

# *Wi-Five* → G ?

**J. Cioffi**

CEO/COB ASSIA

*(Professor Emeritus, Stanford EE)*

**IEEE ICC 2016 Keynote**

*May 24, 2016 - Kuala Lumpur, MALAYSIA*

# High Speed & Internet Consumers?

- **Do Gbps make us happy?**

- 67% of internet users don't know their speed!
- 87% don't care about 1 Gbps or know it exists!

• Telecompetitor group Dec 2014



- **We do know if our favorite (OTT video?) app works**

- 150M OTT video today
- 350M OTT video in 2019

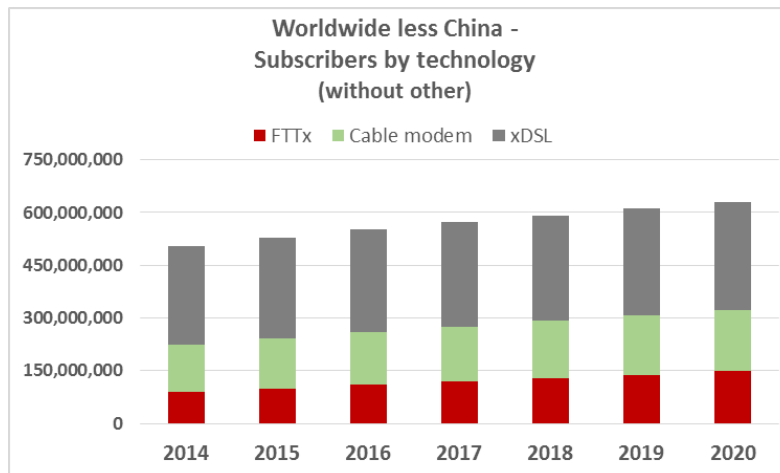
• US Telcom Media, Aug 2015



OR



- **Fixed connection: fiber, copper, coax, who cares?**



Ovum 2015

WiFive→G 2



# Consumer Happiness?

March 25–31, 2016

IneoQuest

The Online Reporter

## 75% of Daily Viewers of OTT Video Get ‘Buffer Rage’



Nearly 3 of 4 consumers who daily watch streaming video from an OTT service, and 3 in 10 who watch weekly, get “buffer rage,” which is defined as “a state of uncontrollable fury or violent anger induced by the delayed or interrupted enjoyment of streaming,” according to a survey by **IneoQuest**.|The report

Two-thirds (66%) said they became frustrated while video buffering took place. One in five (21%) said they experienced severe levels of irritation.

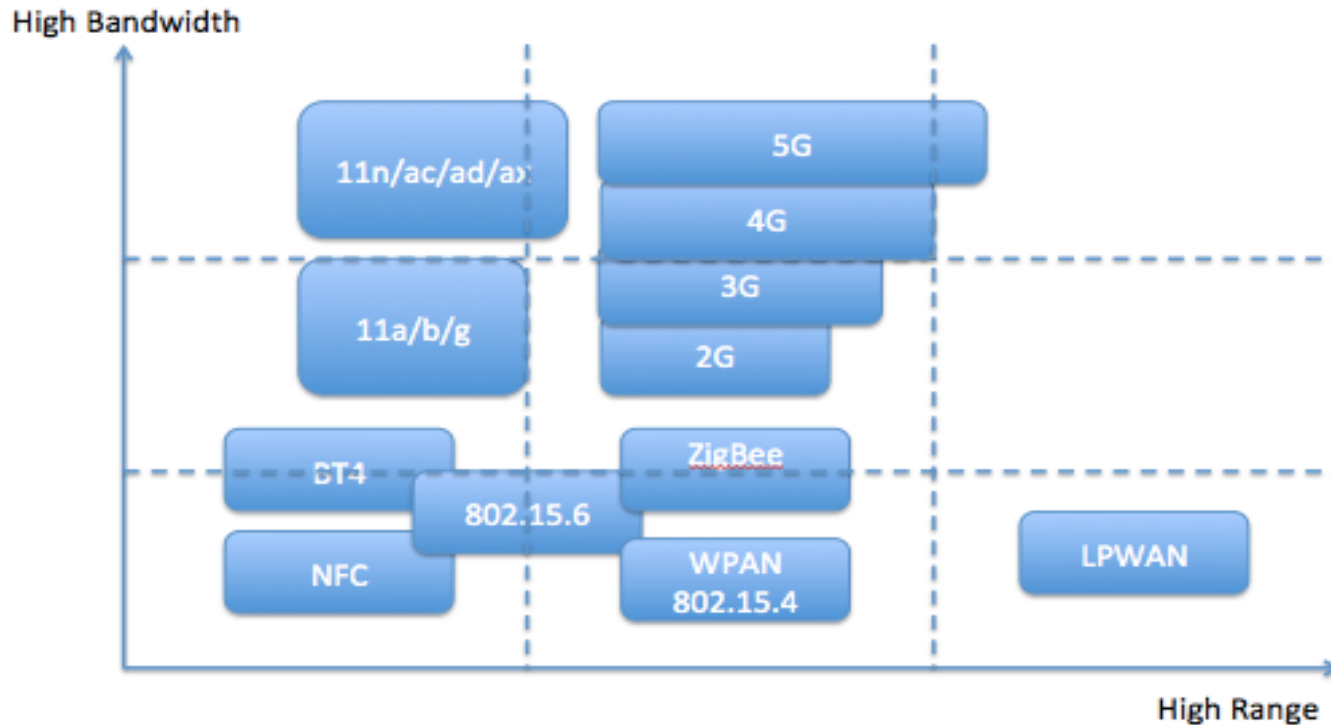
# Buffer Rage ← not enough bandwidth?

Frequency bands	Output port	Frequency range
Band 1	CDMA800+GSM900	825-960MHz
Band 2	GSM1800 +GSM1900	1800-1990 MHz
Band 3	3G	2110-2200MHz
Band 4	4GLTE	725-770 MHz
Band 5	4G WIMAX	2620-2690 MHz
Band 6	WiFi	2400-2500 MHz
Band 7	WiFi	Various 5 GHz

- **500 MHz of LTE/3G**
  - Different service providers
  - Say conservatively, even with MIMO/etc, 6 bits/Hz
  - 3 GBPS
- **Another 500 MHz of Wi-Fi**
  - Different AP's
  - Say 6 bits/Hz also
  - 3 Gbps
- **Together that is 6 Gbps**
  - Flowing through each one of us, HERE, NOW
  - Did we need a fiber to our body to get it?
  - Are we using it? Effectively? (probably not yet)
- **Really no MIMO, no Wi-Gig, etc included yet**



# Present Day “slotting” of bands



- But start to aggregate them and then what?
- Virtual Network Operators can
  - Buy from anyone
  - Buy from more than one

