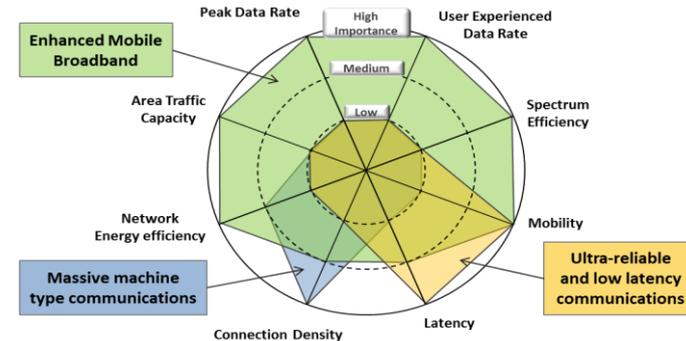
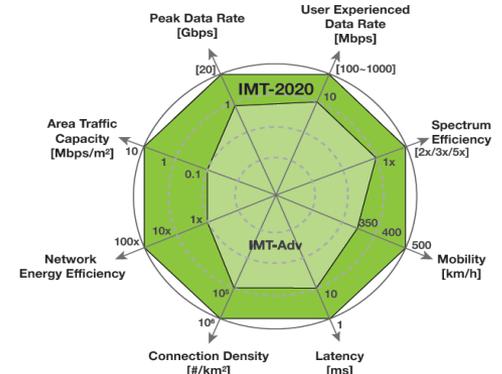
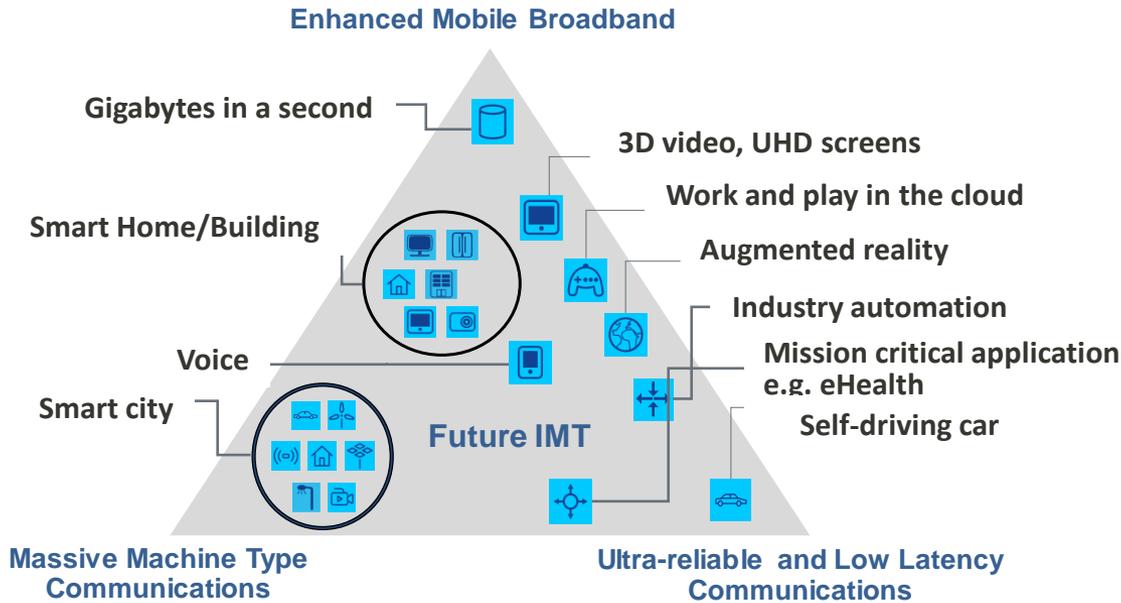


Outline

- High Level Requirements
- Technology Trends
- 5G Standardization Timeline
- Dynamic Channel Model for mmWave
- Summary

Different Product Segments in 5G



Three different usage scenarios
 → very different modem requirements for chipset vendor

1. Enhanced Mobile Broadband (e.g. for smart phone)
2. Massive Machine Type Communications (e.g. for massive sensor nodes)
3. Ultra-reliable and low latency communications (e.g. for car)

Envisioned Market Space at 2020

Enhanced Mobile Broadband

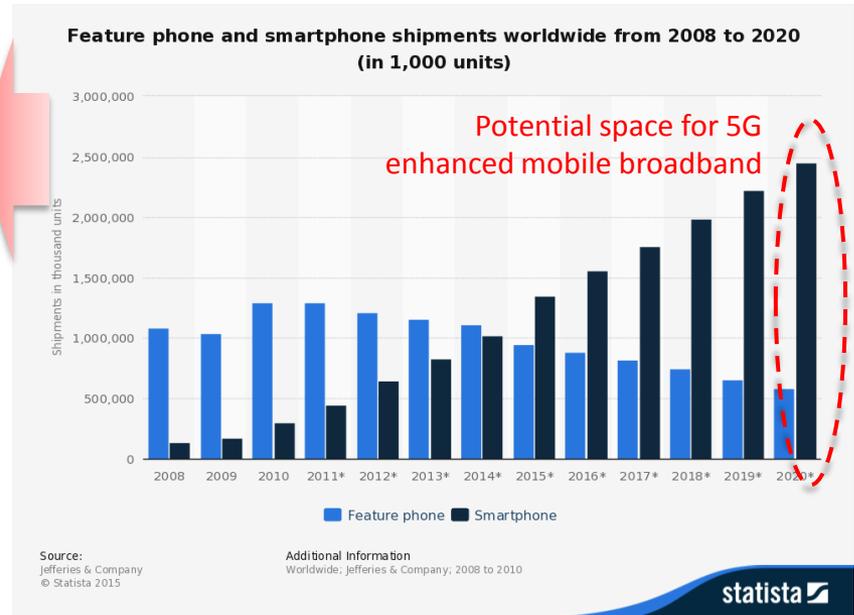
- Overall smartphone market space keep growing steadily
- Premium phones could support 5G ultra high speed as selling point

