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Interference Management for 60 GHz

Brainstorming Broadband: Developing a Roadmap for India

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FACEBOOK MISSION

"Give people the power to *share* and make the world more *open* and *connected*"

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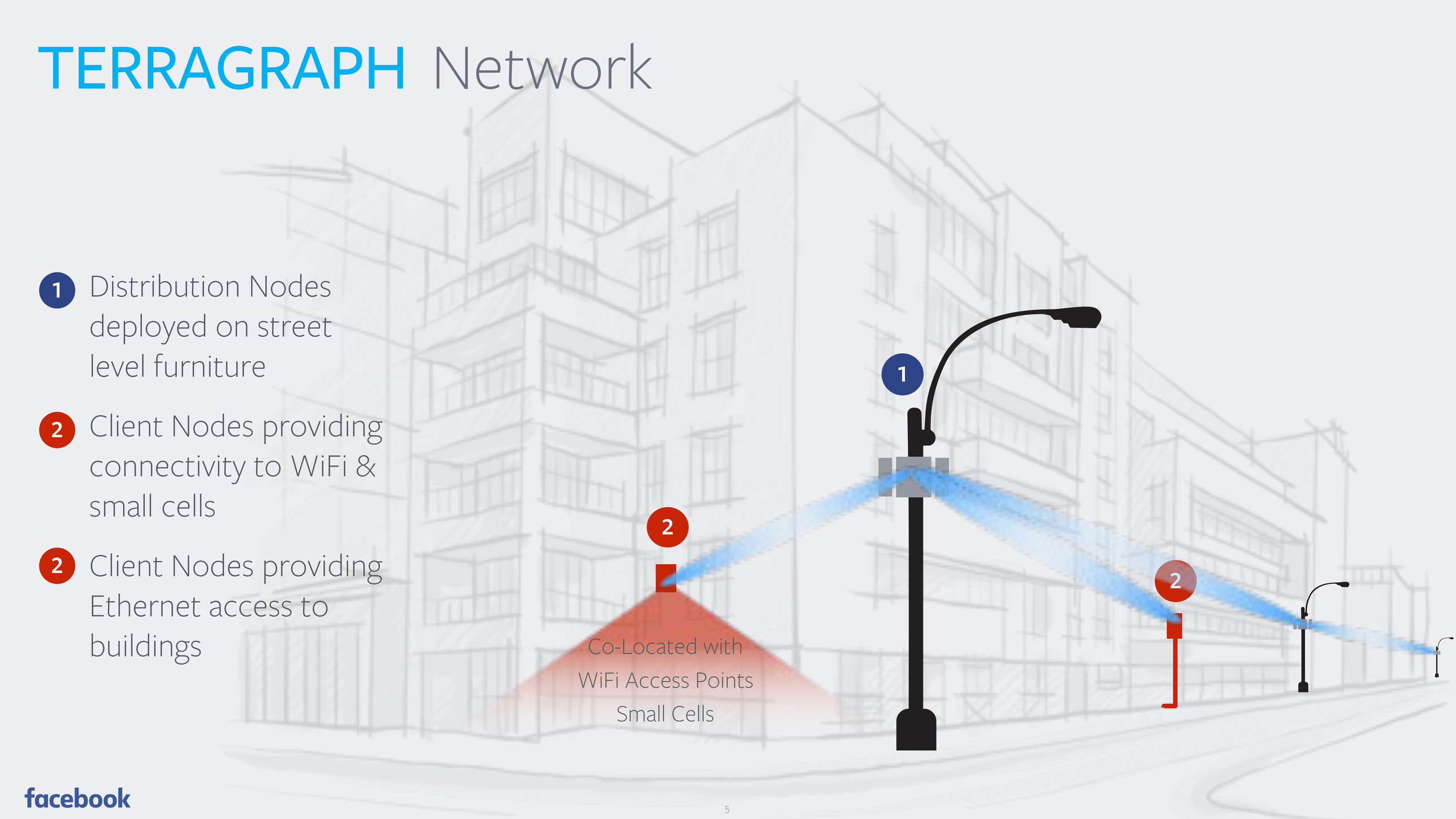
TERRAGRAPH

A 60GHz Wireless Network for Dense Urban environments

- Small nodes on city street furniture
- Utilizes high volume, low cost chipsets (WiGig)
- Enabled by Facebook Connectivity Lab breakthroughs