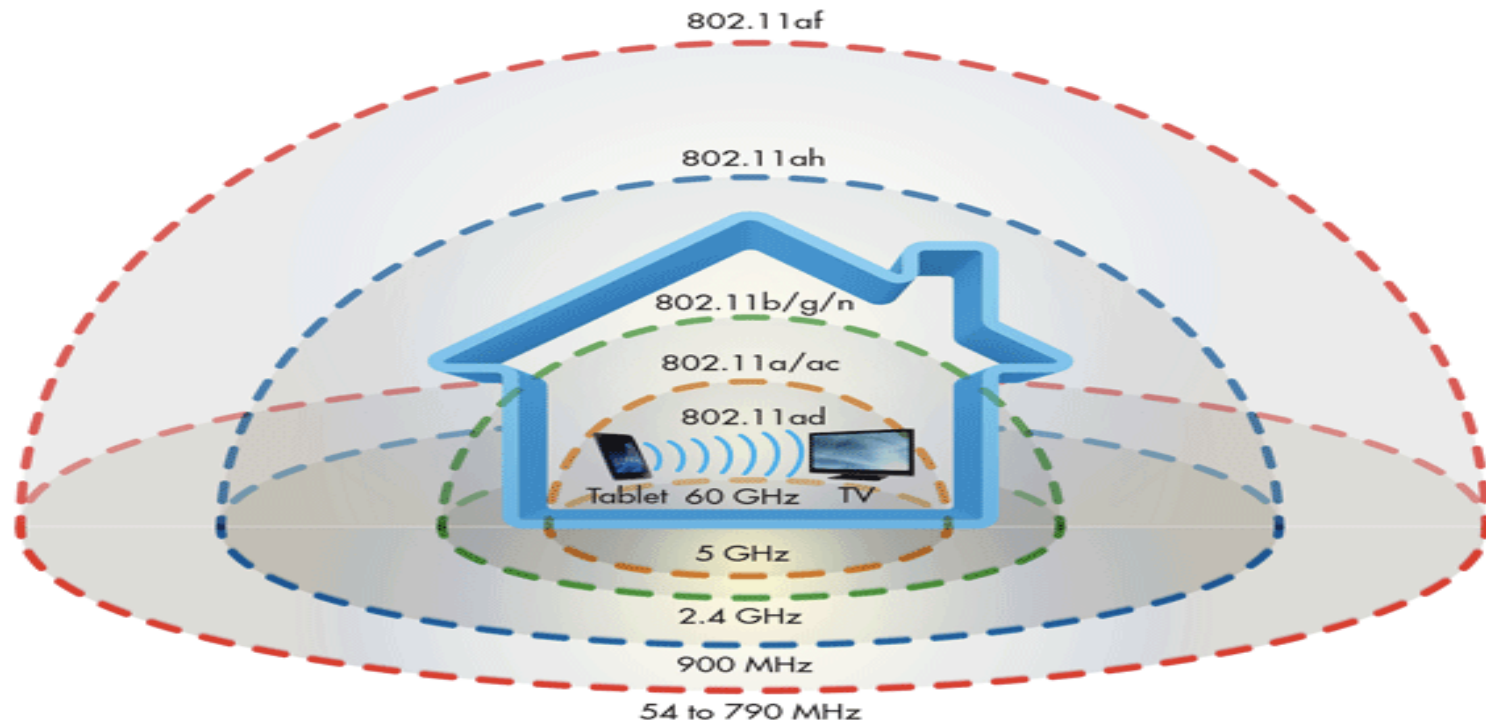


**ASSIA**

# Wi-Fi

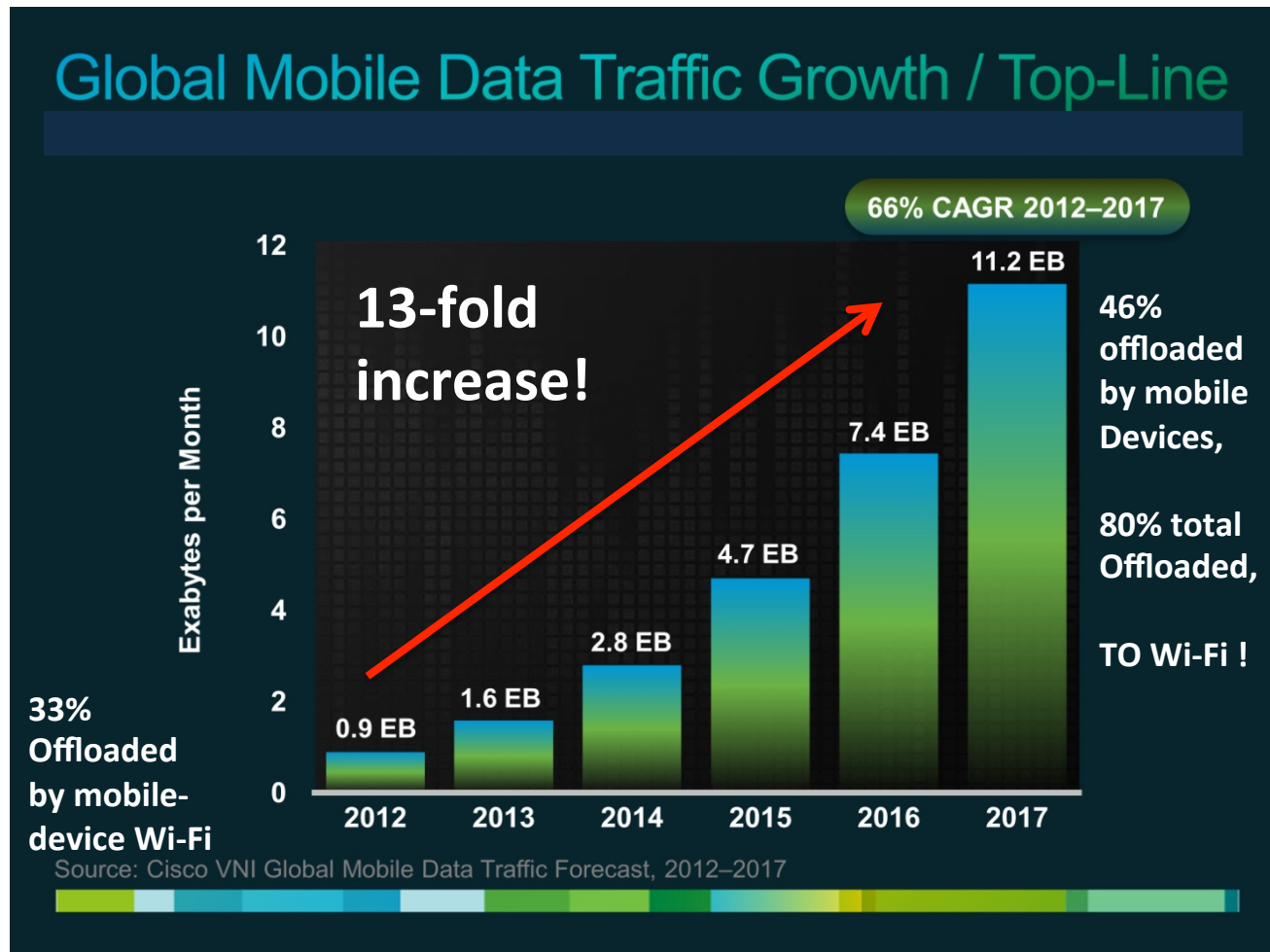


# Wi-Fi coverage and raw speed



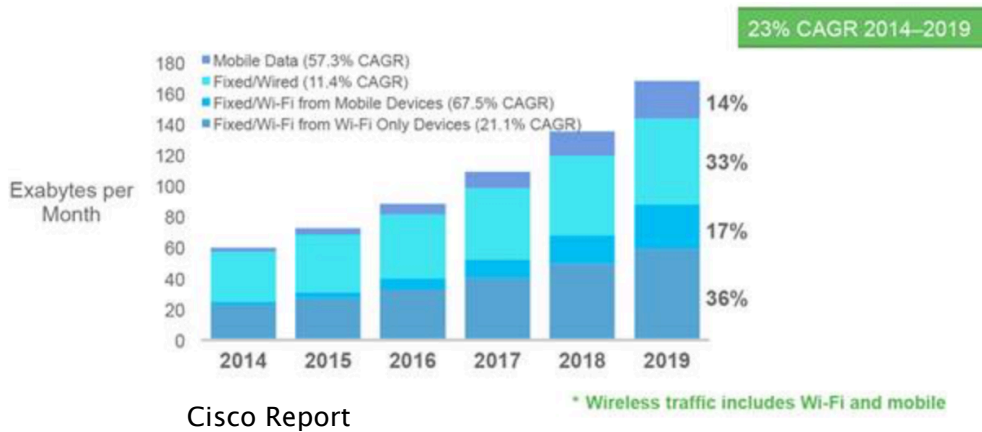
- **From 1 Mbps to 10 Gbps are physical-layer absolute-peak speeds**
  - Bands are shared, available to all consumers (unlicensed)
    - At least so far within each standard
- **Throughput can be much much less**

# Mobile data traffic growing enormously

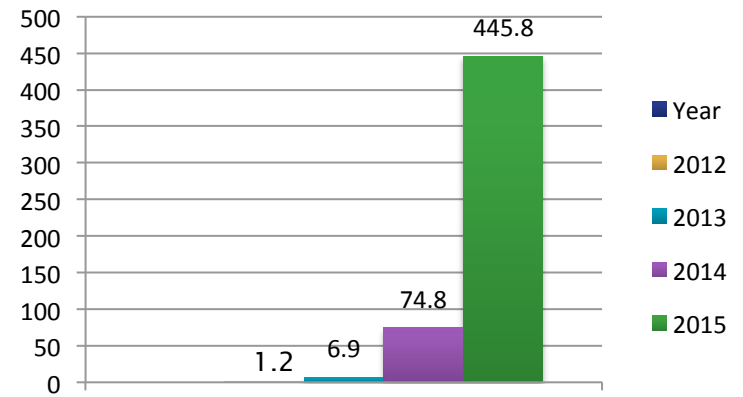


1EB (exabyte) =  $10^{18}$  bytes

# Latest data-use/Wi-Fi

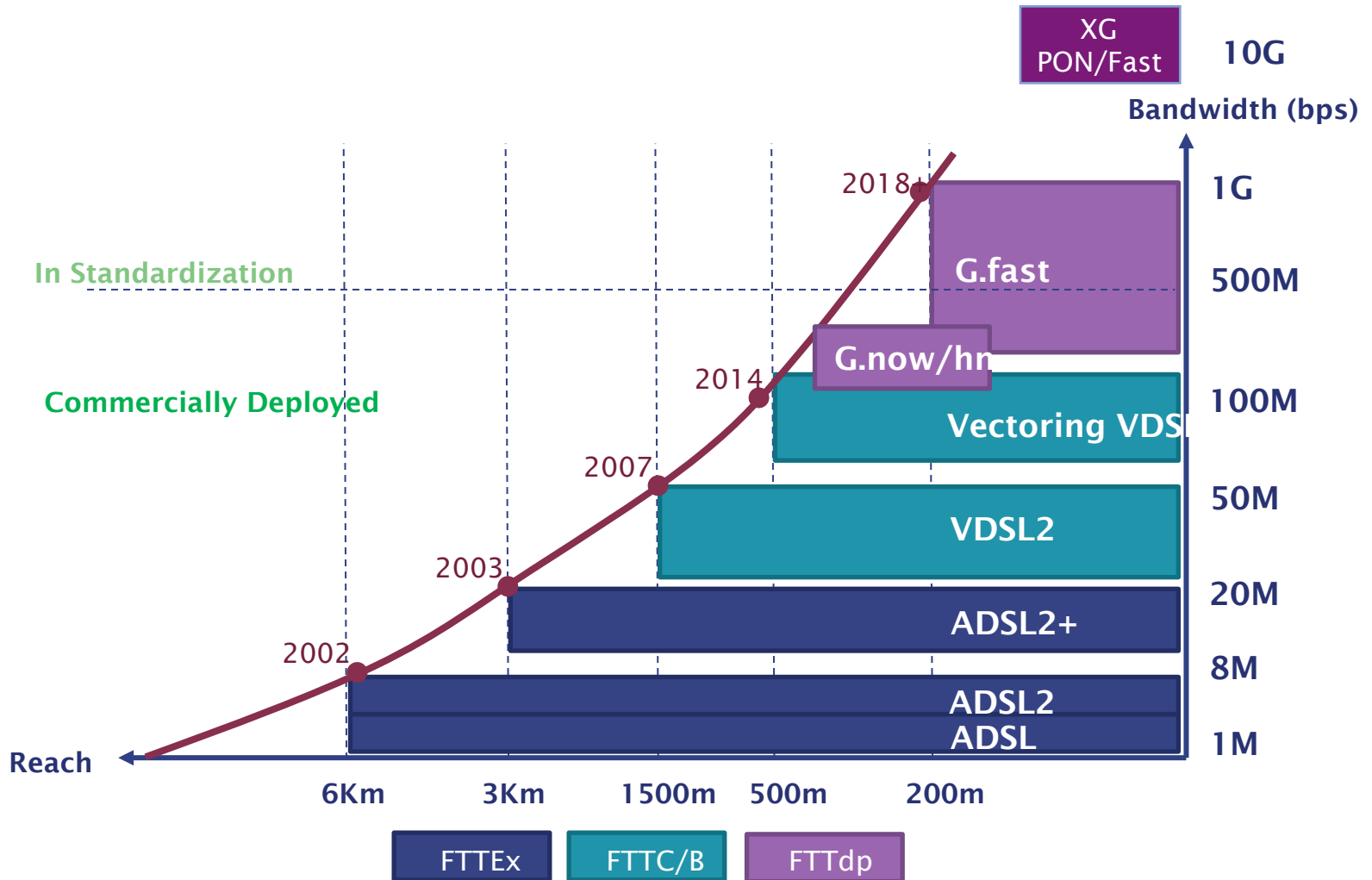


Comcast Wi-Fi data growth (Pentabytes)



- **Wi-Fi bands (all of them) will be increasingly congested**
  - Add in LTE-U and/or LAA in Wi-Fi bands
- **As a percentage, fixed/wired (no Wi-Fi/wireless) decreases**

