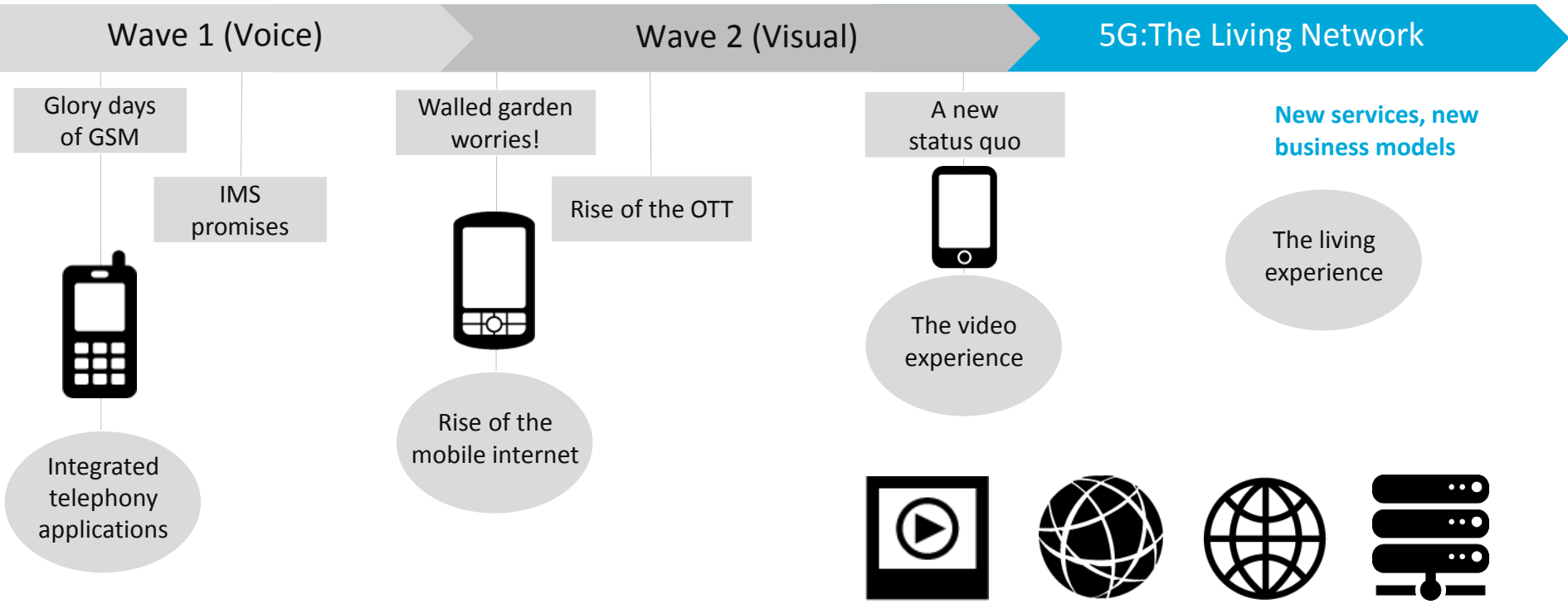


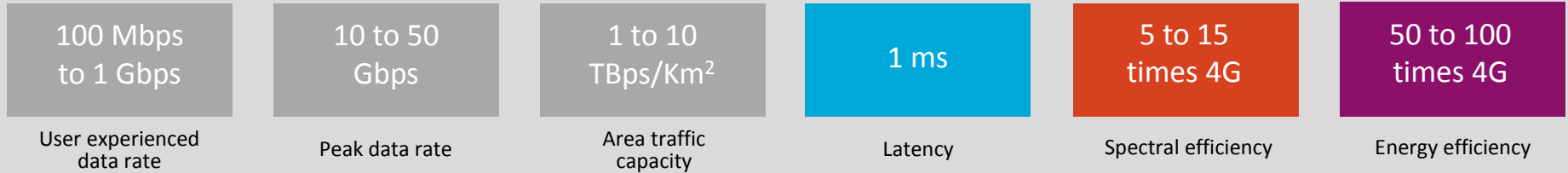
# Spectrum Sharing & Dynamic Spectrum Access

