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FCC OET

Cisco Systems, Inc.

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Overview

- Demand Drivers
- Deployment Model
- TDD & FDD
- Licensing & Coordination
- ATPC
- Technical Rules

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Demand Drivers

Demand Drivers: Network Growth

- **Network Connectivity Upgrade/Expansion**

  Rapid, competitive, flexible deployment

  Gigabit Ethernet Port Growth:

  7.1m in 2002
  12.1m in 2003
  20.6m in 2004

  10 Gig Ethernet Port Growth

  5k in 2002
  30k in 2003
  110k in 2004

  Growth in Distribution to Core, LAN to MAN

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Demand Drivers: Domestic Fiber Hotels

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- There are about 8000 fiber hotels (POPs) today
- Business proximity[1]
  - 750k business buildings in US with >20 employees
  - Only ~5% of these buildings have fiber connections today
  - ~75% of these buildings are within 1 mile of a Fiber Hotel
- Fiber trenching has declined due to economic and Municipal conditions
- The opportunity is to bring these buildings online with fiber-like capacity using millimeter-wave wireless

This is the "Hub and Spoke" deployment

[1]Source: RHK

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Deployment Models

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Basic Hub and Spoke Deployment Model

- **Single Service Provider deployment:**
  - Acquires roof rights for all 70/80 GHz links on Fiber Hotel
  - Responsible for link performance and availability
  - Likely deploys radios from a single vendor
  - Has sophisticated radio planning and deployment departments; can readily resolve installation and commissioning difficulties
- **Enterprise deployment**
  - Enterprise customer owns and installs link from spoke to hub
  - Installation and commissioning costs must be kept low
  - Customer not typically equipped to resolve co-location interference problems
  - Hub location has many radios, independently managed, from multiple vendors
    - Multi-SP deployments share this characteristic

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Hub and Spoke Deployment Objectives

- Objective is to bring the benefits of fiber to customers

  With fiber, customers can upgrade to higher-rate services as their needs grow

  With fiber there is the perception, if not reality, of no practical bandwidth limitations

  These features equate to investment protection for the future

- 70/80 GHz wireless must offer the same benefits

  Wireless services must be capable of scaling to 10+Gbps rates

  As links are upgraded in capacity, there will be a mixture of different radios on the hub's roof—this should be enabled by the FCC's rules

- Technical rules must support/promote both deployment models

  Market will decide preferred model(s)

  Industry/customers win when barriers to deployment are removed

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On the Use of TDD & FDD in 70/80 GHz Paired Spectrum

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Hub and Spoke Interference

- **TDD radios**
  - Transmit and receive in the same band
  - Will interfere with FDD receivers operating in that band (both single-band and dual-band FDD receivers)
  - Will also interfere with other TDD radios from a different vendor
- **Single-band FDD radios**
  - Defined as frequency division duplexed with transmit and receive bands both within 71-76GHz (or 81-86GHz)
  - Nearby transmitters will interfere with dual-band FDD radio
  - Without industry agreement on channelization plan, single-band FDD transmitters may interfere with nearby single-band FDD receivers
- **Dual-band FDD radios**
  - Defined as frequency division duplexed with transmitter in 71-76GHz band and receiver in 81-86GHz band (or vice versa)
  - Nearby transmitters do not interfere with receivers as long as all [hub] outbound transmitters use the same band (assured by path coordinator)

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Benefit of Dual-Band FDD Architecture: Easy Capacity Upgrades to 10+Gbps

- Generally accepted in the industry that 71-76 *and* 81-86 GHz bands will be required for 10+Gbps, full duplex capacity
- Initial deployments using TDD or single-band FDD virtually guarantee transmitter co-location issues as capacity upgrades occur

    Nearby, planned upgrade of full-band 10Gbps transmitter would be operating in the same band as victim receiver

    In this scenario, path coordinator would predict harmful interference and not permit capacity upgrade

- Dual-band FDD radios do not have this problem

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Hub and Spoke Deployment Comments

