



5G Enabling Technologies

An Unified Adaptive Software Defined Air Interface

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5G World



Everything on Mobile



Everything Connected



Everything Virtualized



5G (Beyond Smartphone)



Transform the Industry Verticals

400MHz

Open OTT

D2D

IoT

SDN-RAN

10GHz

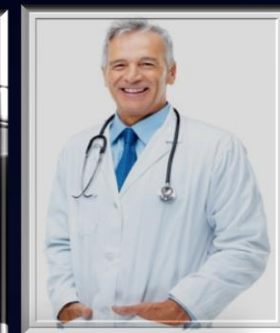
MBB

Verticals

100GHz

Auto-drive

Medicare



Robots

Meters
Sensors

Capacity

1000X
(Capacity/km²)

Speed

100X
(10Gbps)

Latency

Less than
1ms

Links

100x

Energy

1000X
Reduce

5G (Beyond Internet Access and APPs)

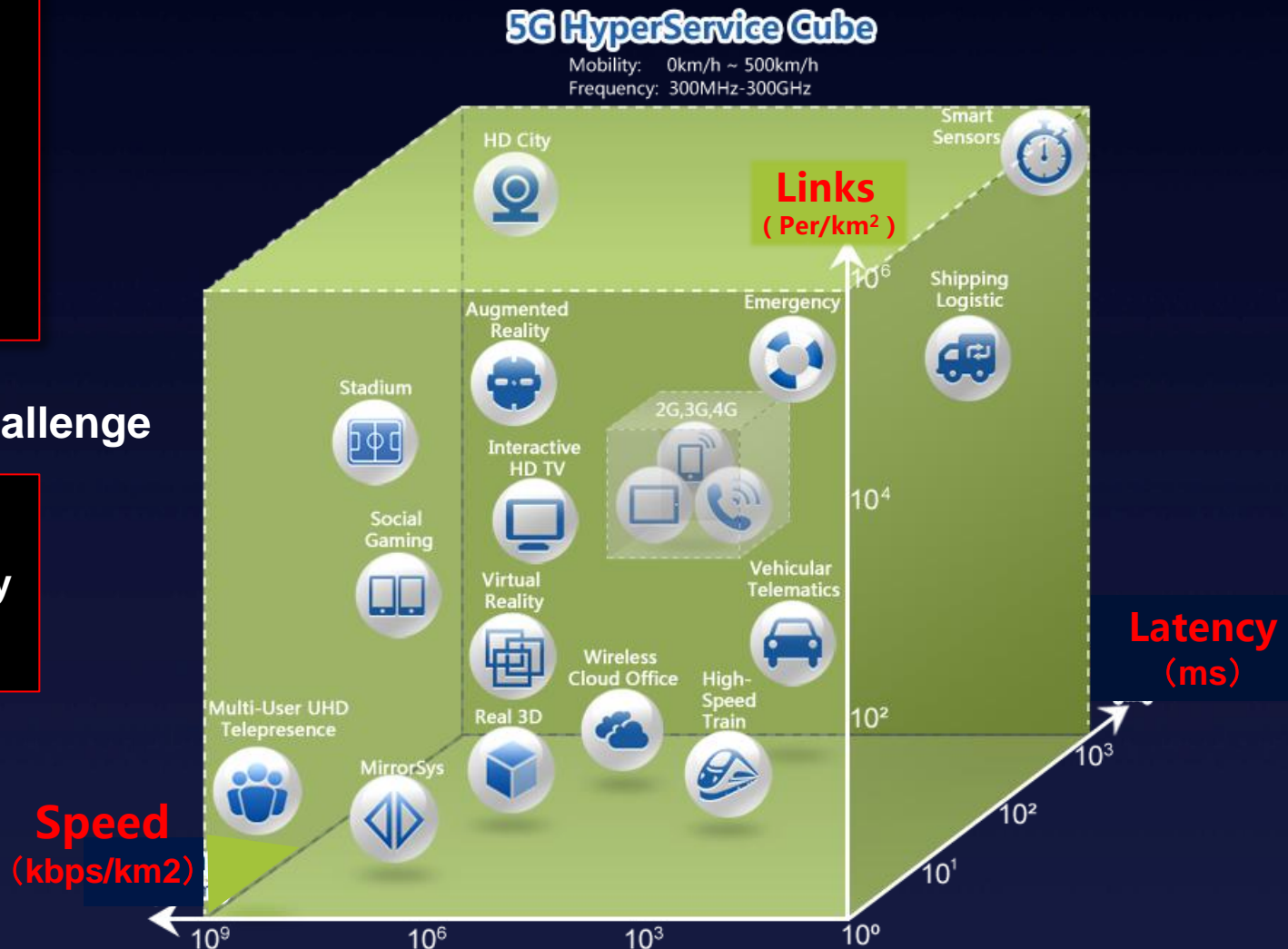


Unprecedented Performance Challenge

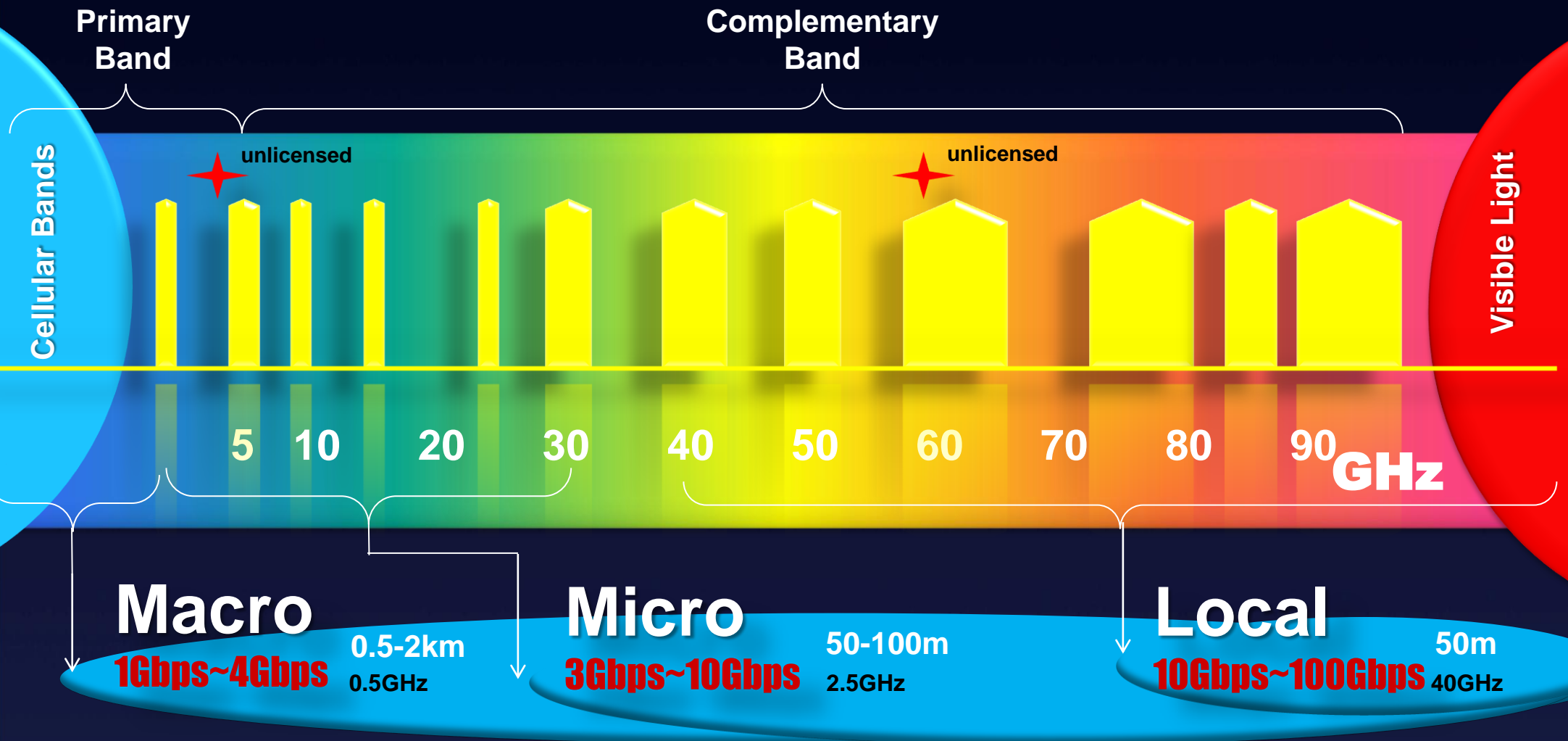
Stretched in 3 Dimensions
Speed
Links
Response
Spectrum Efficiency
All Spectrum Access