Massive Machine Type Communication

- Overall IoT market space grows fast
- Significant growth on LPWA (Low Power Wide Area) market segment
 - 5G massive MTC could be the solution to address this market

Ultra-Reliable and Low Latency Communication

- Market just initiated, need short term solution to test market.
- 5G solution could be long-term roadmap for ultimate performance



A Brand New World



Tablets



Smartphones



Wearables



Sensors, Actuators



Smart homes



Health



Transportation,
Automotive



Robotics,
Automation



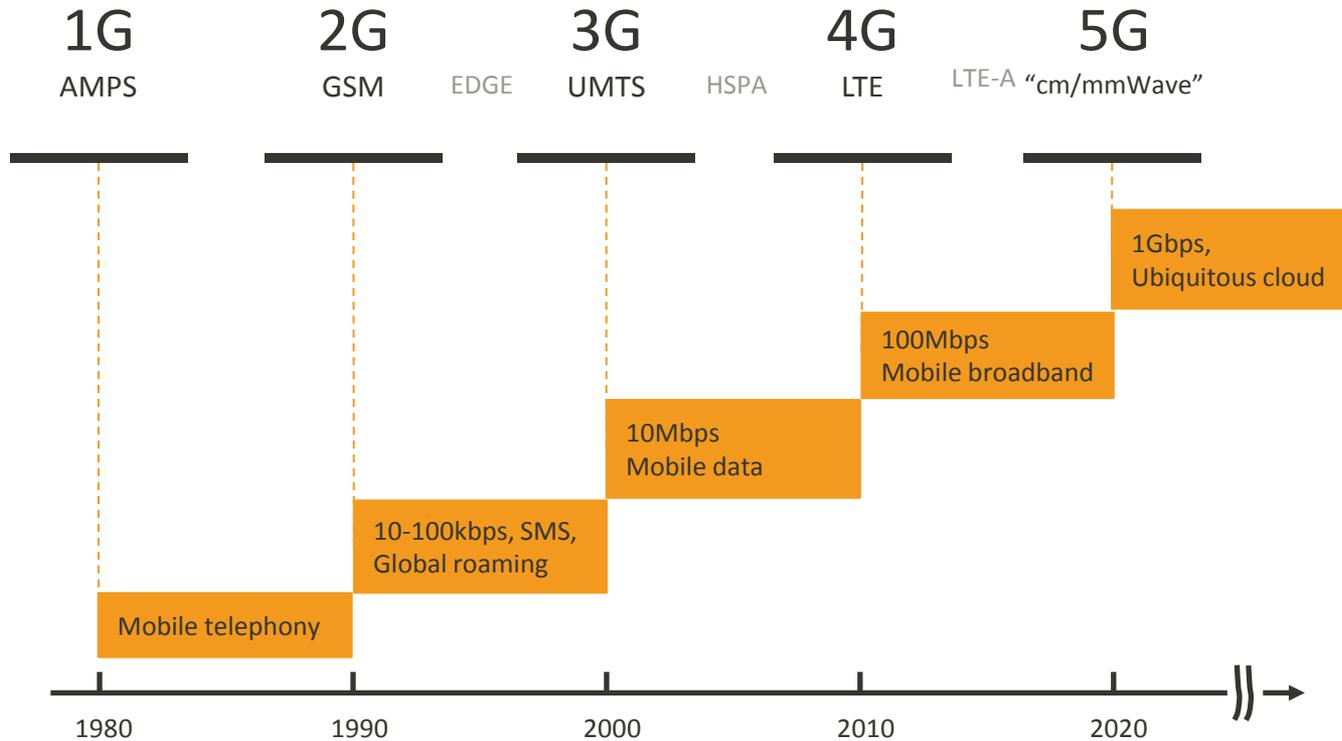
Cloud services,
computing & storage

5G to enable **ubiquitous** and **unlimited**
access to information



- High Level Requirements
- **Technology Trends**
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 - mmWave
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Cellular Evolution toward 5G



~10 years between generations

~20 years from launch to peak

LTE Evolution for 5G

LTE evolution to play a significant role in 5G



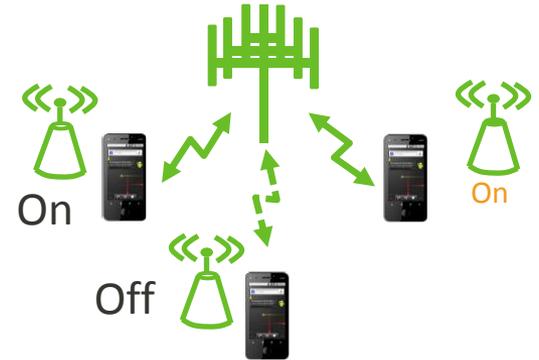
Cellular-WiFi Integration

- > Additional Spectrum
- > Better User Experience



Machine-Type Communications

- > New Services
- > Extended Coverage
- > Long Battery Life
- > High Connectivity



