Supporting weakly-localized whitespace devices

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DySpAN 2014 McLean, Virginia, USA

This work was partially funded by a grant and fellowship from the National Science Foundation.

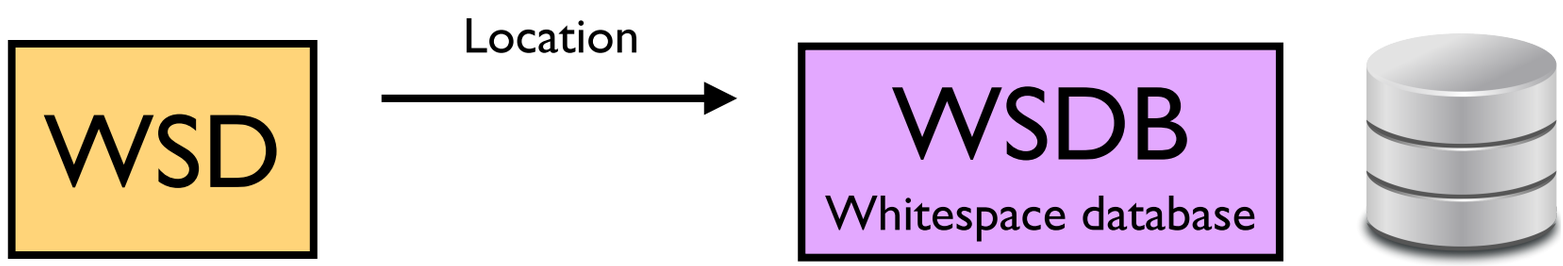
Session 1B

Location

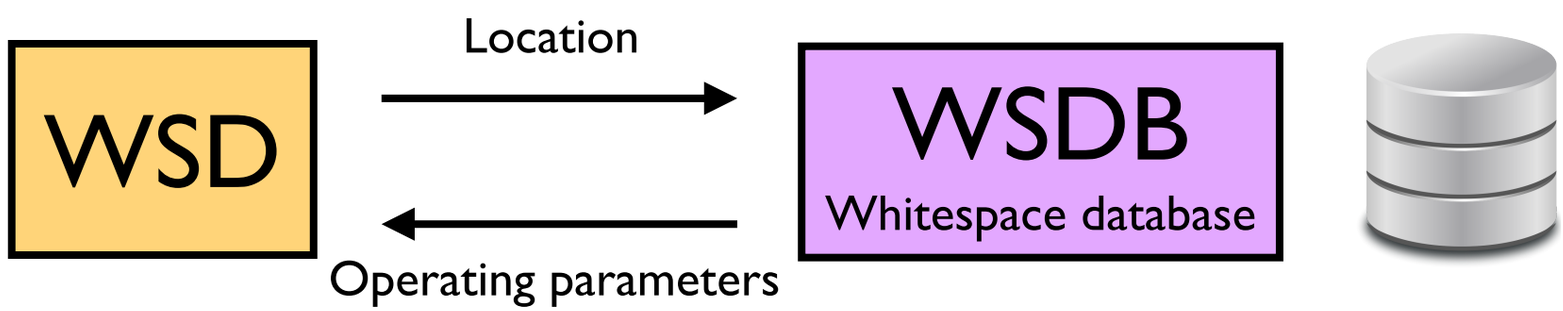
WSD

WSDB
Whitespace database

Location

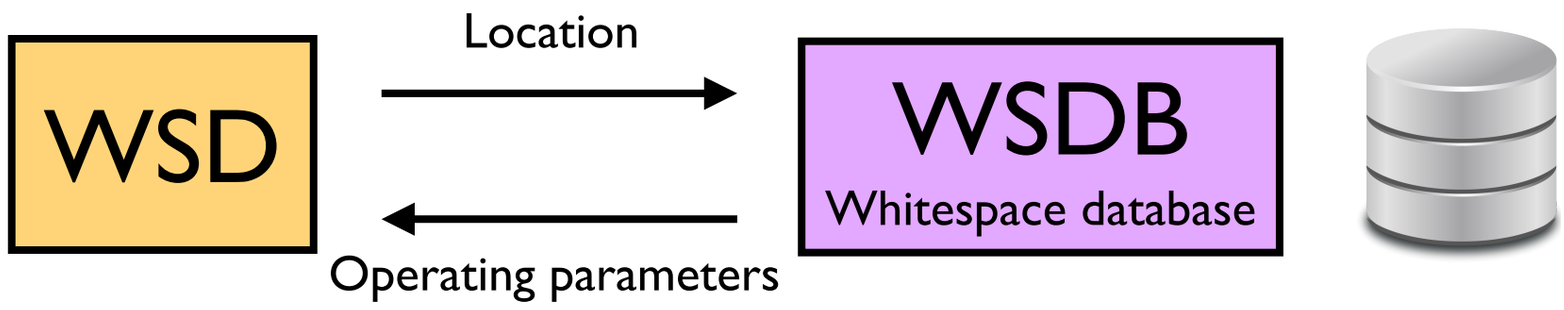


Location


Location
WSD
WSDB
Whitespace database
Operating parameters

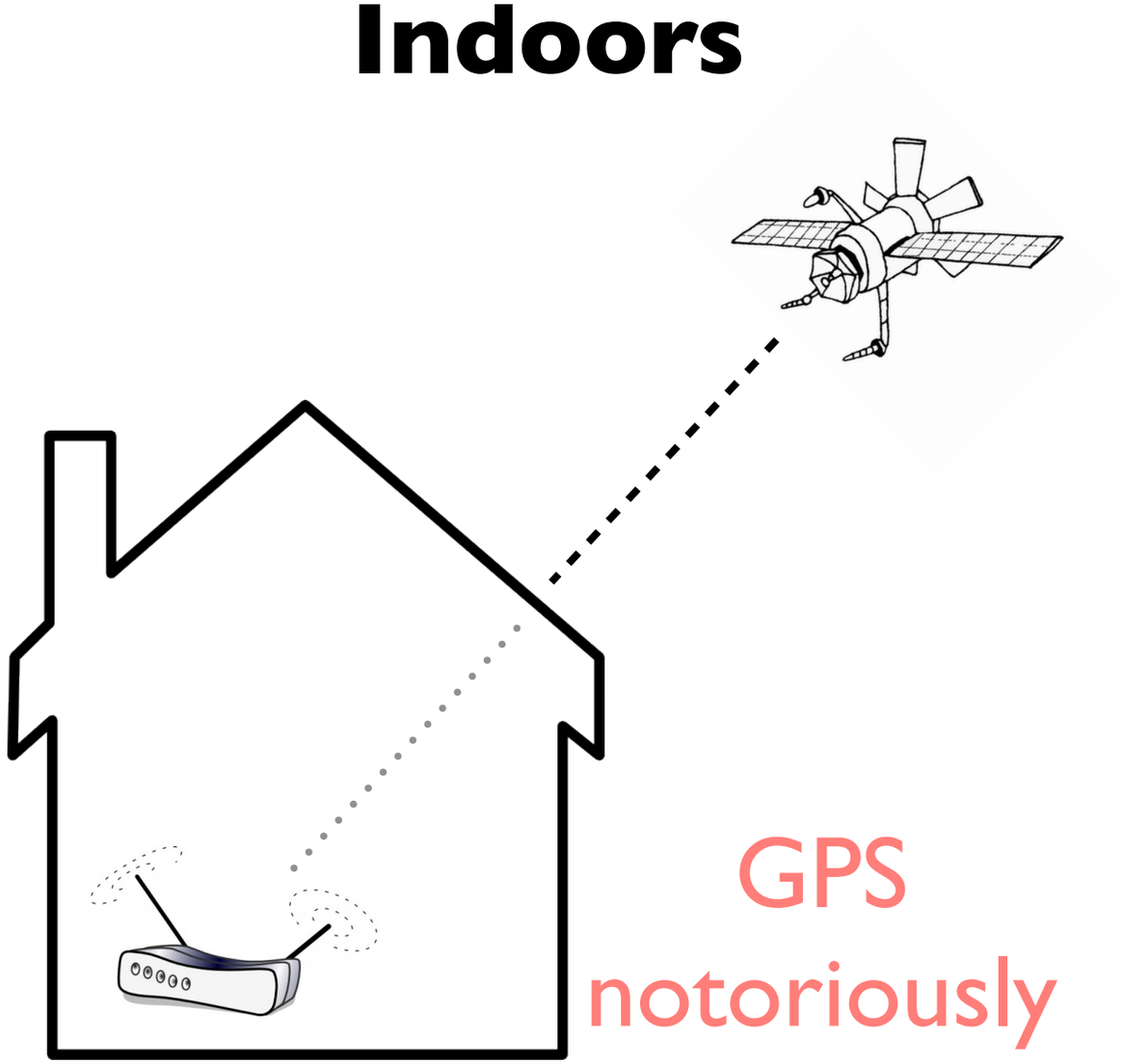
Location


0.2
Stewart Ave
E Ogden Ave
30
Menu
2:18
GARMIN


WSD
Location
Operating parameters
WSDB
Whitespace database

Location

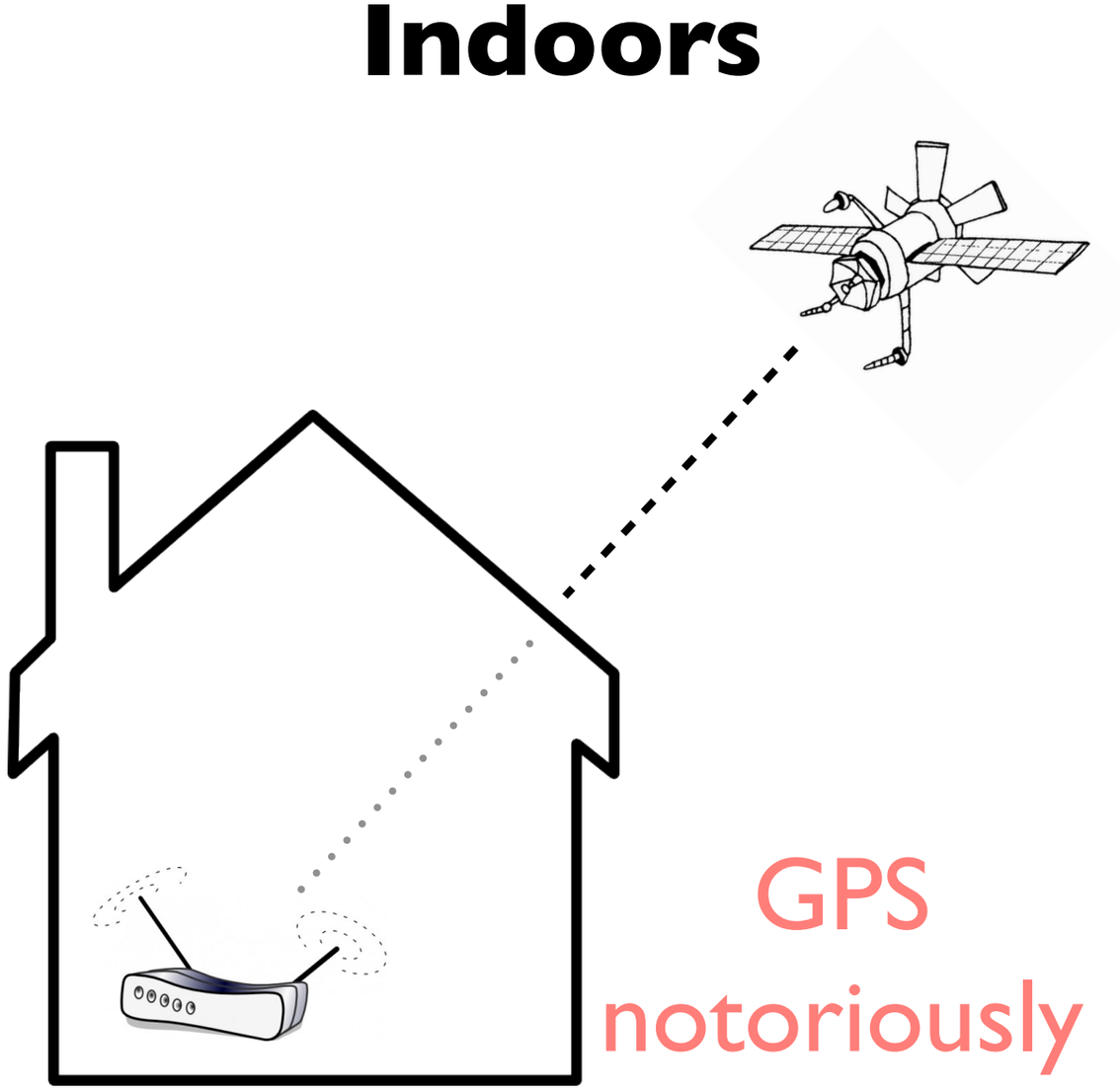
Indoors



GPS notoriously bad indoors

Location

Indoors

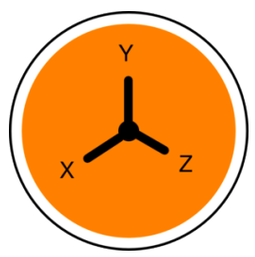


GPS notoriously bad indoors

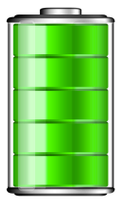
Economical

=

+



+

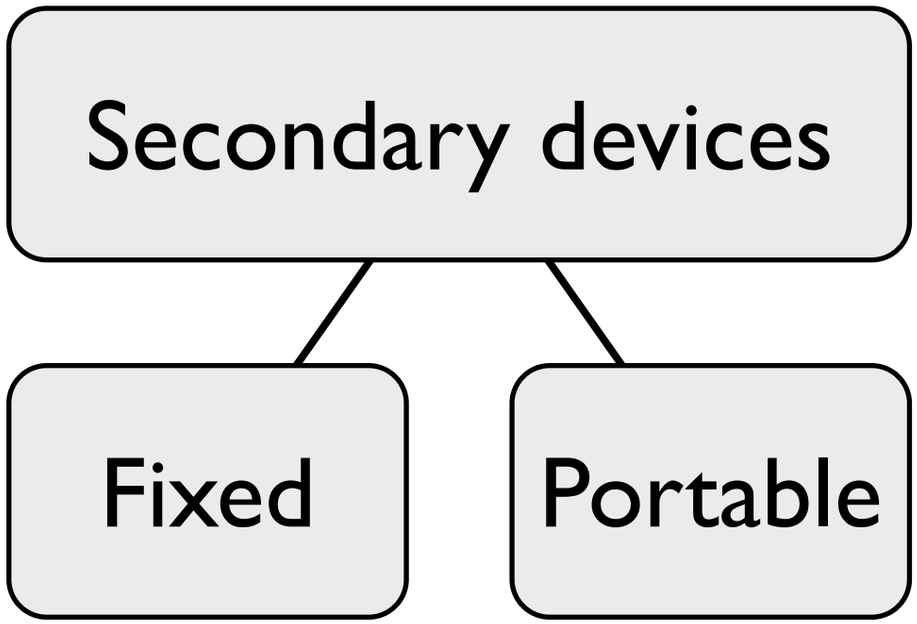


GPS adds cost

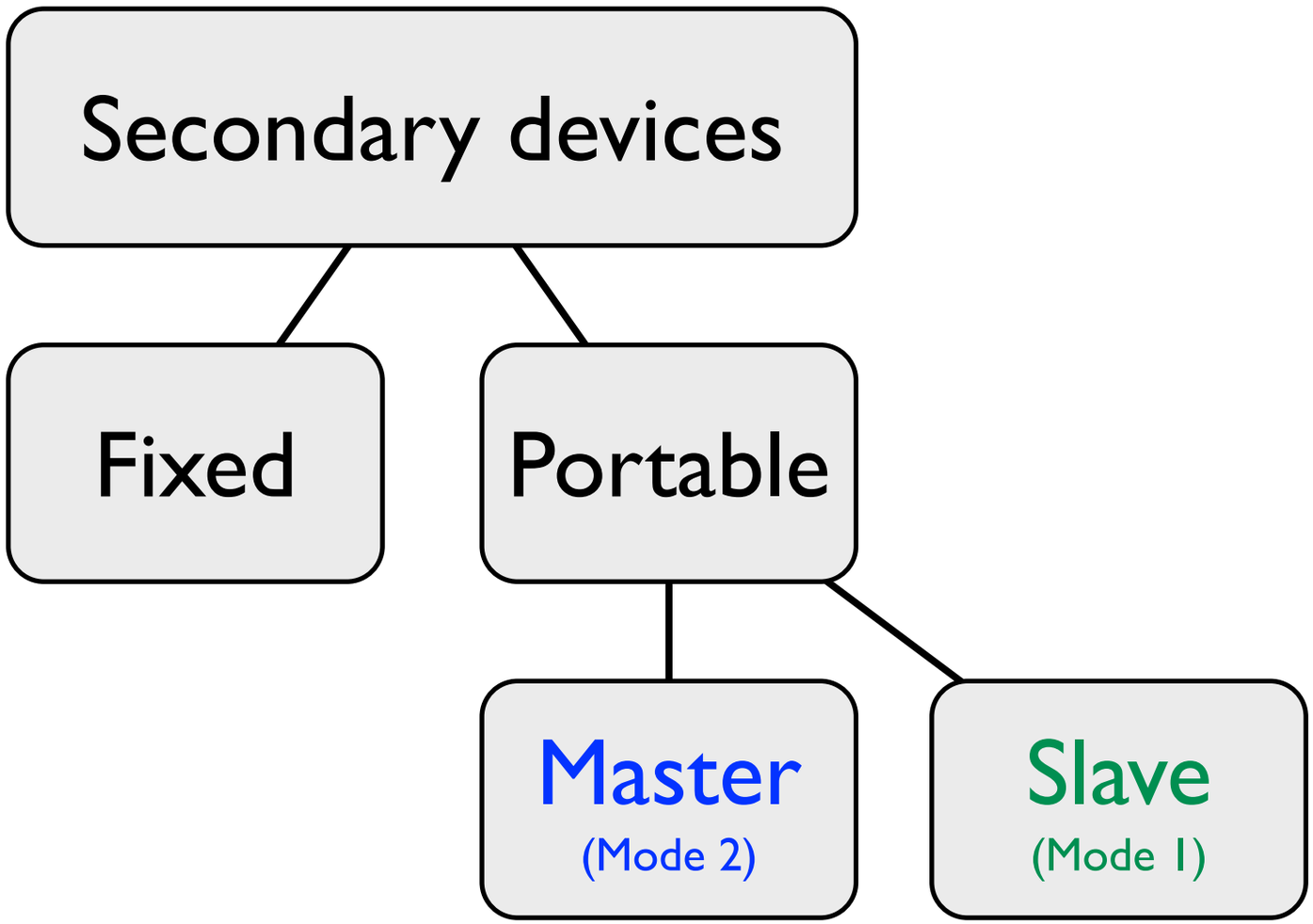
Overview

- FCC approach to TVWS
- Ofcom approach to TVWS
- Illustrative alternative

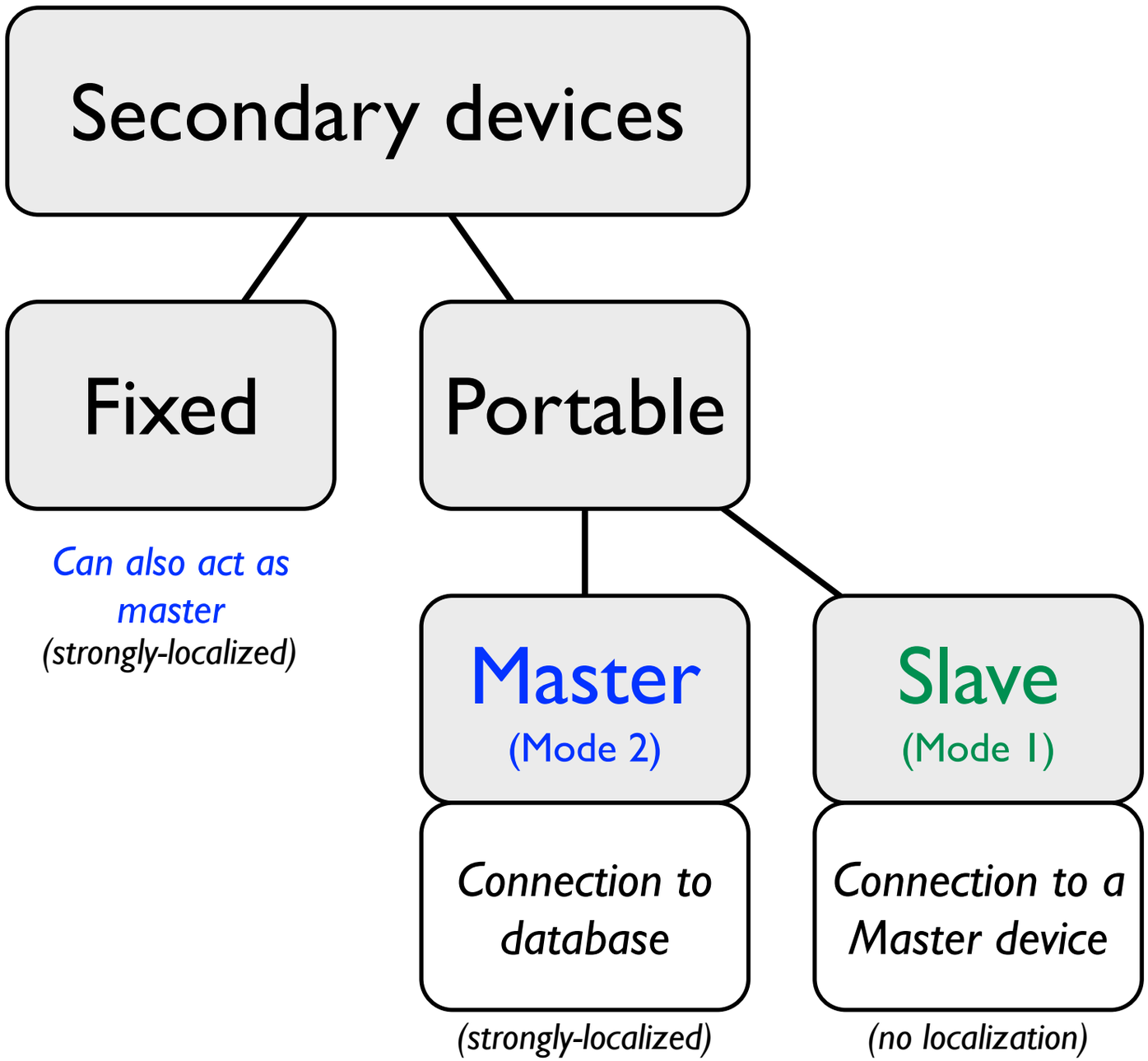
FCC's approach



FCC's approach



FCC's approach



FCC's approach

Secondary devices

Fixed

Can also act as master
(strongly-localized)

