gsmws

An Opportunity for Rural Cellular Service

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Sean Roberts, Anant Sahai, Eric Brewer

Thanks to...

Tapan Parikh

Peter Bloom, Ciaby, and Rhizomatica

Steve Song and Village Telco

David Haag, Scotty and Heidi Wisely, and the OA crew

The OpenBTS community

USAID, NSF

... Many others!


RURAL
CELLULAR NETWORKS

WHITE MEANS NO COVERAGE

WHITE MEANS NO SPECTRUM IN USE

ONE BILLION

PEOPLE WITHOUT

COVERAGE

Source: GSMA

COMMUNITY CELLULAR NETWORKS

Micro-scale GSM networks that rural communities build and run themselves.

280 Subscribers

$1,000/mo revenue

300,000 SMS/Voice Min.

Critical Infrastructure

"Local, Sustainable, Small-Scale Cellular Networks", Heimerl et al. ICTD 2013

RHIZOMATICA

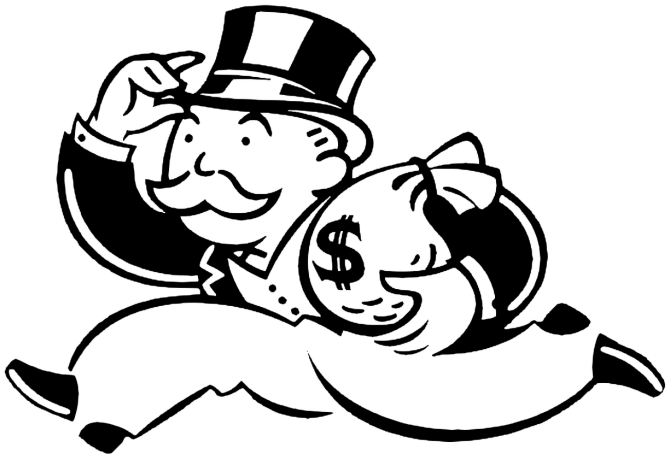
Oaxaca, Mexico

PROBLEM

Limited room for CCNs in today's regulatory frameworks.

So,

How should CCNs be regulated?



GSM WHITESPACE

Let CCN operators
use spectrum on a secondary basis
that licensed carriers aren't using.

GSM WHITESPACE

Safety	Don't interfere with existing licensed operators.
Backwards Compatibility	Don't require new or modified client devices.
Spectrum Flexibility	Avoid another "garage door opener" fiasco.
Independence	Don't make CCNs and Big Telcos talk to each other.
Trustworthiness	Let regulators control what spectrum is used and where.

Why GSM Whitespace?

And why those goals in particular?

	Regulators	CCN Operators	Carriers
Safety	X	X	X
Backwards Compatibility		X	
Spectrum Flexibility	X		X
Independence		X	X
Trustworthiness	X		

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Regulators

1) Control over emerging CCN trend

➔ Put rules in place that encourage good practices

Regulators

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➔ Put rules in place that encourage good practices

➔ Incorporate a database for monitoring and control

- Gives long-term regulatory flexibility

Regulators

2) Improved rural communication access

➔ Current mechanism: USO

- Expensive
- Ineffectual!

	Regulators	CCN Operators	Carriers
Safety	X	X	X
Backwards Compatibility		X	
Spectrum Flexibility	X		X
Independence		X	X
Trustworthiness	X		

CCN Operators

1) Stable regulatory environment

➔ Small-scale businesses: getting shut down rare, but disastrous

CCN Operators

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➔ Small-scale businesses: getting shut down rare, but disastrous

➔ Stability encourages investment

CCN Operators

2) Use existing client devices

➔ GSM phones are EVERYWHERE

CCN Operators

2) Use existing client devices

➔ GSM phones are EVERYWHERE

➔ In Papua, 1500 unique phones detected in village

- No power
- No cellular coverage (yet!)
- Primarily used for listening to music (not smartphones)

CCN Operators

3) Little to no overhead

➔ Yo ho ho! Pirate's life isn't bad

- Enforcement is unlikely
- As easy as running an unlicensed network

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➔ Yo ho ho! Pirate's life isn't bad
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➔ Little power or ability to negotiate with carriers
- Village schools aren't going to send lawyers to Jakarta
- Minimal formal economy

	Regulators	CCN Operators	Carriers
Safety	X	X	X
Backwards Compatibility		X	
Spectrum Flexibility	X		X
Independence		X	X
Trustworthiness	X		

Existing License Holders

1) Garage door openers, v2.0

➔ Problem:
Make sure CCNs don’t become reliant on a particular channel.

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➔ Problem:
Make sure CCNs don't become reliant on a particular channel.

➔ Solution:
Require CCNs to change channels frequently and proactively.

Existing License Holders

2) Sharing overhead

➔ Problem:
Don’t want to interact with 100’s of CCNs.

Existing License Holders

2) Sharing overhead

➔ Problem:
Don’t want to interact with 100’s of CCNs.

➔ Solution:
Use sensing as primary sharing mechanism.
Make database usage optional.

Existing License Holders: Even More Incentives

- → Share spectrum to fulfill rural service obligations
  - DB gives visibility into what spectrum CCNs use to provide rural service
  - License holders could receive credit for CCN activity in their spectrum

- → Opens up new rural markets
  - CCNs prove rural markets, without investment from incumbents
  - CCN customers call incumbents' customers: free money

Nothing bad happens when a CCN uses unused spectrum...

➔ CCNs don't have to talk to anyone

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- ➔ CCNs don't have to talk to anyone
- ➔ CCNs aren't using spectrum anyone else is using
- ➔ Licensed users can still use spectrum as they please
- ➔ Sufficiently low sensing threshold restricts sharing to underserved areas only.

...but plenty of good does.

➔ Rural areas get communications service

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- ➔ Rural areas get communications service
- ➔ Rural entrepreneurs get a sustainable business

...but plenty of good does.

- ➔ Rural areas get communications service
- ➔ Rural entrepreneurs get a sustainable business
- ➔ Existing carriers keep building out their networks like they always have

GSM WHITESPACE

Safety	Don't interfere with existing licensed operators.
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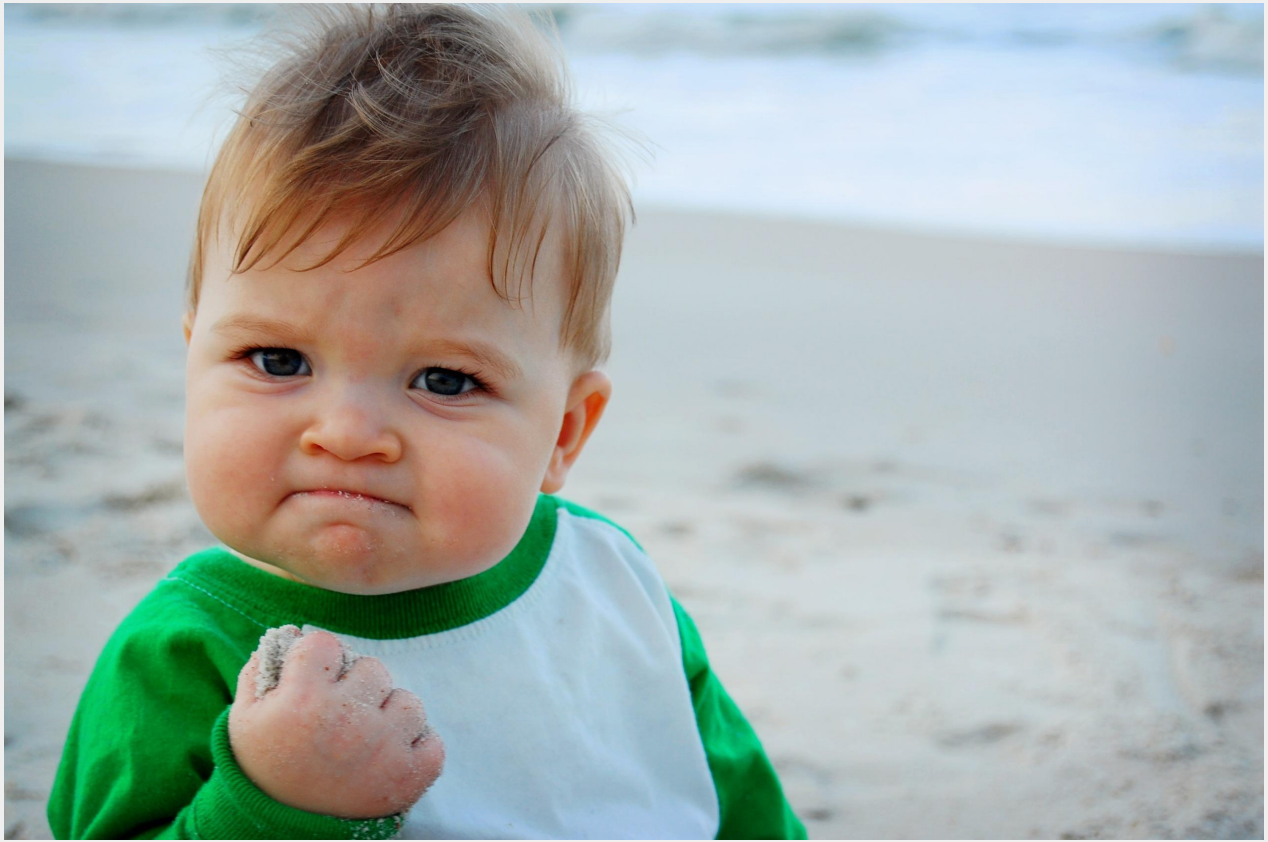
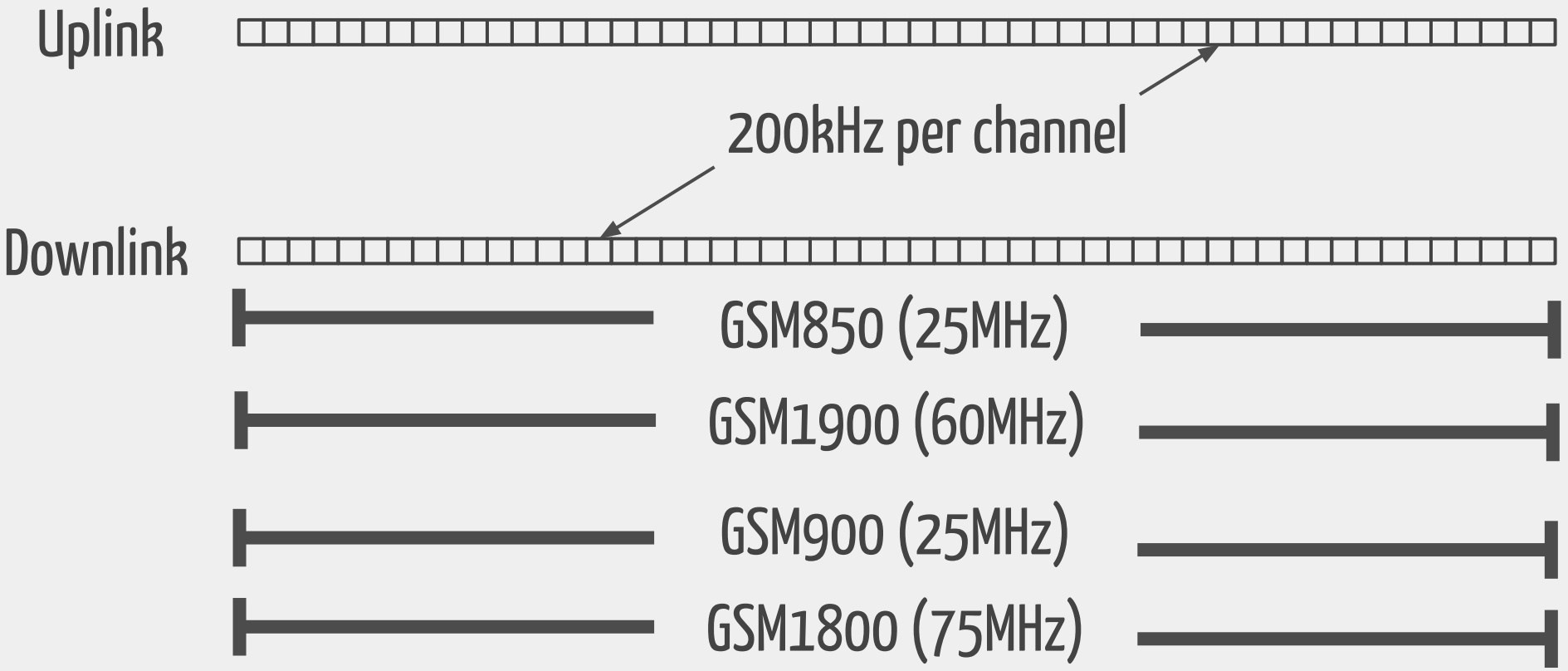
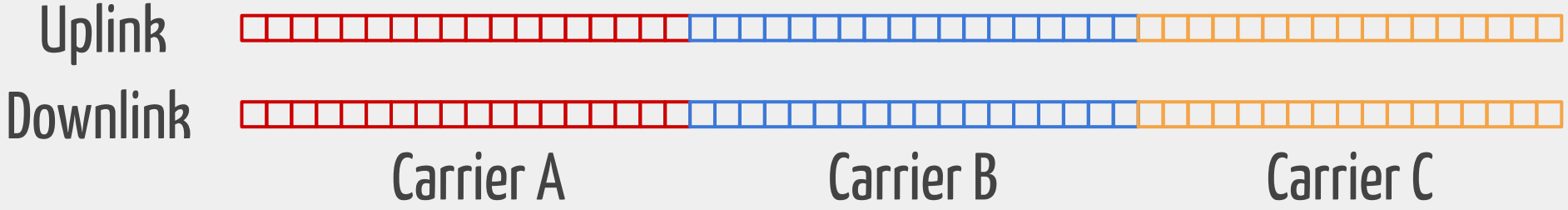
Independence	Don't make CCNs and Big Telcos talk to each other.
Trustworthiness	Let regulators control what spectrum is used and where.

