LTE-ADVANCED AND BEYOND

FUTURE RADIO ACCESS

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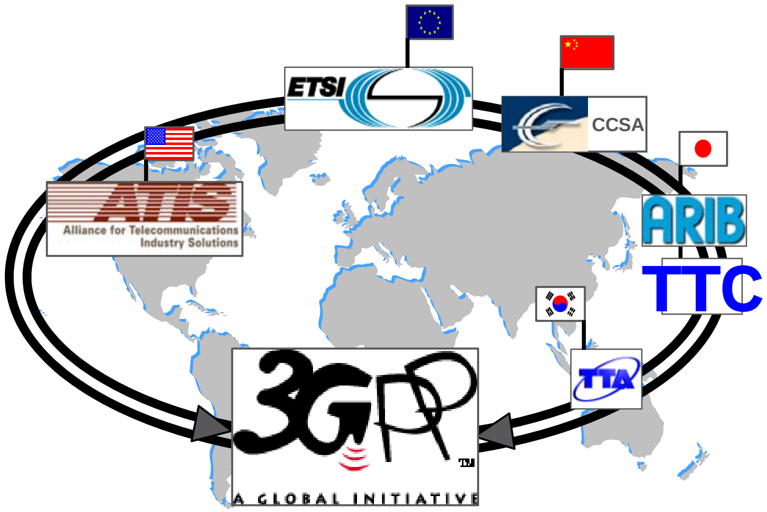
LTE – MOBILE BROADBAND

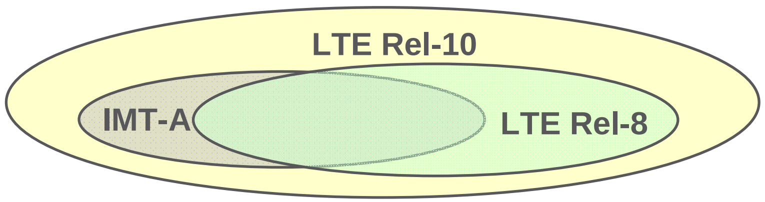
› Developed in 3GPP
  - 2005 LTE development started
  - 2008 First standard (Rel-8)
  - 2009 Commercial operation starts



› Packet-data only (no CS domain)
  - Rel-8 up to 300 Mbit/s DL 75 Mbit/s UL in 20 MHz
  - Rel-10 up to 3 Gbit/s DL 1.5 Gbit/s UL in 100 MHz
  - Low latencies, 5 ms user plane, 50 ms control plane