Small Cell Enhancements

- > Improved Capacity



Interference Cancellation

- > Improved Capacity and Coverage

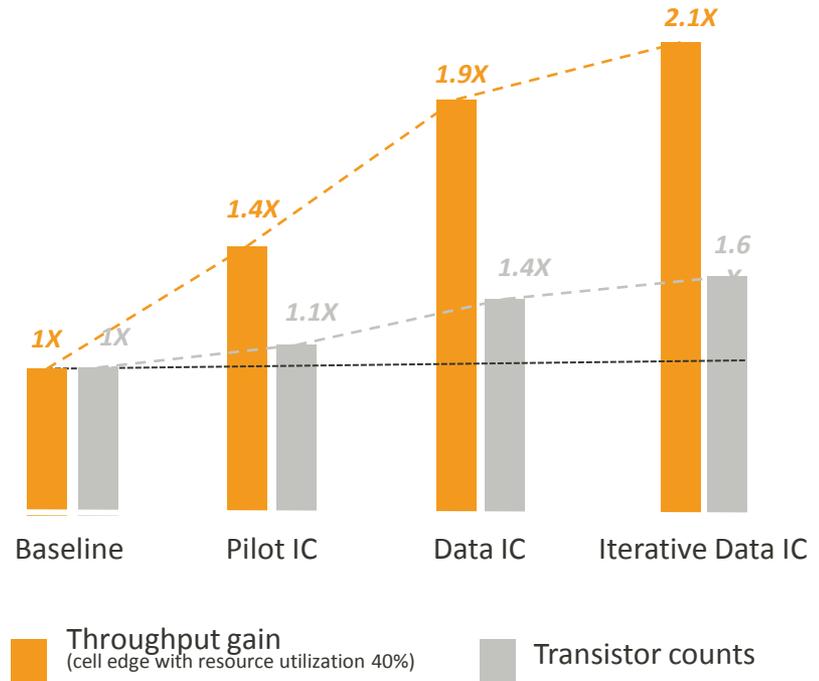
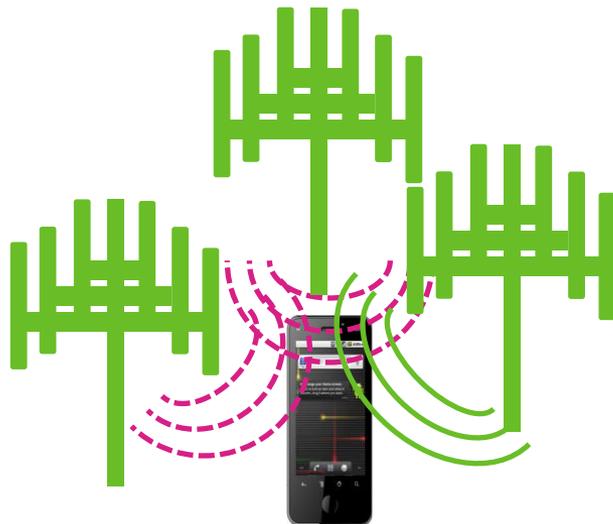


License-Assisted Access

- > Additional Spectrum
- > Better User Experience

Smart Interference Cancellation in Device with Network Assistance

- **Solutions using NAICS Evolution in 3GPP Standards**
 - Network-Assisted Interference Cancellation Suppression (NAICS, Rel-12)
 - Multi-User Superposition Transmission (MUST, Rel-13)
 - ... (TBC, Rel-14)



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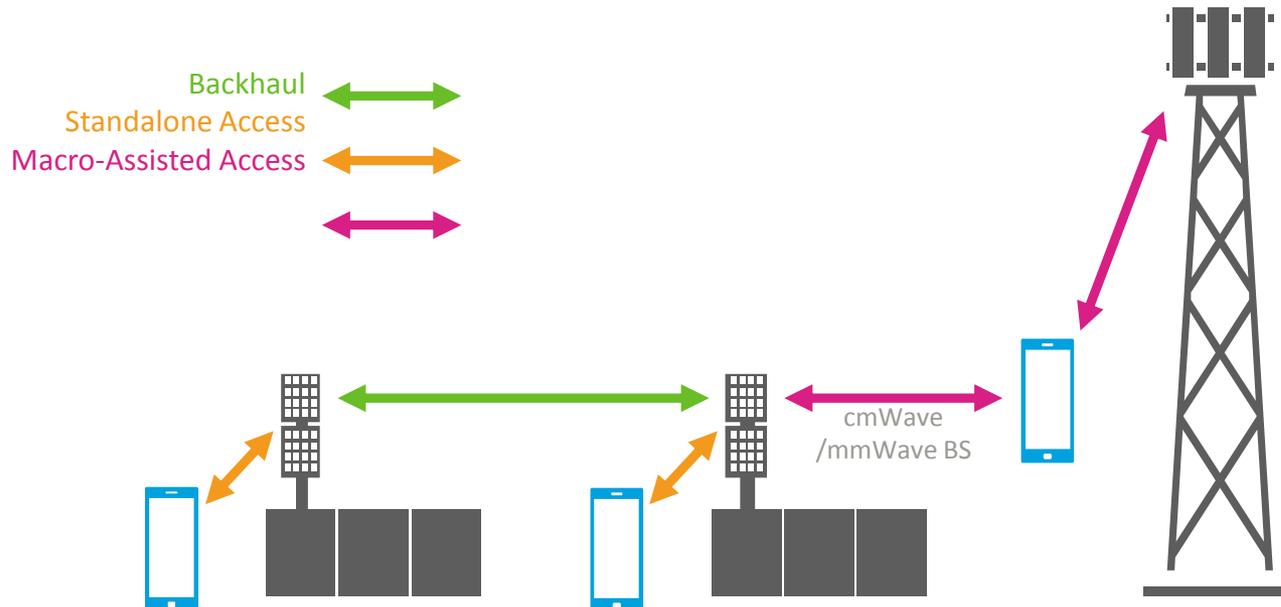
Exploit Higher Spectrum Resources