# xDSL & Fiber: Wi-Fi's "backhaul"



Source : TNO 2012



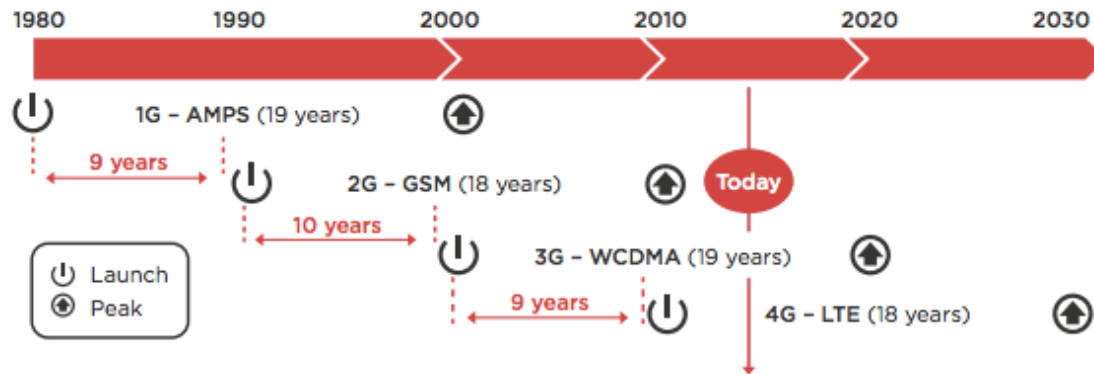


**ASSIA**

## 5G “licensed”



# nG evolution

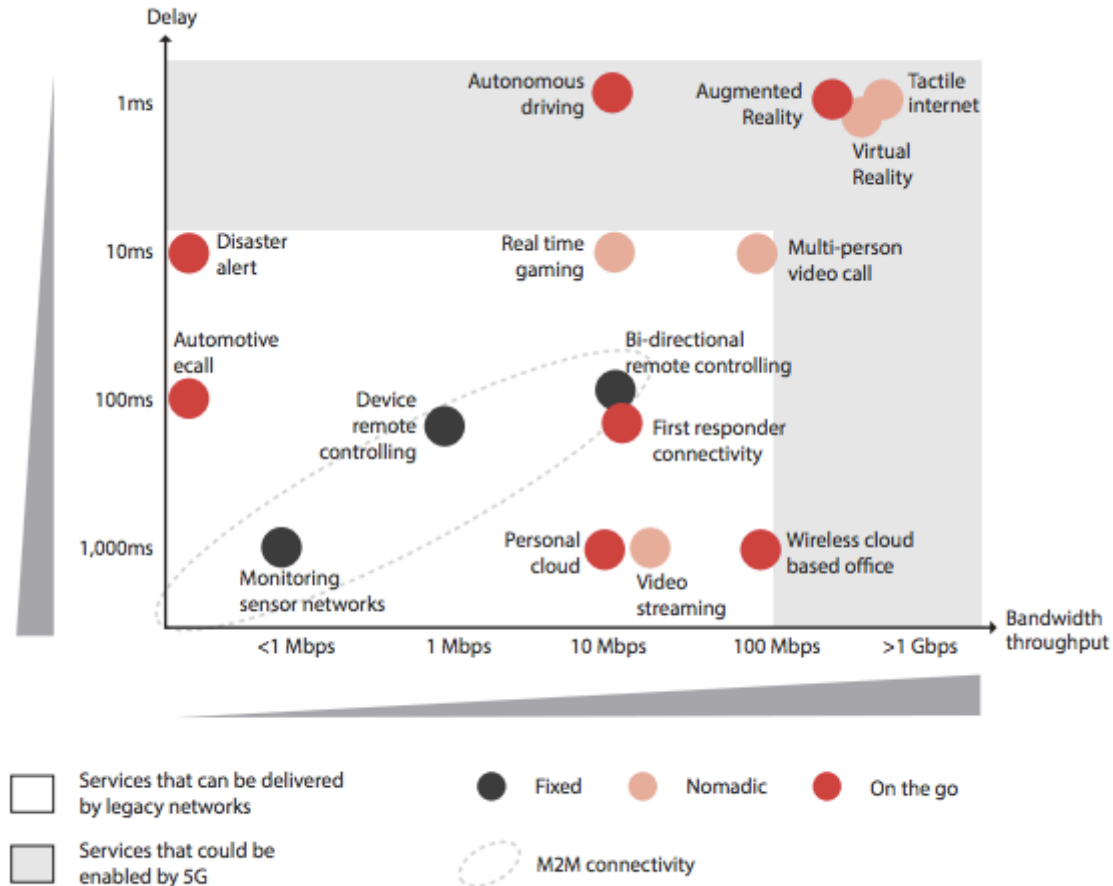


Cellular Technology	Main Benefit	Strengths (vs. previous gen.)	Weaknesses (vs. next gen.)
1G	Analog Phone call	Basic mobility	Poor spectral efficiency, security issues
2G	Digital call + txt messaging	Mass adoption, security	Limited data rate for email/internet
3G	2G+ Data	Internet experience	Failure of WAP
3.5G	3G with faster data	Broadband Internet applications	Legacy backend, architectures, protocols
4G	All IP (call, messaging, data)	Lower latency, faster internet	To Be Determined by 5G

- **Range somewhat fixed**

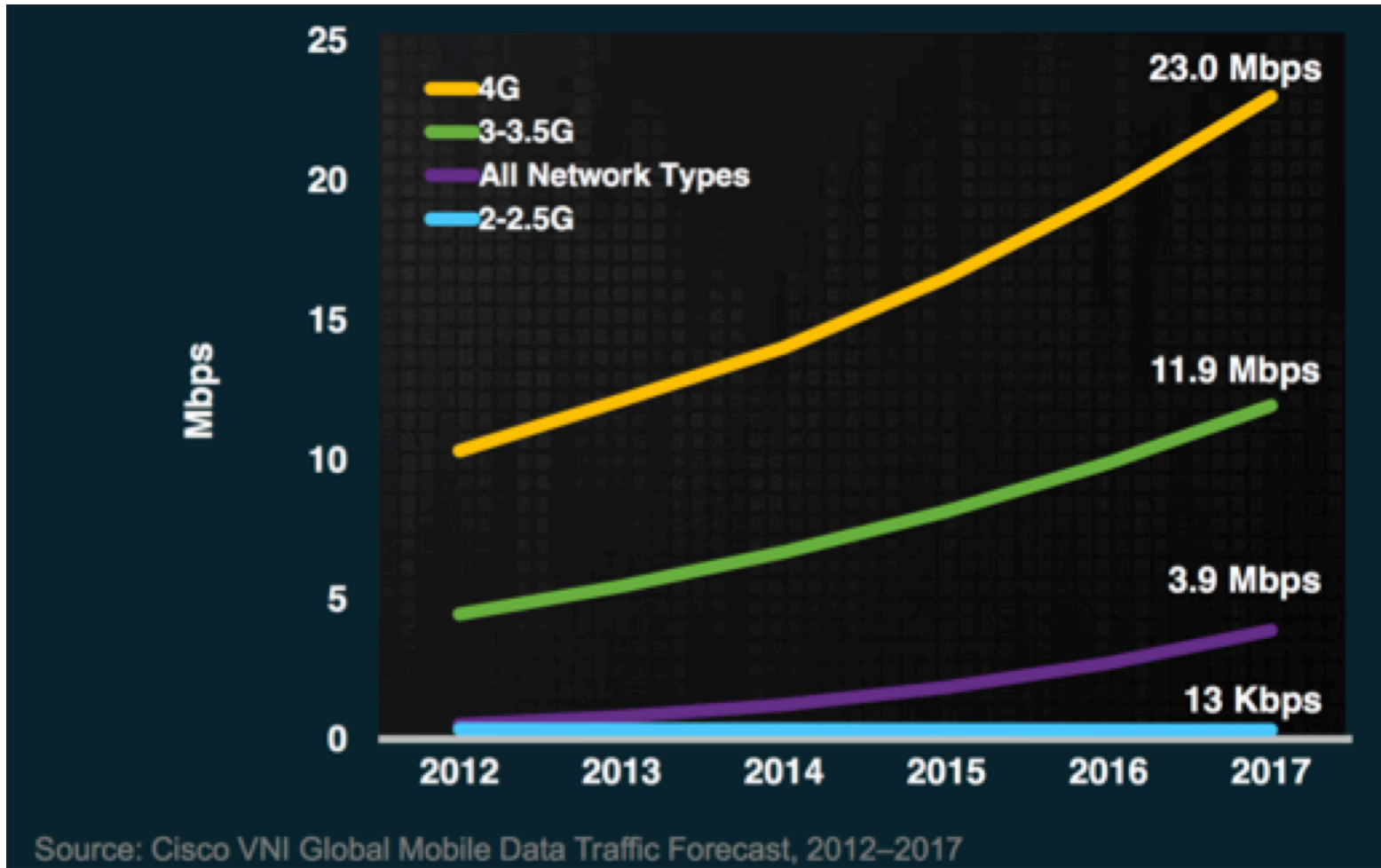
- No sharing, each service provider has their own band
  - Of course they can add MVNO's, but each has dedicated slot when needed

# Present conventional 4G → 5G



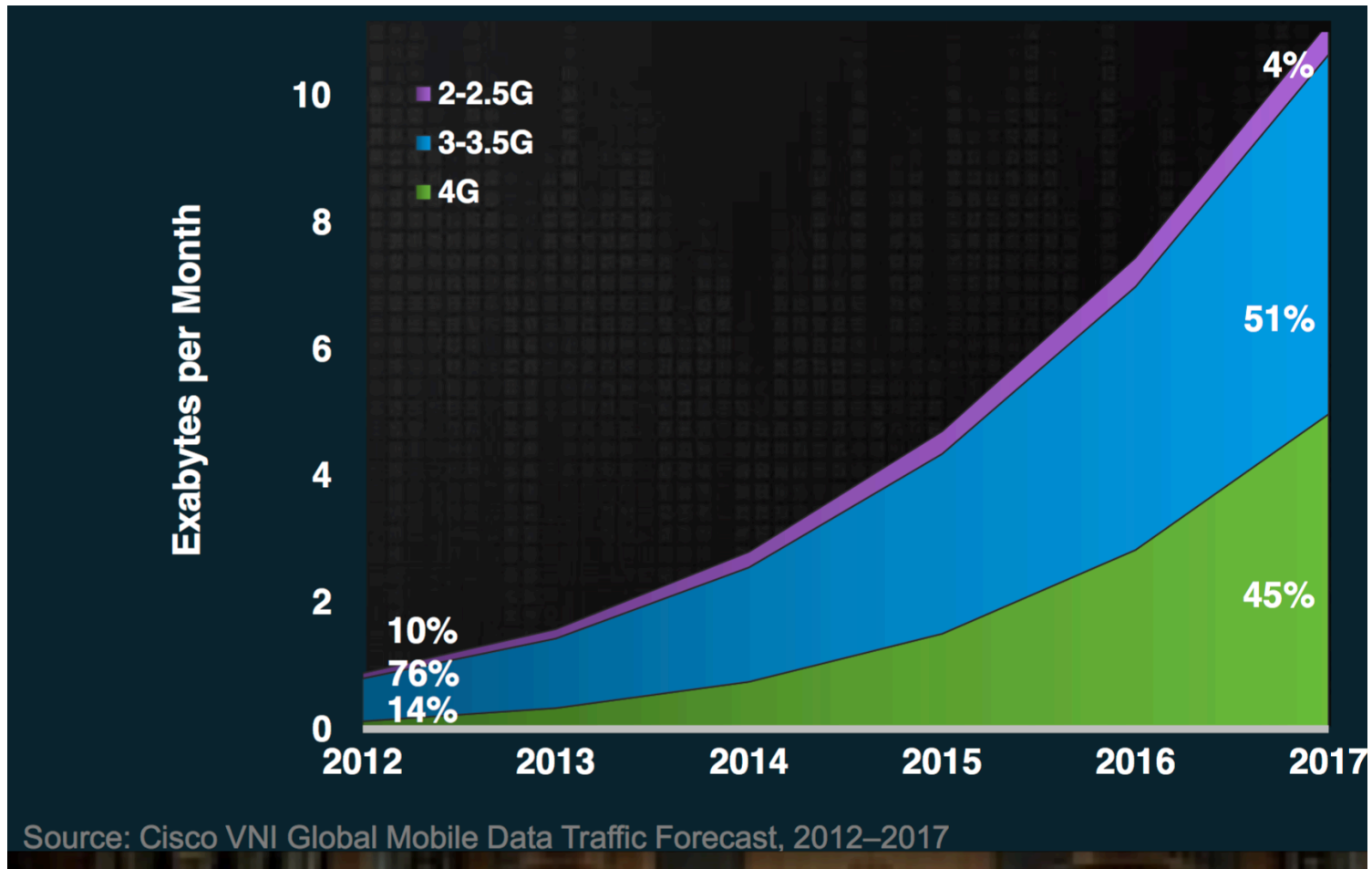
- **Makes 5G just wider spectra of 4G**
  - Each carrier buys more spectrum

# Speeds/device-operator



Throughput can be considerably lower  
(LTE can go to 100 Mbps +)