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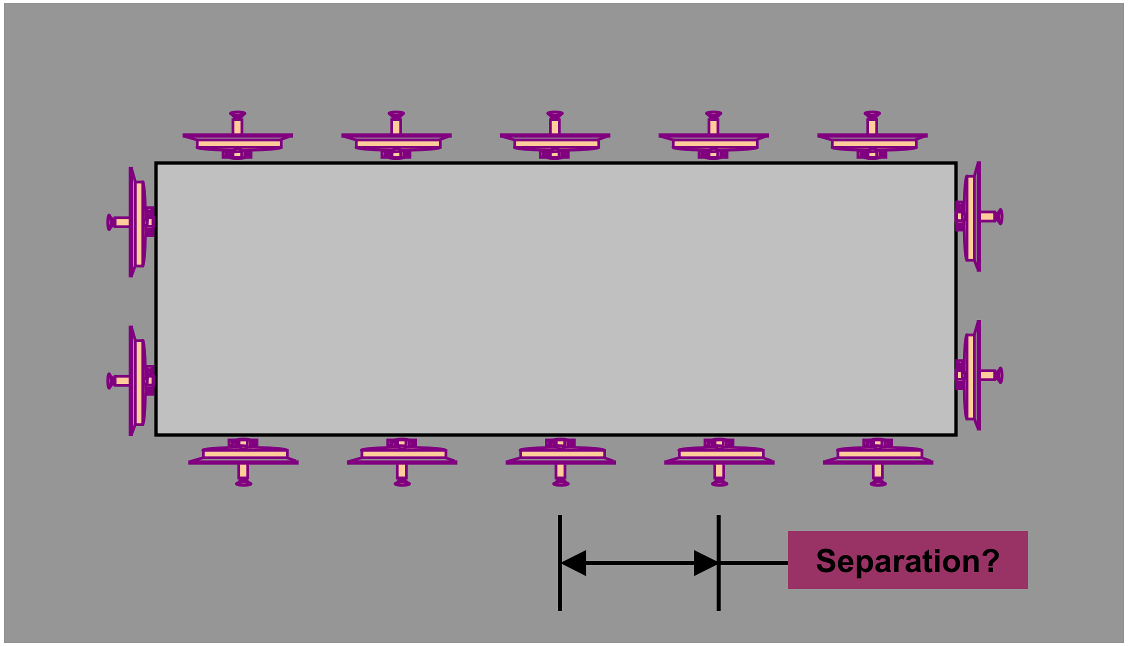

Illustration shows a number of hub radios mounted on the penthouse wall of a roof top

- Antenna sidelobe suppression is important (~90° off boresight)
- Can TDD/single-band FDD co-location issue be solved by increased separation distance?

  Answer: not easily and probably not without application of RF absorption material (see next slide)

Hub and Spoke: Radio Separation

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Transmitted Interference														
Antenna diameter	12	12	12	12	24	24	24	24	24	48	48	48	48	inches
Transmitter Power Available	22	20	15	10	28	25	20	15	10	***29***	25	20	15	dBm
Tx Antenna Gain	43	43	43	43	50	50	50	50	50	56	56	56	56	dBi
Boresight EIRP	**65.0**	**63.0**	**58.0**	**53.0**	**78.0**	**75.0**	**70.0**	**65.0**	**60.0**	**85.0**	**81.0**	**76.0**	**71.0**	**dBm**
Sidelobe level (90° off boresight)	-50	-50	-50	-50	-50	-50	-50	-50	-50	-50	-50	-50	-50	dB
Sidelobe EIRP	**15.0**	**13.0**	**8.0**	**3.0**	**28.0**	**25.0**	**20.0**	**15.0**	**10.0**	**35.0**	**31.0**	**26.0**	**21.0**	**dBm**
Calculate Received Interference														
Separation	**18**	**14**	**8**	**5**	**181**	**128**	**72**	**41**	**23**	**810**	**511**	**288**	**162**	**m**
Pathloss	95.0	93.0	88.0	83.0	115.0	112.0	107.0	102.0	97.0	128.0	124.0	119.0	114.0	dB
Victim Rx Antenna gain	43	43	43	43	50	50	50	50	50	56	56	56	56	dBi
Victim sidelobe level (90° off boresight)	-50	-50	-50	-50	-50	-50	-50	-50	-50	-50	-50	-50	-50	dB
Received interference level	-87.0	-87.0	-87.0	-87.0	-87.0	-87.0	-87.0	-87.0	-87.0	-87.0	-87.0	-87.0	-87.0	
Calculate Tolerable Interference														
Noise Figure	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	dB
Thermal Noise Floor	-76.0	-76.0	-76.0	-76.0	-76.0	-76.0	-76.0	-76.0	-76.0	-76.0	-76.0	-76.0	-76.0	dBm
Multiple signal interference level	-82.0	-82.0	-82.0	-82.0	-82.0	-82.0	-82.0	-82.0	-82.0	-82.0	-82.0	-82.0	-82.0	
Single signal interference level (avg)	-87.0	-87.0	-87.0	-87.0	-87.0	-87.0	-87.0	-87.0	-87.0	-87.0	-87.0	-87.0	-87.0	dBm
Other parameters														
RF safety level	0.87	0.55	0.17	0.05	0.86	0.43	0.14	0.04	0.01	0.27	0.11	0.03	0.01	mW/cm^2

