Potential collapse of whitespaces and the prospect for a universal power rule

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Policy Track
Session 3

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- Unique opportunity: primary and secondary interaction, tradeoff

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- Unique opportunity: primary and secondary interaction, tradeoff
- Needs of primary potentially not met by FCC rules - interference aggregates
- Mitigate tension between types of secondaries

FCC's goals

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- Protect primaries

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- Flexibility for secondaries

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- ~~Protect primaries~~
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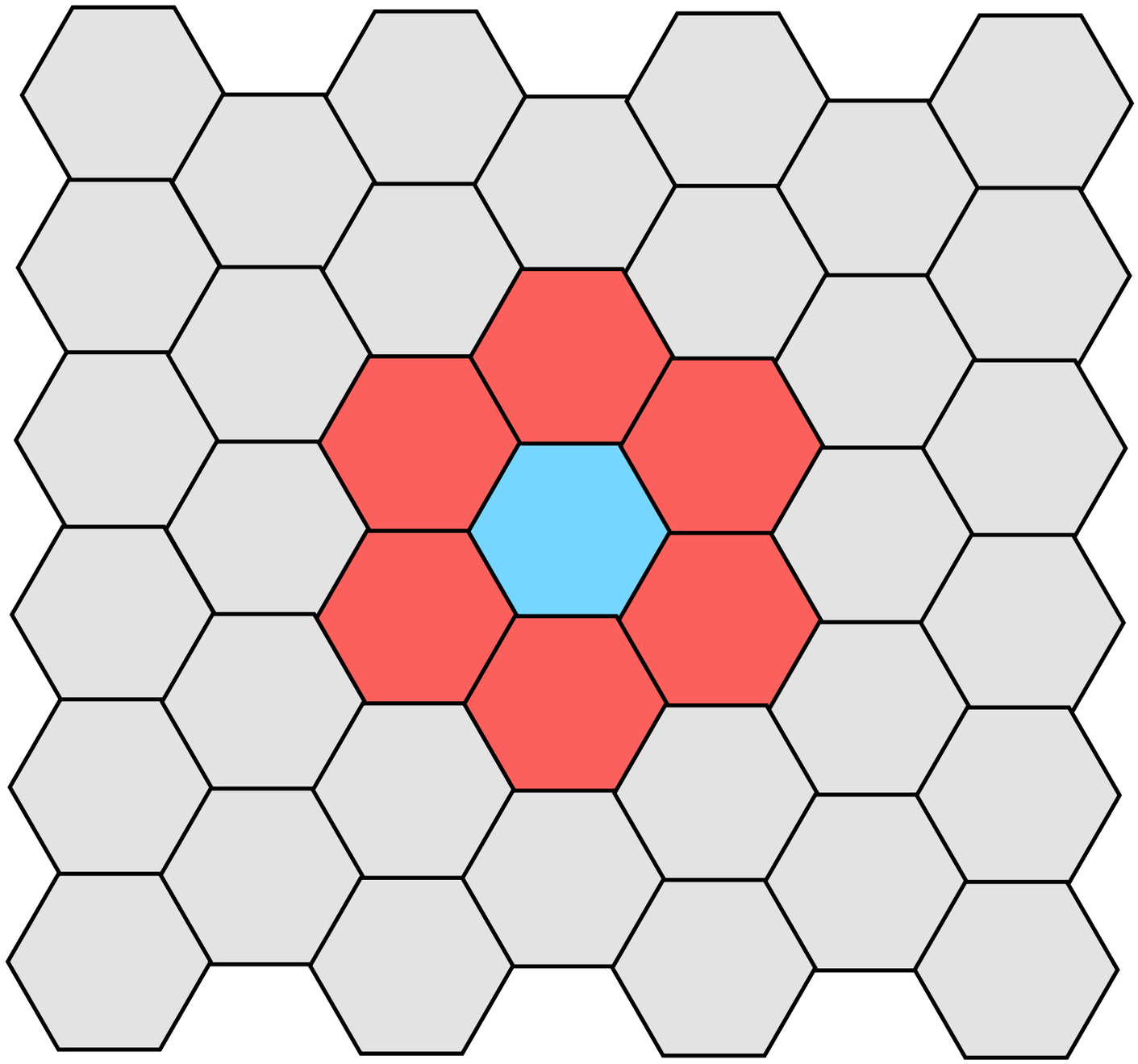
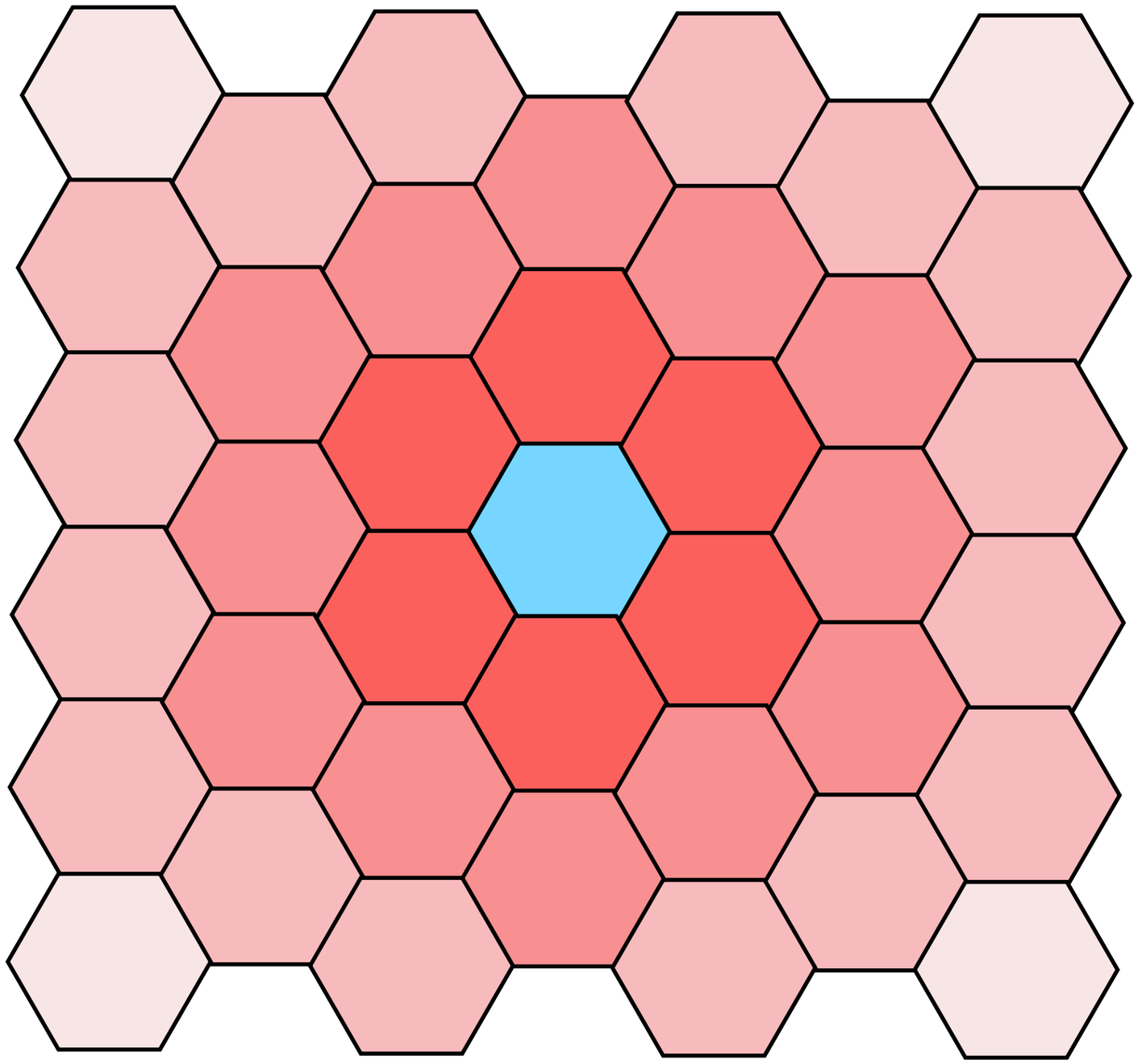
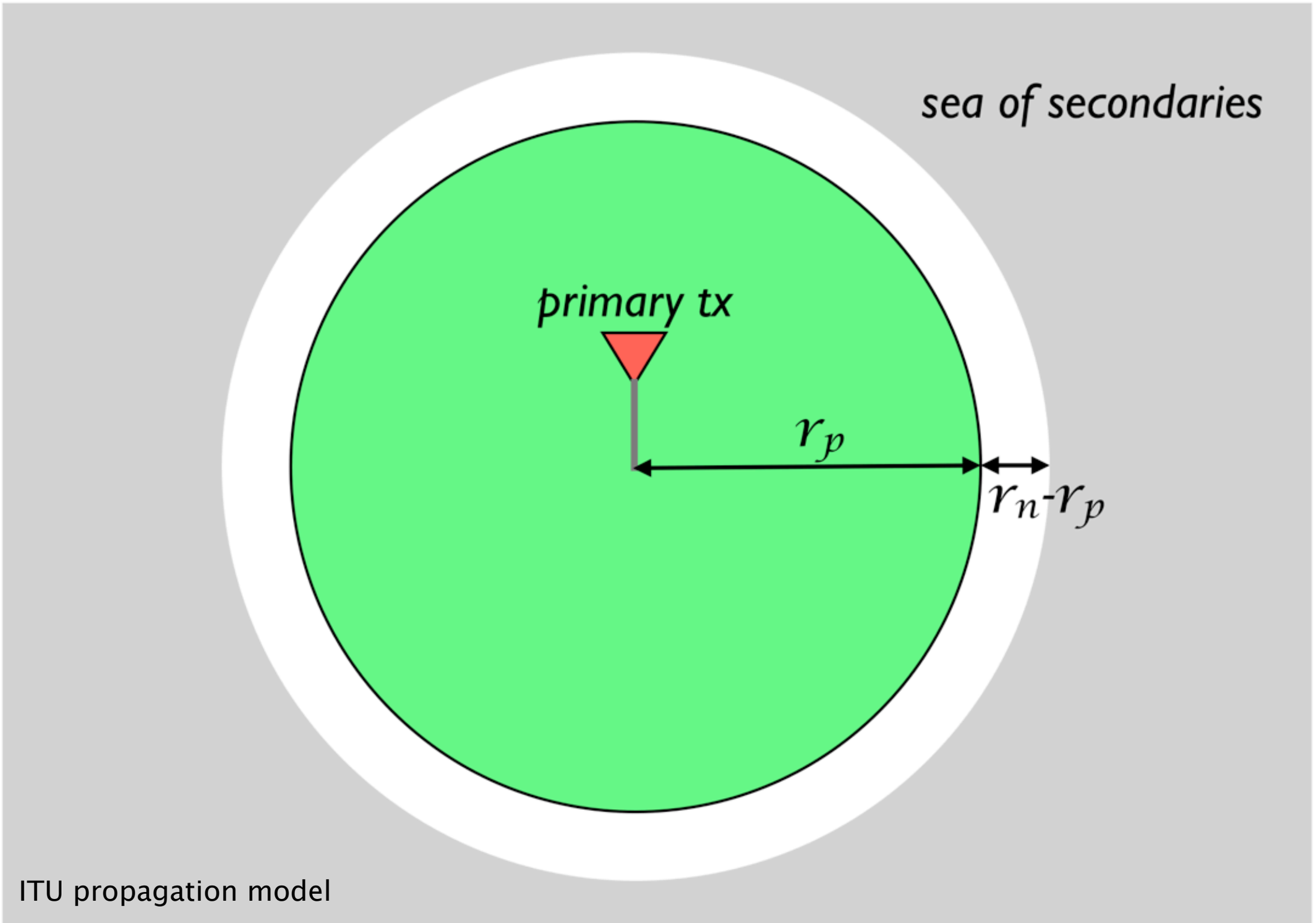
De Vany, et. al. + FCC



