Bell Labs 5G Vision and Activities

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What's driving 5G?

BROADBAND

Massive traffic capacity
Reduce Cost
Spectrum efficiency
Access new spectrum

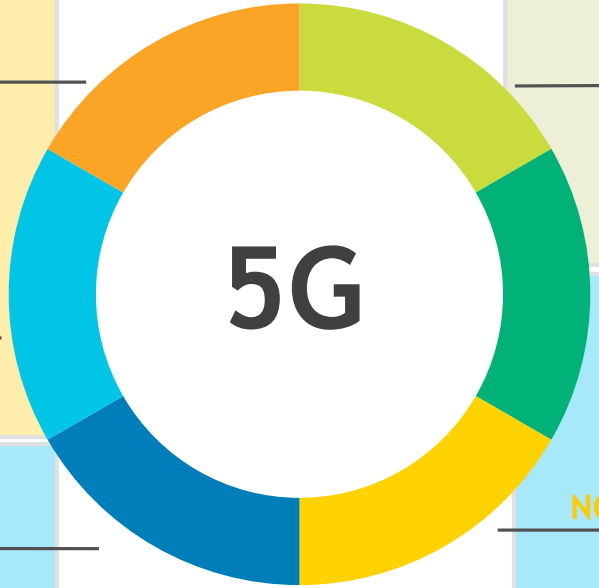
EXTREME DENSITY

Massive user density
User content

(Google)

INNOVATIVE SERVICES

Flexible bearer design
3rd party policy



MISSION CRITICAL

Very low latency
High reliability
High availability
Security

BATTERY LIFE

Signaling reduction
Energy optimization

(ZDF)

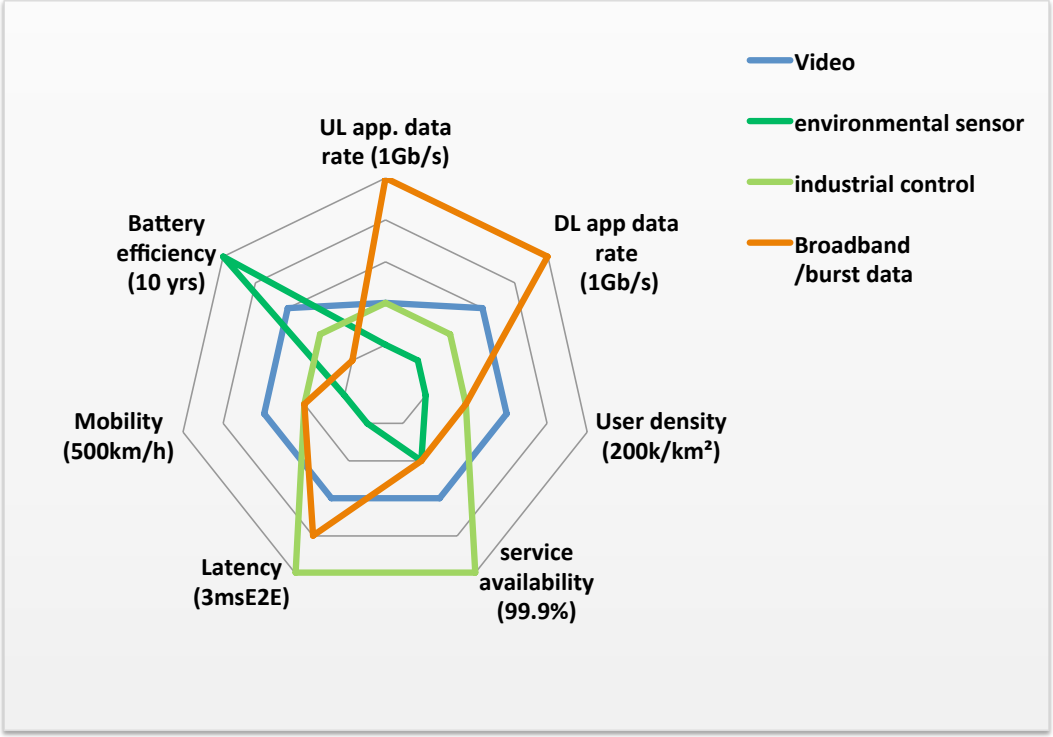
NON TRADITIONAL DEVICES

Short packet
Sporadic access
More devices and
more device types

(Univ. Southampton)