Portable

Master
(Mode 2)

Connection to database

(strongly-localized)

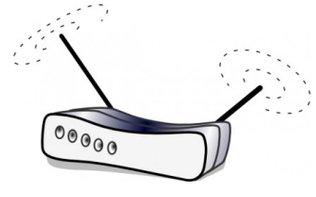
Slave
(Mode 1)

Connection to a Master device

(weakly-localized)

Master

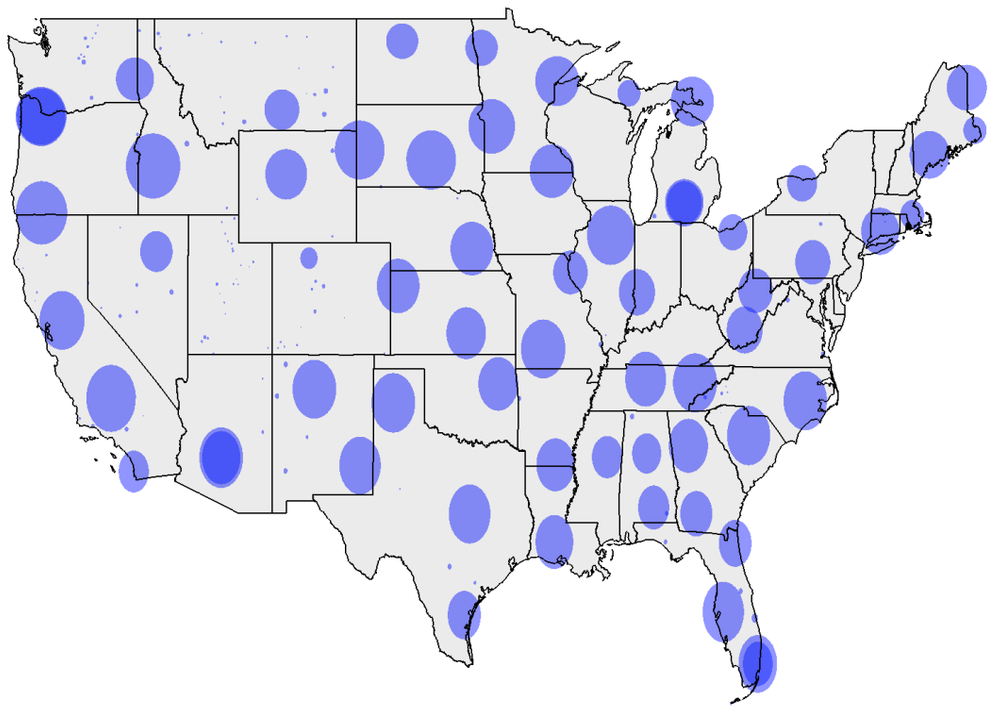
distance
presumed small
presumed high
data rate



Slave

Two different stories

Single-channel



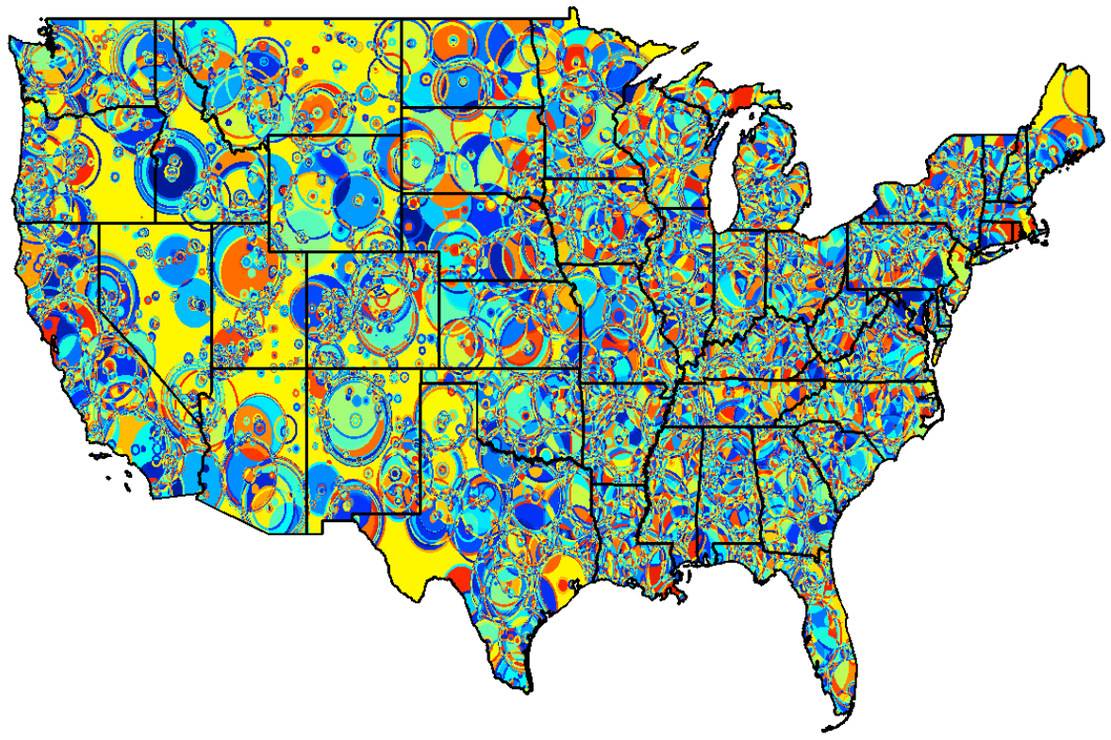
TV service areas on one channel

Two different stories

Single-channel

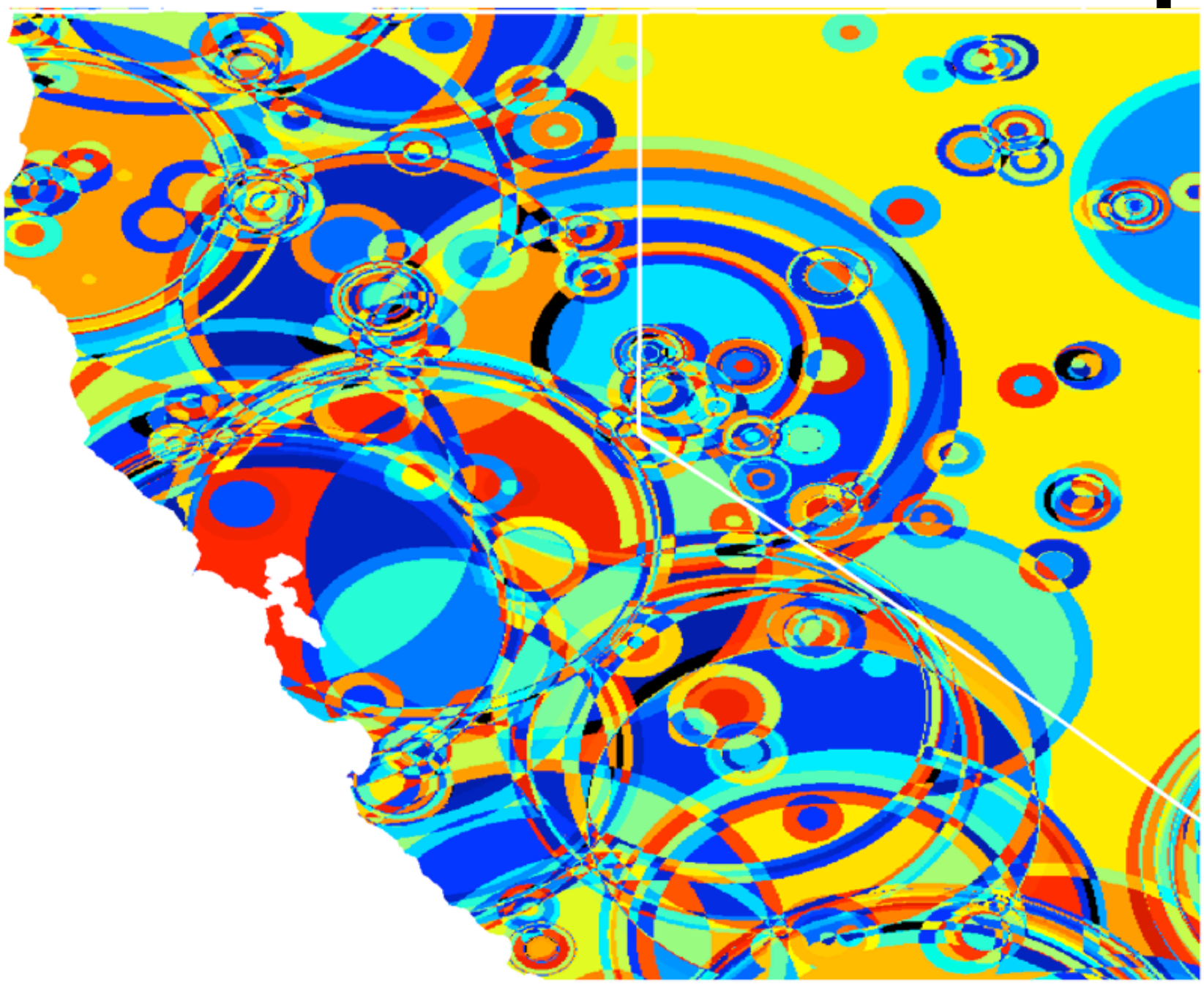
TV service areas on one channel

All channels

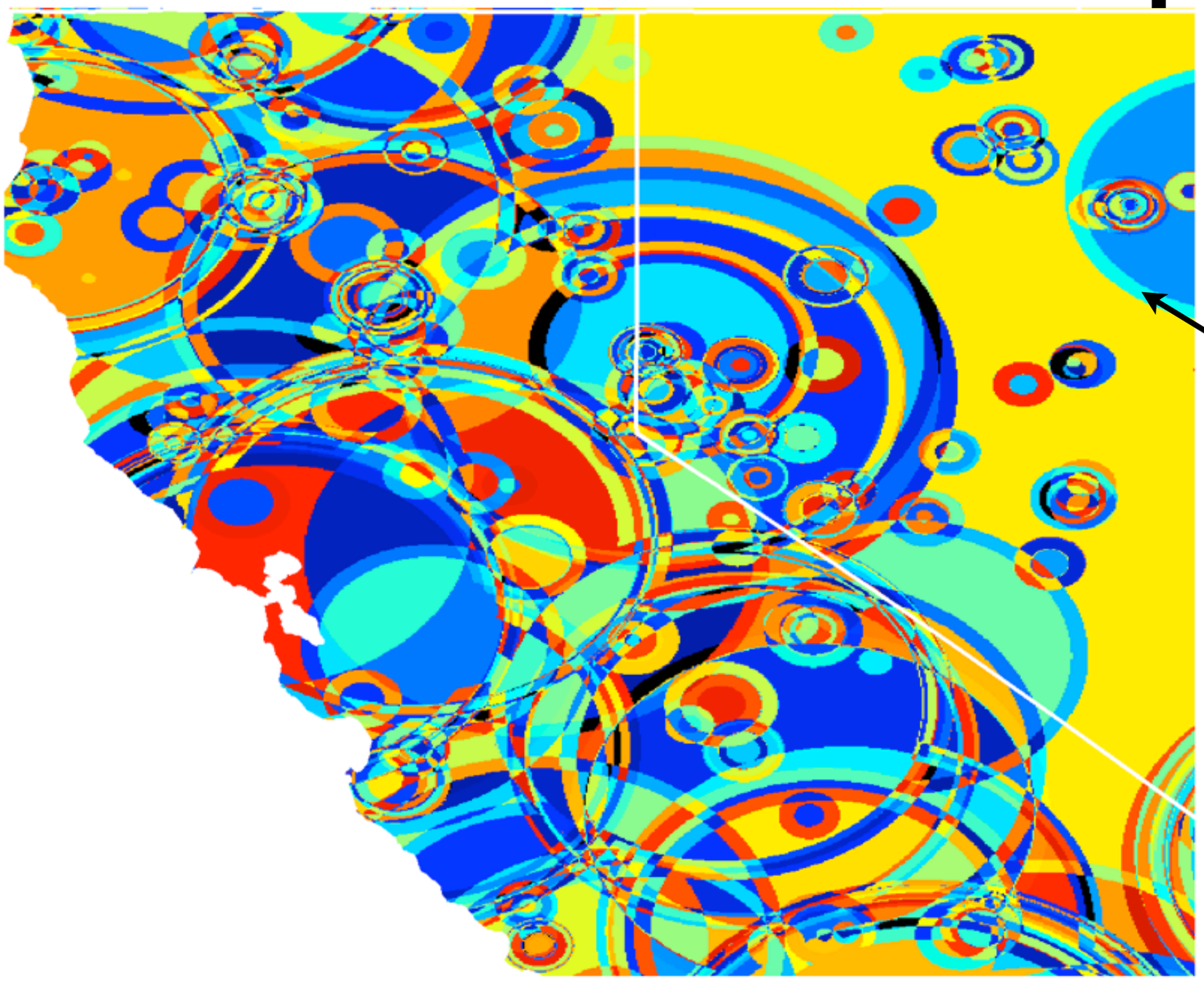


Each color → unique channel list

Several effects in play

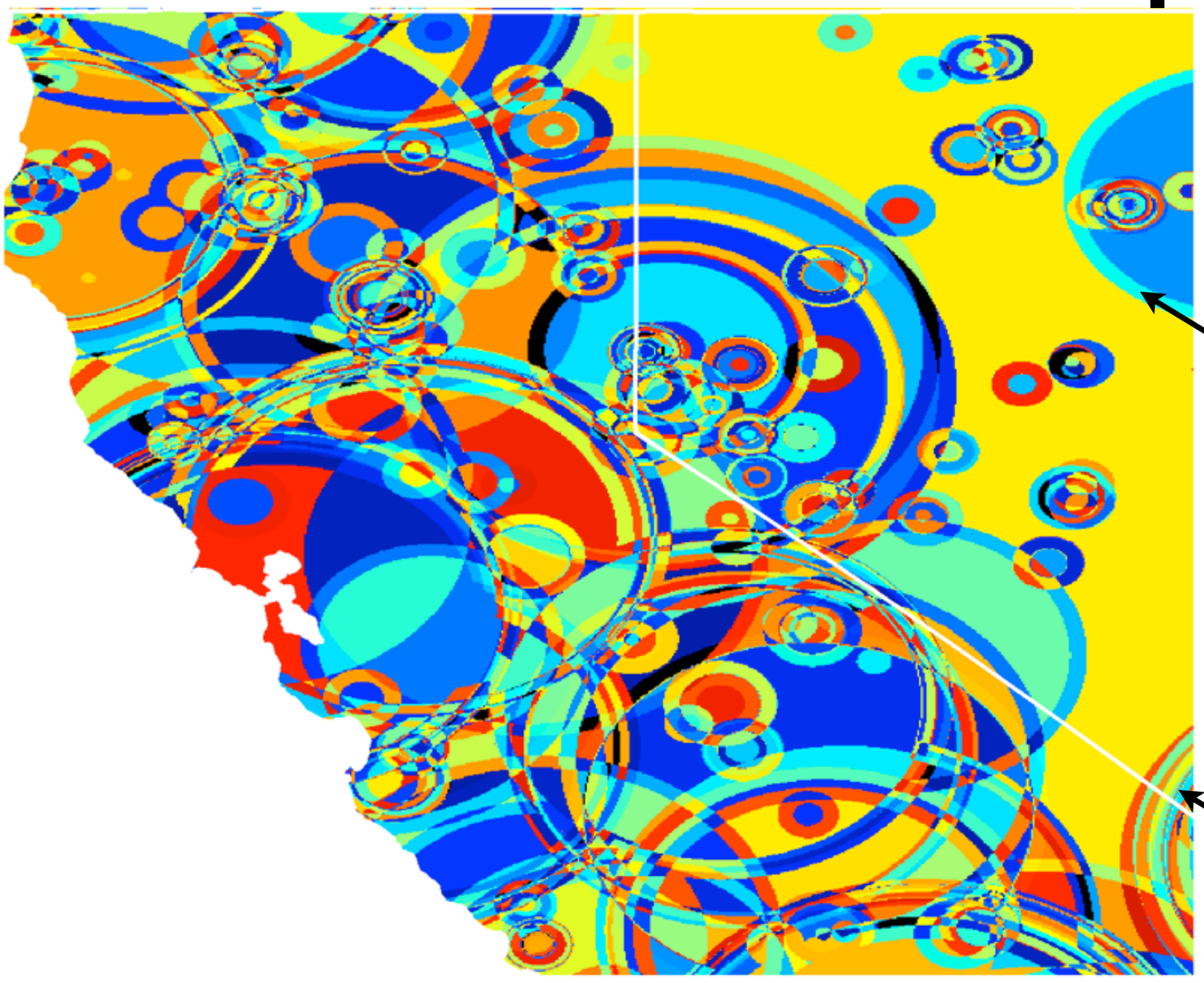


Several effects in play



Cochannel vs. adjacent-channel exclusions

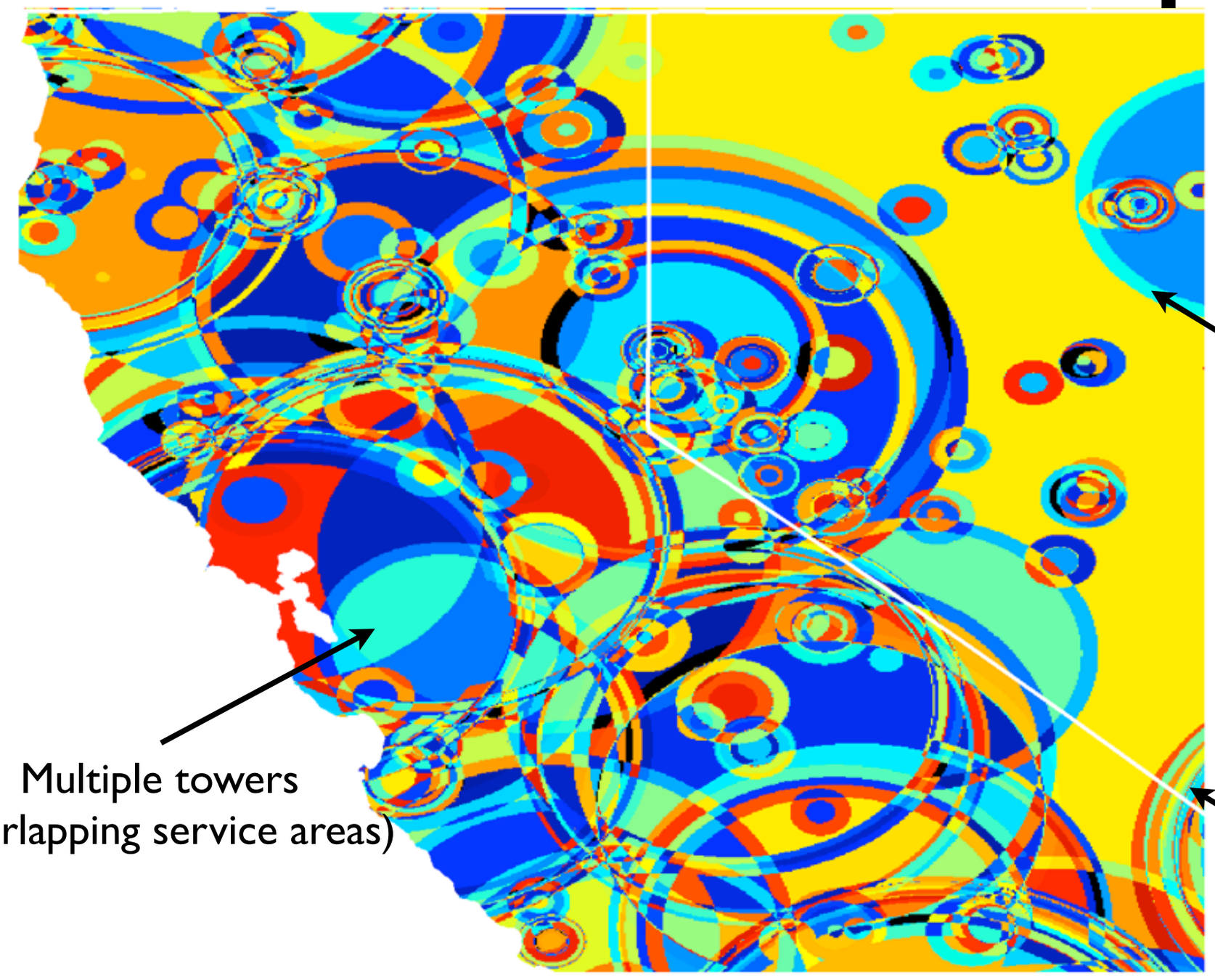
Several effects in play



Cochannel vs. adjacent-channel exclusions

Multiple transmitters (same tower, different service areas)