Interference aggregates

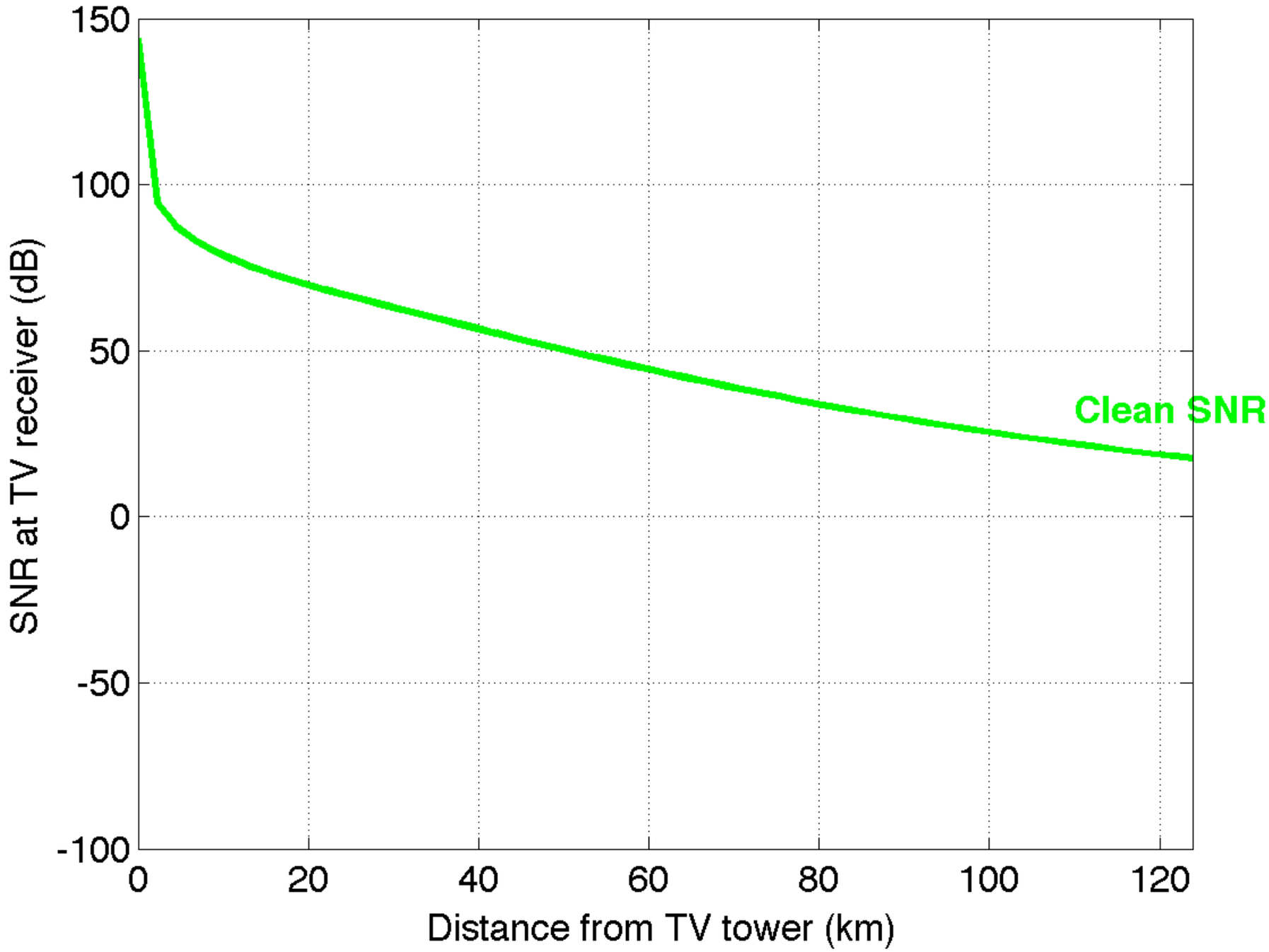


First model



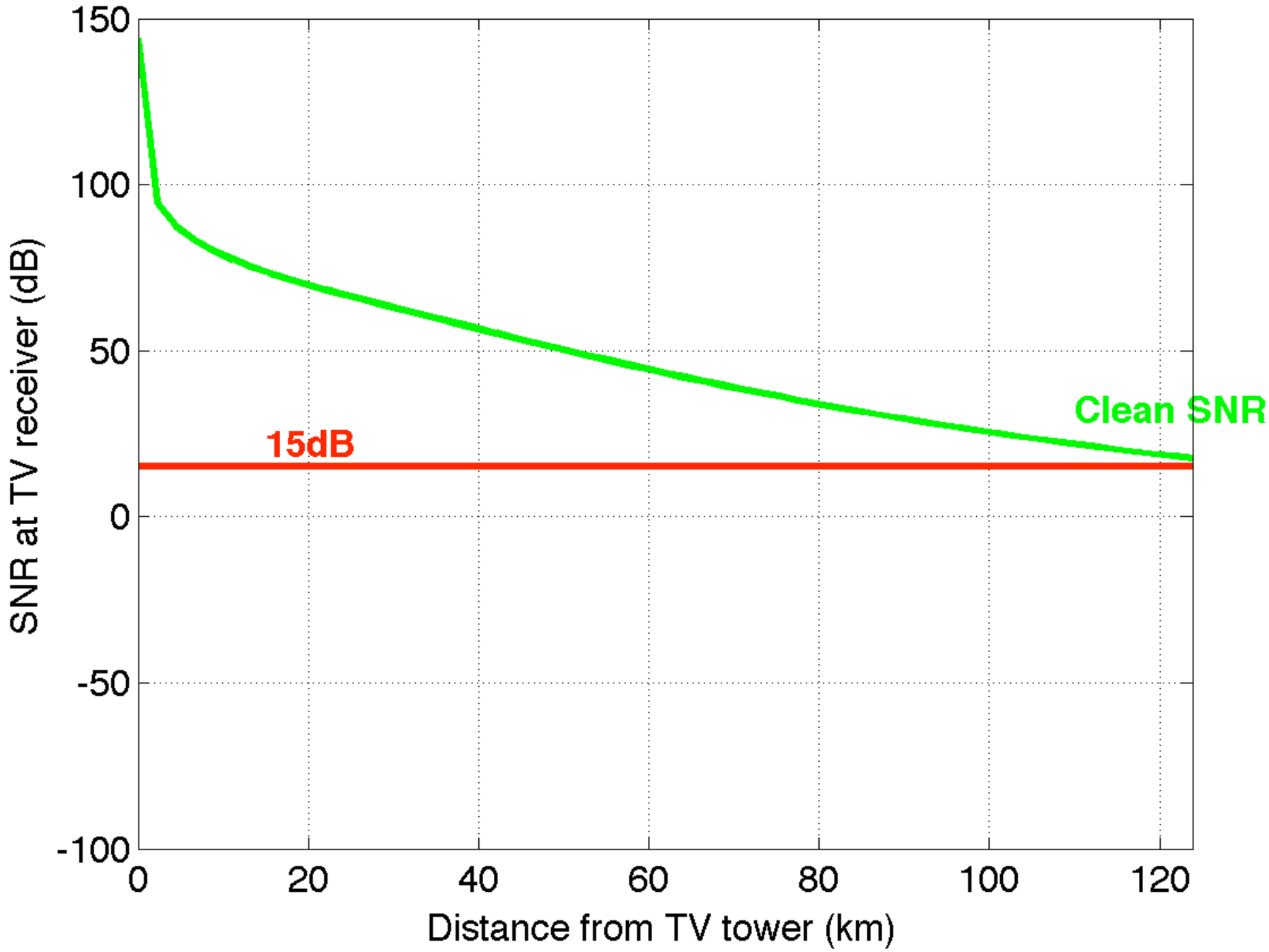
ITU propagation model

Lost primaries



Primary:
500 m
1 kW

Lost primaries



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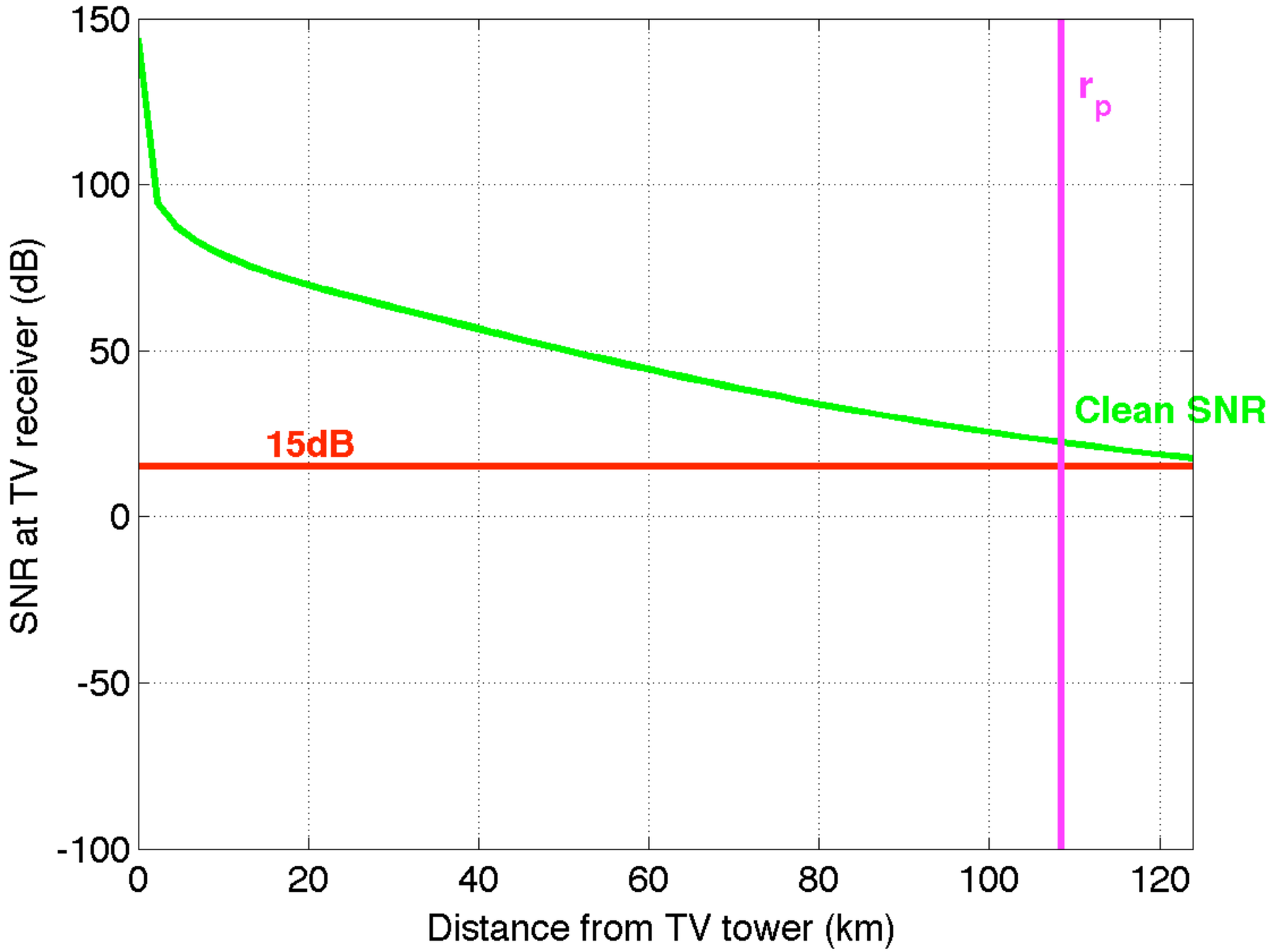

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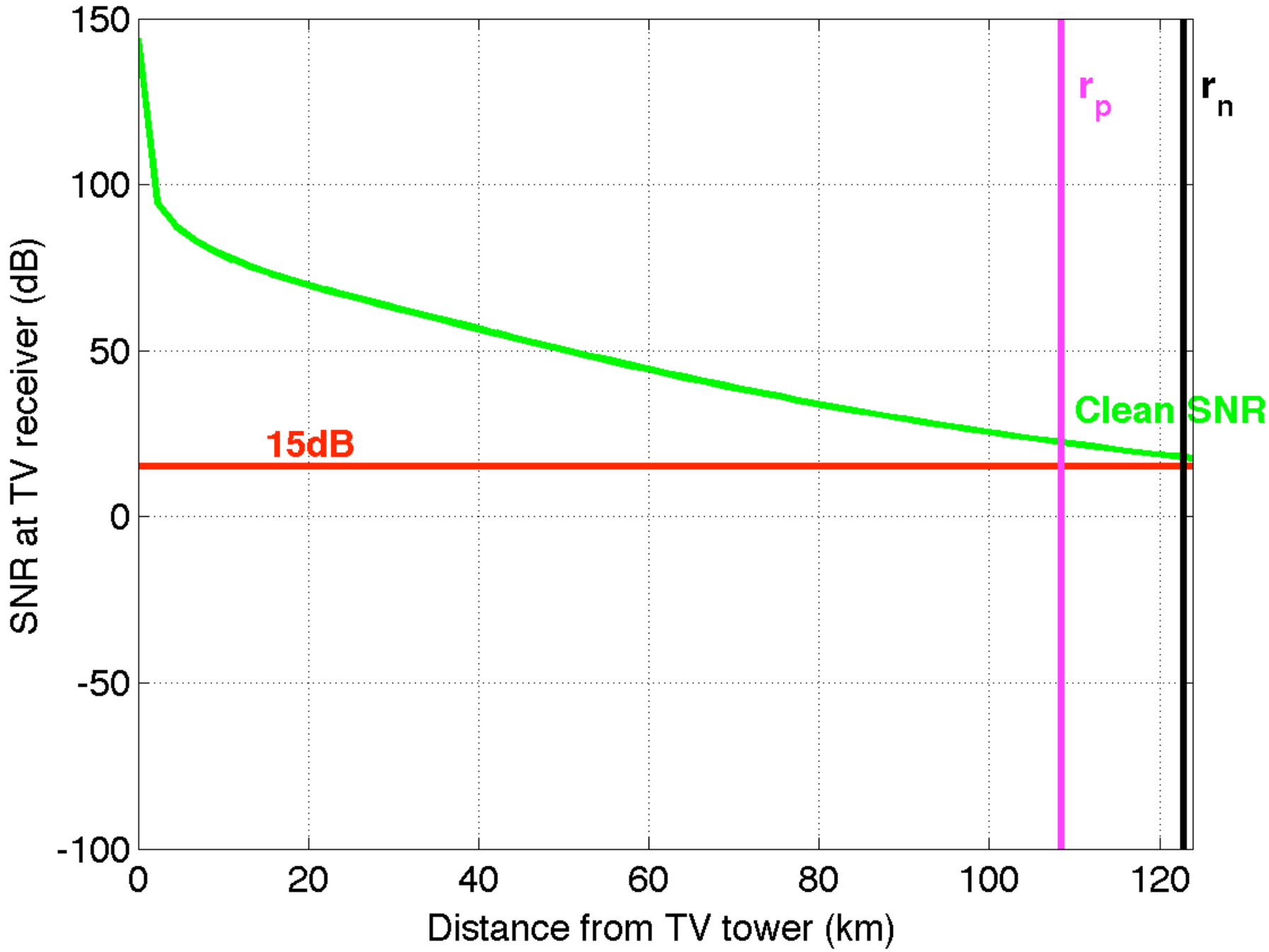

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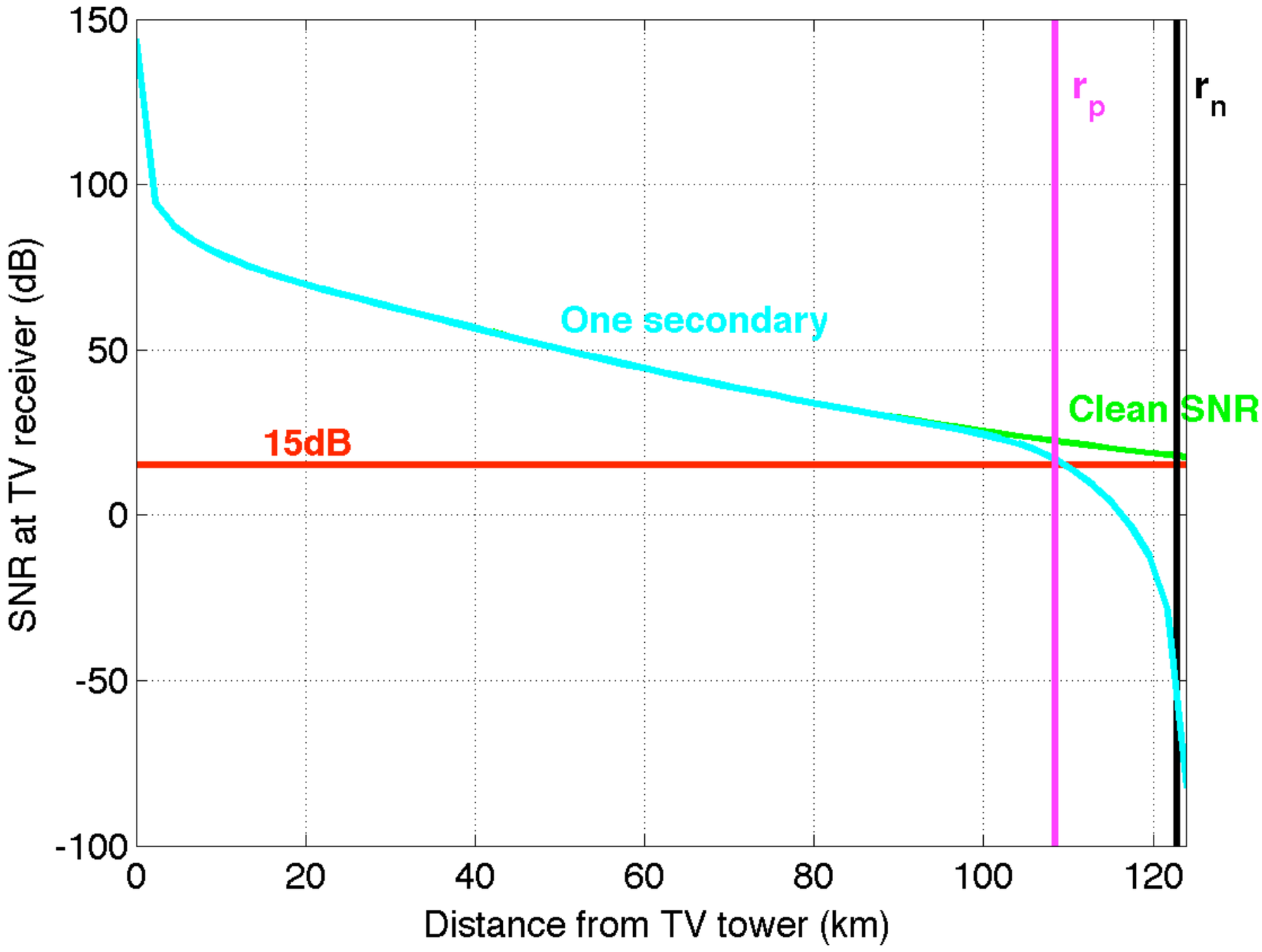
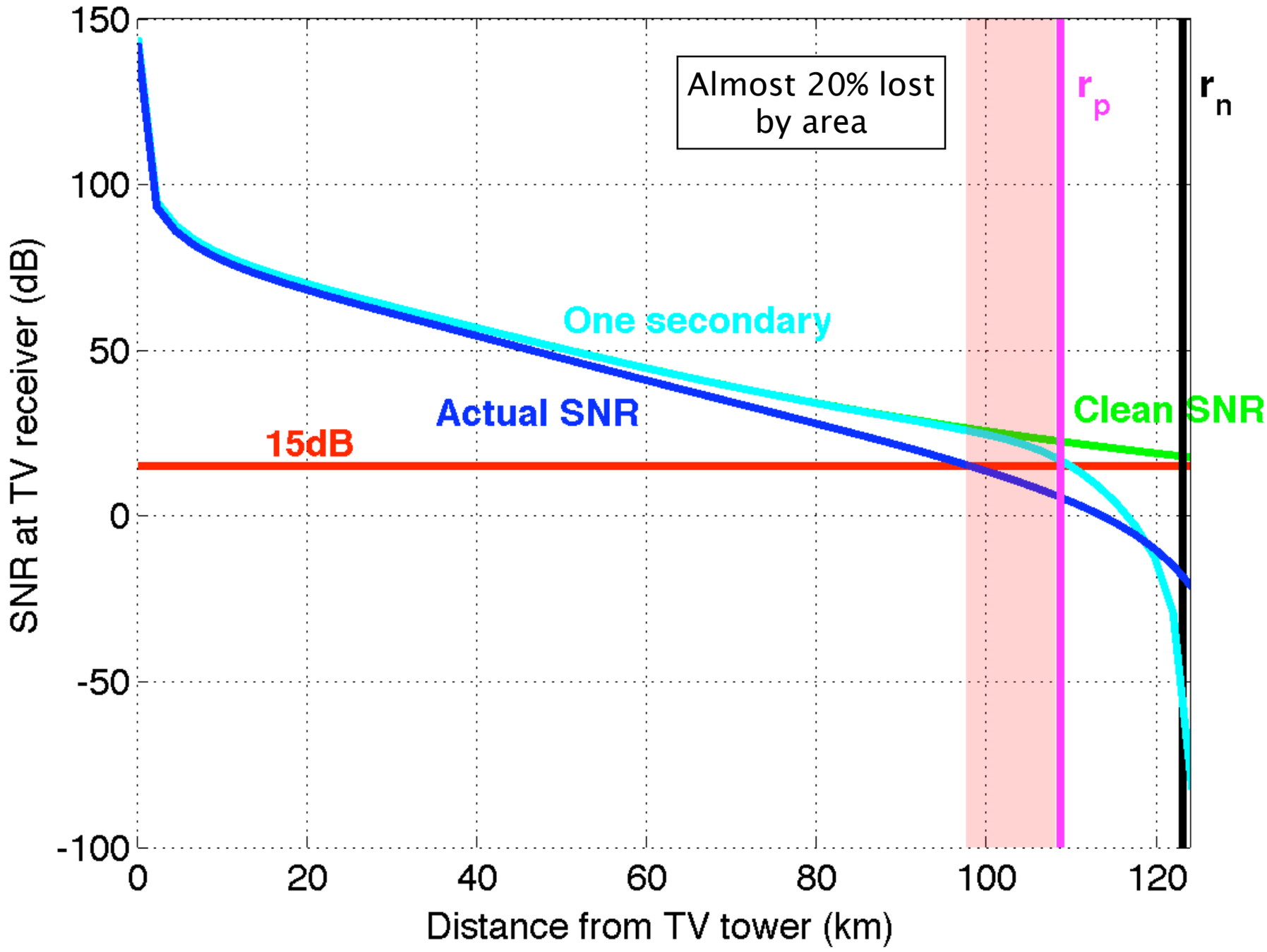


Primary:
500 m
1 kW
Secondary:
30 m
1 W

Lost primaries



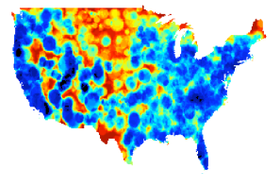
Primary:
500 m
1 kW
Secondary:
30 m
1 W

429 people/km^2
1 device active/500 people

Need for national analysis

- Holes from other protection radii
- Coasts
- Population

Second model

- Place secondaries on map 

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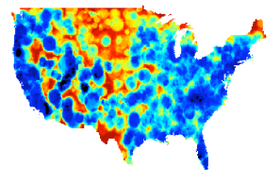
- Place secondaries on map 
- Calculate aggregate interference

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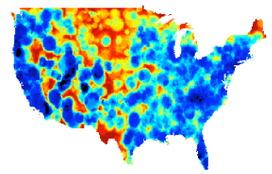
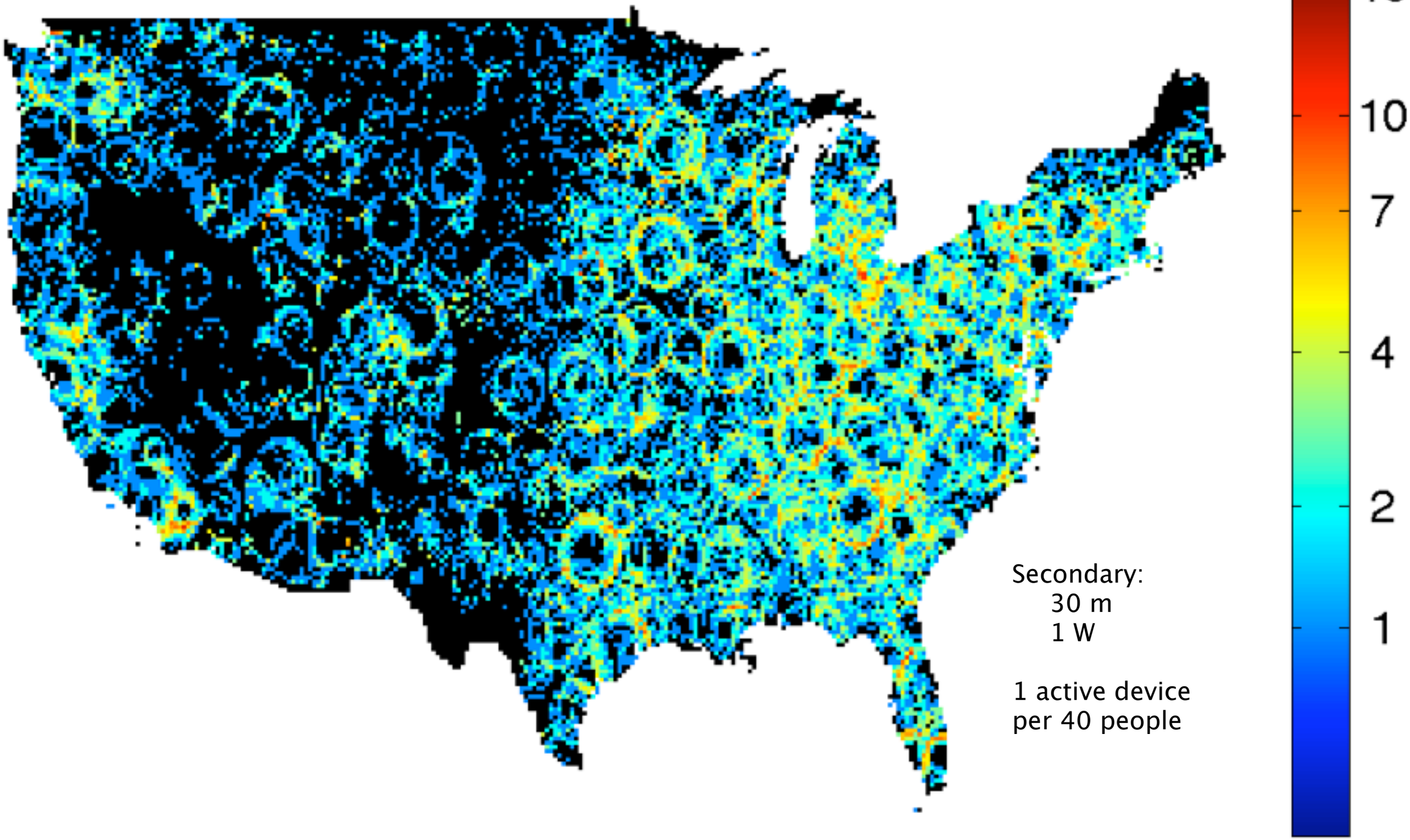
- Place secondaries on map 
- Calculate aggregate interference
- Test for TV reception