TERRAGRAPH Network

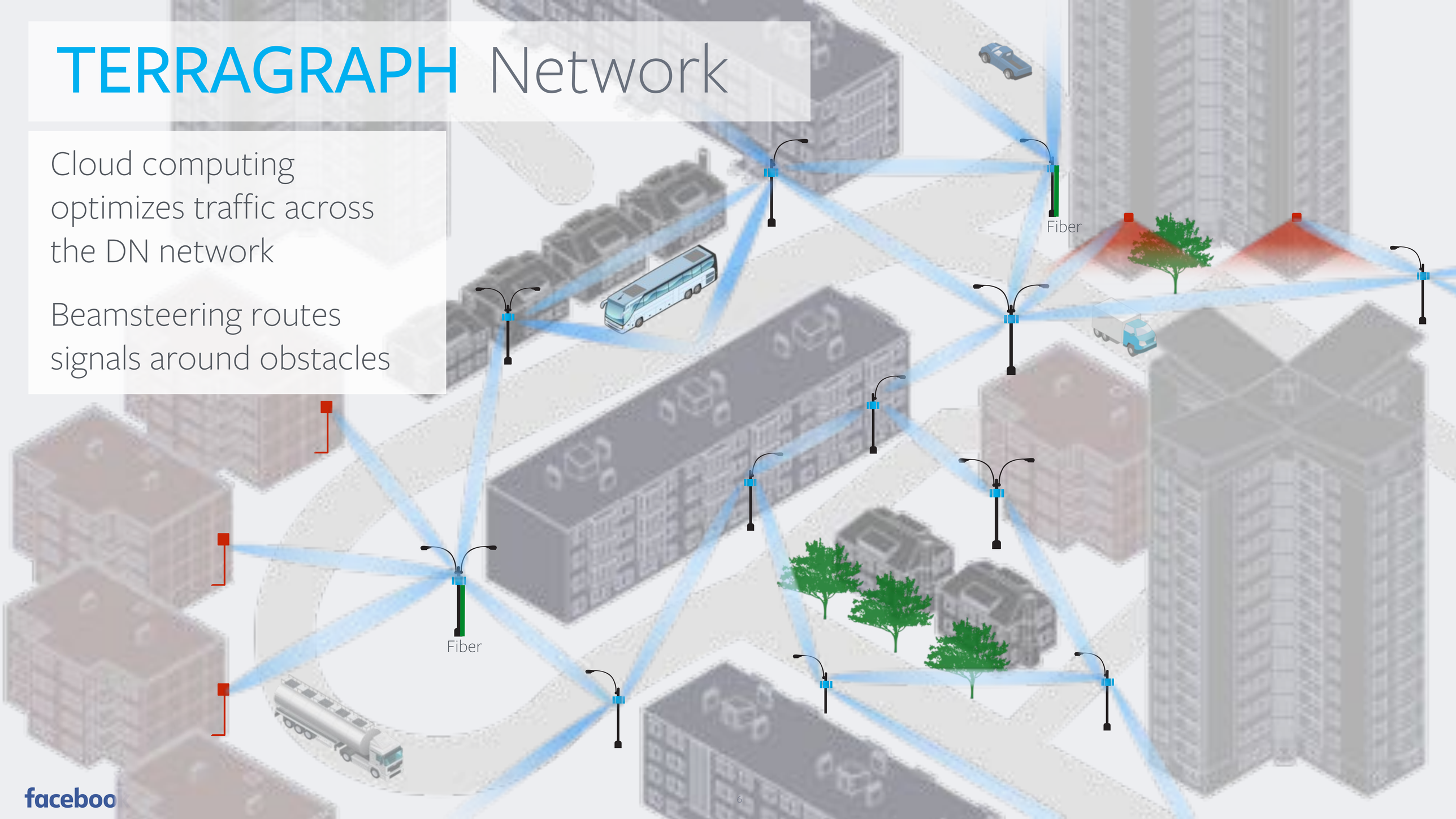
1. Distribution Nodes deployed on street level furniture
2. Client Nodes providing connectivity to WiFi & small cells
2. Client Nodes providing Ethernet access to buildings