Several effects in play

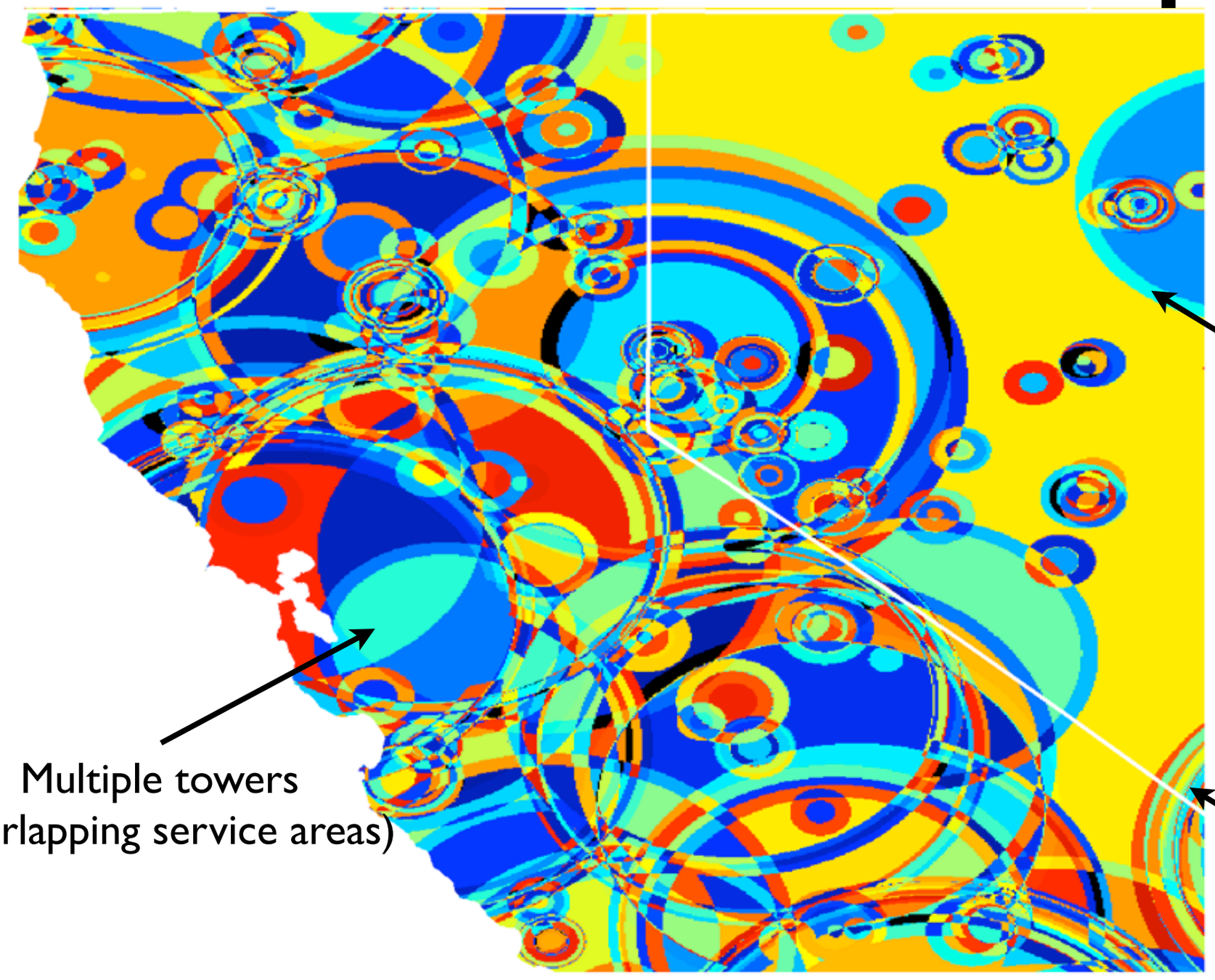


Cochannel vs. adjacent-channel exclusions

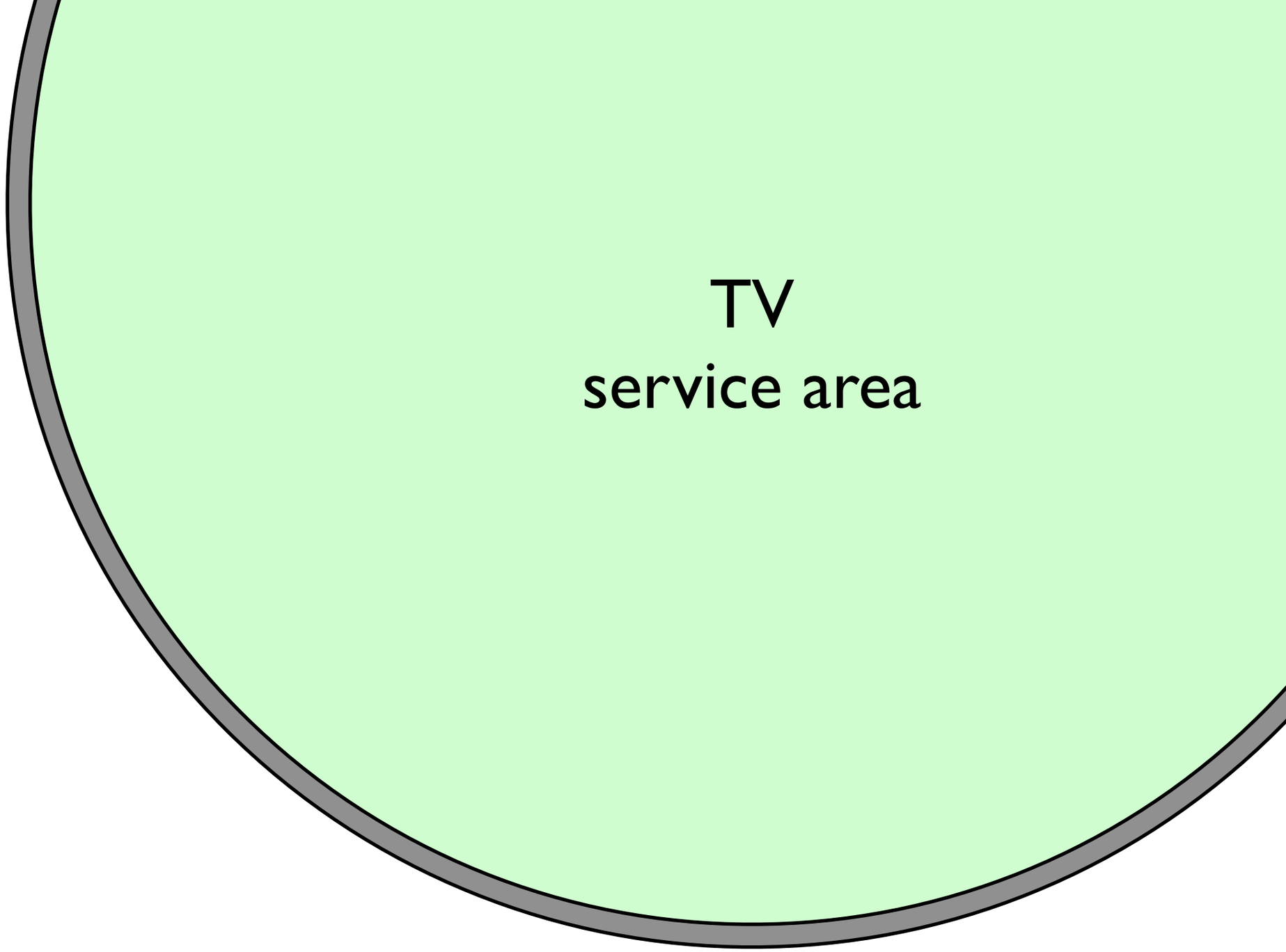
Multiple towers (overlapping service areas)

Multiple transmitters (same tower, different service areas)

Several effects in play

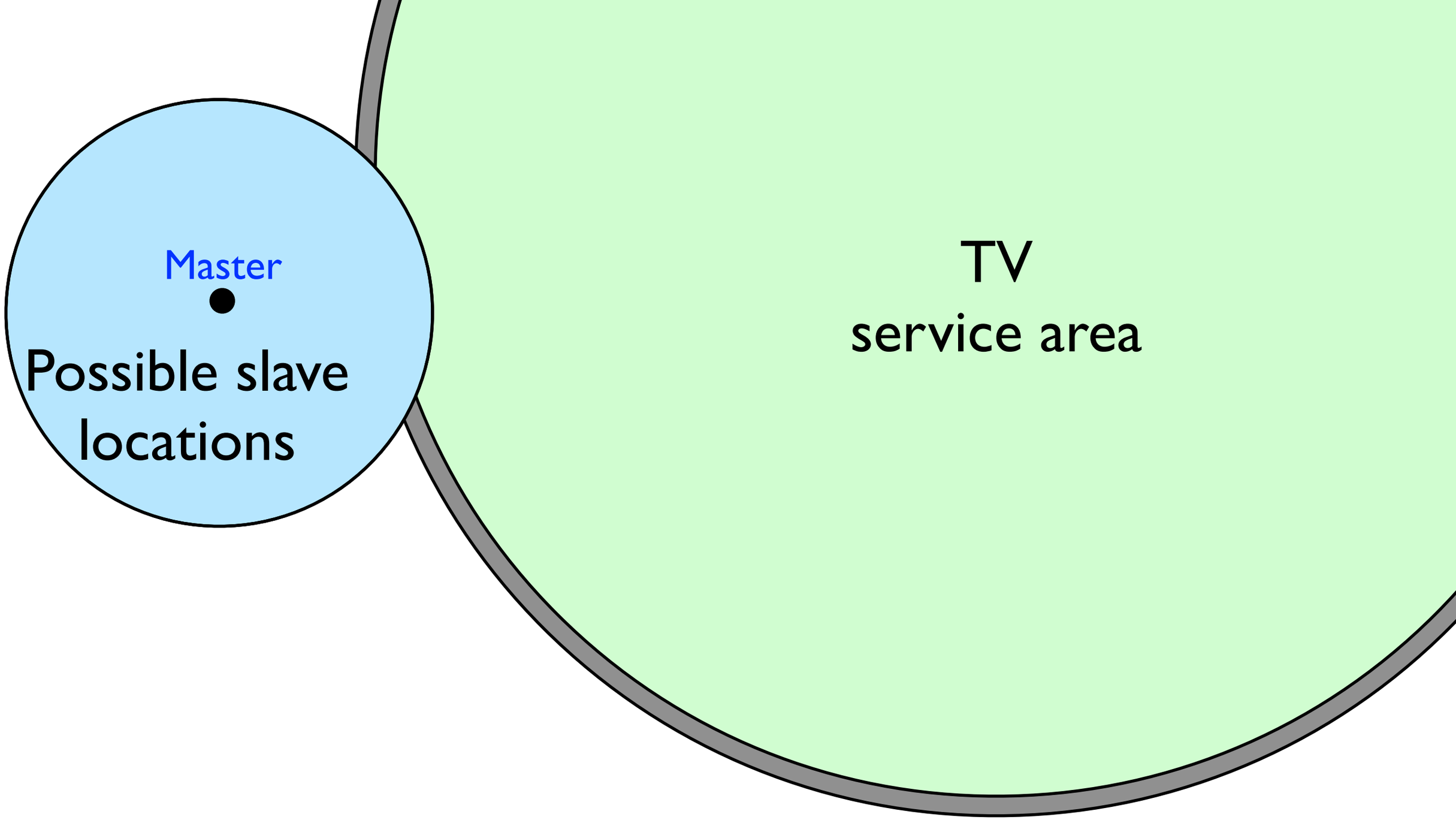


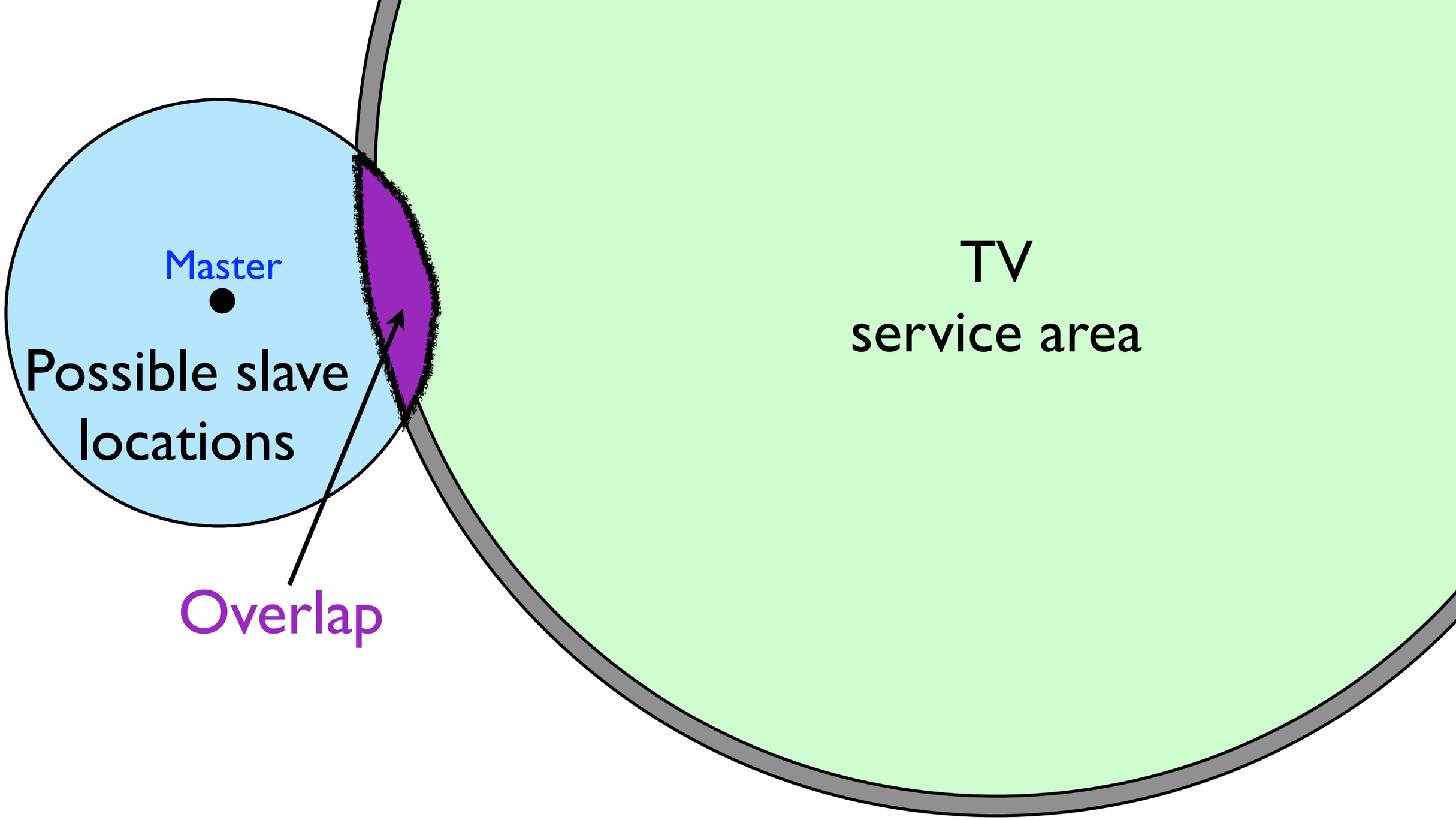
How worried should we be?