- **cmWave/mmWave***

- Extreme high data rate
 - in high spectrum
- 9 Gbps avg. cell throughput achievable in 1GHz BW[†]

- **Challenges**

- Antenna, RF
- Beamforming, tracking
- New spectrum to be secured ITU WRC-18/19



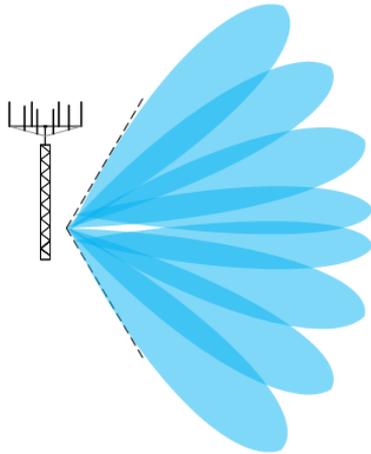
[†] MediaTek, VTC Spring 2015
^{*} cmWave for spectrum above 6GHz

mmWave for spectrum above 30GHz

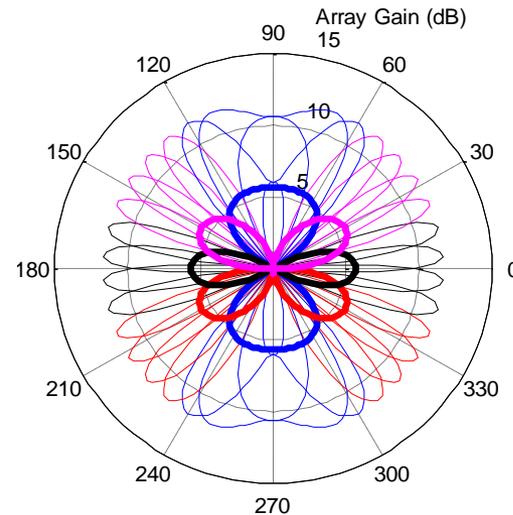
Channel Modeling

Dynamic – Beamtracking

BS 8 control beams



UE *Category 1: 4 Level-1 Beams*
Category 2: 4 Level-1 Beams + 16 Level-2 Beams



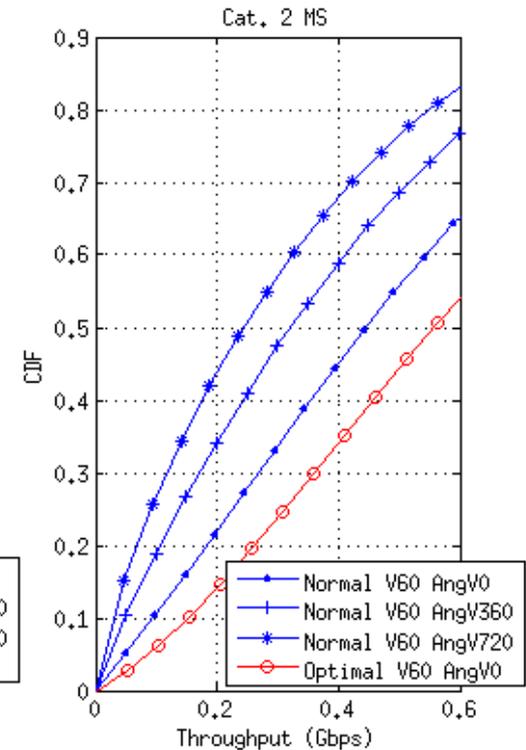
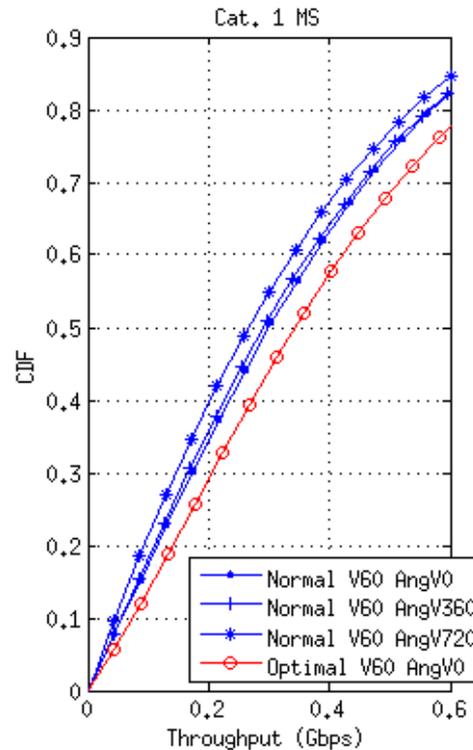
	Array Gain from UE	Required Training Opportunities for Exhaust Search
Cat.1 UE	~ 6 (dB)	8 (BS Beams) x 4 (UE Beams) = 32
Cat.2 UE	~ 12 (dB)	8 (BS Beams) x (16 + 4) (UE Beams) = 160