Crazy Possibilities -> Good Practices

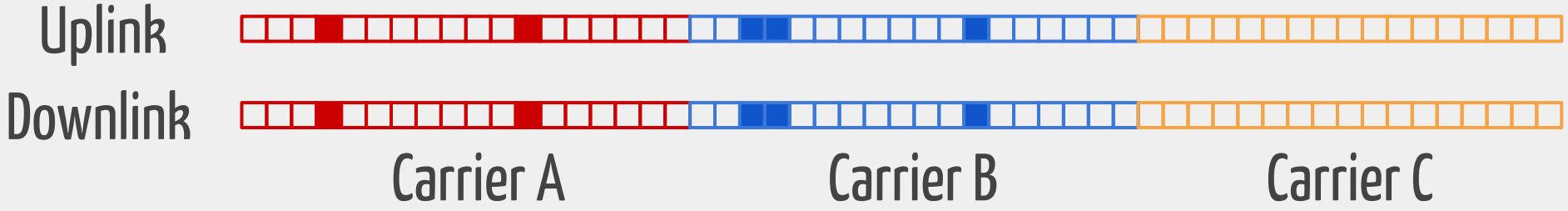



THAT'S UNPOSSIBLE!


Uplink
200kHz per channel
Downlink
GSM850 (25MHz)
GSM1900 (60MHz)
GSM900 (25MHz)
GSM1800 (75MHz)



- 7 concurrent voice calls
- 100's SMS/min
- 100's active subscribers



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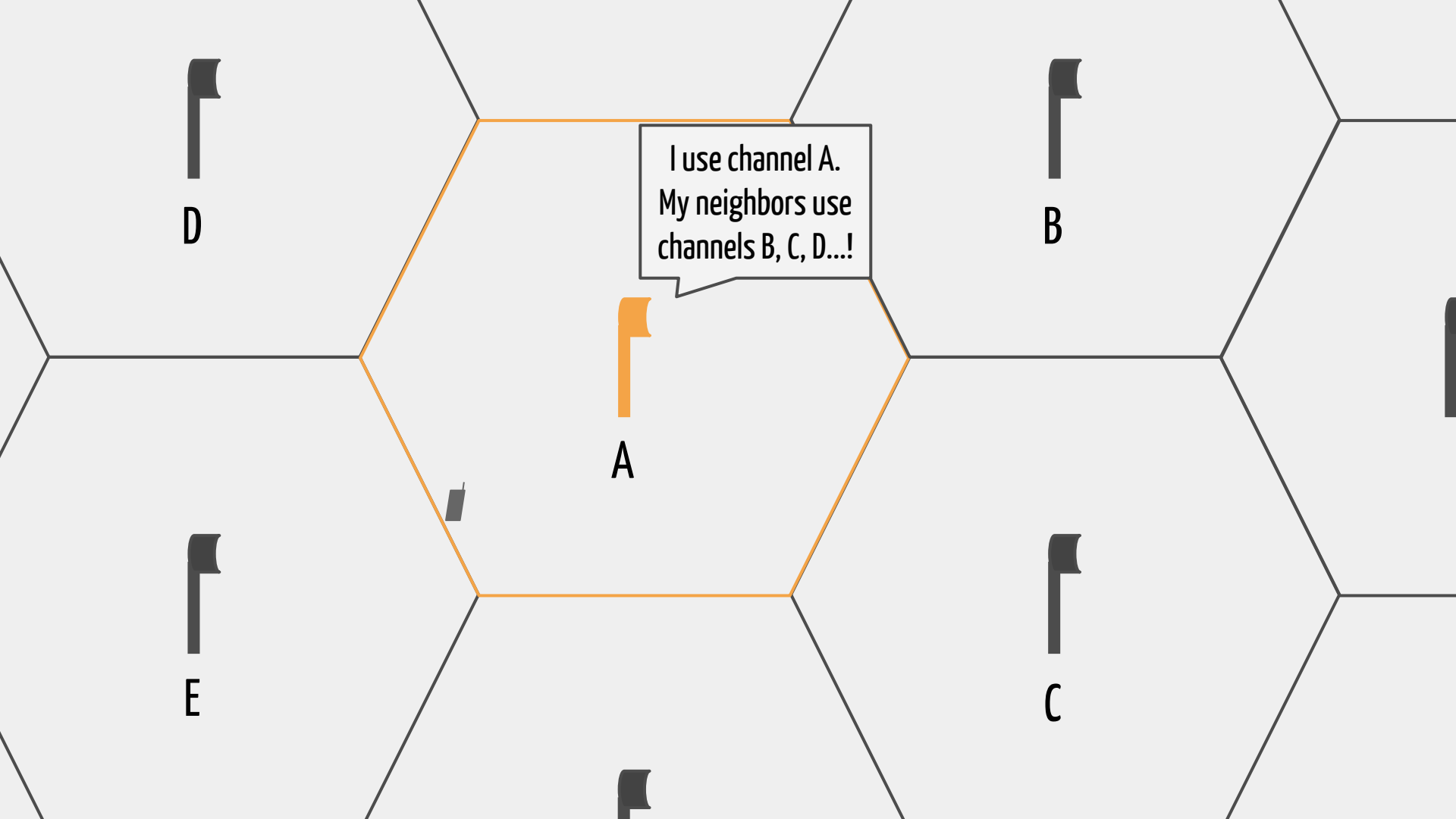
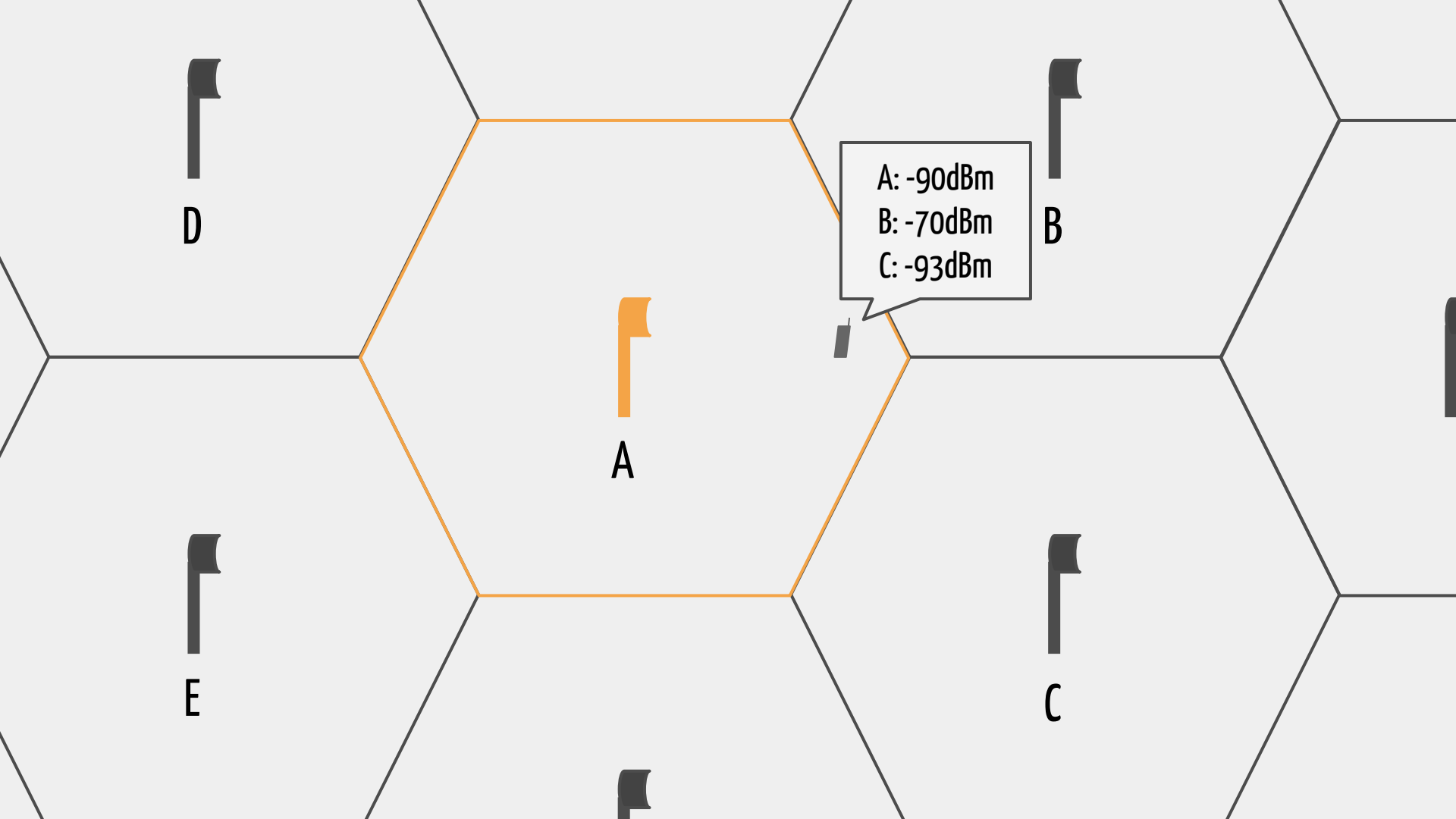
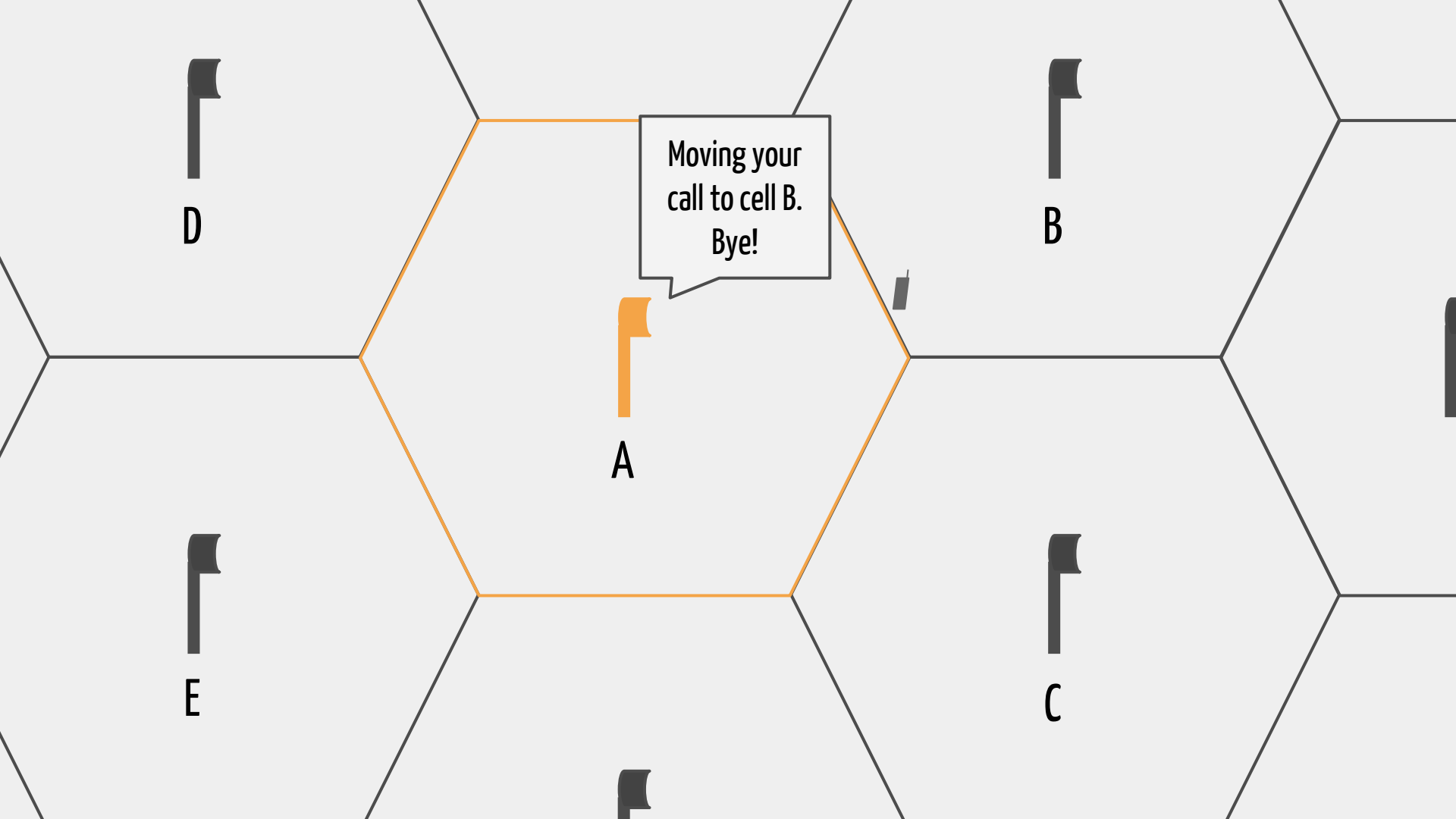
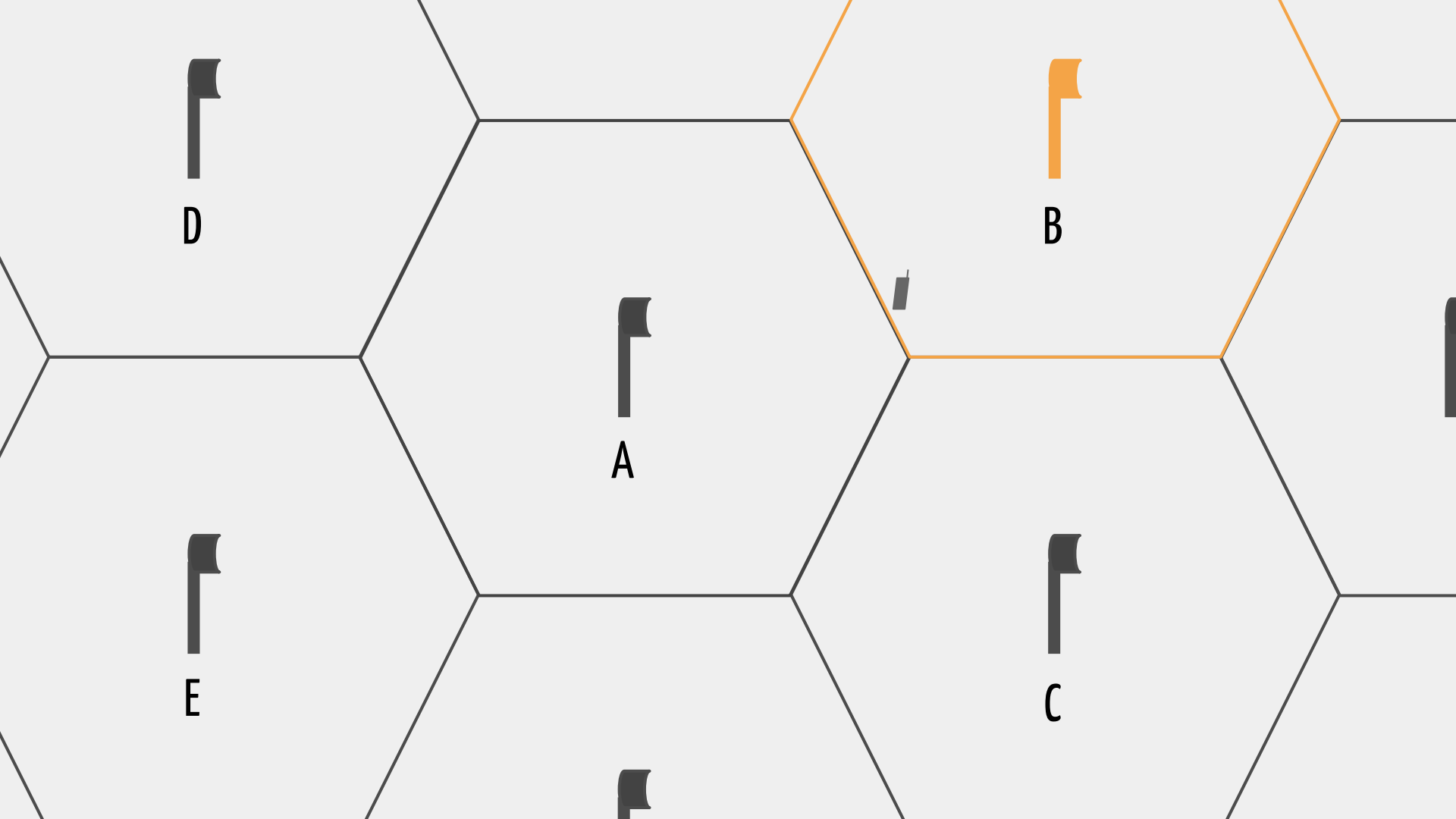