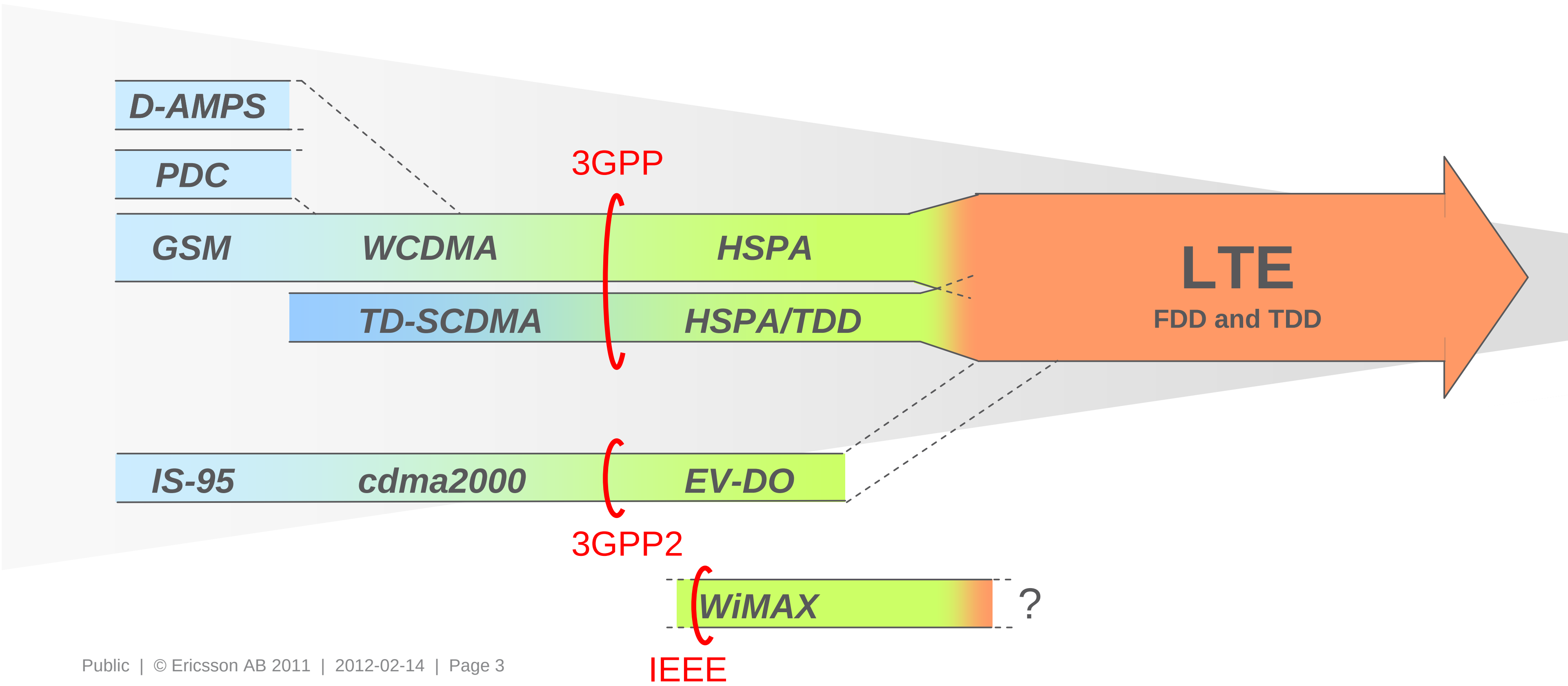
› FDD *and* TDD

› Fulfills all IMT-Advanced requirements



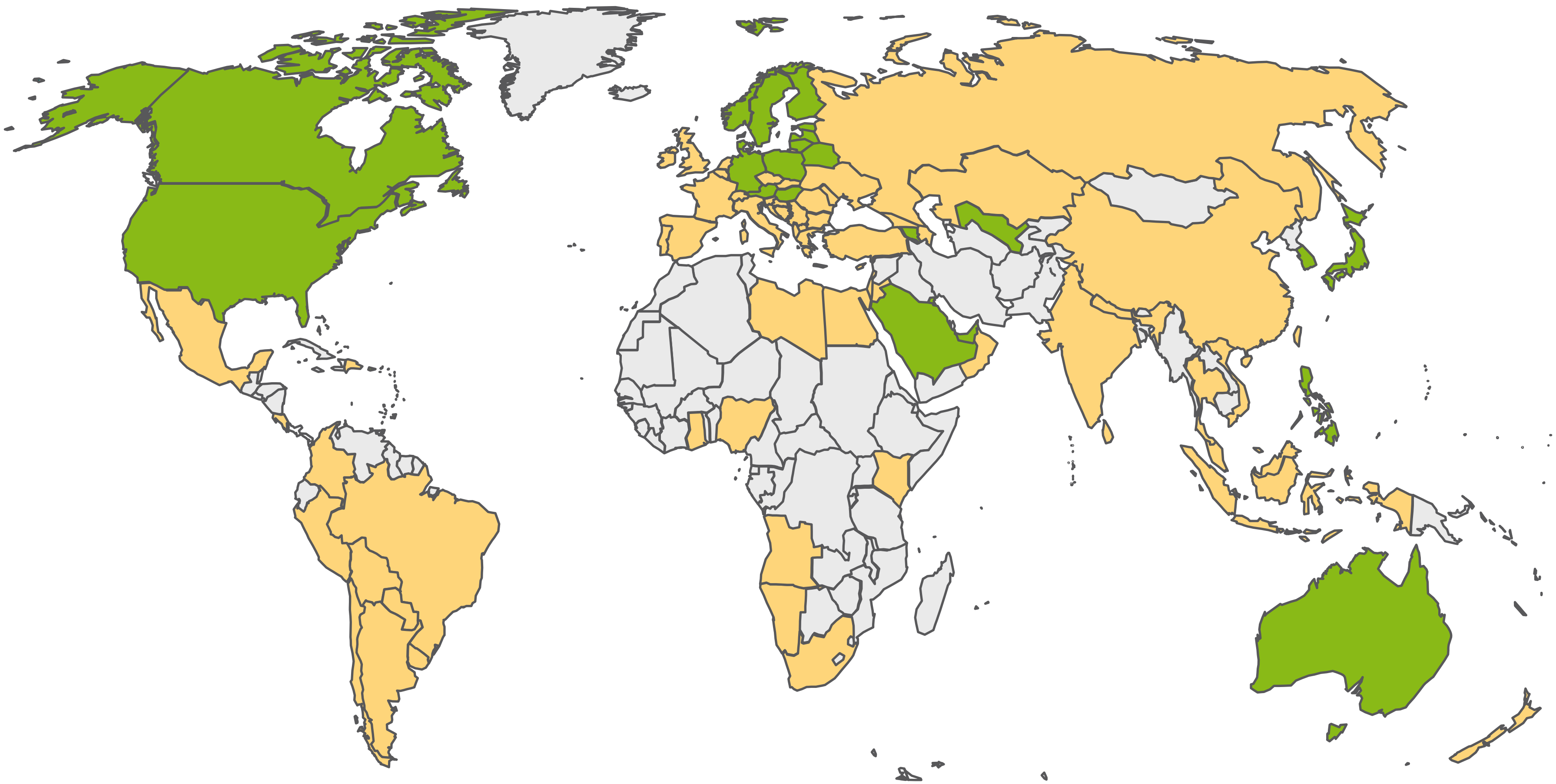
GLOBAL CONVERGENCE

- LTE is the major technology for future mobile broadband
  - Convergence of 3GPP and 3GPP2 technology tracks
  - Convergence of FDD and TDD into a single technology track



LTE NETWORK COMMITMENTS

285 OPERATORS IN 93 COUNTRIES



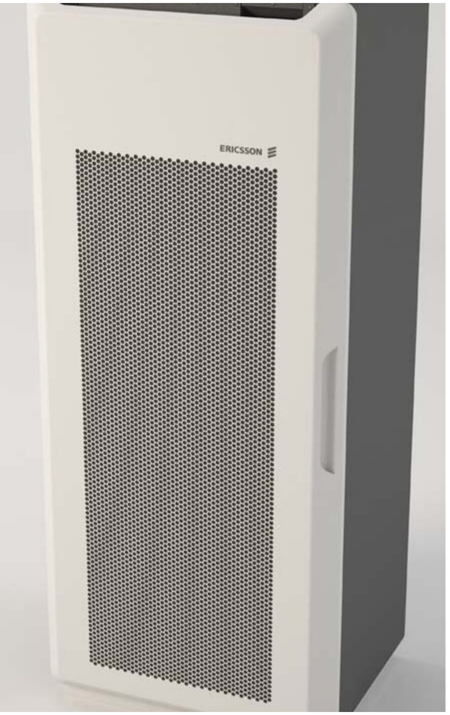
Countries with commercial LTE service (17 networks)

Countries with operators committed to and/or deploying LTE

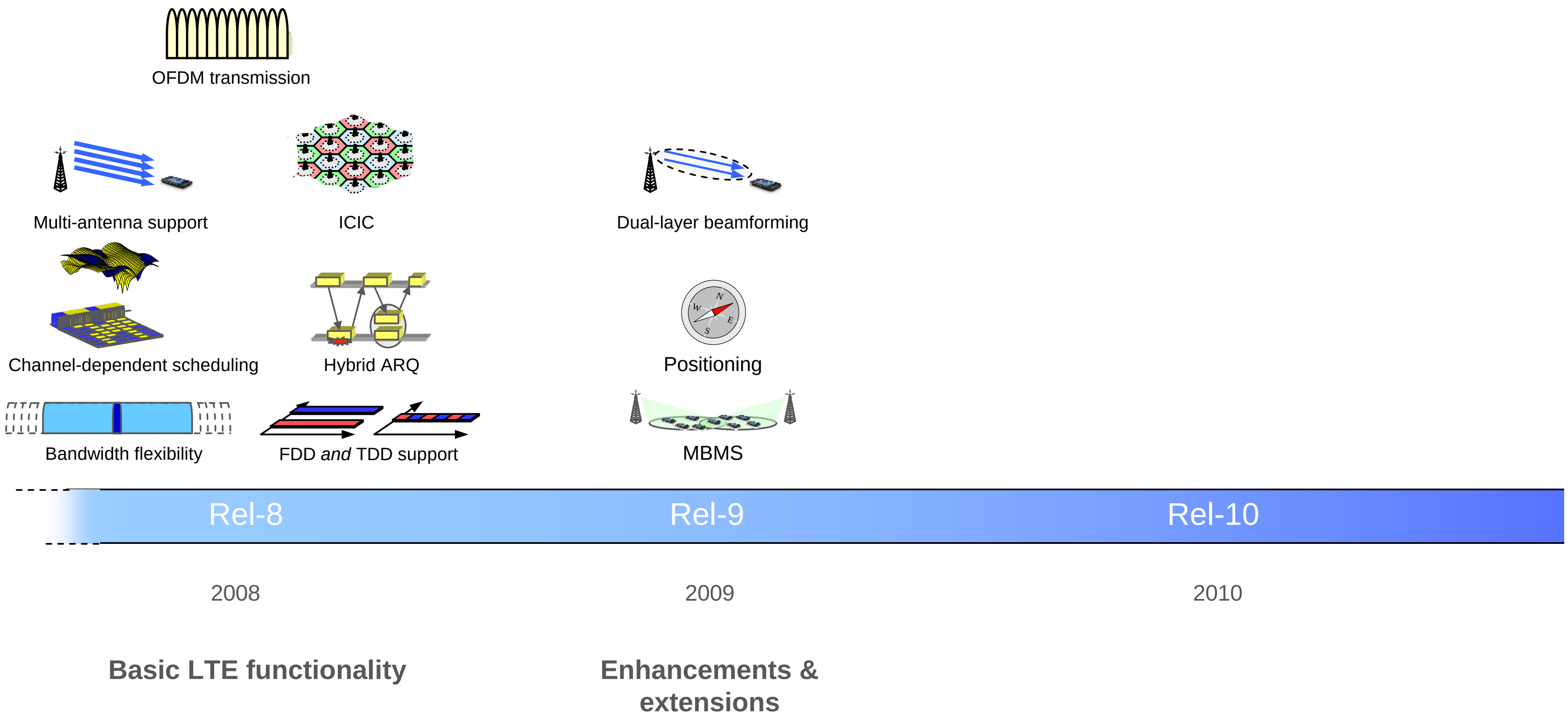
Sources: GSA (Jan, 2012)

LTE

TECHNICAL OVERVIEW

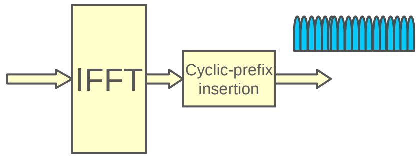


LTE RADIO ACCESS COMPONENTS

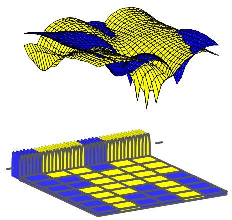


LTE – ONE SLIDE OVERVIEW

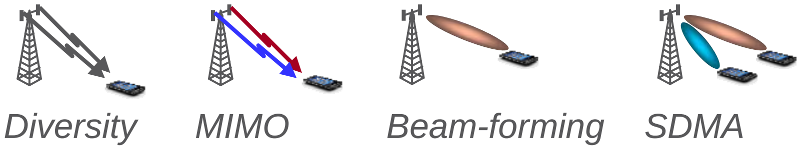
- OFDM
  - DFT precoding in UL to reduce PAR



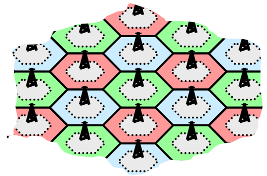
- Scheduled transmissions (UL and DL)
  - 1 ms subframe structure
  - Hybrid ARQ