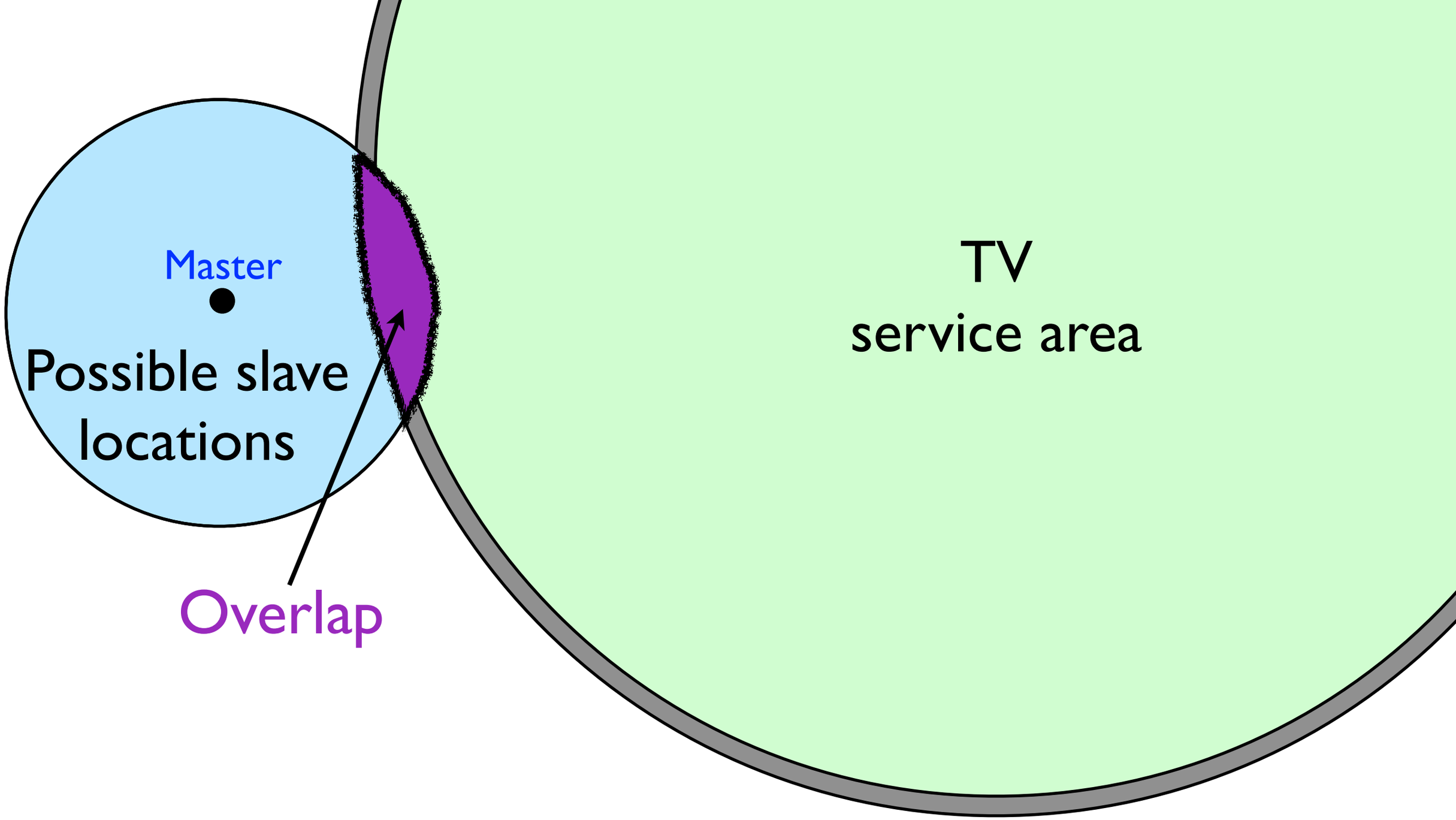

TV
service area

Master

TV
service area

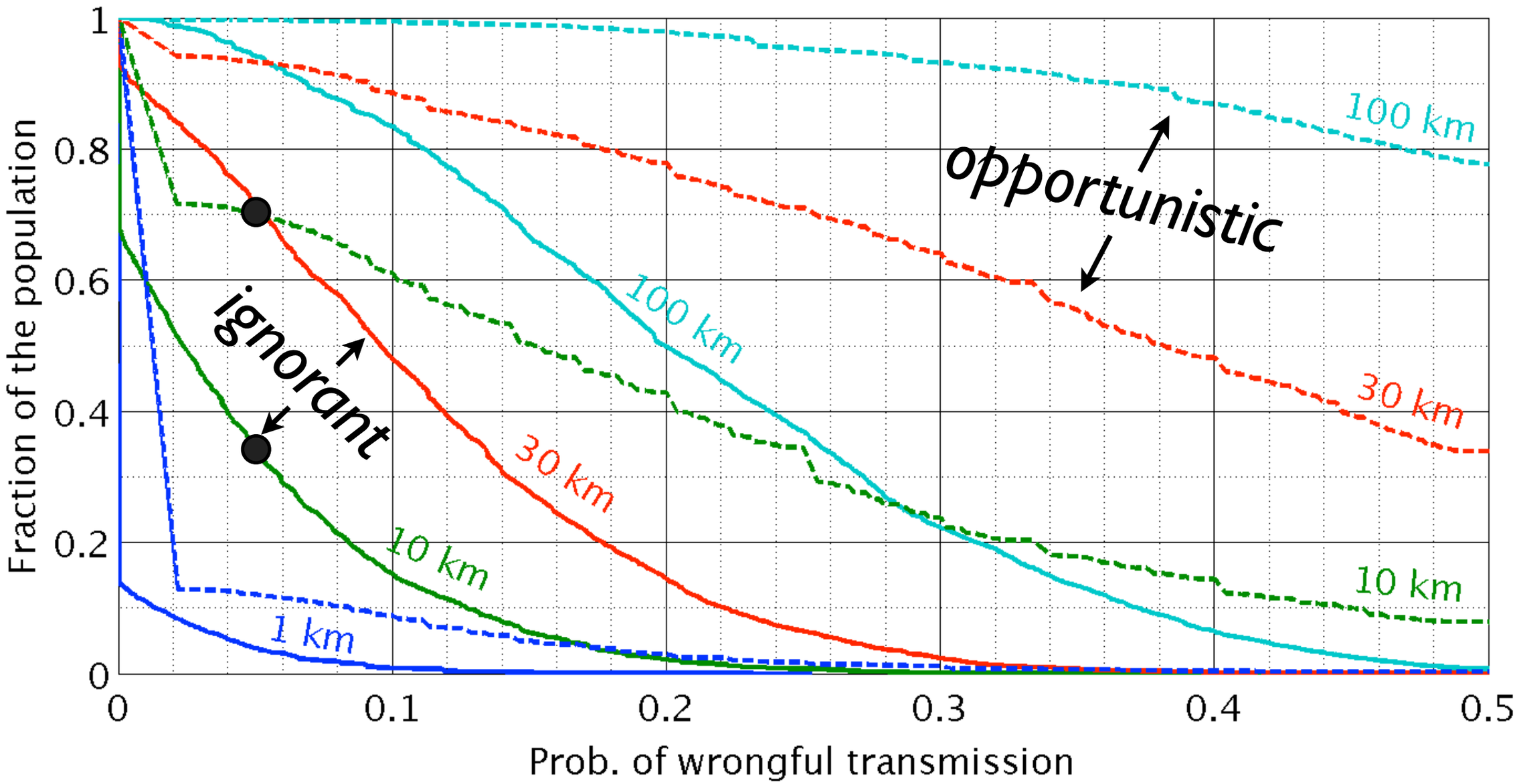

Master
Possible slave locations
TV
service area


Master
Possible slave locations
Overlap
TV
service area

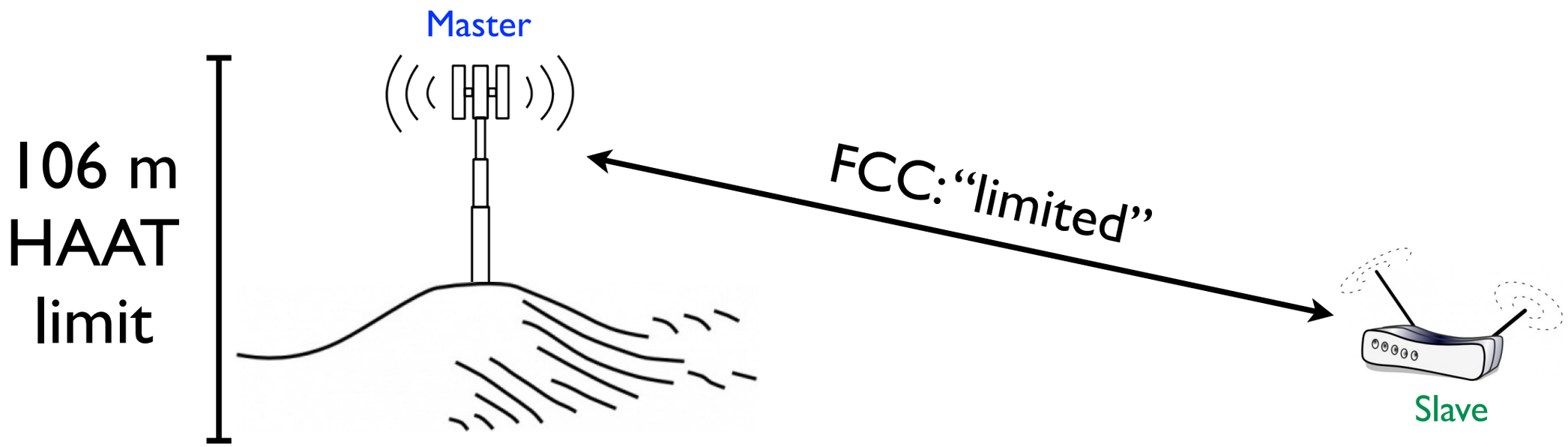


$$\text{risk of wrongful transmission} = \frac{\text{area(overlap)}}{\text{area(possible locations)}}$$

Risk of wrongful transmission



FCC aware of problem



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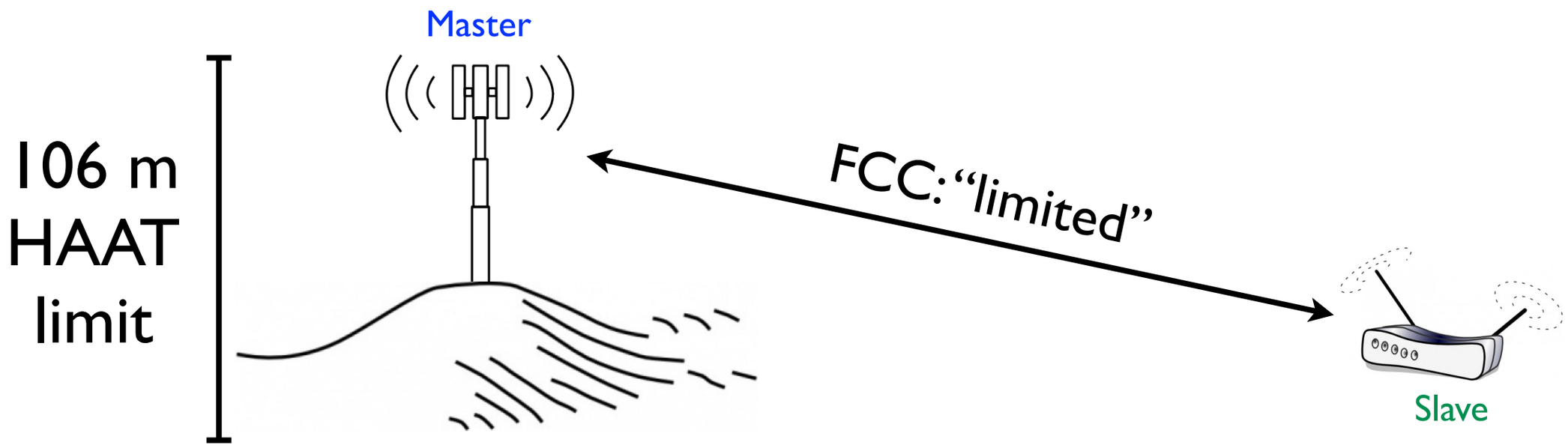
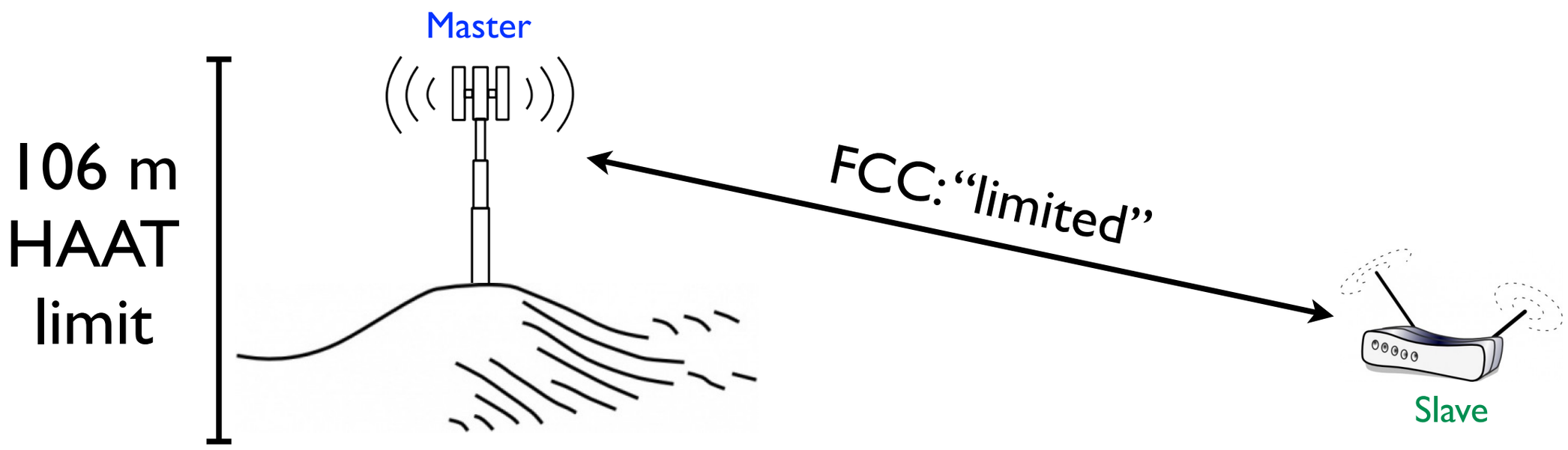


"the communication distance between a [slave] device and the [master] device that provides a channel list is relatively short"

FCC 2012 regulations, ¶19

FCC aware of problem

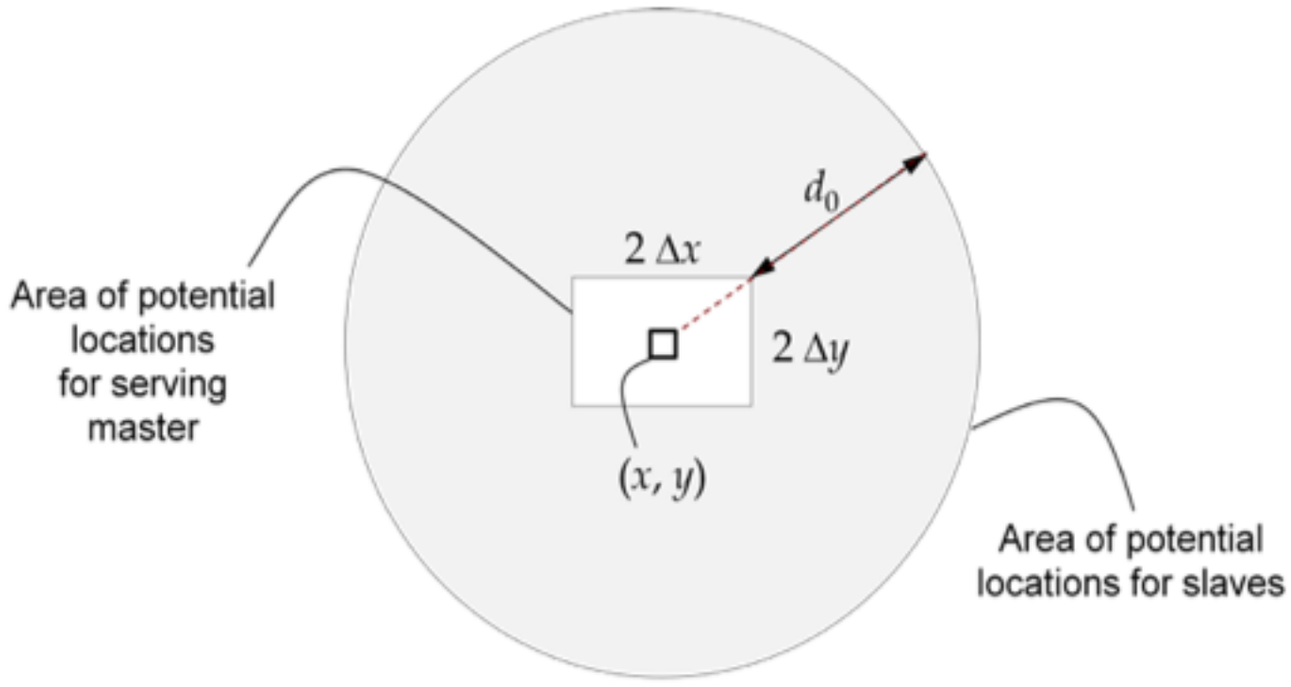


"if the [master] that obtains the channel list for a [slave] operates with greater HAAT than the current rules permit, the [slave] could operate at a greater distance from the coordinates … where the available channel list was calculated"

"the communication distance between a [slave] device and the [master] device that provides a channel list is relatively short"

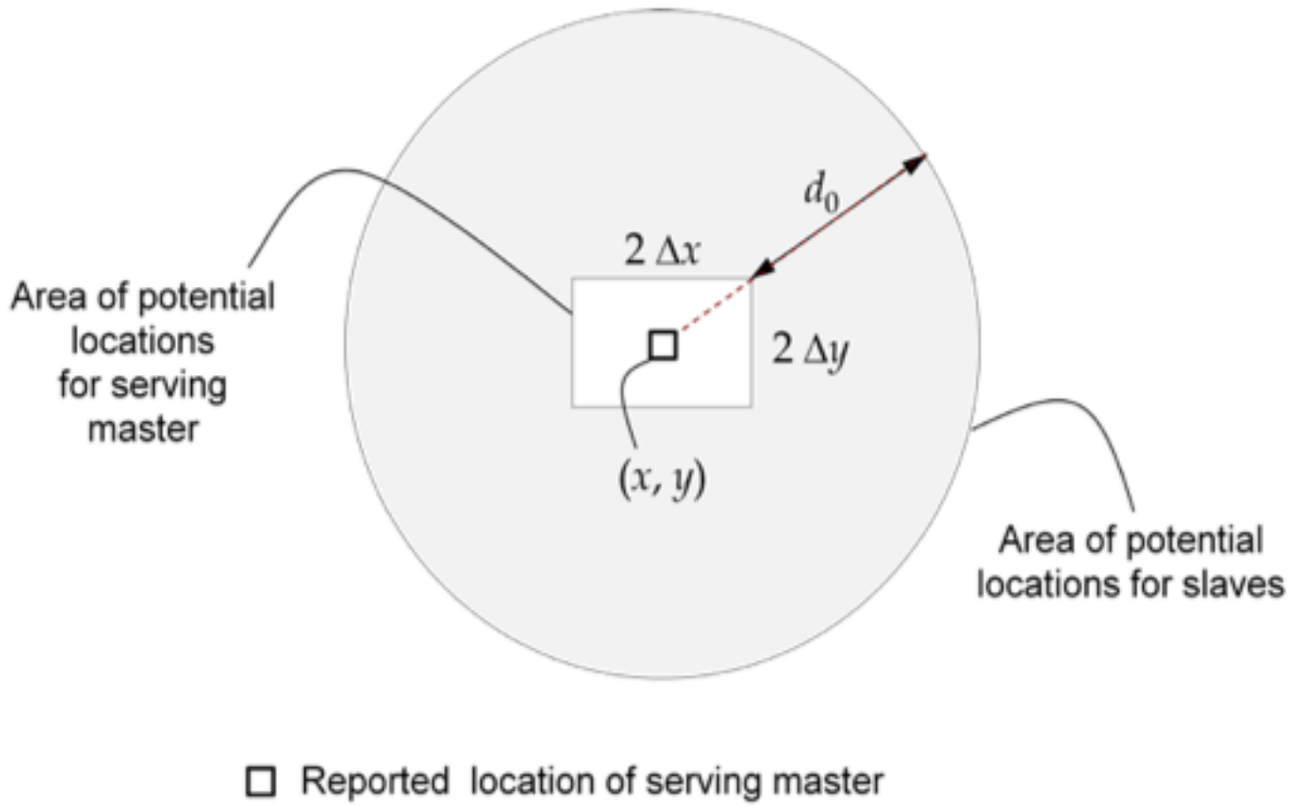
FCC 2012 regulations, ¶19

Ofcom's approach



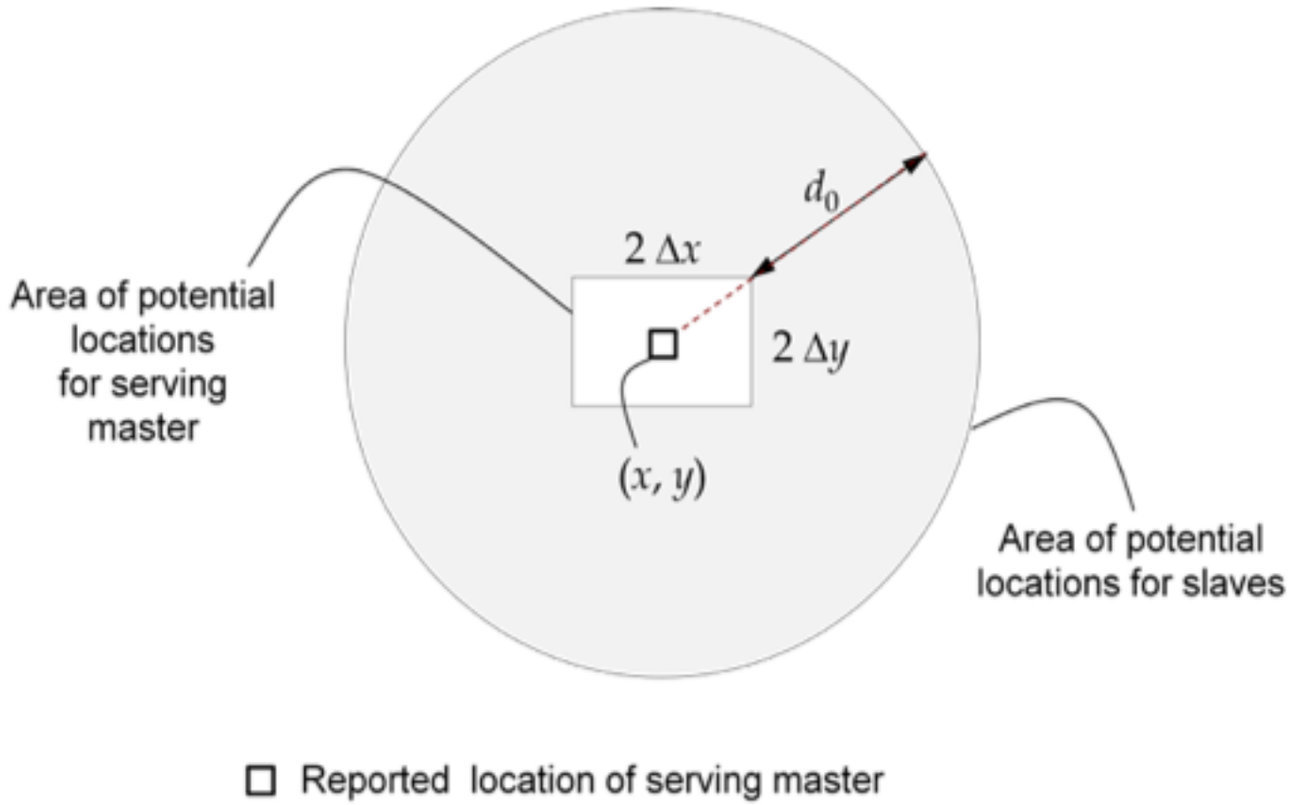
- Use only channels available everywhere