Networks Re-Architect Challenge

No-Cell Virtual RAN
Software Defined & Simplicity
Service Aware and Monetize



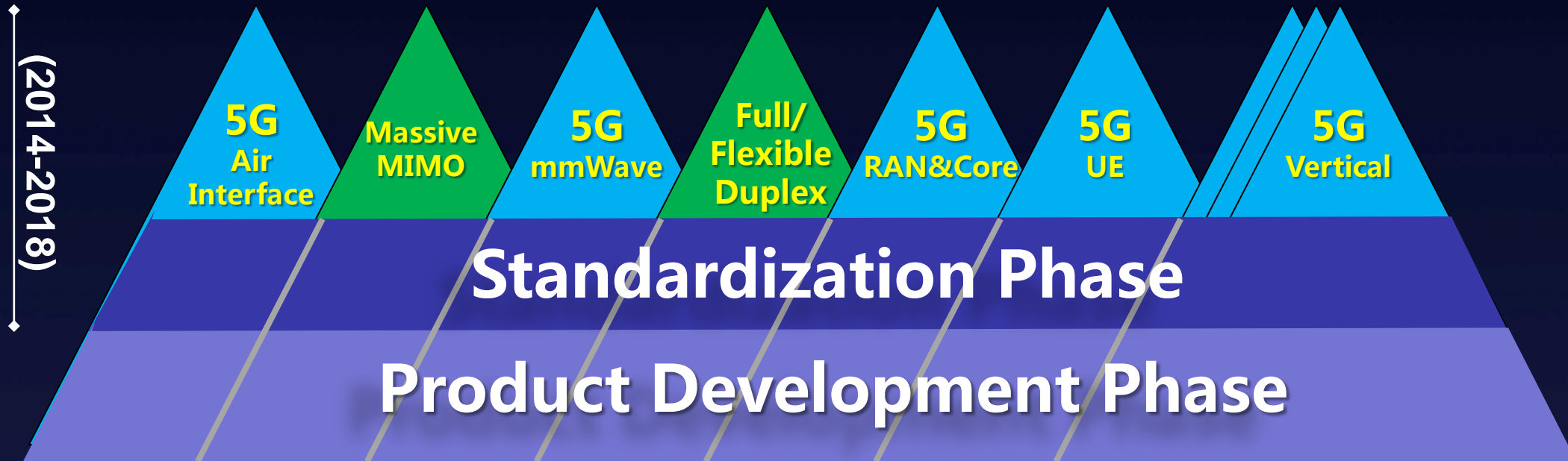
Single & Unified Air-Interface for All Spectrum Access



Foundational Technologies



Research Phase



Air Interface Characteristics



Sparse Code
Multiple Access
(SCMA)

F-OFDM

Orthogonal-
free &
Synchronous
free

Spectral
Localization

Variable
sub-Carrier
Tailored to
Applications

Virtualized
& Software
Defined
RAN
Primitives

Ultra-narrow Bands for Internet of Things Applications
Ultra-wide-Bands for Virtual Reality Applications
Ultra-low Latency for Vertical Applications

Capacity
X1000

Spectrum
Efficiency
X30

Latency
X1/10

Links
X100

Coverage
30dB

Reliability
x1000

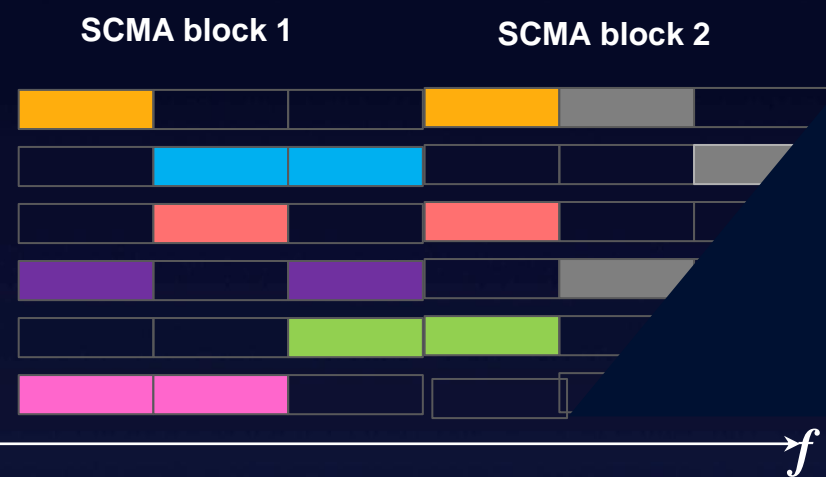
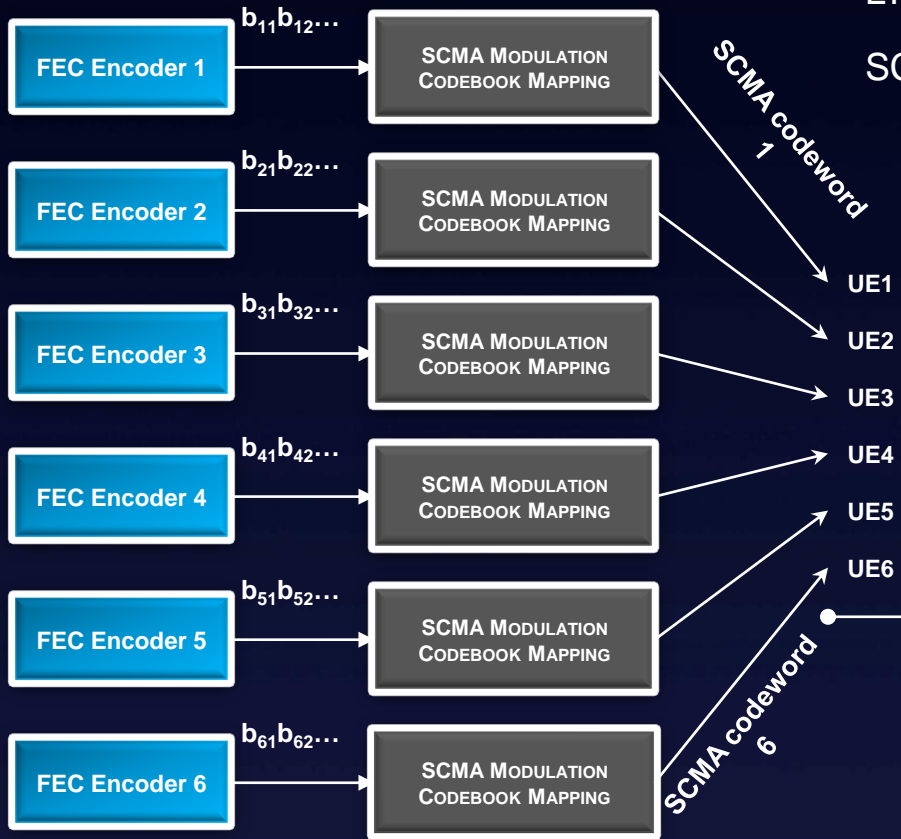
Mobility
500km/h



SCMA (Sparse Code Multiple Access)

LTE: K (4) symbols mapped to K (4) sub-carriers

SCMA: N (6) symbols mapped to K (4) sub-carriers (N > K, overloading)