Mobile World Congress 2015

# 5G: the evolution to the smarter living network



# Initial 5G Requirements Highlight Need for Spectrum



## Traditional Licensed Model

**Cellular**  
Auctions of cleared spectrum  
& exclusive use by winners

## Traditional Unlicensed Model

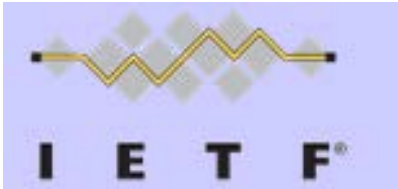
**Wi-Fi**  
Sharing via standards  
& good behavior

## Traditional Government Model

**Public Safety,  
National Defense, ...**  
Exclusive rights to frequency  
bands, often with very light use

Sharing in Licensed, Unlicensed, & Government Controlled Spectrum

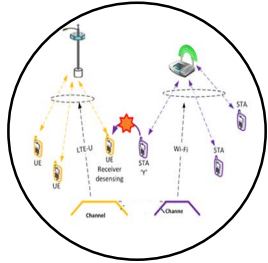
# Industry and Governments Actively Promoting Spectrum Sharing



# Spectrum Sharing: Deeper Dives

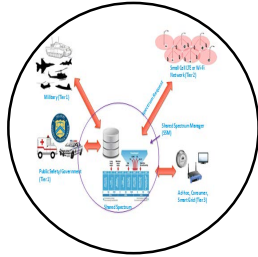
Licensed Assisted  
Access

LAA - LTE

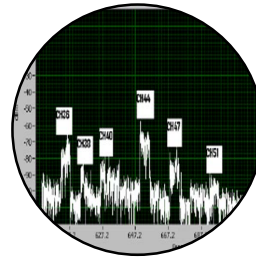


Authorized / Licensed Shared  
Access (ASA/LSA)  
&

Citizens Broadband Radio  
Service (CBRS)



TV White Space  
(TVWS)



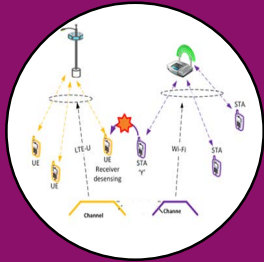
InterDigital's  
DSM Platform &  
Field Tests



# Spectrum Sharing: Deeper Dives

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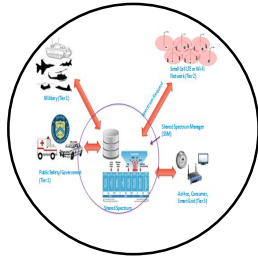
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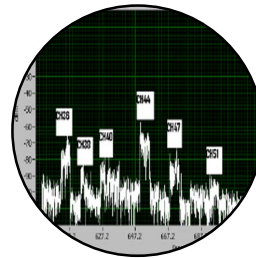
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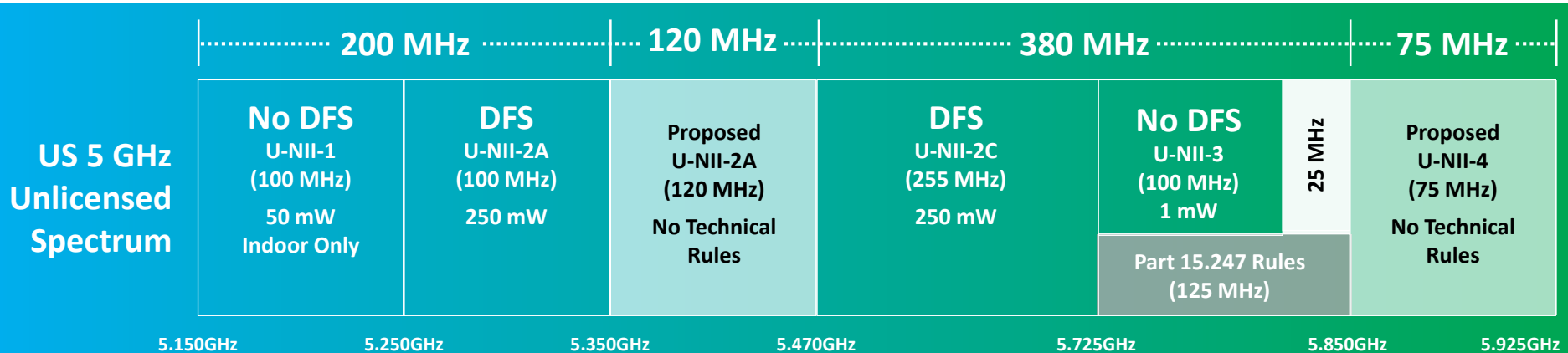