Ofcom's approach



- Use only channels available everywhere
- Benefit: manufacturers choose own point on tradeoff curve

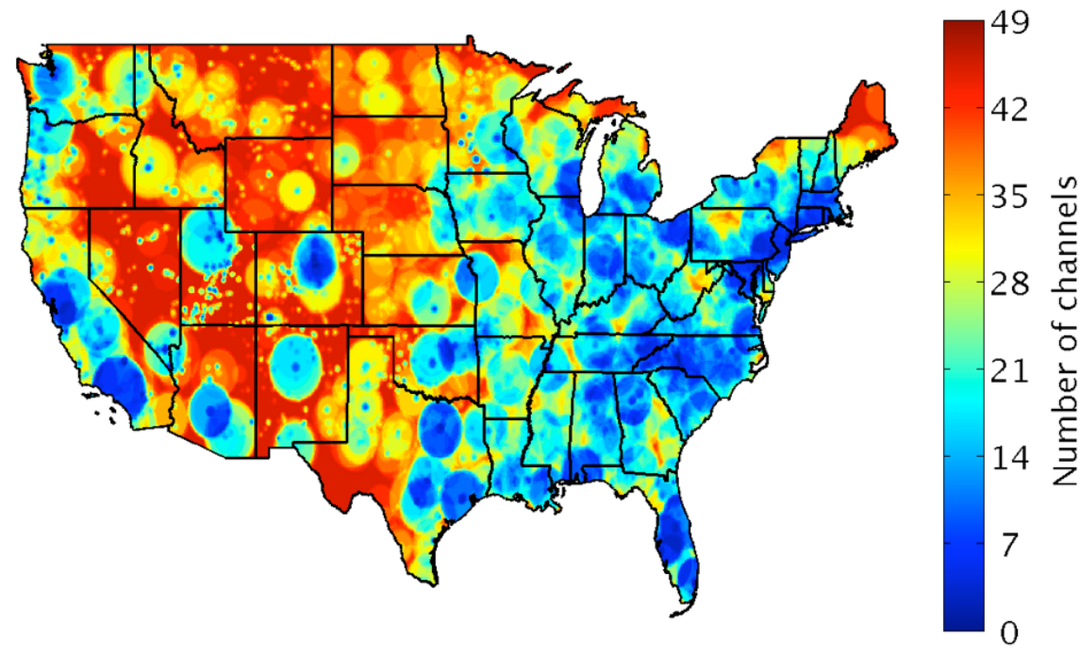
Ofcom's approach



- Use only channels available everywhere
- Benefit: manufacturers choose own point on tradeoff curve
- Safe, but overly-restrictive

Ofcom: conservatively account for distance ("AND" rule)

 # channels actually available



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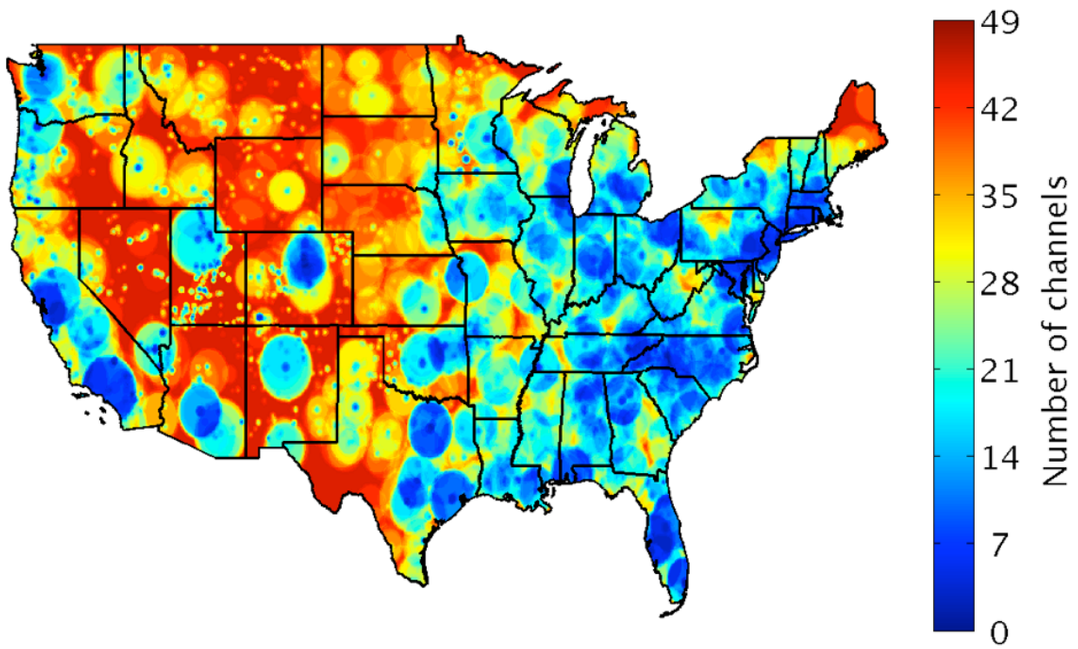
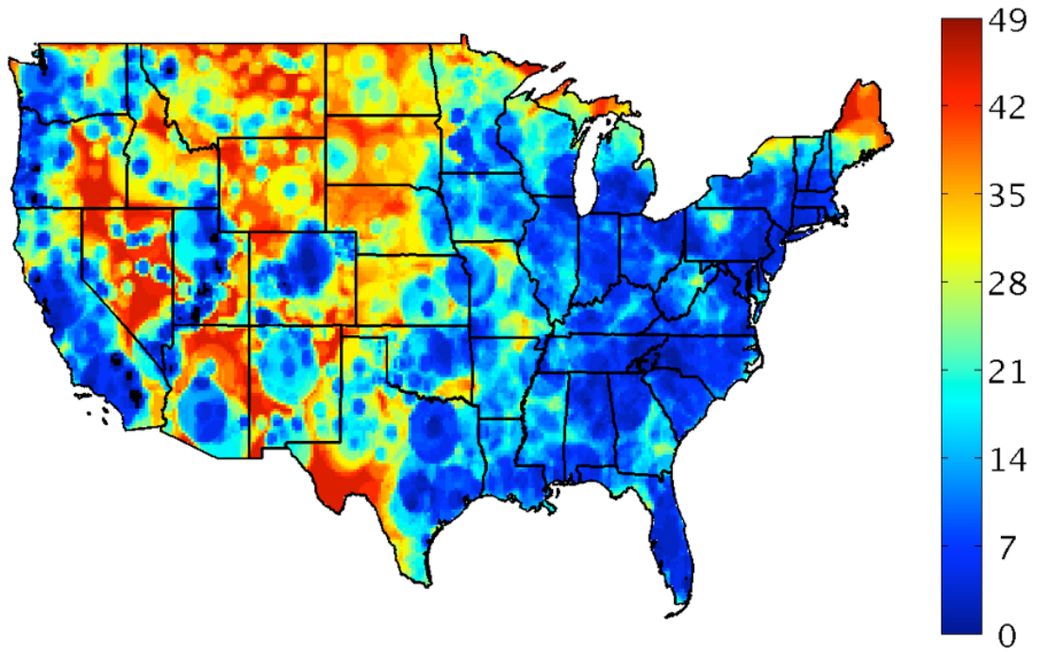


 # channels recoverable



Ofcom: conservatively account for distance ("AND" rule)

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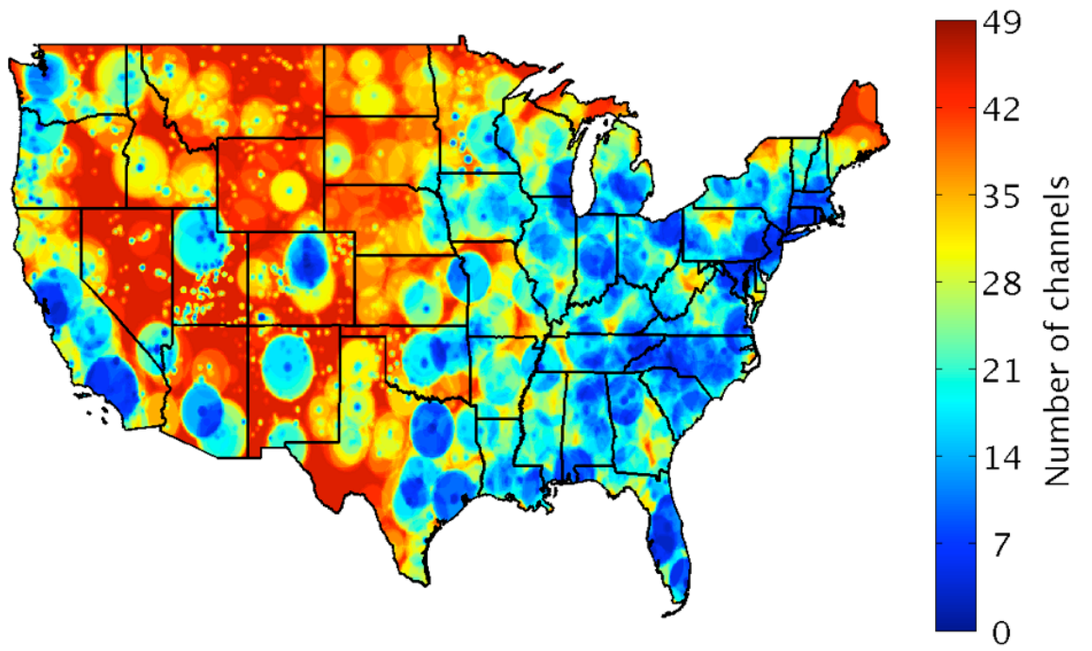

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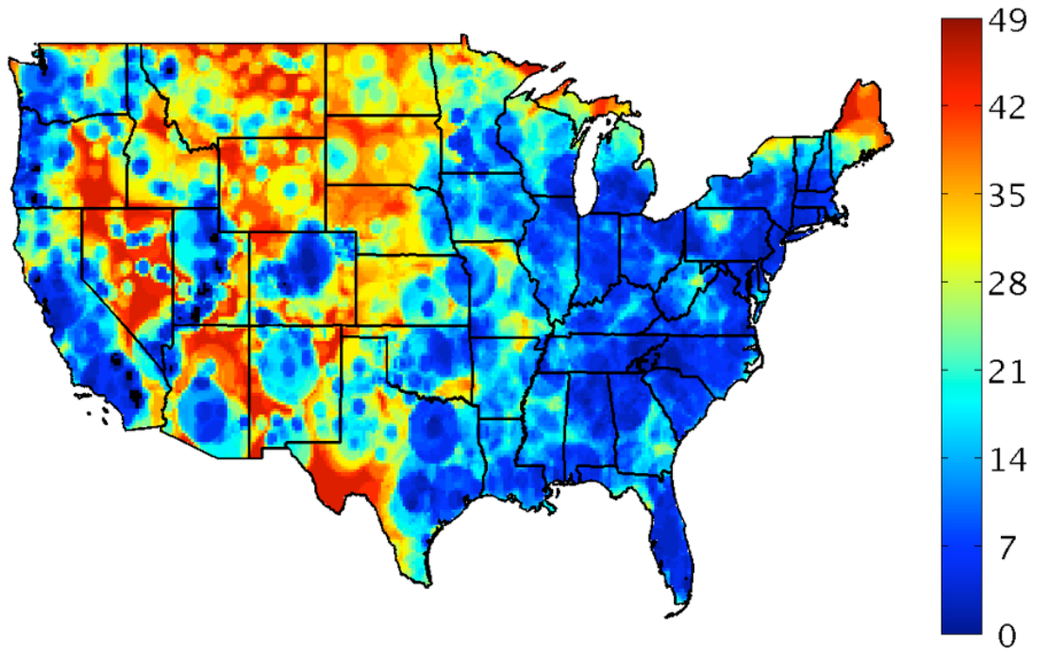
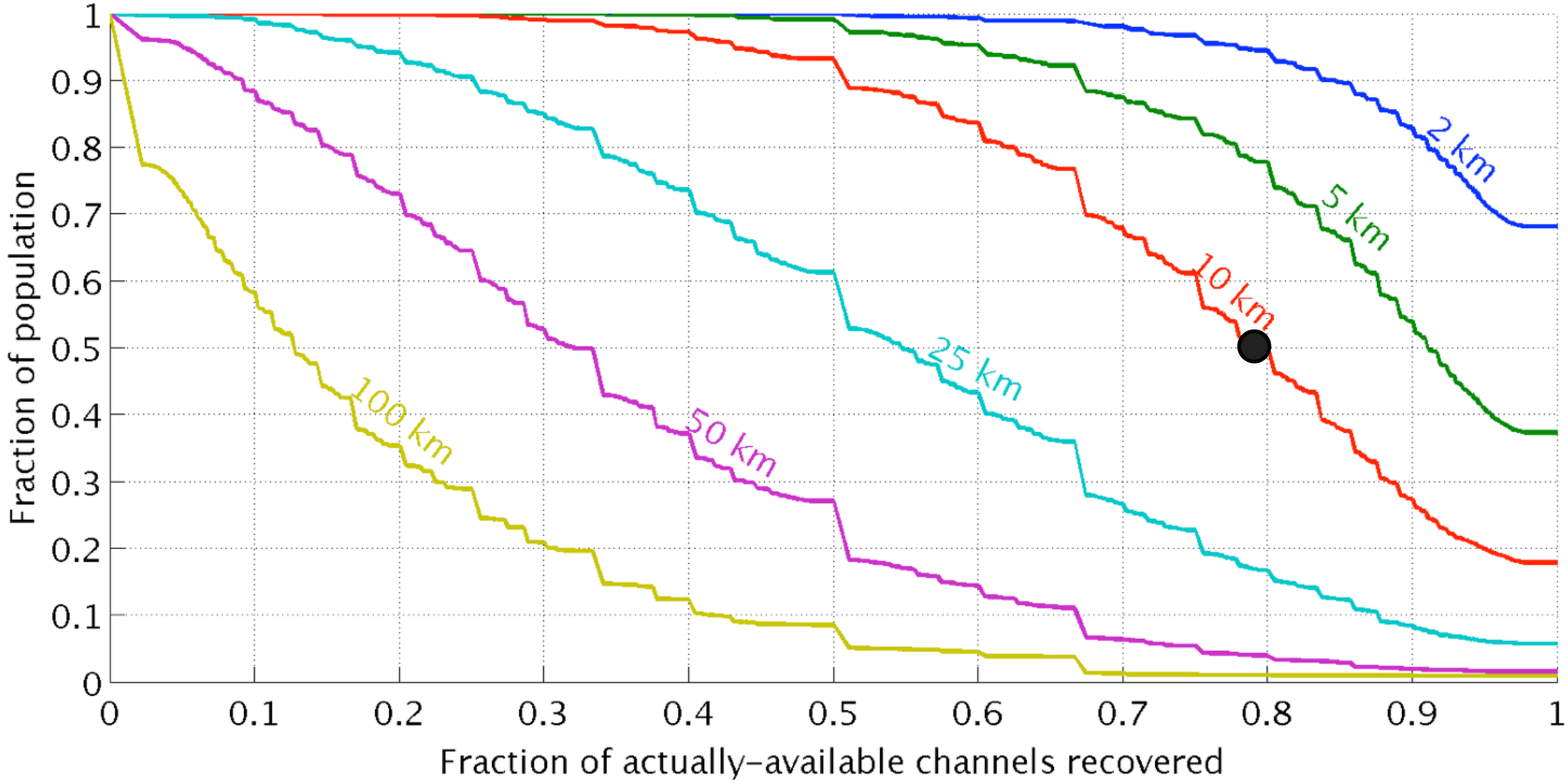
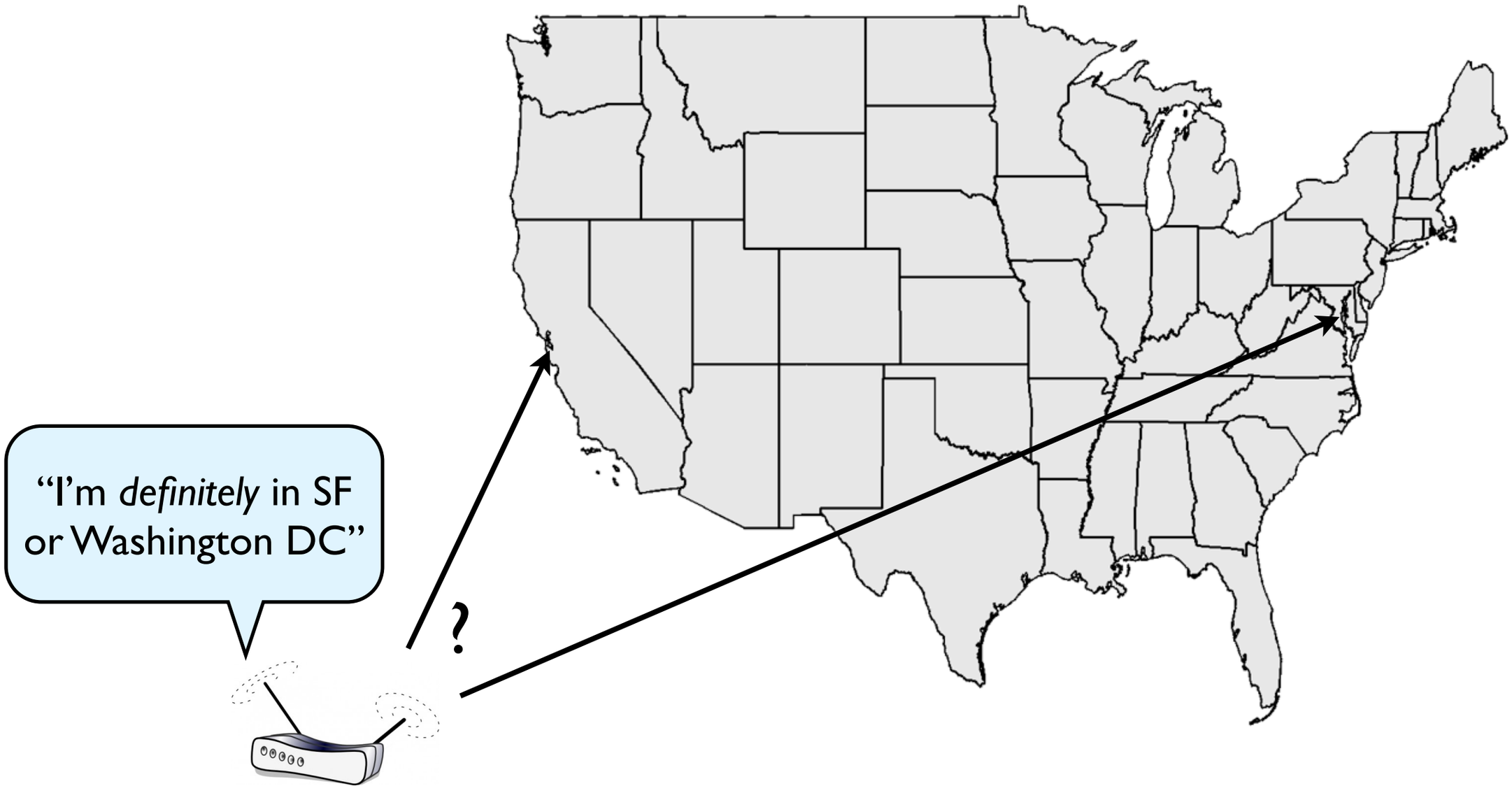