Channels lost



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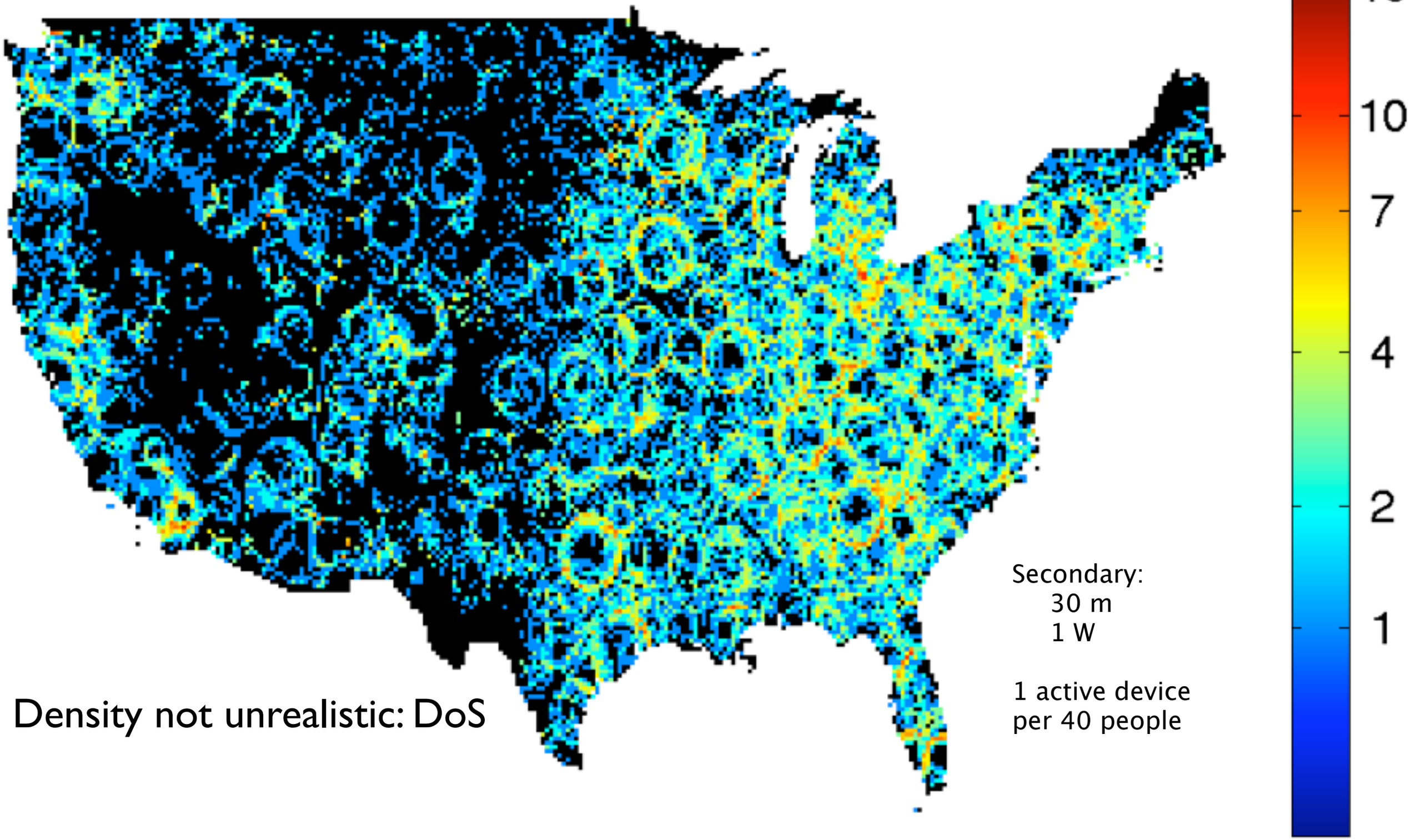
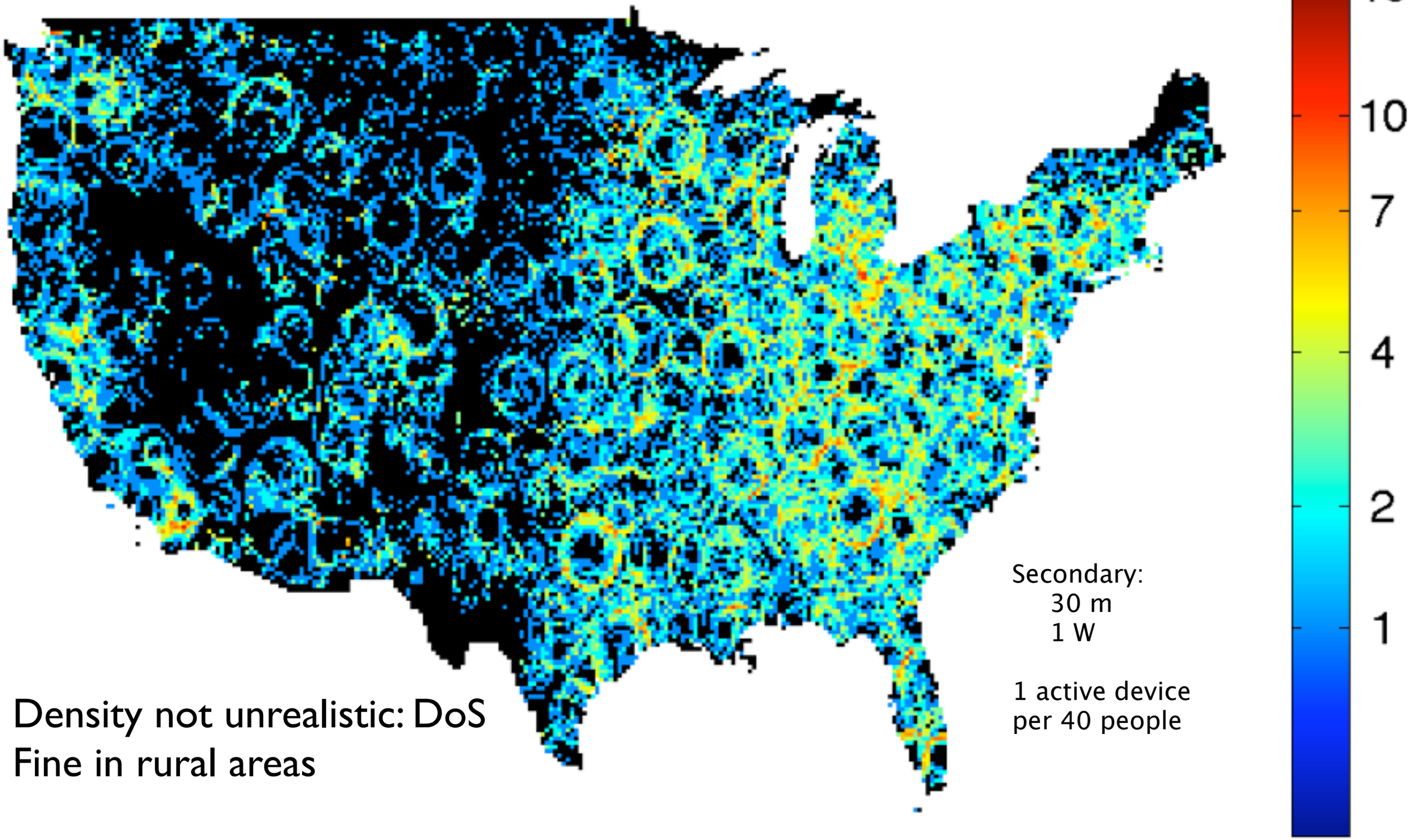


Secondary:
30 m
1 W

1 active device
per 40 people

Density not unrealistic: DoS

Channels lost



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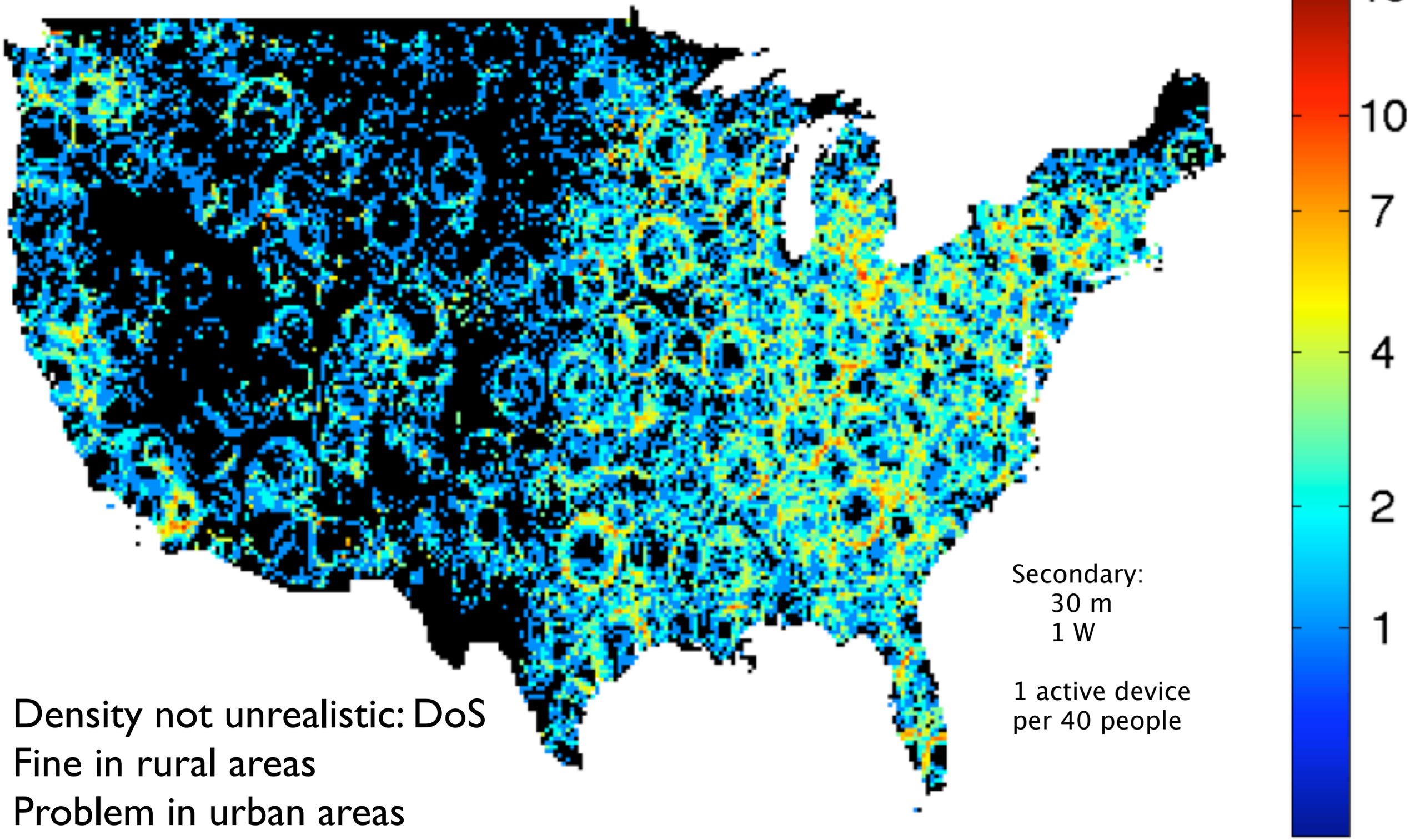
Density not unrealistic: DoS
Fine in rural areas

Channels lost

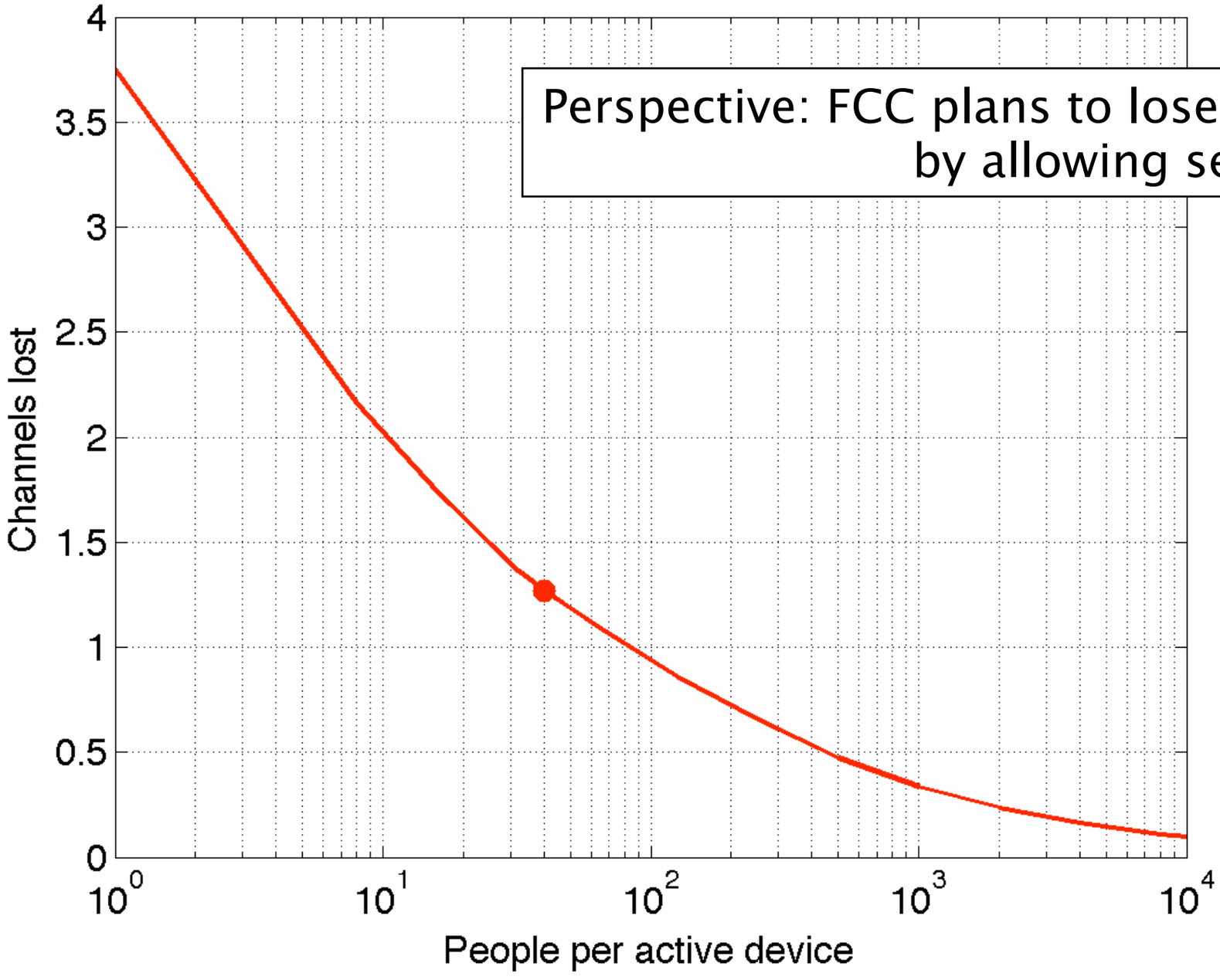


Secondary:
30 m
1 W

1 active device
per 40 people

Density not unrealistic: DoS
Fine in rural areas
Problem in urban areas

Channels lost: vary secondary density



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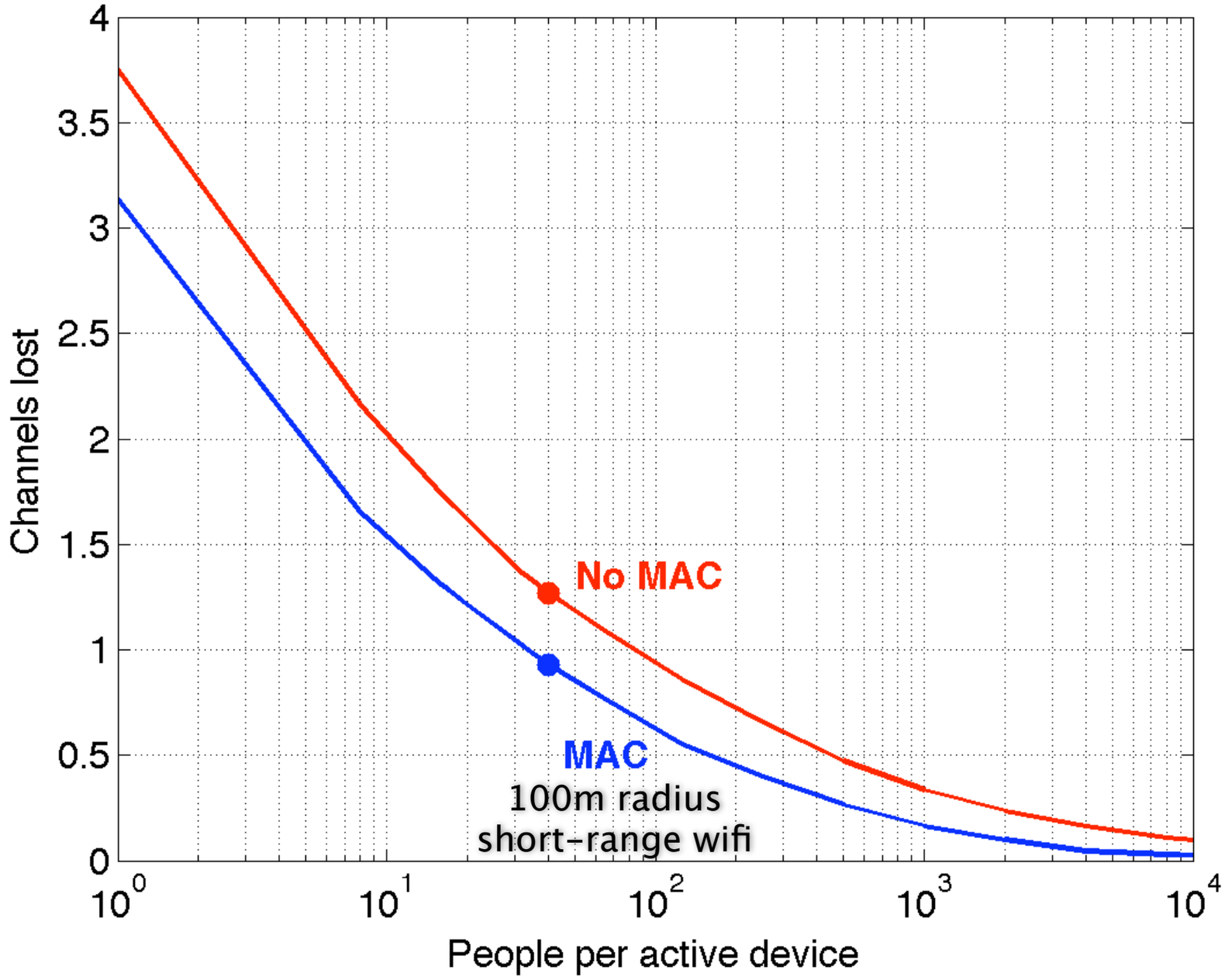

