



Towards a Virtual Cellular Network with Variable Grade Spectrum: Challenges and Opportunities

Milind M. Buddhikot

Alcatel-Lucent Bell Labs

milind.buddhikot@bell-labs.com

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Summary Takeaway

- ❑ Ultra-broadband → **integrated** wideband **variable grade spectrum**
- ❑ Dynamic spectrum database to unify **all** spatio-temporal spectrum use
- ❑ NFV and SDN will rapidly impact wireless network implementation
- ❑ Exciting research challenges and technology creation on the horizon
- ❑ **Disruption in business models underlying wireless networks?**
- ❑ **(Mobicom) Research community should focus on component problems**

Increasing Capacity to Keep up with Traffic Growth

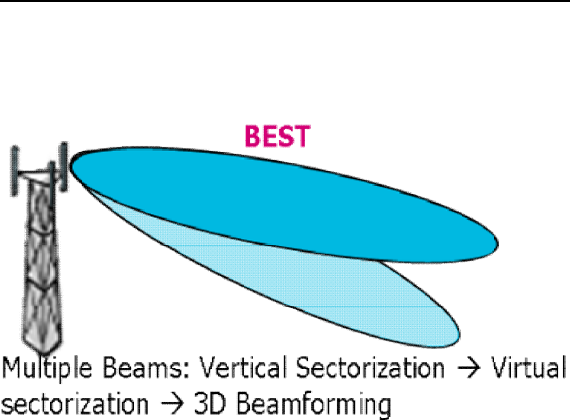
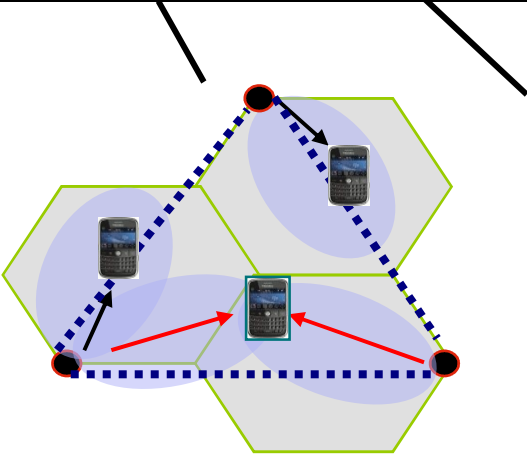
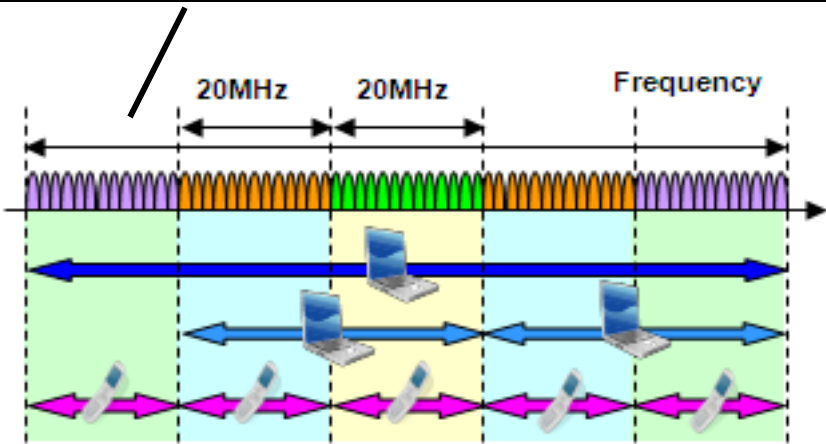
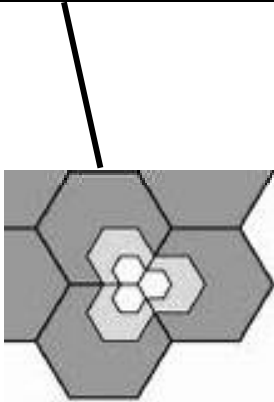
- ❑ Wireless traffic **67-100% (<= doubling)** every year
- ❑ Expected increase **~25x in 5 years**
- ❑ 4G Americas target technologies: **1000x capacity improvement**

How to Increase Capacity in Existing Cellular?