TERRAGRAPH Network

Cloud computing optimizes traffic across the DN network

Beamsteering routes signals around obstacles



Interference Management

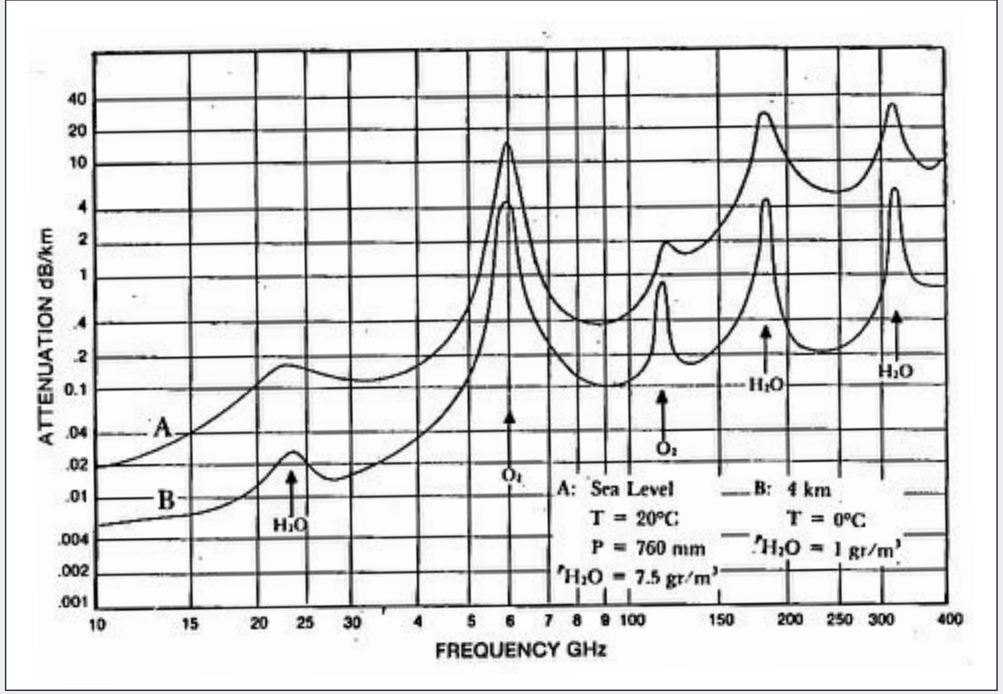
Interference Management at 60 GHz

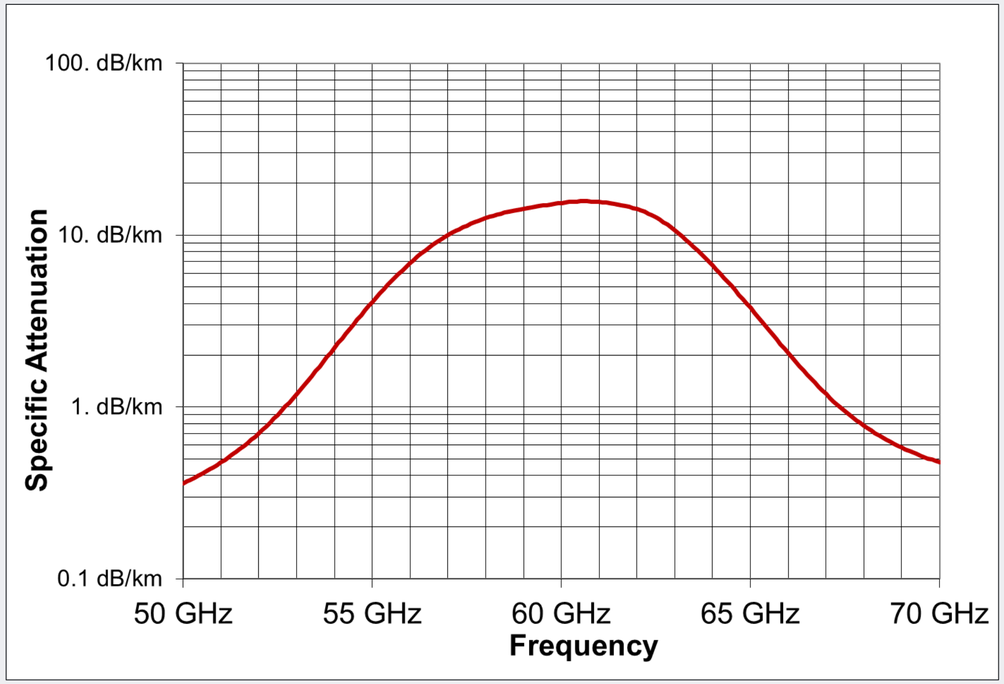
1. Significant discussion on 60 GHz interference management and how it pertains to licensing of the band
   - License exempt status important as “Innovation Band” similar to WiFi success at 2.4 GHz and 5 GHz.
2. 60 GHz possesses inherent interference mitigation properties
3. Interference is easily managed via well known and easily implementable techniques at both the micro (link) and macro (system) level
4. Leverage existing IEEE standards based based 60 GHz radios