# Mobile nG distribution

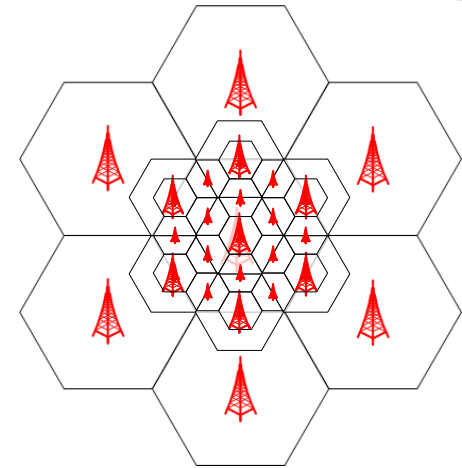


# 5G Themes

(Any and/or All fixed and wireless)

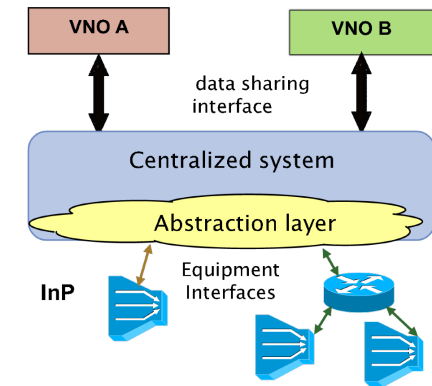
- **Convergence of fixed-line and wireless**

- Smaller and smaller cells
  - Need “wire” to each antenna
  - Frequencies and channels used
  - Power levels, contention choices
  - Aggregation of bands
- Wi-Fi is a small cell



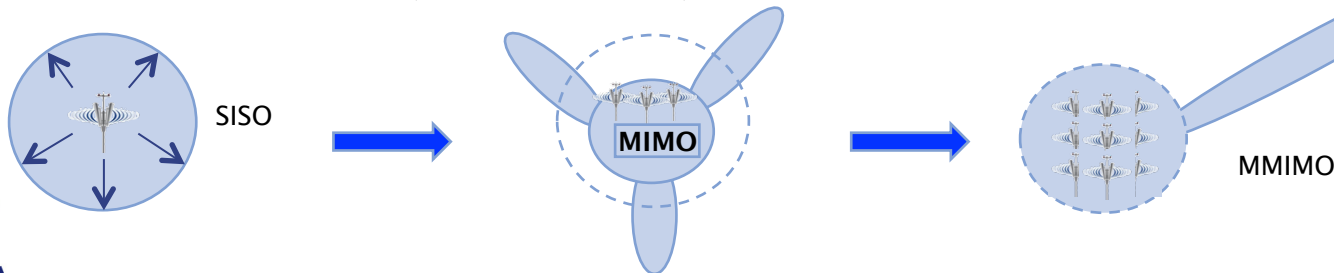
- **Software-Defined and Virtualized Networks**

- Provision services in real time
- Also used with Wi-Fi (MVNO → VNO)



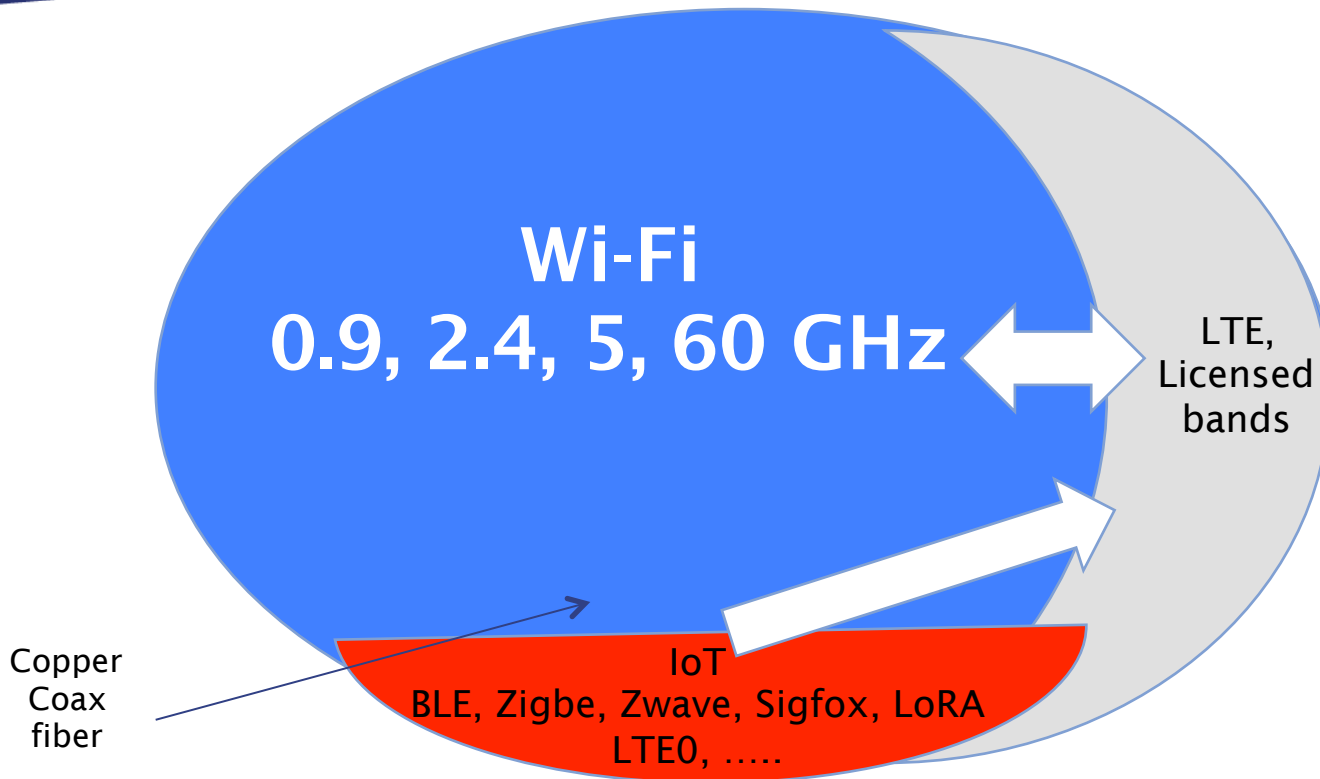
- **Massive mmw (also in Wi-Fi)**

- Above 5 GHz (28-200 GHz)





# Wi-Five → G ?



- **Unlicensed Wi-Fi bands will grow**
- **Low frequencies, af and ah**
- **mmW frequencies, ad**
- **3.5 GHz ?**



**ASSIA**

# Connection Stability and Problems



# Unstable connections → cost/churn

(ASSIA experience on 80M connections)

**Instability:** Combination of speed variation, packet errors, outages, consumer calls/complaints, the type of app running

Instability based on field measurements			
connection	Nominal	Best (managed)	Speed
Fiber (PON)	16%	6%	90 Mbps
Cable	20%	---	15 Mbps
ADSL2+	15%	7%	10 Mbps
VDSL2	18%	7%	25 Mbps
Vec VDSL	45%	8%	75 Mbps
Wi-Fi (11g)	50%	15%	10 Mbps
4G – LTE	Not good	→ 10% ?	10 Mbps

- **Based on 90-95% distributions**

- Meaning these fractions of customers are seeing worst case 5-10% daily or more frequent

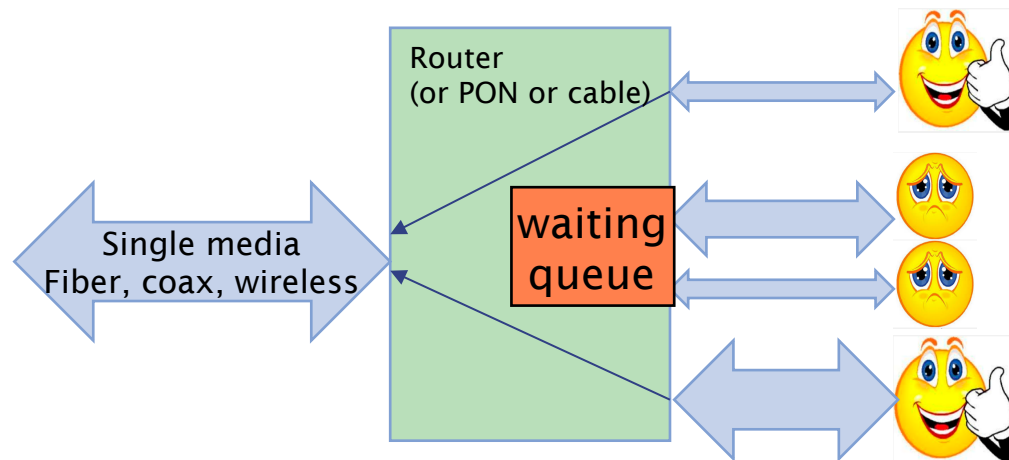


# Throughput Variation (peak-to-ave) → cost

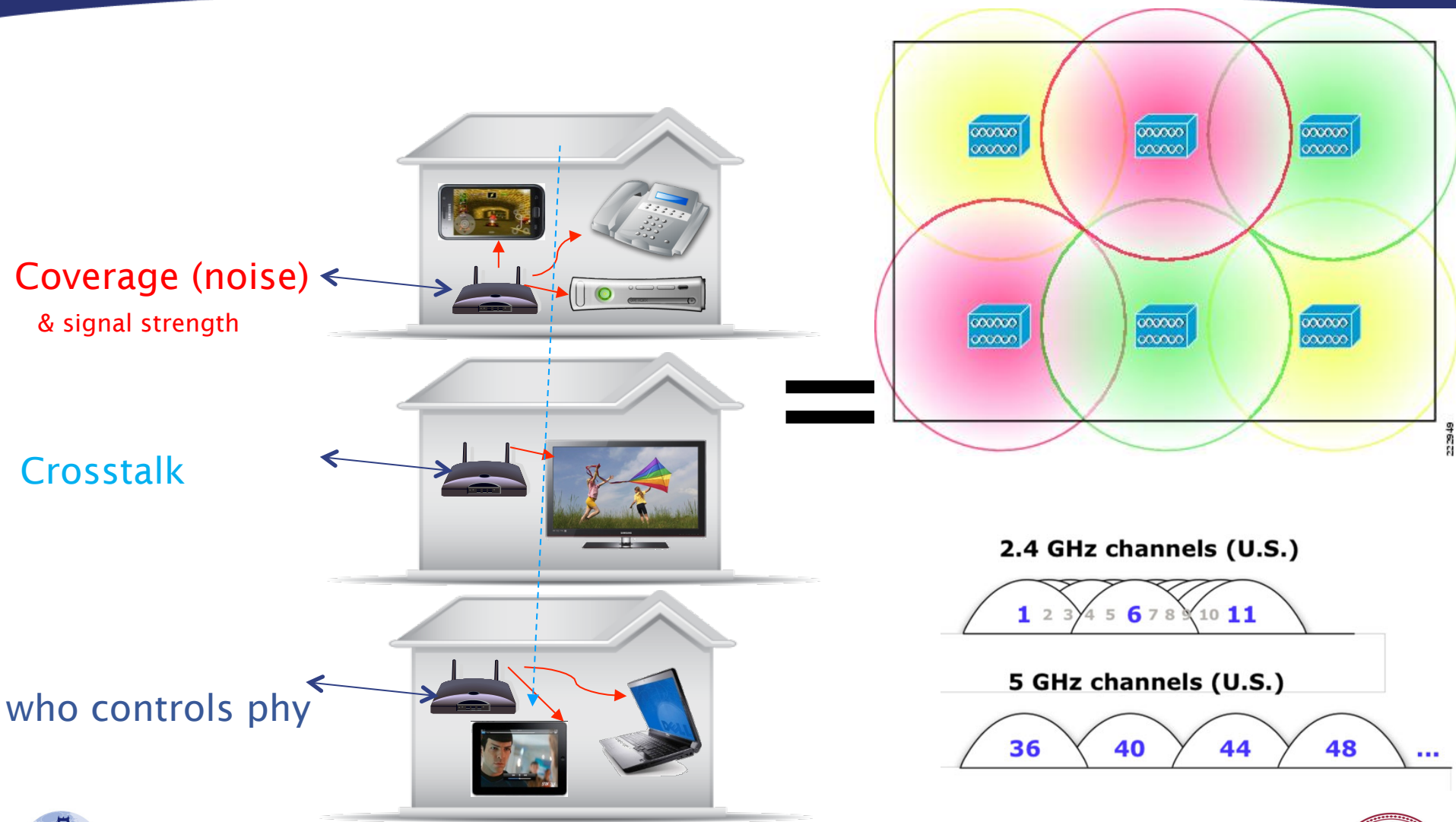
- **BB access connect variation**

Source	Ratio
FCC 2013 Report (ave) 80%	1.2:1 2:1
Akamai 2014 ave of 100% (over all)	8:1
ASSIA @95% @ 80%	4:1 1.3:1