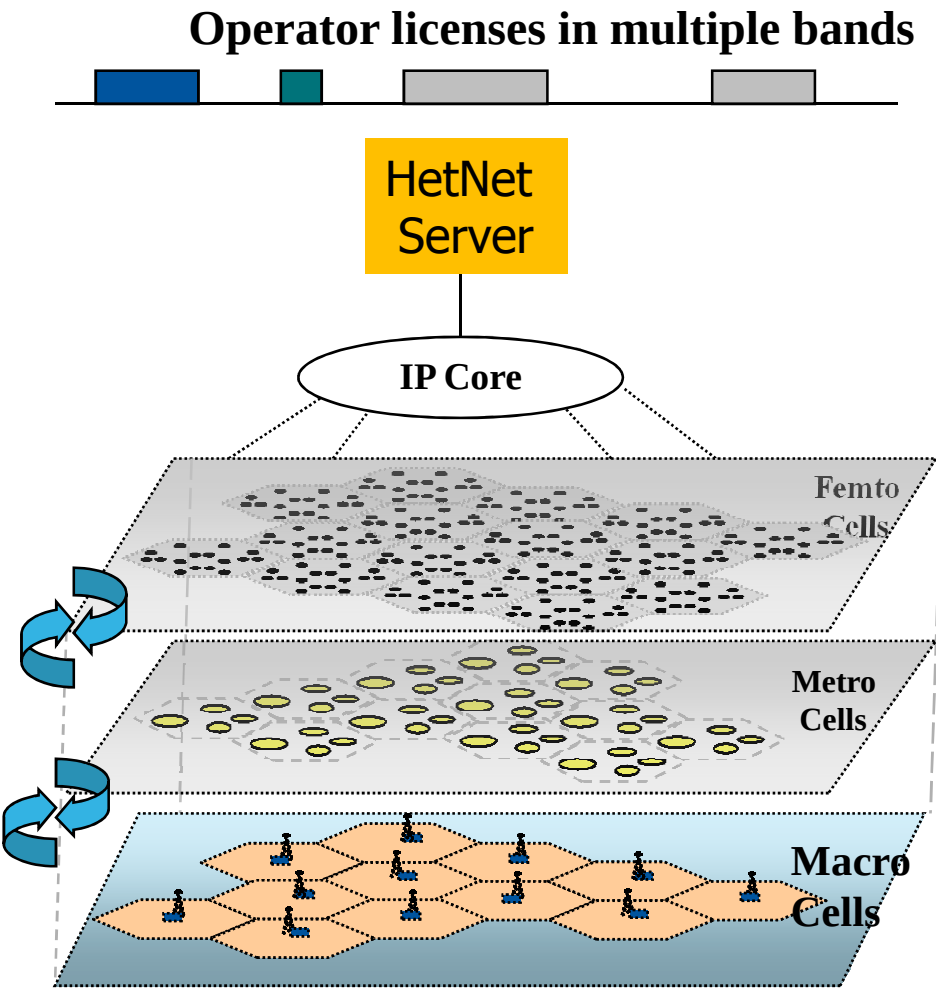
Promising
↓

Downlink Comparison

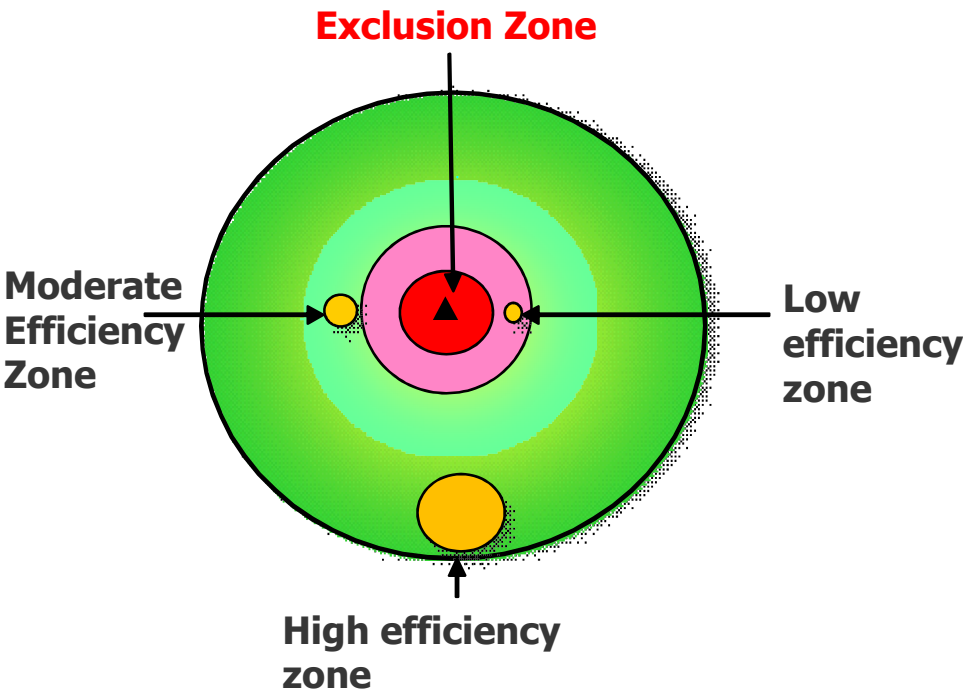
Cell Split	Add Carriers	Carrier Aggregation	MIMO (4Tx)	eICIC	CoMP	AAA or 6 Sector	Metrocells/ HetNet	Centralized Baseband
Expensive	Requires Spectrum	<1.2x gain under load	<1.2x gain under load	~1.25x gain on top of HetNet	<1.1x gain through Rel-11	1.4x to 2x for certain deployment scenarios	Gain = N (number of metros per eNB)	Large gains for stadiums, venues



HetNets with Small Cells



Shared Carrier: Same channel used in macro and small cells → interference interactions



Dedicated Carrier: Independent channels in macro & small cells → **Needs more spectrum**

ALCATEL-LUCENT METRO CELL PORTFOLIO

METRO CELL INDOOR V2

1

W-CDMA



250mW
All-in-one

Available in
850 MHz
1900 MHz

METRO CELL OUTDOOR V2

2

W-CDMA



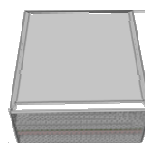
250mW
All-in-one

Available in
850 MHz
1900 MHz
2100 MHz

METRO CELL INDOOR (MCI)

3

LTE



2 x 250 mW
All-in-one
Cube-based

Avail Date:
Jun 2013 (B25)

METRO CELL OUTDOOR (MCO)

4

W-CDMA

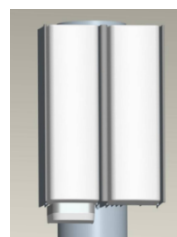


1W
All-in-one
Cube-based
Wi-Fi AP option

Avail Date:
Mar 2013 (B1)
Mar 2013 (B2)

5

Multi-standard



3x1W
All-in-One
Cube-based
Wi-Fi AP option

Avail Date:
Sept 2013 (B2)

6

LTE



2x1W
All-in-one
Cube-based
Wi-Fi AP option

Avail Date:
Mar 2013 (B25)
Sept 2013 (B2/B7)

7

LTE



2x5W
All-in-one

Avail Date:
Mar 2013 (B13)
Sept 2013 (B17)

METRO RADIO OUTDOOR (MRO)

8

LTE



2 x 5W (B38)
Distributed BBU
Cube-based

Avail Date:
Now (B13)
Sept 2013 (B38)