- **Antenna RPE from Joint Reply Comments**
- **Total (hub+spoke) interference 6dB below noise floor; 5dB MEA (multiple exposure limit), 1000MHz bandwidth**
- **Without dual-band FDD, deployments should plan for at least 180m separation**

Licensing and Coordination

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Licensing and Coordination

- **Traditional Approaches**

  Geographic auctions are not appropriate in this case because they would unnecessarily constrain deployment and usage

  Although Site Licensing is the most appropriate model for RF purposes, the large number of sites or links would create an administrative burden during the initial application process as well as renewals or changes

  The current the path coordination process requires manual coordination between the FCC and IRAC

    ULS Staff indicated 35 day average processing time for private, fixed, point-to-point ULS applications (45 days for common carrier)

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Licensing and Coordination

- **Blanket Licensing with Path Coordination**

  First link authorized by traditional site-by-site licensing.

  Coordination completed in advance, with conditional operation permitted until application approval (based on Part 101)

  Coordination will be based upon GPS coordinates. Vertical coordination could be based on AGL utilizing the same side of a building or from a GPS-calculated roof height, with a floor count

  Upon grant of license, licensee could operate additional paths based upon coordination and notification of the Commission (could be done by Path Coordinator)

  Equipment upgrades would require re-coordination, with Commission notification.

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Licensing and Coordination with USG

- **Coordination Time between USG & commercial use**

  Comsearch filing supports 50-60 day best case coordination with FAS/IRAC, although there is no worst case limit. The lack of transparency into the process makes business planning impossible.

  We support a Trusted Path Coordinator, which the NTIA supported in their reply comments but with reservations that this requirement would limit the number of coordinators.

  NTIA agrees Government/Commercial coordination is a 'critical factor'. Continuation of the current process could lead to 'significant burdens' and 'unacceptable delays'

- **Cisco proposes:**

  1) All USG assignments, <u>excluding</u> classified, should be entered in the database used by accredited "Commercial Path Coordinators".

  2) All USG assignments, <u>including</u> classified, should be entered in the database used by authorized "Trusted Path Coordinators".

  3) Commercial Path Coordinators can query the database maintained by the Trusted Path Coordinator for a yes/no answer.

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Licensing and Coordination

- No Unlicensed use in band
  - Creates unacceptable uncertainty for Enterprise or SP use of OC-192 equivalent
  - Discovering, identifying and notifying an Unlicensed interferer is time prohibitive based on the negative business impact
- No Channelization
  - As depicted by our simulations, channelization of the band is not required to achieve a high density of deployment within a geography
  - Channelization will erode the multi-Gigabit data speed potential of this band, and reduce commercial interest
- Fixed Satellite Service
  - USwww: future commercial satellite priority over previously licensed terrestrial service will preclude commercial and SP use.
- Defer Mobile allocation
  - Would present new, potentially intractable coordination challenges

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On the Need for ATPC in 70/80 GHz Spectrum