- **Buffering issue**



# Wi-Fi "Hot" Spots and Problems



# Cocktail Party Effect (crosstalk)

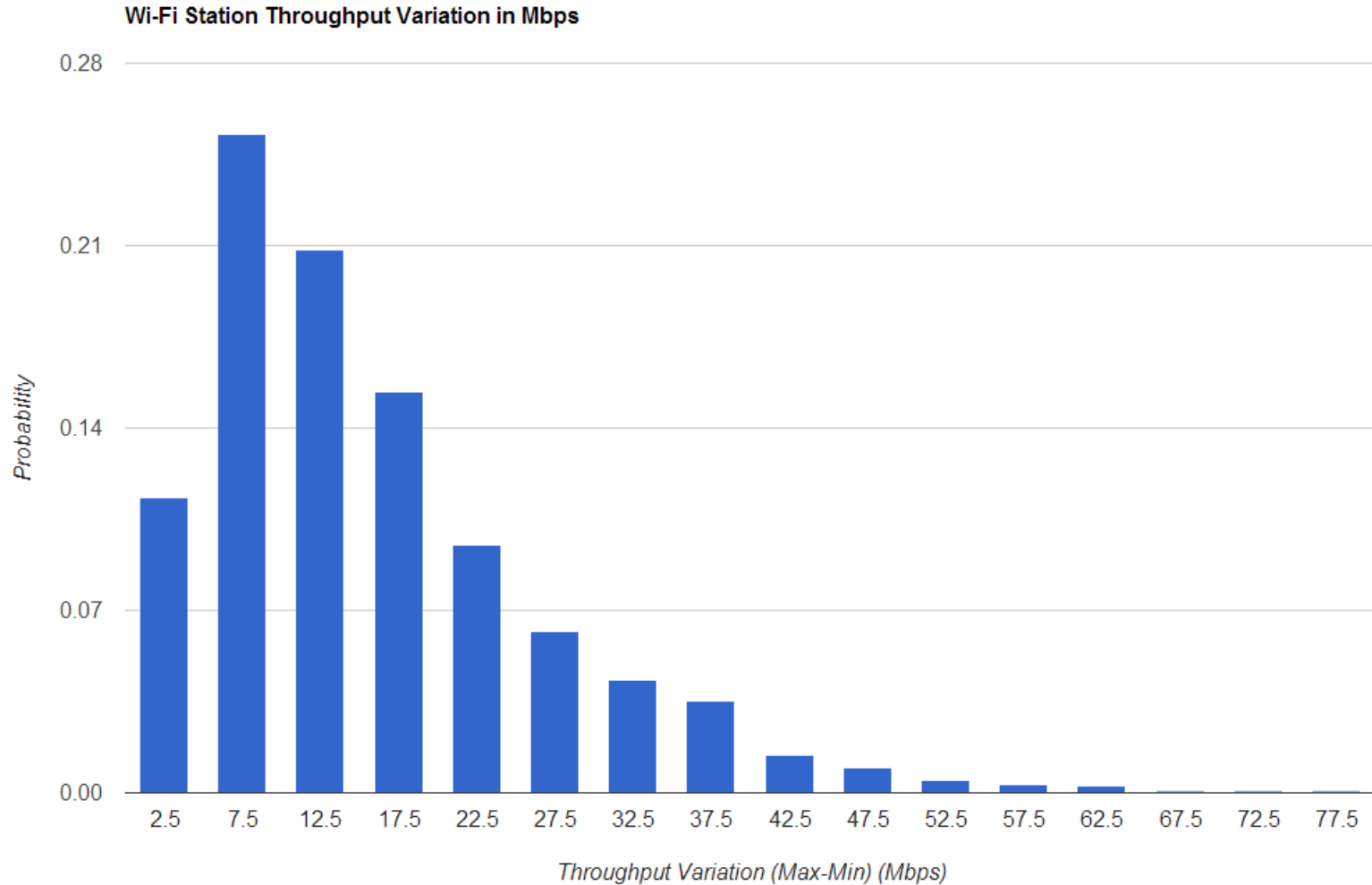


- **Solution: All speak politely at low volume (lower power)**
  - All send more information (more power and/or higher data rate)
- **This is how dynamic management works with DSLs, Wi-Fi, sharing**
- **EG: Wi-Fi Box/Chips blasting at 1-10 Gbps !**
  - *Or worse yet – install repeaters/mesh and have them all blast*



# Wi-Fi Speeds & Stability

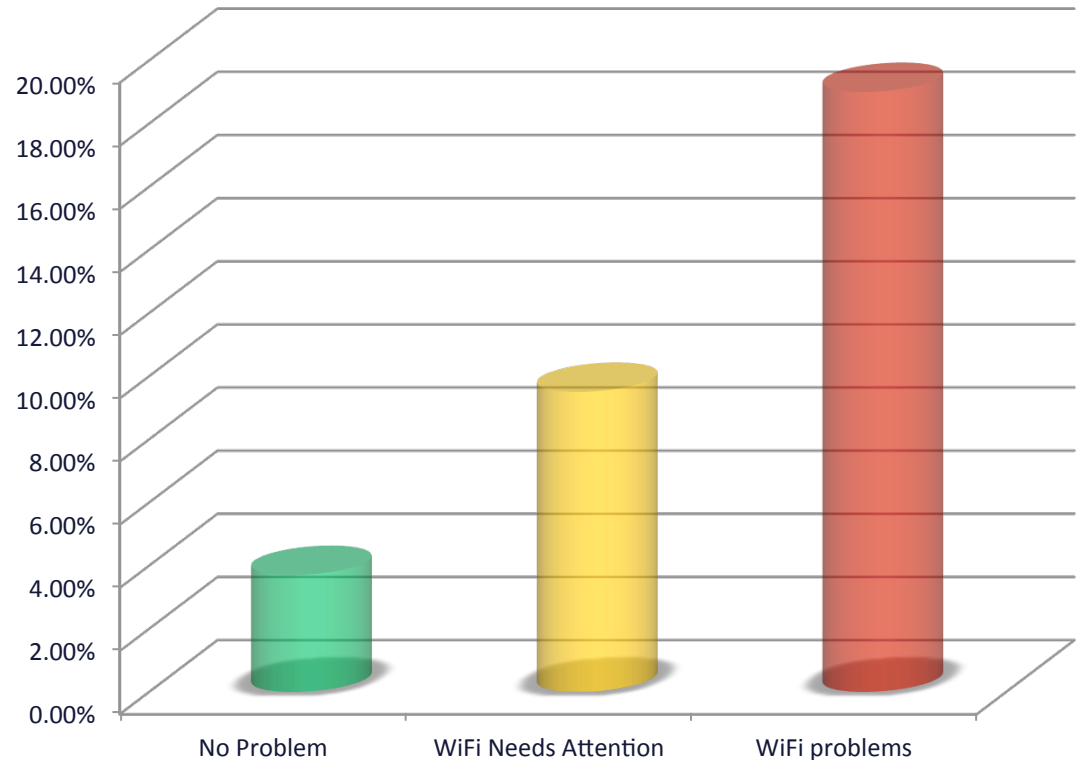
Neighborhood (same supplier) of 300 AP's 3000 devices



# Poor Wi-Fi can drive customer complaints

- Strong correlation between WiFi problems (as identified by ASSIA ) and Complaint Rate
- 48% of APs have WiFi issues
- Customers identified as having poor WiFi performance are 5 times more likely to complain

Customer Complaint Rate

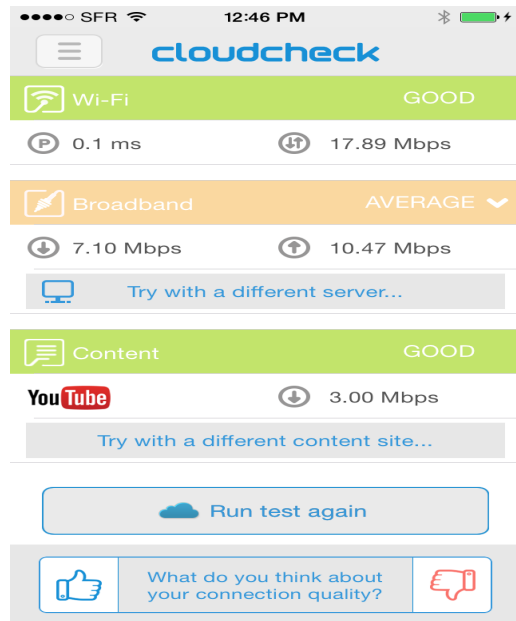


ISP's now beginning to deal with it, especially if their gateway has Wi-Fi

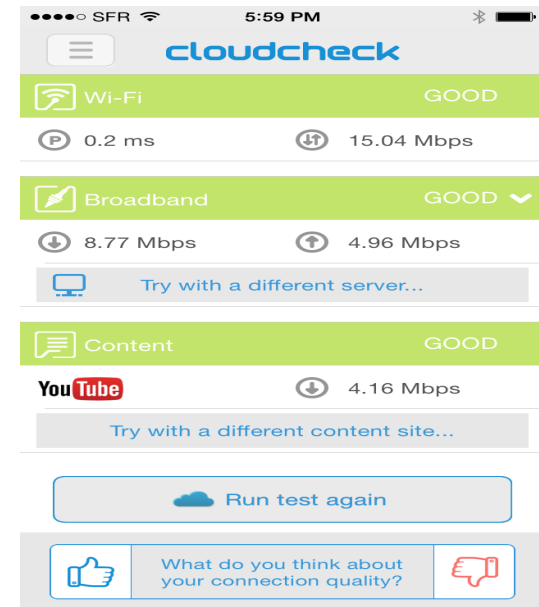
Google Head of On-Hub- "It's Comcast's Problem"  
no, not really, it's your problem too - think about it