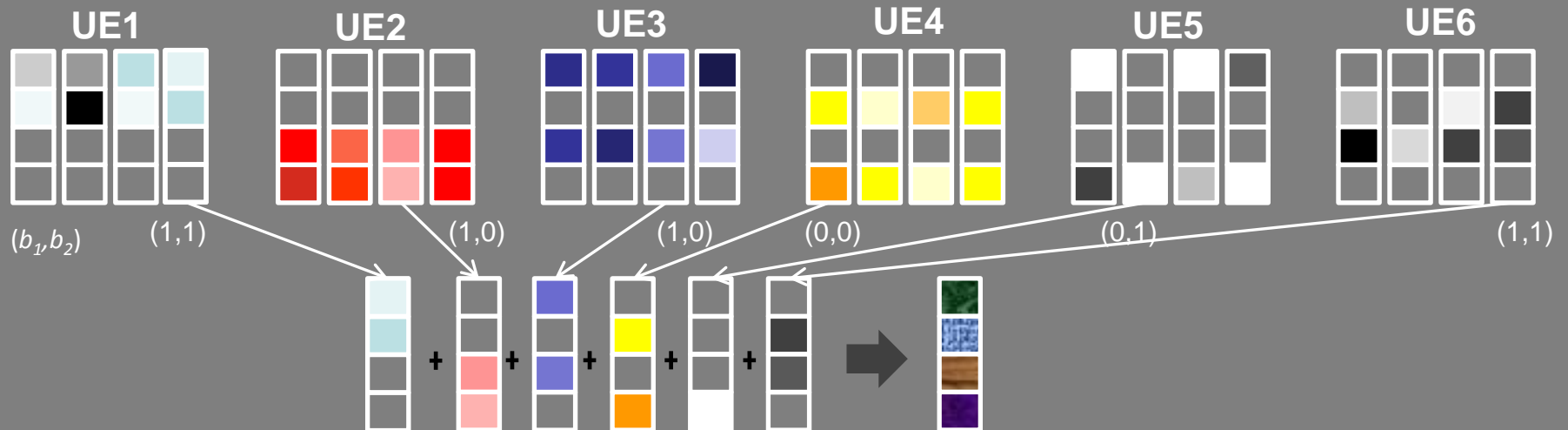
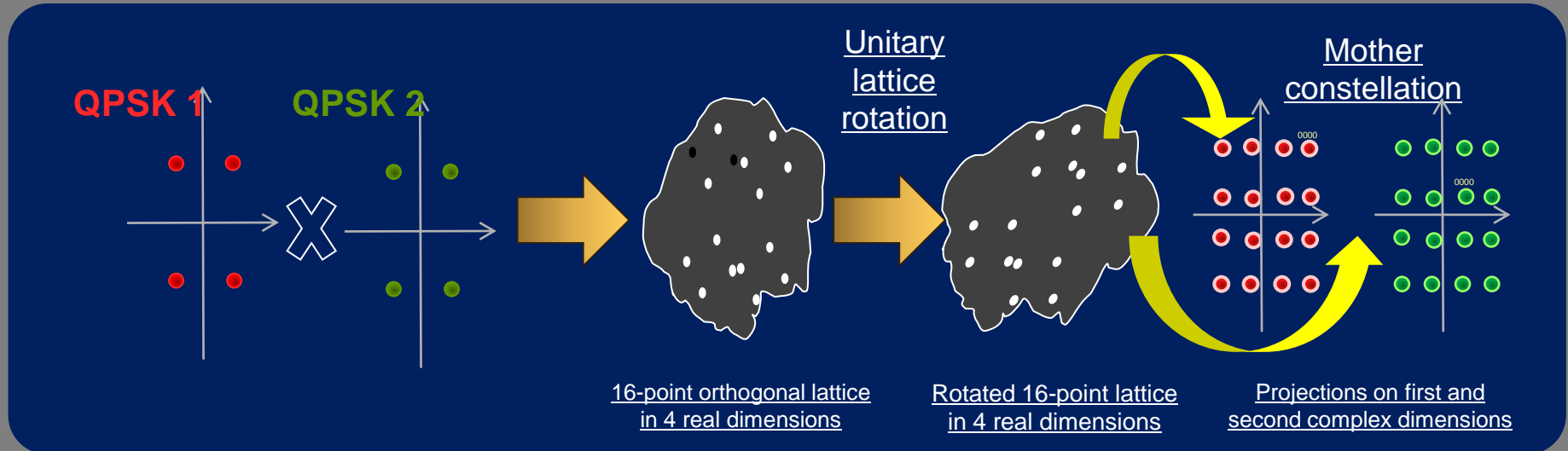


A new frequency domain non-orthogonal waveform

- ❑ Input bits are directly mapped to codewords and spread over multiple sub-carriers
- ❑ Codewords can be assigned to same UE (SU-SCMA) or different UEs (MU-SCMA)

- ❖ **Non-orthogonal** multiplexing of code layers
- ❖ **Over-Dimension** to increase overall rate and connectivity
- ❖ **Sparsity** to limit Rx complexity for detection
- ❖ **Multi-dimensional** codewords with shaping gain
- ❖ **Spreading** for robust link-adaptation, coverage

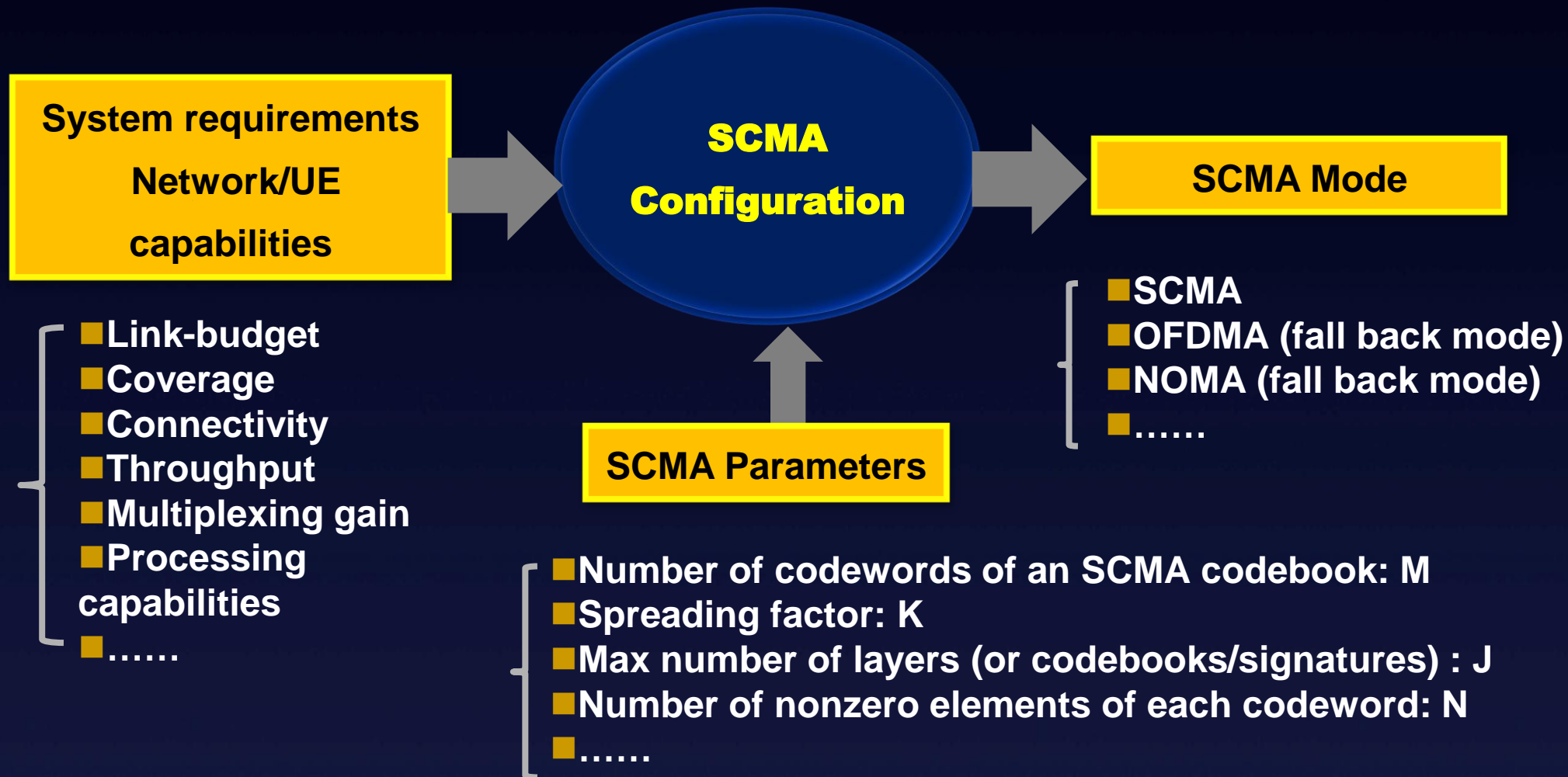
SCMA Code Book



- SCMA codebook based on Multi-dimensional Lattice Constellation to exploit shaping gain and coding gain
- Each UE/layer stores a unique codebook
- Binary input data is mapped to a codeword of the corresponding codebook
- Low PAPR and low projection codebooks possible