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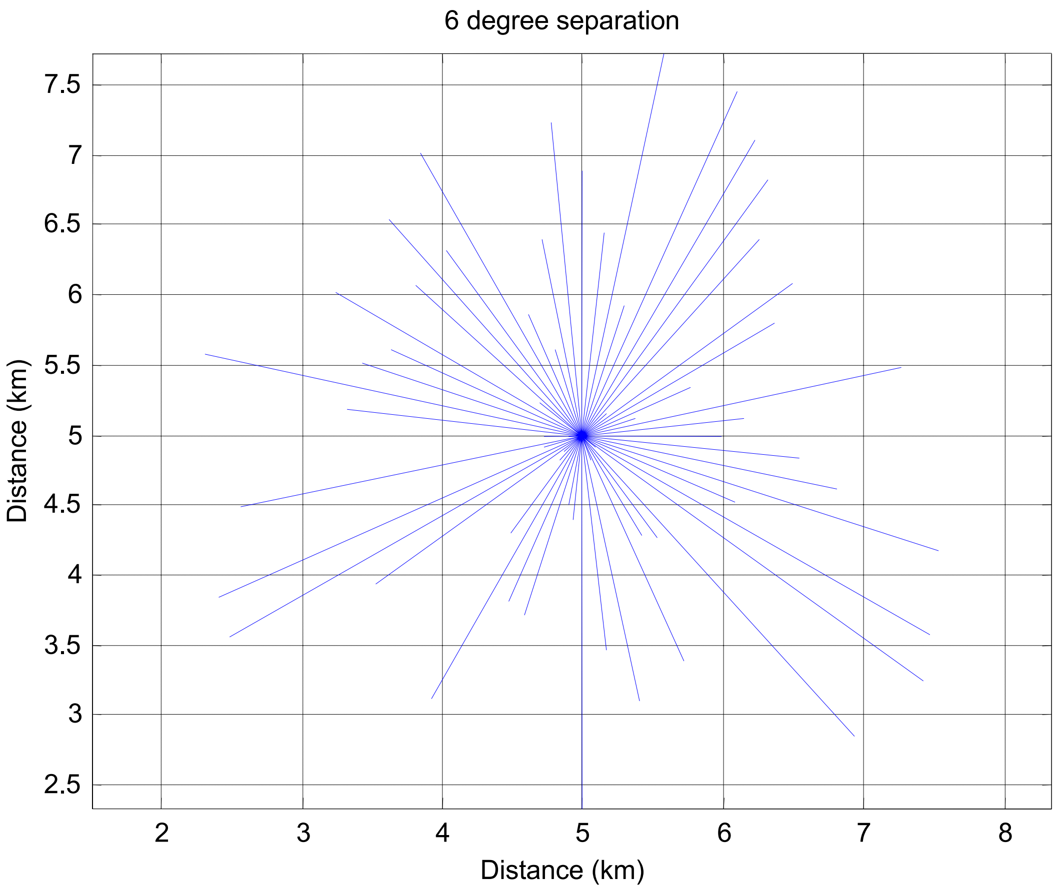
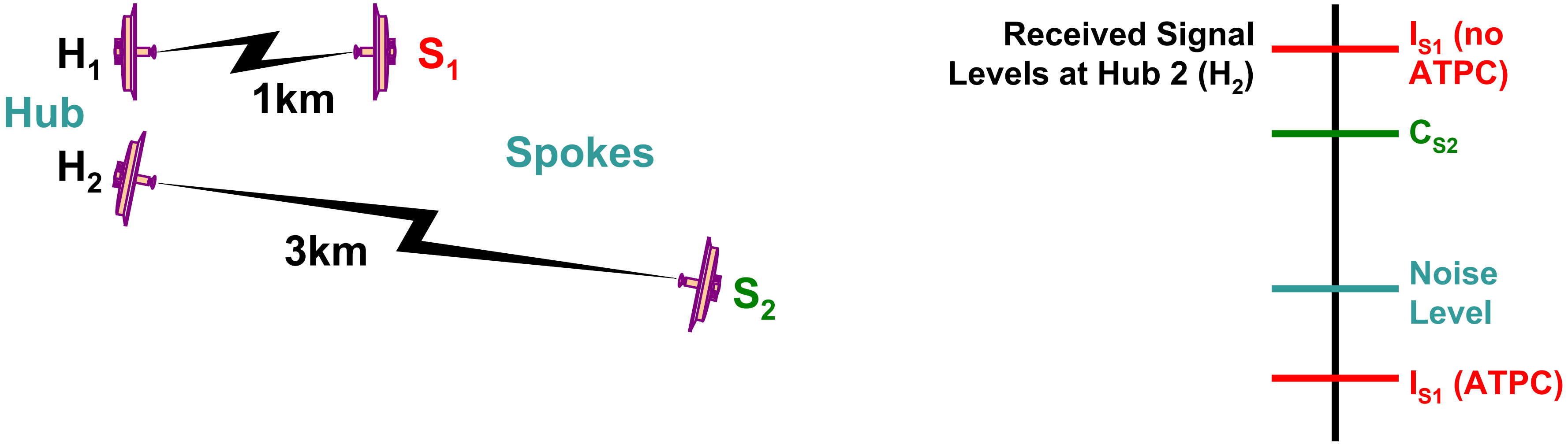
Hub and Spoke System Model



- This system models a tall building in the center linked to remote sites.
- Center building height is 50m.
- Links are equally spaced in angle around the center building, with random path lengths.
- Adjacent links are on opposite polarizations.
- All links transmit and receive with the same frequency plan (FDD).