- Integral multi-antenna support

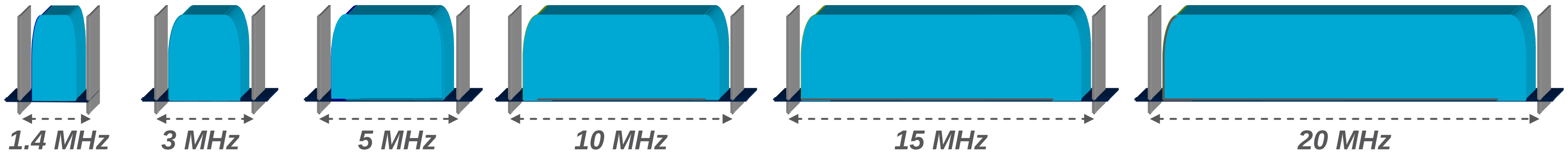


- Inter-cell interference coordination

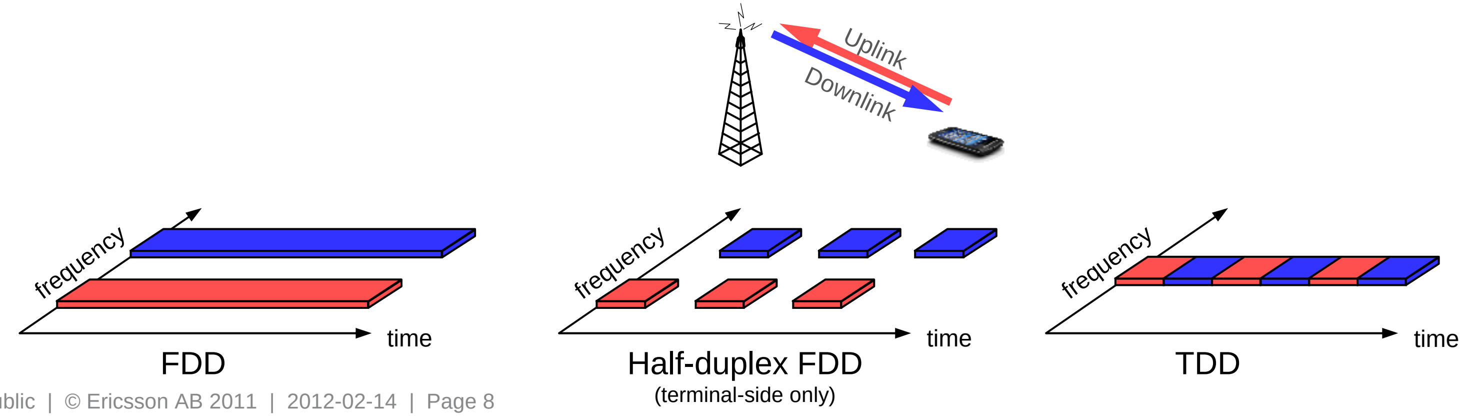


SPECTRUM FLEXIBILITY

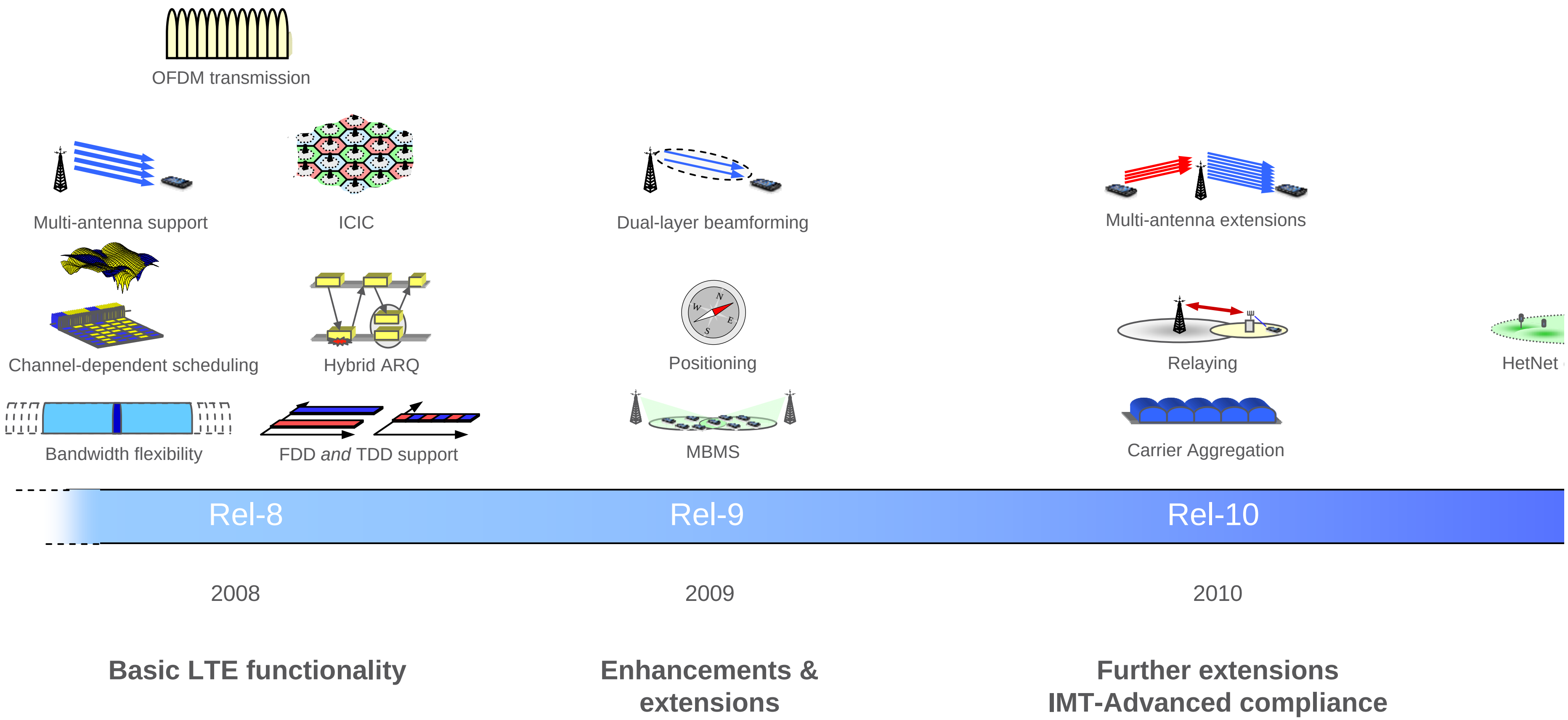
- Operation in differently-sized spectrum allocations
  - Baseband/protocol specifications support anything from 6 to 110 RB (Resource Block, RB=180 kHz)
  - RF requirements currently defined for 1.4, 3, 5, 10, 15, 20 MHz



- Support for paired (FDD) *and* unpaired (TDD) spectrum allocations
  - Common solutions ➡ economy of scale

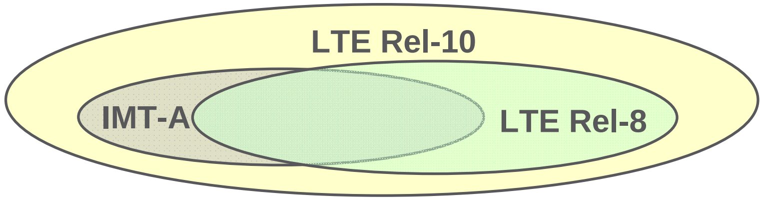


LTE EVOLUTION



LTE REL-10 (LTE-ADVANCED)

› Part of the LTE evolution…
…but timing and scope heavily influenced by IMT-Advanced



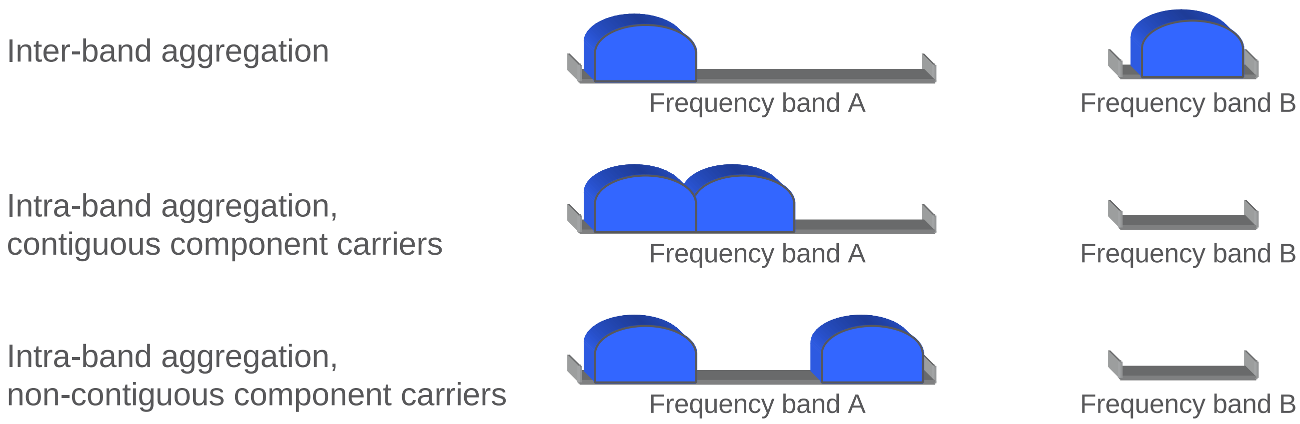
› LTE Rel-10 exceeds IMT-Advanced requirements