Secondary:
30 m
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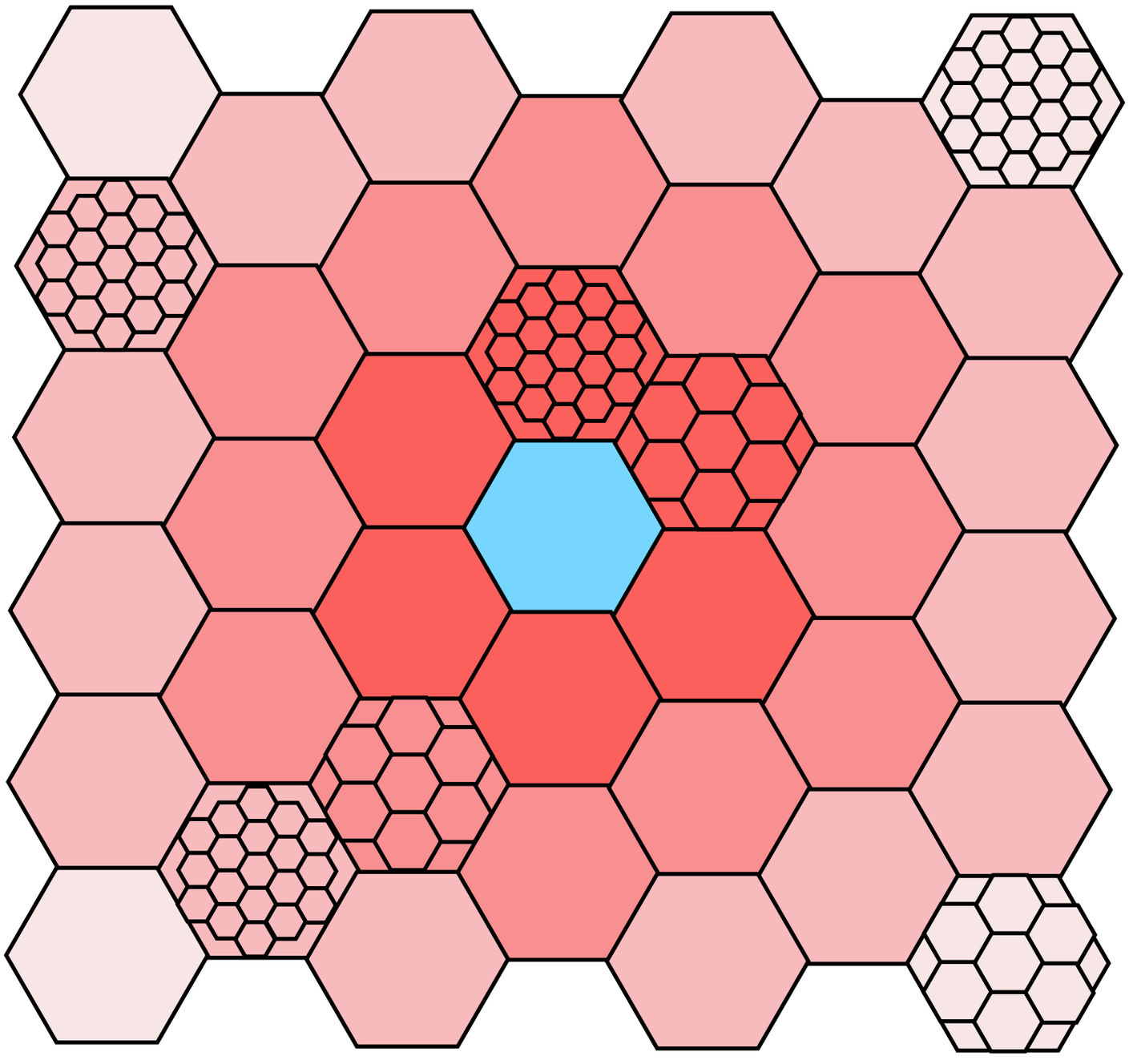
Regulate power density



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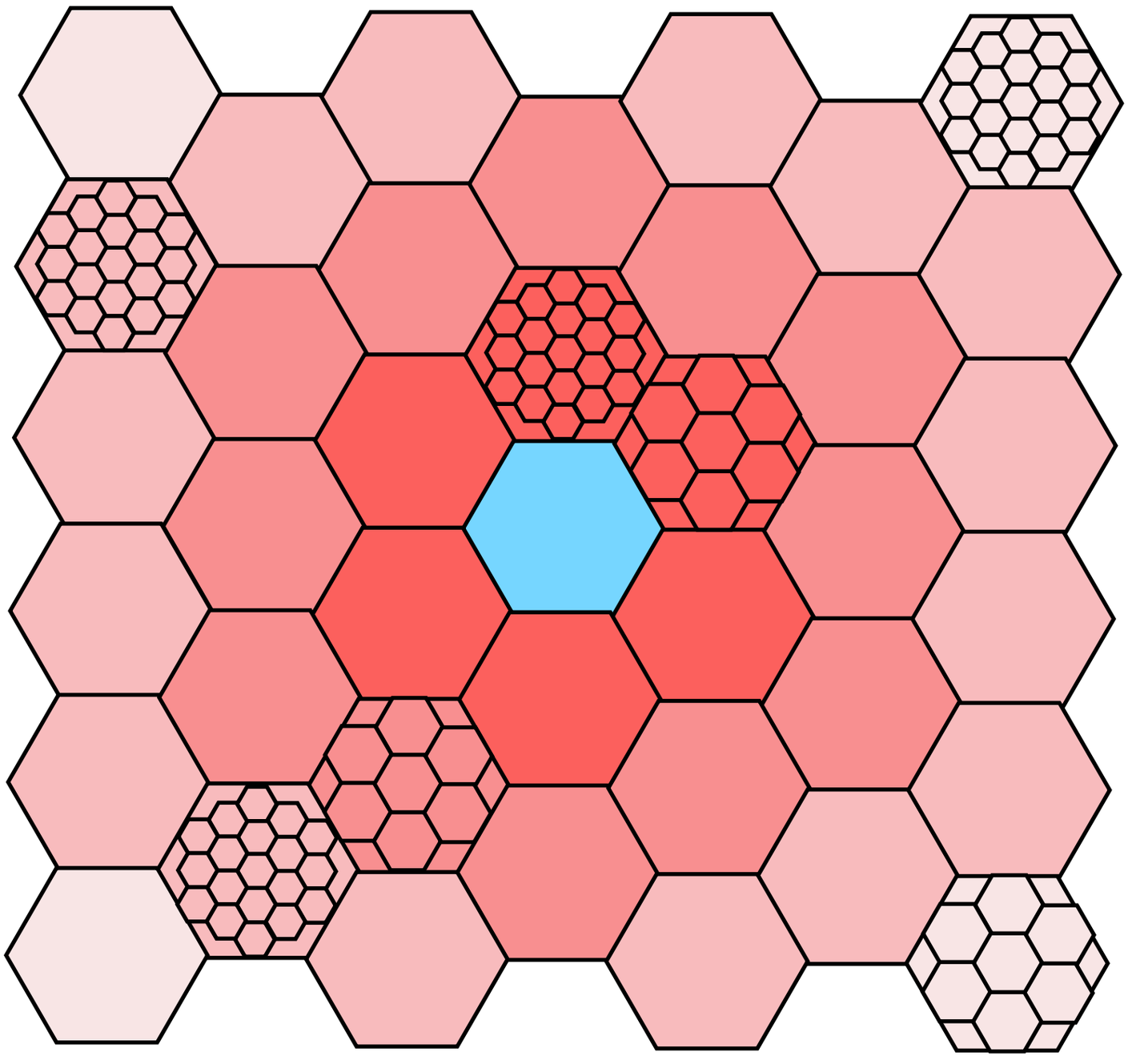
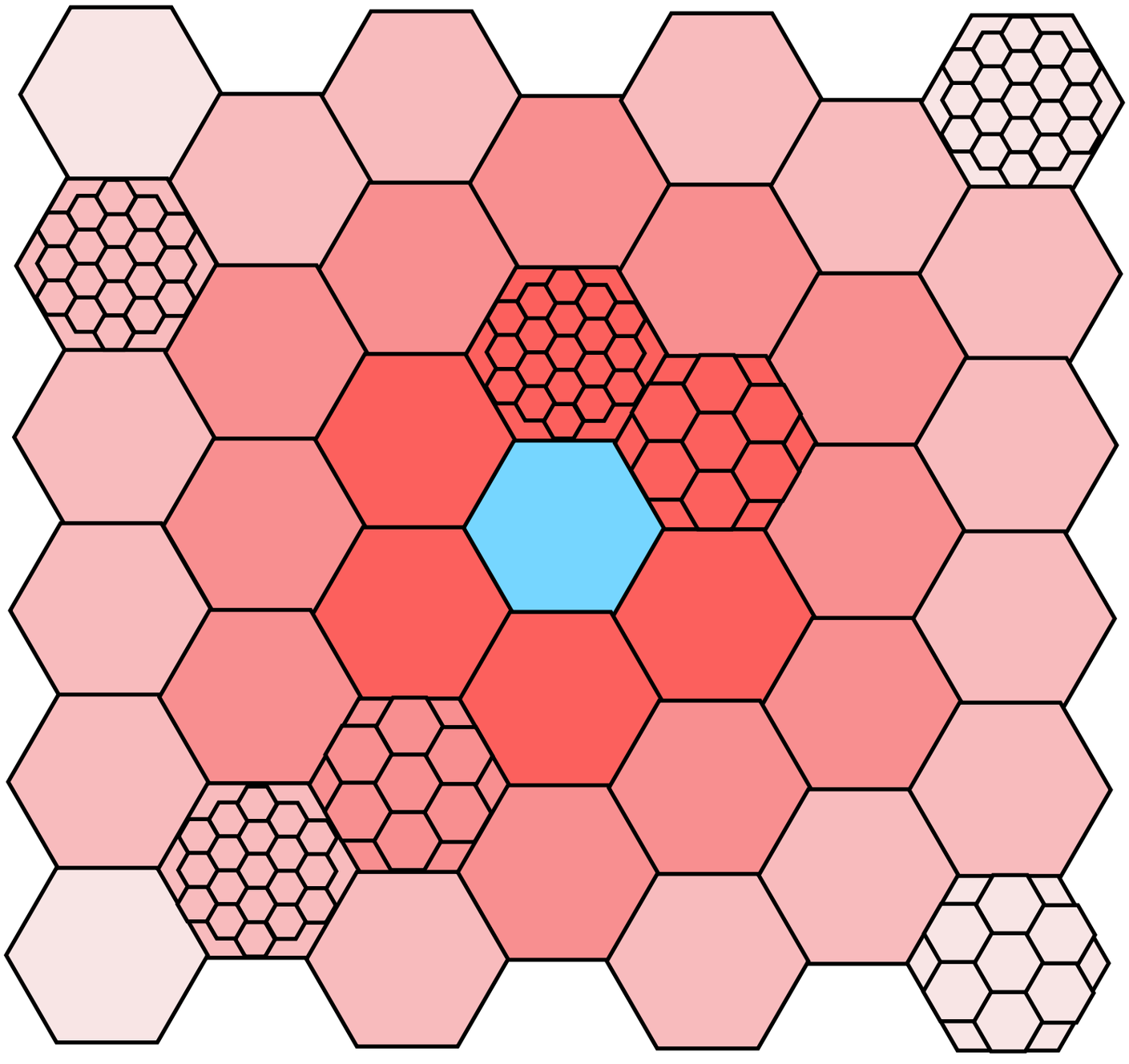


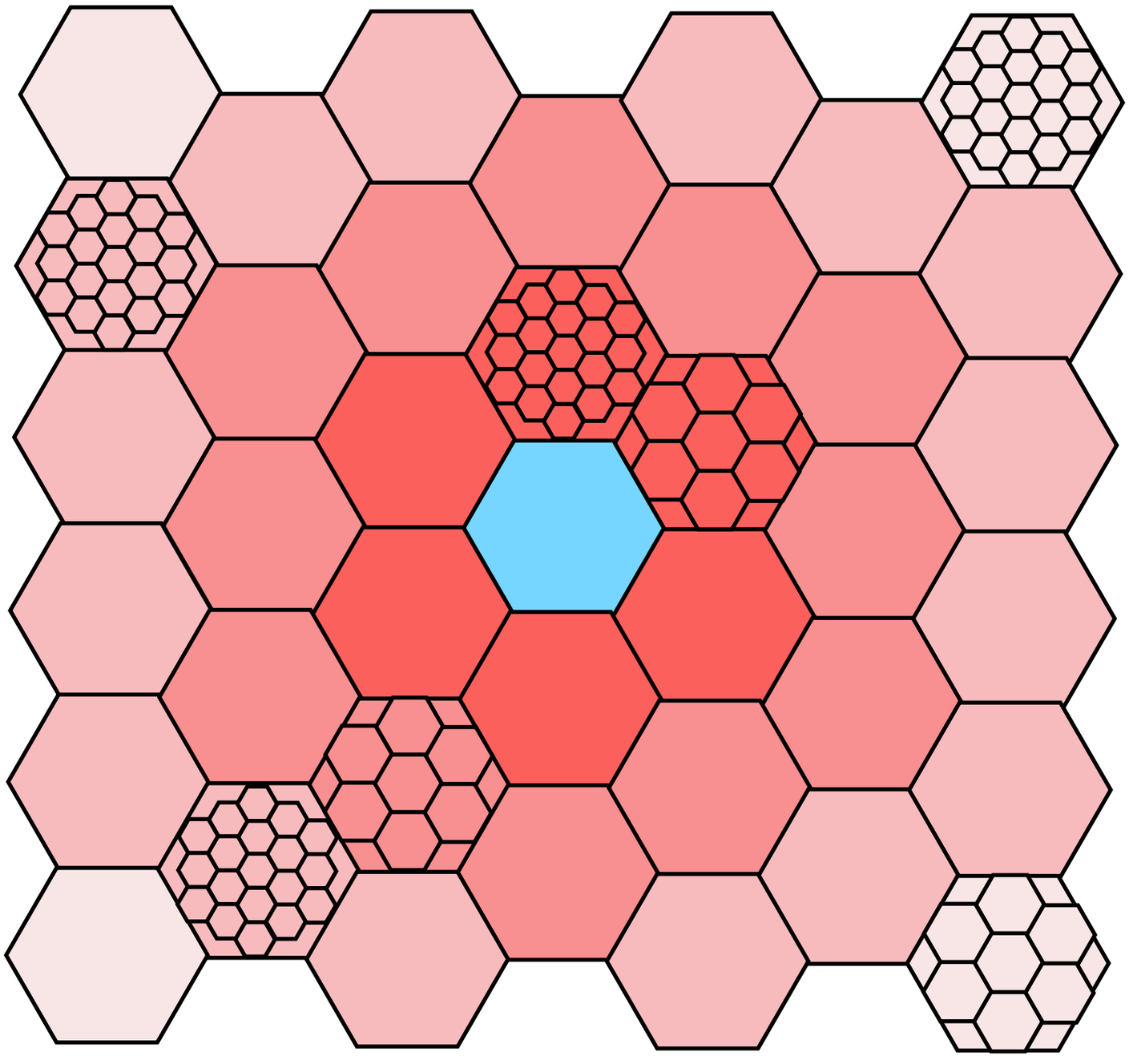
Databases

Regulate power density



Databases
MAC

Regulate power density



Databases
MAC
Density = ?