Common Metro Dock
GE= Now
GPON = Q3 2013

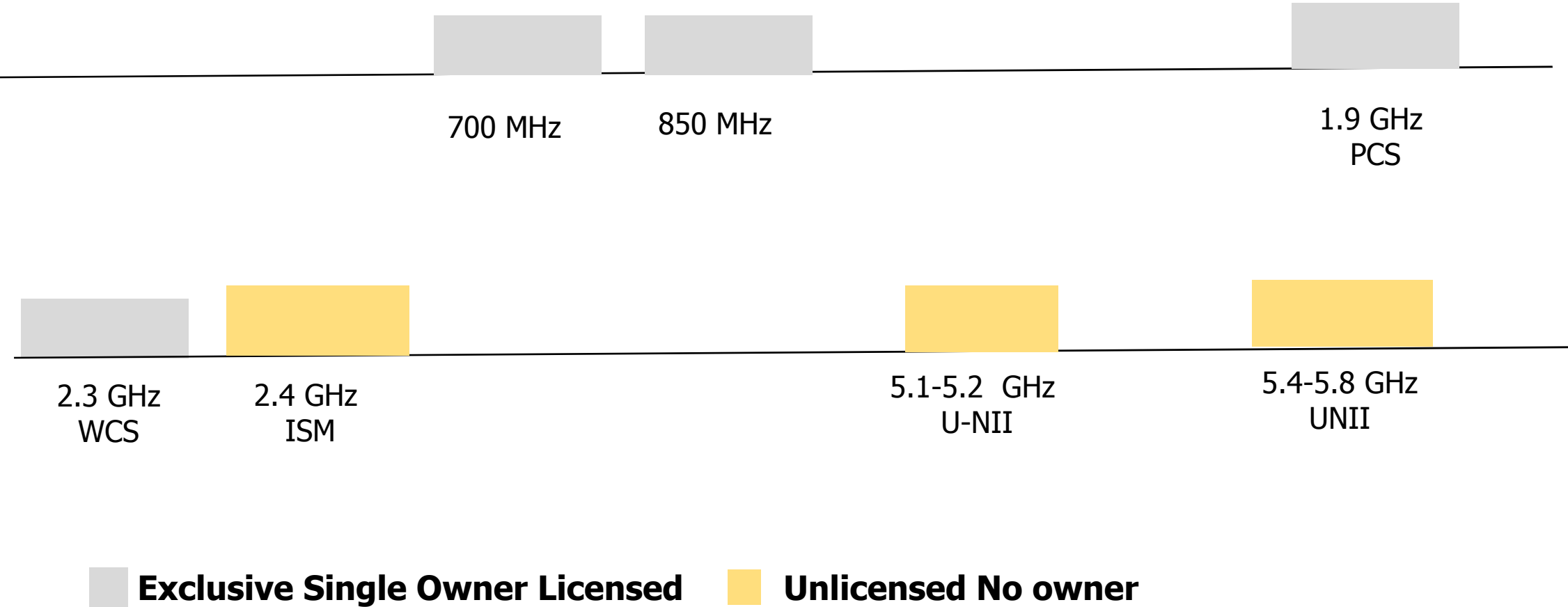


Common Wi-Fi AP
Sept 2013



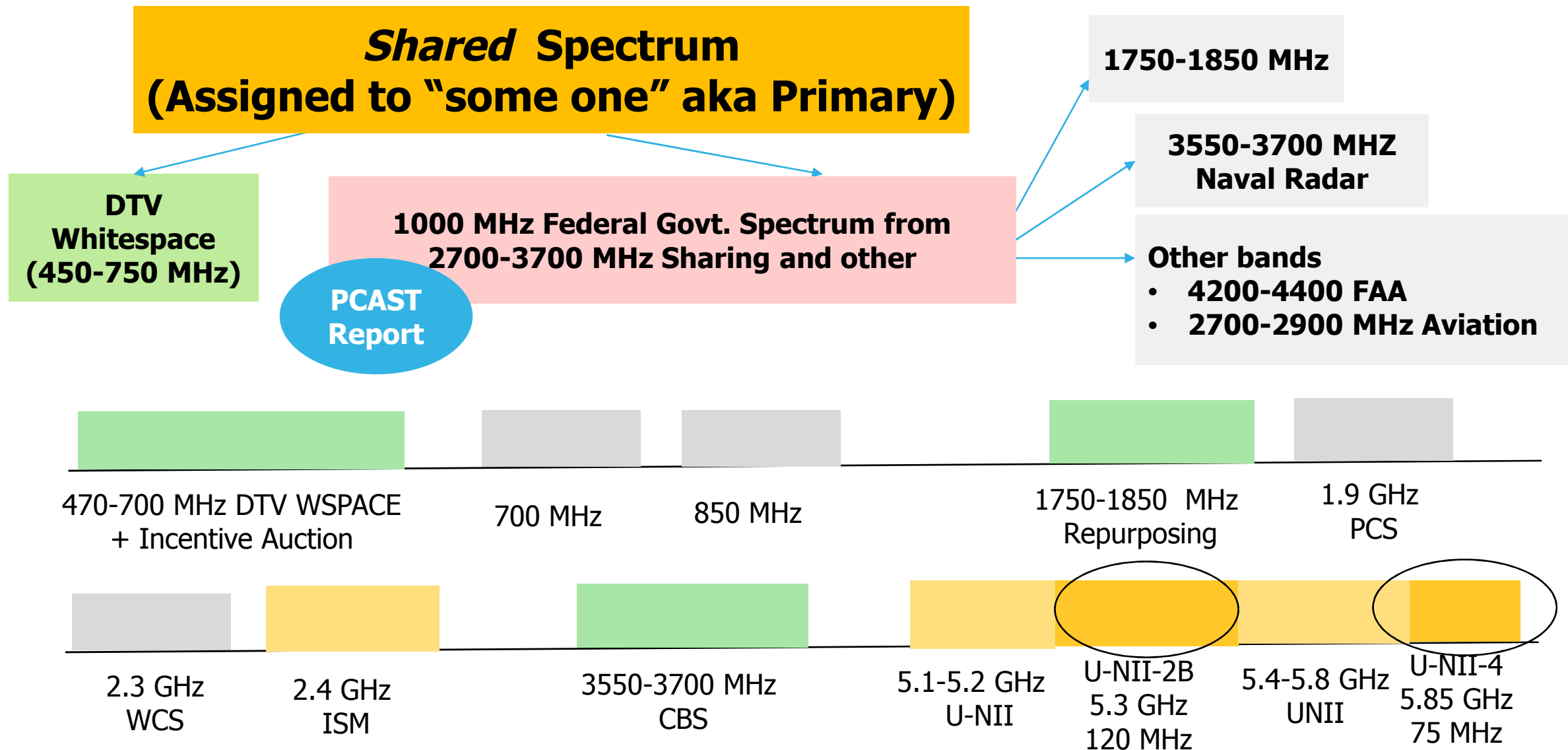
COVERING MULTIPLE TECHNOLOGIES AND DEPLOYMENT SCENARIOS

Need For More Spectrum

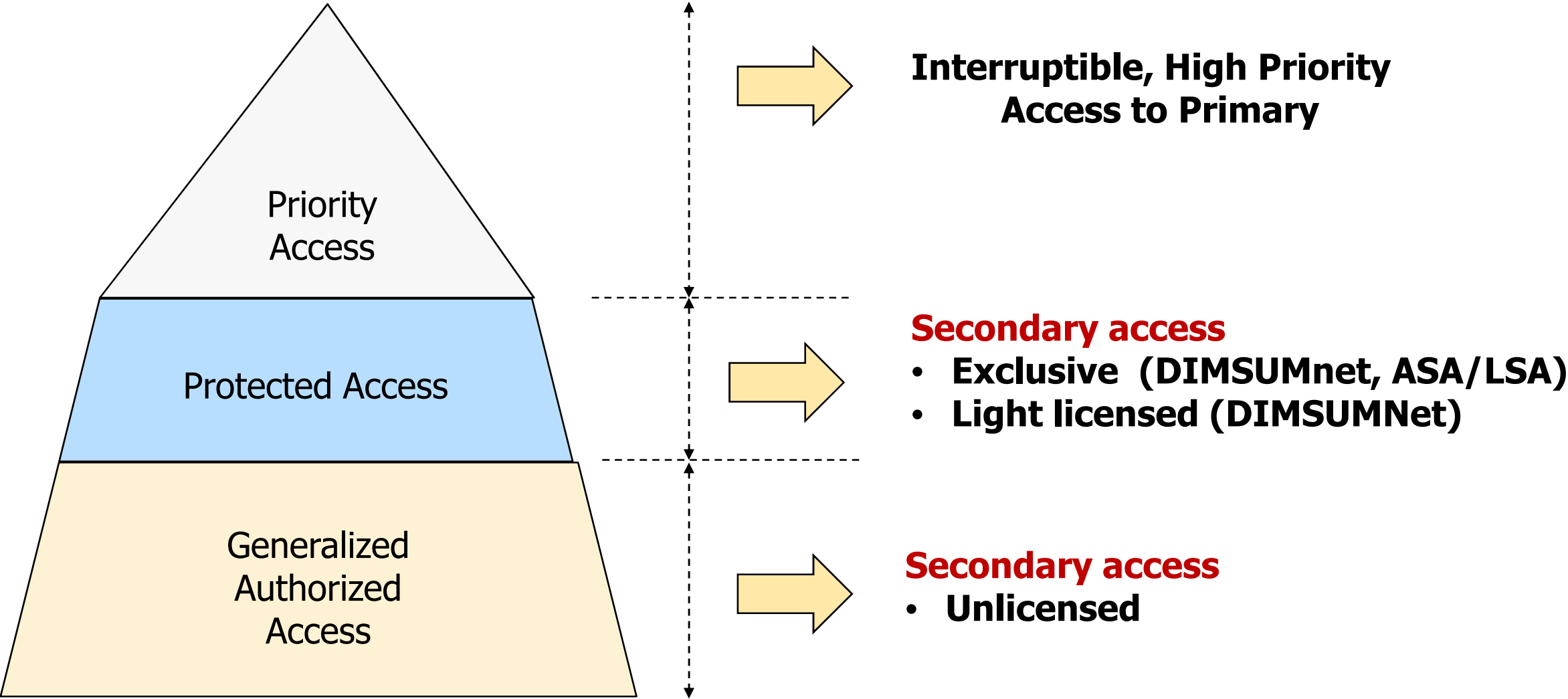