Channel Modeling

Dynamic – Beamtracking

- UE: constant speed of 60 kmph and spin at one of 3 angular velocities
- Signal strength between all 4x8 level-1 TX/RX beams combinations updated at 50Hz

Example scenario: phone rotation
(e.g. pick up the phone from pocket)



Z Angular Velocity (degree/s)		Cat. 1 UE	Cat. 2 UE
0		0.36 (Gbps)	0.50 (Gbps)
360	Slight Drop	0.35 (Gbps)	Rapid Drop 0.39 (Gbps)
720		0.33 (Gbps)	0.32 (Gbps)

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5G Requirements for Cellular IoT

Most relevant to Cellular IoT

	5G		IMT-Advanced (4G)
	ITU-R WP5D ^[1]	NGMN ^[2]	
User experienced data rate	[100 Mbit/s – 1 Gbit/s]	[300 Mbit/s-1 Gbit/s] (minimum @95% location and 95% time)	10 Mbps
Peak data rate	[20 Gbit/s]	Tens of Gbps	1 Gbit/s
Connection density	10 ⁶ /km ²	10 ⁶ /km ²	10 ⁵ /km ² (see appendix, ^[4] , ^[5])
Mobility	500 km/h	500 km/h	350 km/h
Latency	1 ms (one-way radio access) [†]	1ms vehicular & industry automation / 10 ms general ^{††} (2-way e2e), no connection delay	8 ms two-way user plane latency ^[3] (see appendix)
Energy efficiency (for network)	100 times IMT-Advanced Lower total energy consumption than IMT-Advanced.	x2000 times 4G Half of 4G network energy consumption (with x1000 traffic increase)	--
Averaged Spectrum efficiency	[2/3/5 times IMT-Advanced]	Better than 4G Evolution	--
Area traffic capacity	10 Mbps/m ²	15 Tbps/km ²	0.1 Mbps/m ² (InH)
Network Based Positioning	N/A	[10m-1m] outdoor, <1m indoor	N/A
Ultra-high reliability	N/A	>99.999%	•/A

^[1]Source: ITU WP5D #21 meeting

^[2]Source: NGMN 5G White paper

^[3]Source 3GPP rel-9 TR 36.912

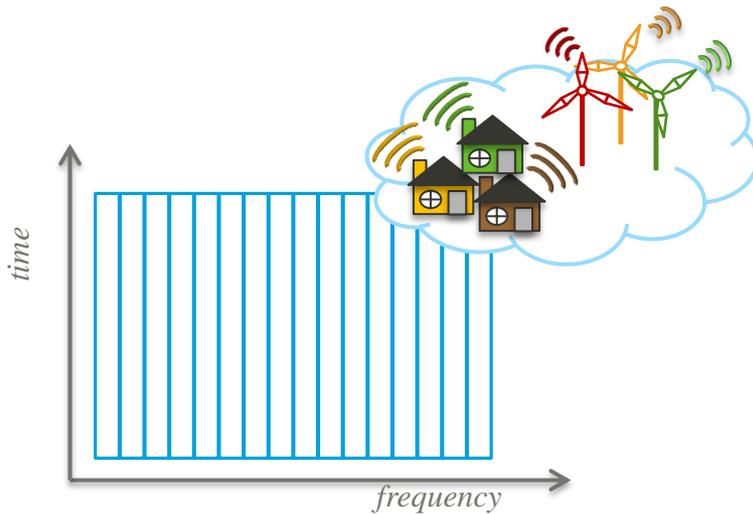
^[4]Source: Rel-12 TR 36.888

^[5]Source: GERAN GP-140421

Design Considerations of New Air Interface

- **Longer Symbol, Smaller Sub-carrier Spacing.**

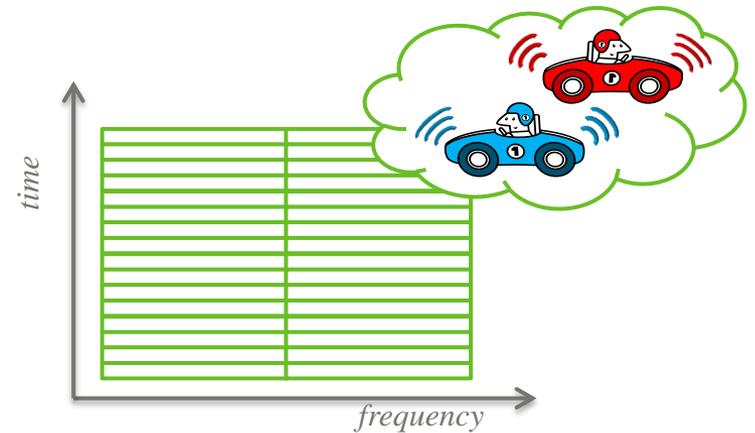
- Massive MTC connections
- Easier synchronization, deeper coverage (e.g. PSD boosting)