Unique Regulations & Coexistence Requirements

# Licensed Assisted Access: LAA-LTE

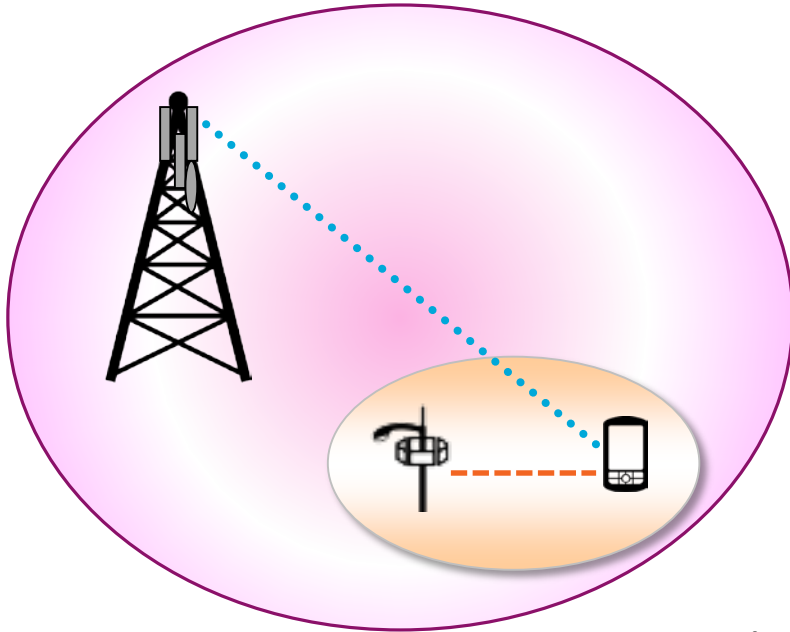
100's of MHz of unlicensed spectrum are a tempting target

But, coexistence with Wi-Fi raises questions about availability and Quality of Service



# LAA-LTE

## Aggregating Licensed and Unlicensed Channels



LTE Anchored in Licensed Band .....

Supplemental Channel in 5 GHz Band - - -

### A Small Cell Solution

Anchor an LTE connection in a licensed band

- Guaranteed QoS

Opportunistically aggregate with a downlink supplemental channel in the unlicensed band