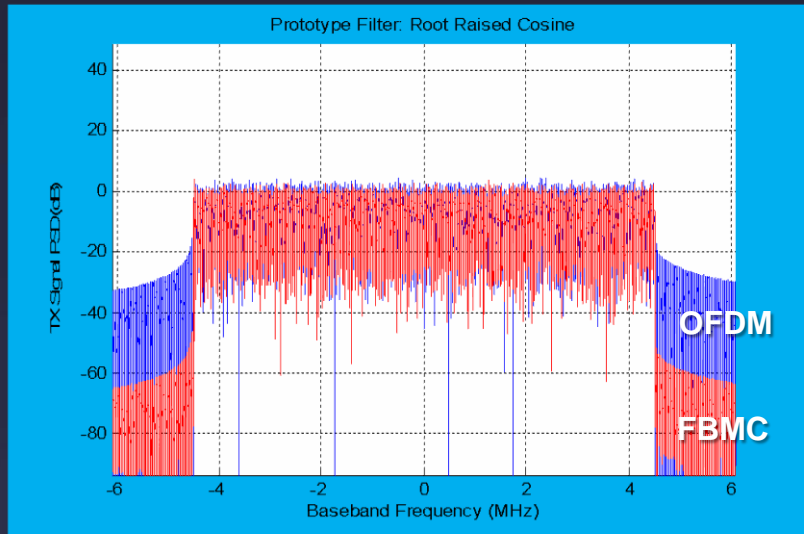
Scalable SCMA

with Adaptive System Parameters

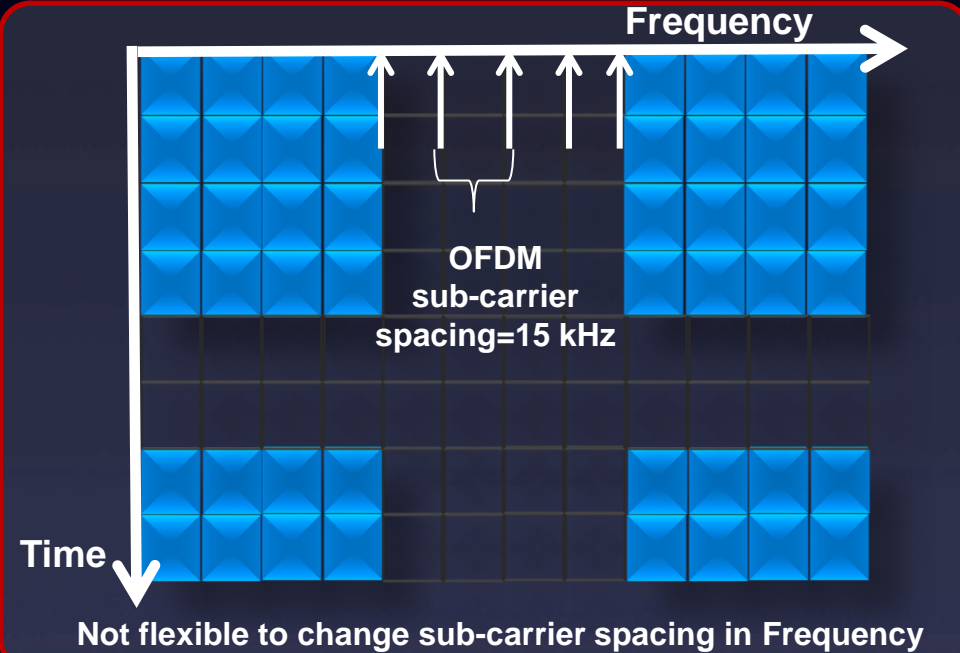


Flexible and scalable SCMA based access scheme which can compromise among spectral efficiency, coverage, detection complexity, connectivity, and link budget to adapt to different application scenarios