How ATPC Helps Mitigate Interference During Rain



- ATPC helps on the "uplink" (Spoke to Hub direction)
- When it rains, link 2 (being longer) is impaired much more than link 1, exacerbating the near-far problem (example rain loss ≈15 dB/km at 40mm/hour precipitation rate)
- With ATPC, spoke transmitter on shorter link powers up less during rain
- The more the S_1 transmitter lowers its power using ATPC, the greater the probability link 2 (as well as other subsequent paths) can be coordinated
- The greater the EIRP of S_1, the more ATPC dynamic range is needed

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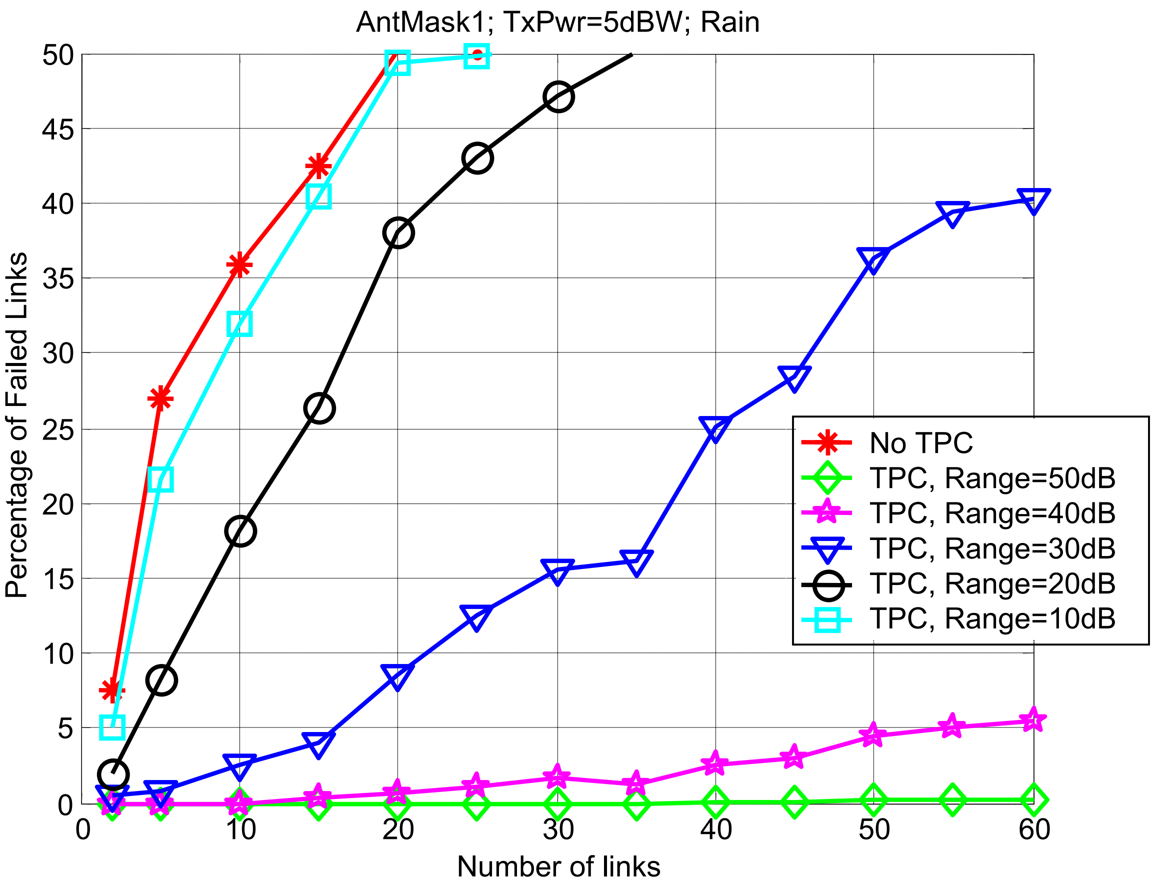
Simulation Results on the Effects of ATPC in Rain



- **In the rain, the system becomes significantly degraded without ATPC.**
- **This system layout is challenging since all interferers are pointed at the carrier of interest. Little antenna rejection is achieved on transmissions from the interferers.**
- **However with ATPC, a system with links separated by 6° can be supported in the rain with 5% of the links failing.**
- **The performance of ATPC is highly dependent upon the dynamic range of transmit power control. The larger the dynamic range, the more the Tx power can be reduced thereby reducing interference.**

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Proposed Technical Rules
(Joint Reply Comments Agreements)

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Proposed Technical Rules

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From Joint Reply Comments filed by Cisco, Bridgewave, Ceragon, Endwave, LOEA, Stratex:

- Dual-band FDD
  - 71-76 and 81-86 designated as paired spectrum
  - Given radio transmits in one band and receives in the other
- ATPC
  - Required only for radios with EIRP > 23dBW
  - Dynamic range (dB) = $EIRP_{dBW}$ - 23
- EIRP
  - Maximum is 55dBW when antenna gain is $\geq$50dBi
  - Maximum (dBW) = 55 - 2(50 - G) when antenna gain is $<$50dBi

Proposed Technical Rules (cont.)