Need 1.2-1.7 GHz of new spectrum

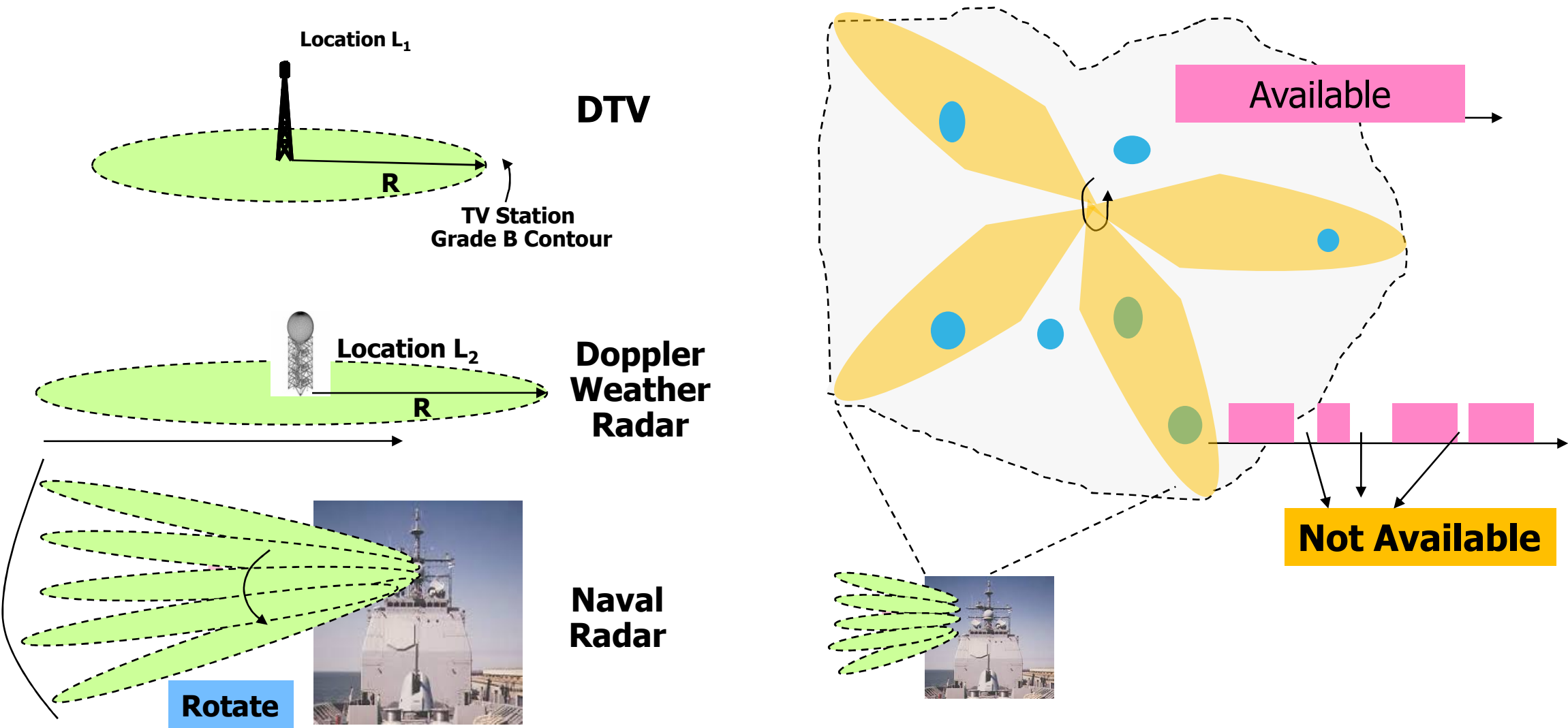
Large Part of New Spectrum May be “Shared Spectrum”



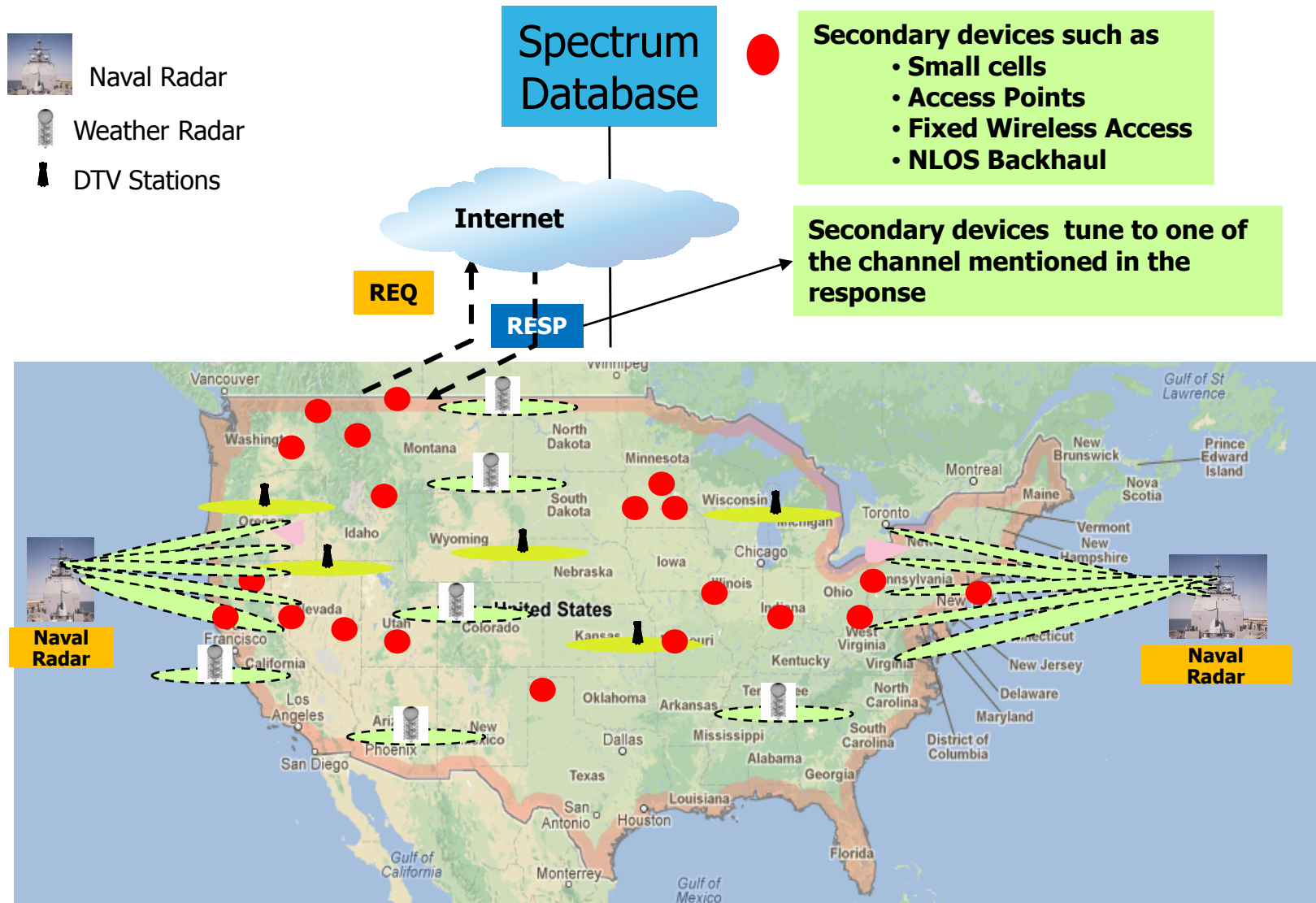
How Do We Share? “Tiered Access”



How Do We Implement Secondary Access?