	IMT-Advanced requirement	LTE Rel-8	LTE Rel-10
Transmission bandwidth	At least 40 MHz	Up to 20 MHz	Up to 100 MHz
Peak spectral efficiency - Downlink - Uplink	15 bps/Hz 6.75 bps/Hz	16 bps/Hz 4 bps/Hz	16.0 bps/Hz [30.0 bps/Hz]* 8.1 bps/Hz [16.1 bps/Hz]**
Latency - Control plane - User plane	Less than 100ms Less than 10 ms	50 ms 4.9 ms	50 ms 4.9 ms

* Value is for a 4x4 antenna configuration. Value in parentheses for 8x8
** Values is for a 2x2 antenna configuration. Value in parentheses for 4x4

CARRIER AGGREGATION

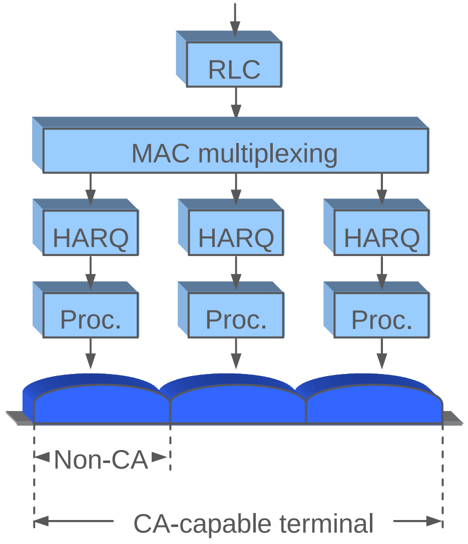
- What is it?
  - Multiple component carriers operating in parallel



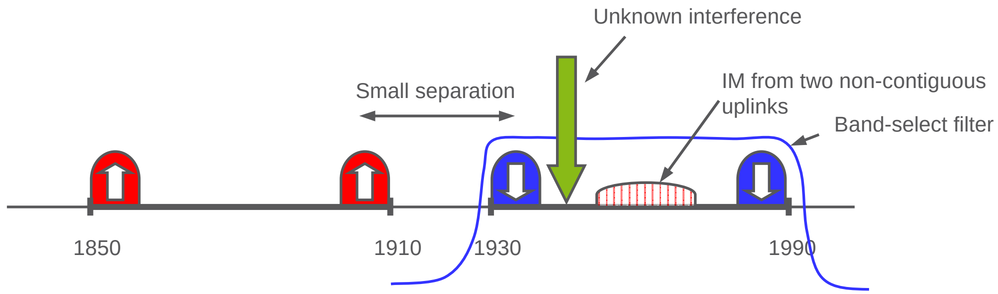
- Why?
  - Exploitation of fragmented spectrum
  - Higher bandwidth ➡ higher data rates

CARRIER AGGREGATION

- Baseband implementation
  - Processing per component carrier
  - Relatively straightforward,
    Complexity ~ aggregated data rate



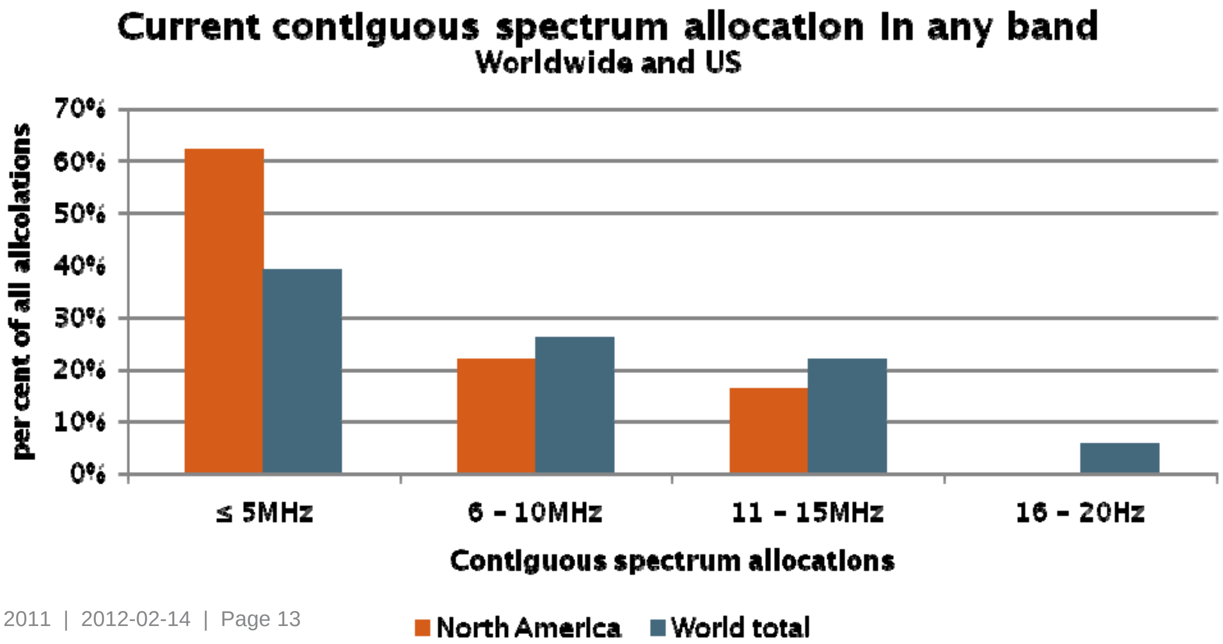
- RF implementation
  - Challenging, especially on the terminal side
    - *True for any radio-access technology!*
  - Complexity highly dependent on band combinations
  - Insertion loss, harmonics, intermodulation, …



WHERE IS THE SPECTRUM TO AGGREGATE?

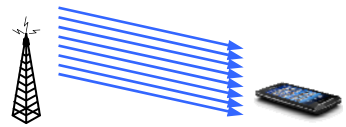
- Current allocation not aligned with rapid evolution of 3GPP technologies
  - > 90% of all contiguous spectrum ≤15 MHz
  - 65% of all allocations ≤10 MHz
  - 0% of US allocation are ≥20 MHz

- High data rates require large bandwidths
- ‘No’ contiguous wide spectrum ➡ inter-band aggregation

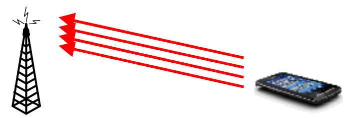


ENHANCED MULTI-ANTENNA SUPPORT

- › Enhanced downlink spatial multiplexing
  - Up to 8 layers spatial multiplexing ➡ 30 bps/Hz
  - Can be combined with beamforming



- › Uplink spatial multiplexing
  - Up to 4 layers spatial multiplexing ➡ 15 bps/Hz



- › Enhanced downlink multi-user MIMO

- › …but most important – enhanced reference-signal structure
  - Enabling novel multi-antenna structures
  - Improved beamforming, heterogeneous deployments, future CoMP arrangements, …

ENHANCED MULTI-ANTENNA SUPPORT

- Separation of reference signals for *demodulation* and *feedback*
  - Different purposes, different requirements ➡ different reference signals
  - Rel-8 essentially relies on a single reference signal structure for both

- DM-RS for demodulation *when transmitting data*
  - Precoded with data ➡ antenna setup transparent to UE
  - Overhead scales with number of spatial layers

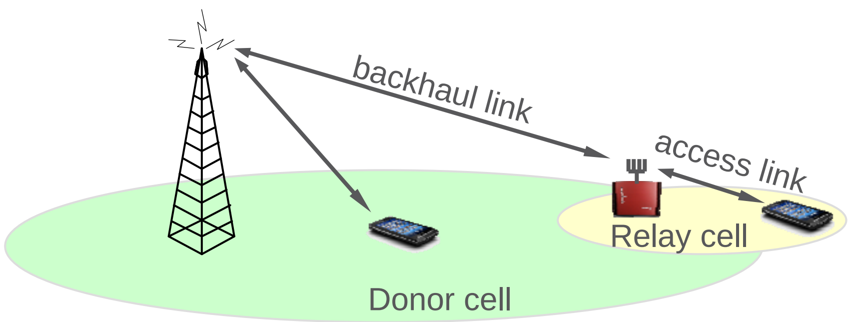
- CSI-RS for channel-quality reporting *periodic but infrequent*