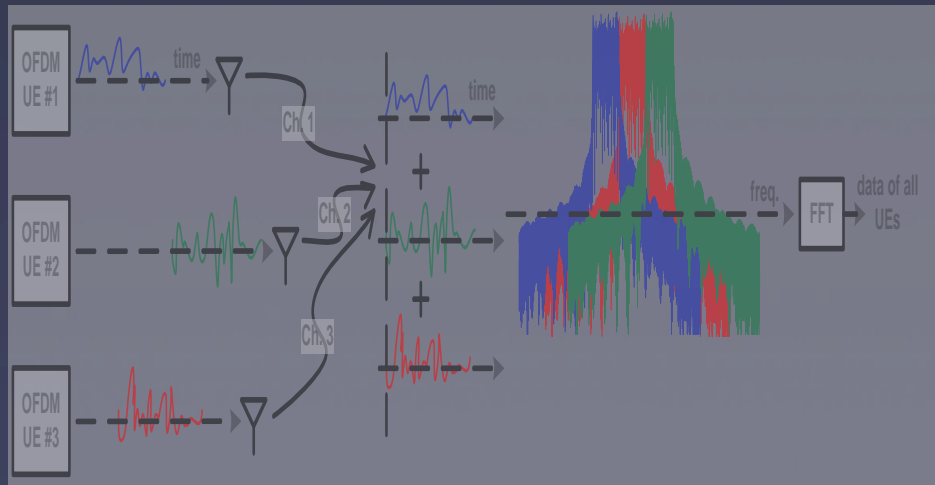
Issues for OFDM Waveform



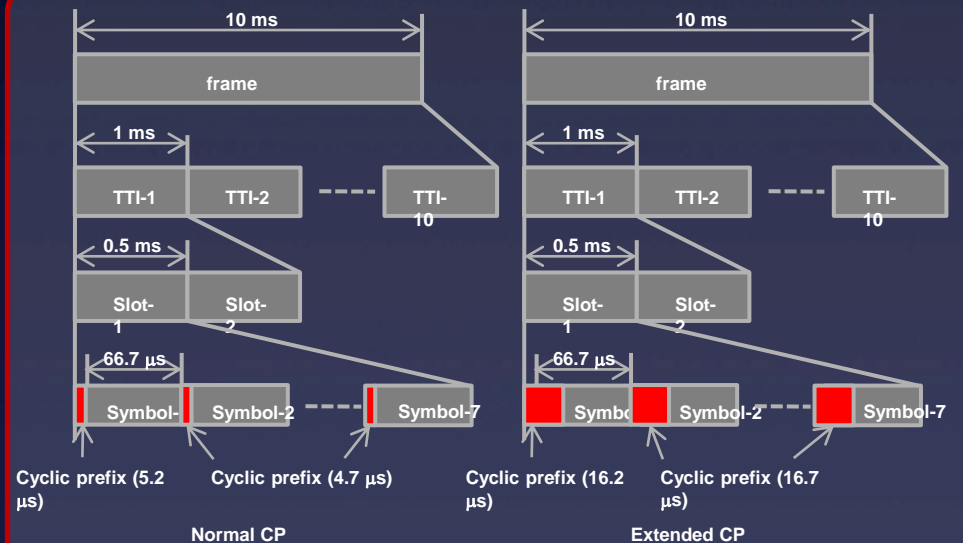
Spectrum not localized, need guard band



Not flexible to change sub-carrier spacing in Frequency



Synchronous Tx, large overhead for time alignment

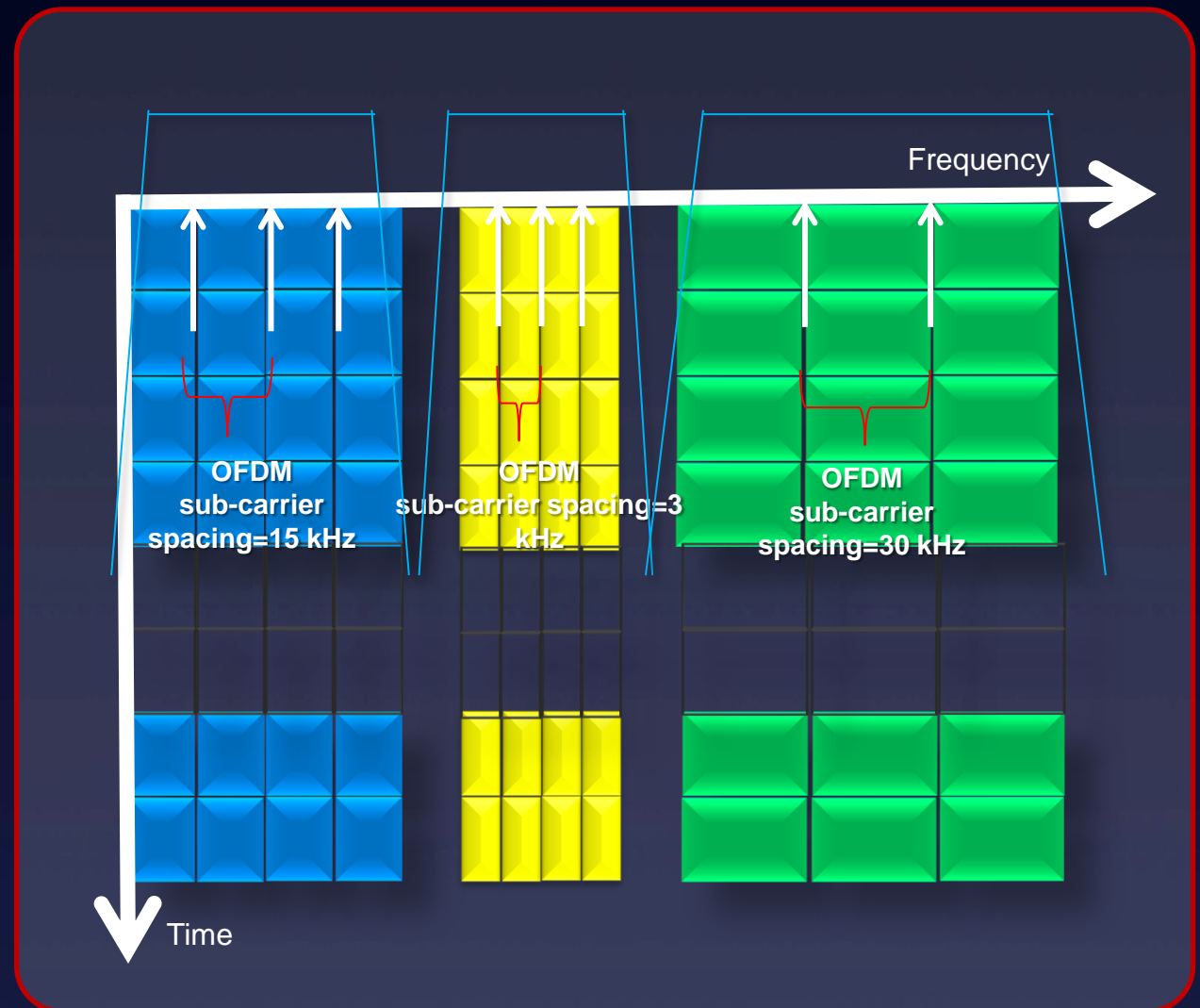


Fixed symbol duration, not flexible to change CP

Spectrum Filtered OFDM (f-OFDM)



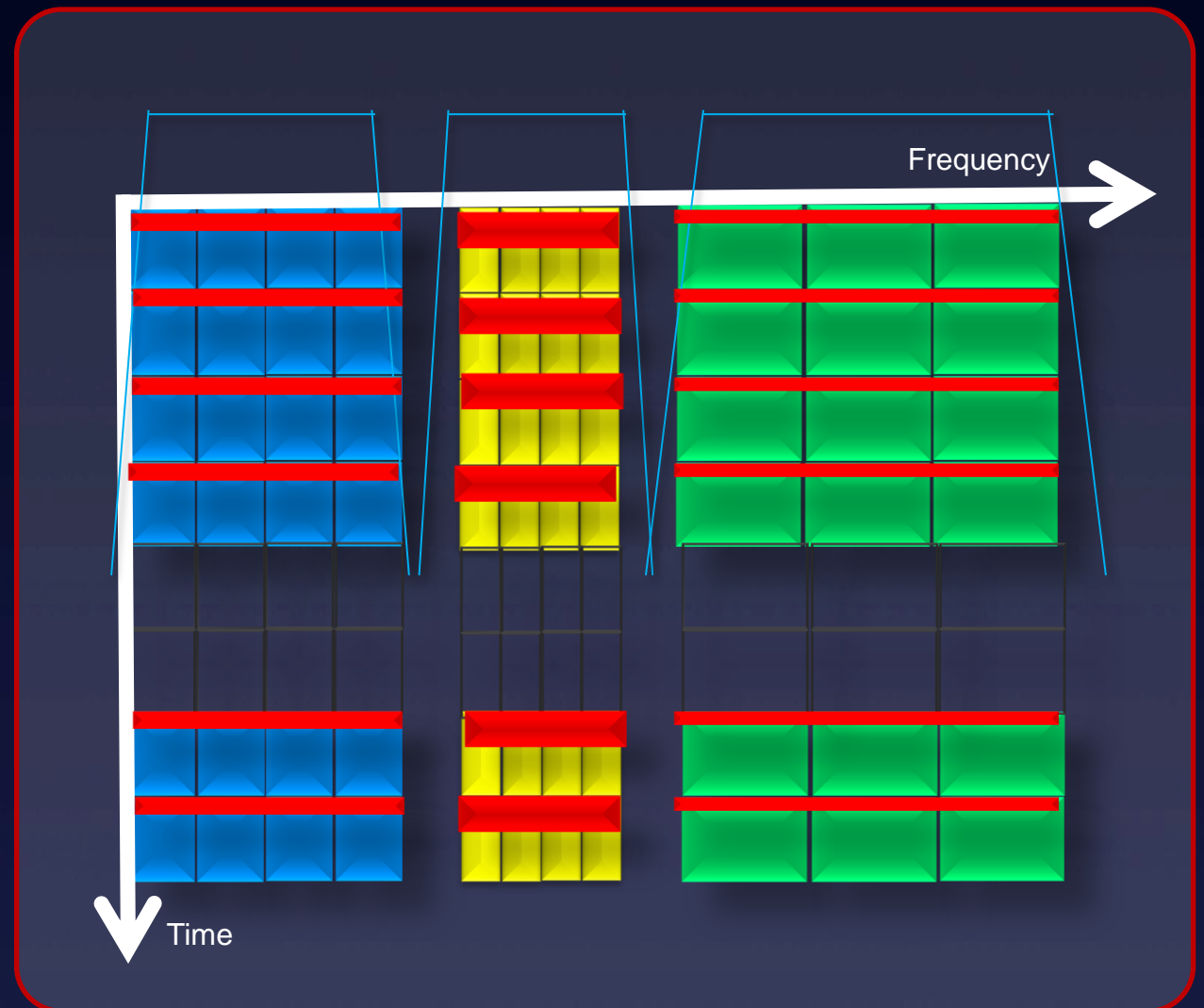
1. Sub-band digital filter is applied to shape the spectrum of subband OFDM signal.
2. Orthogonal subcarriers within each subband
3. Allow co-existence of waveforms with different OFDM Primitives



Spectrum Filtered OFDM (f-OFDM)