Facebook has synthesized and incorporated these techniques into Terragraph

60 GHz at a Glance

- Gaseous absorption peak at 60 GHz by 0^2 & H^2O
- 16 dB/km at center of band
- >10 dB/km other parts of V-band
- Reduced co-channel and intersystem interference





'Millimeter Wave Propagation: Spectrum Management Implications', FCC OET, Bulletin No 70, 1997

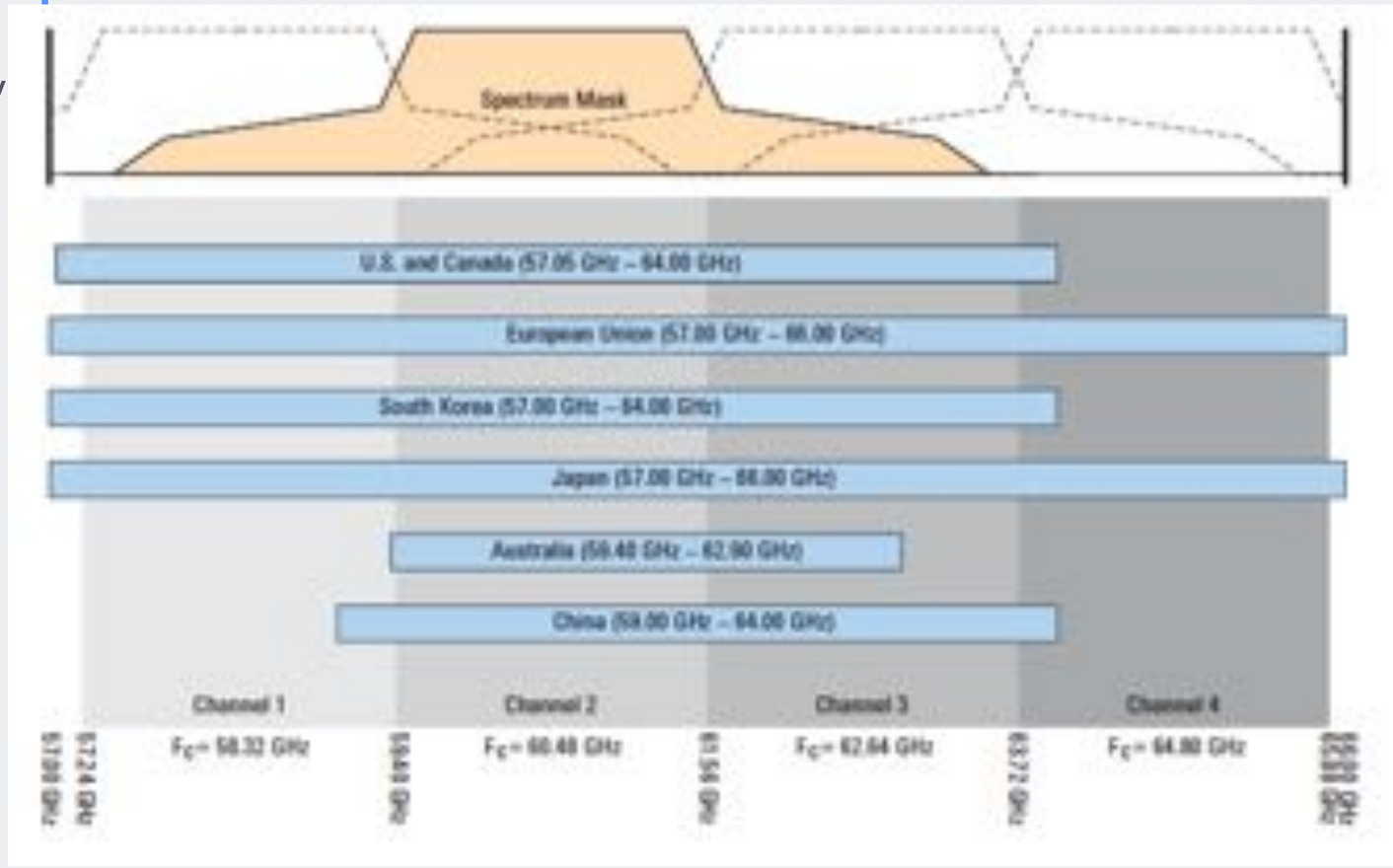
Techniques

1. **Single Frequency Network** allows multiple carriers to exist in the same spectrum
2. **Route Diversity** bypasses obstructions and routes along alternate paths
3. **Reflected Signals** improve link availability
4. **Null Steering** attenuates interference
5. **TDD/TDM** for future cognitive networks