Naïve approach: fixed power density

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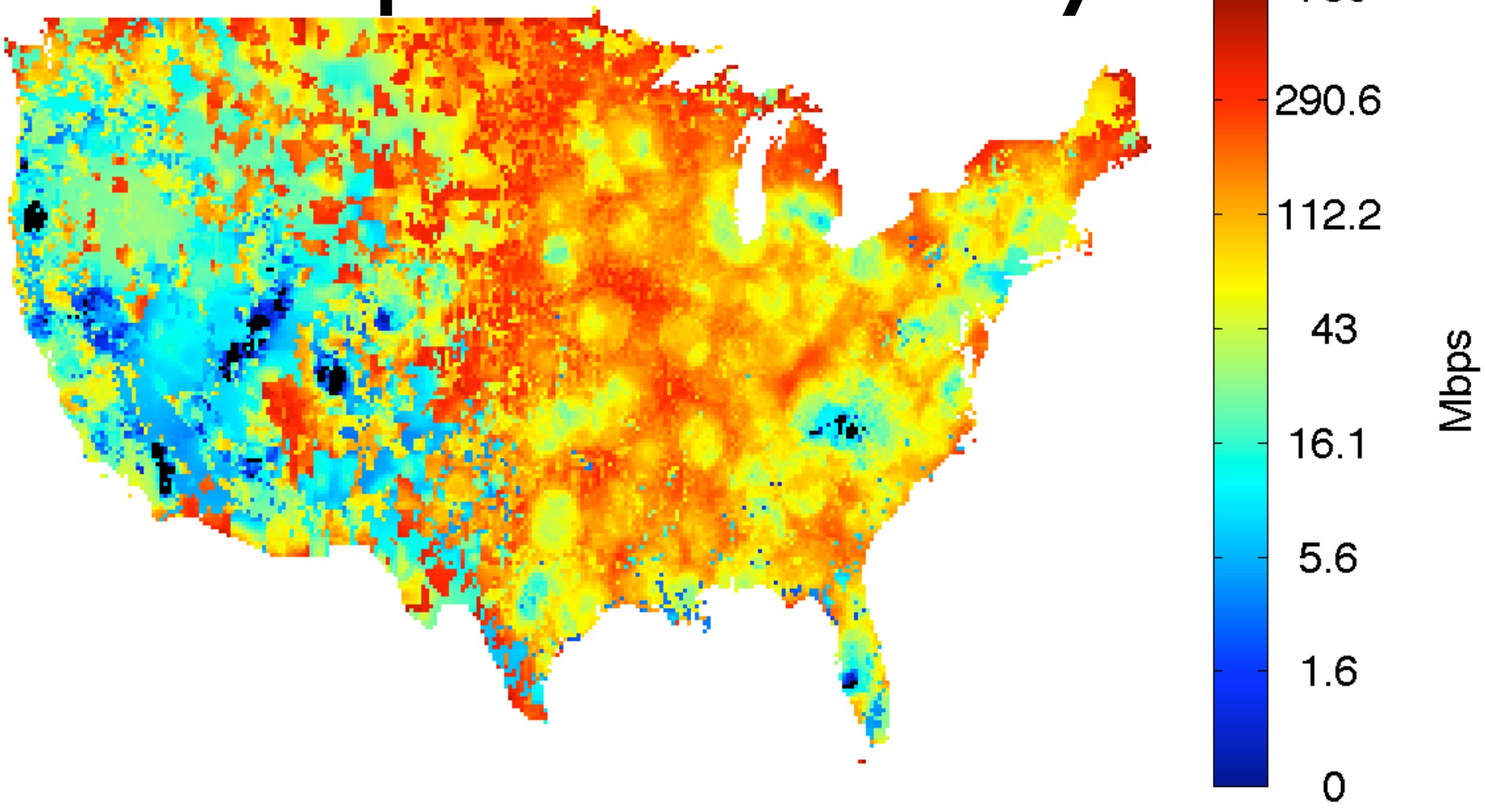
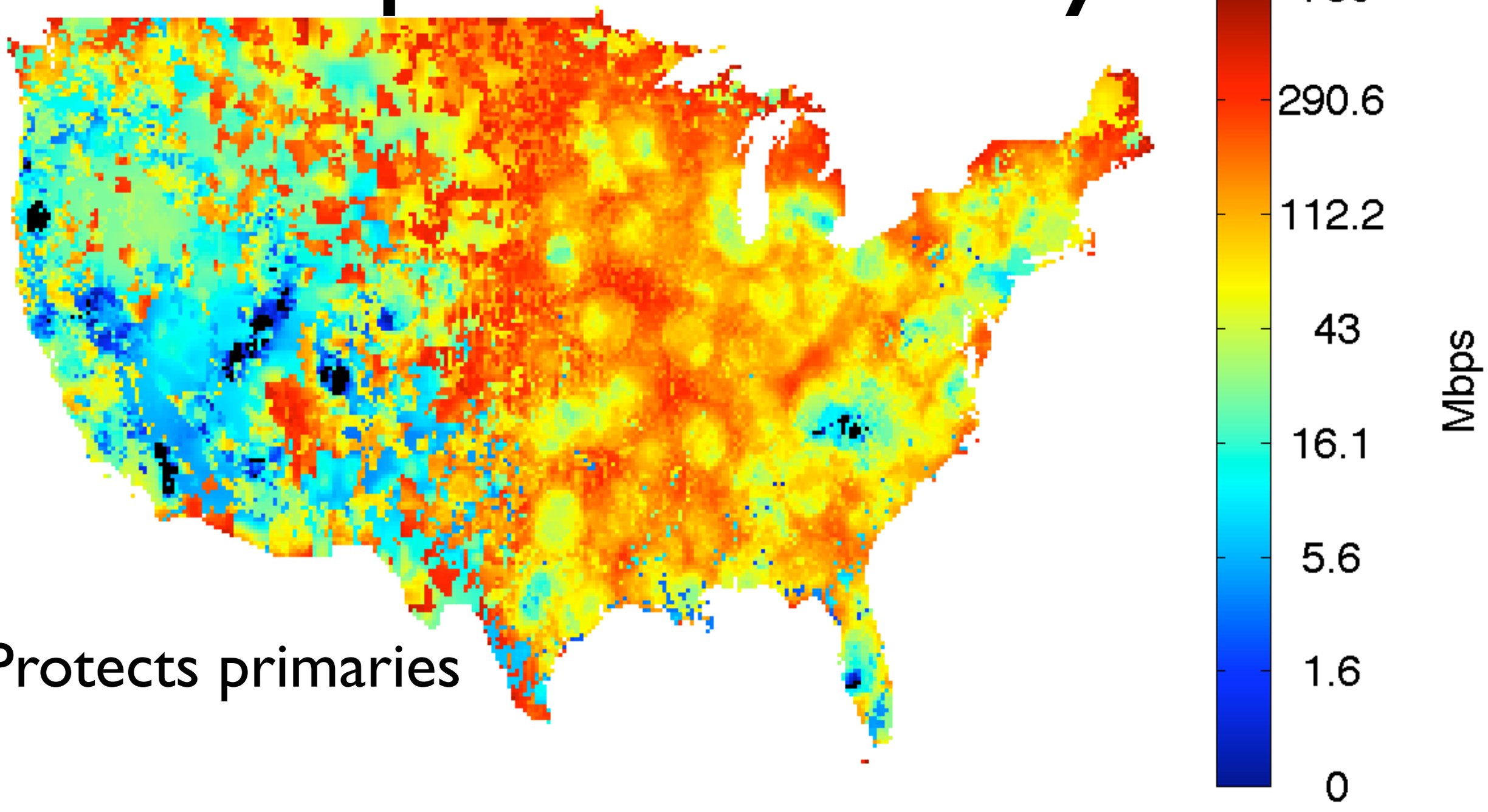
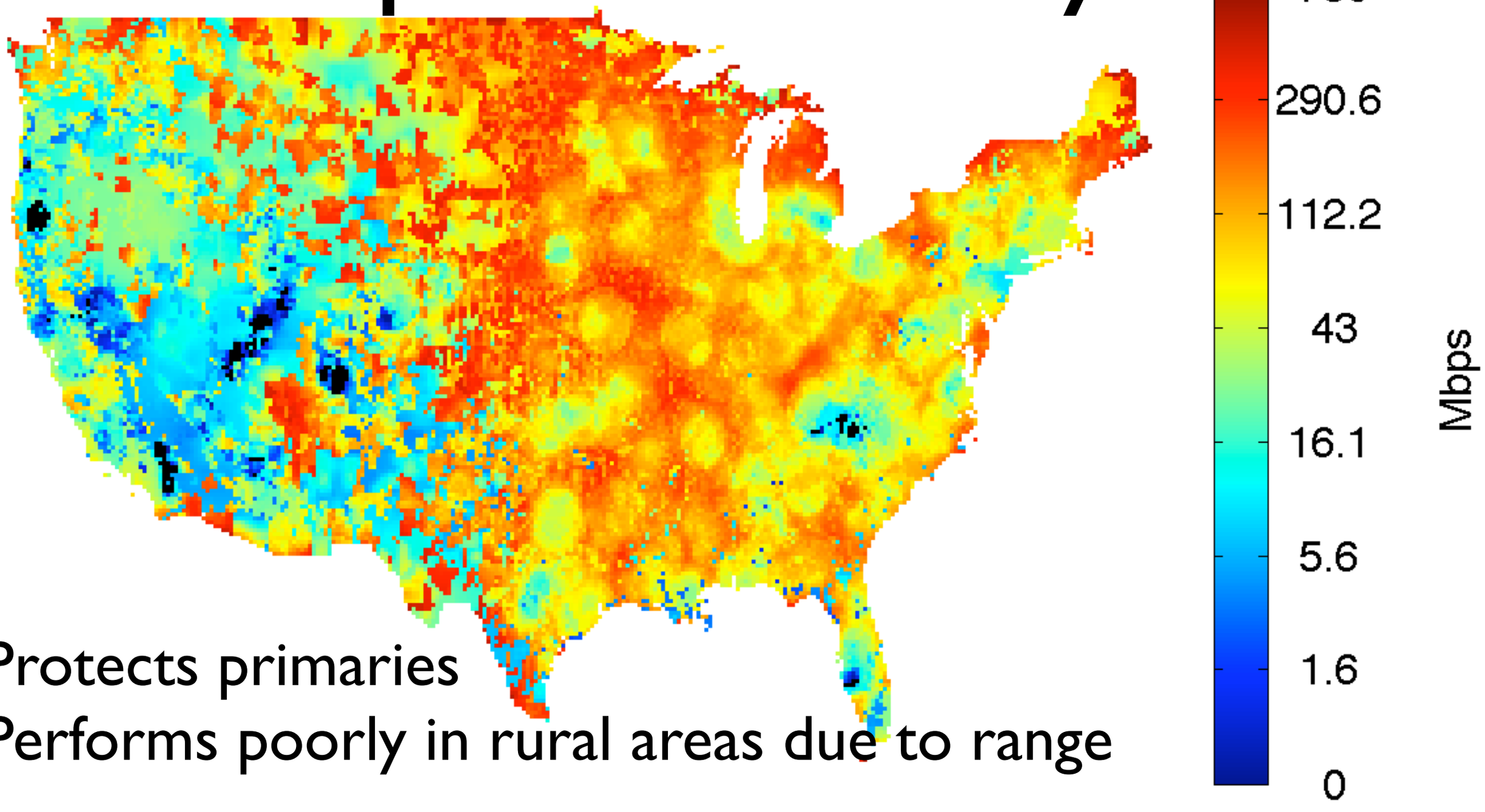


Naïve approach: fixed power density



Protects primaries

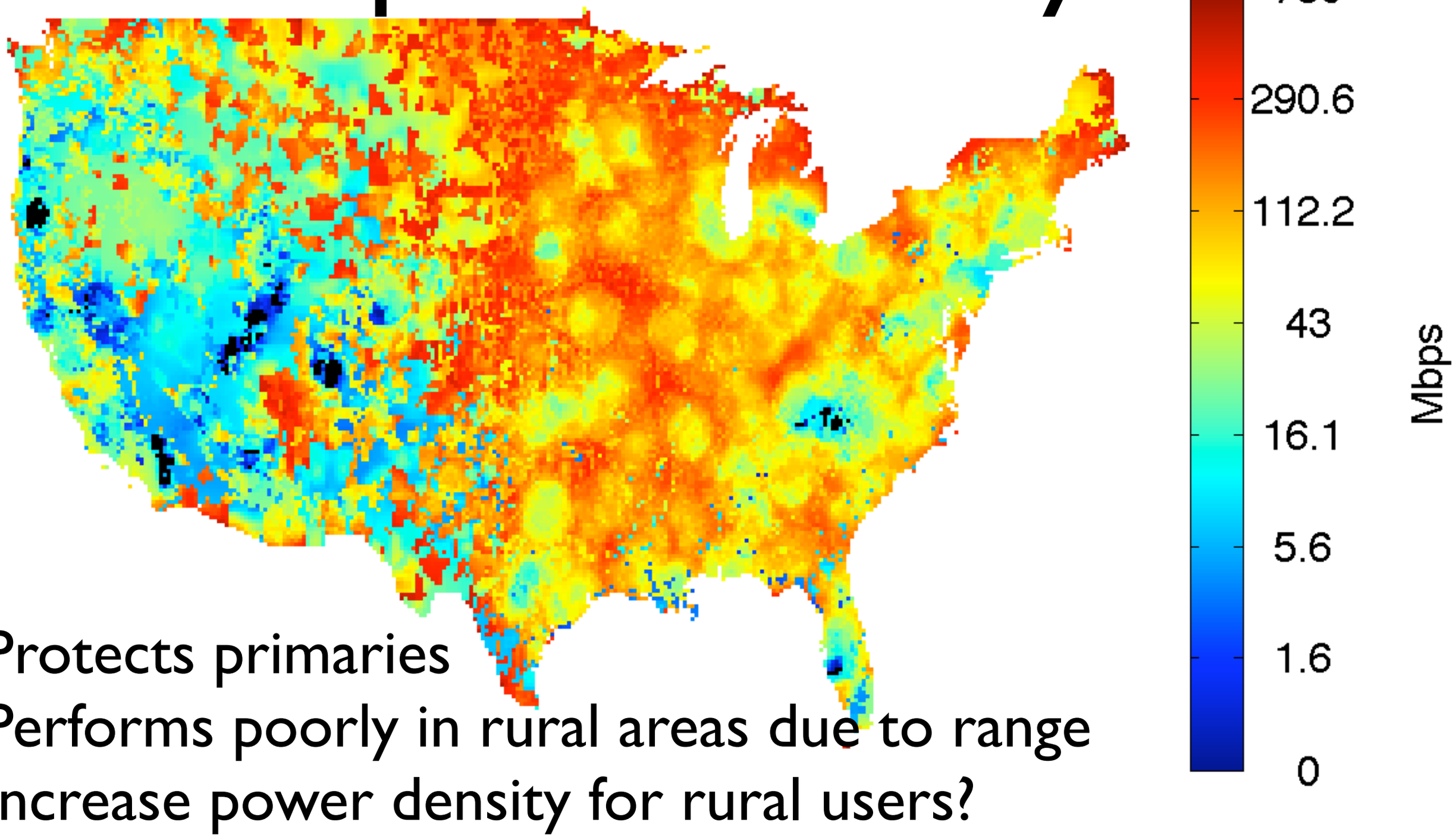
Naïve approach: fixed power density



Protects primaries

Performs poorly in rural areas due to range

Naïve approach: fixed power density



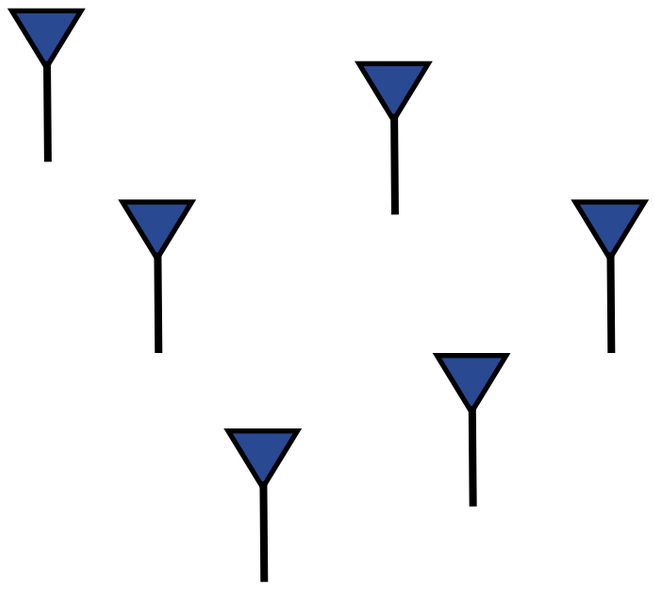
Protects primaries

Performs poorly in rural areas due to range

Increase power density for rural users?

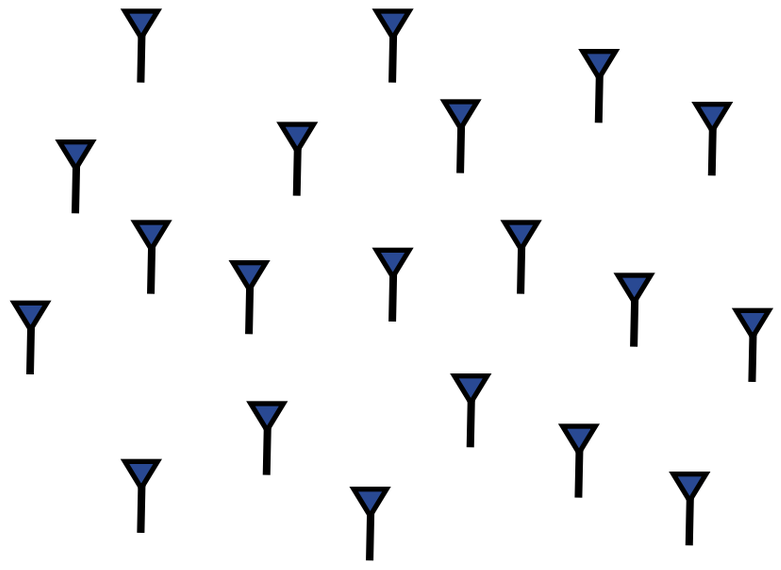
Naïve approach: fixed power density

Rural preference



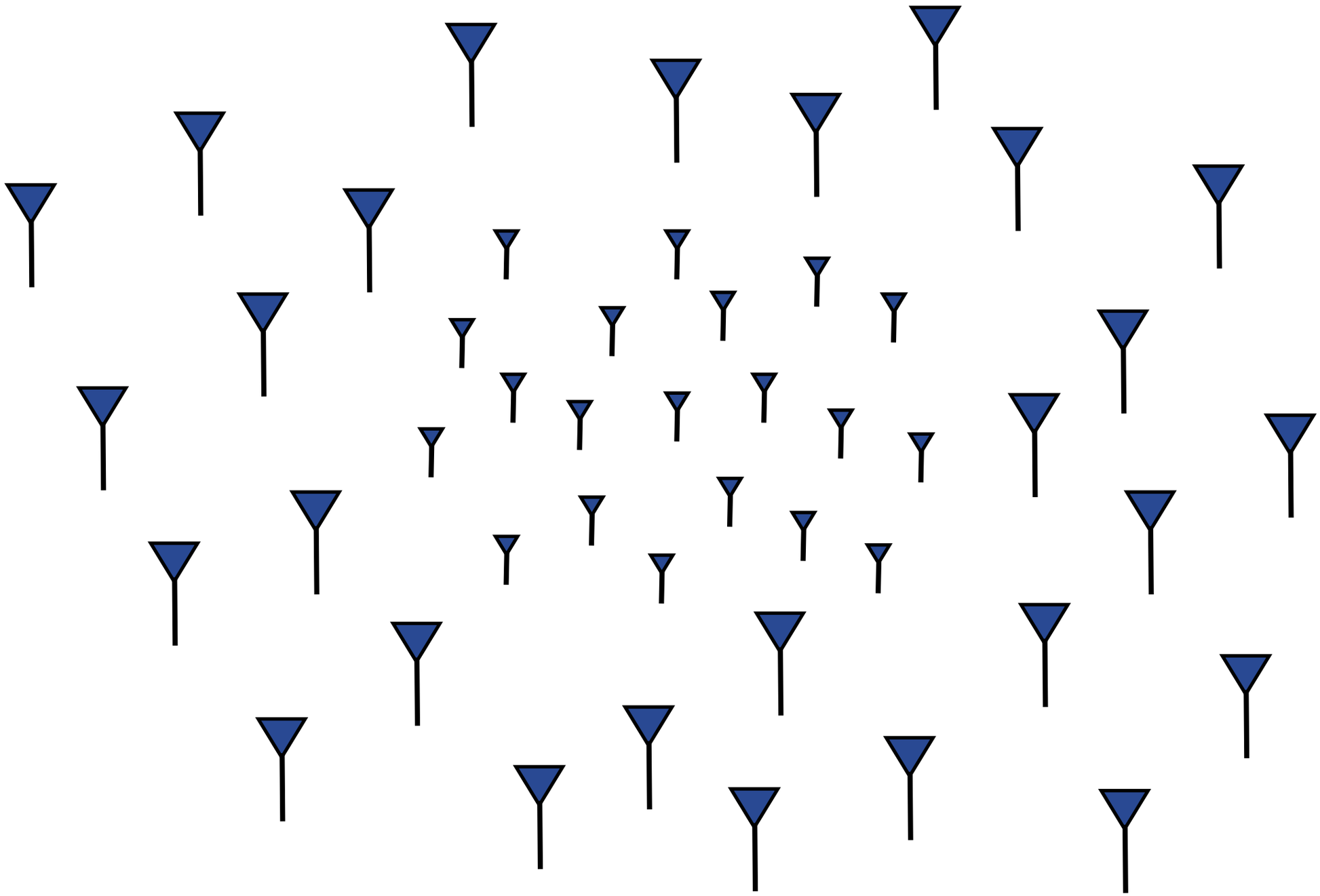
Have spectrum
Hungry for more power
Increase r_n