I use channel A.
My neighbors use channels B, C, D...!
D
B
A
E
C


A: -90dBm
B: -70dBm
C: -93dBm
D
B
A
E
C


Moving your call to cell B. Bye!
D
B
A
E
C


D
B
A
E
C

1996's hottest gadget.

Also a cognitive radio.

(Thank you for the quote, unknown person from Qualcomm Research at a previous DySPAN)

Key idea #1:

Use phones to scan for in-use channels.

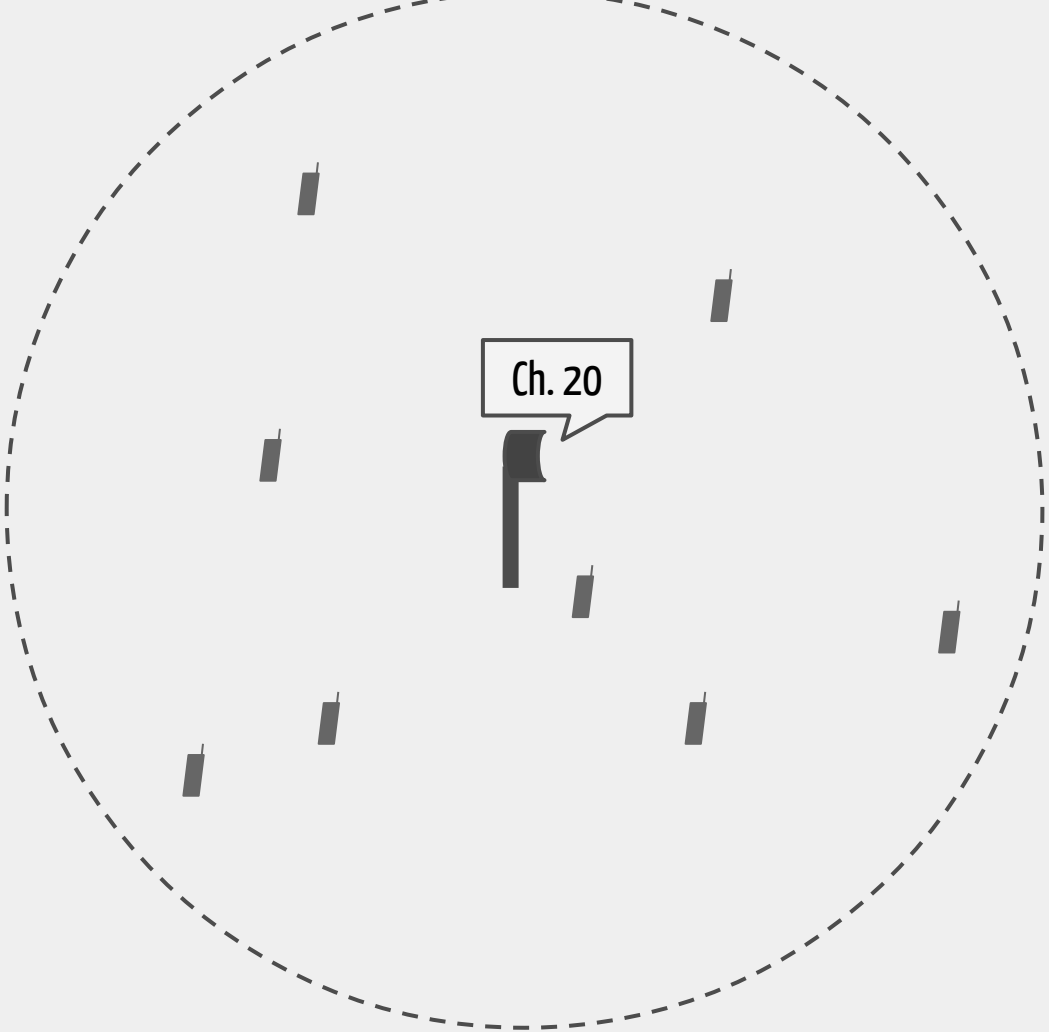
Key idea #2:

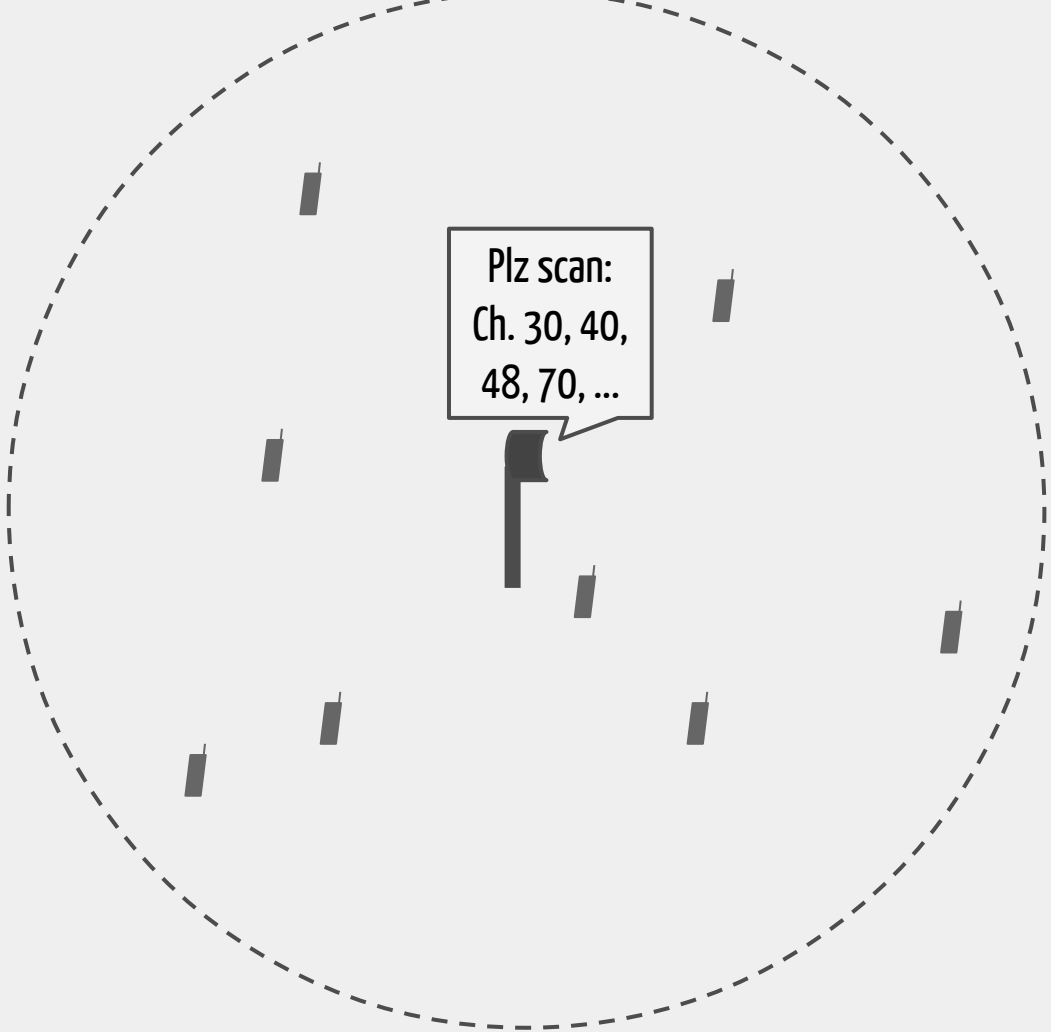
Constantly change channels to prevent squatting.

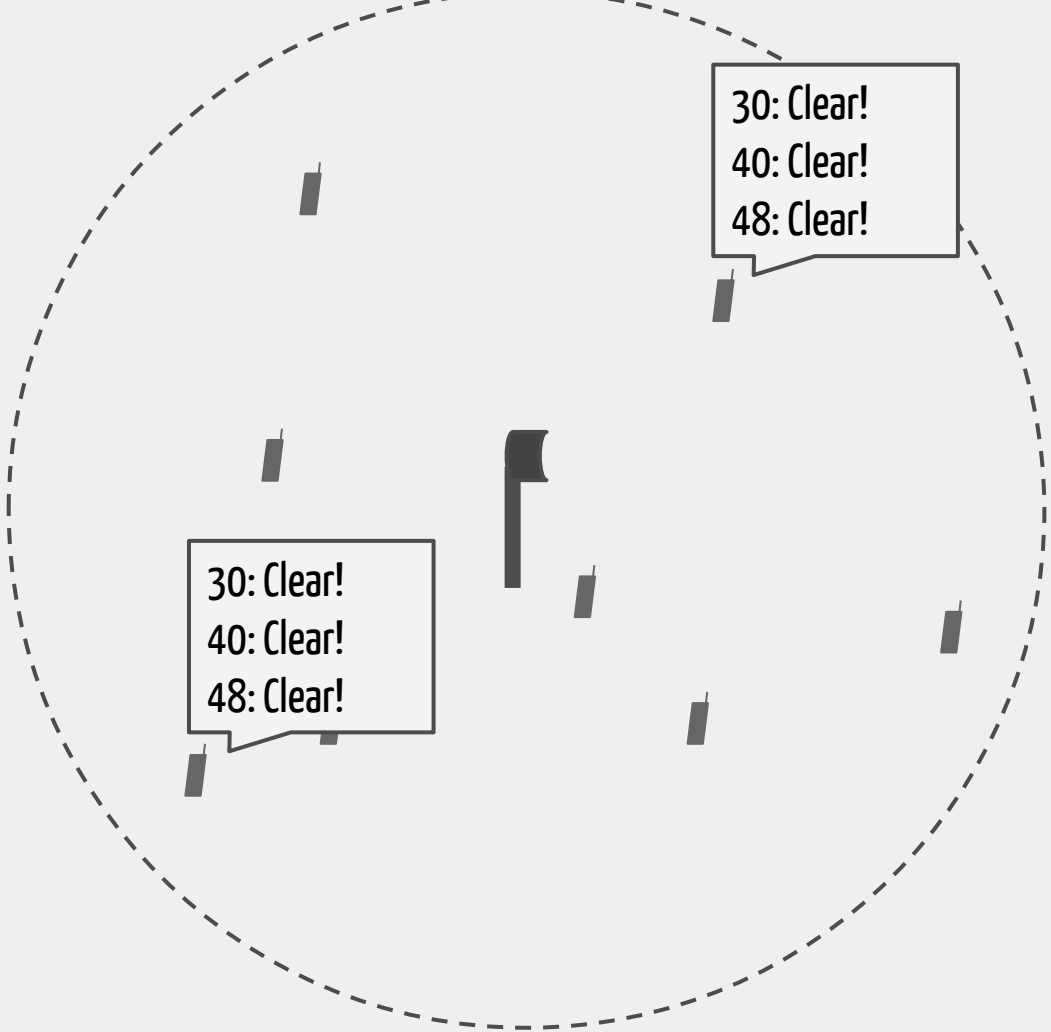
Key idea #3:

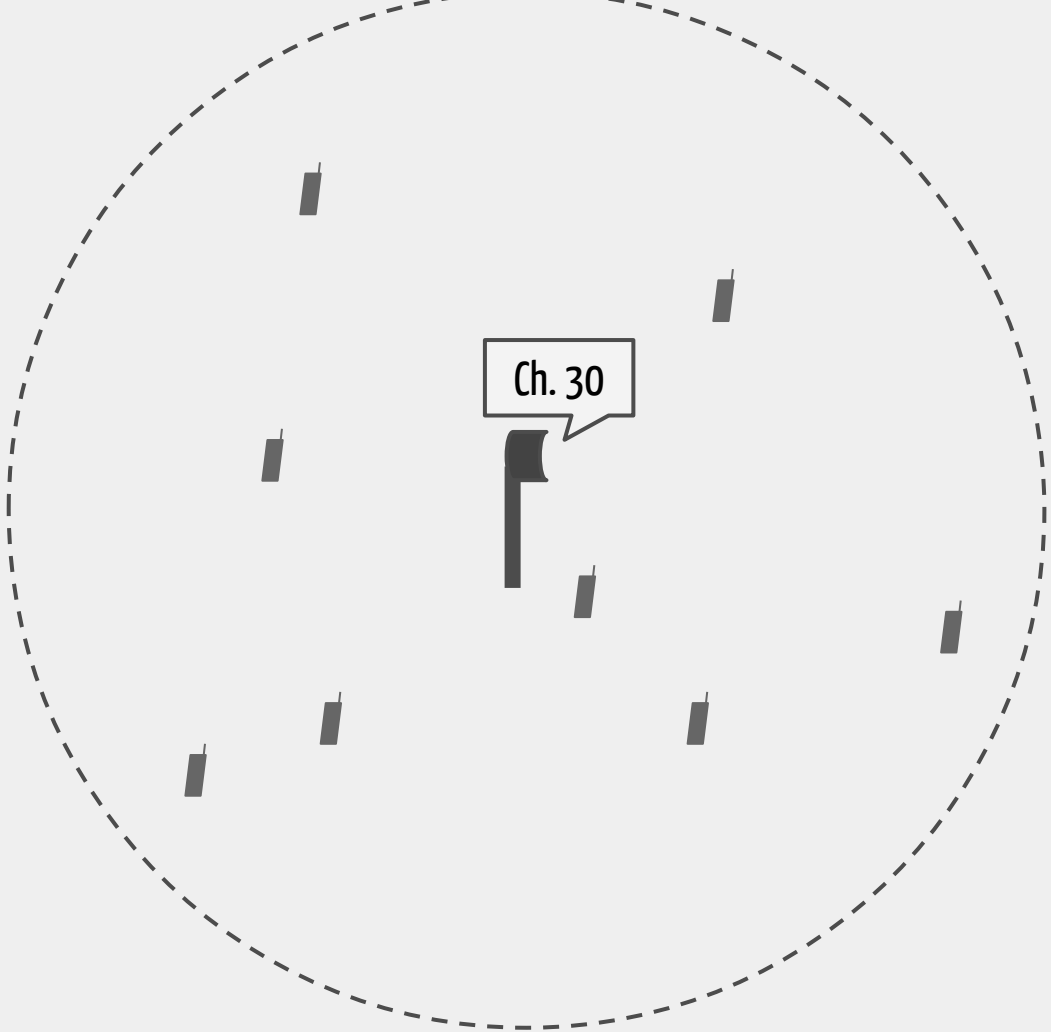
Use a database to monitor and control CCNs.


Ch. 20

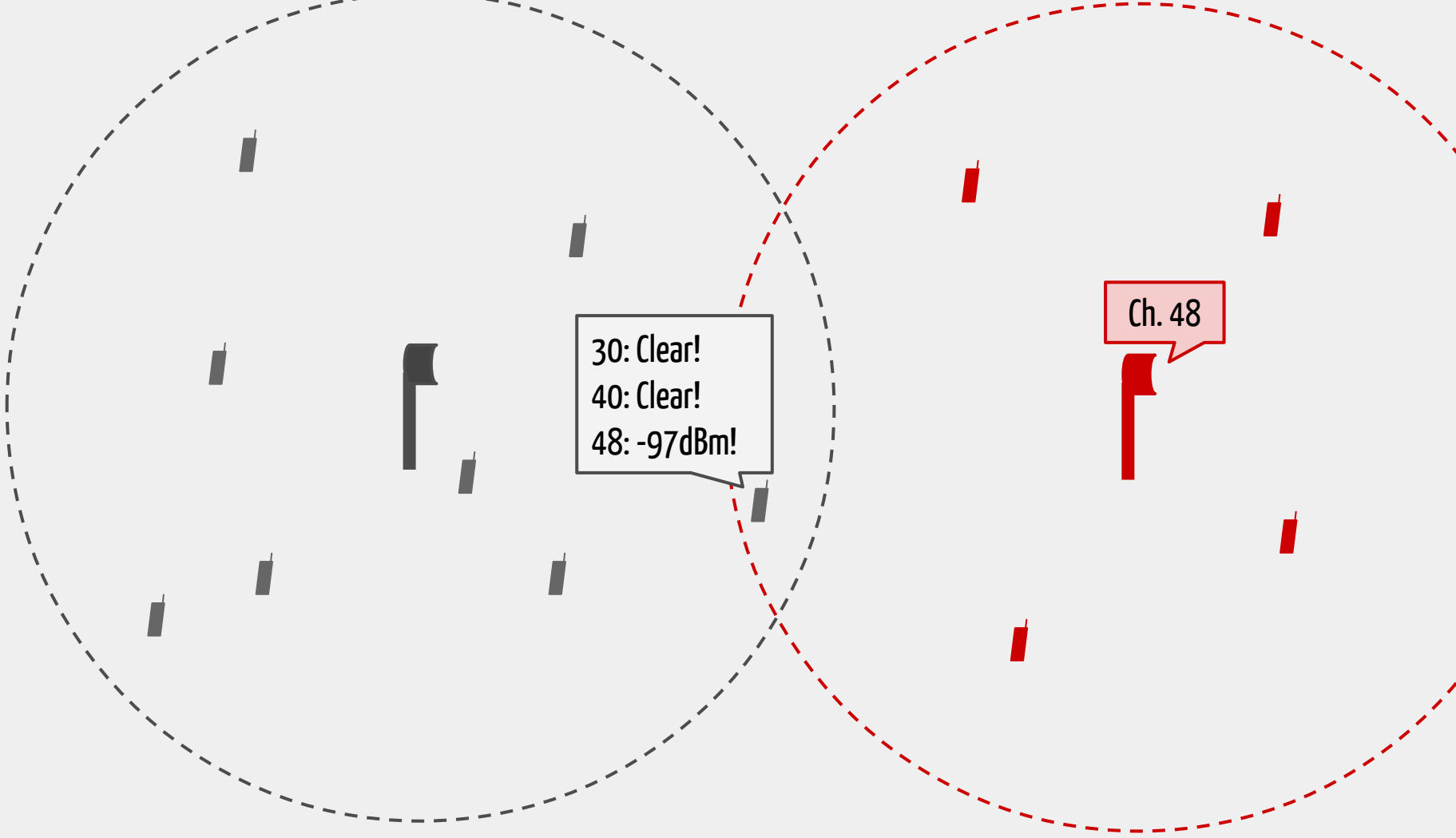

Ch. 20

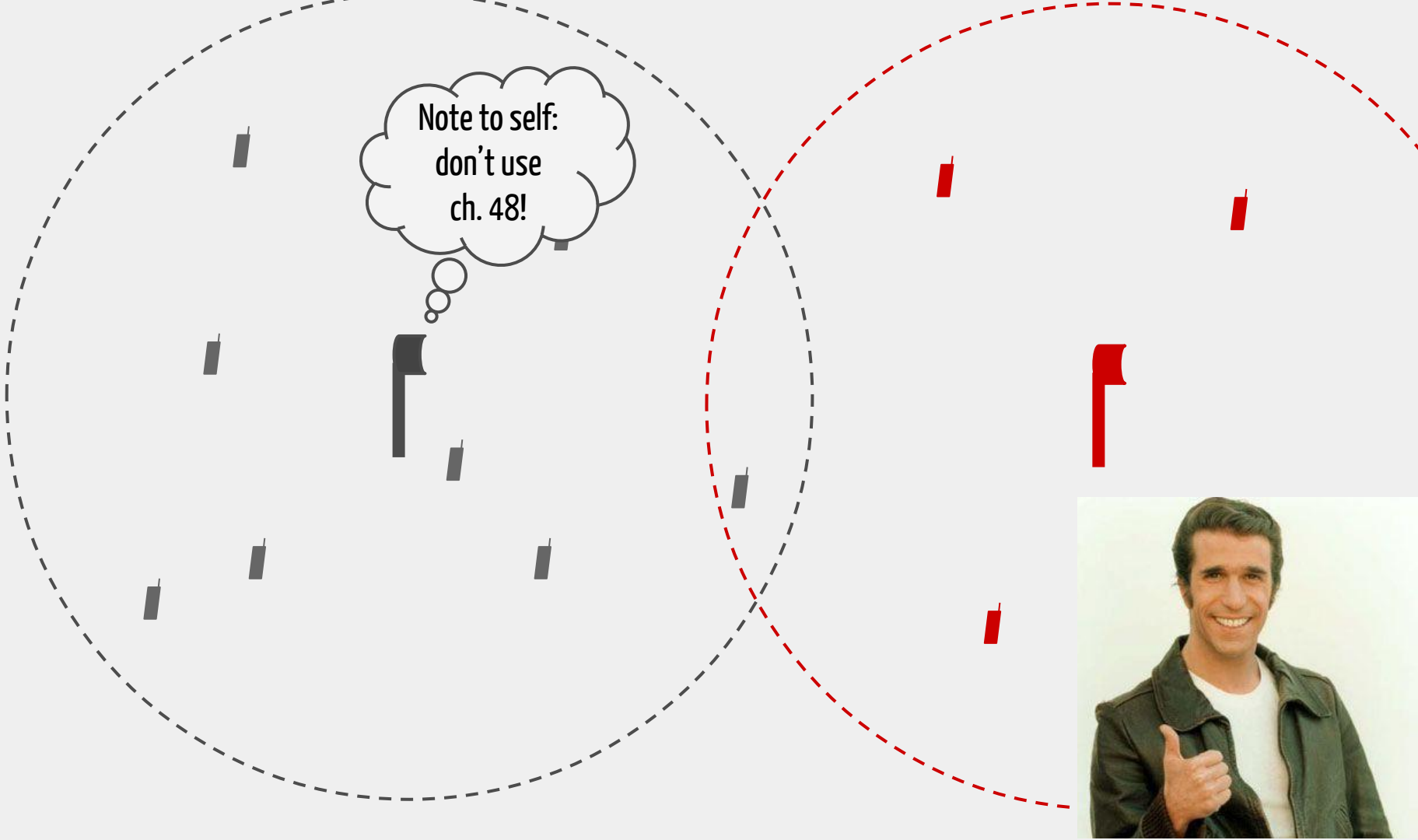

Plz scan:
Ch. 30, 40,
48, 70, ...


30: Clear!
40: Clear!
48: Clear!
30: Clear!
40: Clear!
48: Clear!



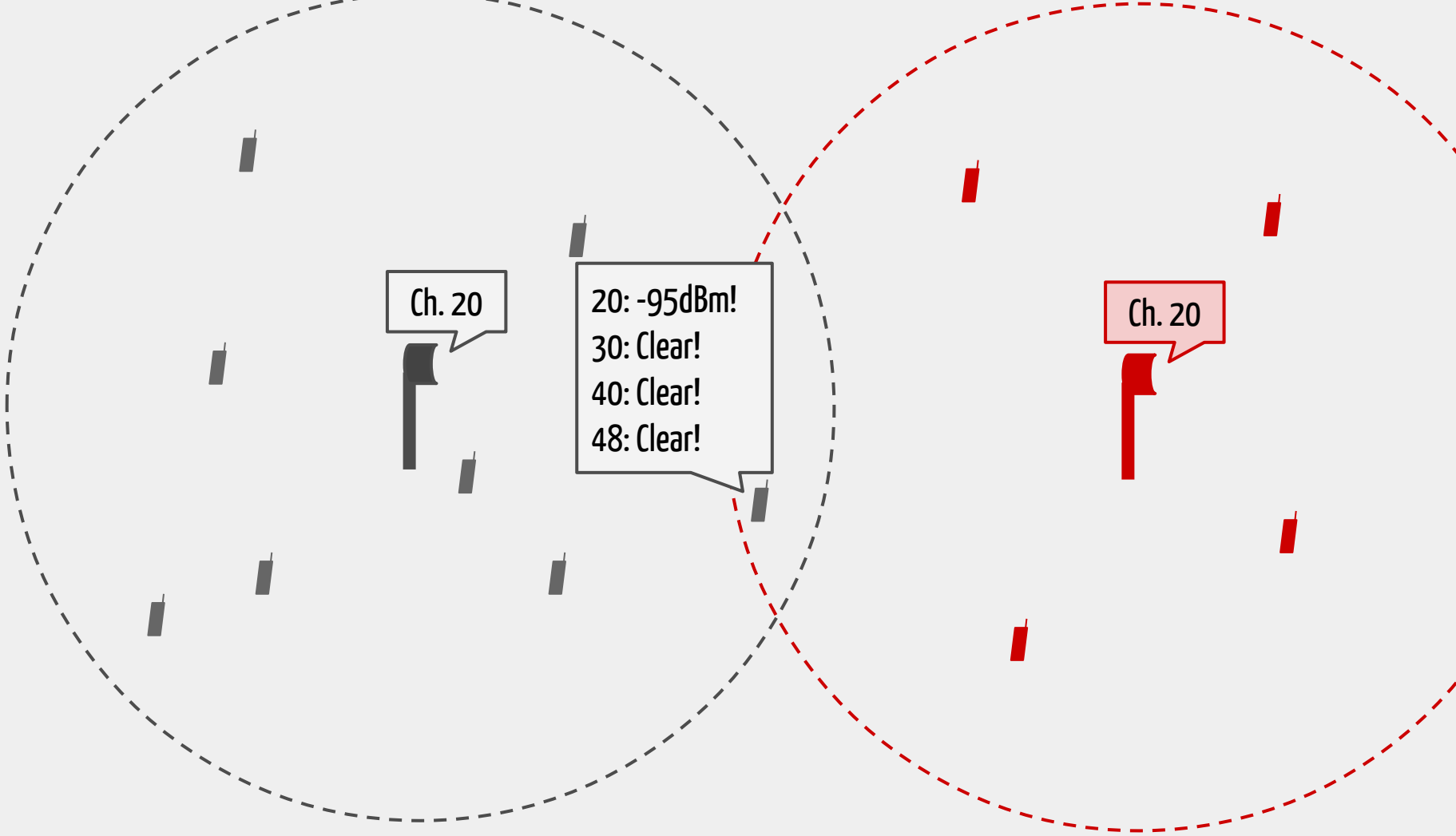
After a few hours...