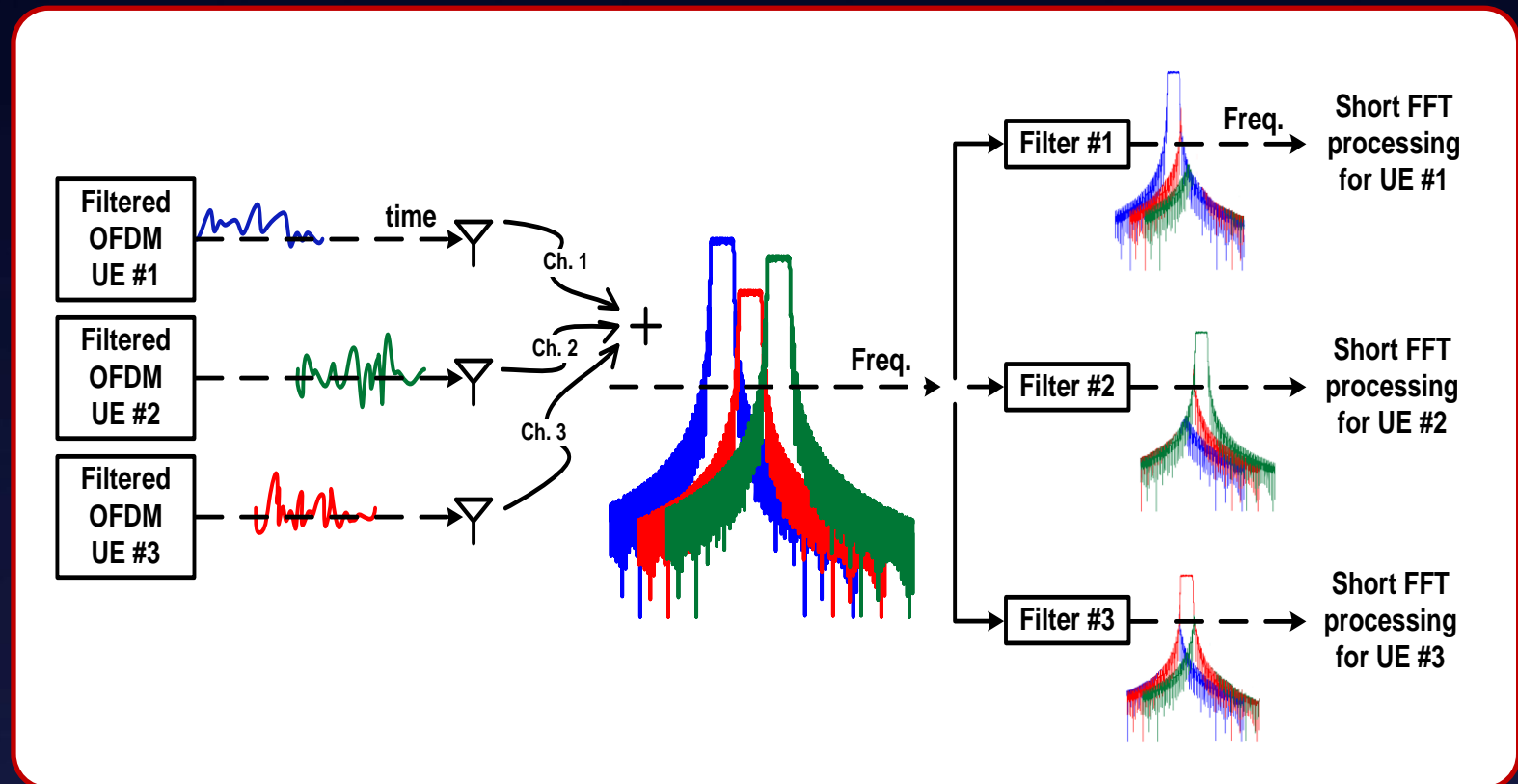
1. Sub-band digital filter is applied to shape the spectrum of subband OFDM signal.
2. Orthogonal subcarriers within each subband
3. Allow different cyclic prefix for each specific sub-band



F-OFDM Supports Asynchronous OFDMA



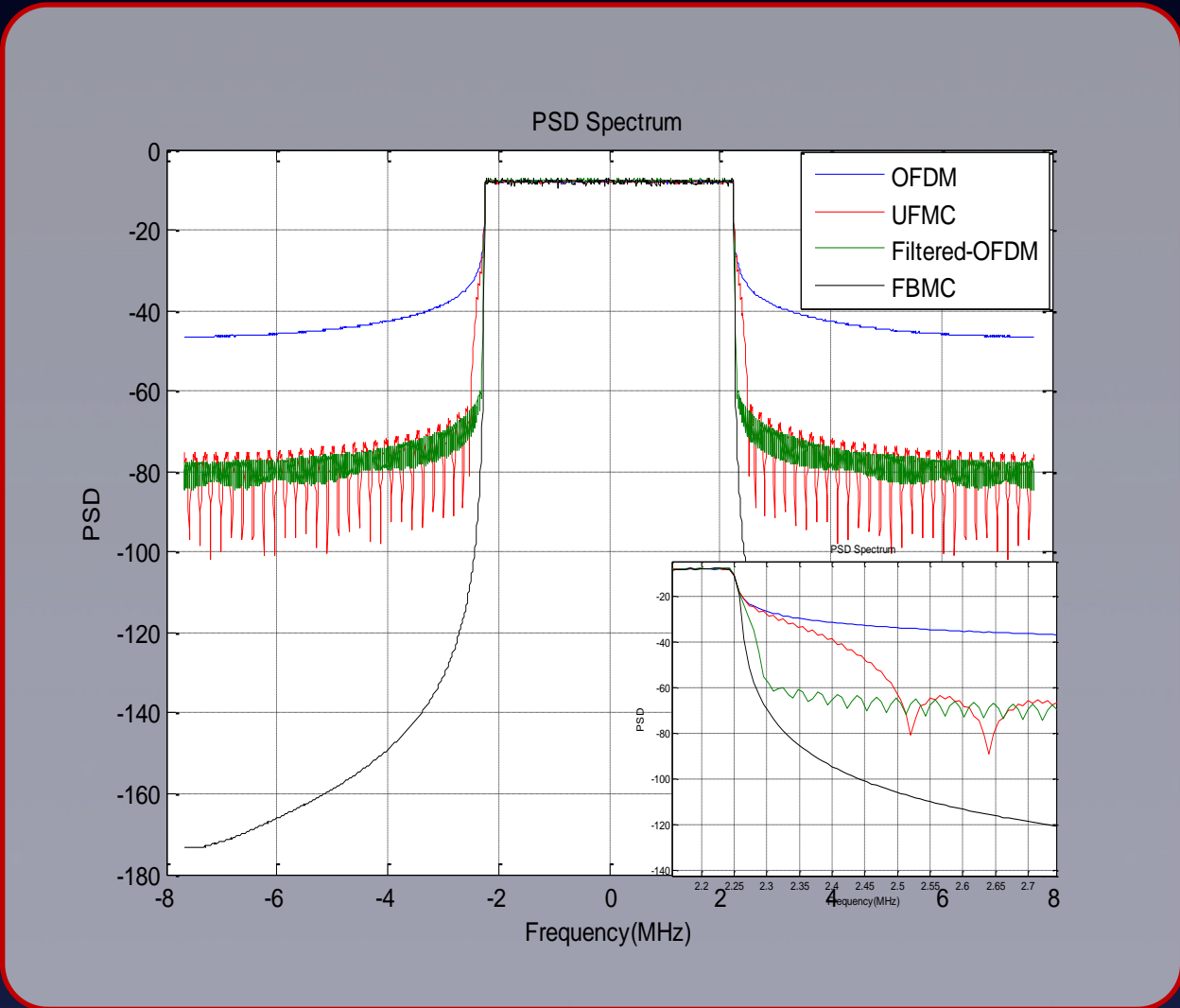
1. Support asynchronous OFDMA transmission
2. Non timing advance signal needed