Three main groups: Broadband, Mission critical and Small payload traffic

5G Services: Heterogeneous requirements



- Very diverse requirement profiles
- Requirements will change over time,

  New use cases and profiles will appear
- No profile covers whole parameter space "One fits all" would be extremely wasteful
- Need differentiated solutions
  - Air interface
  - Access to network
  - Networking: Topology, protocols
- Use these profiles for validation and testing
  - Derive KPIs

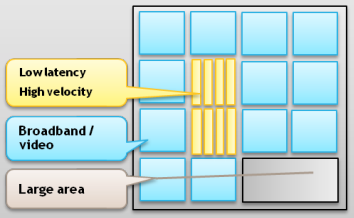
How to deal with diverse requirements?

Broadband, Mission critical and Small payload traffic

Separation of signals

Integration of services

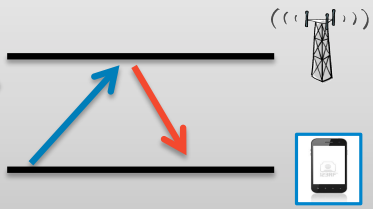
Flexible Air Interface



Reduced signaling

Reduced latency

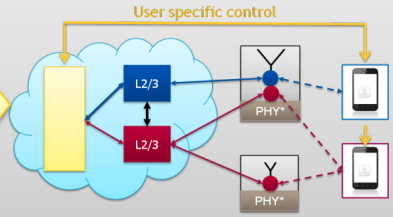
Small traffic, connectionless service



Localized control

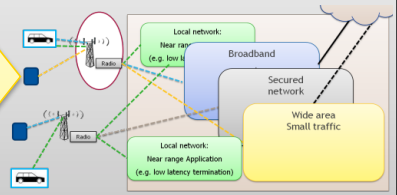
Flexible link assignment

User specific control



Service-specific networks, topology and protocols

Virtualization and sliced network



Broadband

Higher spectral efficiency

Scalability

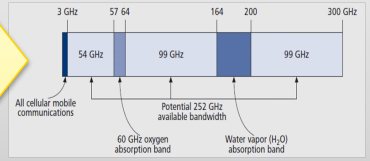
Scalable / Massive MIMO

Multi-Gbps rates

Wider bandwidth

Adaptive beams

Mm-wave access



Every success has its network

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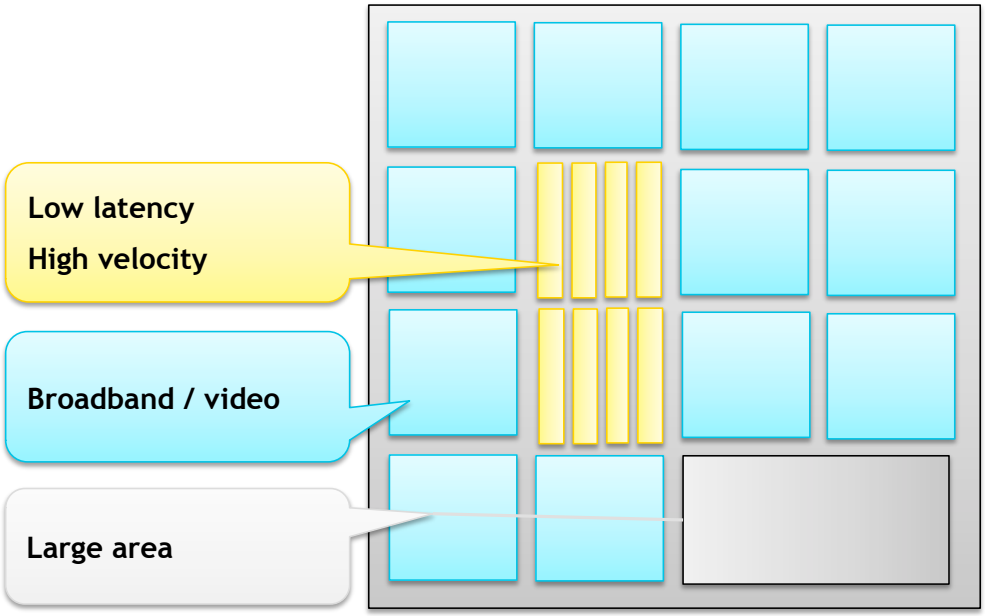
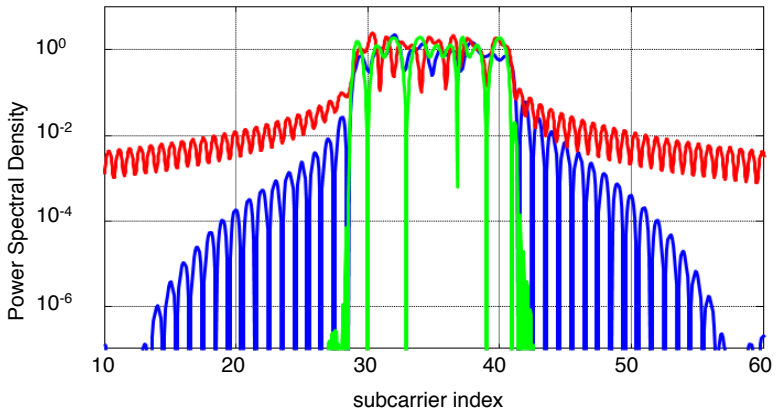
Flexible air interface