# Wi-Fi is not always the problem

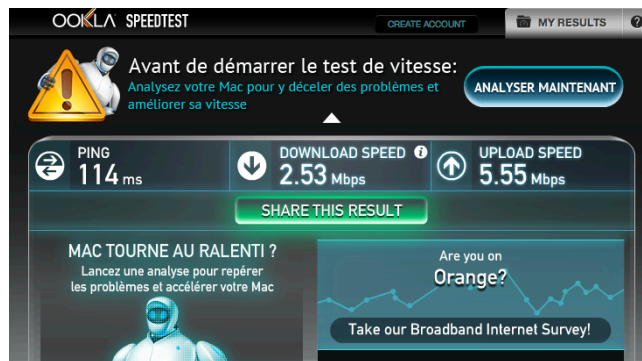
- Orange Fiber – Sept 24, 2014



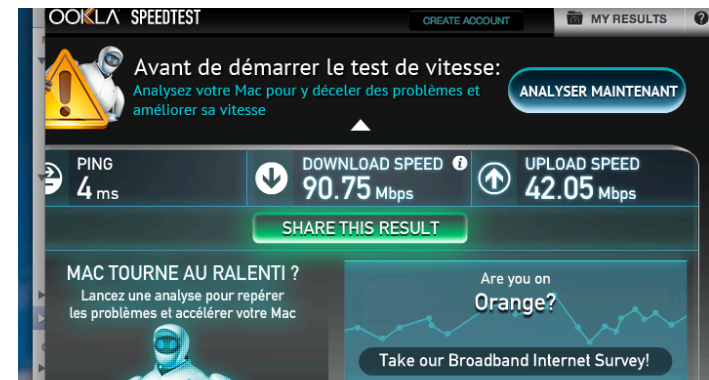
- 5 hours later



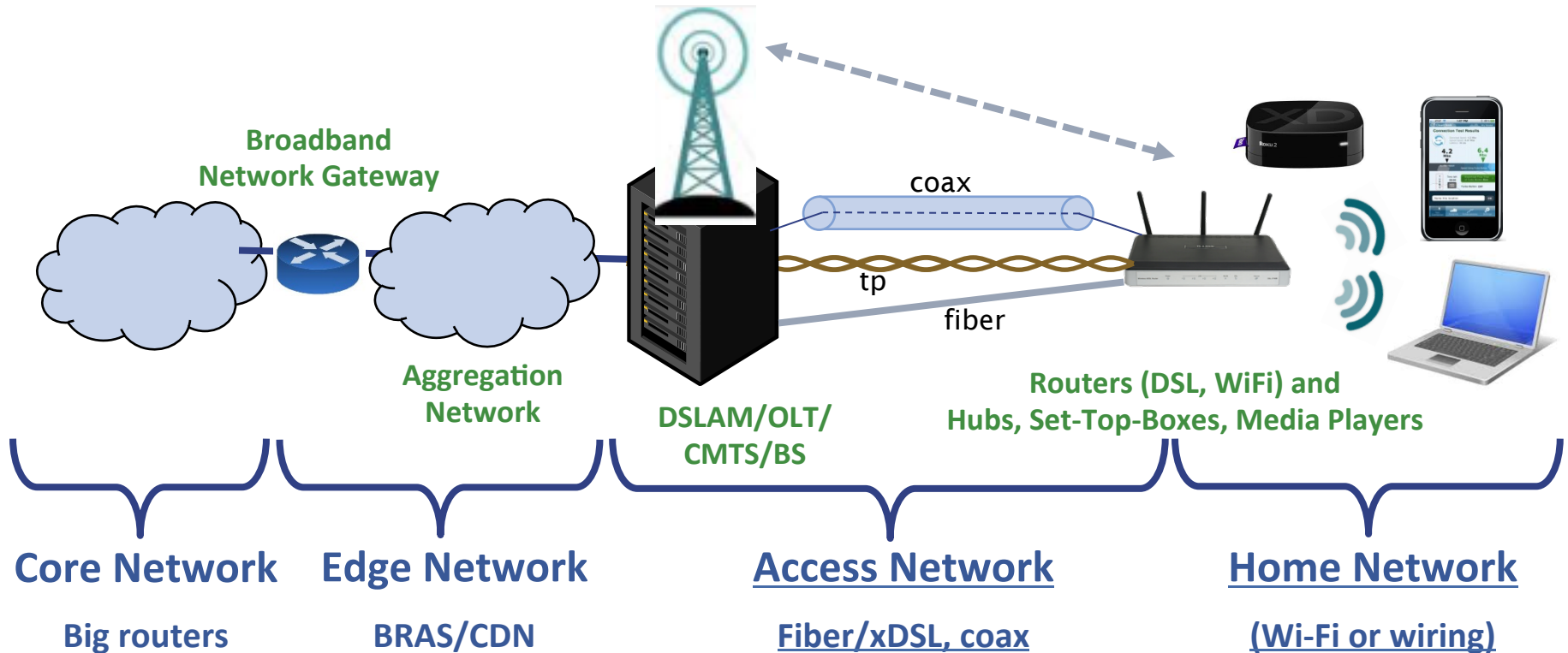
- 20 Oct 2013, 18:45



- Next day, 7am



# Where is the problem? (5G needs this)



Increasingly likely to reduce stability



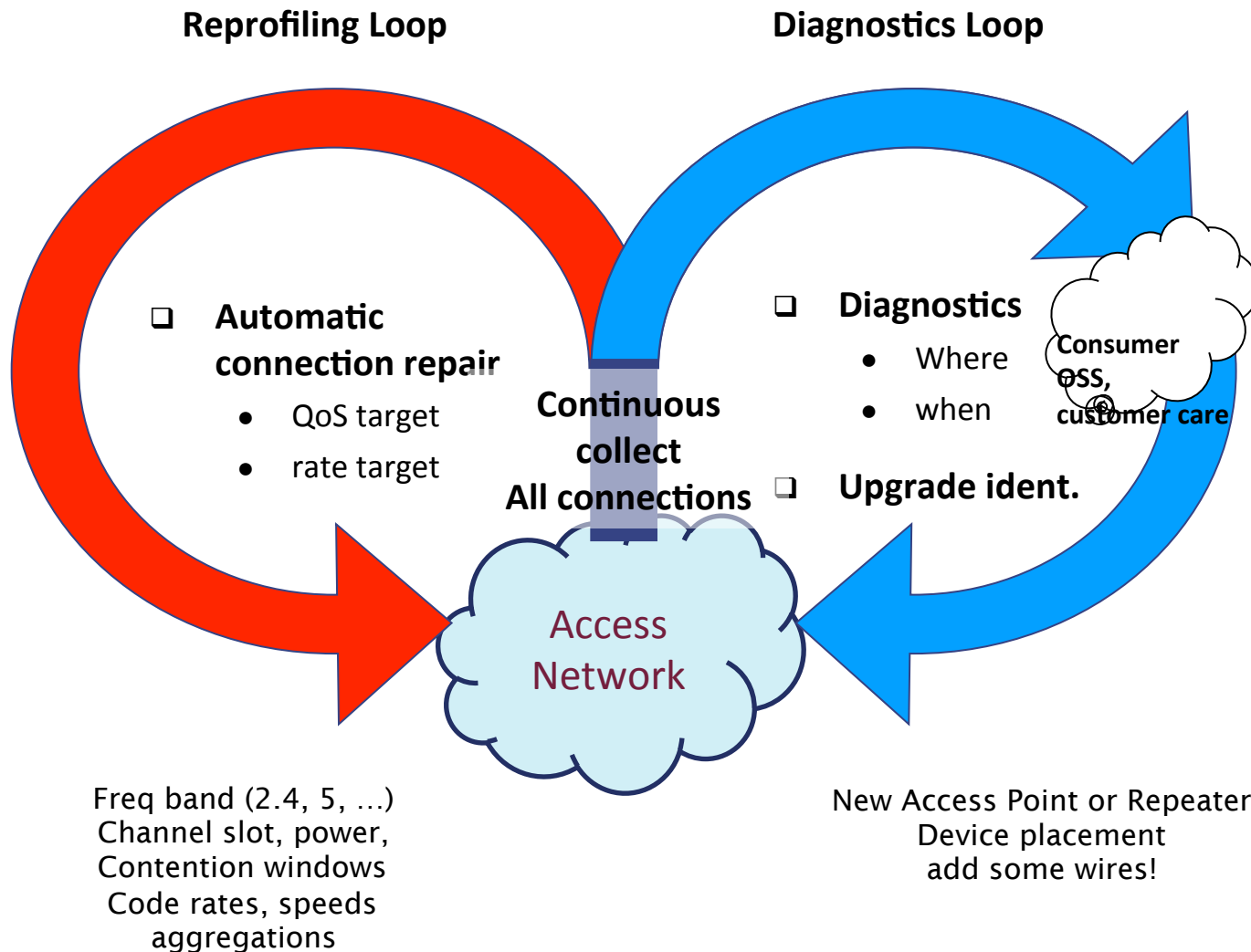
**ASSIA**

# Dynamic Optimization

*A Fix*



# Basic Optimization and Diagnosis



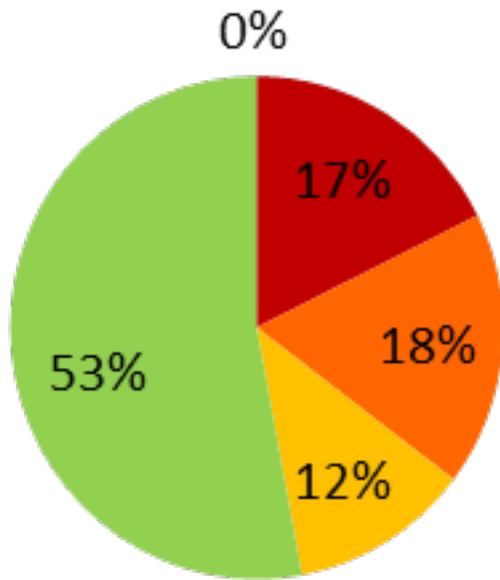


# Which touch points needed/nice? (for optimization)

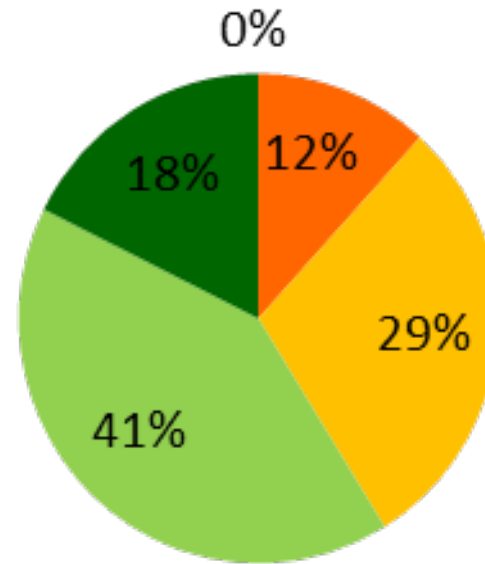
- **One end point (typically device app)**
  - Good first step, but not needed if AP supports
- **Access point may be better when possible**
- **OLT/DSLAM/Cable-Head (SNMP/TL1)**
- **Other server network URL's**