- Power spectral density is ≤150mW per 100MHz
- Antenna radiation pattern envelope (RPE)
  - 1.2° minimum HPBW
  - 43 dBi minimum gain
  - Refer to Joint reply comments for co-pol and cross-pol sidelobe and backlobe levels
- Linear polarization

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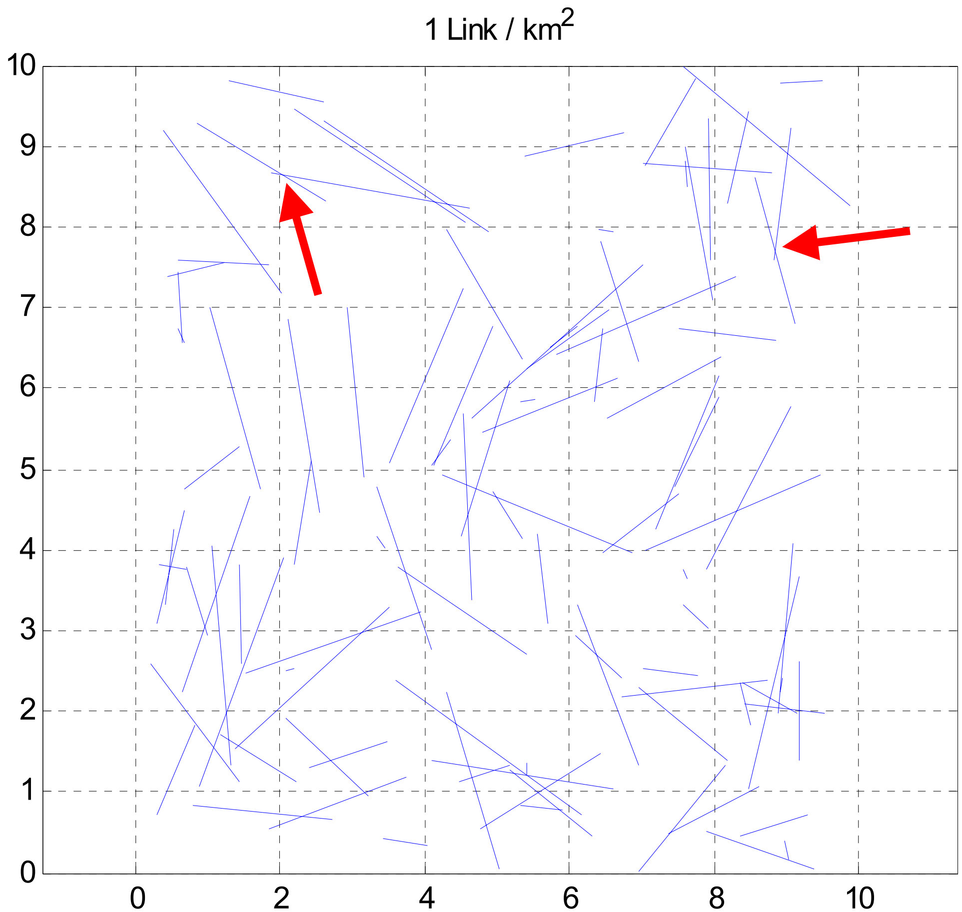
Background Material

Random Deployment Simulation Method



- This study simulated a square region 10 km by 10 km (roughly the size of San Francisco).
- The figure shows 100 links distributed over the 100 sq km area.
- The potential points of interference are when the end of one link shows up near the middle of the path for another link. Some of those points are shown as arrows in the figure.
- In this example the maximum length was approximately 2.5 km.