Urban preference

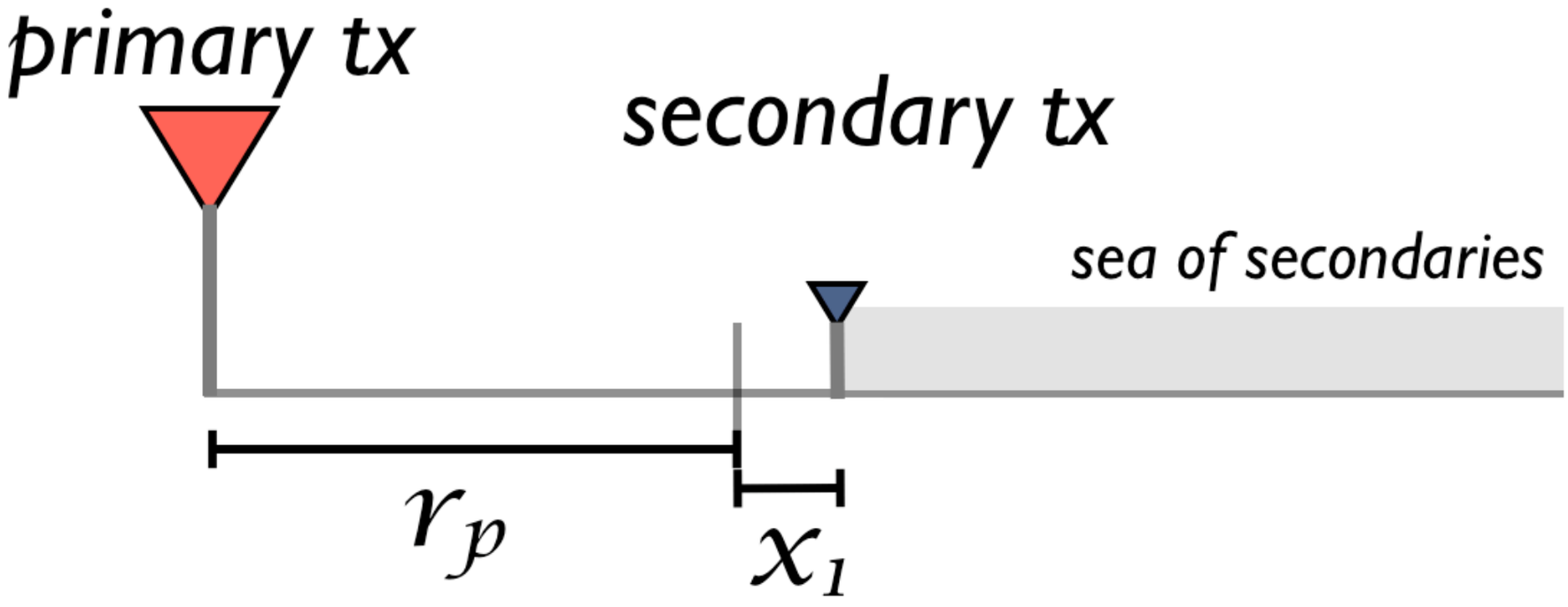


Sacrifice power
Need spectrum
Decrease r_n

Goal

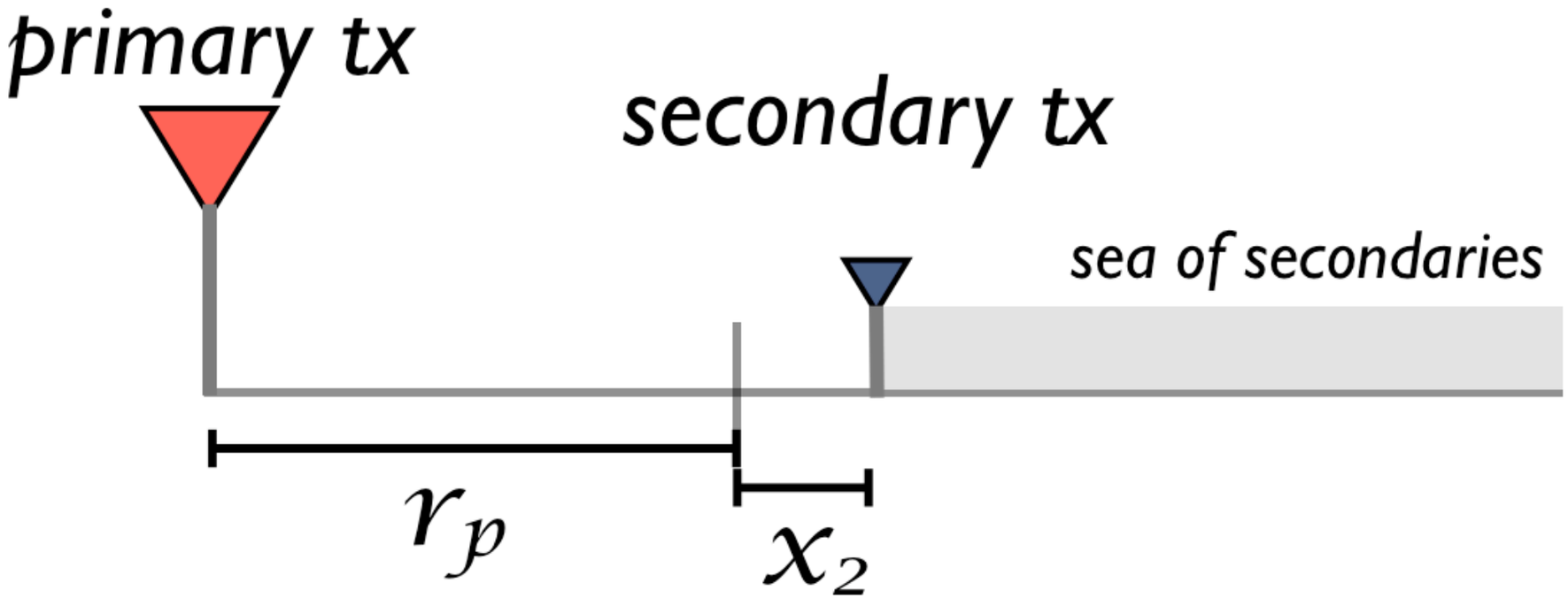


Naïve approach #2



Ideal world: everyone wants the same thing

Naïve approach #2



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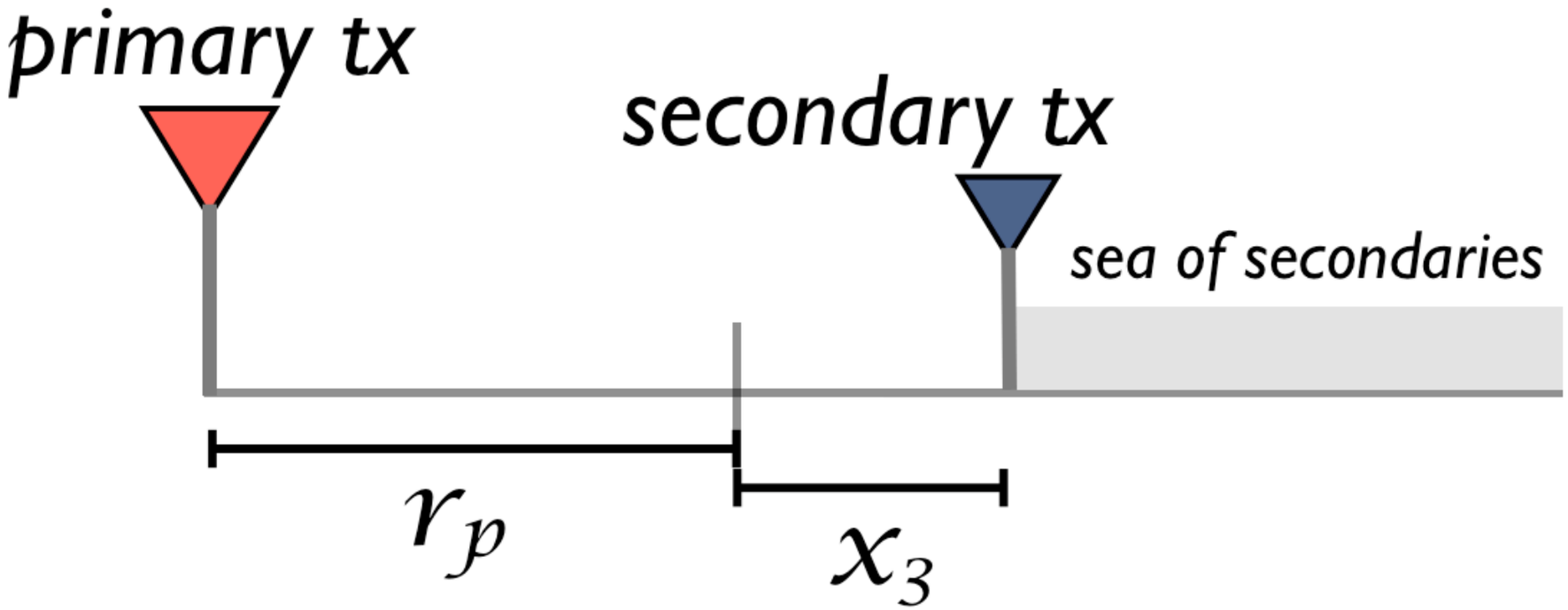
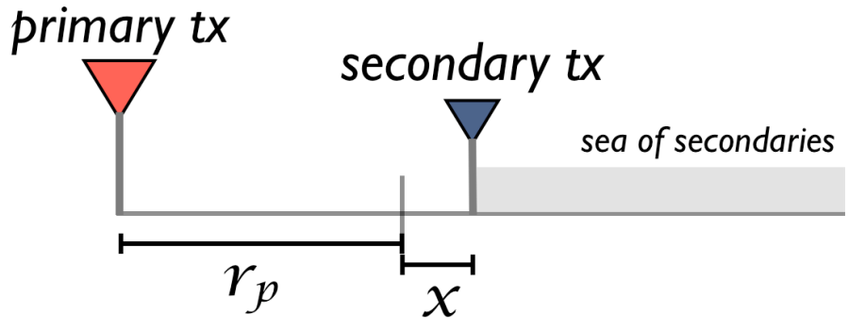


Ideal world: everyone wants the same thing

Naïve approach #2

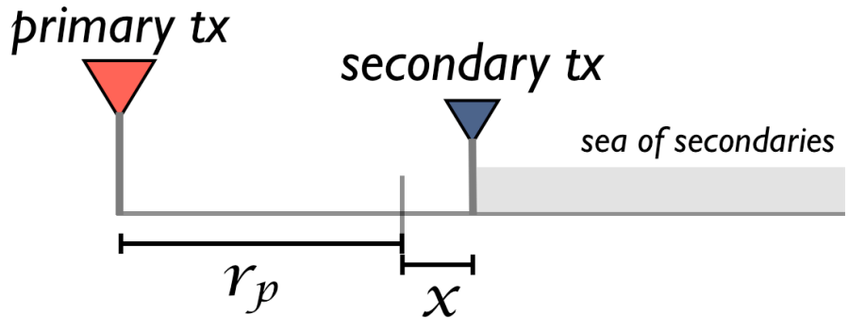
Path loss function: $r^{-\alpha}$



Naïve approach #2

- Primary can handle fixed interference

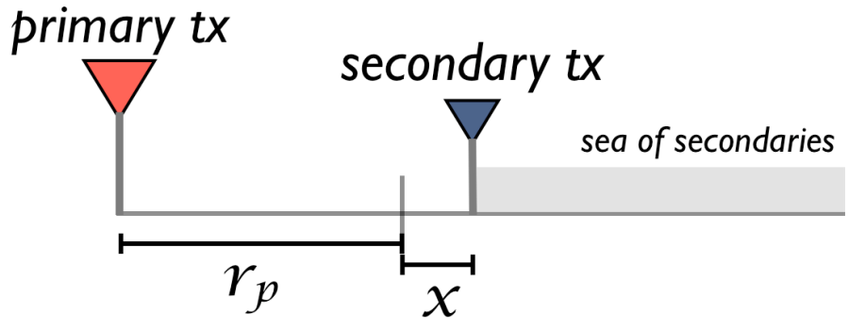
Path loss function: $r^{-\alpha}$



Naïve approach #2

- Primary can handle fixed interference
- Secondary can use power $P_{dream}(x)$

Path loss function: $r^{-\alpha}$

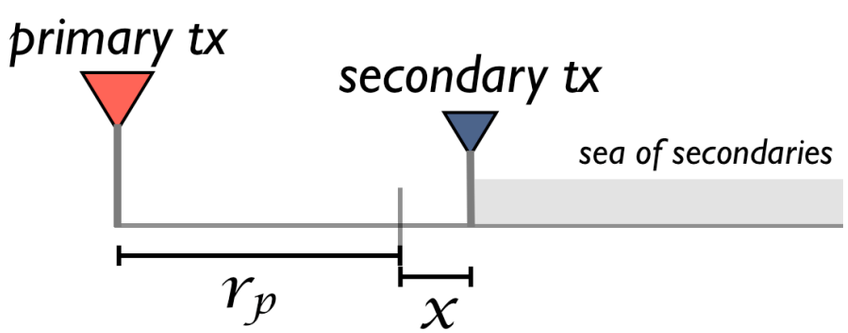


Naïve approach #2

- Primary can handle fixed interference
- Secondary can use power $P_{dream}(x)$
- Assumes other secondaries use same

$$P_{dream}(x) = K \cdot x^{\alpha-1}$$

Path loss function: $r^{-\alpha}$



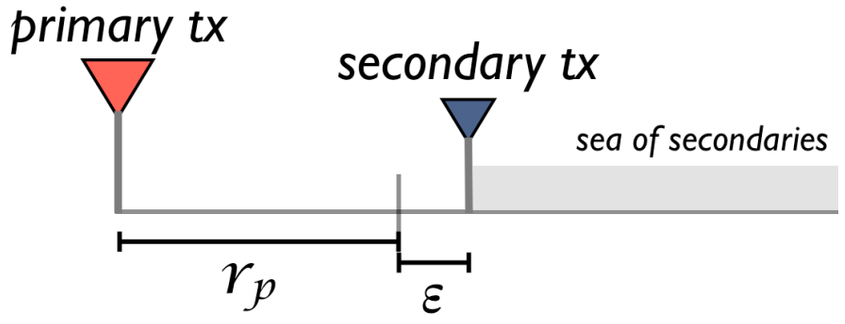
Naïve approach fails

Interference seen by primary is unbounded!

$$\int_{\epsilon}^{\infty} P_{dream}(r) r^{-\alpha} dr = K \cdot \int_{\epsilon}^{\infty} \frac{1}{r} dr = \infty$$

Distance between TV receivers and secondaries

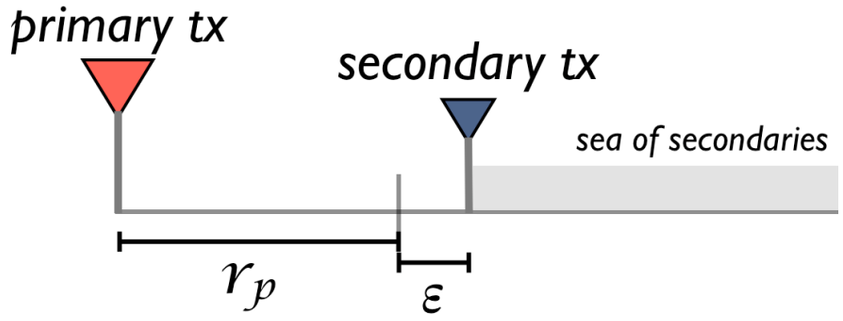
Path loss function: $r^{-\alpha}$



New approach

- Cannot increase power so aggressively

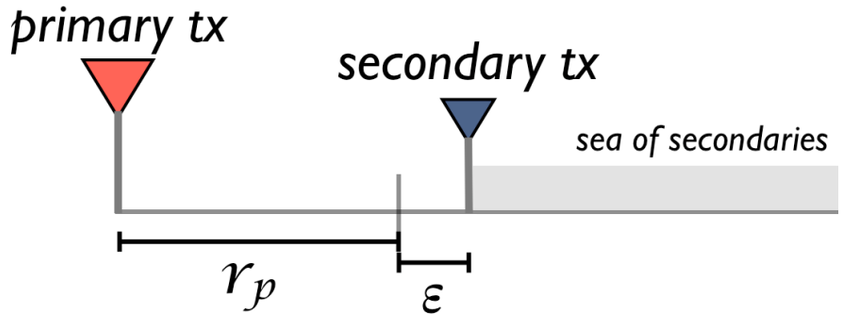
Path loss function: $r^{-\alpha}$



New approach

- Cannot increase power so aggressively
- Many choices for power scaling rule

Path loss function: $r^{-\alpha}$



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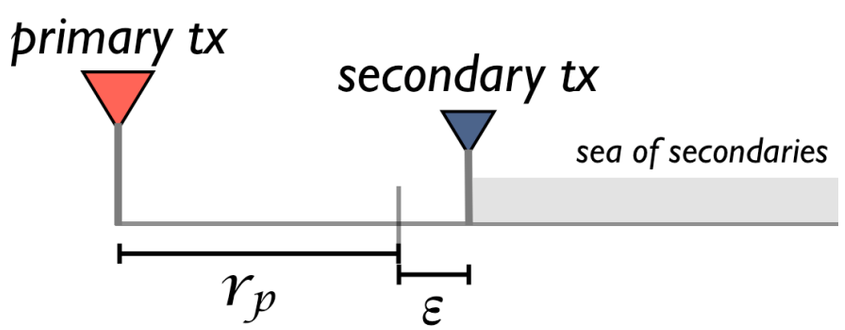
- Maintain fairness: scale data rate

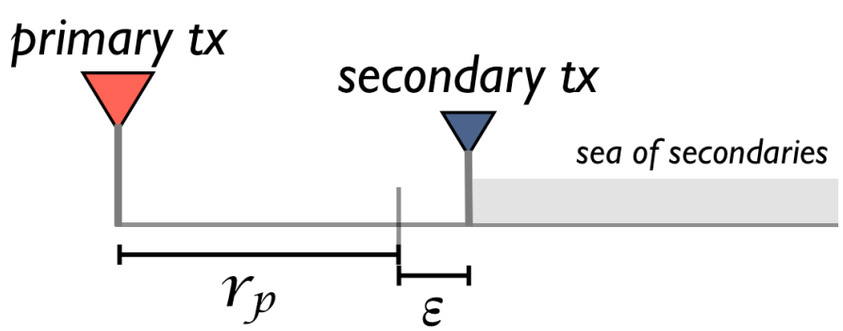
Path loss function: $r^{-\alpha}$



New approach

- Cannot increase power so aggressively
- Many choices for power scaling rule
  - Maintain fairness: scale data rate
    - **Shannon:** $\text{rate} = \log_2\left(1 + \frac{\text{signal power}}{\text{noise power}}\right)$