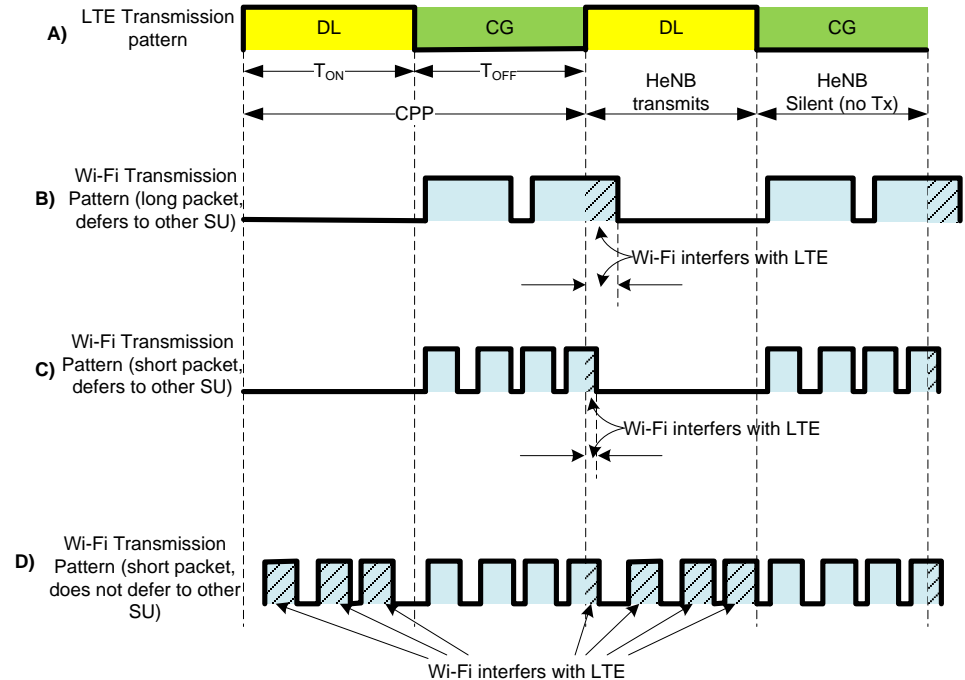
- Potentially huge capacity increment



# LTE Coexistence with Wi-Fi

Wi-Fi stations and access points already pose significant interference to each other due to the CSMA MAC

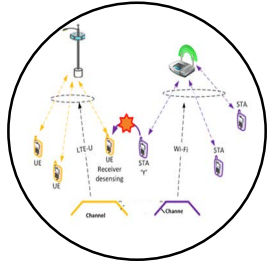
LTE, with properly designed coexistence gaps (CG) and/or listen before-talk (LBT), can do as well or better in managing interference



# Spectrum Sharing: Deeper Dives

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Access

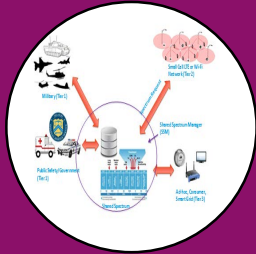
LAA - LTE



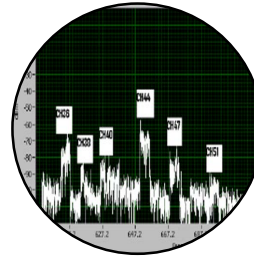
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InterDigital's  
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Unique Regulations & Coexistence Requirements

# Authorized Shared Access (ASA) Licensed Shared Access (LSA)

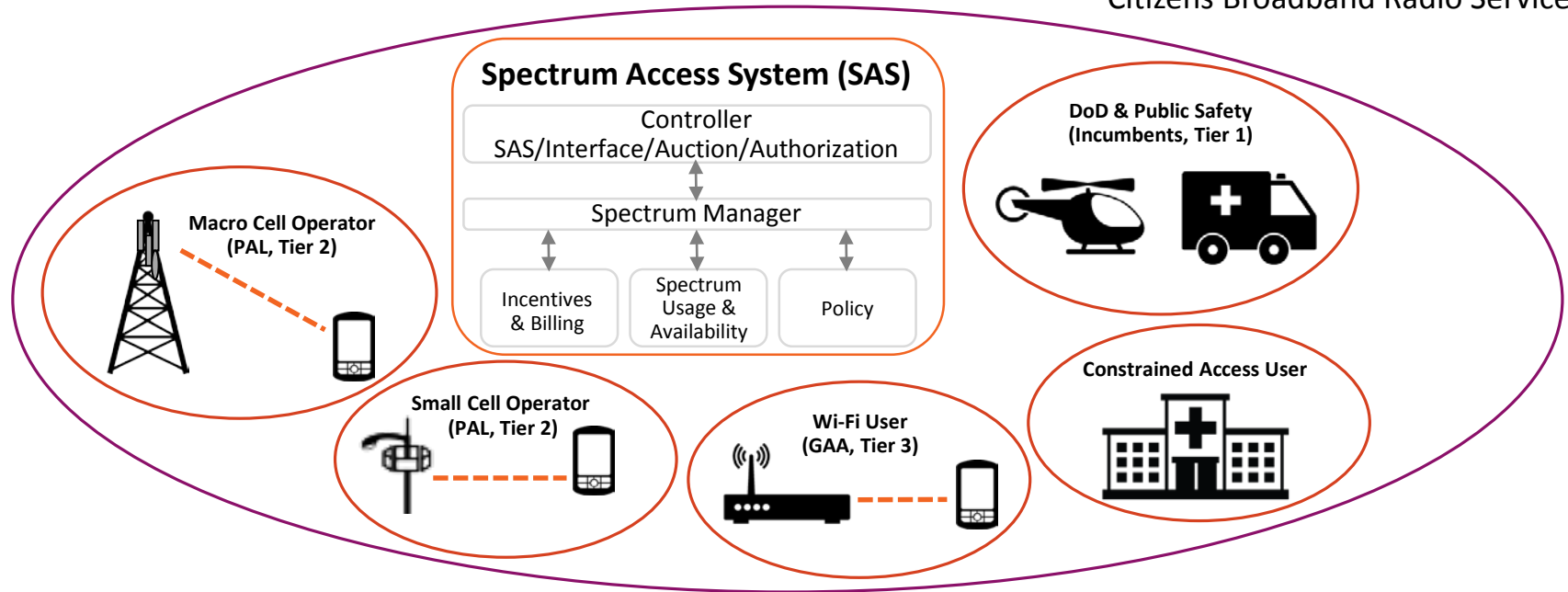
Large blocks of spectrum that cannot be cleared, but are frequently unused, can provide 100's of MHz of Bandwidth to alleviate the rapidly growing demand