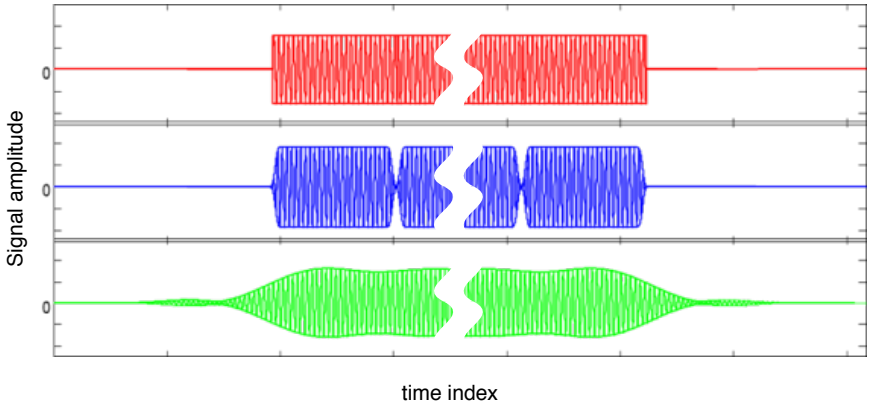
- Target is
  - to enable the air interface to be configurable
  - in a per user/device/service manner
  - within a single carrier
  - to allow for highest scalability and flexibility
  - ➢ Motivates new multi-carrier waveform



- Test cases:
  - Improved support of low-end devices with reduced signaling overhead
    - Relaxed synchronization in time and frequency
  - Improved support of high Doppler, coexisting with efficient low-Doppler operation
  - Support of low latency (via reduced TTI length)

Candidate Waveforms for 5G under Investigation





Waveforms to investigate

- CP-OFDM /SC-FDMA (LTE design – for benchmark)
- UF-OFDM (Universal Filtered OFDM)
- FBMC-OQAM (Filter-Bank Multi-Carrier – Offset-QAM)

5G Candidate Waveform Overview

Property	OFDM	FBMC (SMT)	UF-OFDM
Robustness to time-frequency misalignment (Relaxed synchronicity reduces signaling overhead and adds robustness for e.g. CoMP)	low	high	high
Suitability for fragmented spectrum	low	high	high
Suitability for short bursts/frames (e.g. for fast TDD switching + low latency modes)	high	medium	high
Suitability for small control elements (e.g. UL sounding symbols, PUCCH ACK/NACK)	high	low	high
Applicability to MIMO (e.g. complex precoding, spatial multiplexing, multi-user, time-frequency selective)	high (QAM)	low (Offset-QAM)	high (QAM)
Complexity	low	medium	low-medium
Adaptivity (w.r.t. Modulation and Coding, subcarrier spacing, filter shape)	medium	medium	high
Reuse of existing technology know-how (e.g. channel estimation, MIMO processing)	high	low	high

Performance with Asynchronous Transmissions

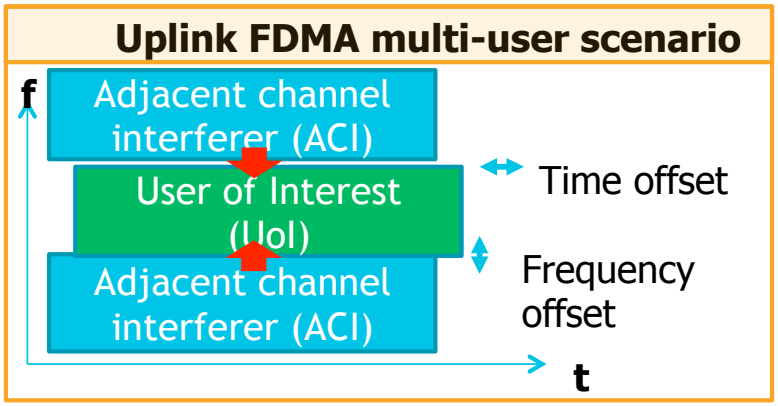
Why relaxing synchronization?