Single Frequency Network

Reduce interference with multiple channels

- Single frequency networks are easily implementable at millimeter wave
  - Cloud based software + inexpensive radios in mass production
- Enables 3 IEEE channels to coexist at 60 GHz as multiple operators
  - Expansion to 6 channels[#]



60 GHz Band Channel Plan and Frequency Allocations by Region*

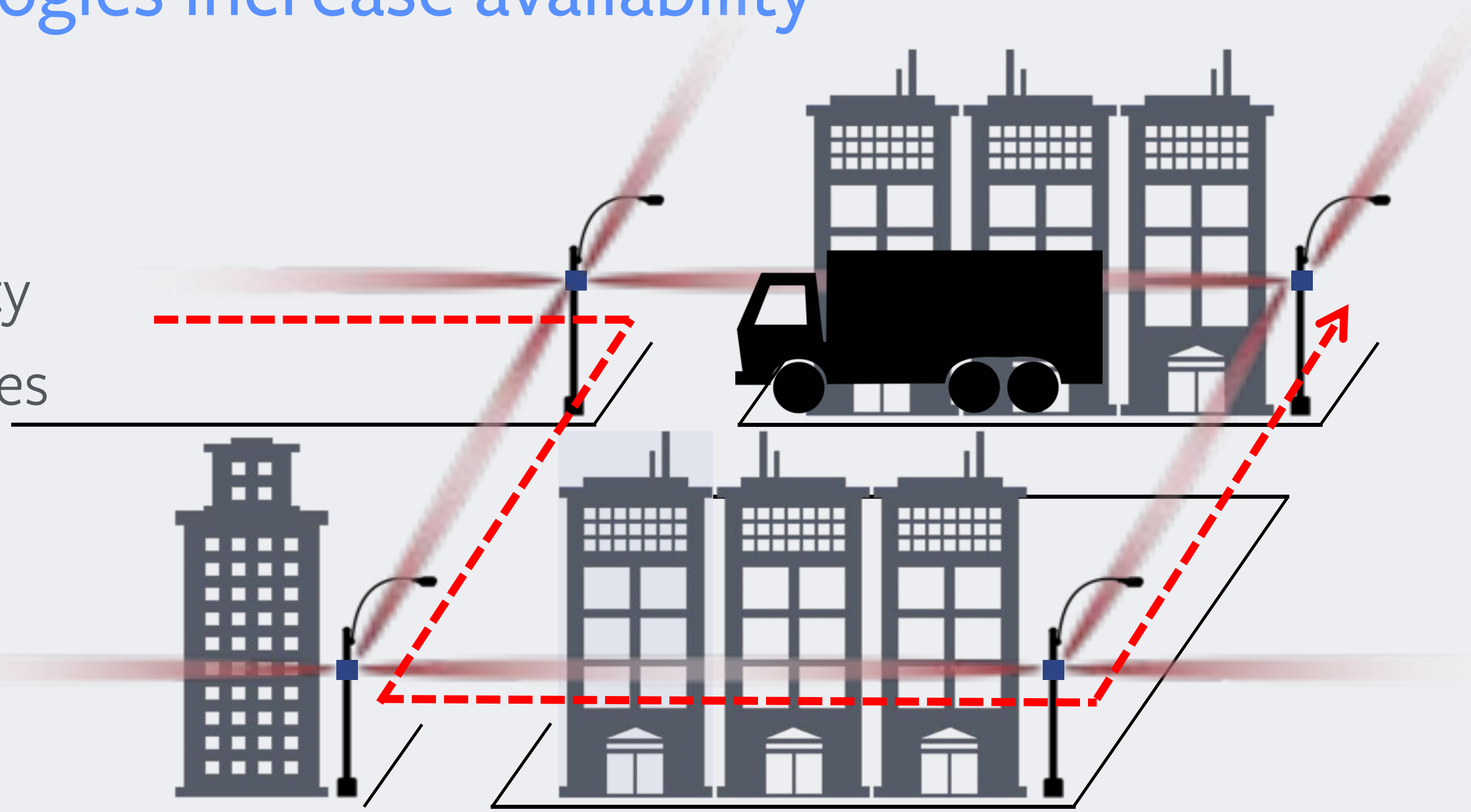
* Image courtesy of: 'Wireless LAN at 60 GHz - IEEE 802.11ad Explained', Agilent Application Note , 2013