Key Architectural Innovation: Spectrum Database^[1,2,3]



❑ Central point of control for spectrum coordination

❑ **Primary protection**

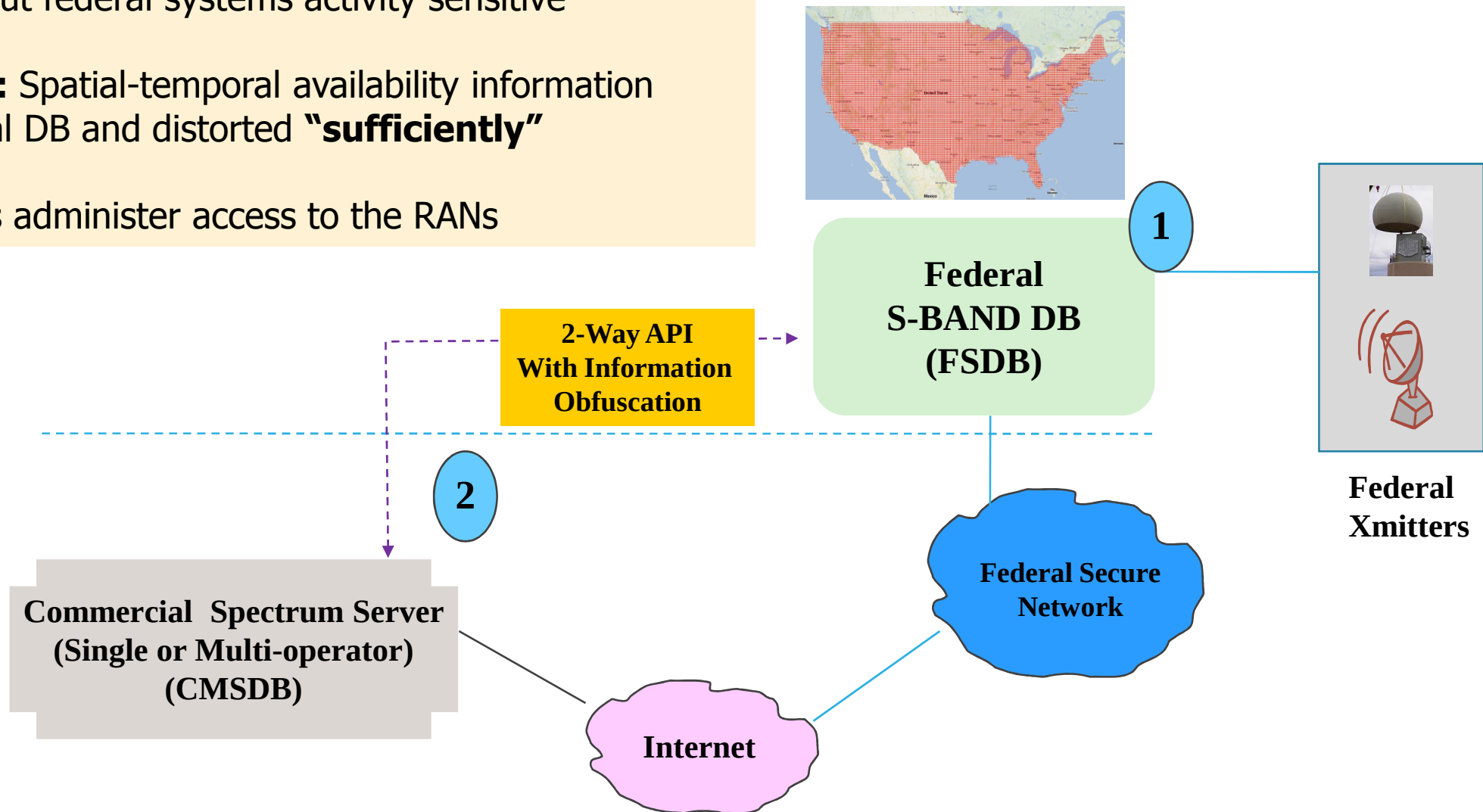
❑ **Secondary access**

- **Different access types**

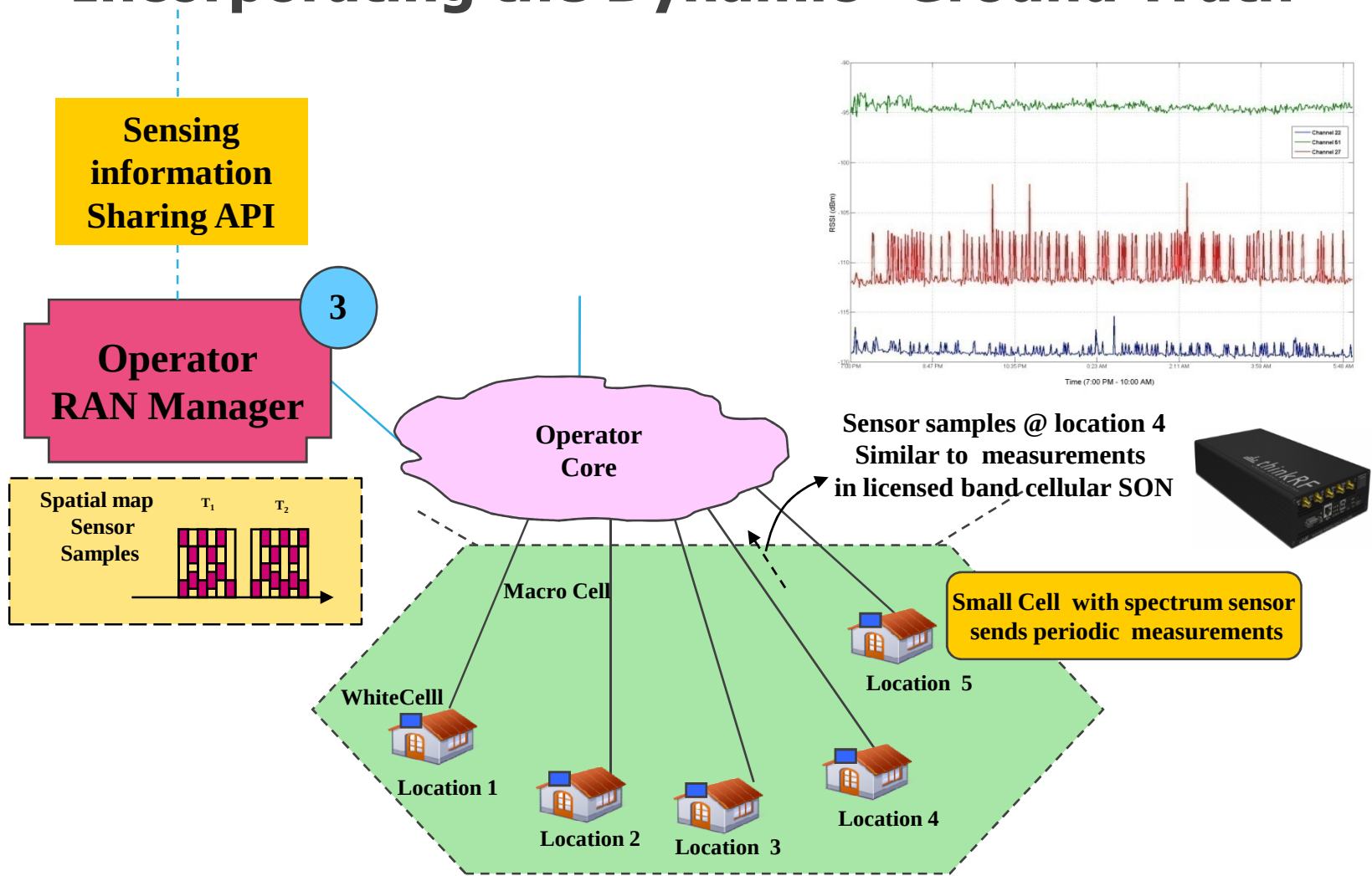
- Exclusive (DIMSUNnet, ASA/LSA)
- Light licensed (DIMSUNNet)
- Unlicensed
- Secure access
- Monetizable access

Split Database For Federal Spectrum Sharing

- Information about federal systems activity sensitive
- **Secure access:** Spatial-temporal availability information provided federal DB and distorted “**sufficiently**”
- Commercial DBs administer access to the RANs



Dynamic Radio Environment Activity Mapping (DREAM)^[4] : Incorporating the Dynamic “Ground Truth”



Ground truth

- Primary signal strength
- Secondary activity in channels *deemed white*
- Adjacent channel activity
- Adjacent band activity

Network and Client assisted collection

→ How do we use this?