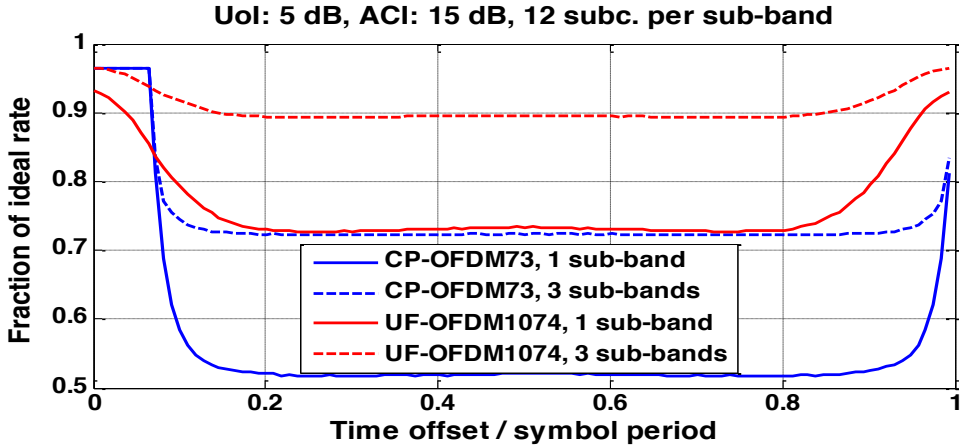
Create an option for dropping closed-loop synchronization for:

- Less signaling overhead
- Less battery consumption
- "Connection-less" mode
- Reduced cost

Coexistence of mobile broadband (MBB) and small packet services

- MBB will operate synchronous
- Small packets may operate asynchronous in adjacent subbands
- 5G waveform is an enabler for this mix, avoiding inter-carrier interference (ICI)





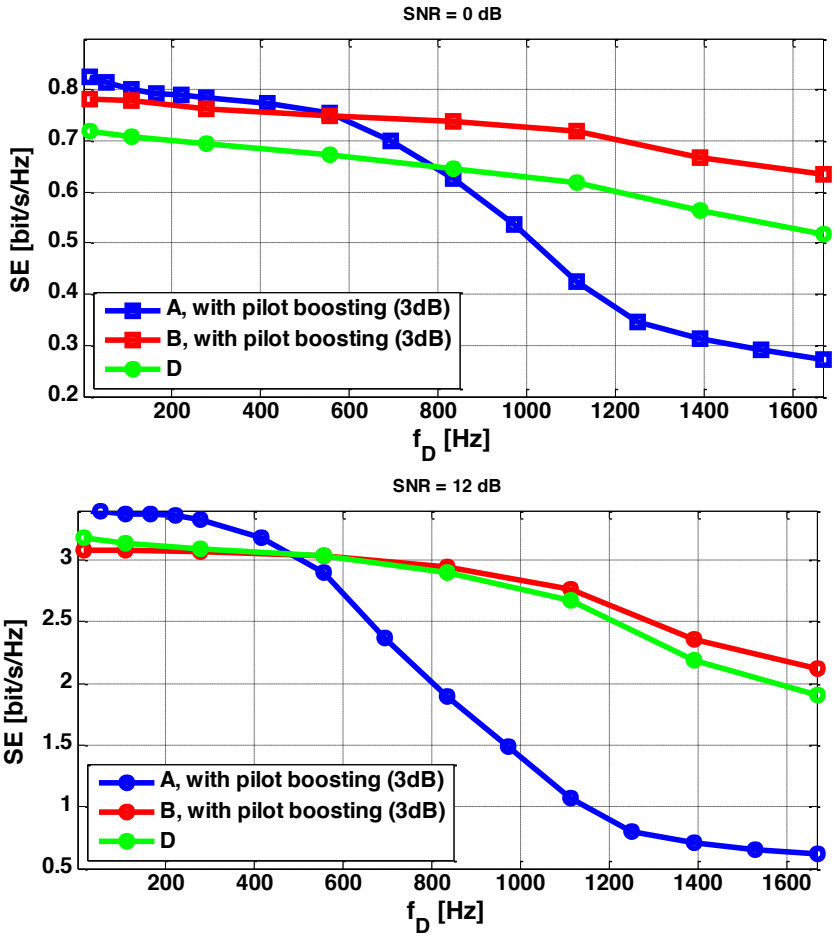
UF-OFDM superior in scenarios with relaxed synchronization

