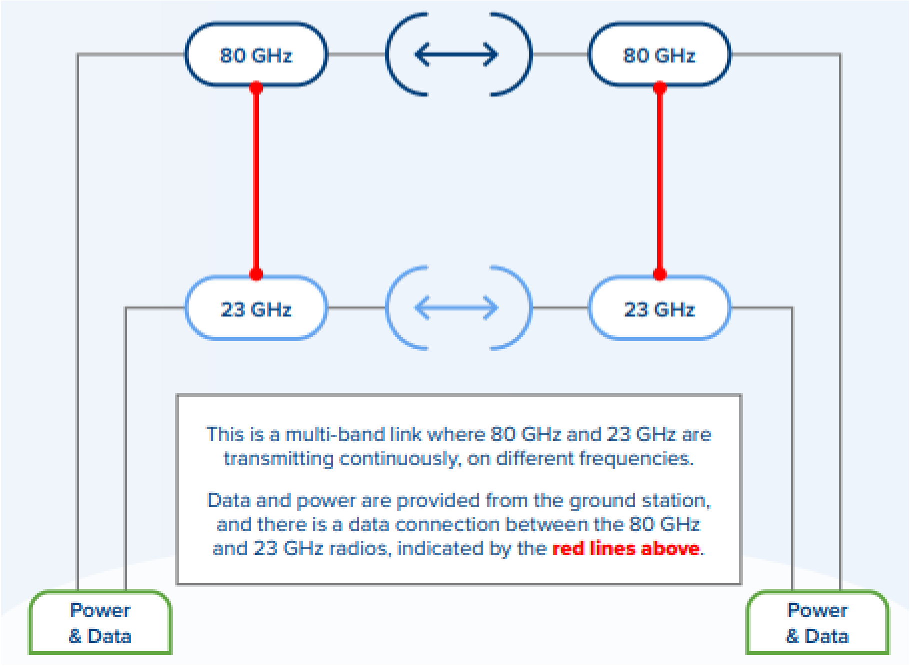




Understanding Multiband

- Multi-band radios are links that have two radios in different frequencies being used to transport data.
- Example: 60 GHz and 5 GHz – 60 GHz has high capacity but limited range. To counter this, cnWave 60 GHz can be used with ePMP PTP solutions to provide an alternate route when the link has low availability (i.e., in case of rain).
- 80 GHz & 18/23 GHz – 80 GHz has high capacity but limited range. In licensed microwave, 18/23 GHz provides alternate guaranteed availability.





Terminology

- **CONNECTORIZED VS INTEGRATED:**
  - Integrated radios: The radio is permanently attached to the antenna, which cannot be changed. Simpler installation and sometimes smaller form factor.
  - Connectorized radios: Radio connects to various antennas, which can be adjusted per the link design to tailor capacity and availability at a given range.
- **2+0 Doubles Capacity**
  - **CCDP (XPIC)** XPIC doubles capacity using both vertical and horizontal polarity.
  - **ACAP** Adjacent Channel Alternate Pol
  - **ACCP** Adjacent Channel Co-Pol
- **NARROW CHANNEL SIZE VS WIDE CHANNEL SIZE:**
  - Narrow channel size improves receiver sensitivity and improves SNR (signal-to-noise ratio); ideal in high noise congested areas.
  - Wide channel size increases capacity but is susceptible to noise; ideal in low noise environments.

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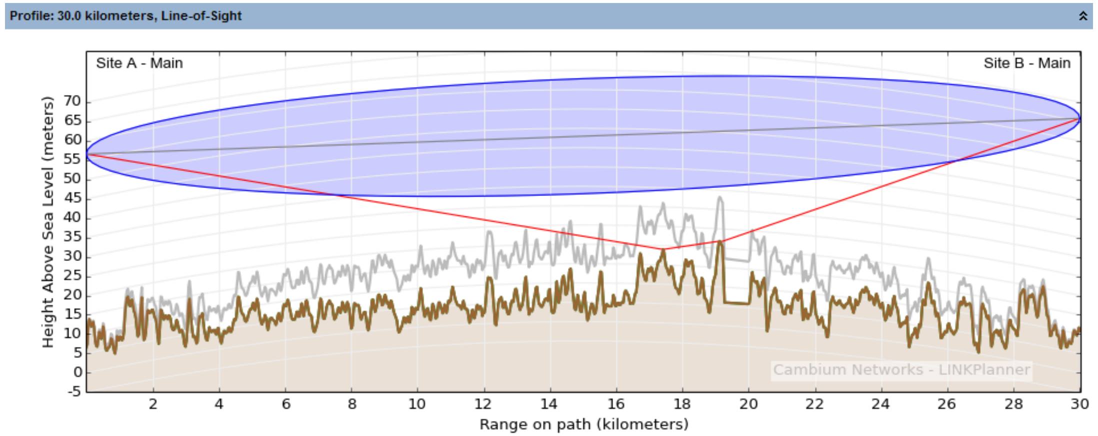
- LINKPlanner IS A FREE TOOL FROM CAMBIUM NETWORKS THAT PROVIDES NETWORK DESIGN CAPABILITIES.
- Why is link planning important?
- » Provides estimated system performance before product purchasing.
- » Helps design complex networks for optimal deployment and cost effectiveness.
- » Generates reports that validate projected performance and serve as time-saving deployment guidelines.
- » Creates a bill of materials for PMP and PTP networks, including accessories.



Thank You.