Spectral Filtered OFDMA Characteristics



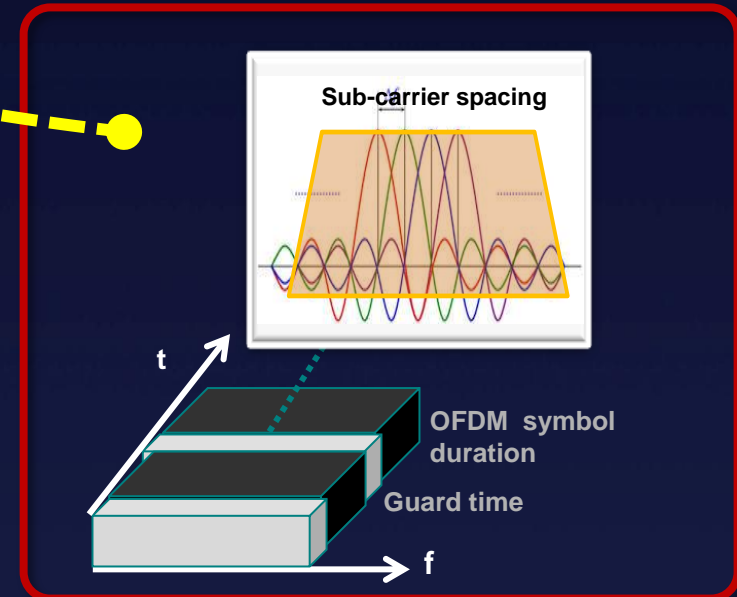
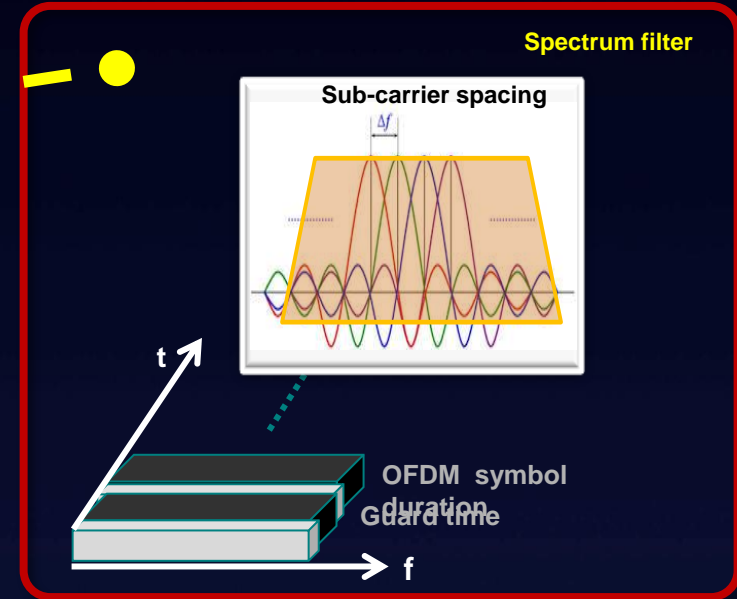
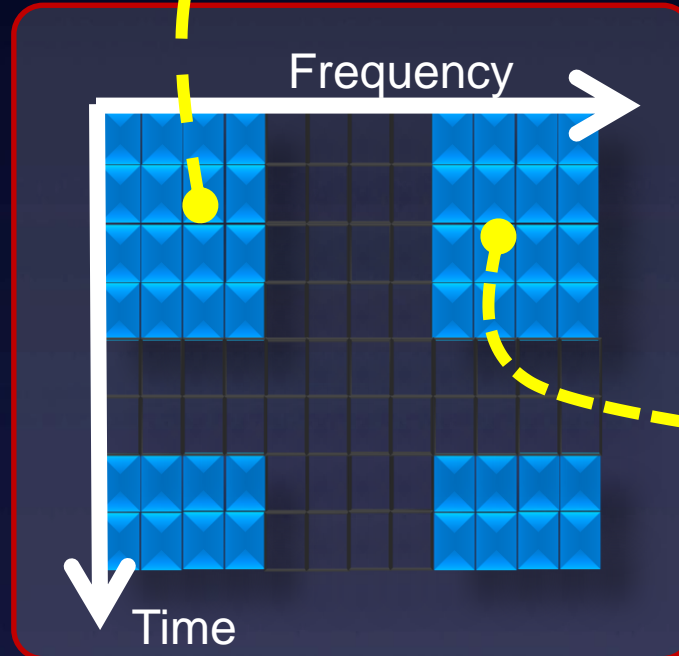
1. Good out-of-band leakage rejection
2. Similar spectrum localization performance compared to FBMC
3. Maintain all the benefits of OFDM
4. Easy for m-MIMO



Flexible Time-frequency Lattice



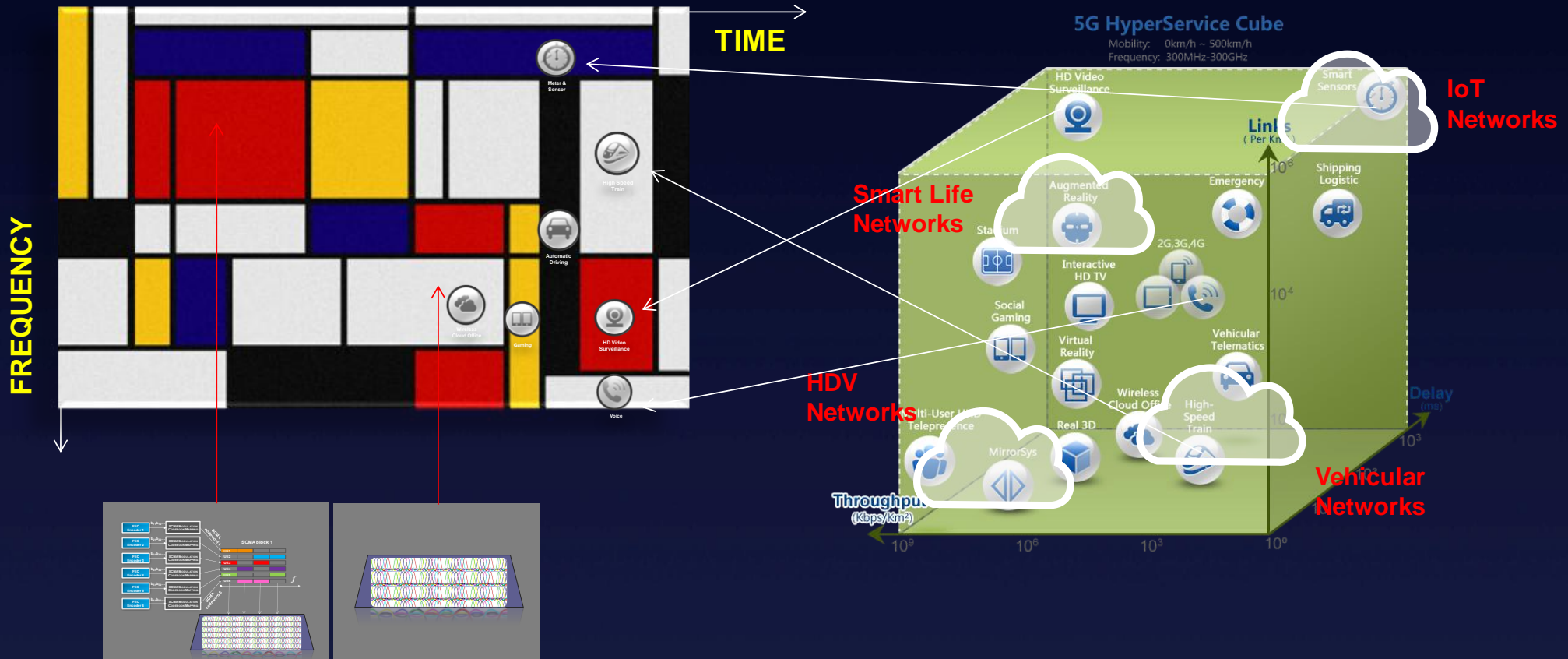
1. Co-existence of different time-frequency granularities
2. Waveform optimized for different transmission condition and applications
3. Regional broadcasting, high speed train, fixed devices,.....
4. Subband spectrum filter to control inter-block interference



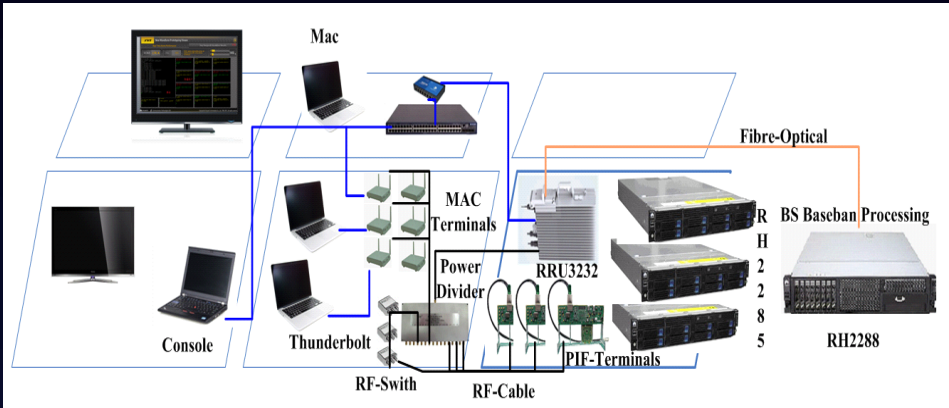
An Unified Adaptive Software Defined Air Interface to Meet Diverse Services Demand