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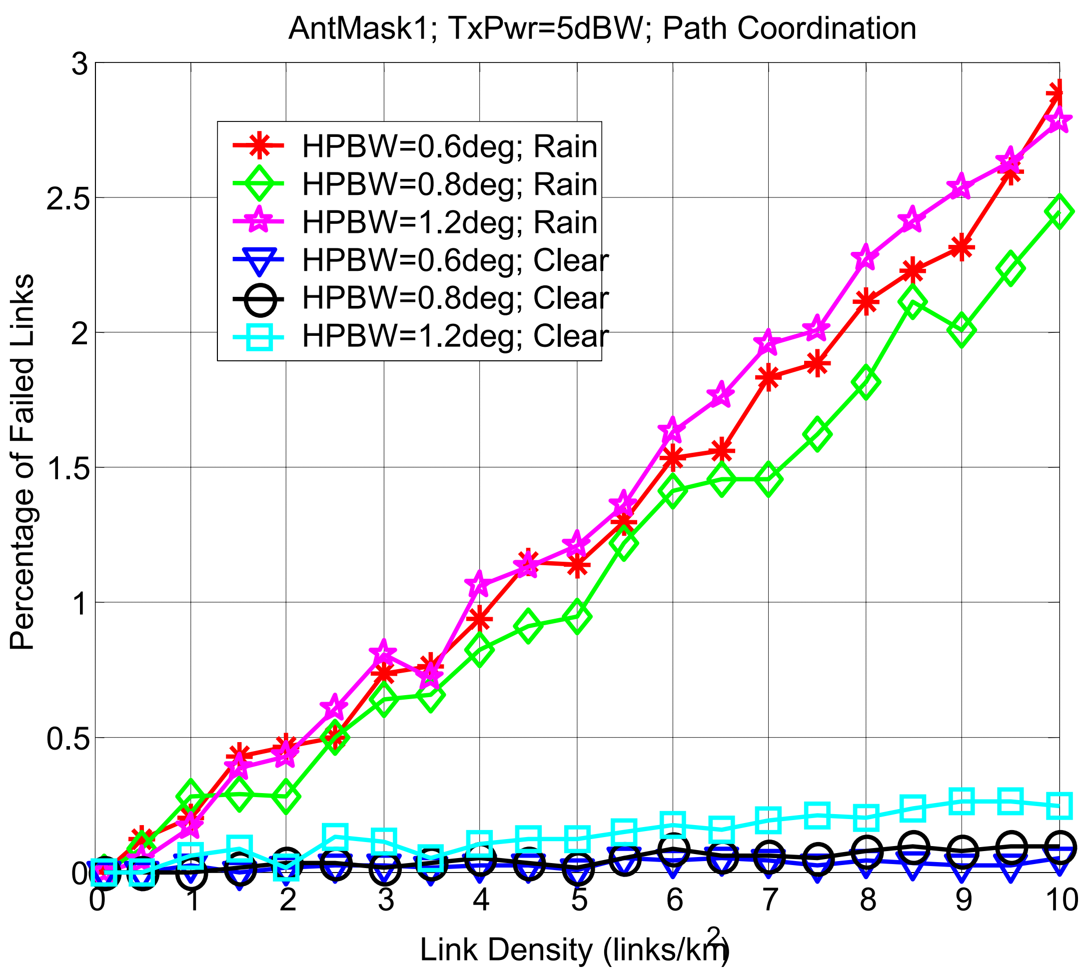
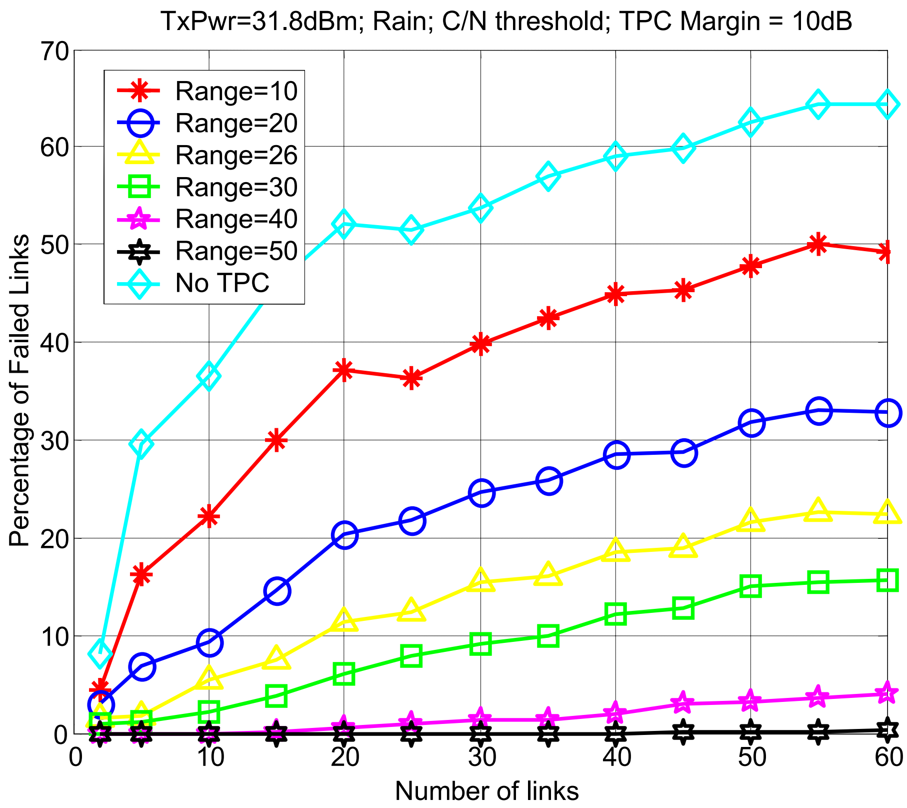
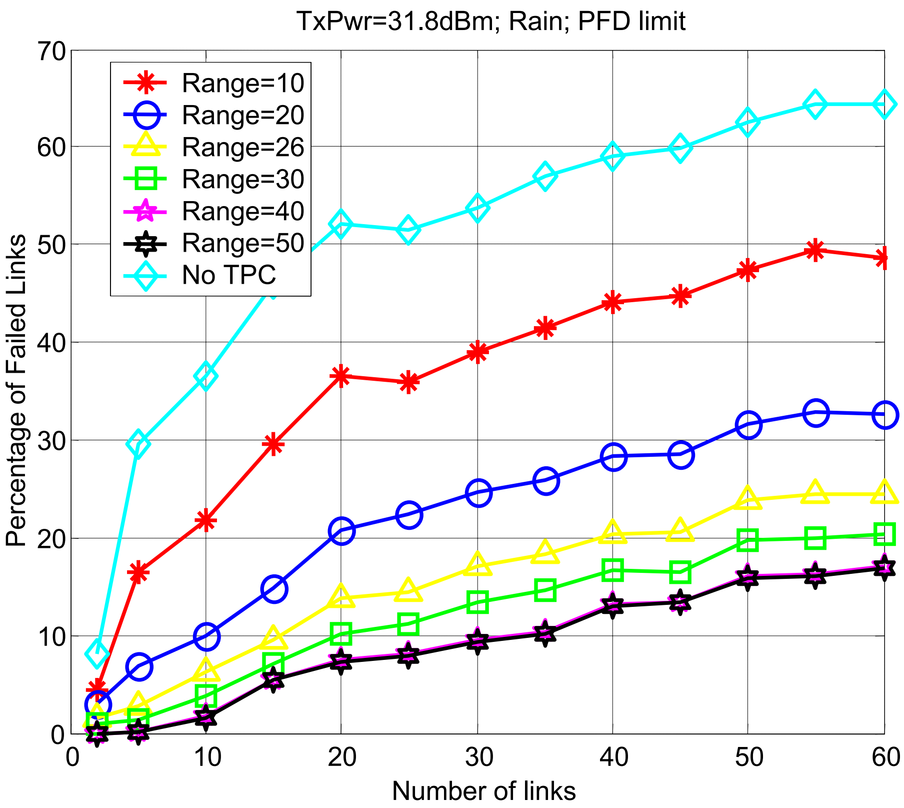
Simulation Results for Random Deployments with Different Antenna Beamwidths