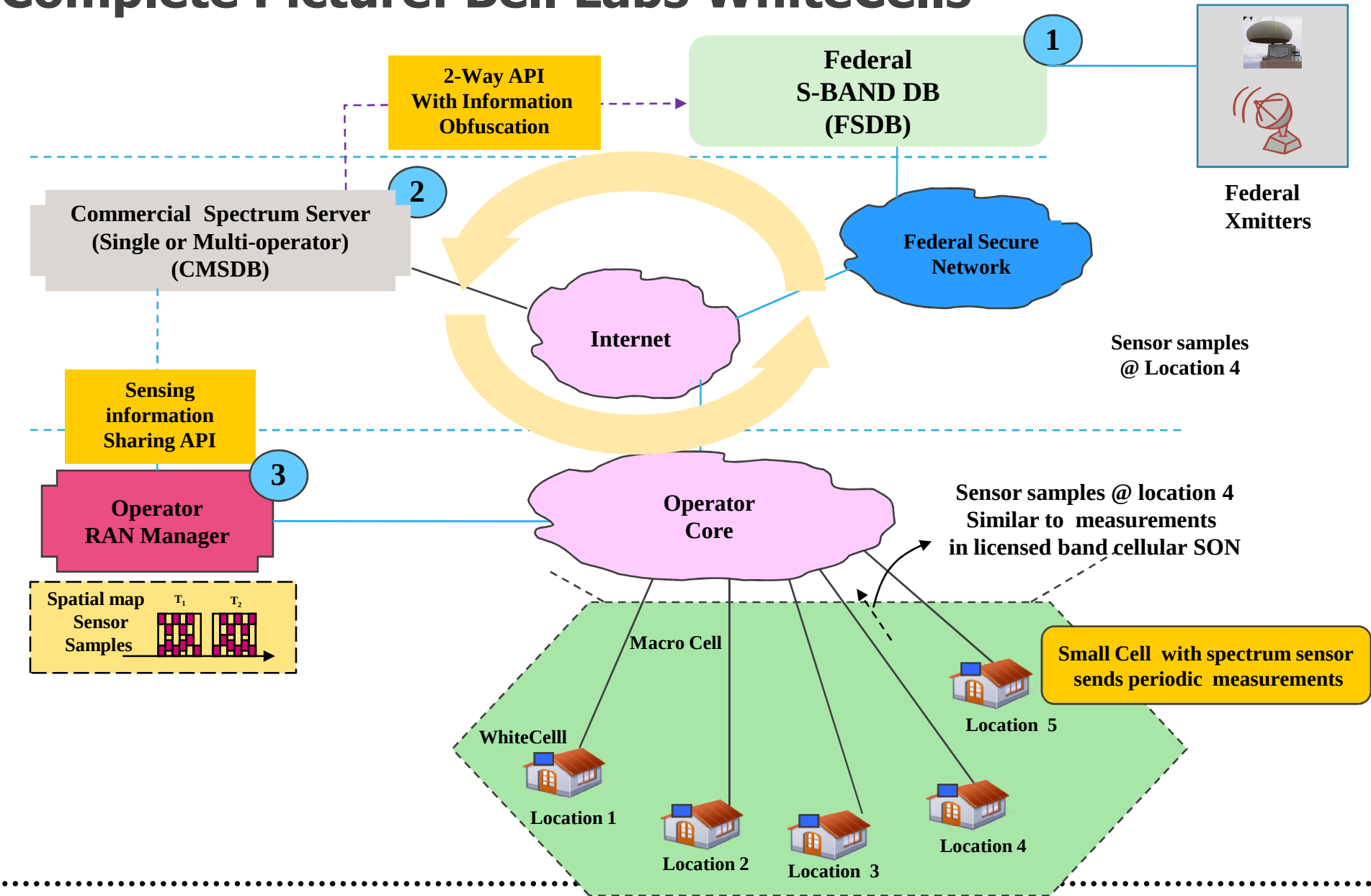
Exploiting REM: Dynamic Ranking of Secondary Channels and Finding More Whitespace (Secondary Transmitter perspective)

- ❑ Sense TV Spectrum during 15 hours (7:00 PM – 10:00 AM)
- ❑ Scan every minute during 30 seconds
- ❑ Location {Lat : 40.68691, Long : -74.39718} in the lab (fifth floor)
- ❑ Portable Device Channel [21-51] except 37
- ❑ **WS channels [22,27,32,42,46,47,48,49] from official DBAs are not the best options**

Ranking with Average RSSI for the experiment time, Red Color : WS Channels from official DBAs

Rank	Channel	Avg RSSI (dBm)	Rank	Channel	Avg RSSI (dBm)	Rank	Channel	Avg RSSI (dBm)
1	22	-118.9723	11	33	-111.2699	21	39	-108.1211
2	21	-118.6064	12	36	-111.2457	22	48	-107.5307
3	23	-115.1224	13	25	-111.0240	23	30	-107.3896
4	38	-113.6022	14	27	-110.4862	24	45	-106.9321
5	26	-112.3652	15	41	-110.4683	25	47	-106.8143
6	24	-112.1441	16	32	-110.4371	26	44	-106.5032
7	34	-112.0327	17	43	-110.3331	27	46	-106.2404
8	31	-111.8473	18	40	-110.2666	28	28	-106.1710
9	49	-111.5402	19	50	-109.8531	29	29	-99.6048
10	42	-111.4835	20	35	-109.2027	30	51	-94.4028

Complete Picture: Bell Labs WhiteCells^[1,4]