e.g. subcarrier spacing = 3.75kHz

- **Shorter Symbol, Larger Sub-carrier Spacing.**

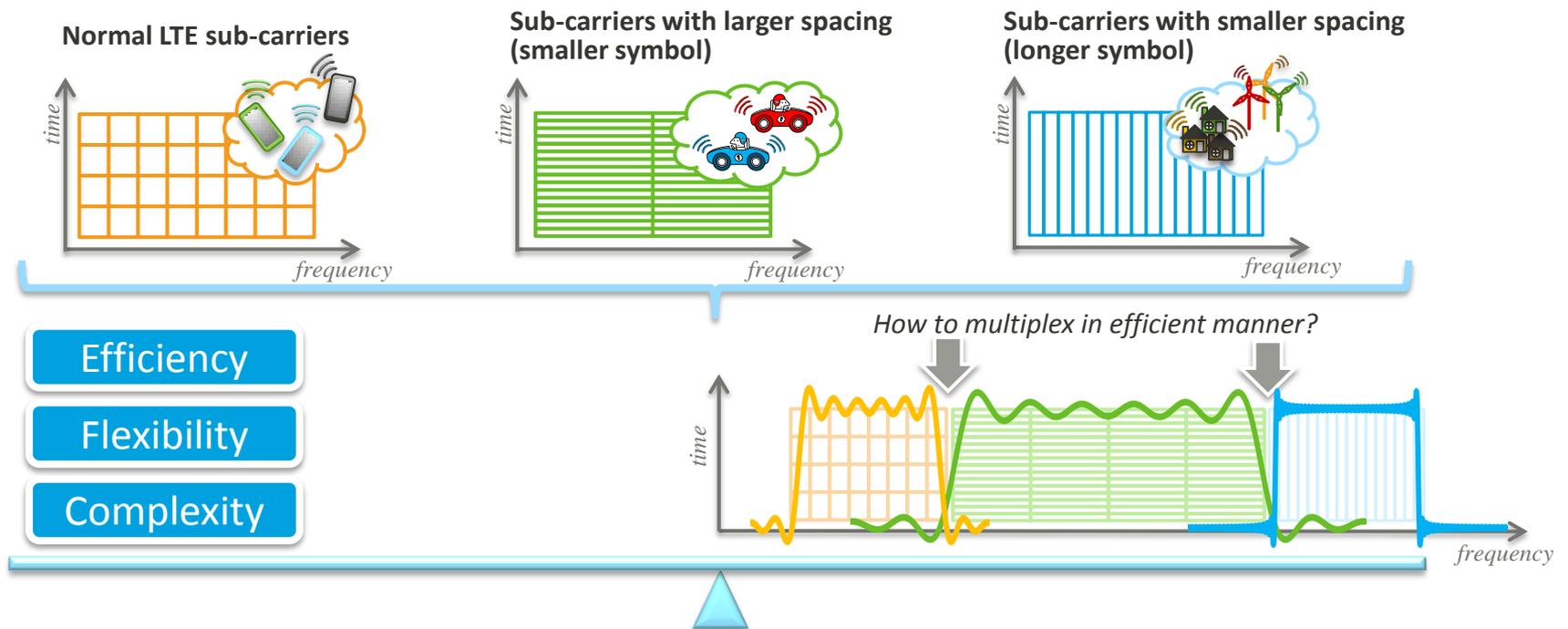
- Finer time granularity for latency reduction