Frequency Band	Amount of Spectrum	Primary Part of the World	Notes
3550 to 3650 MHz	100 MHz	USA	<b>Incumbent: Naval Radar</b> Shared per 3-tier model proposed by FCC
3650 to 3700 MHz	50 MHz	USA	<b>Incumbent: Fixed Satellite Systems</b> Shared per 3-tier model proposed by FCC
2300 to 2400 GHz	100 MHz	Europe	<b>Incumbent: Military Satellite Telemetry</b> Shared per LSA 2-tier model Already used widely as 3GPP Band 40

# Sharing Federal Spectrum

## FCC 3.5 GHz NPRM 3 Tier Model

Citizens Broadband Radio Service (CBRS)

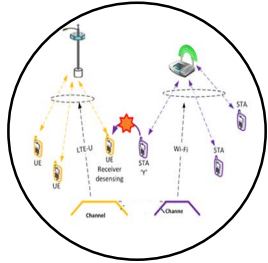


Provide protection of the incumbent, reliable operation for Priority Access Licensees (PAL) and opportunistic access for General Authorized Access (GAA) users

# Spectrum Sharing: Deeper Dives

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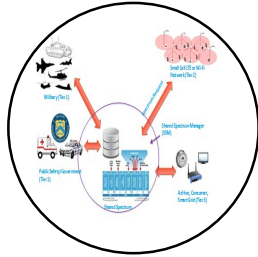
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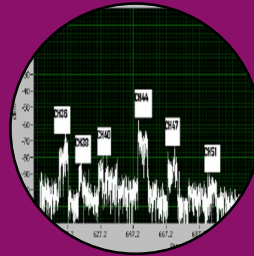
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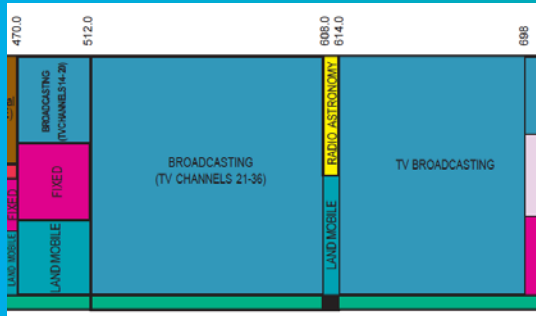
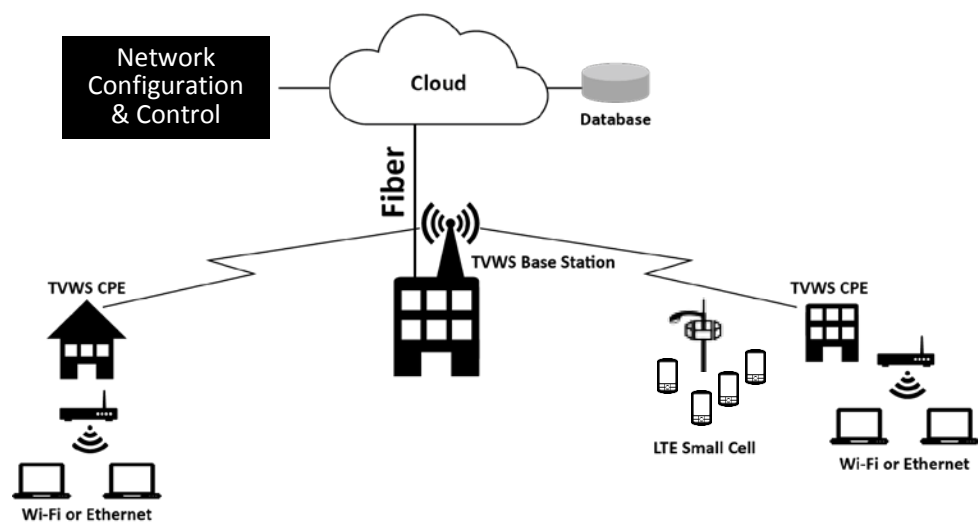
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Unique Regulations & Coexistence Requirements