Remember: must be conservative to account for maximum possible distance

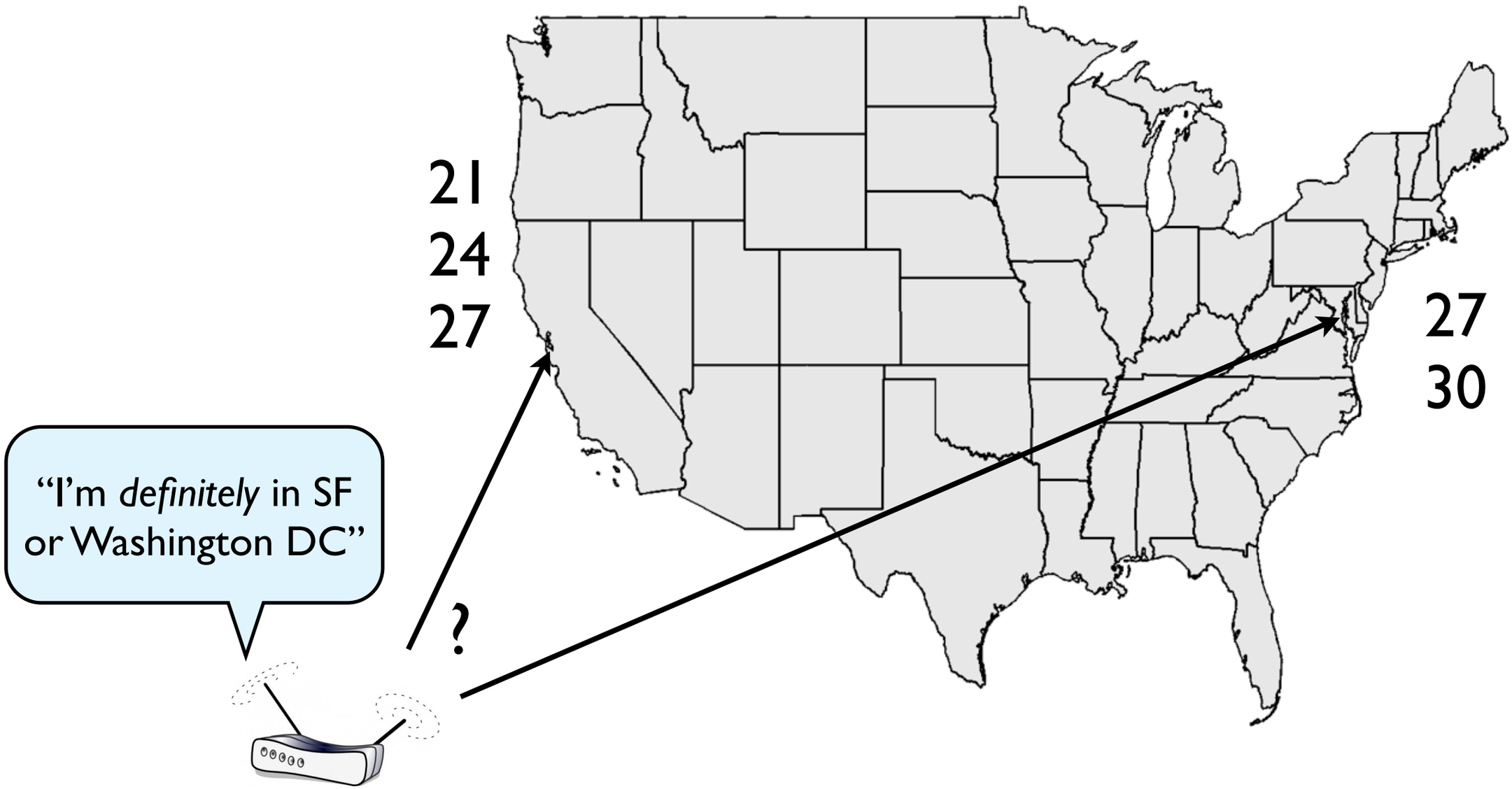
% of channels recoverable via Ofcom approach



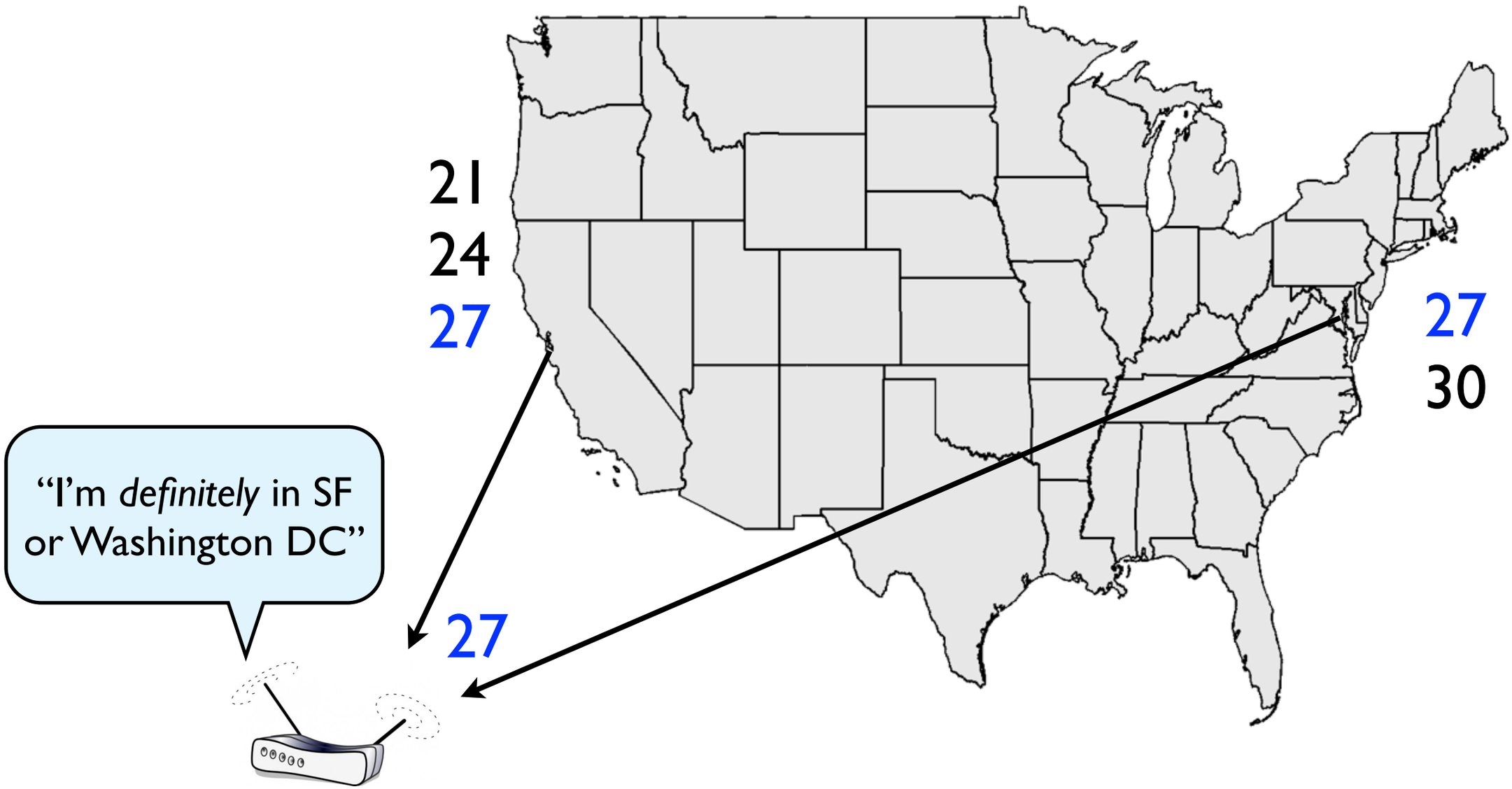
Thought experiment



Thought experiment



Key observation



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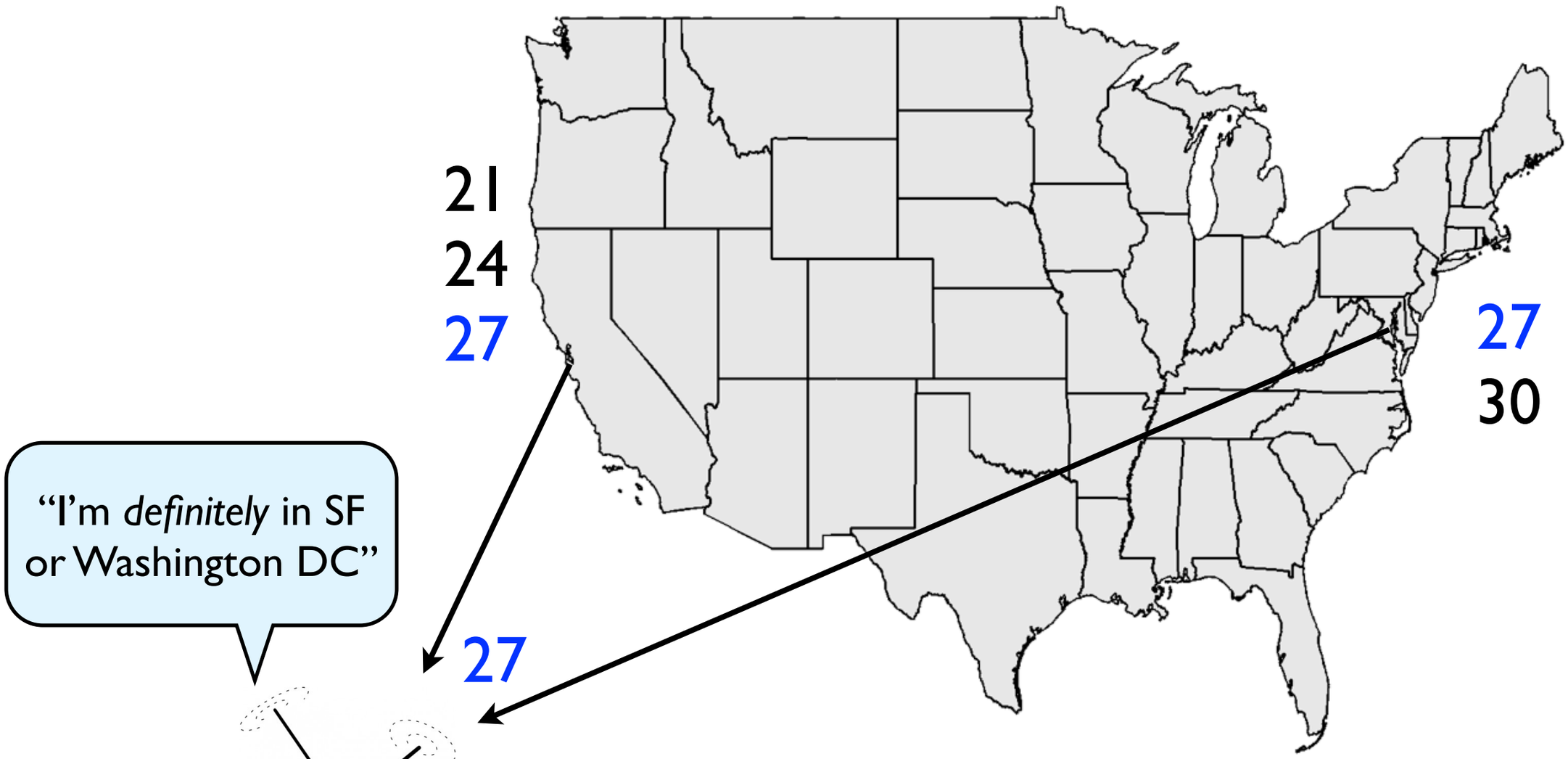


Location isn't important --
safe operating parameters are!

Modeling of possible locations

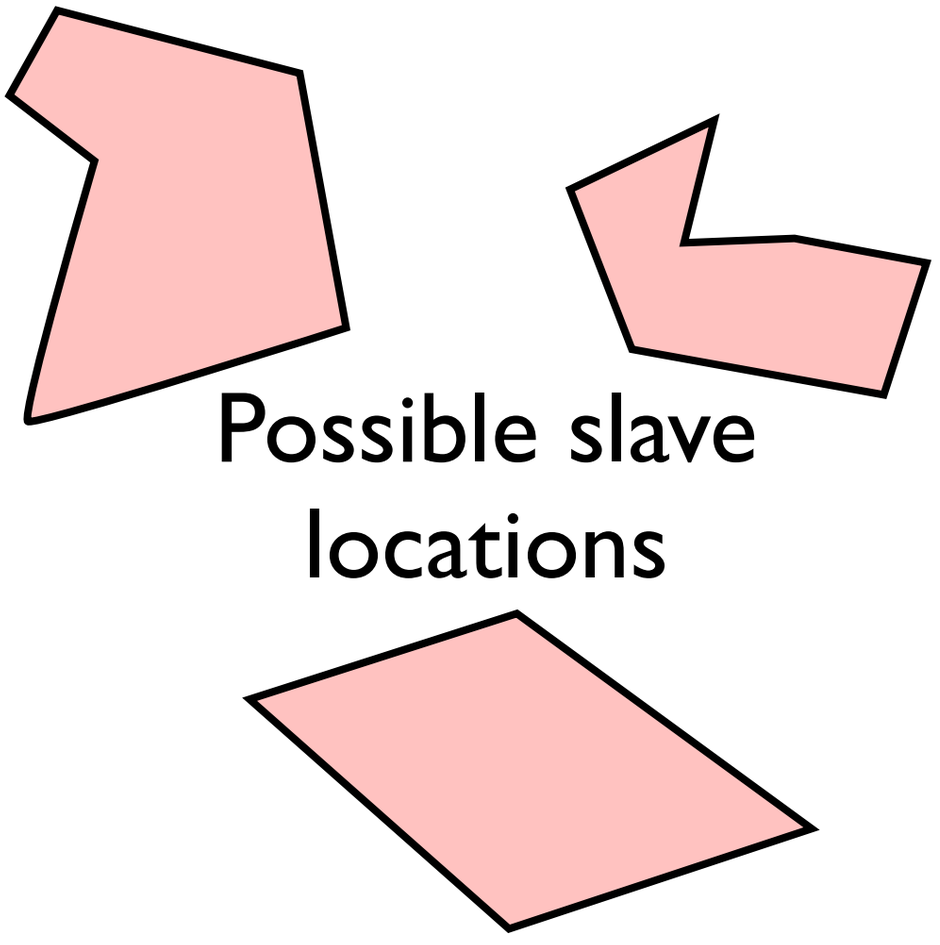
Then

Now

Modeling of possible locations

Then

Now



Modeling of possible locations

Then | **Now**

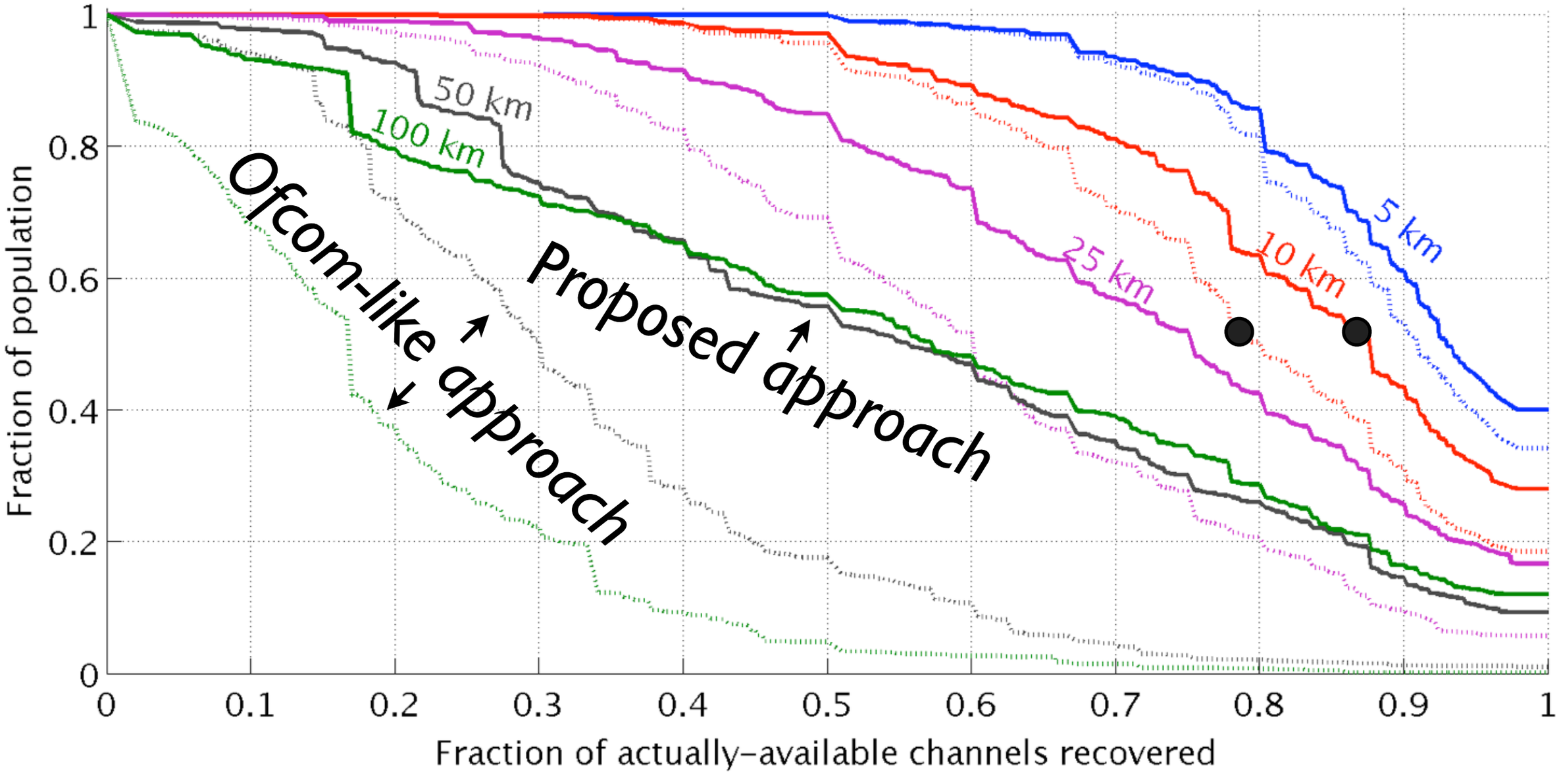
Possi
loc

le slave
tions

Is it worth it?