e.g. subcarrier spacing = 60kHz

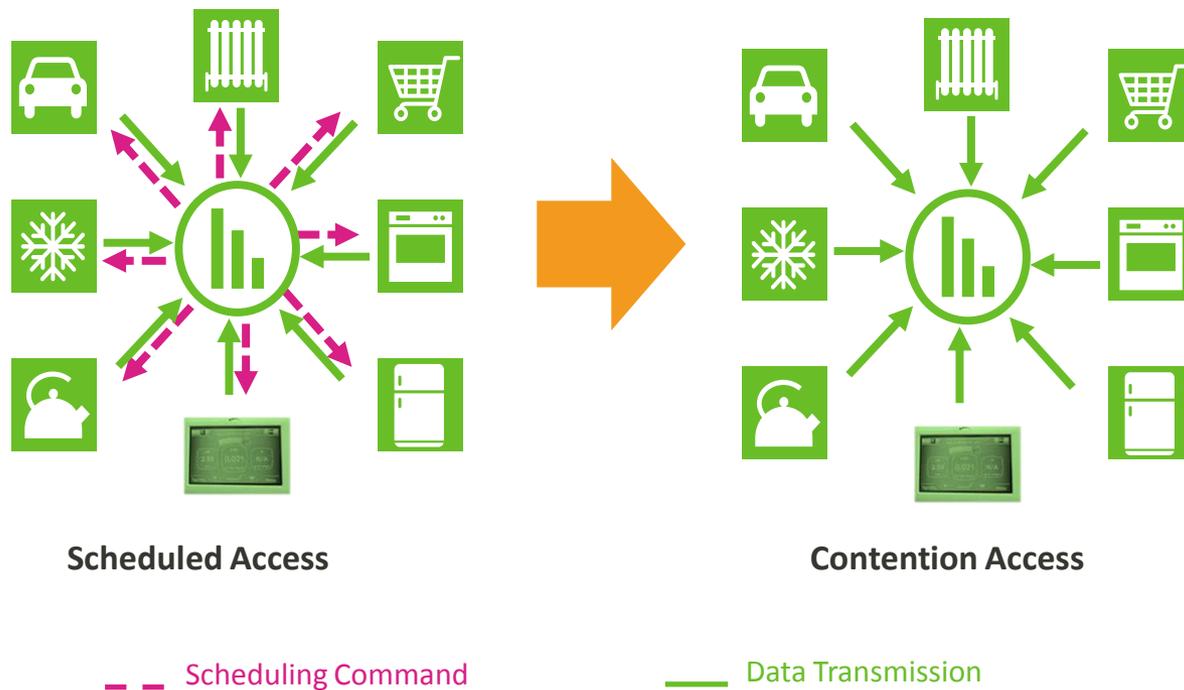
Scalable 5G Air Interface

- Better coexistence with legacy LTE waveform
 - Keep OFDM structure, consider LTE will occupy most low-band spectrum in next decade.
- Flexible support of different sub-systems within the same carrier
 - Reuse the same spectrum resource to deploy new IoT services when needed



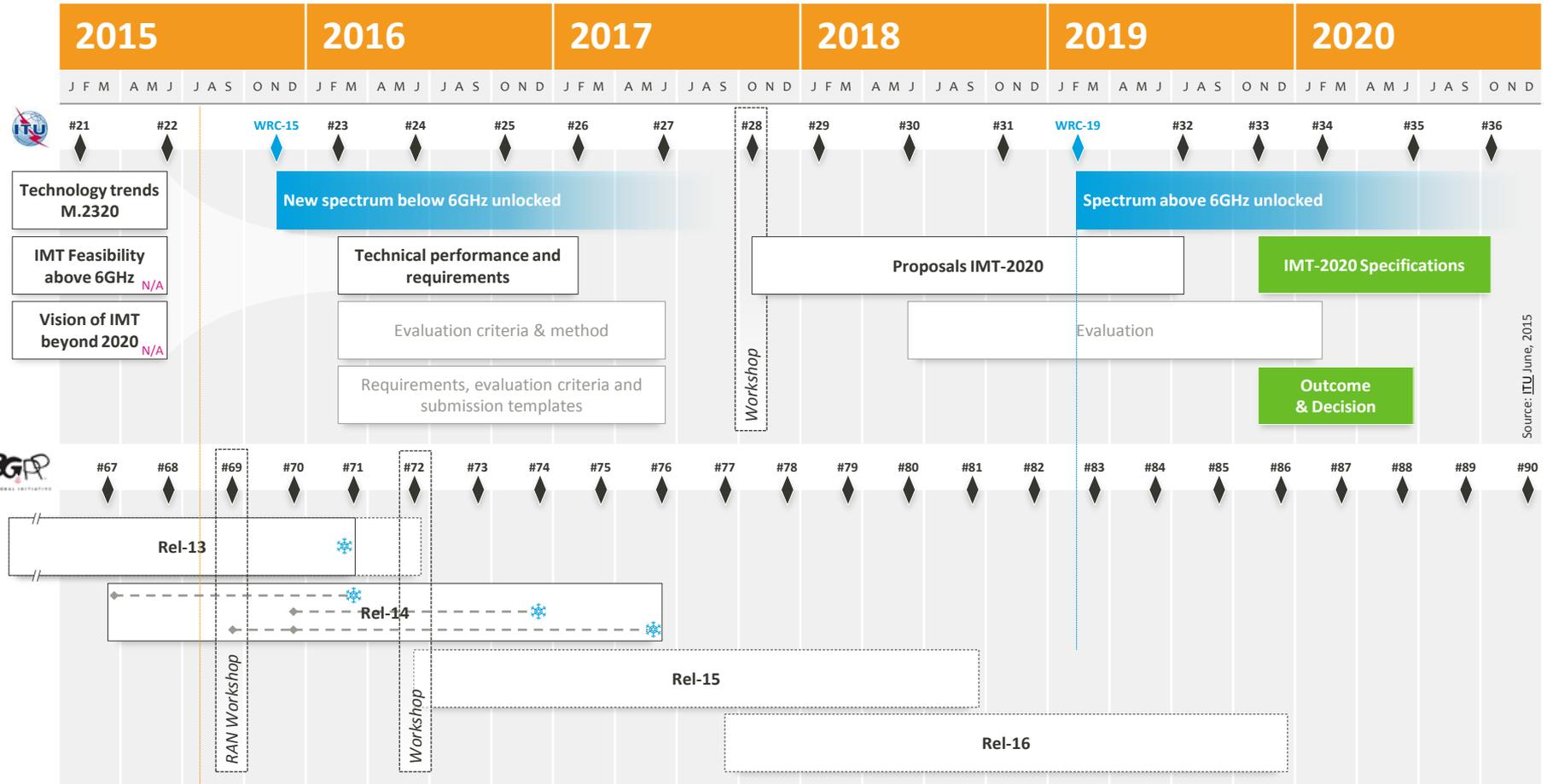
All Things Connected

- **New access scheme based on contention is promising**
 - Less overhead, shorter latency suitable for bursty small packets
 - Contention based access for latency and capacity (connection density) improvements
 - Avoid TA adjustment by longer symbol length (smaller sub-carrier)