- This slide shows the results when the links are deployed using 0.6°, 0.8°, and 1.2° HPBWs with directivities of 50, 47, and 44 dBi respectively.
- Wider beamwidths lead to shorter ranges and lower ATPC dynamic ranges; narrower beamwidths result in higher ATPC dynamic ranges, which reduces interference.
- Overall the performance for the three different beamwidths is very similar, indicating that the maximum EIRP and required ATPC dynamic range is balanced.

ATPC Performance as a Function of Dynamic Range





- **C/N threshold performs much better than PFD limit as the ATPC dynamic range increases**

Power Flux Density Calculation

- **From Joint Reply comments, maximum PFD = 100pW/cm2 (corresponds to 10Gbps link)**

  8PSK, 8dB NF, 1 foot dish antenna, 10dB margin

Parameter	Base	Better BER	Higher Rate
Bandwidth (MHz)	5000	5000	5000
NF (dB)	8	8	8
Antenna dish size (in)	12	12	12
Beamwidth (deg)	1.2	1.2	1.2
Power Control Margin (dB)	10	10	10
Required C/N	18.0	21.0	24.0
Power Flux Density (pW/cm^2)	**100**	**200**	**400**

- **Conclusion:**

  Performance is similar to C/N-based approach for agreed-upon ATPC dynamic range

  However, little margin for future growth in linkrates (and consequent C/N required)

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