US FCC

Route Diversity

Redundant network topologies increase availability

- Packets route around interfered links
- Cloud maintains route integrity and continuously pre-computes alternate routes
- Cubic route diversity for full formed network topology

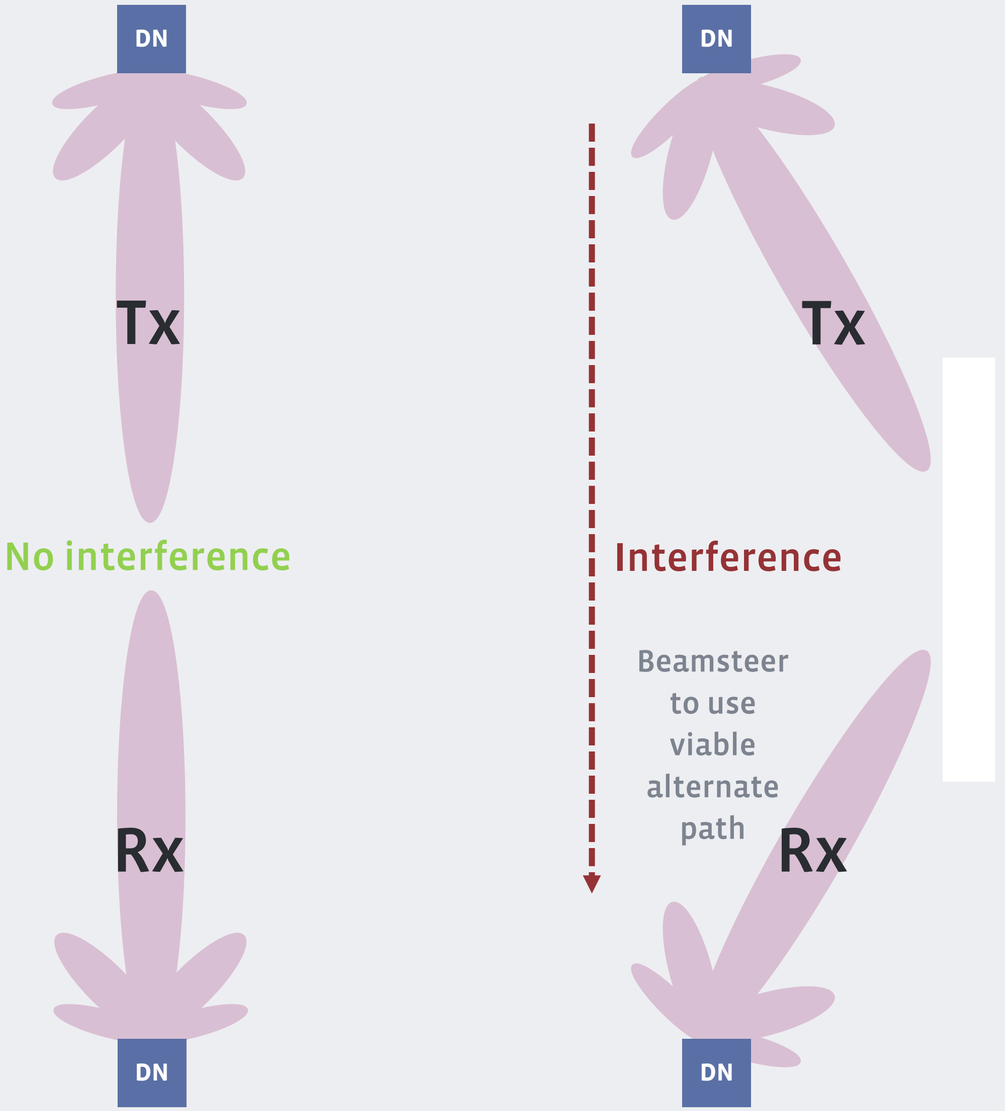


1. Original packet route obstructed by truck
2. Obstruction noted
3. Node selects pre-computed alternate route

Reflected Signals

13 dB of suppression via beam steering

- Utilize beamsteering to change angle of beams to pre-computed alternate routes leveraging reflectors
  - Relies on cloud/centralized coordination of both ends
- Gives a 13 dB advantage over the interferer (20x) less reflection loss
- Research indicates viable single reflections exist