- High Level Requirements
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5G Standardization

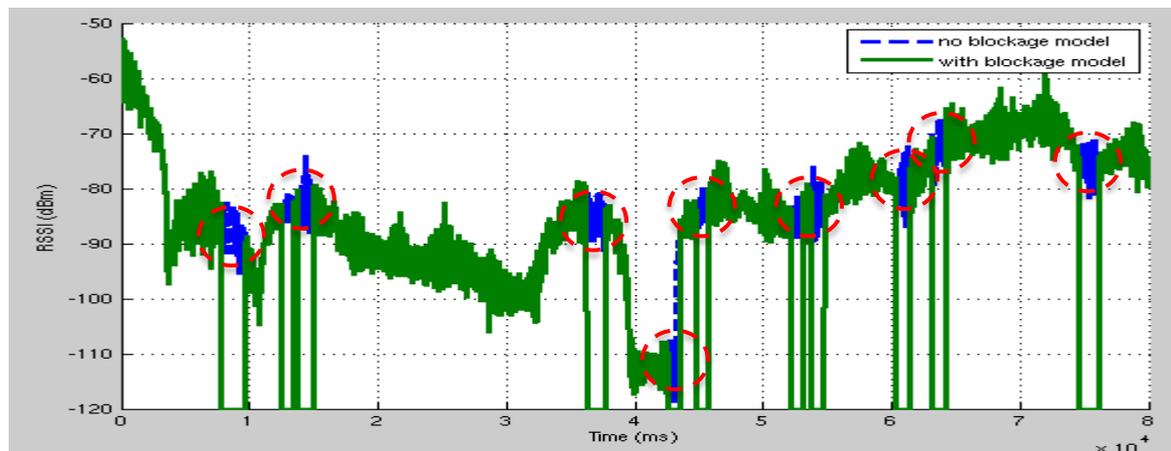
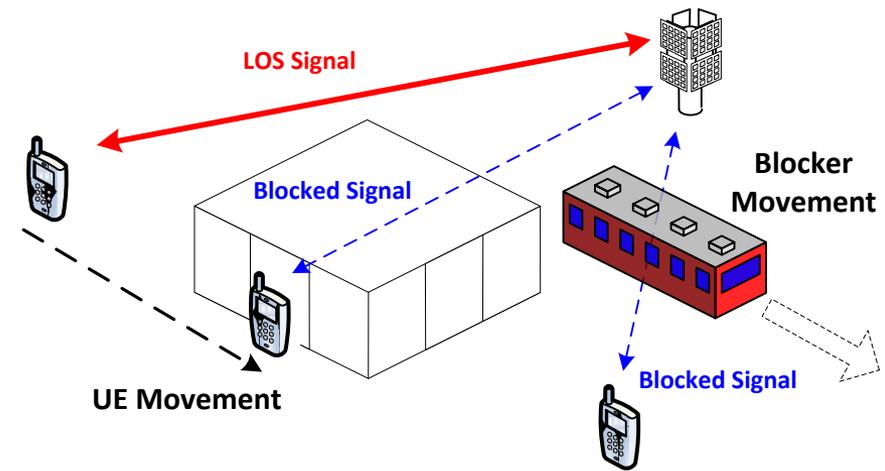


(1) Release driven by NB-CIoT discussions. Possibly moved to Rel-14

- High Level Requirements
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mmWave Channel Blockage Effect

- Highly directional signal will easily be blocked in real deployment
 - In addition to slow fading, the signal may suddenly drop rapidly.
 - Blockage model is critical to correctly capture the spatial characteristics for mmWave system design
 - Existing SCM model cannot properly capture such effect → need new model



Study on Channel Model for mmWave

- Candidate models could be studied
 - Spatial Channel Model (SCM)
 - WINNER / IMT-Advanced / 3GPP Channel Model
 - COST-2100 Model
 - METIS Map Based Model
 - METIS Stochastic Model
 - Quadriga
 - MiWEBA Model
 - ...
- Sufficient time for channel model study is very important
 - Avoid poor system design due to wrong assumption
- Deployment Scenarios
 - Mobile access?
 - Backhaul?
- Mobile Access
 - Need dynamic model with time-varying scatterers parameters for beam tracking and mobility management
- Backhaul
 - SCM-based static model sufficient?
 - May require path structure refinement

- High Level Requirements
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Summary

- **Dynamic channel model is very critical for mmWave system design**
 - Blockage effect is dynamic for mmWave access
 - Need to capture spatial characteristics to ensure quality design
 - Sufficient standardization time shall be allocated (e.g. 4Q)
- **5G will be a cohesive set of technologies**
 - LTE Evolution will play a major role
 - New mmWave to tap into spectrum above 6GHz
 - Need for global standards
- **3GPP standardization will be the key for 5G success**
 - Standardization priority should consider deployment needs

MediaTek is committed to 5G success



everyday genius