RELAYING

› Logically an eNodeB as seen from a UE perspective...
  - Creates new cells – can serve Rel-8 UEs
  - Uses LTE spectrum/air interface for backhaul transport (”self-backhauling”)

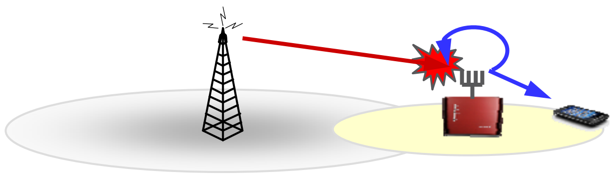
…but physically typically smaller and lower output power than macro

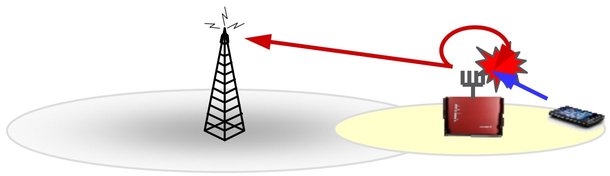
› Main usage scenario
  - When fiber/microwave backhaul is more expensive than LTE spectrum



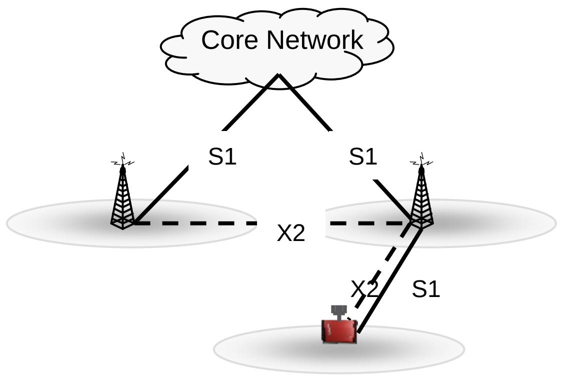
RELAYING

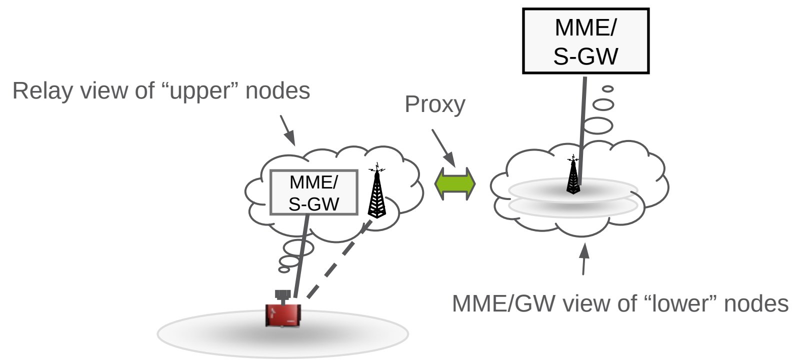
› Inband relaying ➡ self interference handling
  – Non-simultaneous access-link transmission and backhaul-link reception





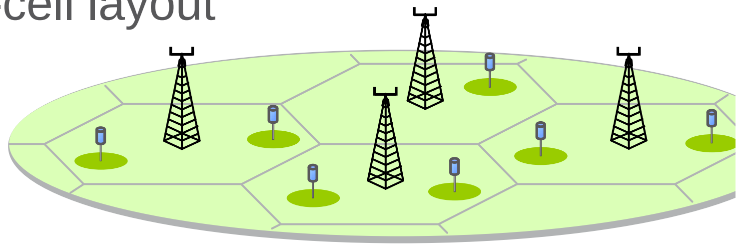
› Architecture – donor eNB act as proxy between relay and remaining RAN





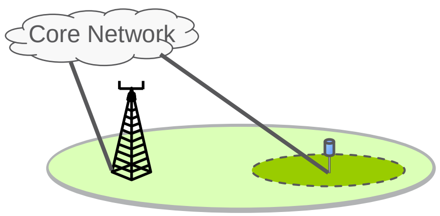
HETEROGENEOUS DEPLOYMENTS

- *What?*
  - Low power nodes placed throughout a macro-cell layout

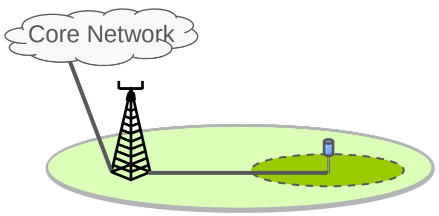


- *Why?*
  - Data rates – reduced path loss
  - Capacity – ”cell splitting” gains

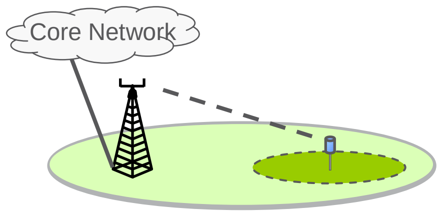
- *How?*
  - Some examples



“Conventional” pico
- Processing at pico
- “Any” backhaul



Remote Radio Unit
- Processing at macro
- High-speed backhaul

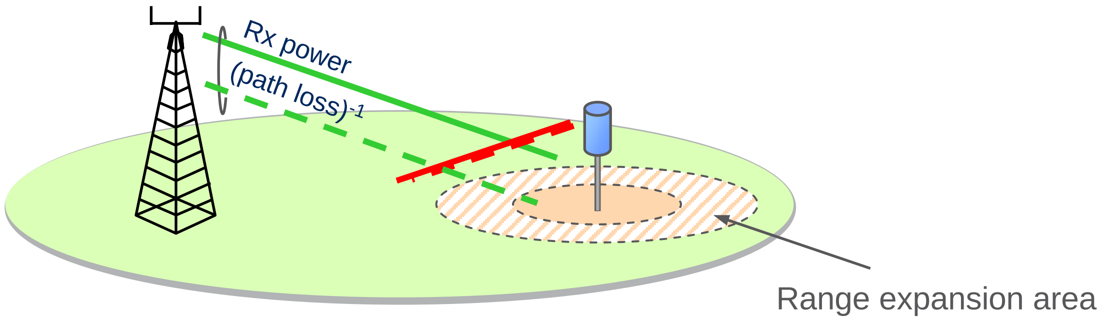


Relay
- Processing at pico
- Backhaul using LTE

HETEROGENEOUS DEPLOYMENTS

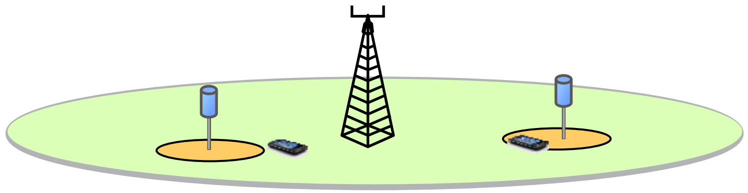
- Deployment philosophy, *not* a technology component
  - Possible in Rel-8
  - Rel-10 provides tools for partial support of *excessive* range expansion

- Heterogeneous deployments – which node to connect to?
  - Traditionally UEs connected to the node with the best downlink (best RSRP)



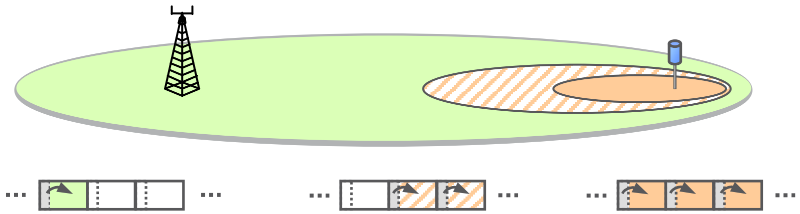
- *Range expansion* – increasing pico node uptake area (RSRP+offset)
  - Data rates – lower path loss
  - Capacity – offloading
  - *How to ensure reception of control signaling from pico in range expansion zone?*