30: Clear!
40: Clear!
48: -97dBm!
Ch. 48

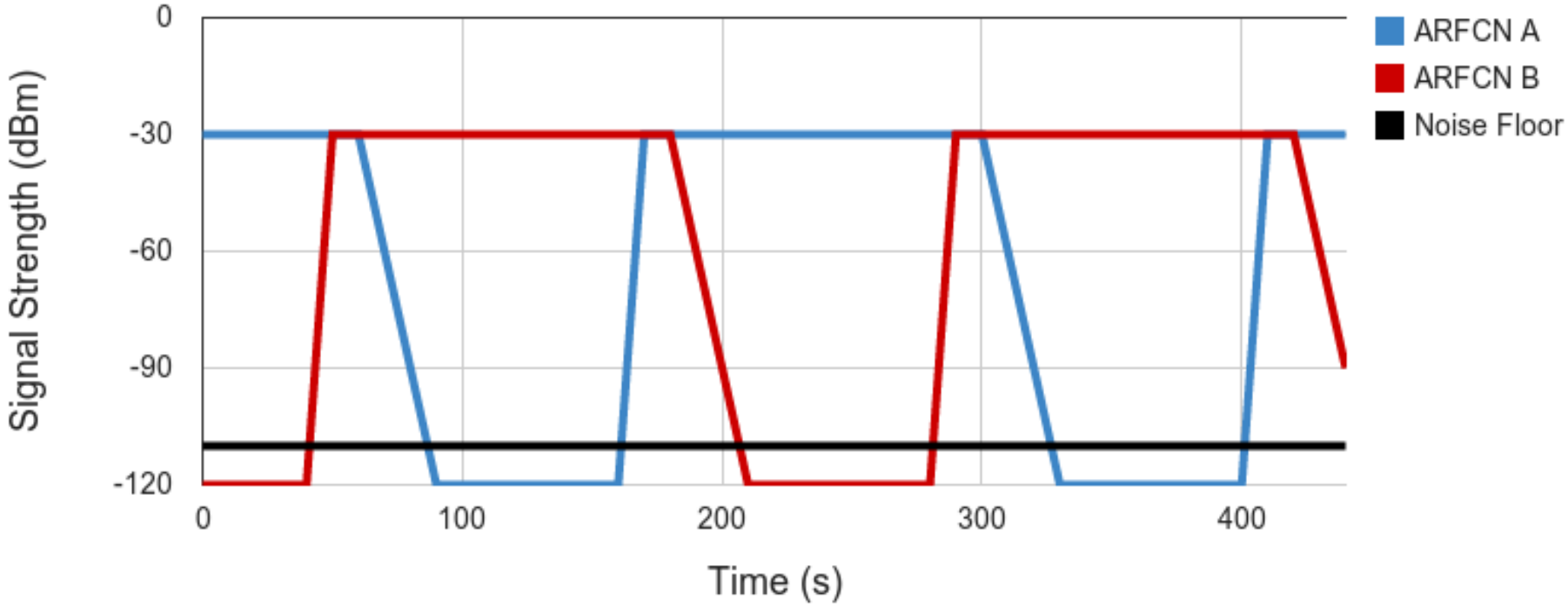

Note to self:
don't use
ch. 48!

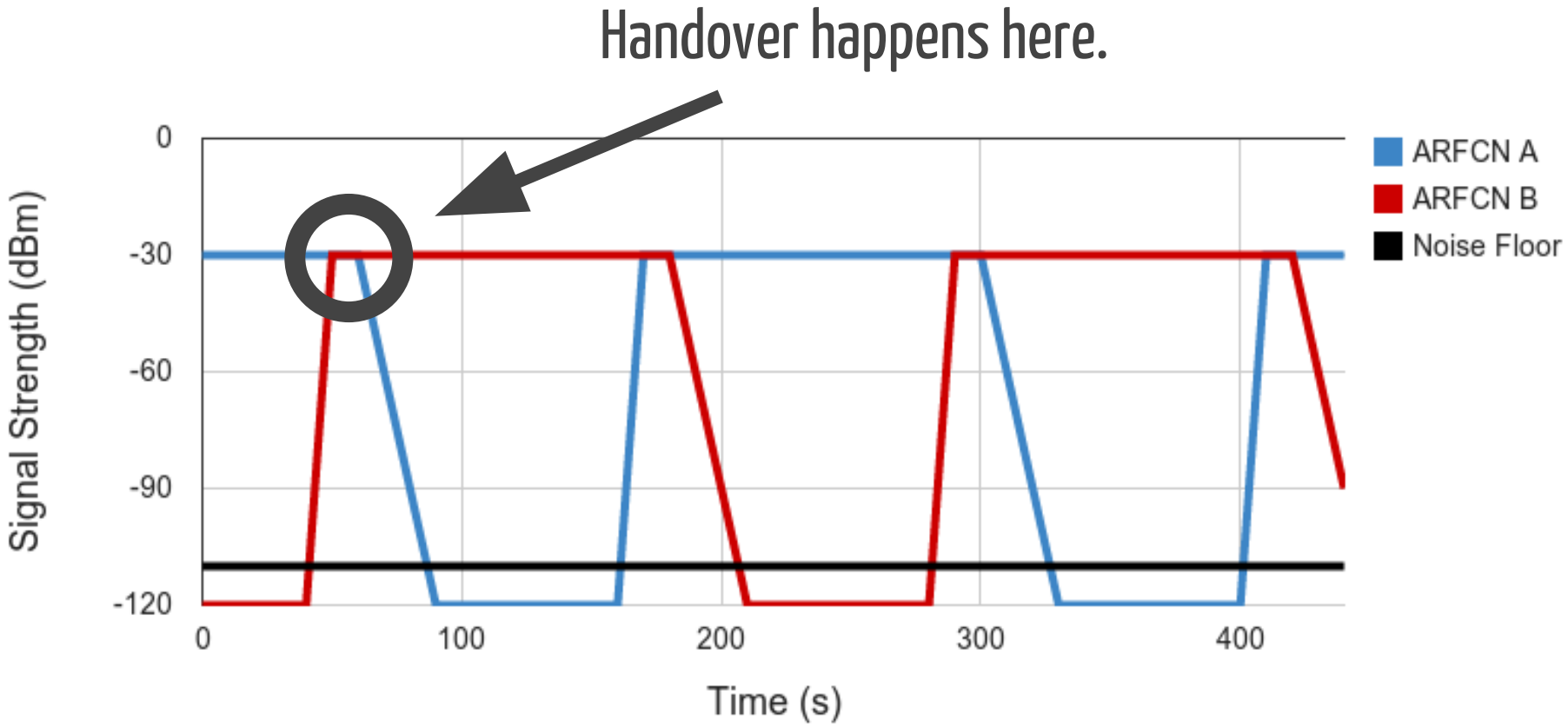
30: Clear!
40: Clear!
48: Clear!

Ch. 98

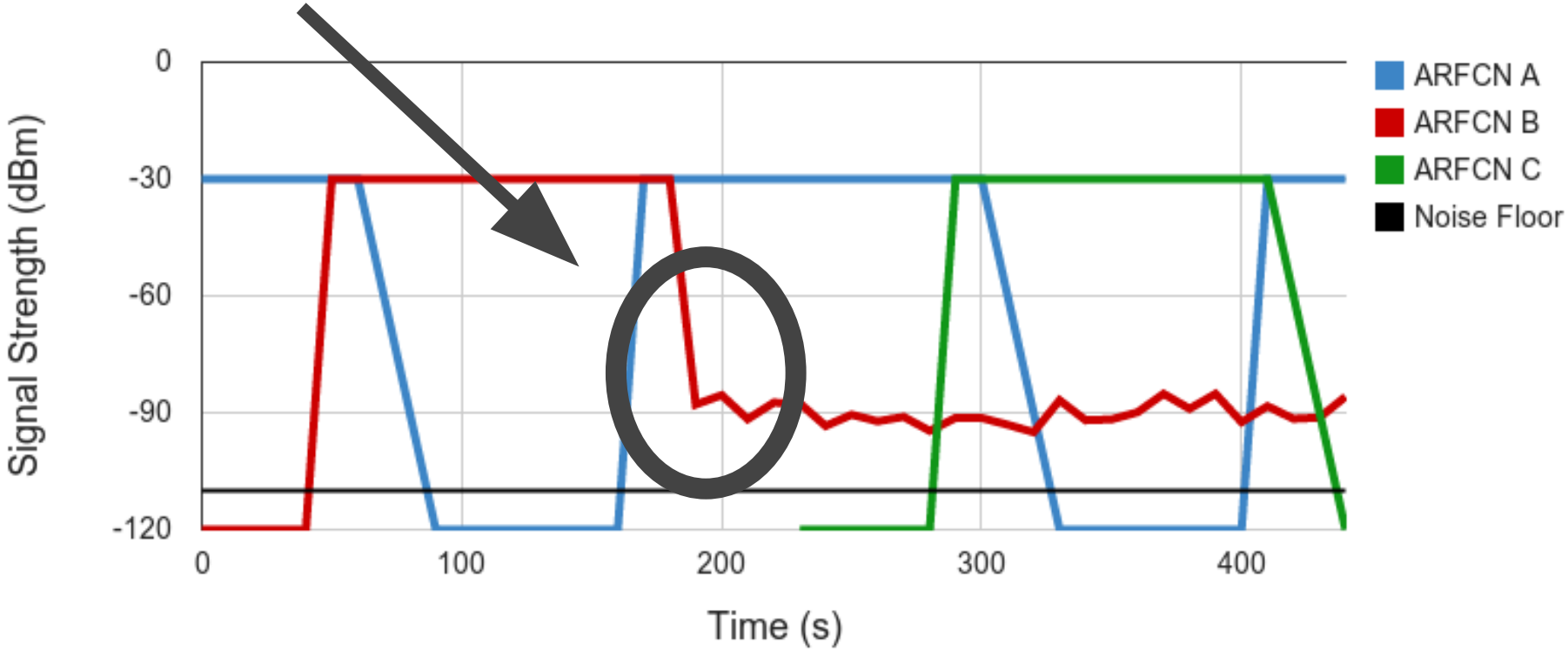

Ch. 20
20: -95dBm!
30: Clear!
40: Clear!
48: Clear!
Ch. 20

Solution: Simulate Handover!

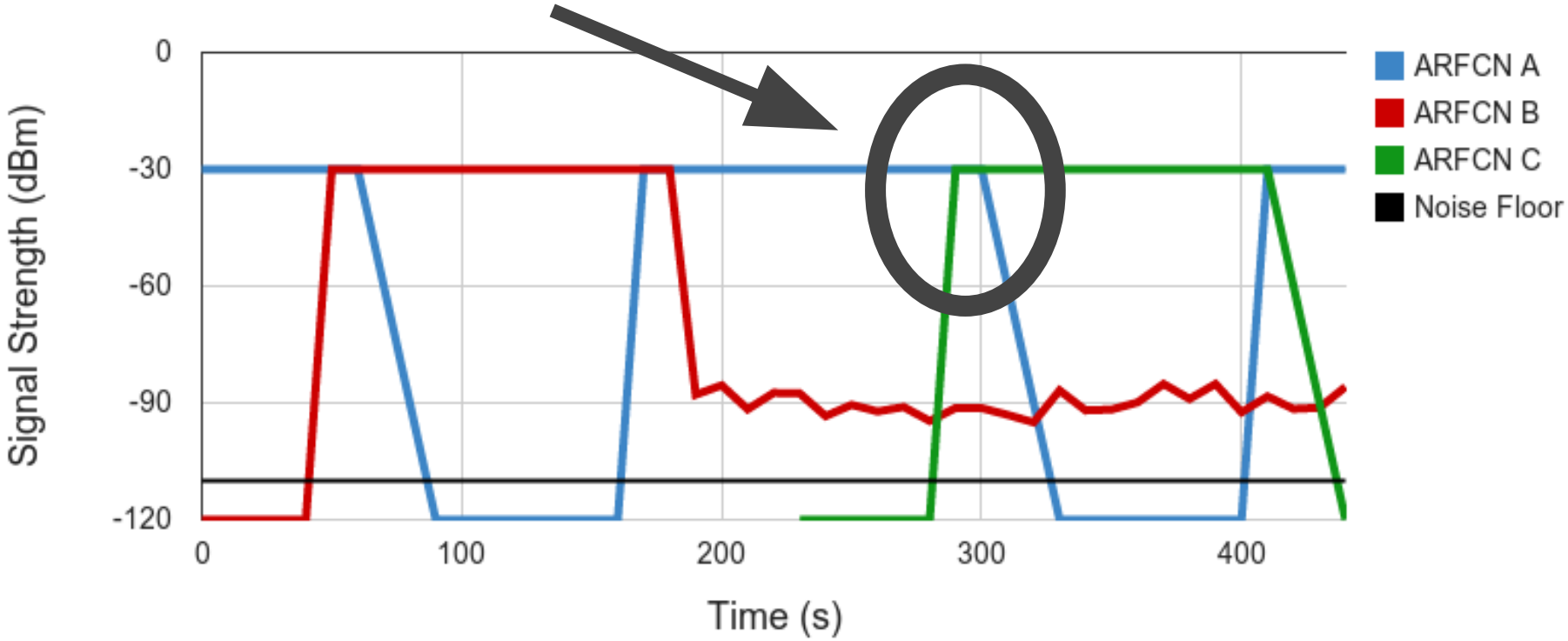



Handover happens here.
Signal Strength (dBm)
0
-30
-60
-90
-120
0
100
200
300
400
Time (s)
ARFCN A
ARFCN B
Noise Floor