Path loss function: $r^{-\alpha}$

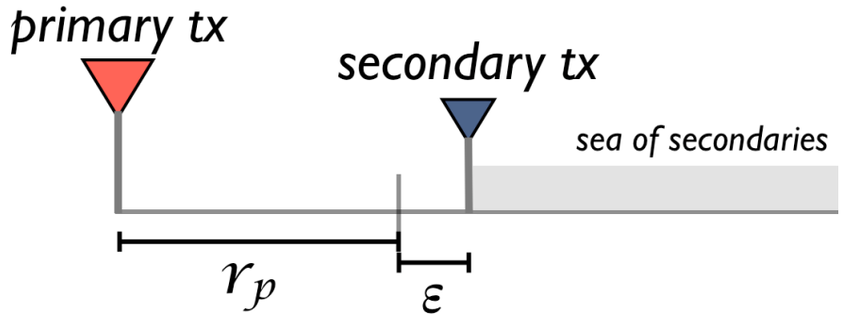


New approach

- Give users percentage of "dream rate"

$$0 \leq \gamma < 1$$

Path loss function: $r^{-\alpha}$



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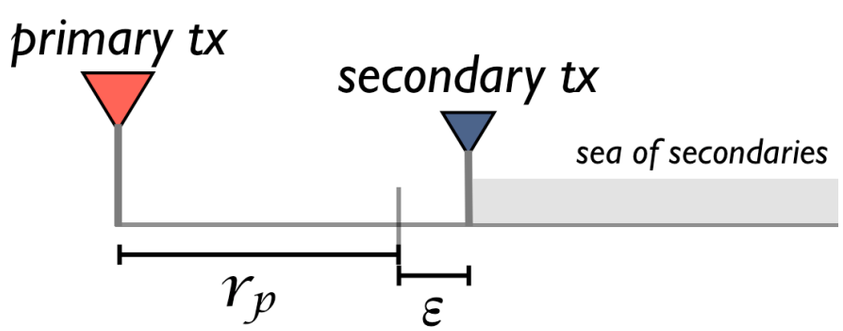
Path loss function: $r^{-\alpha}$



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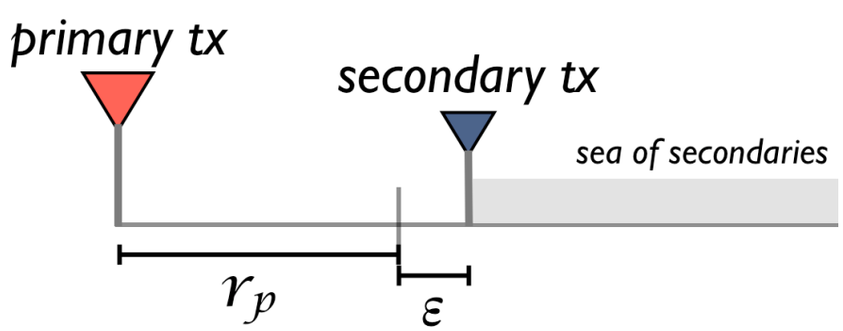
- Given this γ, we know that

$$P_{new}(x, \gamma) = K' \cdot x^{\gamma(\alpha-1)}$$



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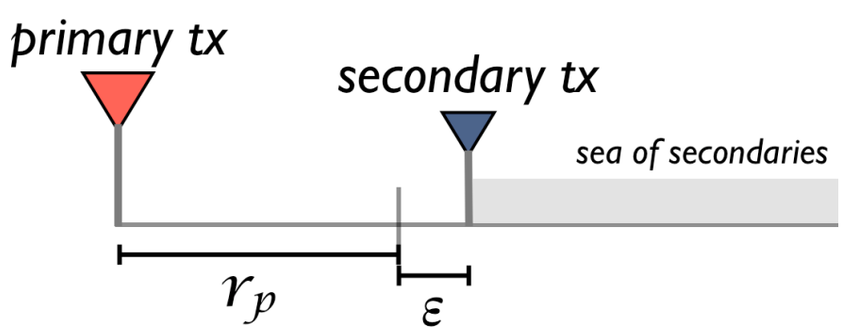
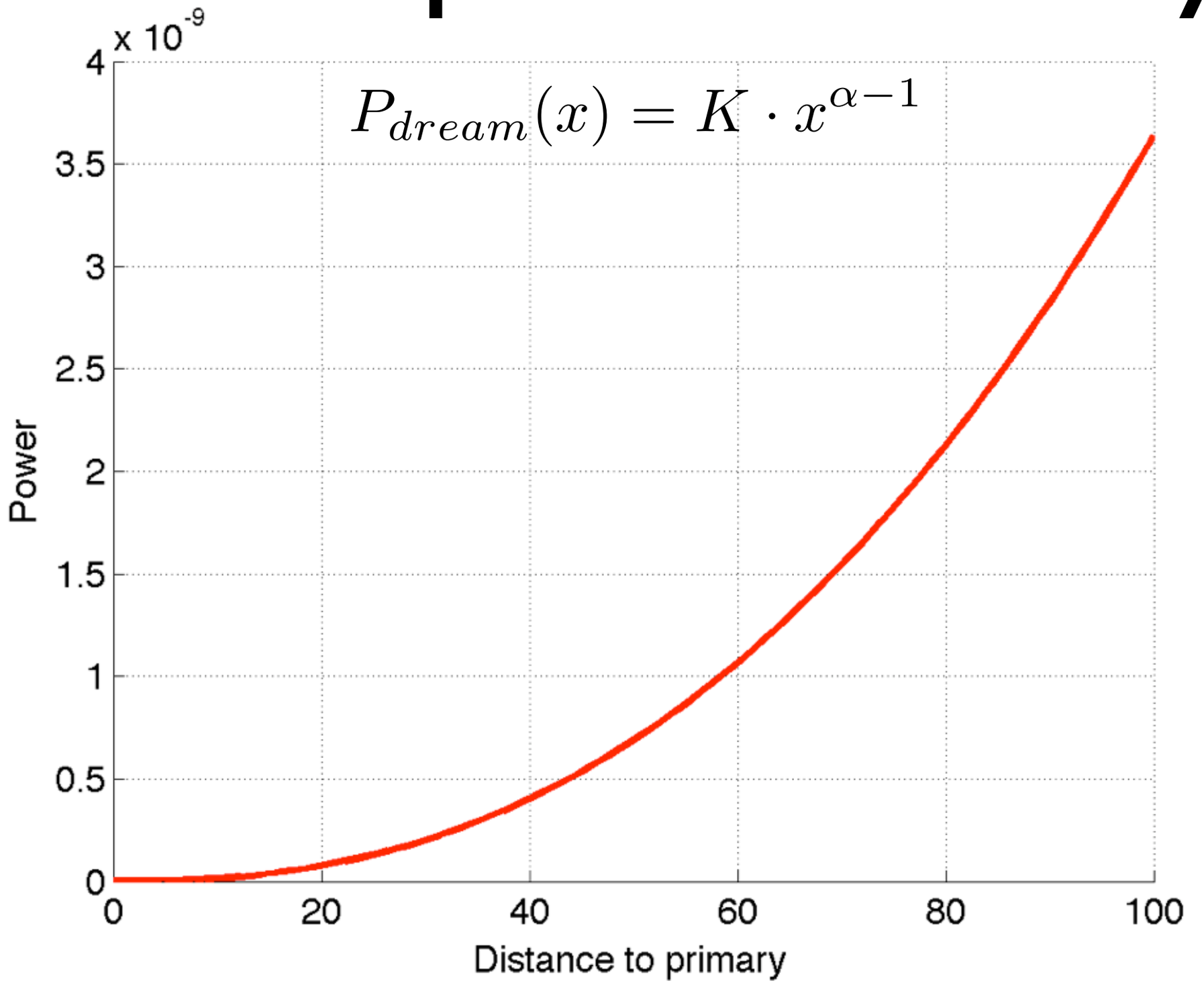
- Guaranteed to be bounded



Path loss function: $r^{-\alpha}$

Dream power density



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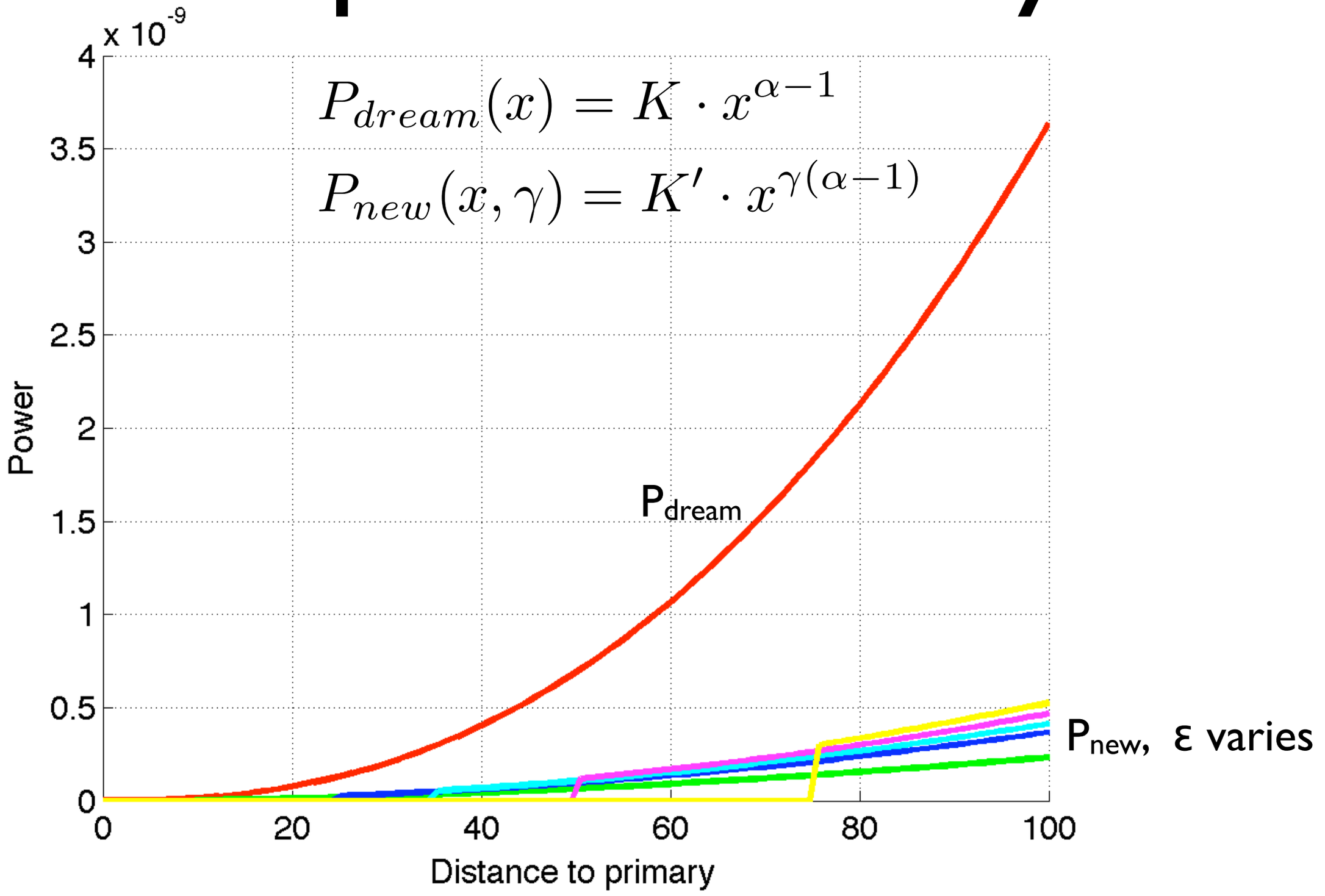

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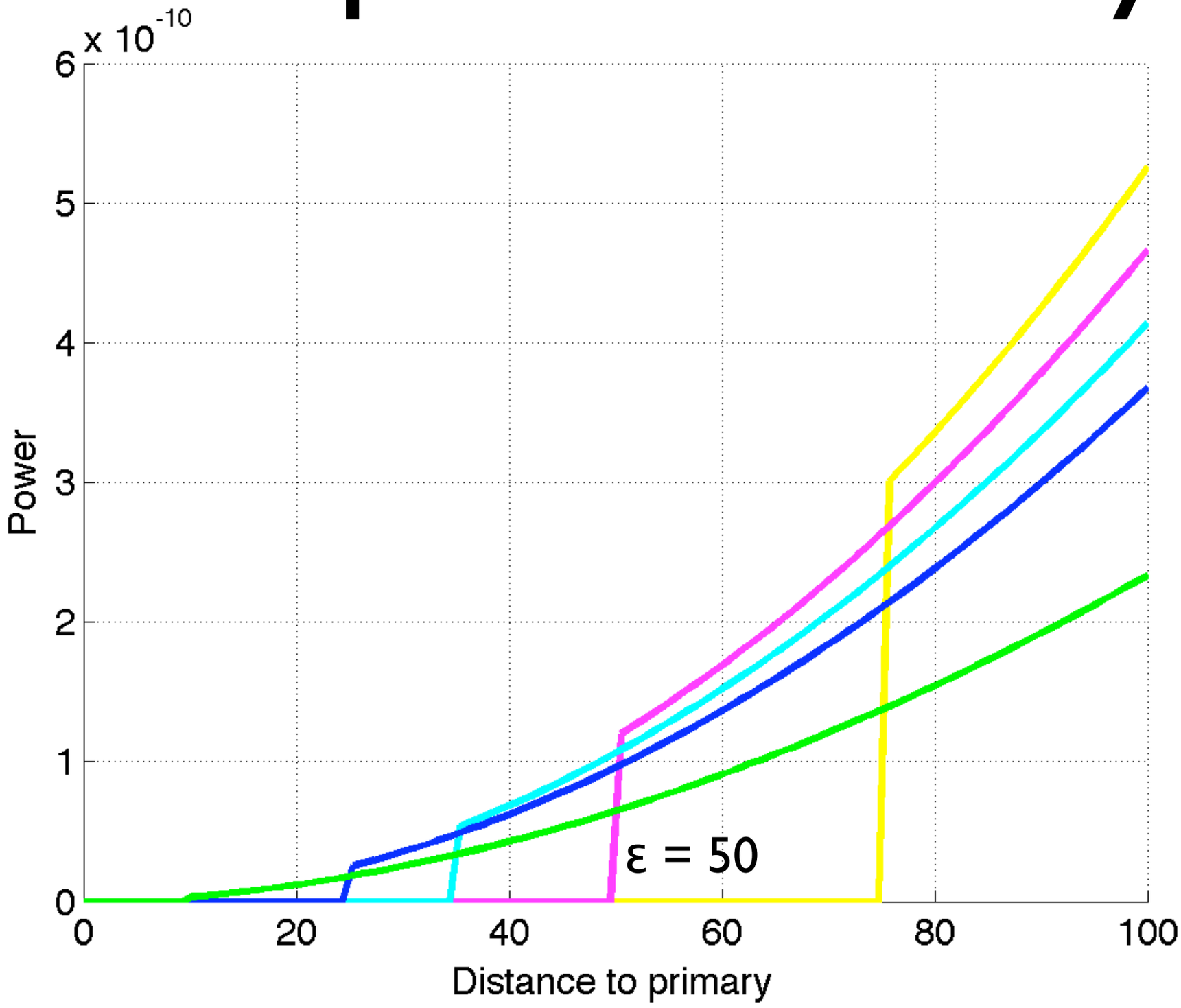
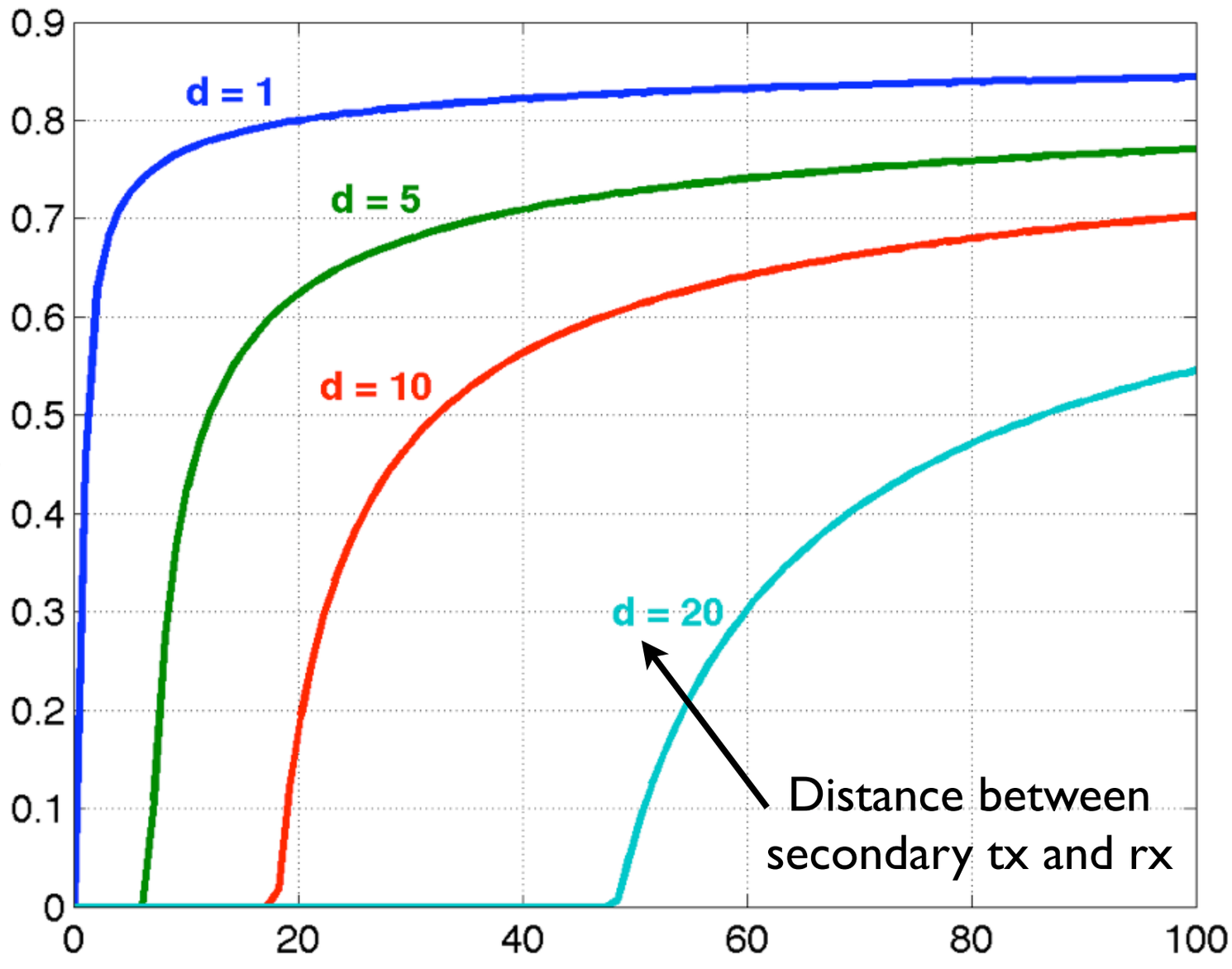