# TVWS Technology

- Share unused TV channels
- A location-indexed database identifies available channels
- Comply with regulations regarding power, bandwidth, out-of-band emissions, ...



US 470 to 698 MHz  
6 MHz wide channels

UK 470 to 790 MHz  
8 MHz wide channels

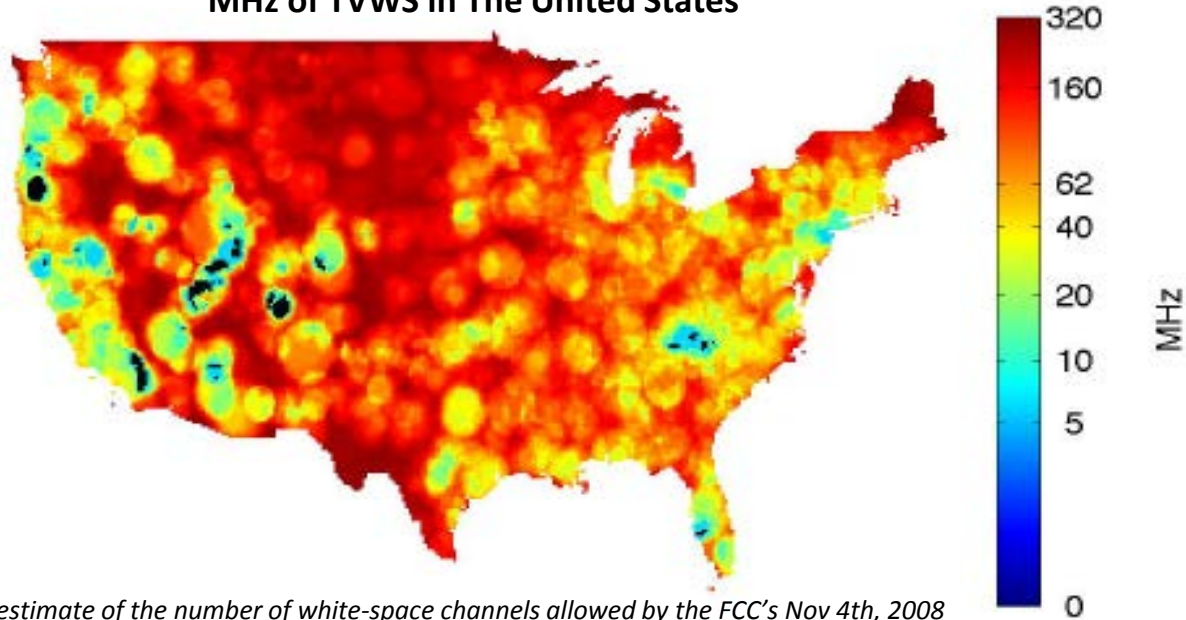
21	22	23	24	25	26	27	28	29	30	31	32
470-478	478-486	486-494	494-502	502-510	510-518	518-526	526-534	534-542	542-550	550-558	558-566
33	34	35	36	37	38	39	40	41	42	43	44
566-574	574-582	582-590	590-598	598-606	606-614	614-622	622-630	630-638	638-646	646-654	654-662
45	46	47	48	49	50	51	52	53	54	55	56
662-670	670-678	678-686	686-694	694-702	702-710	710-718	718-726	726-734	734-742	742-750	750-758
57	58	59	60	61	62	63	64	65	66	67	68
758-766	766-774	774-782	782-790	790-798	798-806	806-814	814-822	822-830	830-838	838-846	846-854
69											
854-862											

Retained/interleaved spectrum
  Cleared spectrum
  PMSE

# Plenty of TVWS Where Needed & Tools to Use It

Expected to be even much better in under-developed countries

MHz of TVWS in The United States



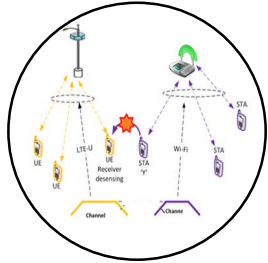
*An estimate of the number of white-space channels allowed by the FCC's Nov 4th, 2008 ruling accounting for both co-channel and adjacent-channel protection.*

From: K.Harrison, S. Mubaraq Mishra, and Anant Sahai, "How much white-space capacity is there?," Dyspan 2010.