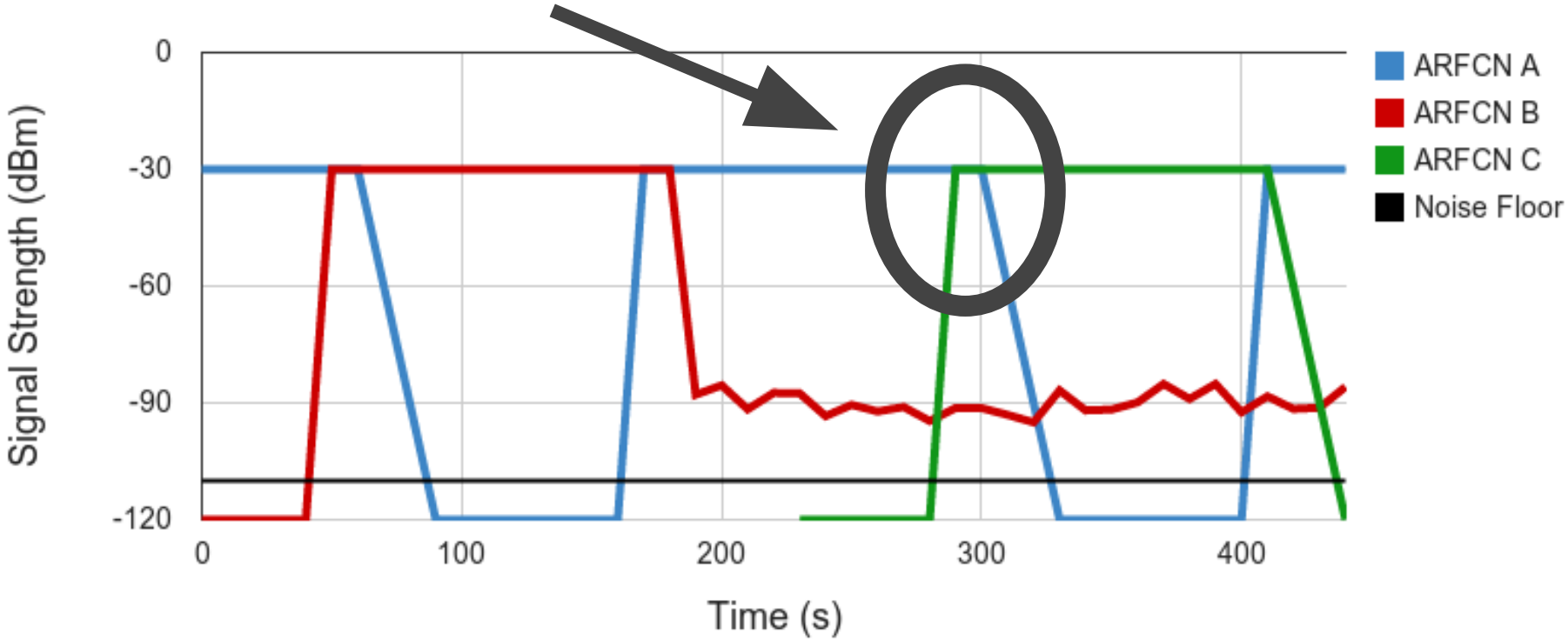
Someone else is on a channel we're using!



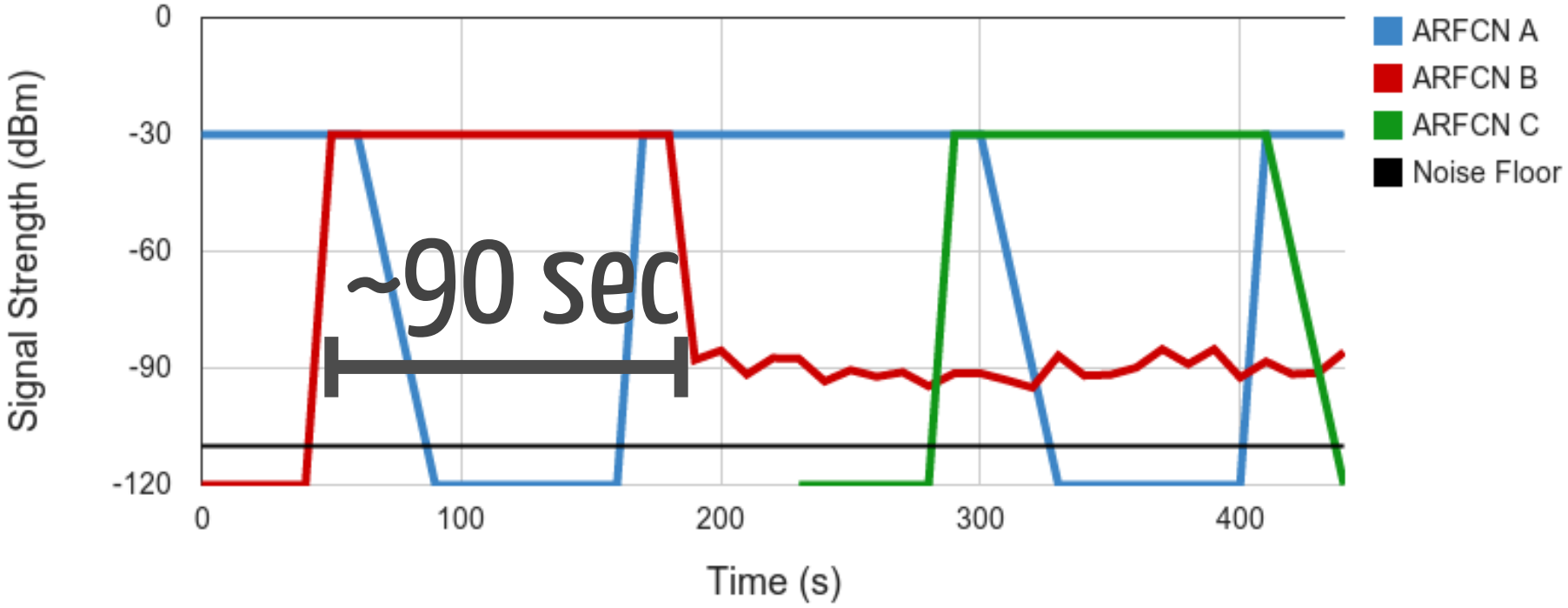
We should switch to a new safe channel.



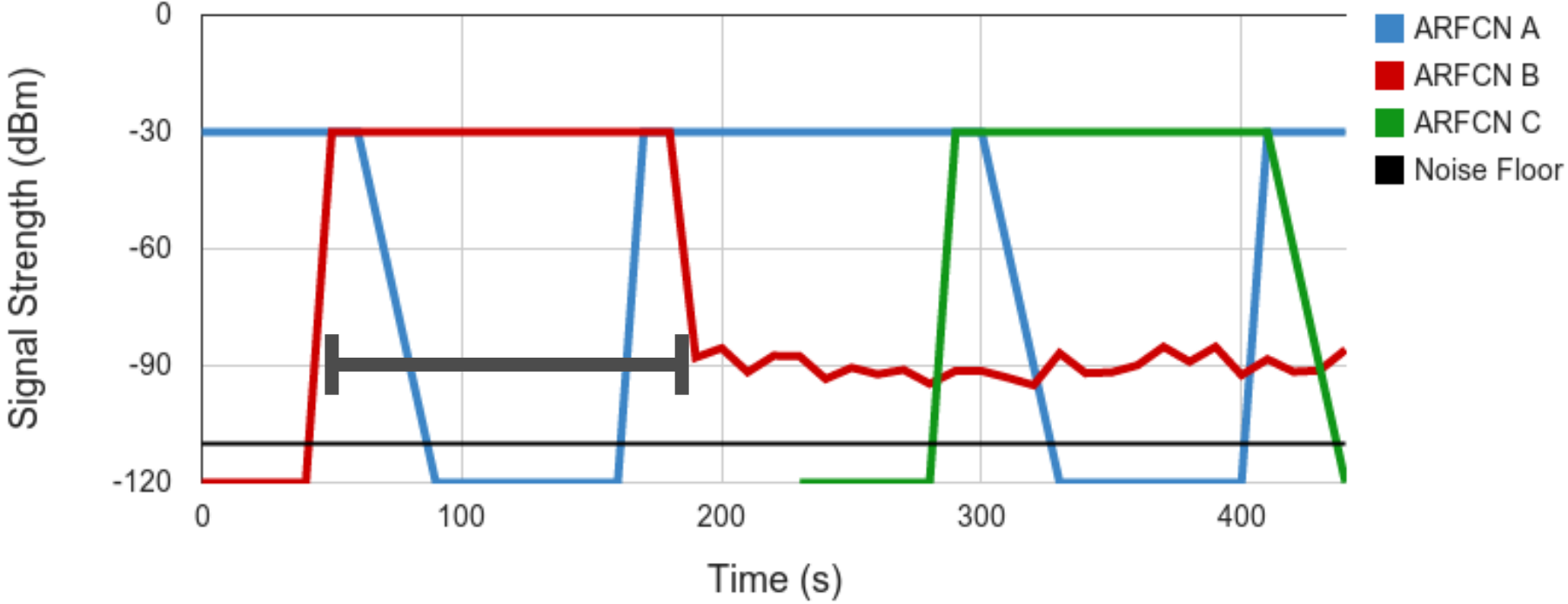
Phones handover to the new channel.