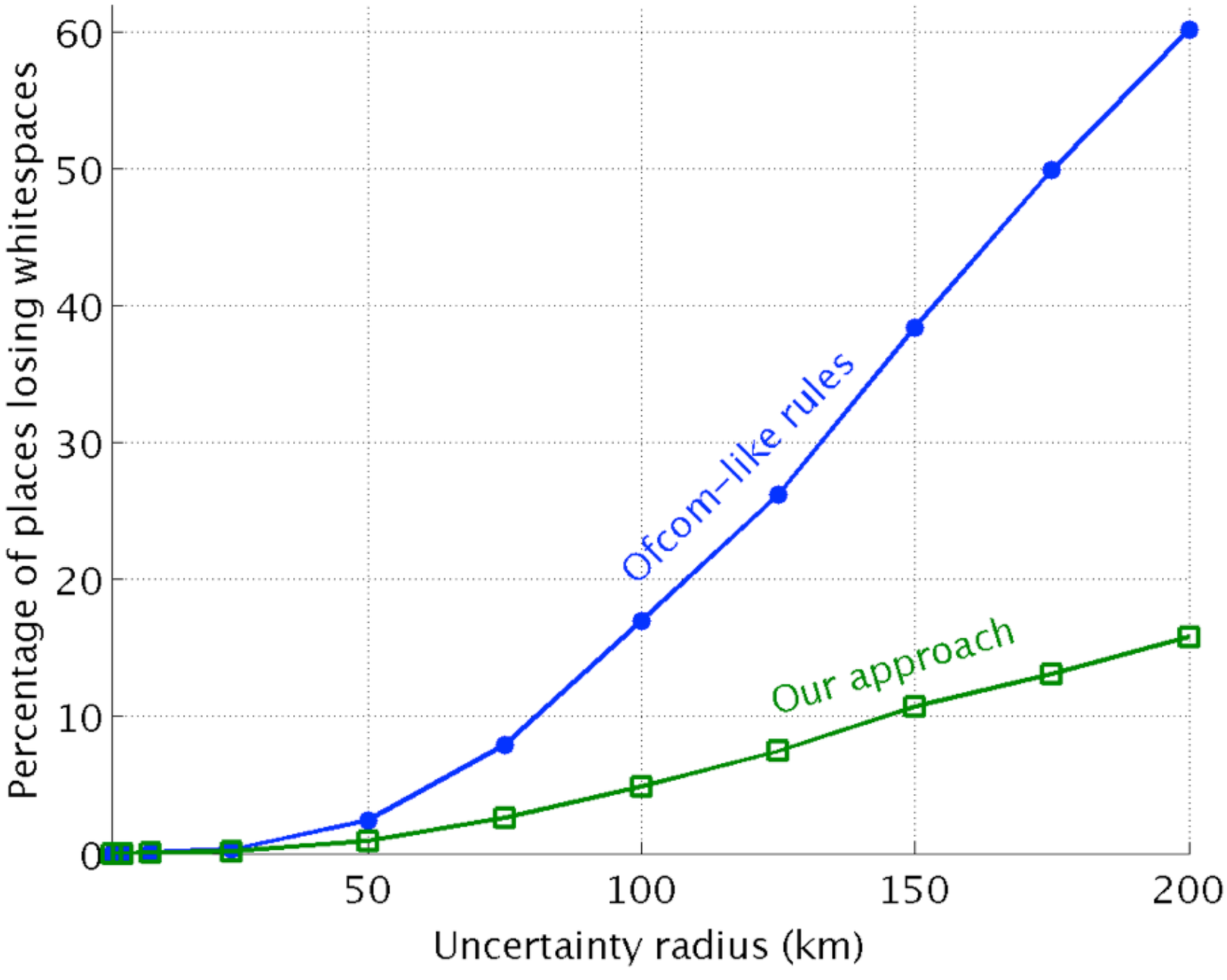
Metrics

Fraction of whitespace channels available to slave



Metrics

Places which lose all whitespaces



Location beyond GPS

- Cellular triangulation

Location beyond GPS

- Cellular triangulation
- IP localization

Location beyond GPS

- Cellular triangulation
- IP localization
- Location fingerprinting via WiFi

Location beyond GPS

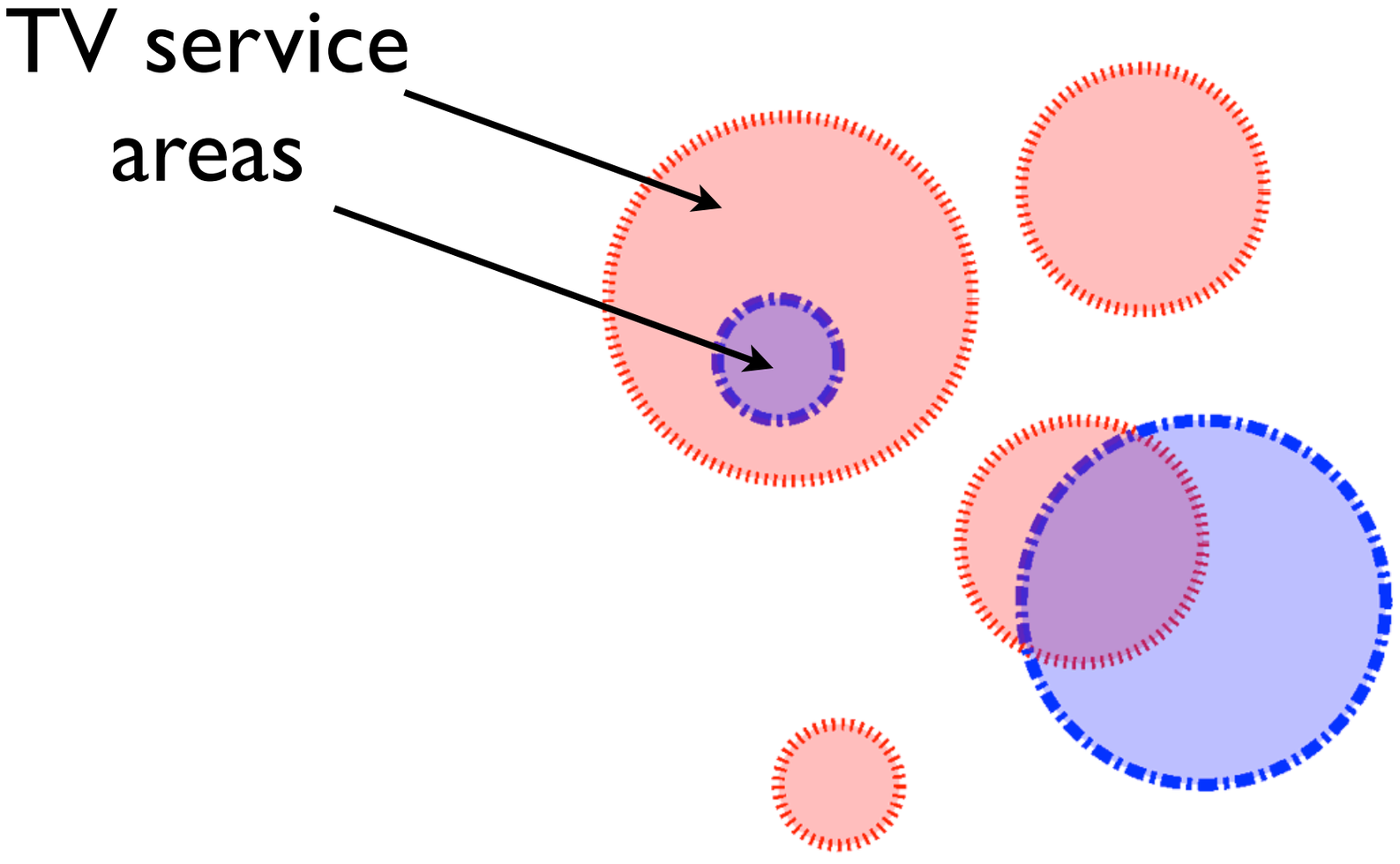
- Cellular triangulation
- IP localization
- Location fingerprinting via WiFi
- Location fingerprinting via TV signals
  (sensing strong signals is easy!) (already have TV band radio)

Location beyond GPS

- Cellular triangulation
- IP localization
- Location fingerprinting via WiFi
- Location fingerprinting via TV signals
  (sensing strong signals is easy!) (already have TV band radio)
- Whatever you want! (just need uncertainty regions)