# Spectrum Sharing: Deeper Dives

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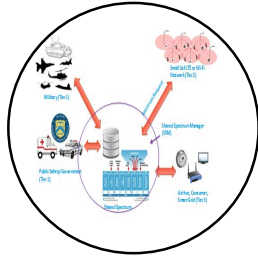
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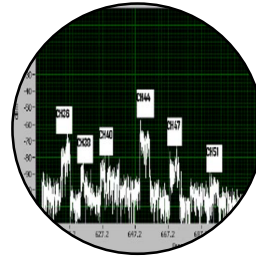
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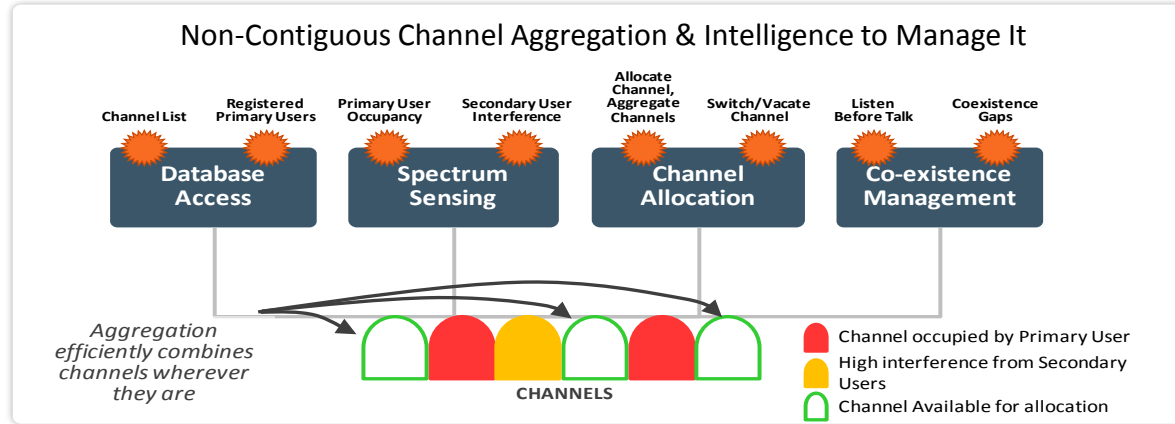


Unique Regulations & Coexistence Requirements



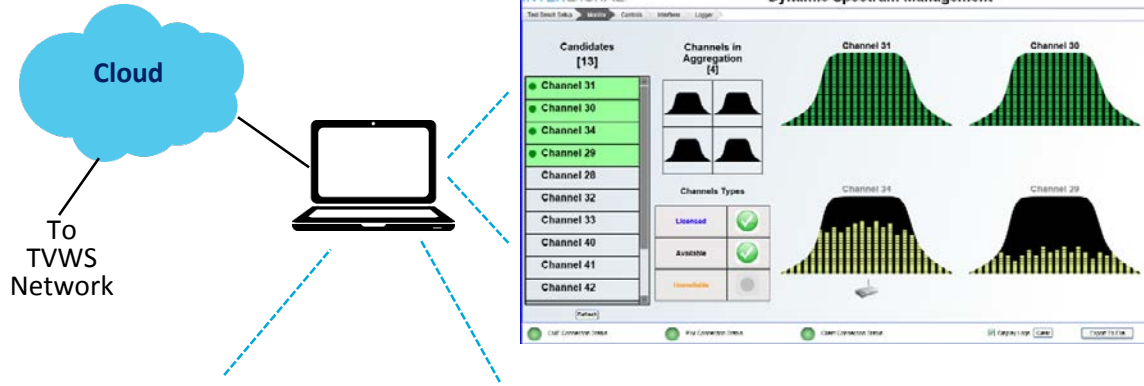
# InterDigital's DSM Platform

## Integrating Technology Blocks for a Complete Spectrum Sharing Solution



- Carrier Aggregation
  - Combines up to 4 non-contiguous channels
  - “Quarter-clocked” operation of 20MHz 802.11n chipset
- Sensing enabled channel switching
  - Scans for interference, DTV, & microphones
- Agile Spectrum Allocation
  - Dynamically selects best available channels
- TVWS database
  - Identifies open channels and primary users
- Wideband radio
  - 200 MHz wide transceiver