F. Schaich, T. Wild, "Relaxed Synchronization Support of Universal Filtered Multi-Carrier including Autonomous Timing Advance", IEEE ISWCS'14, Barcelona, August 2014

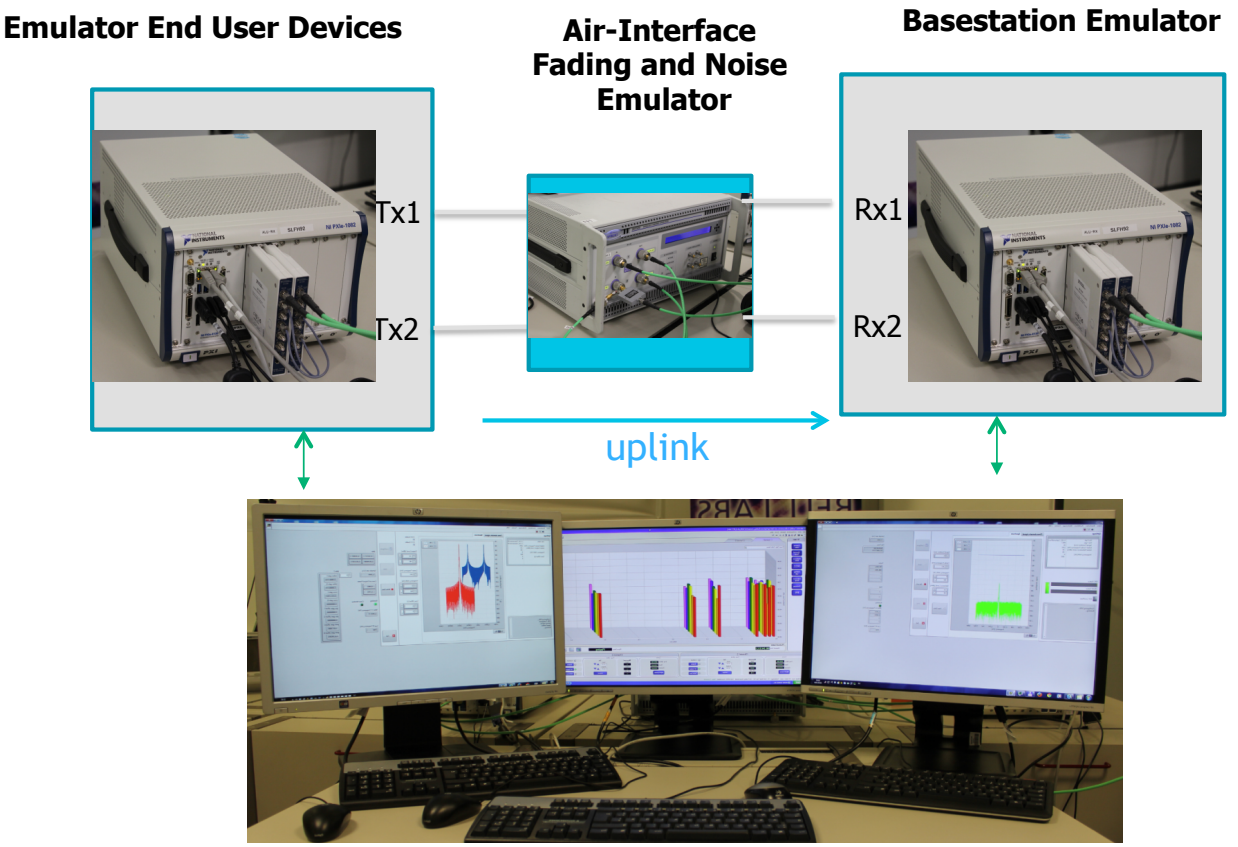
Performance in High Doppler Scenarios

- For high Doppler LTE frame structure (A) has significant rate loss.
  - i.e. high velocities (> 100 km/h) and „high“ carrier frequencies (> 2 GHz)
  - Changed design can gain up to **factor 3**
- Two options for dealing with this:
  - Via increased subcarrier spacing/shortened symbols (B) (synergy with low latency modes)
  - Adapt pilot placings (as given in D)
  - To adapt the spacing is superior (B) for high Doppler with making use of pilot boosting
- 5G will benefit from user-specific numerology