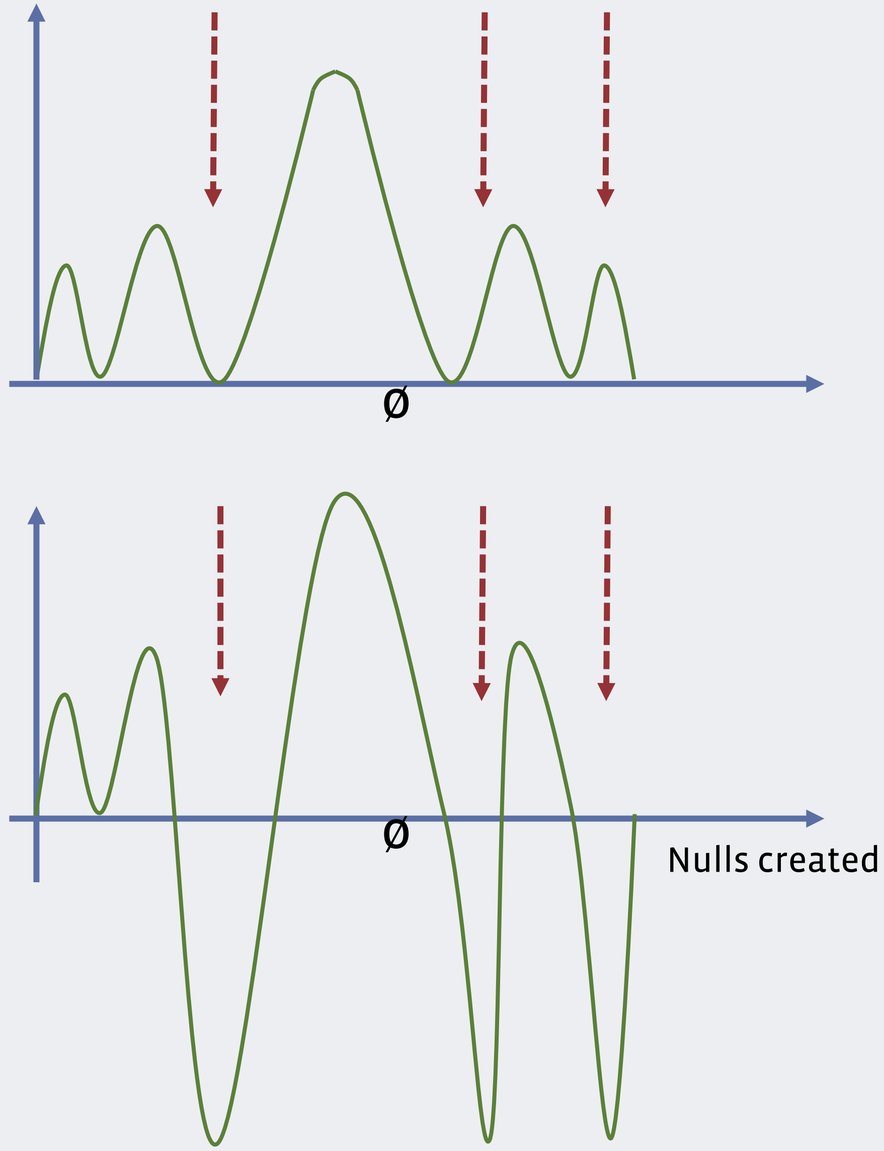


Source: “Non-line-of-sight microwave backhaul for small cells”, Ericsson Review, Feb 22, 2013,