# Typical Field Wi-Fi Results (11n – 90%)

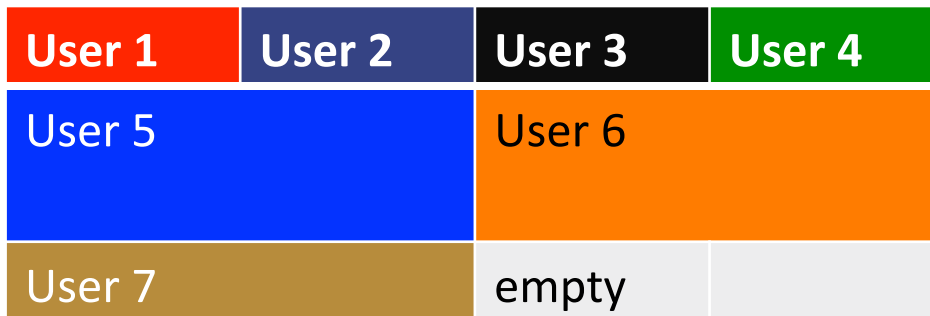
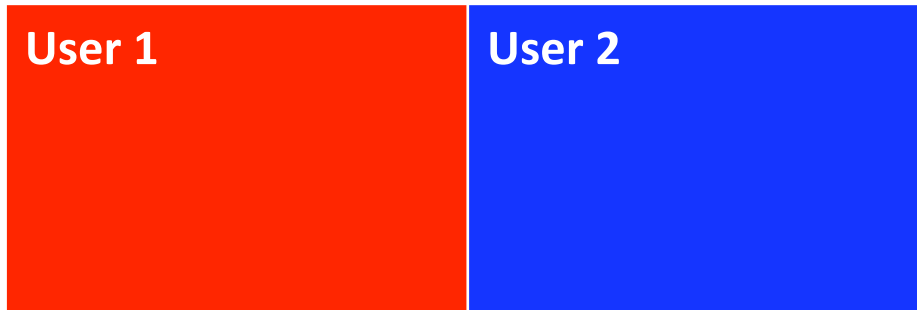
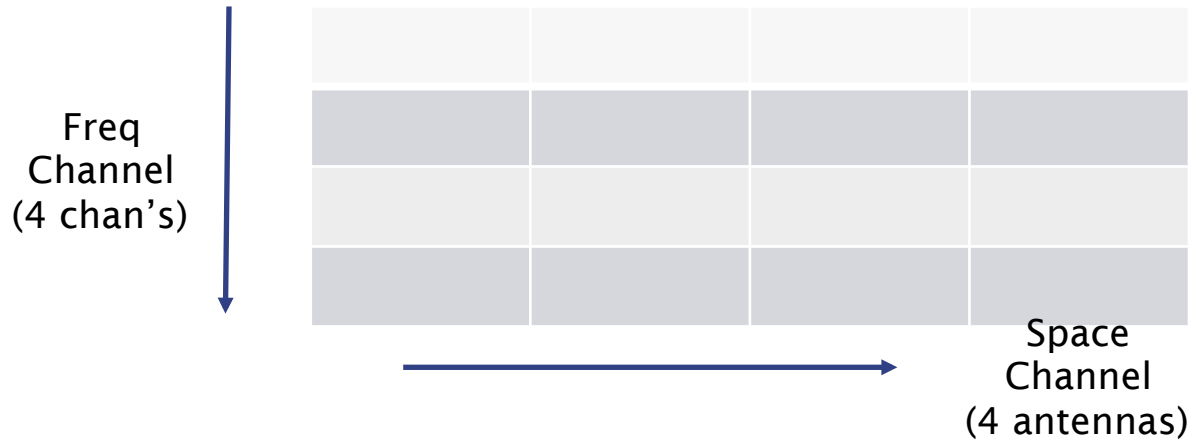
Before opt



After opt



# Neighborhood Management of channels & space (MIMO)

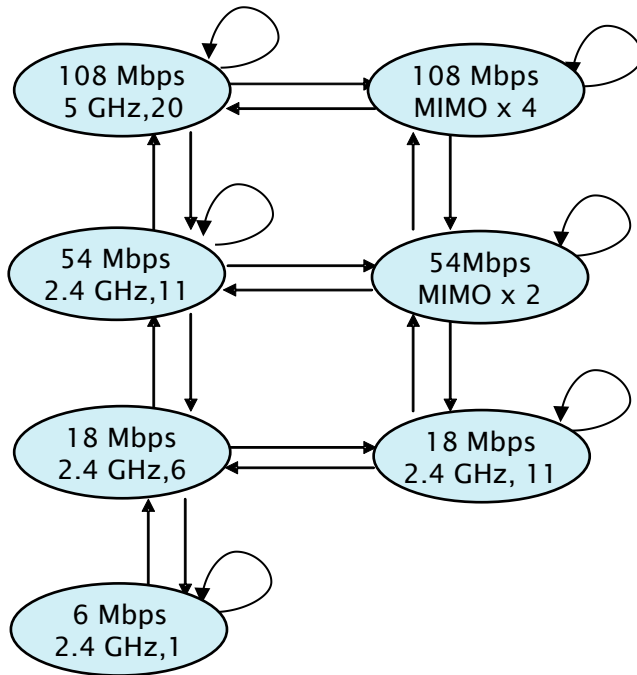


- Basically 16 slots (each say ~ 54 Mbps)

- How a box vendor does it

- Cloud managed
  - multiple SSIDs

# A Wi-Fi State Management Diagram



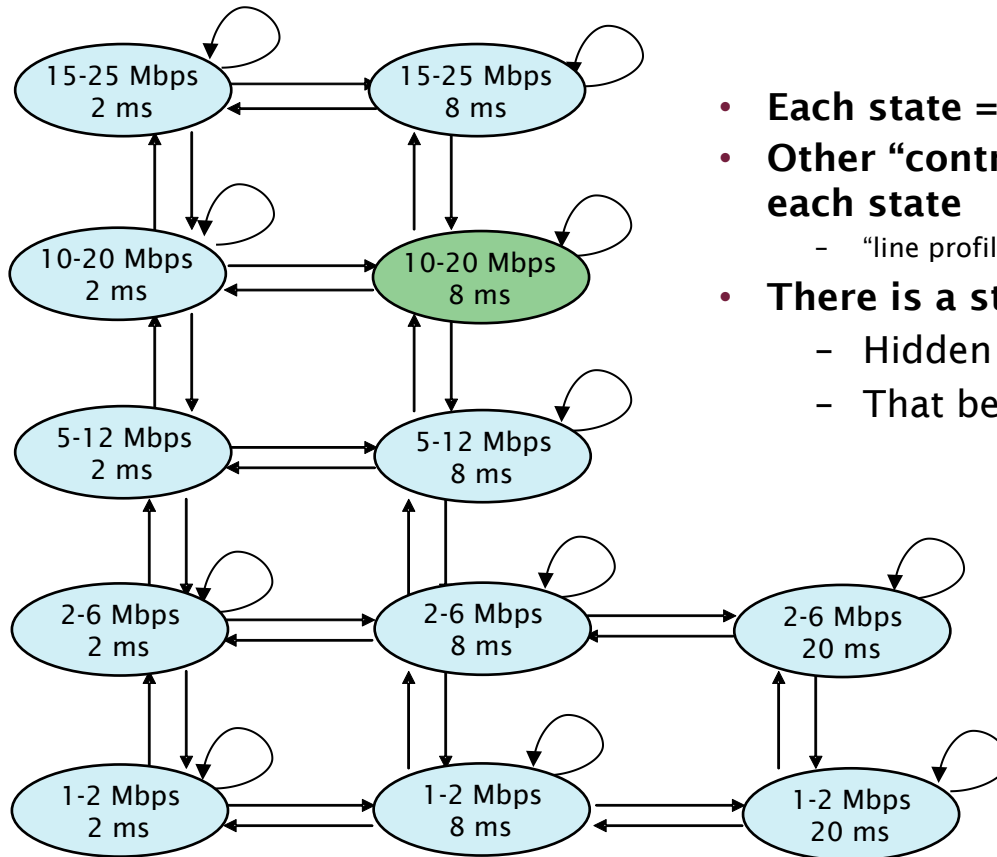
Oversimplified

Often more states and  
More rate ranges

# Combined Optimization State Diagram

- **Vectors of States  $\rightarrow$  state**
- **State = [fixed-line , Wi-Fi ] – single connection**
  - Or with multiple connections
- **State = [Wi-Fi, LTE] – single connection**
  - Or with multiple connections
- **State = [state of device 1, device 2, .... , device n]**
- **Any combinations of the above**

# A DSL State Management Diagram



- Each state = “service” profile
- Other “controls” function of data collected in each state
  - “line profile”
- There is a state where consumer is happiest
  - Hidden Markov (1=happy, 0 = enraged)
  - That best state can move with time/situation