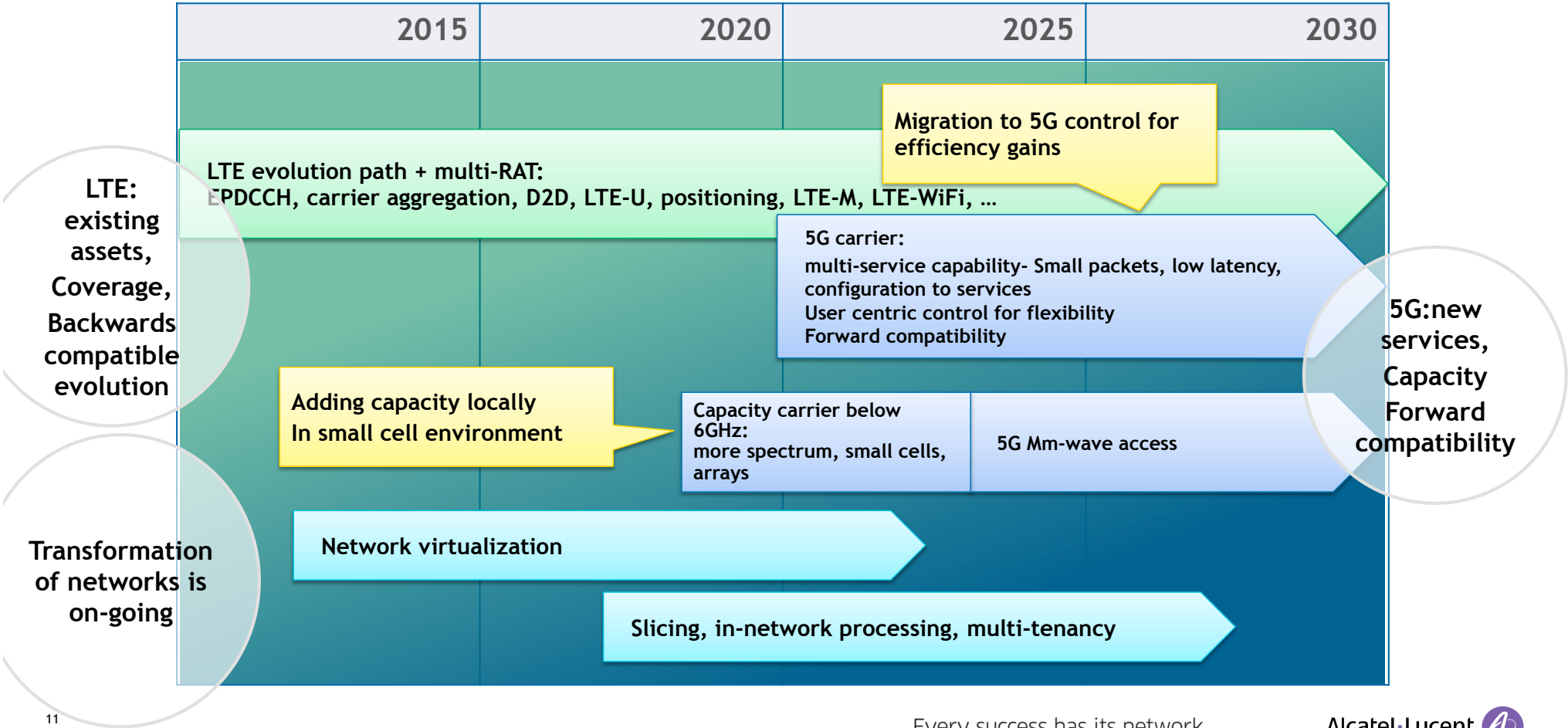
500 km/h @ 2 GHz → f_D = 925Hz



Open-Loop Demonstrator for 5G Waveforms



Transformation



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