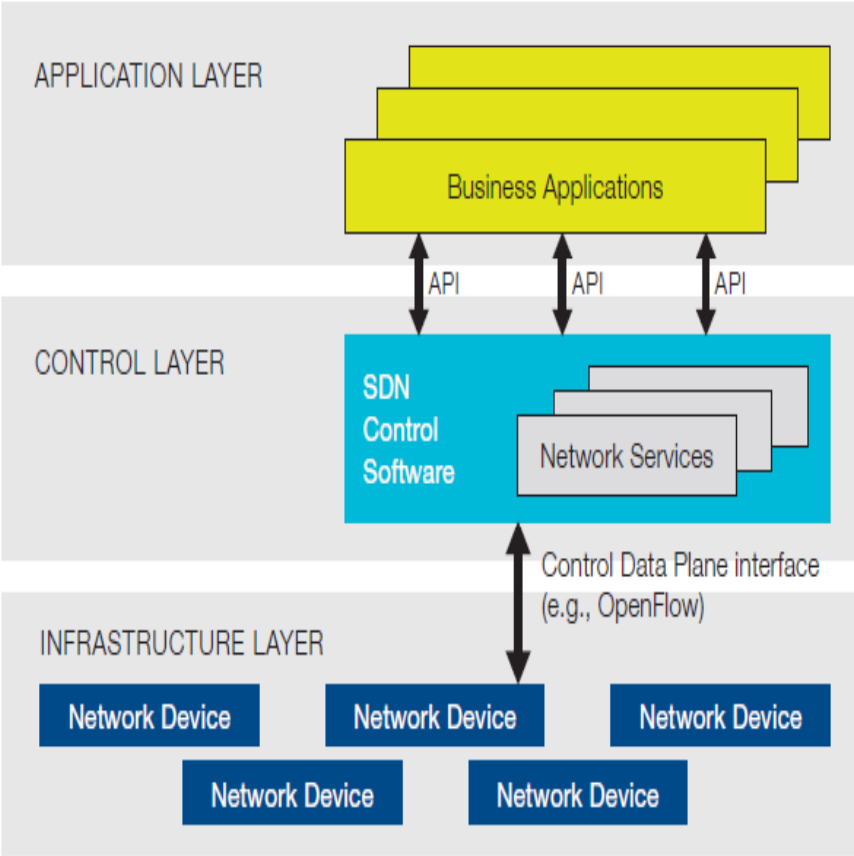
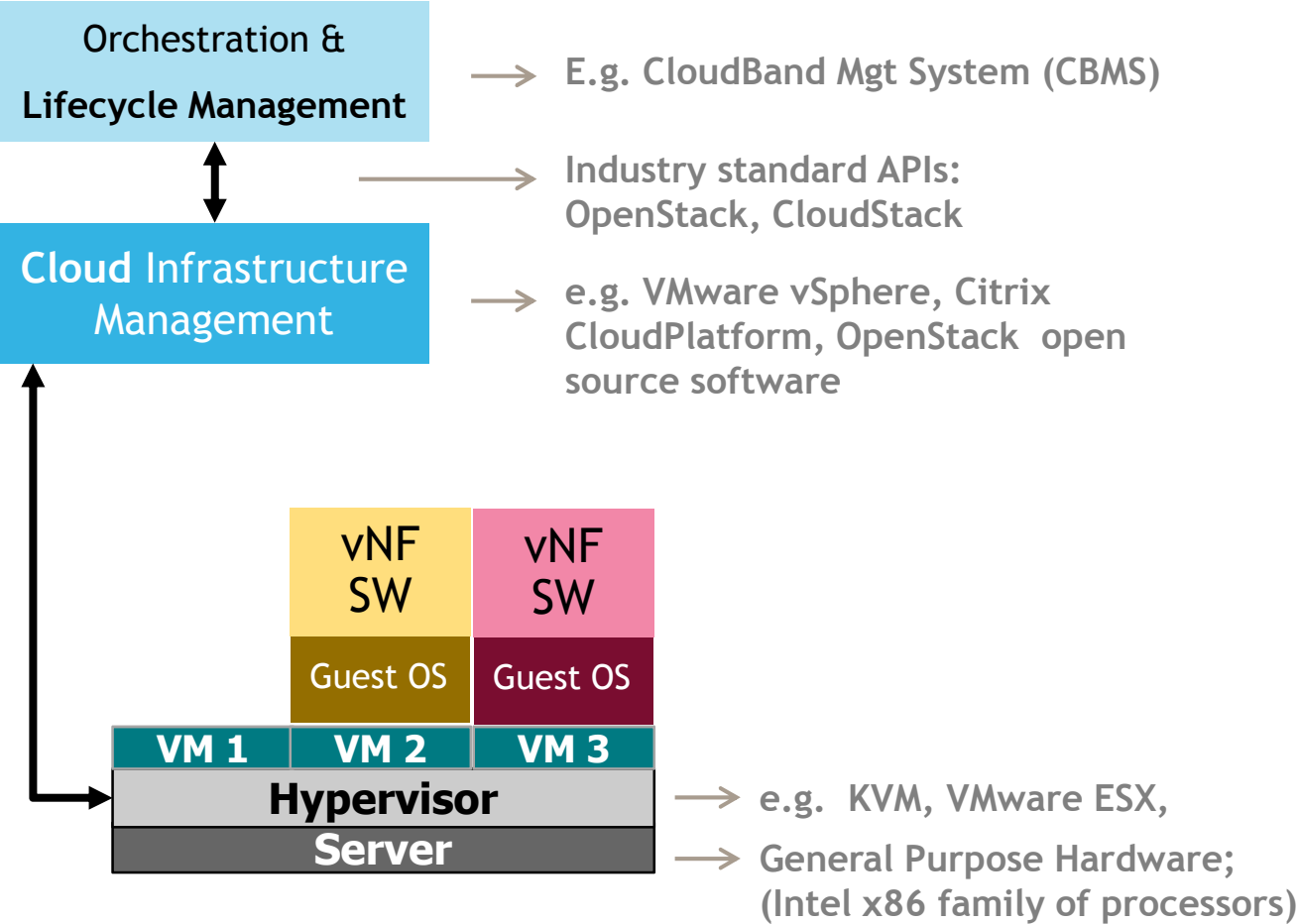
Current prototype supports

- DTV
- 3550 MHz
- 4900 MHz
- 2300 MHz
- Unlicensed
 - 900,ISM
 - U-NII

NETWORK FUNCTIONS VIRTUALIZATION and SDN

Virtual Network Function: Software instance of a network function that leverages **virtualization**

SDN: Separate data and control path with centralized control, virtualized network