# Flexible Channel Management and Monitoring Software and Network Management



Interference				Policy				
Interferer	Output Channel	Output Power	Type		Channels in Aggregation	Channel Types		
			DTV	Mic		Licensed	Available Unlicensed	Unavailable Unlicensed
1	23 ▼	xx dB	<input checked="" type="checkbox"/>	<input type="checkbox"/>	3 ▼	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
2	05	xx dB	<input type="checkbox"/>	<input type="checkbox"/>				
3	47 ▼	xx dB	<input type="checkbox"/>	<input checked="" type="checkbox"/>				
4	▼	xx dB	<input type="checkbox"/>	<input type="checkbox"/>				

- Aggregation of up to four non-contiguous channels
- Geolocation database provides channel list
- Sensing-based channel ranking
- Channel selection combines database, ranking and user preference information
- Real-time interference management
- Channel management runs as PC application

# InterDigital's DSM Technology

Showcased many times

- Telus, Toronto (Oct. 2012)
- DySPAN in Seattle, Washington (Oct. 2012)
- ETSI Workshop on Reconfigurable Radio Systems, Cannes, France (Dec. 2012)
- Mobile World Congress in Barcelona (Feb. 2013)
- QoS MOS in Washington, DC (Mar. 2013)
- NTIA's Innovative Spectrum Sharing Technology Day in Washington, DC (Nov. 2013)
- DSA Global Summit in Bangkok (Nov. 2013)



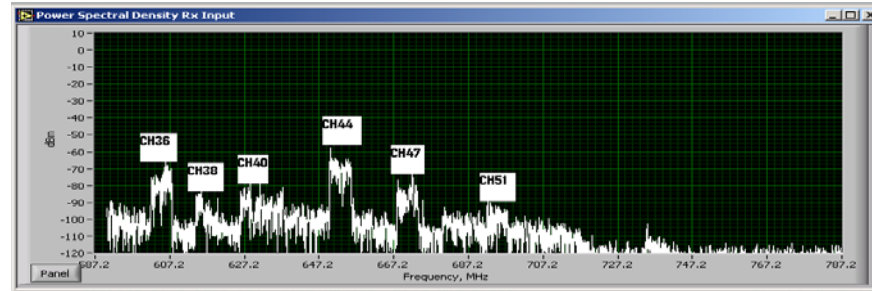
# DL Throughput Rates Indoor Testing

## Cabled and Over-the-Air (OTA)

RATE	Number Of Channels	UDP (Mbps)		TCP (Mbps)	
		Cable	OTA	Cable	OTA
MCS7	4	35.2	34.7	27.3	25.6
MCS6	4	33.1	32.6	25.5	24.5
MCS5	4	30.4	29.8	23.6	22.9
MCS4	4	24.9	24.5	19.7	18.1
MCS3	4	18.2	17.7	14.7	13.8
MCS2	4	14.1	13.9	11.5	10.4
MCS1	4	9.82	9.74	7.74	7.3

# DSM Wi-Fi Outdoor Field Test

Melville, NY, Aug 2013



Sample test results: 1 TVWS channel, 1.7 km LOS, MCS5, Tx power=20 dBm, Measured DL TCP data rate = 5 Mbps (single channel)

# DSM Wi-Fi Platform - Generation 2

## TVWS + 3.5 GHz Operation

- 200 MHz coverage in 3.5 GHz or TV White Space frequency bands
- Dynamic allocation & aggregation of up to 4 non-contiguous channels
- Wi-Fi based physical layer for coexistence
- Integrated sensing for channel selection & interference management
- Compatible with US and UK certified geolocation databases
- Available first quarter 2015



# Thank You!

INTERDIGITAL.



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