HETEROGENEOUS DEPLOYMENTS



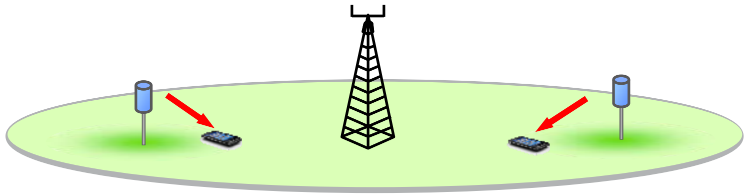
Baseline

- Modest range expansion
- Existing Rel-8 functionality



Resource partitioning

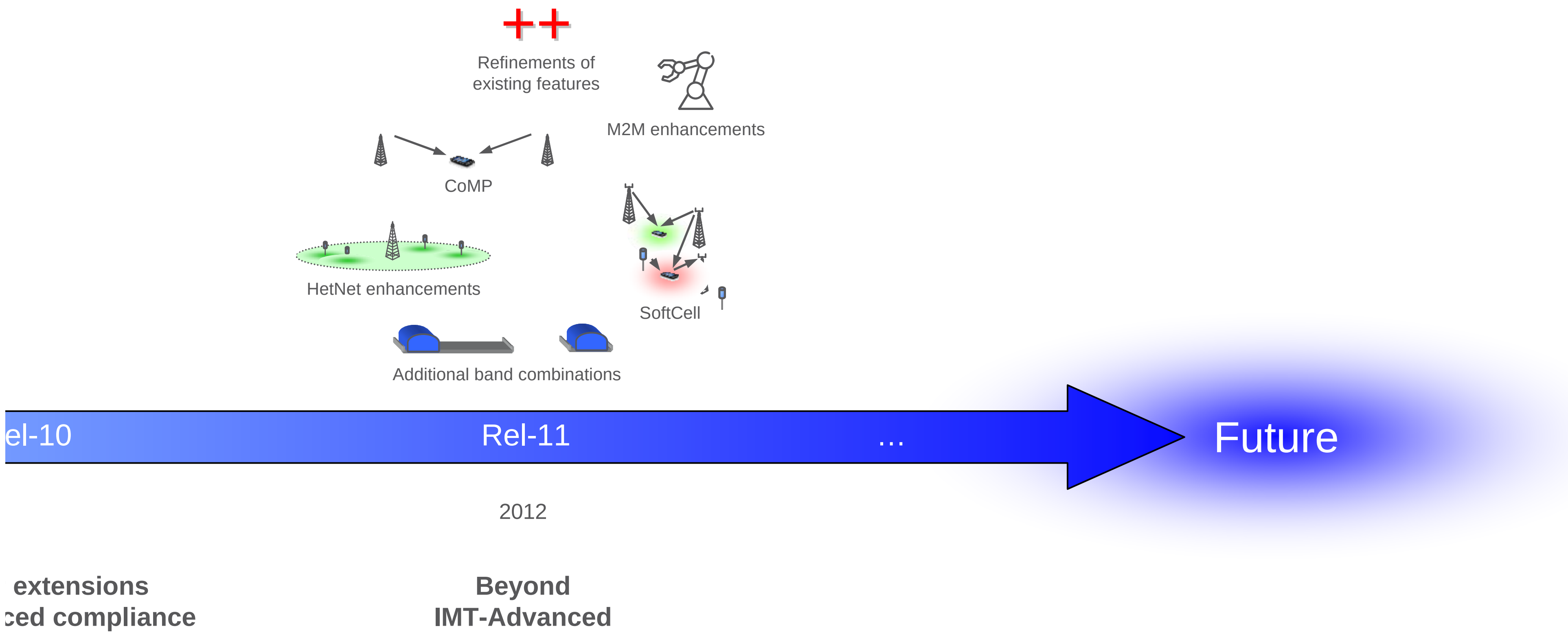
- Macro almost silent ➡ reduced interference in range expansion zone
- Excessive range expansion
- Not transparent to UEs – Rel-11 functionality



Shared Cell

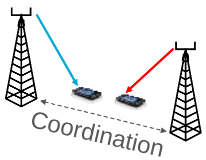
- RRUs connected to macro
- Distributed antenna placement
- Any range expansion
- Transparent to UEs

LTE EVOLUTION

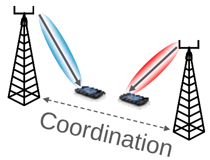


LTE EVOLUTION – COMP

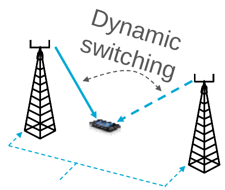
› Numerous schemes under discussion…



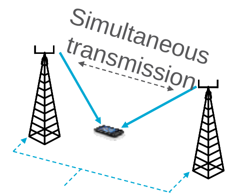
Coordinated Scheduling



Coordinated Beamforming

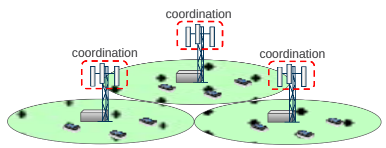


Dynamic Point Selection

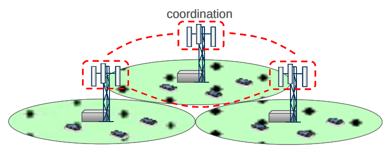


Joint Transmission

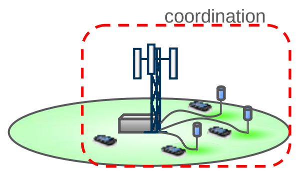
› Different deployment scenarios investigated…



Intra-site coordination



Inter-site coordination

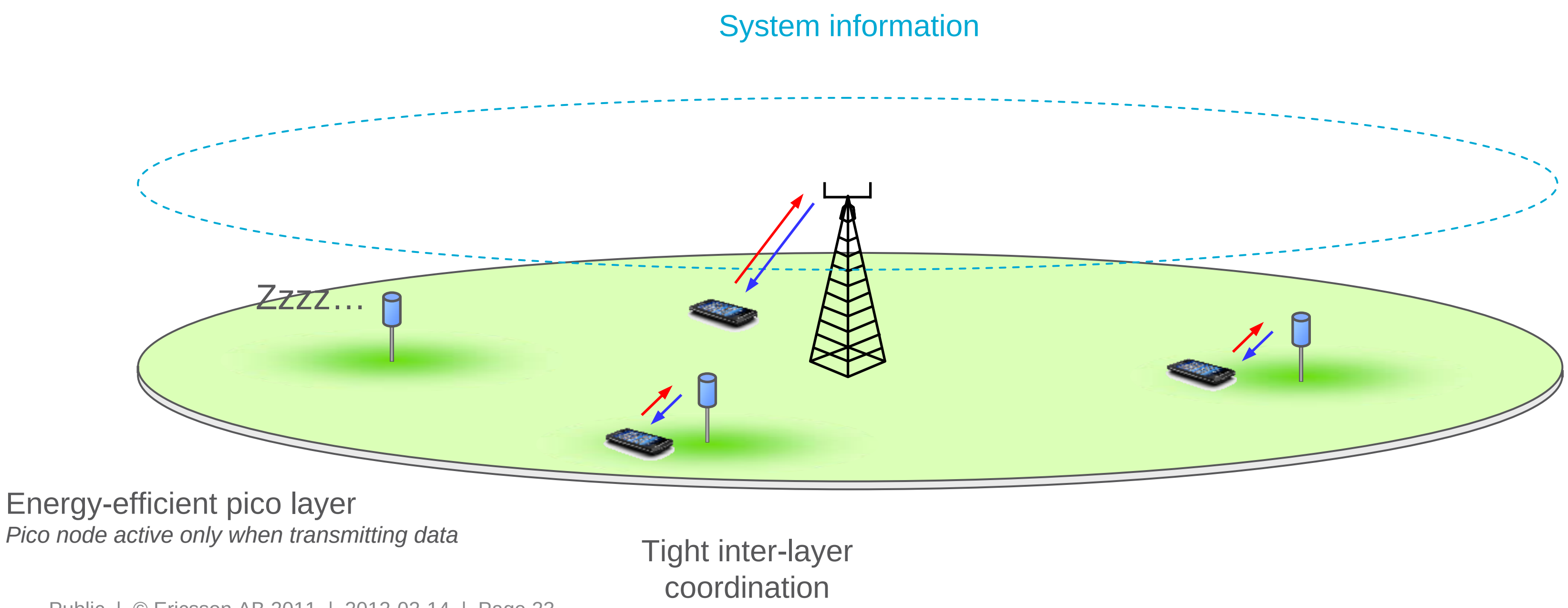


Heterogeneous deployment

› Challenge – *robustness*

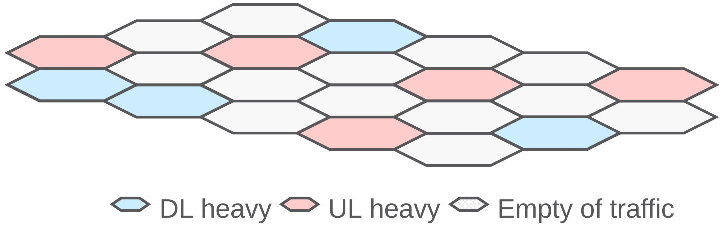
LTE EVOLUTION – SOFT CELL

- Pico nodes *part of* an overlaid macro cell
  - Macro – basic coverage (sysinfo, data, control)
  - Pico – enhanced capacity and data rates (data and control only)
- Pico node 'on' in essence only when transmitting user data
  - Improves energy efficiency, reduces interference
- Dynamic and light-weight selection of pico node
  - Robustness

