5G Regulation and standardization: What's past is prologue?

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(Some) Key issues that will shape 5G

1. **Spectrum regulation**
   - Getting more
   - Sharing more

2. **Technical standards**
   - LTE + IEEE 802.11 = evolution
     - *Or revolution?*

3. **Measurements and standards**
   - MIMO
   - mm-wave

US Spectrum outlook: summary

NBP (March 2010) Goals: 300 MHz by 2015; 500 MHz by 2020

Category	Band (MHz)	Quantity	Timing	Comments
WCS	2305-2320 2345-2360	15 MHz 15 MHz	Oct. 2012	
AWS-4	2000-2020 2180-2200	20 MHz 20 MHz	Dec. 2012	
H block	1915-1920 1995-2000	5 MHz 5 MHz	Feb. 2014	Identified by spectrum act / NBP
AWS-3	1695-1710 1755-1780 2155-2180	15 MHz 25 MHz 25 MHz	Nov. 2014	NTIA Fast track, NBP, and/or spectrum act
Broadcast	600 block	Up to 120 MHz	2015	Incentive auction – rules set May 2014
*U-NII 1 band**	*5150-5250*	*100 MHz*	*April 2015?*	*Indoor restrictions removed; power restrictions increased*
U-NII-2B *U-NII-4*	*5350-5470* *5850-5925*	*120 MHz* *75 MHz*		*Spectrum act: under study by NTIA and FCC*
NBP identified	1780-1850	70 MHz		*Constrained by relocation from AWS-3?*
FastTrack	3550-3650 3650-3700	100 MHz 50 MHz		FCC Citizens Broadband Radio NPRM Possible expansion
mm-wave				FCC NOI on feasibility in 2014? WRC-18?

FCC proposed 3.5 GHz “innovation band” (April 2014)

1) Three-tiered access
   - Tier 1: Incumbent Access (Radar and fixed satellite)
   - Tier 2: Priority Access (though a Spectrum Access System)
   - Tier 3: General Authorized Access (have of spectrum designated as “unlicensed”)

2) Encourages small cells
   - Priority Access initially for 1 year, 10 MHz, single census tract

3) Requires “development and implementation of a robust SAS”
   - Tier boundaries based on usage, dynamically managed by SAS
   - Assumes multiple SAS nationwide collecting “reasonable fees”

4) Requires interoperability of all PAA & GAA devices for economies of scale

(Some) Key technical standards

Licensed/unlicensed convergence: LTE + WiFi =???

3GPP – WLAN interworking study group

- Operator controlled WLANs
- LTE-U

IEEE 802.11

- IEEE 802.11ac/ax to ??
- Coordination of device certification standards

Sharing standards

Spectrum Access Systems

- Interworking among multiple databases
- Security
- Proprietary information
- Sensing vs location

Macro-network control vs. UE control

(Some) Key measurement standards

Massive MIMO: a key technology for throughput

- **A Massive characterization challenge**
- Compare CTIA MIMO OTA Test (TM3) (draft plan 2014)
  - "Anechoic Chamber, Multi-Cluster" method: 8 transmitters cluster multipath with specific time response and arrival angle.

Millimeter waves: a key technology for additional spectrum

- Improvements needed in
  - Channel sounding (directional)
  - 3D Channel modeling
    - Large-scale path loss and blocking
    - Small-scale delay characteristics
    - 3D Spatial channel characteristics for MIMO