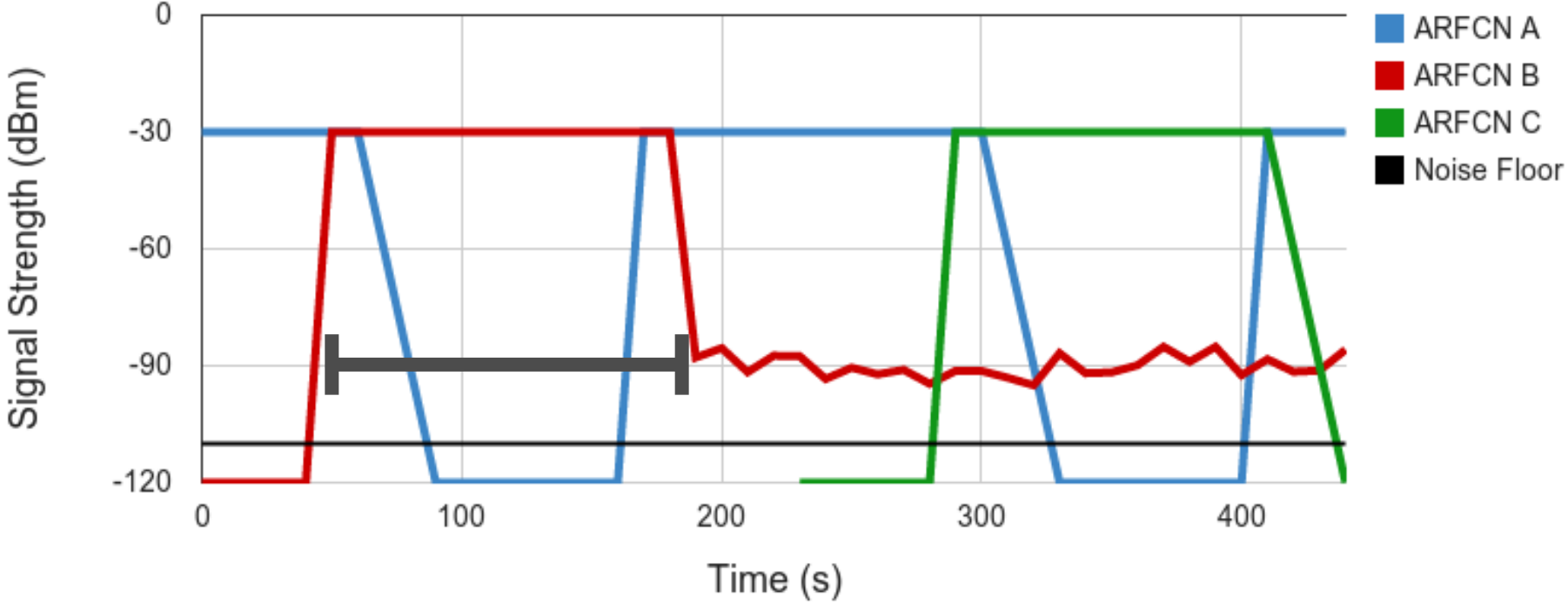
Worst case detection speed = cycle time



90 sec << rate carriers add rural base stations

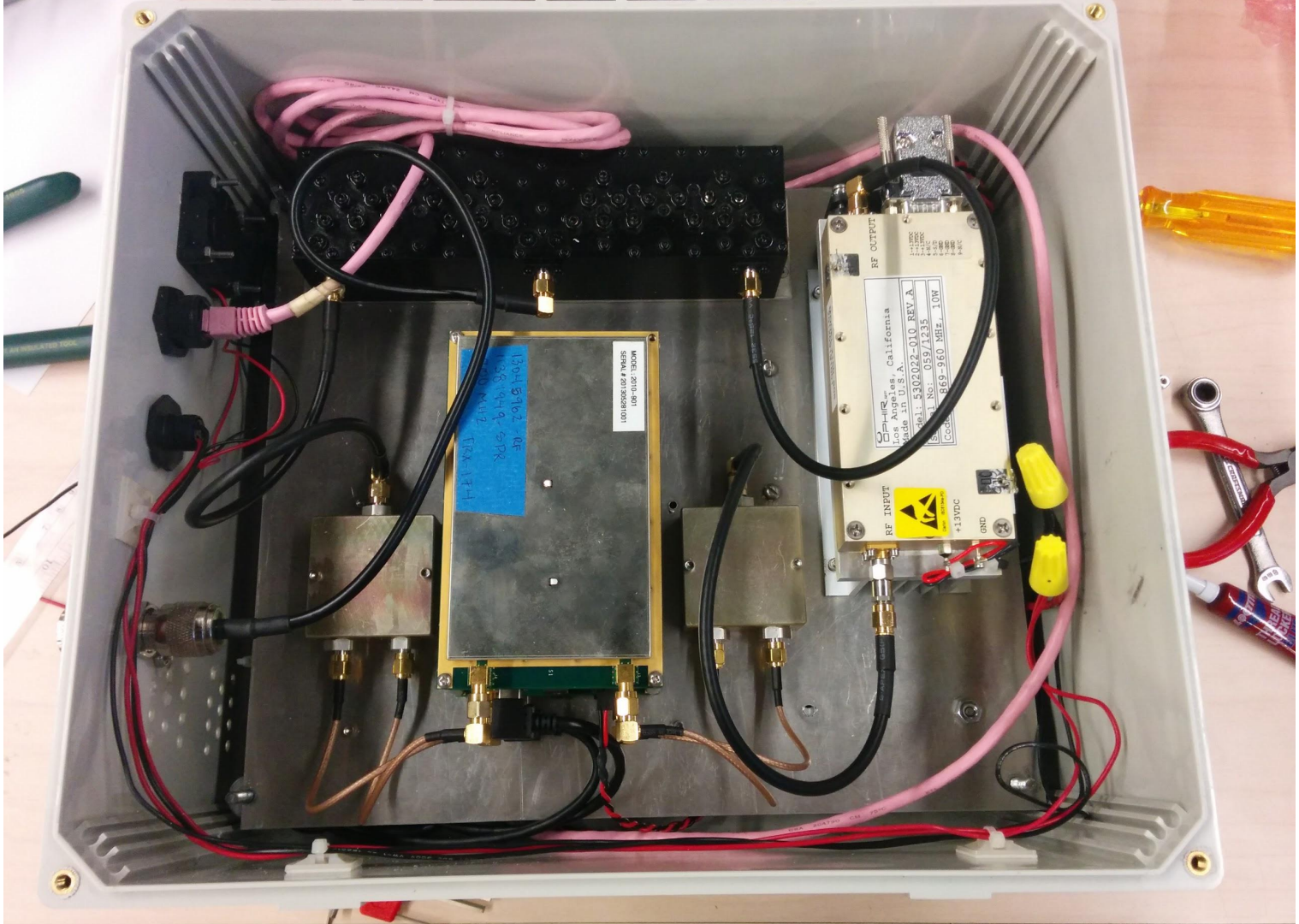


90 sec = probably excessive



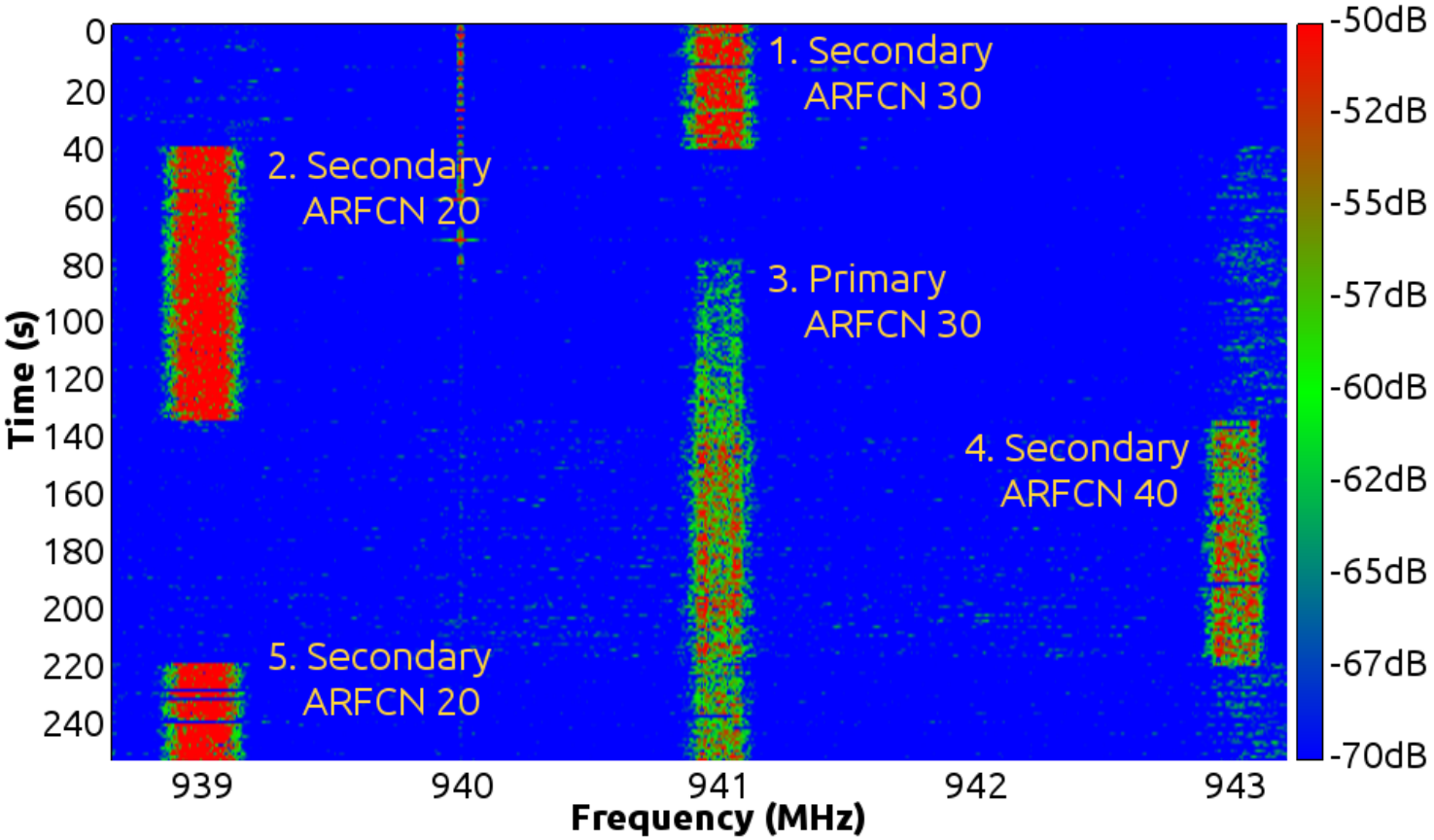
Evaluation

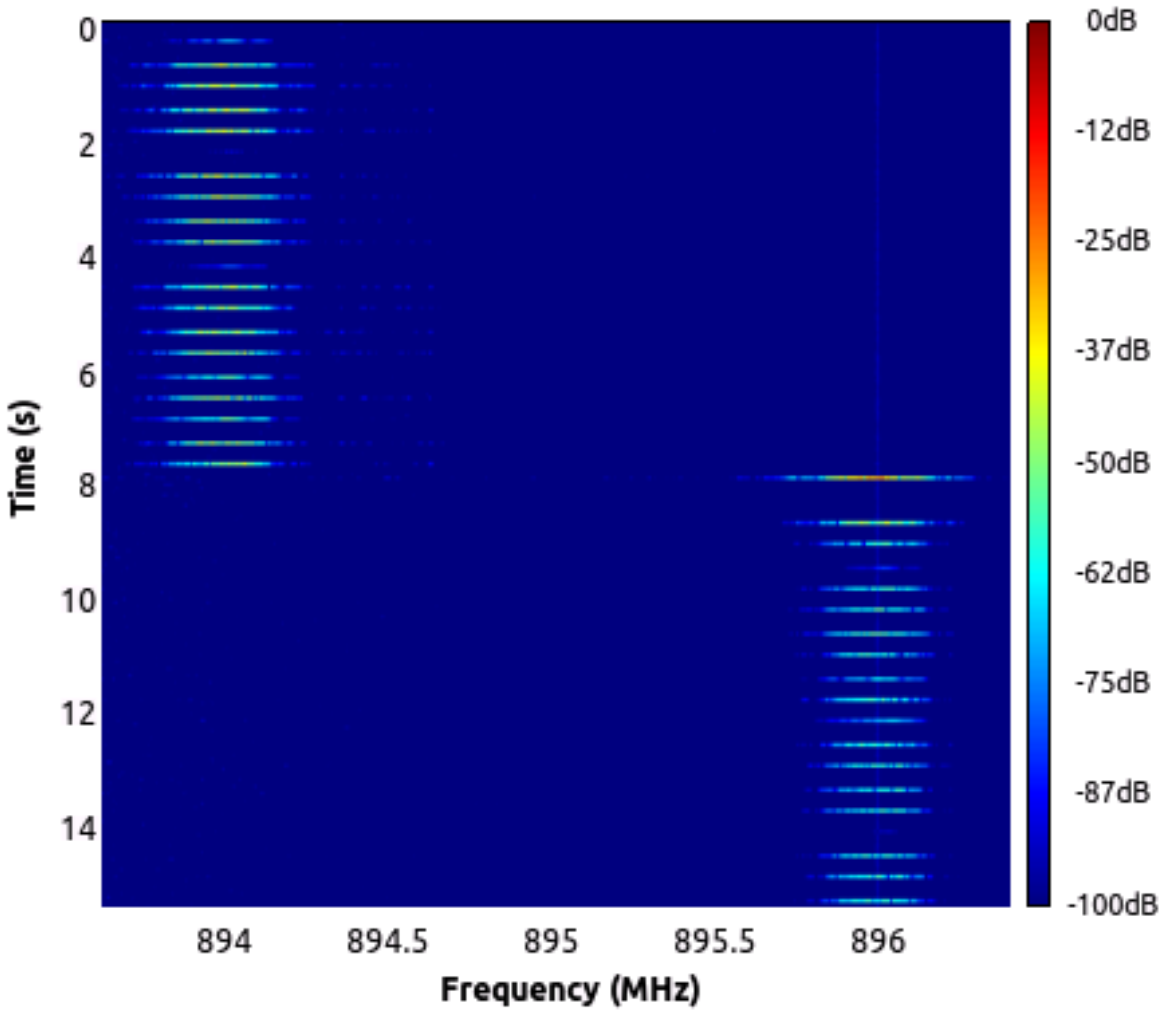
Lab Experiments + Real World Deployment

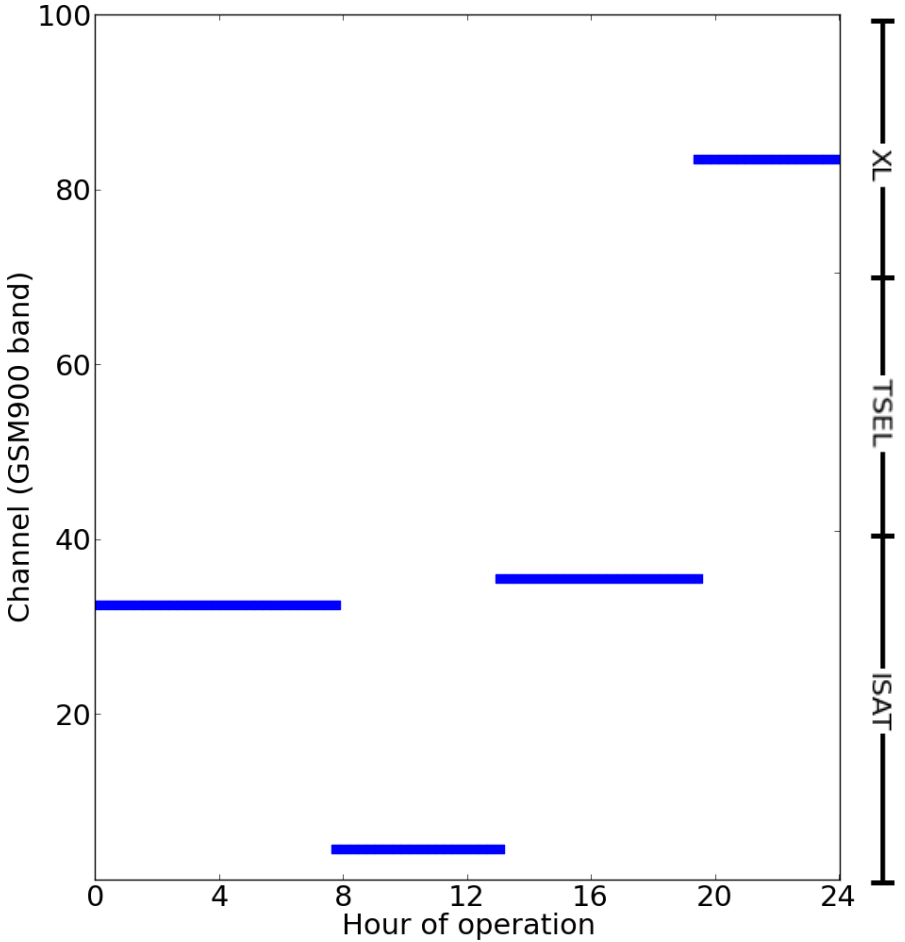

RF OUTPUT
RF INPUT
+13VDC
GND
MODEL: 2010-901
SERIAL # 201305091001

github.com/shaddi/gsmws
(Runs on OpenBTS)