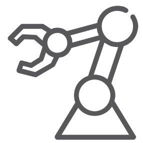


LTE EVOLUTION – FURTHER EXAMPLES

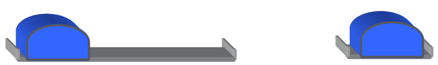
- Flexible TDD allocations
  - Adapt to traffic variations [in small cells]



- Machine-type communication
  - Number of connections, low-cost terminals, …



- Enhancements of existing features
  - Additional band combinations
  - Carrier aggregation enhancements
  - Receiver improvements
  - …



FUTURE RADIO ACCESS

THE FOLLOWING SLIDES CONTAIN FORWARD-LOOKING STATEMENTS WHICH MAY OR MAY NOT MATERIALIZE

LONG-TERM VISION OF THE FUTURE

A world with unlimited access to information and sharing of data available anywhere and anytime to anyone and anything

Provide wireless technology that will enable this future in an affordable and sustainable way

CHALLENGES FOR THE FUTURE

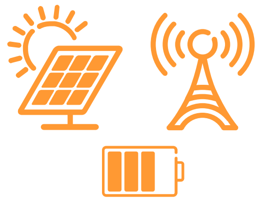
Massive growth in **Traffic Volume**	Massive growth in **Connected Devices**	Wide range of **Requirements & Use Cases**
"1000x" in ten years **Further expansion of mobile broadband** Additional users and increased usage **+** **New types of devices ("communicating machines")**	**"50 billion devices" in 2020** **Massive amount of communicating machines**	**Multi-Gbps in specific scenarios** **Tens of Mbps "almost everywhere"** **New requirements and use cases due to communicating machines**

Affordable and sustainable

ENERGY EFFICIENCY

- Important for *existing* as well as *future* radio access
  - Largely implementation issue
  - Minimize transmission of always-on signals

Operating cost



New deployment possibilities

Market/political aspects

MACHINE-TYPE COMMUNICATION

- Very different characteristics/requirements
  - Very low cost ... *but not always*
  - Very low latency ... *but not always*
  - Very high reliability *... but not always*
  - Very small amount of data ... *but not always*
  - Very low energy consumption ... *but not always*
  - *...*

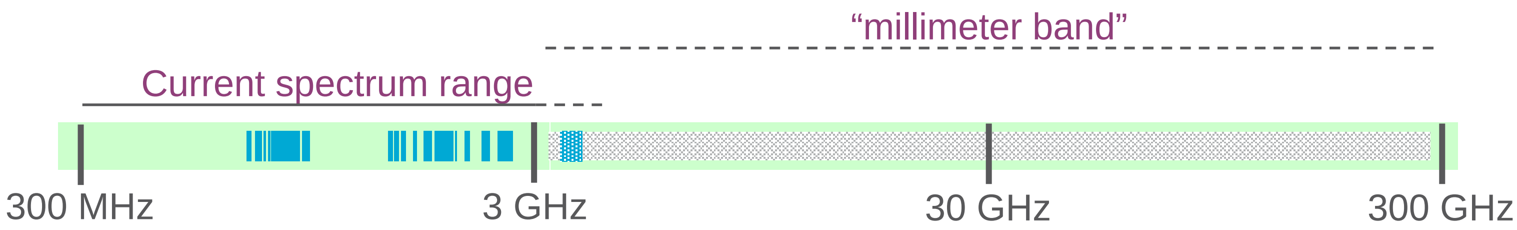
- *Some applications served well by cellular*
- *Some may be better served by other means*

NEW SPECTRUM SCENARIOS

- Bandwidth of several 100 MHz needed for multi-Gbps transmission
  - Hard to envision operator-dedicated spectrum of several 100 MHz

- *Complementary* use of alternative spectrum?
  - *Unlicensed spectrum, secondary spectrum usage, spectrum sharing, …*

- Usage of *very high frequency bands*?
  - Lots of spectrum available ➡ Extreme capacity and data rates
  - Small wave length ➡ Possibility for massive antenna solutions

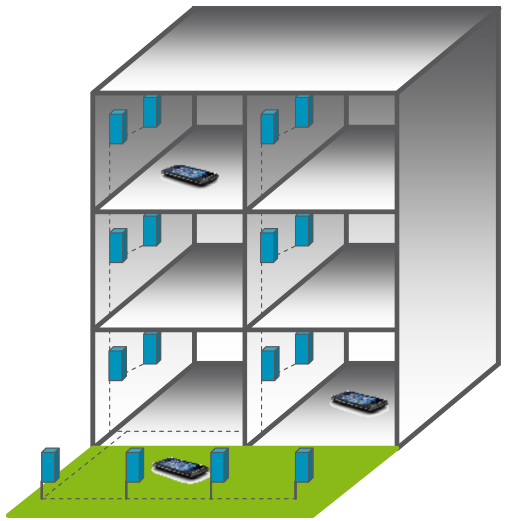


ULTRA-DENSE DEPLOYMENTS

- Order-of-magnitudes more dense than most-dense networks of today
- Locally, infra-structure density of the same order or higher than device density
- Indoor or very-dense outdoor environments

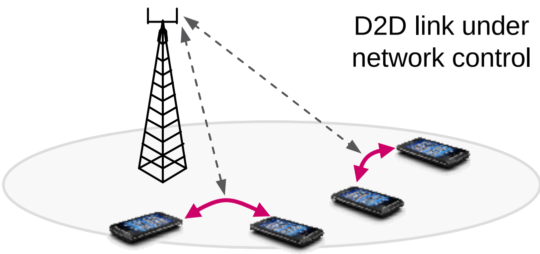
- *Extreme data rates and traffic capacity*
- *Minimized energy consumption*

- *Very-low-cost deployment/maintenance*
- *Availability of very dense and flexible backhaul*

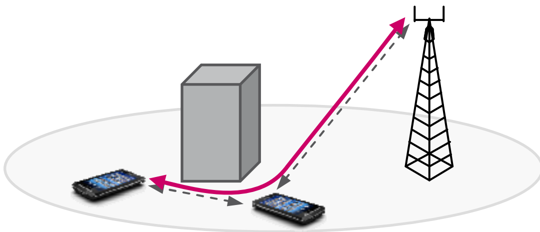


DEVICE-TO-DEVICE COMMUNICATION

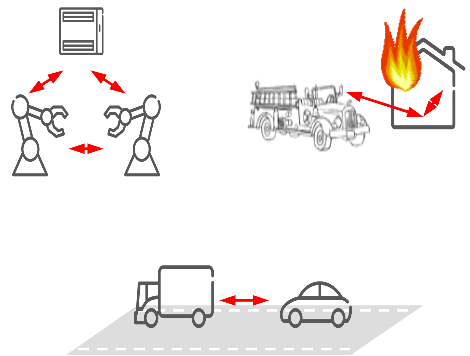
- *Discovery* of and *direct communication* with peer devices
  - User terminals, machines, cars, ...
  - For enhanced service quality and to off-load cellular network
  - To enable communication when cellular network not available
- D2D communication as integrated part of a cellular network
  - D2D link partly under network control – network-assisted D2D
  - Enhanced quality and possibility to operate in operator/licensed spectrum



Offloading



Coverage extension

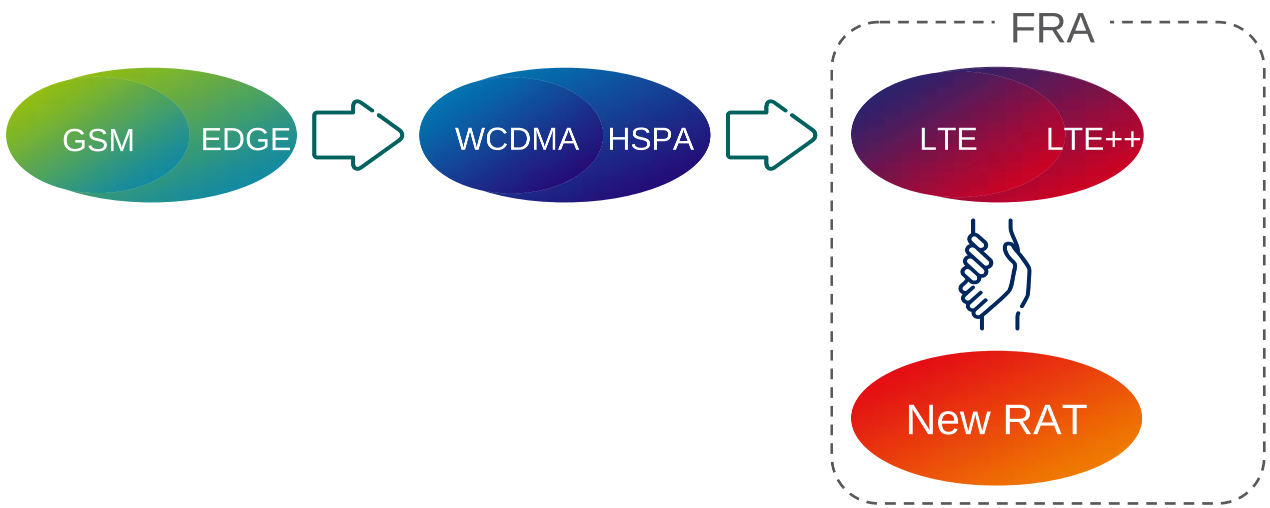


New applications

WHAT IS FUTURE RADIO ACCESS?