Fraction provided



Fraction of "dream rate"

Distance between secondary tx and rx

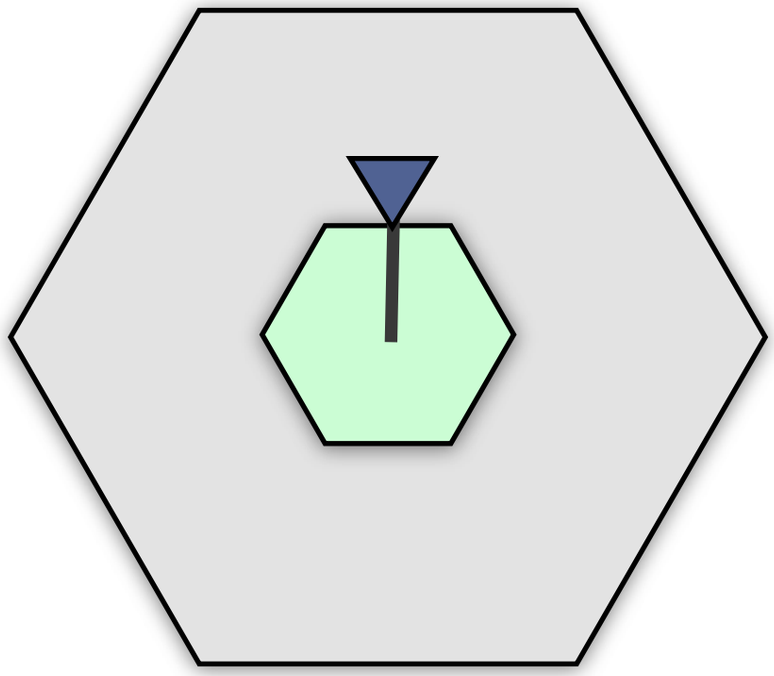
Distance between TV receivers and secondaries

Metric

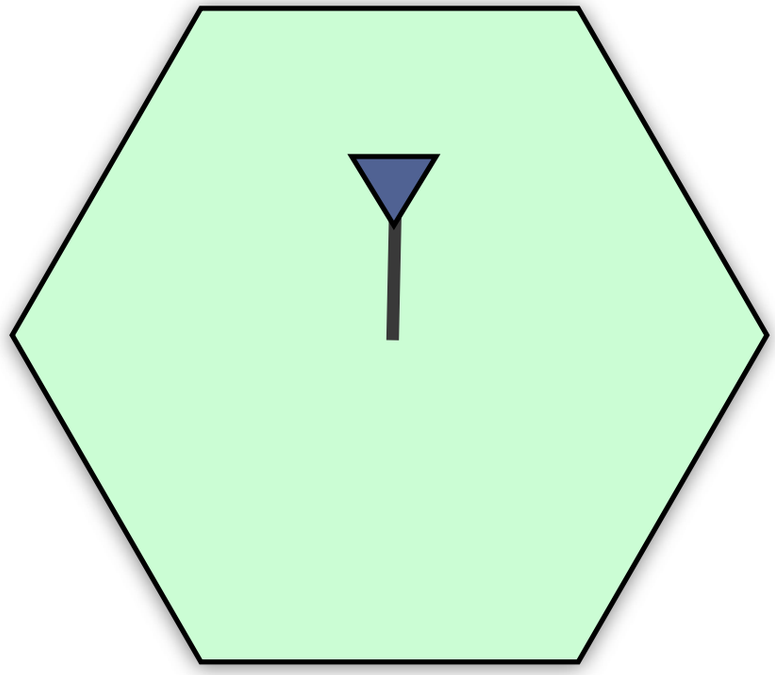
- Ratio of "dream rate" to real rate (γ)
- *Dream rate*: rules made for that user
- *Real rate*: rules made for everyone

Two models: secondary transmission distance

Hotspot

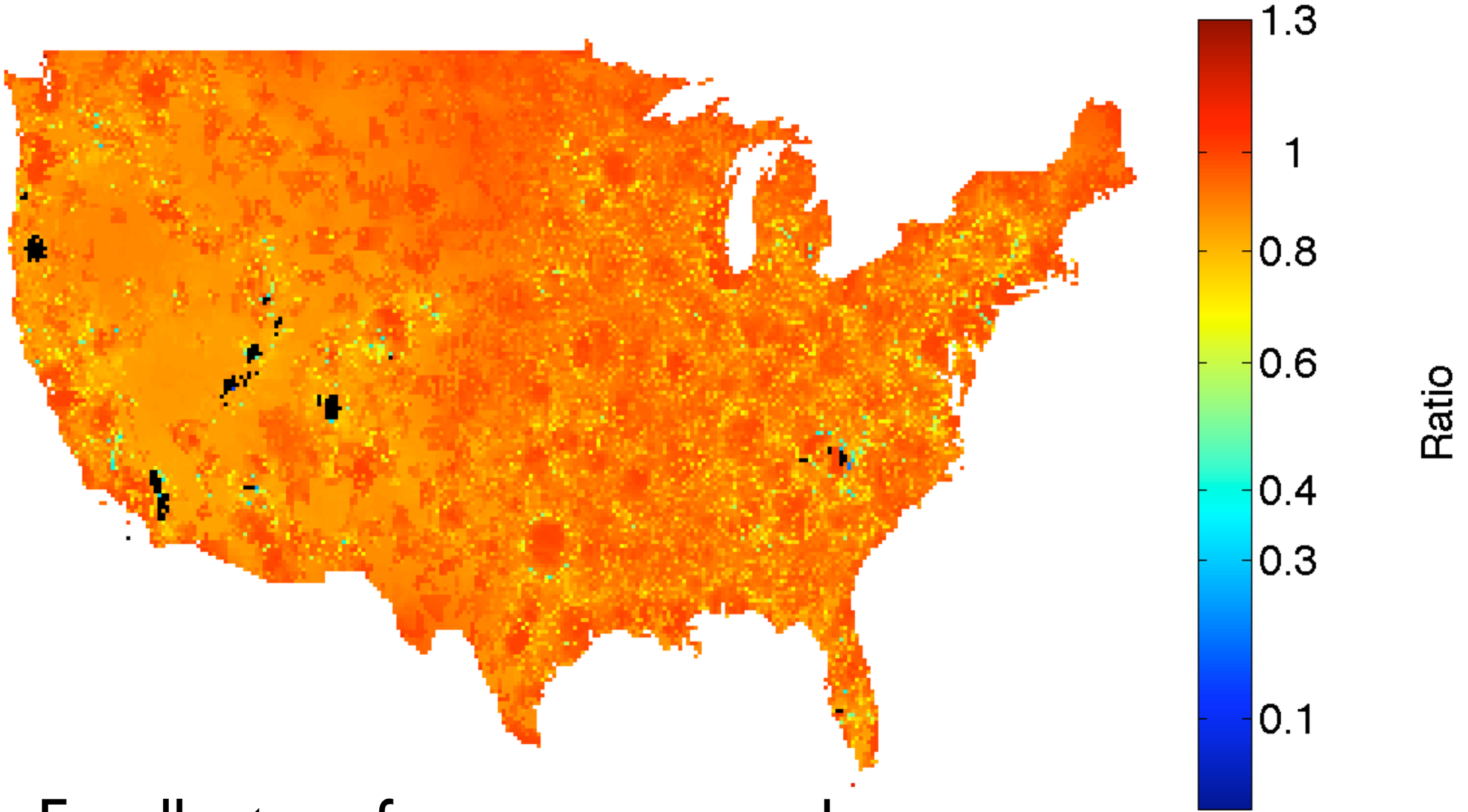


Cellular



- Same power
- Different user placement

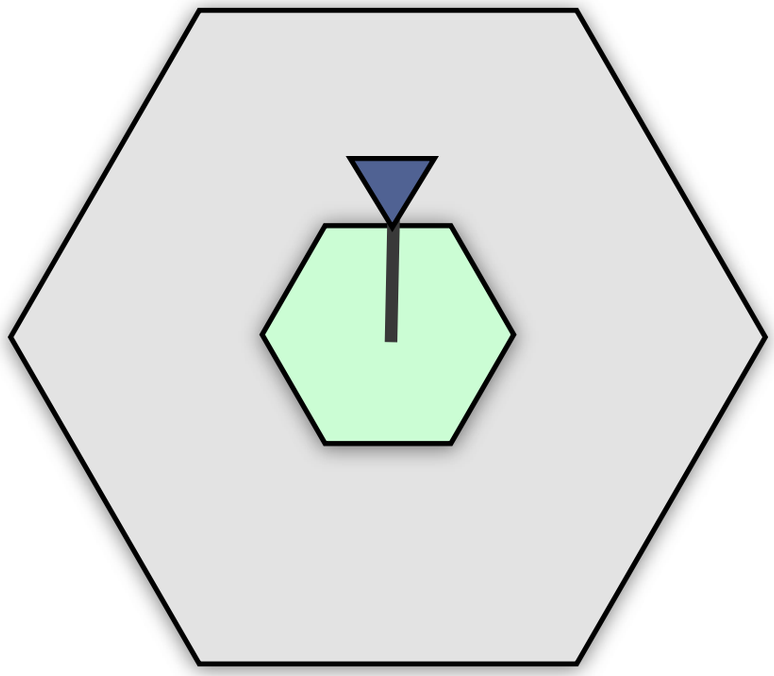
Hotspot rules and use



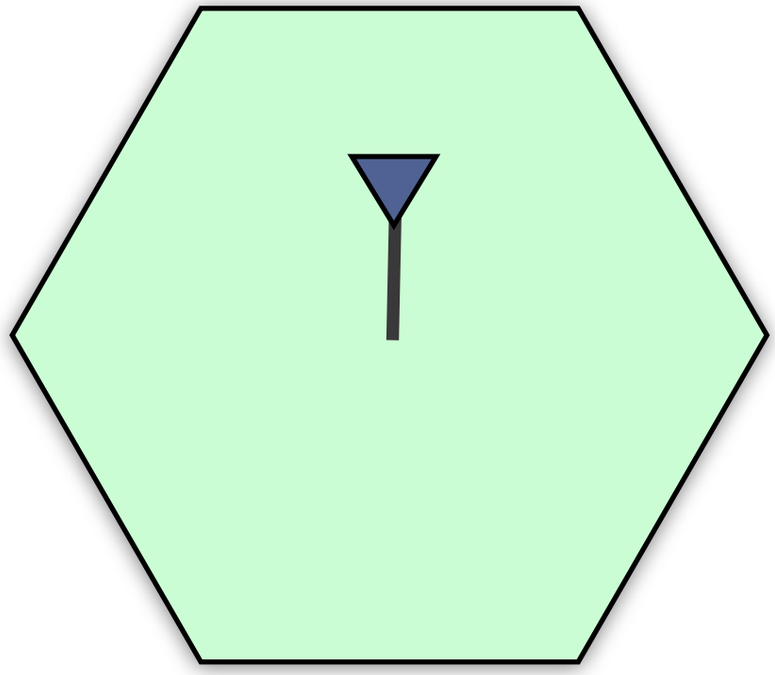
Excellent performance everywhere

Two models: secondary transmission distance

Hotspot

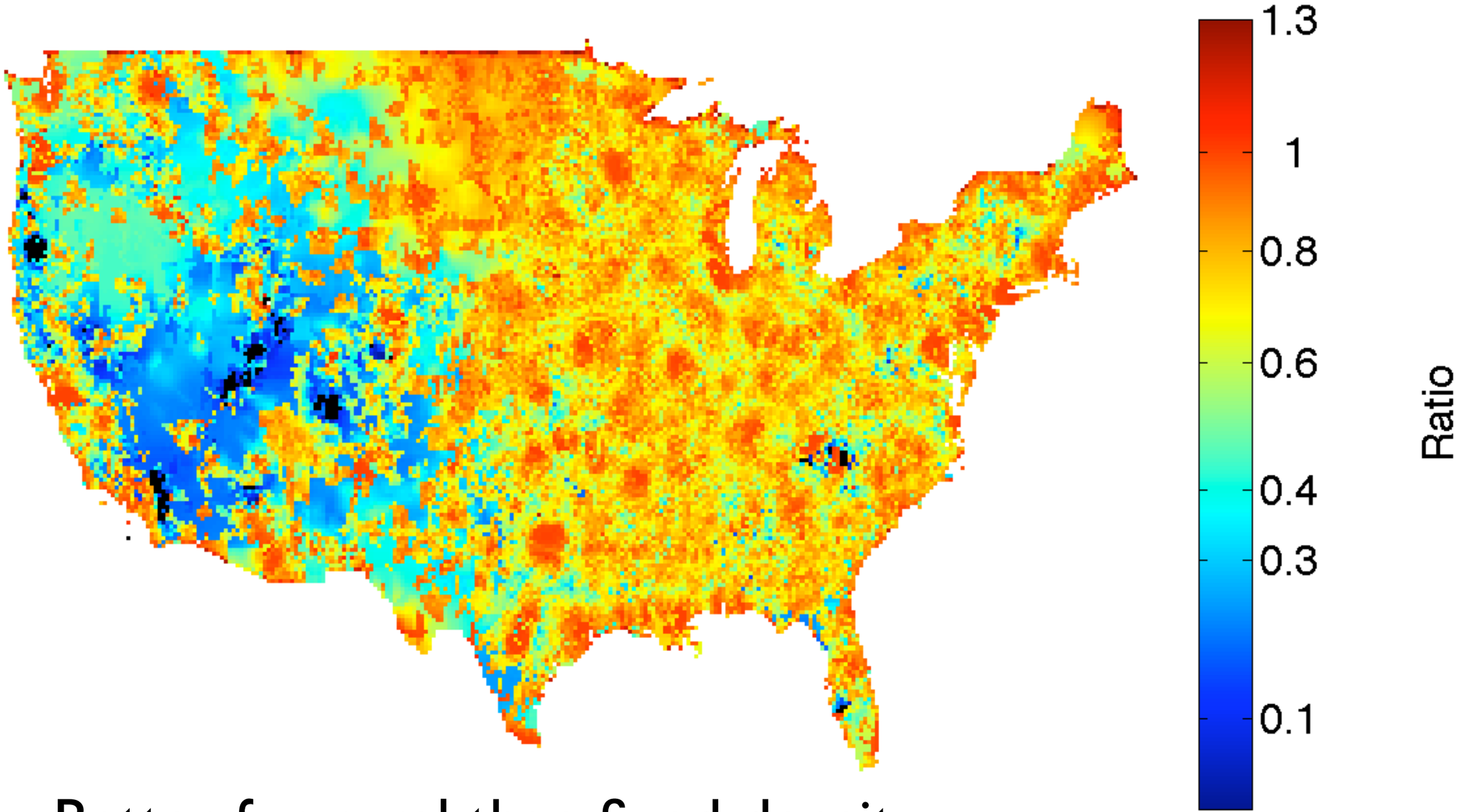


Cellular



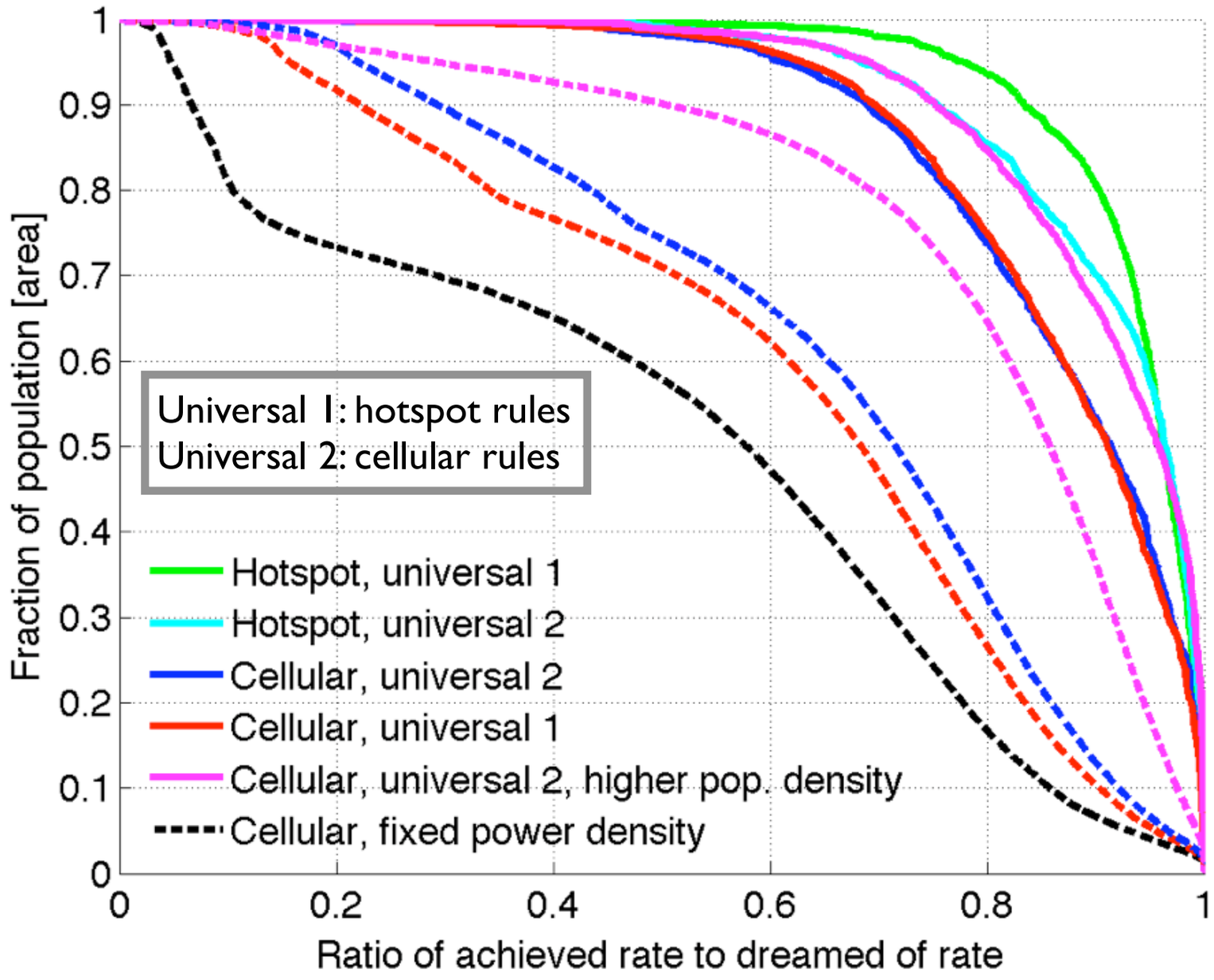
- Same power
- Different user placement

Cellular rules and use



Better for rural than fixed density

Rate-ratio CCDFs



Review

- Problem: primary protection
  - Solution: power density
- Tension: rural vs. urban users
  - Solution: intelligent power scaling