Detecting a new primary user

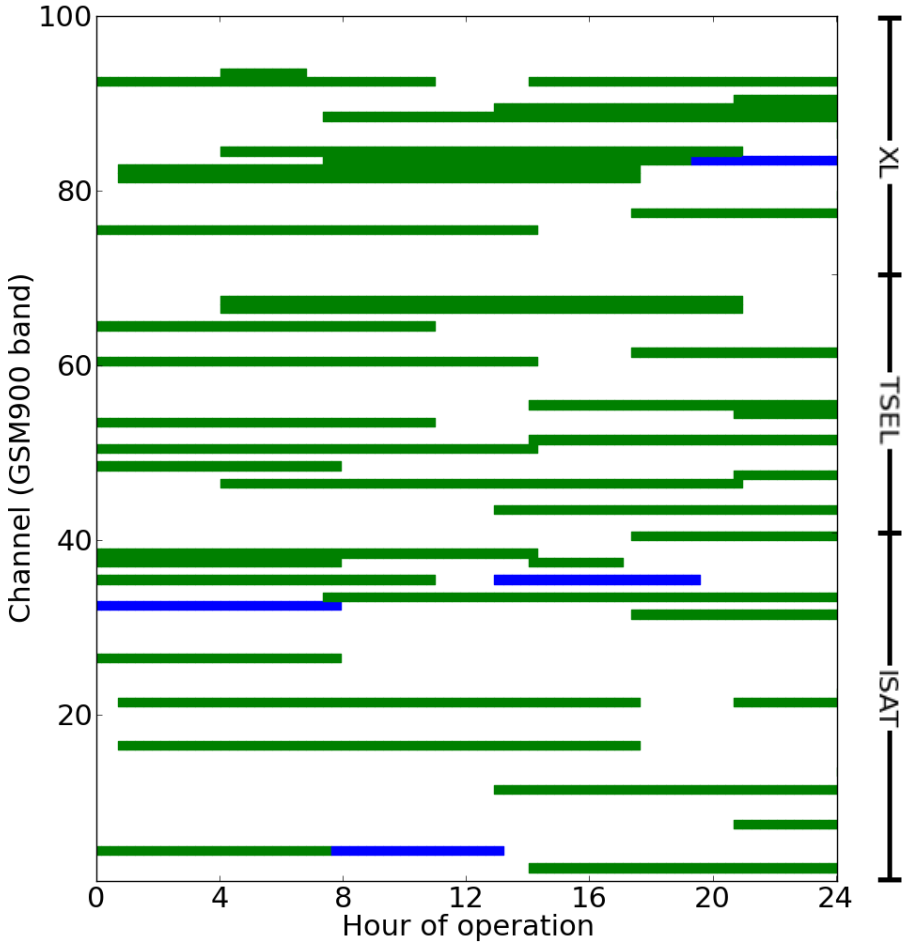



0
2
4
6
8
10
12
14
Time (s)
894
894.5
895
895.5
896
Frequency (MHz)
0dB
-12dB
-25dB
-37dB
-50dB
-62dB
-75dB
-87dB
-100dB



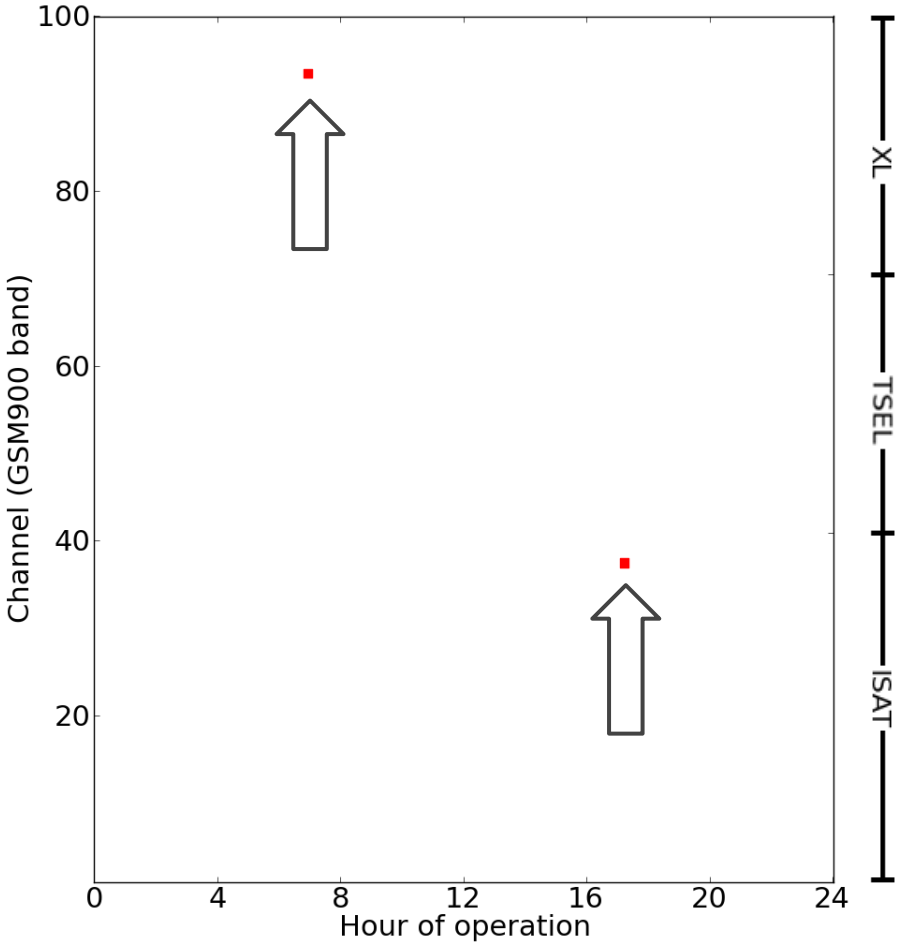
Papua: Measured spectrum usage

In-use channel



Papua: Measured spectrum usage

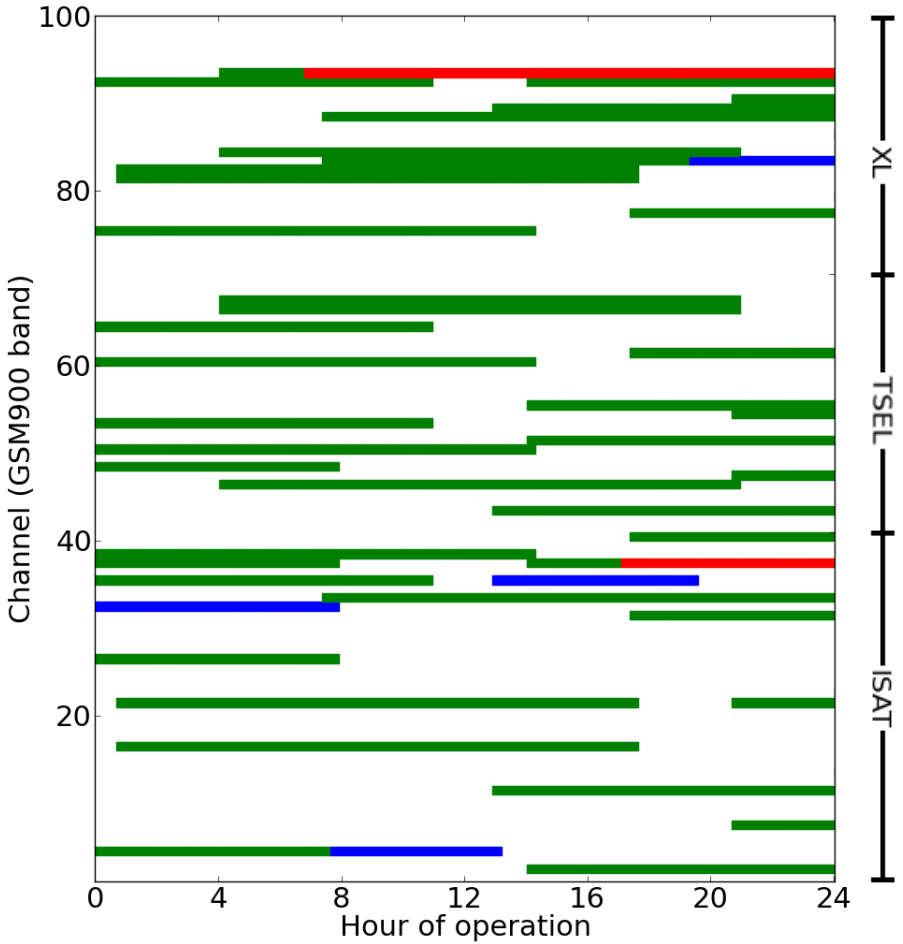
In use + “safe” chans



Papua: Measured spectrum usage

Two detection events

(probably spurious reports)



Papua: Measured spectrum usage

- → Switched channel every night, after power failures
- → No impact on usage of network

Future Work

- → Field trial in South Africa
- → Applications in 3G/4G networks
- → Integrating location data from handsets

We're looking for
telco and regulator partners for
GSMWS trial deployments.

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cs.berkeley.edu/~shaddi

Backup

WiFi: WiNot?

When all spectrum is plentiful, use technically best solution.

1. Lack of ubiquitous client devices
2. High power consumption
3. Lower capacity per base station
4. Shorter range

WHITE MEANS 100+ EMPTY CHANNELS*

*A CCN needs just 1-2

COMMUNITY CELLULAR NETWORKS

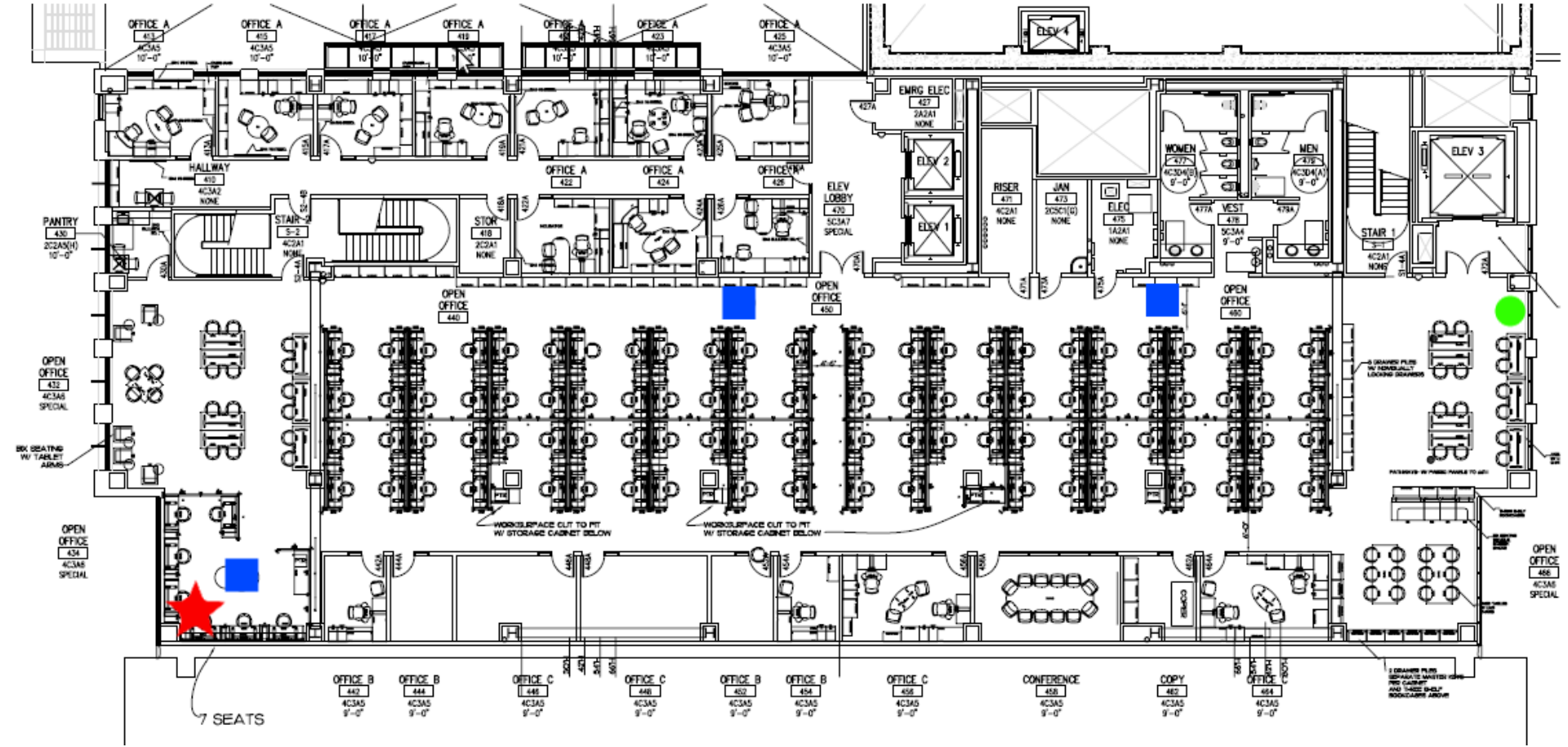
Micro-scale GSM networks that rural communities build and run themselves.

ONE BILLION

PEOPLE LIVE IN THE

WHITE SPACE

Source: GSMA


OFFICE A
OFFICE A
OFFICE A
OFFICE A
OFFICE A
OFFICE A
OFFICE A
ELEV 4
EMRG ELEC
HALLWAY
OFFICE A
OFFICE A
OFFICE A
ELEV 2
ELEV 1
ELEV LOBBY
RISER
JAN
ELEC
WOMEN
MEN
VEST
ELEV 3
PANTRY
STAIR-2
STOR
STAIR 1
OPEN OFFICE
OPEN OFFICE
OPEN OFFICE
OPEN OFFICE
OPEN OFFICE
OPEN OFFICE
8X SEATING W/ TABLET ARMS
WORKSURFACE CUT TO FIT W/ STORAGE CABINET BELOW
WORKSURFACE CUT TO FIT W/ STORAGE CABINET BELOW
OFFICE B
OFFICE B
OFFICE C
OFFICE C
OFFICE B
OFFICE B
OFFICE C
CONFERENCE
COPY
OFFICE
7 SEATS

```
a = bootstrap_arfcn()
bts.run(arfcn=a)
while True:
  a = find_safe_arfcn()
  if need_to_change():
    bts.change_arfcn(a)
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