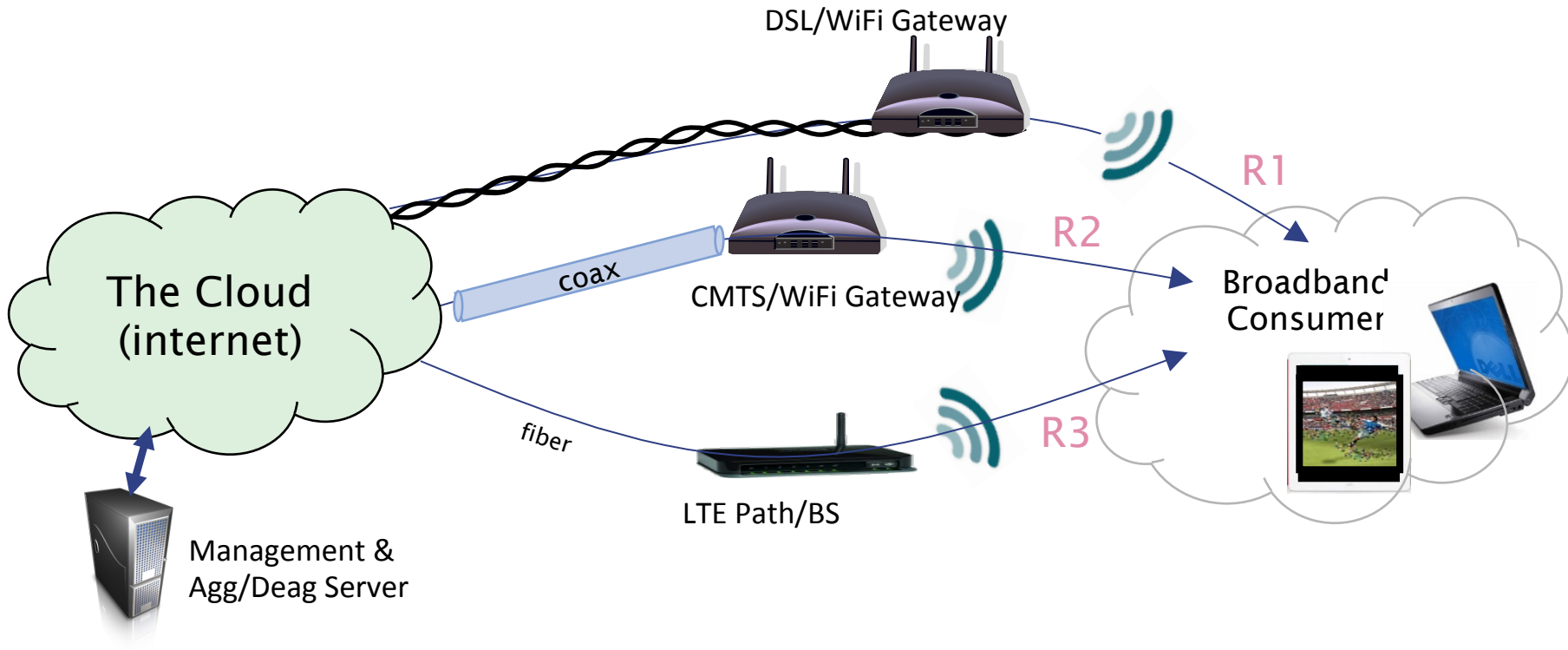


**ASSIA**

# Aggregation and Bonding



# IP Layer Bonding & Mesh Networks

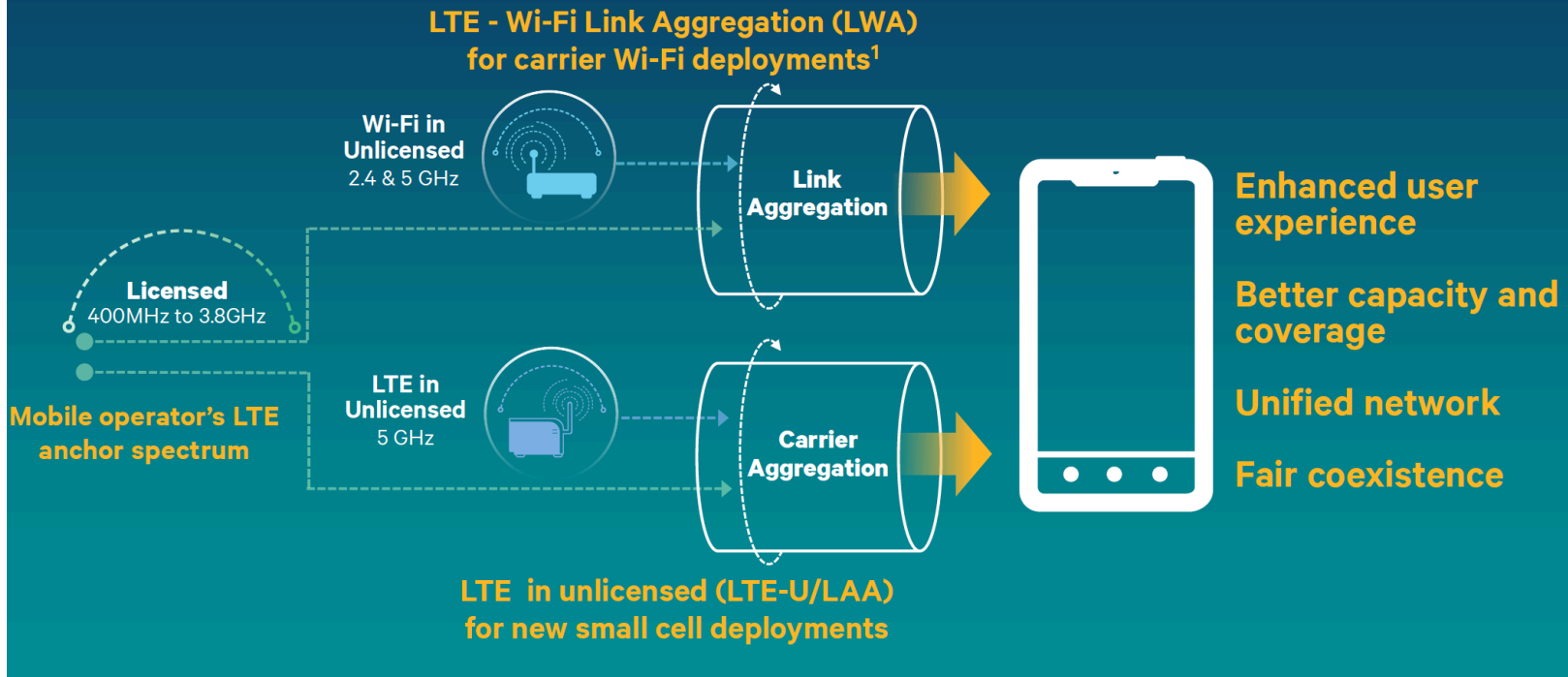


- **Total data rate  $R1+R2+R3$** 
  - Increase speed
  - Or allow hand-over
  - Insure secure link, both from stability and from other viewpoints
- **Allows RELIABLE Gbps PER Consumer**
- **Much cheaper than fiber to the customer, and sooner**



# LTE-U and LAA

Aggregation with licensed spectrum provides best performance

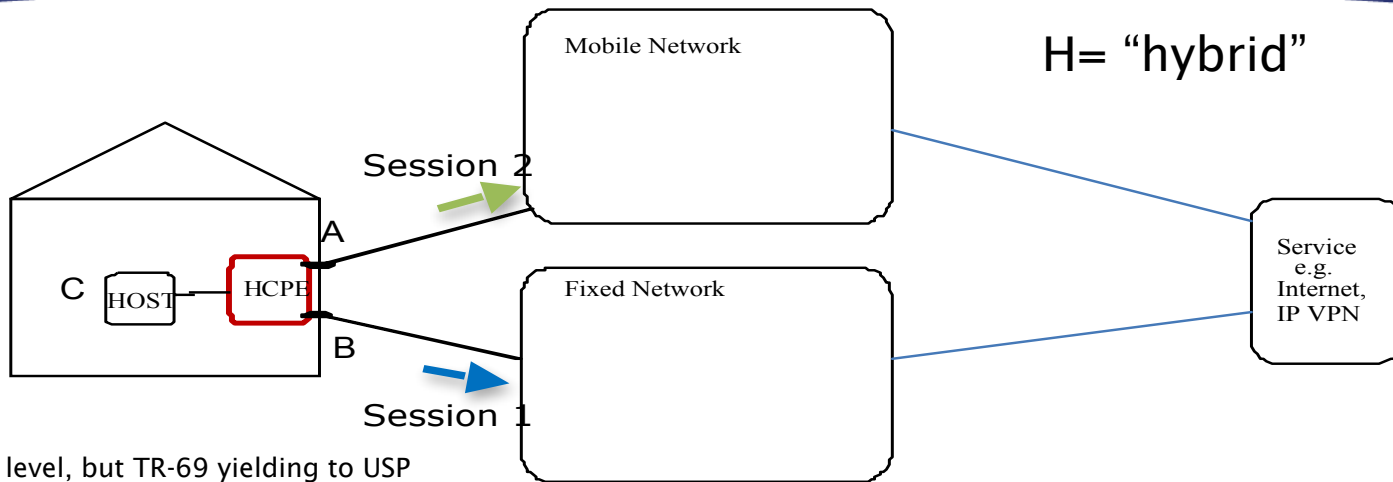


Qualcomm 09/15

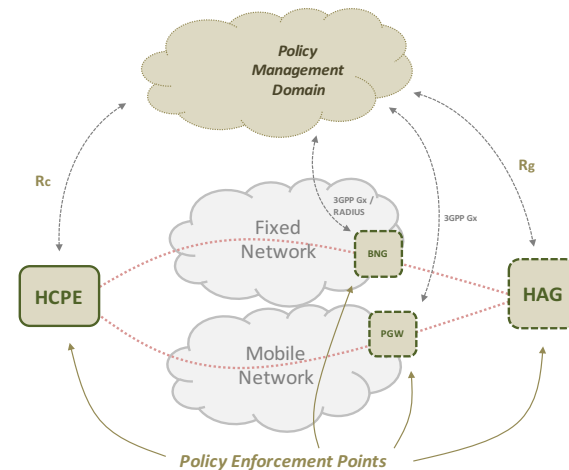
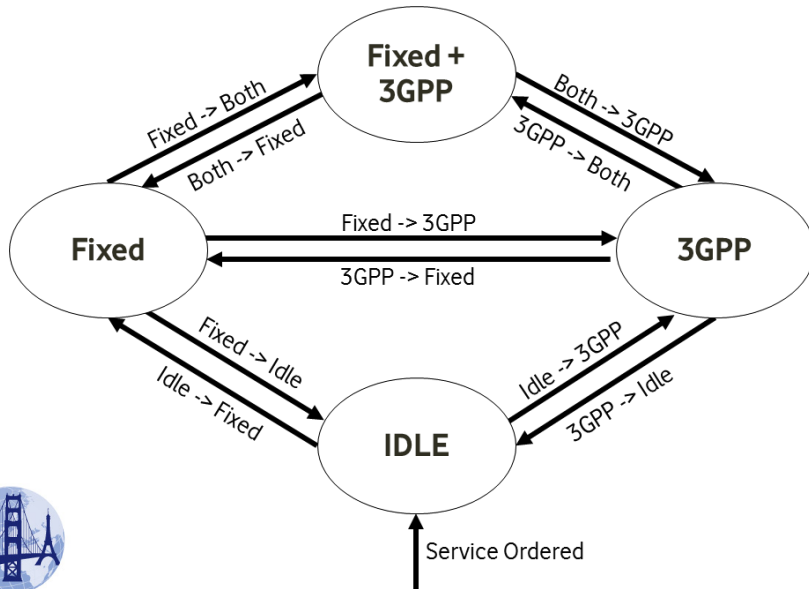
Similar, but may use different wires for backhaul  
*(theoretically must use more space-time spectrum - unless only at femtocells)*

# Early Sharing Standards

## Broadband Forum – WT348

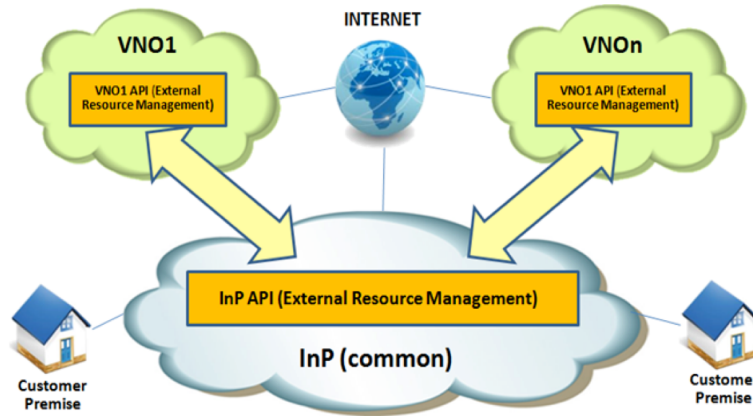


Not yet at device level, but TR-69 yielding to USP (universal service protocol)

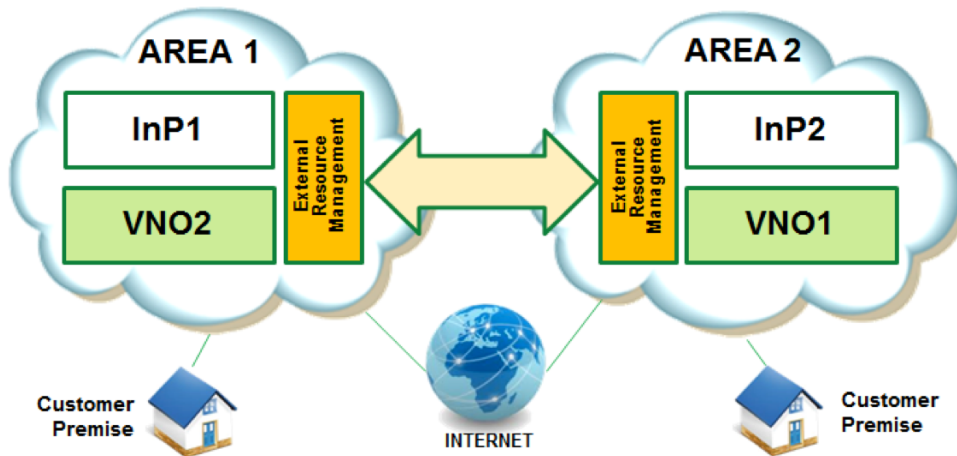


Use the least expensive path

# VNO's and use of infrasture (WT-348)



Centralized approach  
(say on telco or cable  
Provider in given region)



Distributed approach  
(shared between telco  
And cable provider)

# Essentially “internet insurance”

- **Remember Buffer Rage?**
  - More paths permit more robust response if one path becomes unstable
  - Matter of cost for a VNO (maybe that means app provider with SDNFV?)
- **This should get rage under control**
- **It also offers some interesting security/privacy options**



**ASSIA**

# 5G may be coming through your Wi-Fi

[cioffi@stanford.edu](mailto:cioffi@stanford.edu)