Null Steering

28 dB of suppression via null steering

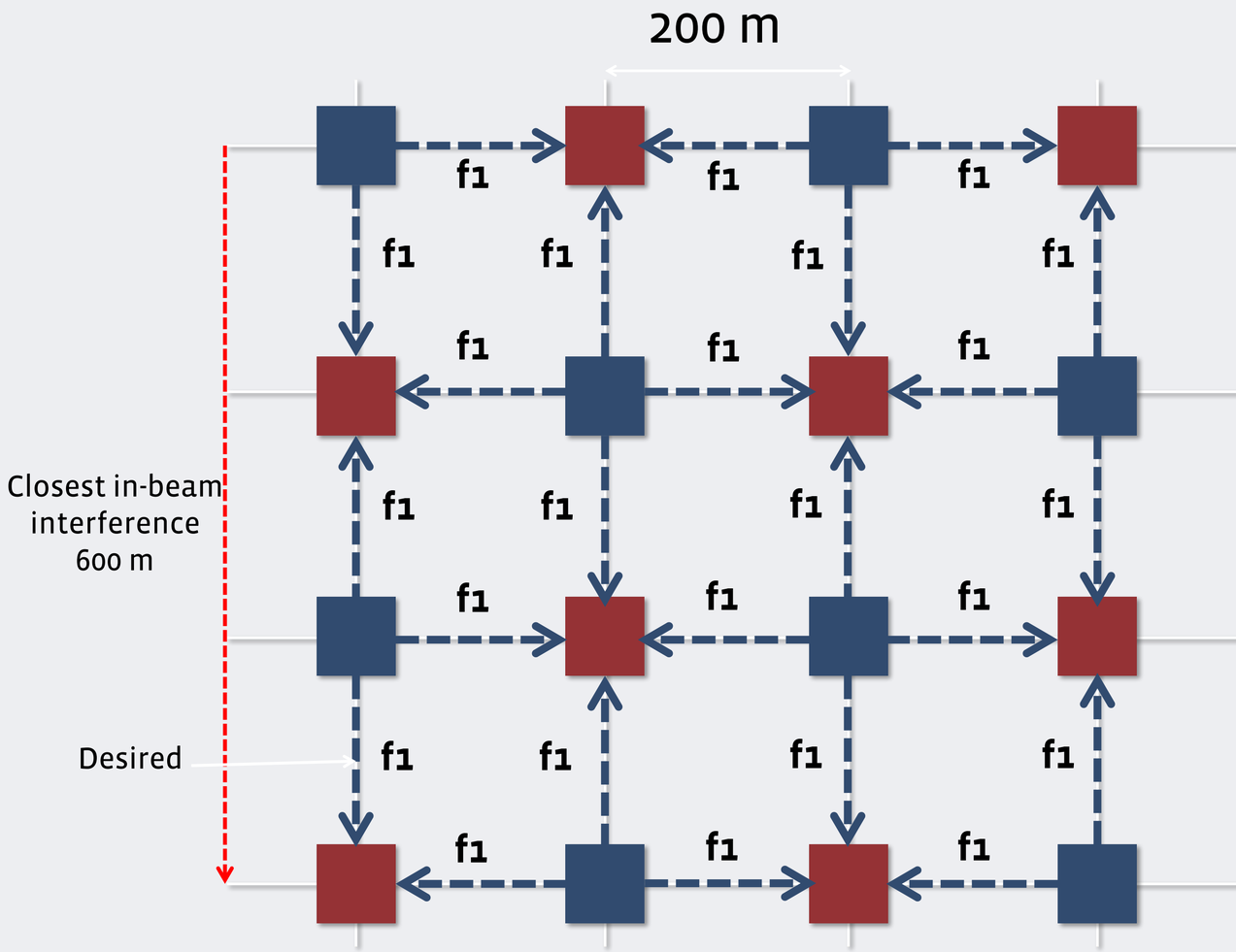
- Reduce number of beamforming elements to create steerable nulls
- Each sector cancels up to three interferers
  - 28 dB performance advantage (reduces interference by more than 500x)
- Widely implemented at 5.8 GHz



TDD/TDM

Choice of network topology can reduce intersystem interference

1. **Red** and **Blue** nodes alternate transmit and receive
   - Even slots: **Blue** tx on all faces, **red** rx
   - Odd slots: **Red** tx all faces, **blue** rx
2. Closest interferer that falls in line of the beam is 15.5 dB lower than desired signal (600 m)
   - 9.5 dB due to free space
   - 6 dB due to oxygen
3. Coordinated scheduling across network to avoid interference – cognitive radio



Summary

- 60 GHz possess inherent interference mitigation attributes
- Traditional interference fighting techniques can be applied to 60 GHz
- Leverage existing IEEE 60 GHz radios
- License exempt status important to innovation – Terragraph

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