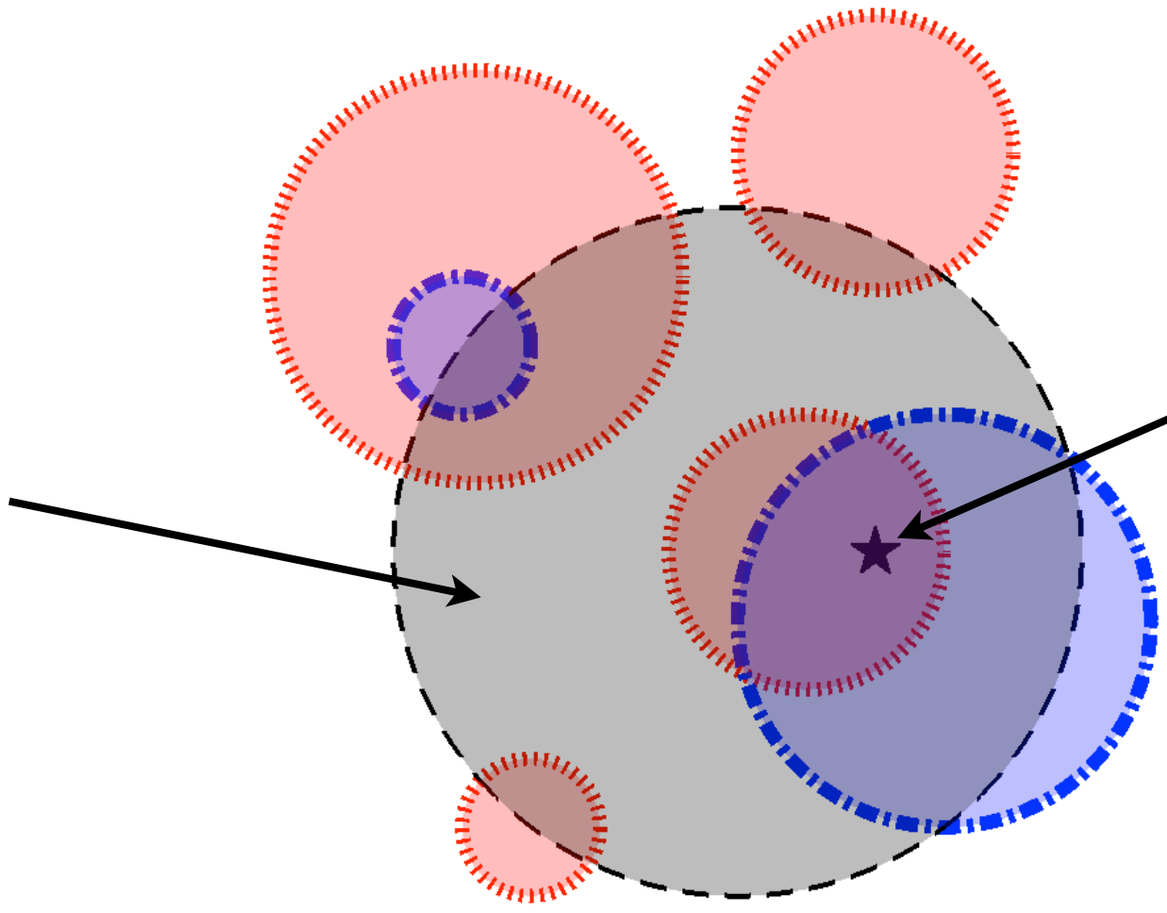
Noncontiguous localization example

Location fingerprinting using TV signals



Noncontiguous localization example

Location fingerprinting using TV signals

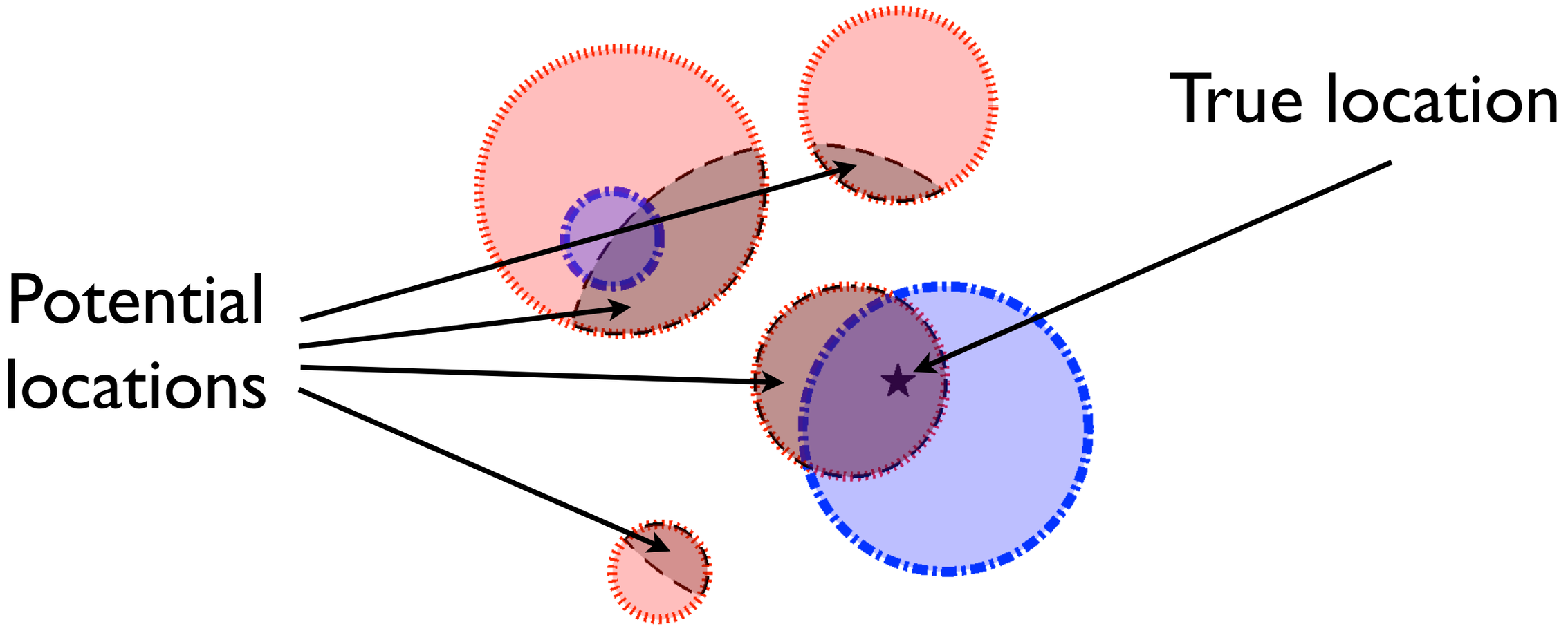


True location

Potential locations

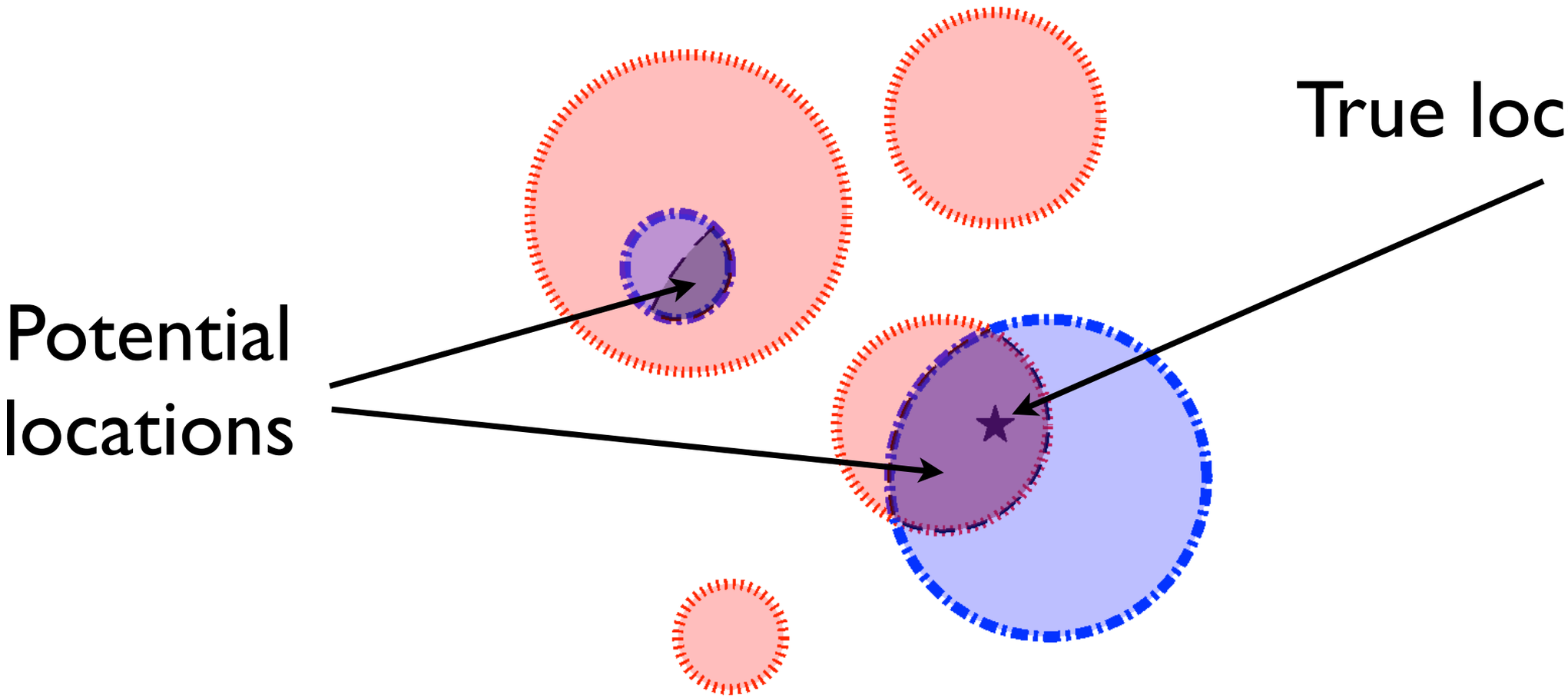
Noncontiguous localization example

Location fingerprinting using TV signals



Noncontiguous localization example

Location fingerprinting using TV signals



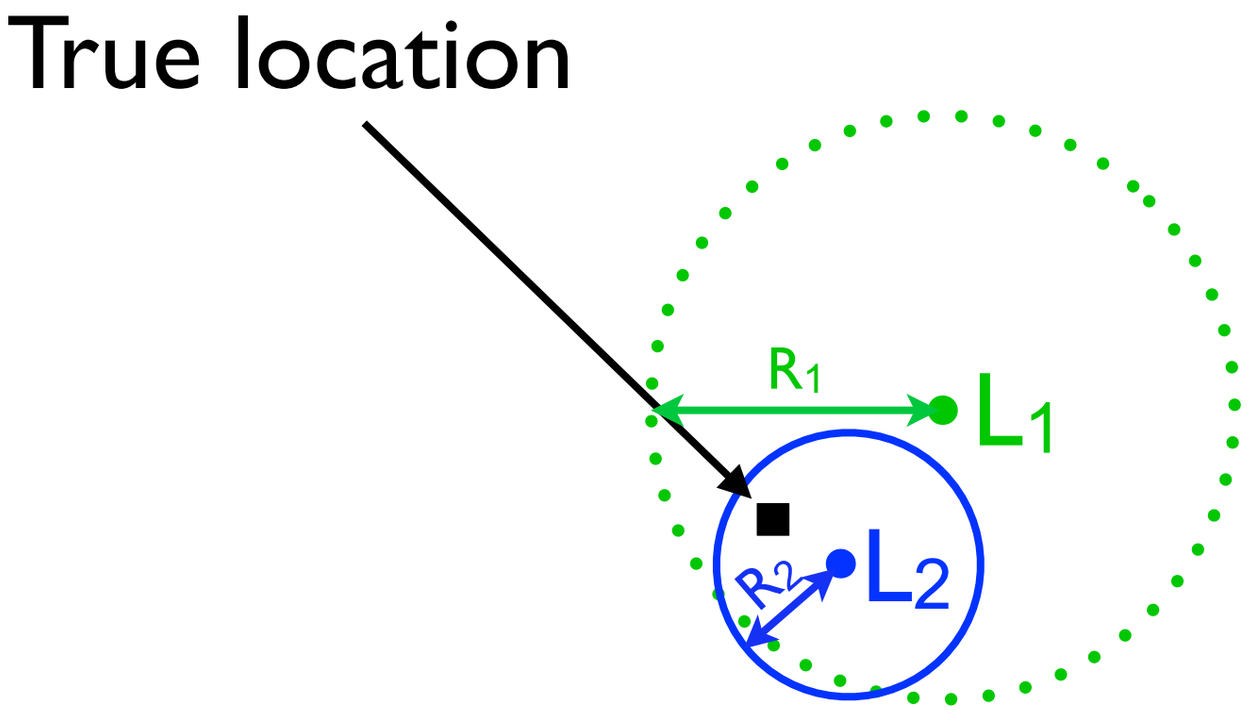
Technical caveats

- Incorrect channel state estimates
- Propagation model inaccuracies

Technical caveats

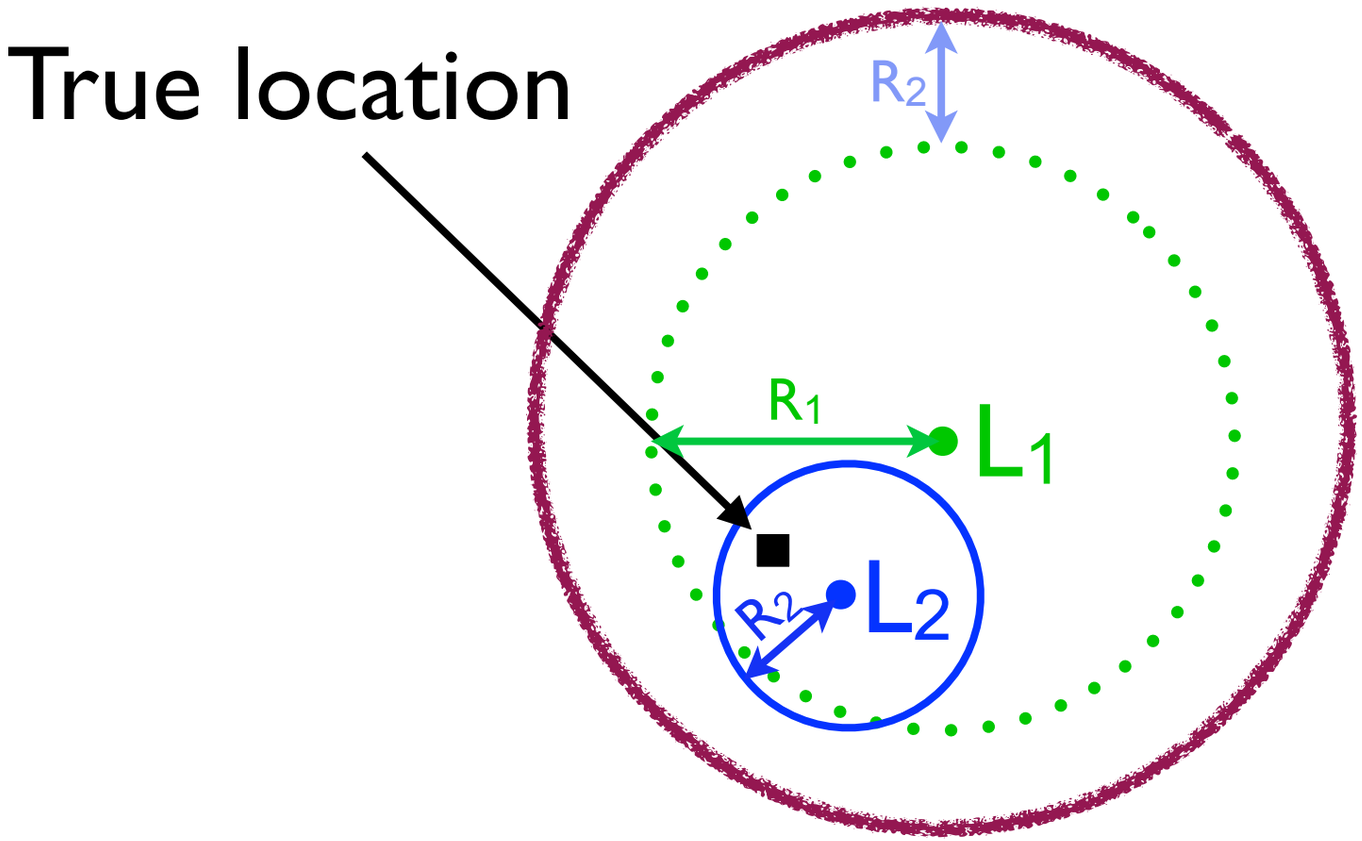
But this is just a proof of concept...

Our vision of the future



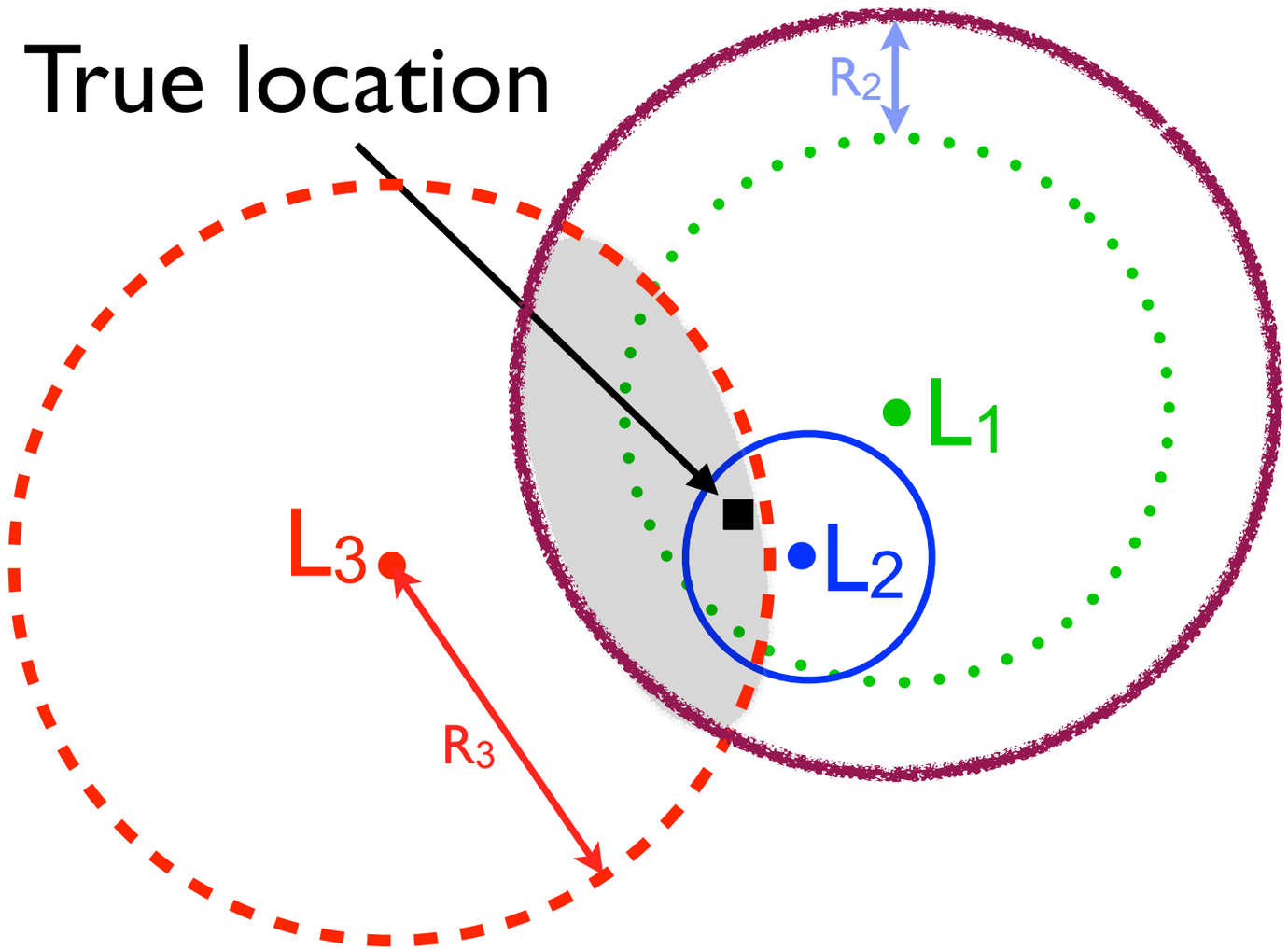
Localization information can be chained and combined

Our vision of the future



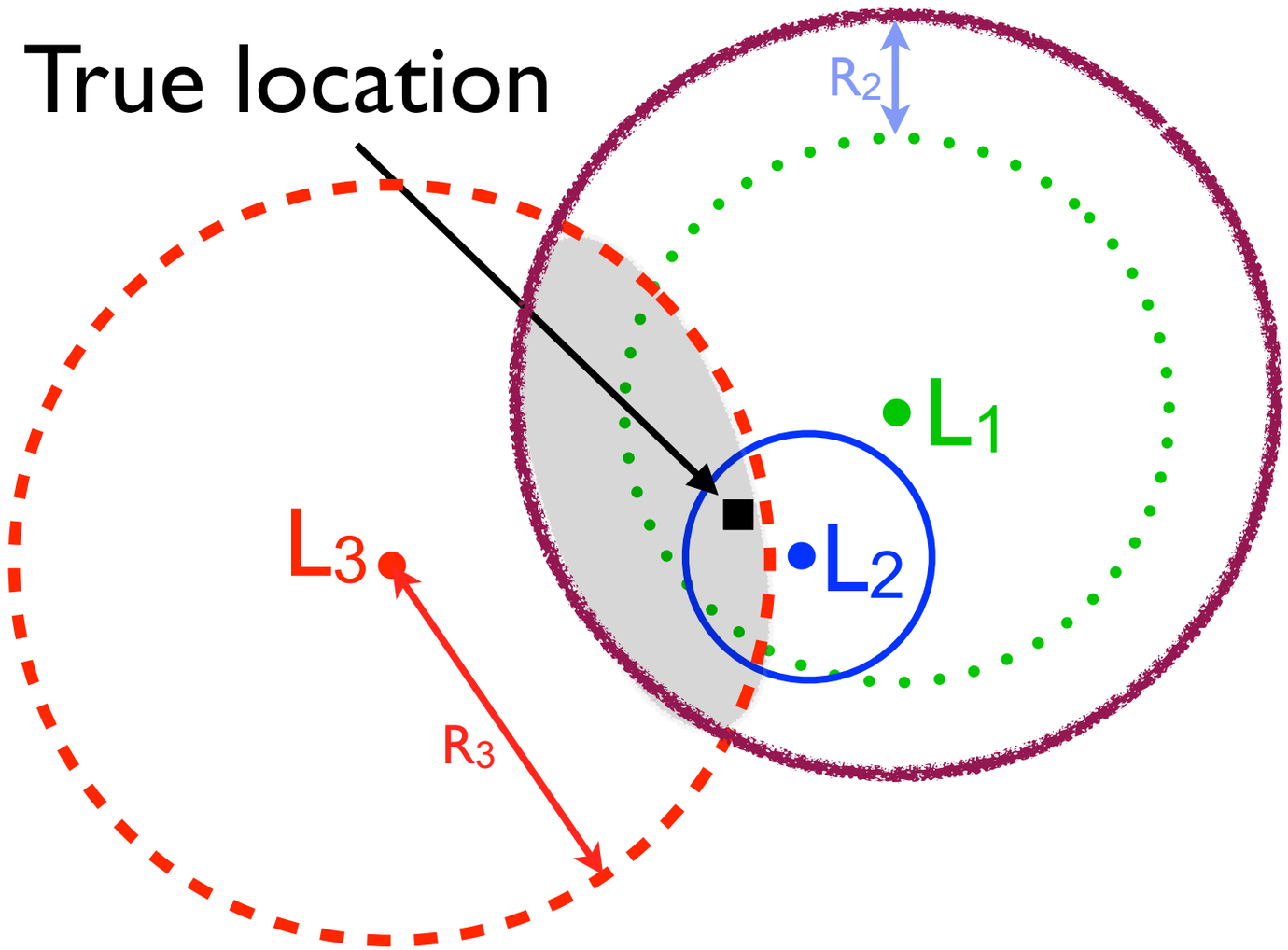
Localization information can be chained and combined

Our vision of the future



Localization information can be chained and combined

Our vision of the future

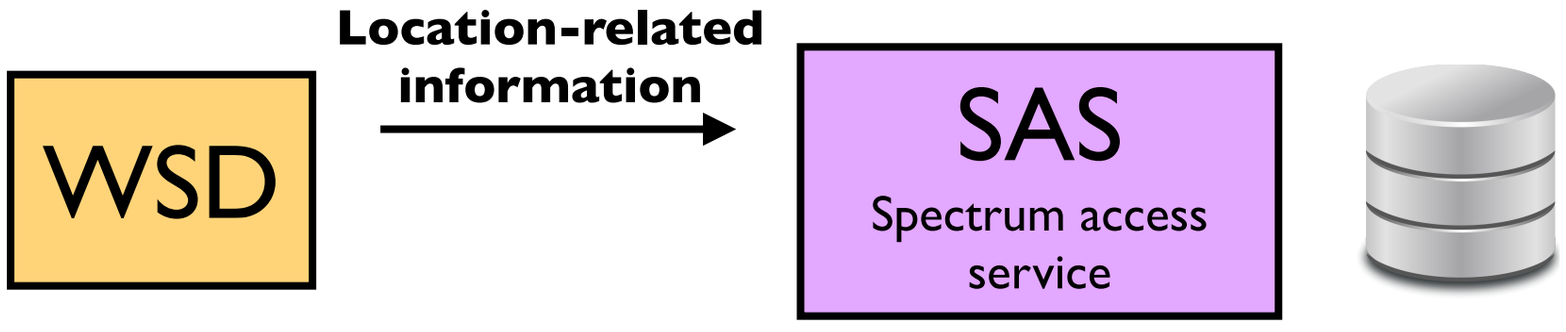


Localization info. isn't just GPS coordinates!

Localization information can be chained and combined

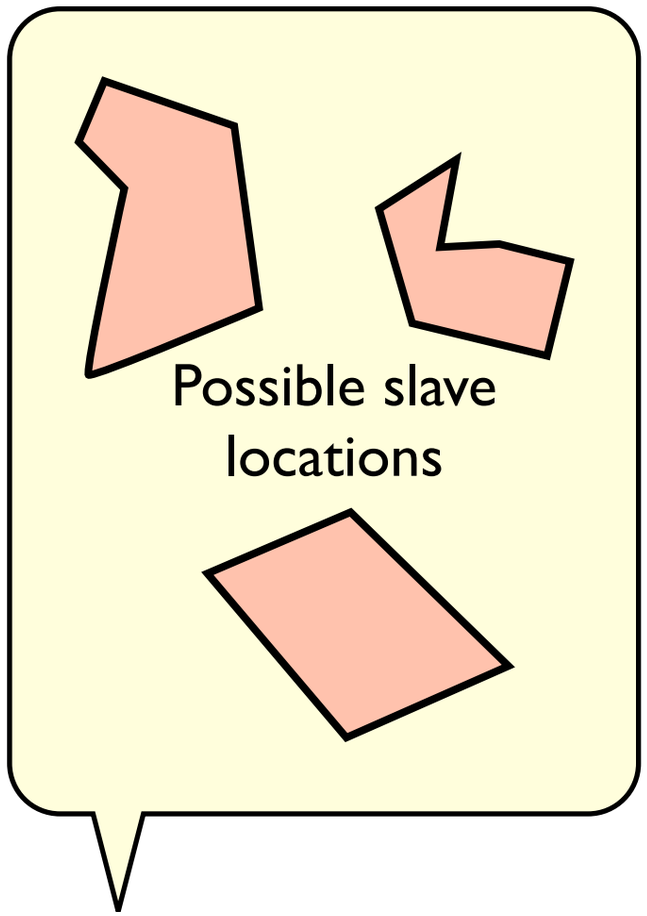
"Location"

- Within 10 km of (lat, long)
- *Could* decode TV channel 10
- See WiFi SSID "Starbucks"



“Location”

- Within 10 km of (lat, long)
- *Could* decode TV channel 10
- See WiFi SSID “Starbucks”



WSD

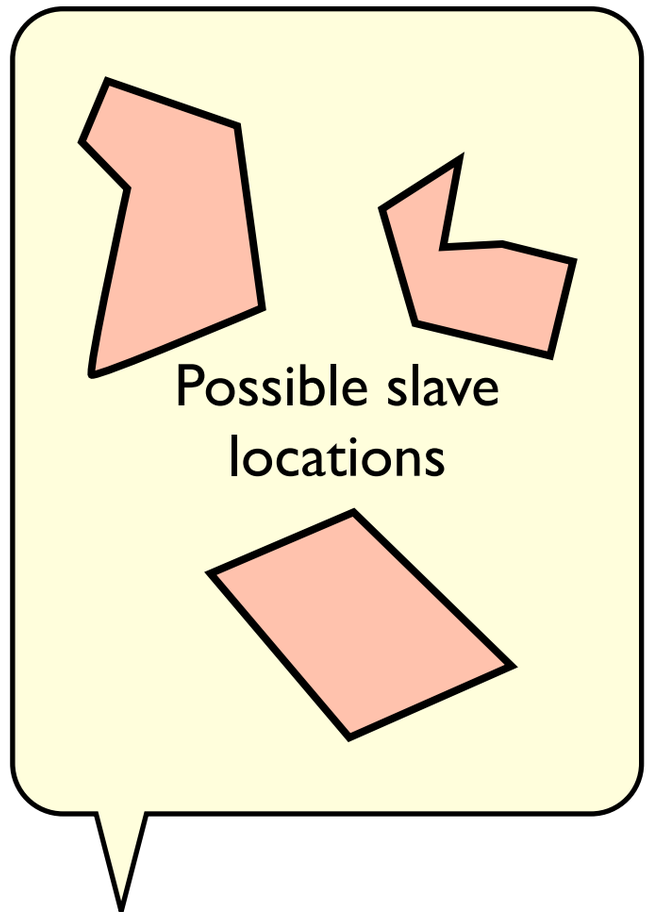
Location-related information

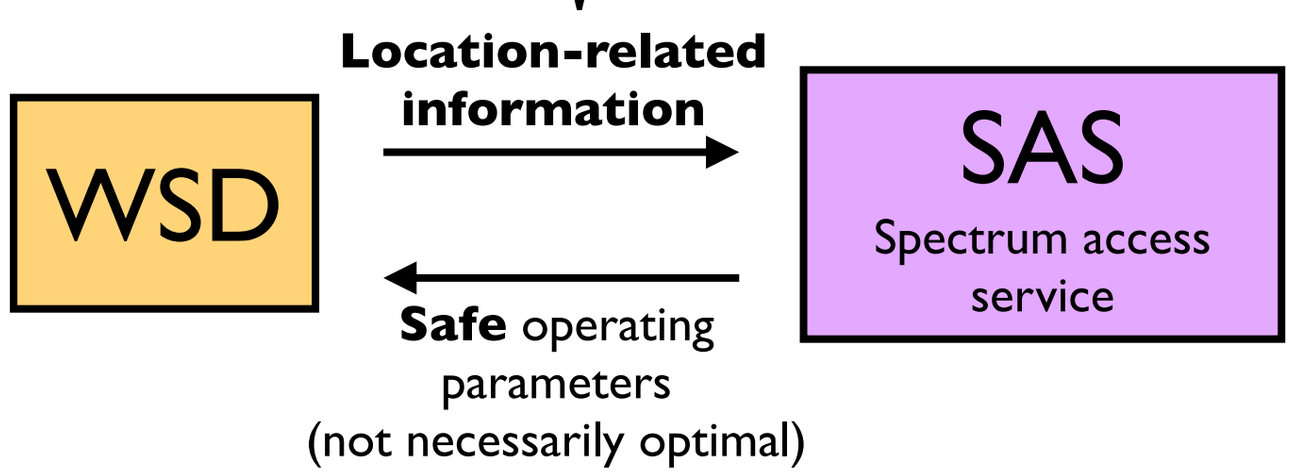
SAS

Spectrum access service

“Location”

- Within 10 km of (lat, long)
- *Could* decode TV channel 10
- See WiFi SSID “Starbucks”





Summary

- FCC approach: too lax
- Ofcom approach: right idea, too restrictive
- Flexible notion of "localization"
  - Protects incumbents
  - Increases recoverable whitespace

Important takeaways

- It's all about safe operating parameters, *not* location

Important takeaways

- It's all about safe operating parameters, *not* location
- Can add support for new localization tech. over time
  - Most computations done at the database
  - Regulations need only acknowledge the nature of location uncertainty