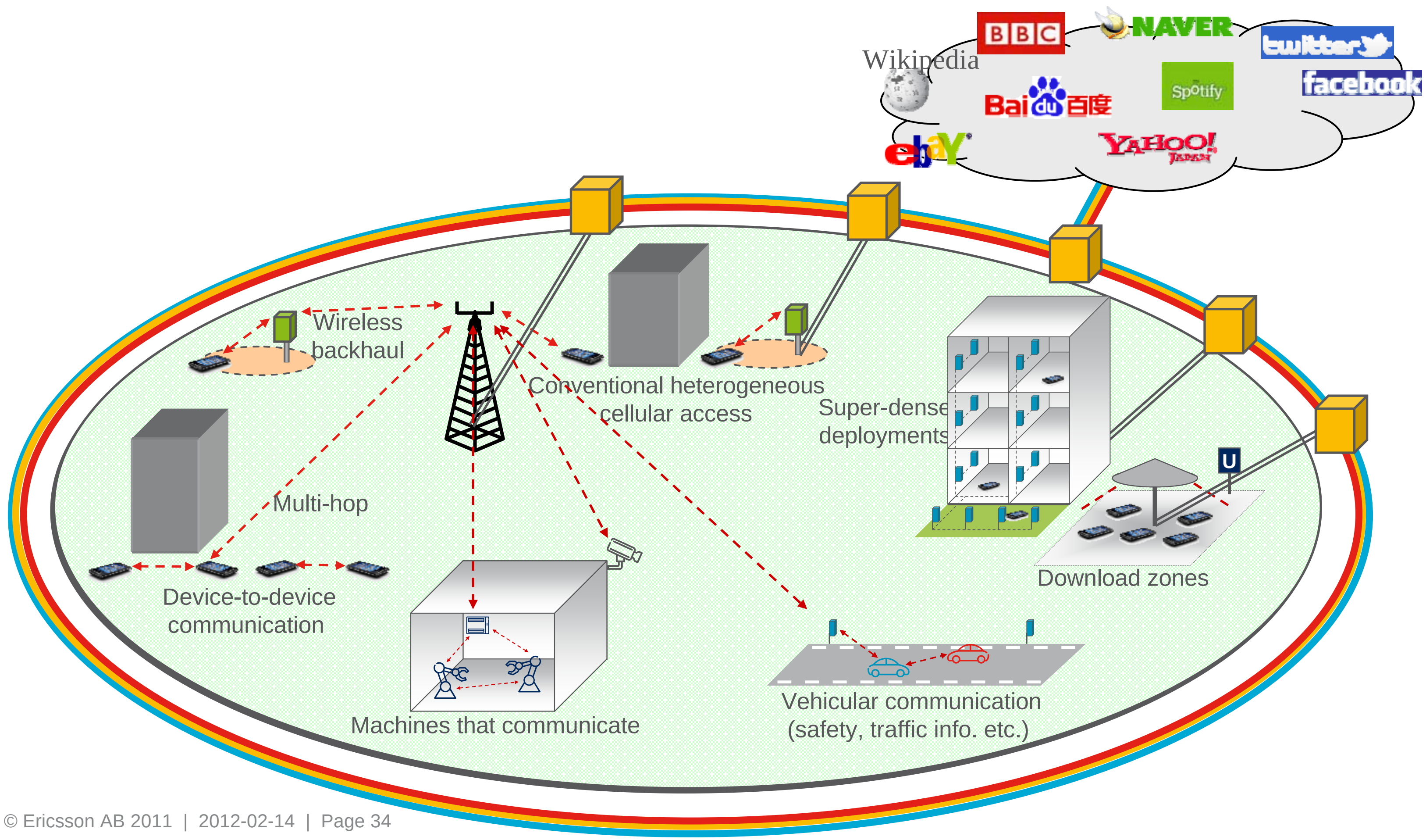
- LTE will continue to evolve
  - *Inter-site coordination, heterogeneous networks, energy efficiency, …*
  - *No reason to radically deviate from LTE track*
  - *LTE capable of handling massive increase in capacity*

- New applications and scenarios
  not supported sufficiently well by the LTE evolution
  ➡ *complementary* radio-access technologies



FUTURE RADIO ACCESS

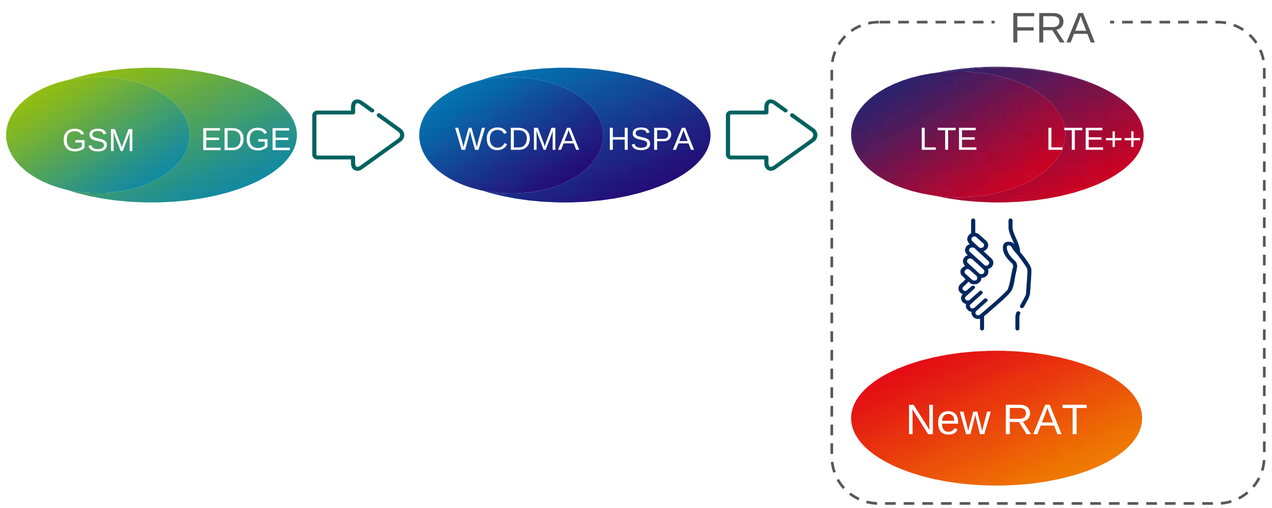
A range of radio-access solutions enabling anytime/anywhere access to information, sharing of data, and machine communication



SUMMARY

- LTE is *the* global technology for future mobile broadband
  - Convergence of 3GPP/3GPP2 tracks, of FDD/TDD technologies
  - Evolution; carrier aggregation, relaying, HetNet, CoMP, energy efficiency, …
  - Expanding into new usage scenarios and applications

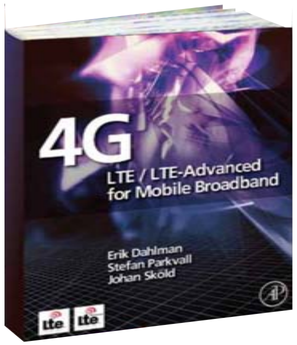
- New radio access solutions
  - *Complementing* LTE in new scenarios/applications not supported sufficiently well by LTE



FOR FURTHER INFORMATION…

Open the 3GPP specifications...

...or read The Book!



ERICSSON