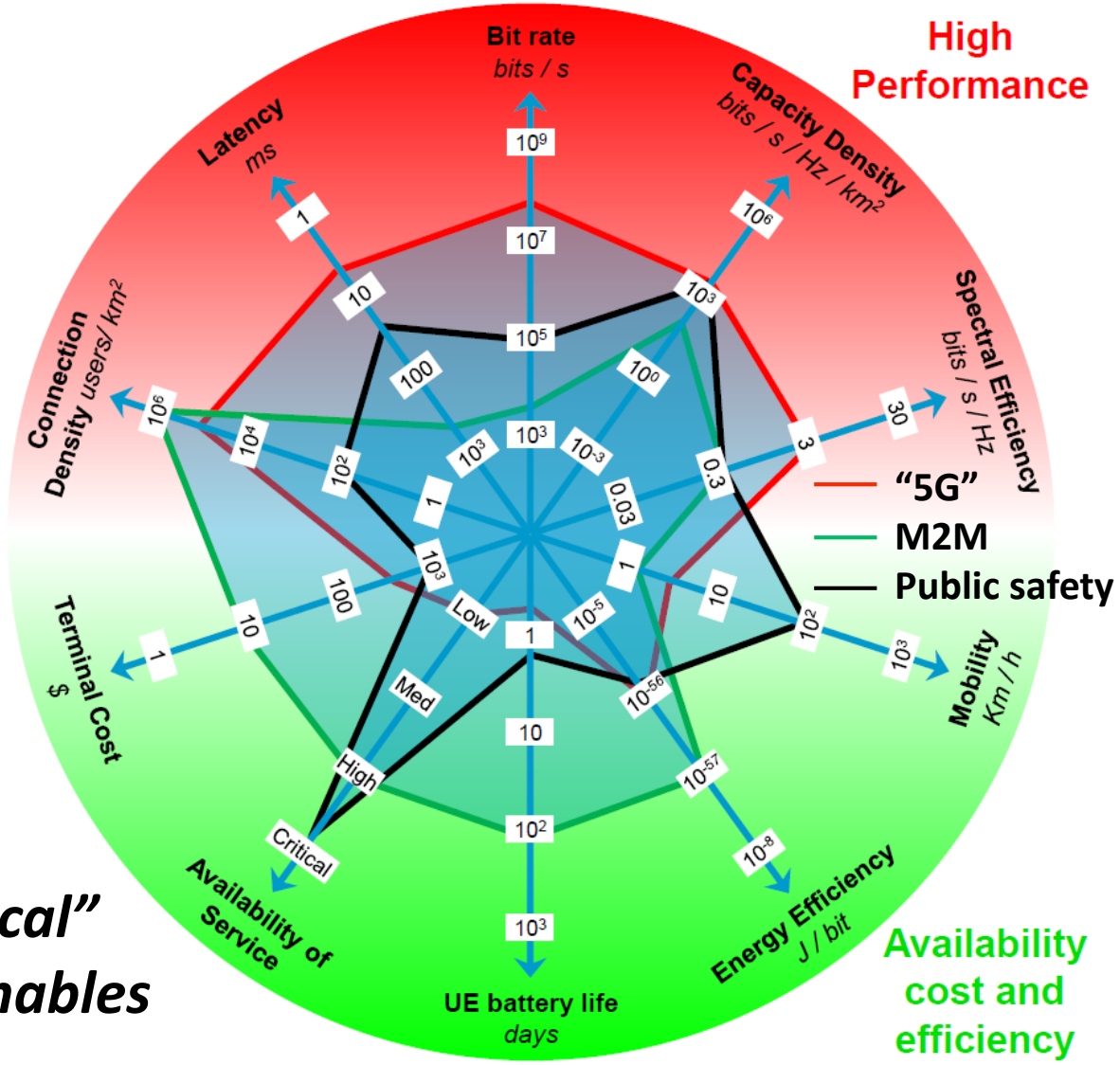
Robot-mounted array of 16 directional receive antennas

“Atypical” use cases push performance standards…

M2M pushes
- Energy efficiency
- Battery life
- Terminal cost
- Connection density

Public safety requires
- Availability
- Mobility
- *Priority/preemption*
- *Coverage*
- *Direct mode; groups*

…accommodating “atypical” use cases in standards enables innovation



From Moray Rumney, Keysight Technologies

Competing challenges

1. **Technical**

2. **Harmonization**
   - International spectrum harmonization
   - Allied standards harmonization
   - Uniform dynamic sharing standards

3. **Adoption influences**
   - Incumbency and economies of scale
   - How does 4G penetration influence 5G?