- Unified air interface to support
- different waveform / multiple access schemes / flexible TTI



SCMA Prototype and Field Trial



NWTF New Waveform Prototyping Viewer

Real Time Demo Performance | Key Designs & Simulation Results

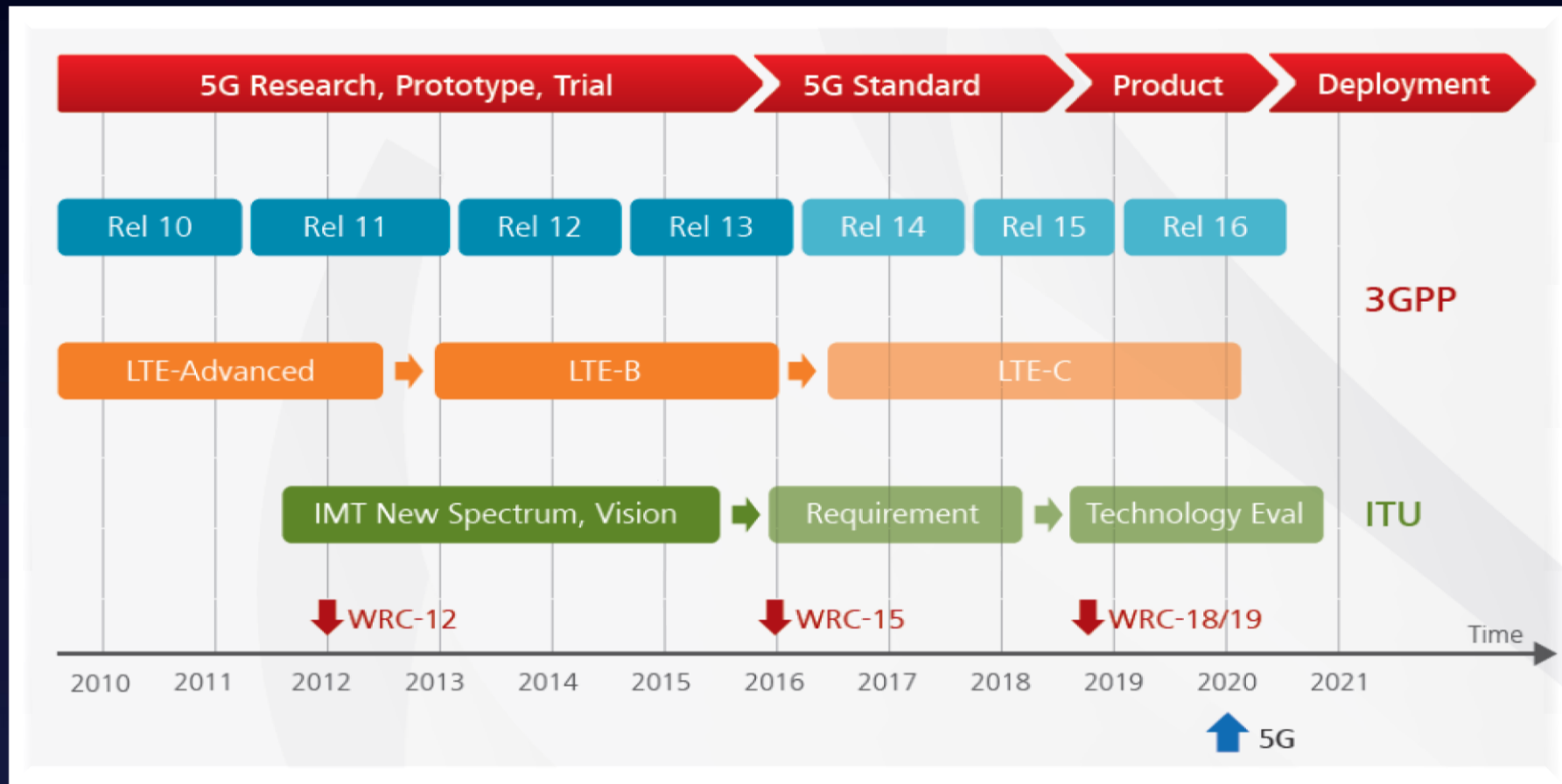
SCMA LTE-A | 8RE | 4RE | SCMA, sparse code multiple access: an enabler of up to 300% more network connections!

299%

<pre> ms 9 ms -100 Access successful! ms 10 ms -100 Access successful! ms 11 ms -100 Access successful! ms 12 ms -100 Access successful! ms 13 ms -100 Access successful! ms 14 ms -100 Access successful! ms 15 ms -100 Access successful! ms 16 ms -100 Access successful! ms 17 ms -100 Access successful! ms 18 ms -100 Access successful! ms 19 ms -100 Access successful! ms 20 ms -100 Access successful! ms 21 ms -100 Access successful! ms 22 ms -100 Access successful! ms 23 ms -100 Access successful! ms 24 ms -100 Access successful! ms 25 ms -100 Access successful! ms 26 ms -100 Access successful! ms 27 ms -100 Access successful! ms 28 ms -100 Access successful! ms 29 ms -100 Access successful! ms 30 ms -100 Access successful! ms 31 ms -100 Access successful! ms 32 ms -100 Access successful! ms 33 ms -100 Access successful! ms 34 ms -100 Access successful! ms 35 ms -100 Access successful! ms 36 ms -100 Access successful! ms 37 ms -100 Access successful! ms 38 ms -100 Access successful! ms 39 ms -100 Access successful! ms 40 ms -100 Access successful! ms 41 ms -100 Access successful! ms 42 ms -100 Access successful! ms 43 ms -100 Access successful! ms 44 ms -100 Access successful! ms 45 ms -100 Access successful! ms 46 ms -100 Access successful! ms 47 ms -100 Access successful! ms 48 ms -100 Access successful! ms 49 ms -100 Access successful! ms 50 ms -100 Access successful! ms 51 ms -100 Access successful! ms 52 ms -100 Access successful! ms 53 ms -100 Access successful! ms 54 ms -100 Access successful! ms 55 ms -100 Access successful! ms 56 ms -100 Access successful! ms 57 ms -100 Access successful! ms 58 ms -100 Access successful! ms 59 ms -100 Access successful! ms 60 ms -100 Access successful! ms 61 ms -100 Access successful! ms 62 ms -100 Access successful! ms 63 ms -100 Access successful! ms 64 ms -100 Access successful! ms 65 ms -100 Access successful! ms 66 ms -100 Access successful! ms 67 ms -100 Access successful! ms 68 ms -100 Access successful! ms 69 ms -100 Access successful! ms 70 ms -100 Access successful! ms 71 ms -100 Access successful! ms 72 ms -100 Access successful! ms 73 ms -100 Access successful! ms 74 ms -100 Access successful! ms 75 ms -100 Access successful! ms 76 ms -100 Access successful! ms 77 ms -100 Access successful! ms 78 ms -100 Access successful! ms 79 ms -100 Access successful! ms 80 ms -100 Access successful! ms 81 ms -100 Access successful! ms 82 ms -100 Access successful! ms 83 ms -100 Access successful! ms 84 ms -100 Access successful! ms 85 ms -100 Access successful! ms 86 ms -100 Access successful! ms 87 ms -100 Access successful! ms 88 ms -100 Access successful! ms 89 ms -100 Access successful! ms 90 ms -100 Access successful! ms 91 ms -100 Access successful! ms 92 ms -100 Access successful! ms 93 ms -100 Access successful! ms 94 ms -100 Access successful! ms 95 ms -100 Access successful! ms 96 ms -100 Access successful! ms 97 ms -100 Access successful! ms 98 ms -100 Access successful! ms 99 ms -100 Access successful! ms 100 ms -100 Access successful! </pre>	<pre> SCMA UE00: 2 data streams in the multiplexing! </pre>	<pre> SCMA UE01: 2 data streams in the multiplexing! </pre>	<pre> SCMA UE02: 2 data streams in the multiplexing! </pre>	<pre> No additional system resources are accessed </pre>
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5G Timeline





THANK YOU

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