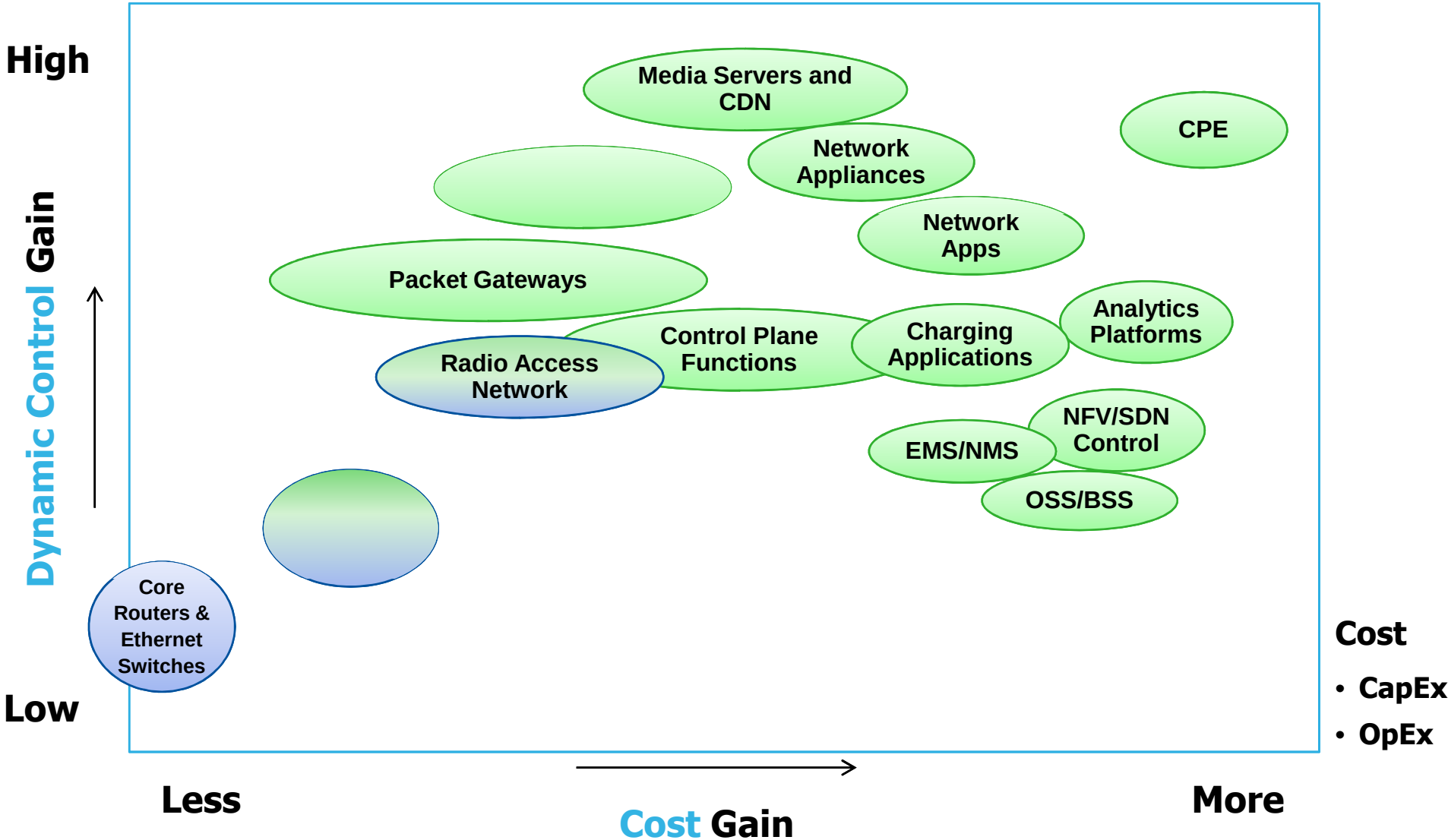


Network Components to Virtualize

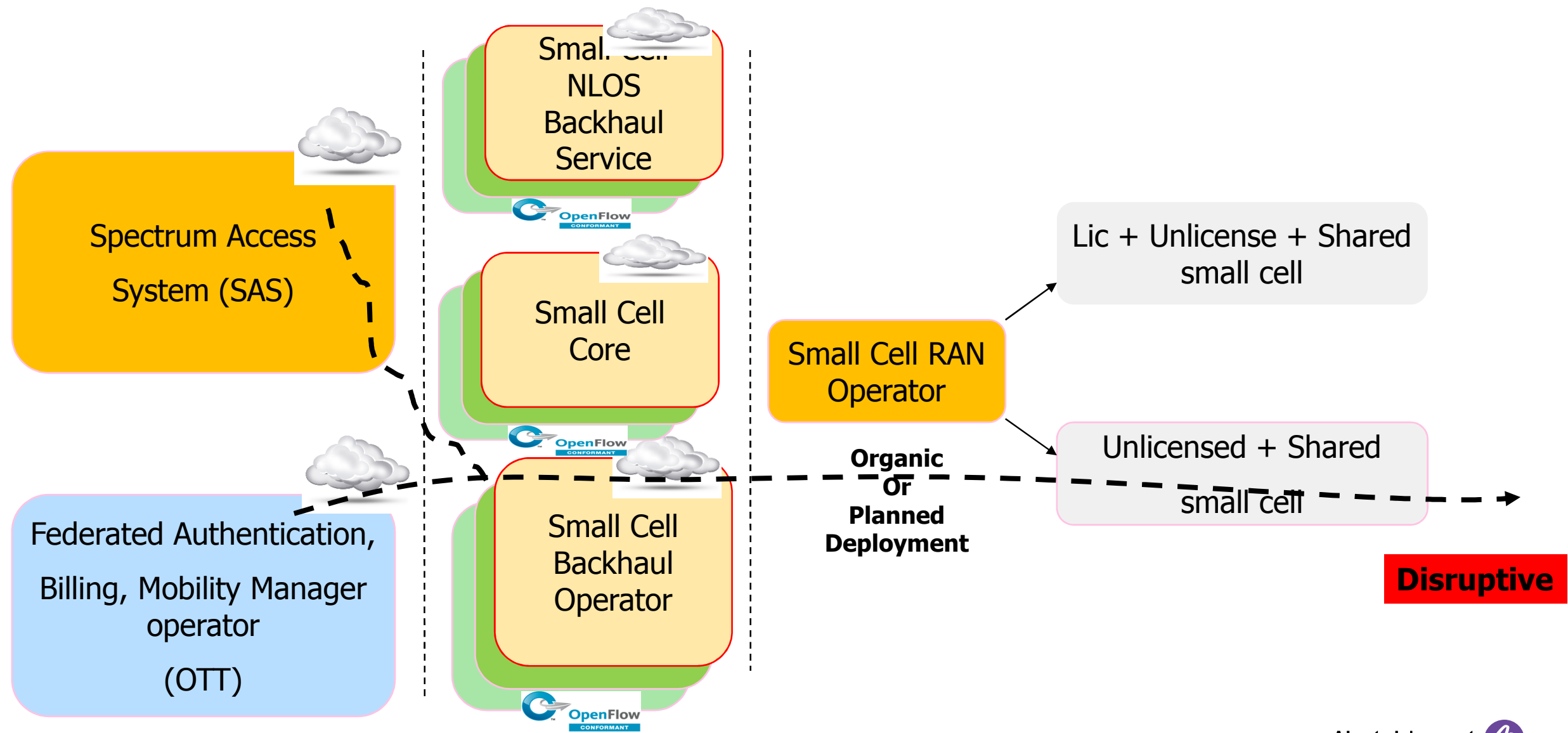
- Dynamic Control:** **High**
- Elastic scale
 - Resource pooling
 - Rapid deployment
 - Location optimization



ALU
CloudBand



Implications on Business Models



Conclusions

- ❑ Future networks will be impacted by confluence of trends that involve
 - Support for variable grade spectrum in an integrated fashion
 - Moving value chain into control plane
 - Virtualization of infrastructure and control plane
 - Business model innovation and new entrants

- ❑ Intellectual capital in Mobicom community should be expended in solving these problems “at scale”

For More Information Check ..

1. Sayan Sen, Tan Zhang, M. Buddhikot and S. Banerjee, "Dual Technology Small Cells Using Spectrum Whitespaces", **(Best Technical Paper)**, IEEE DySPAN 2012, Oct 2012.
2. M. Buddhikot, P. Kolodzy, S. Miller, K. Ryan and J. Evans, *DIMSUMnet: New Directions in Wireless Networking Using Coordinated Dynamic Spectrum Access*, **Position Paper** in IEEE International Symposium on a World of Wireless, Mobile and Multimedia Networks (IEEE WoWMoM 2005), Taronina/Giardini Naxos, Italy, Jun 2005.
3. M. Buddhikot, P. Kolodzy, S. Miller, K. Ryan and J. Evans, *DIMSUMnet: New Directions in Wireless Networking Using Coordinated Dynamic Spectrum Access*, Bell Labs Technical Report, Sept 2003. Updated Oct 2004.
4. M. Buddhikot, I. Kennedy, F. Mullany, and H. Viswanathan, *Ultra-Broadband Femtocells via Opportunistic Reuse of Multi-Operator and Multi-Service Spectrum*, Bell Labs Technical Journal (BLTJ) Special Issue on 4G Networks, Feb 2009.

Thanks !!!

Contact: Milind.Buddhikot@bell-labs.com

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