The sky is not the limit

Standardization aspects of using LTE/NR to connect the skies

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Drone served by LTE network

- LTE is well positioned to serve drones
  - Beyond visual line of sight
  - High mobile broadband data rate, low latency, large system capacity and robust reliability.
  - UAV identification and registration using on-board sim cards
  - Maintaining privacy and data protection
- The mobile industry has developed 4G LTE standards and is working on LTE evolutions and 5G standards.
- 3GPP standards are based on industry-wide consensus, and they are evolving in a backward compatible manner.
- They provide a global, interoperable, and scalable platform for the drone ecosystem.

Introduction to 3GPP

TSG SA
(Service & System Aspects)

- WG1 Services
- WG 2 Architecture
- WG 3 Security
- WG 4 Codec
- WG 5 Telecom Management
- WG 6 Mission-critical Applications

TSG CT
(Core Network & Terminals)

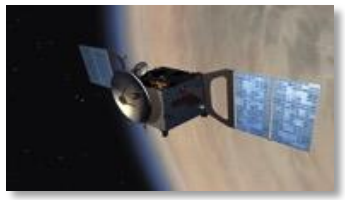
- WG 1 MM/CC/SM (Iu)
- WG 3 Internetworking with External Networks
- WG 4 MAP/GTP/BCH/SS
- WG 6 Smart Card Application Aspects

TSG RAN
(Radio Access Network)

- WG1 Radio Layer 1 spec
- WG 2 Radio Layer 2 spec Radio Layer 3 RR spec
- WG 3 Iub spec, Iur spec, Iu spec UTRAN O&M Requirements
- WG 4 Radio Performance & Protocol Aspects
- WG 5 Mobile Terminal Conformance Test
- WG 6 Legacy RAN Radio & Protocol

3GPP Rel-15 scope

Low Earth and GEO Satellites



Not To Scale

>~600,000 ft. (180km)

High Altitude Platform Systems

~60,000 ft. (18km)

Special Airspace Requirements starting at 1000ft. (300m)

Commercial Jet Aircraft

Medium Altitude Long-Endurance UAV

~30,000 ft. (9km)

~10,000 ft. (3km)

Low Altitude Small UAV

FAA reference definition*

- Weight <= 55 pounds (25kg)
- Speed <= 100 mile/h (44m/s)
- Altitude <= 400 feet AGL (120m)

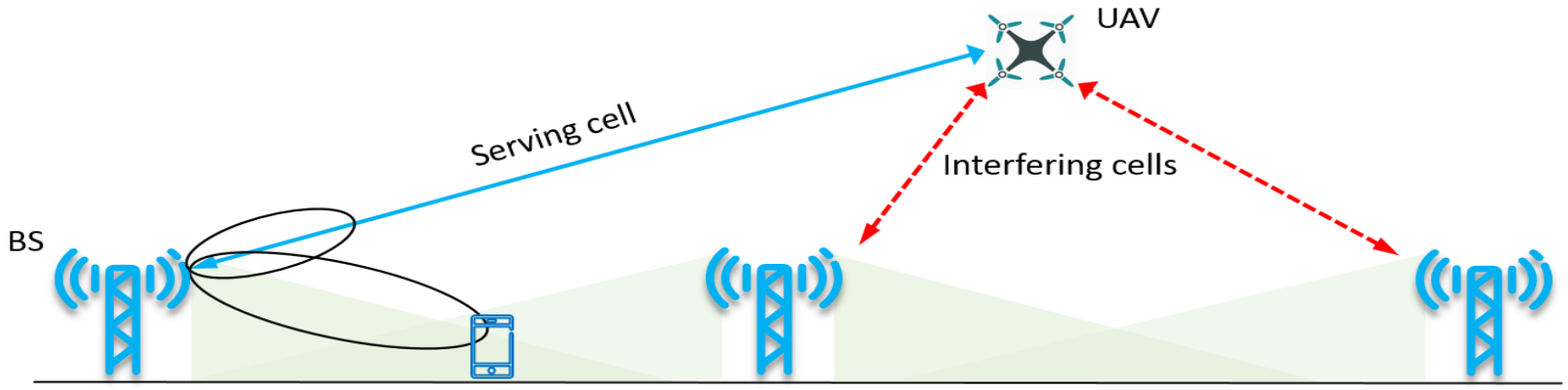
200-1000 ft. (up to 300m)

Ground Level

*Federal Aviation Administration (FAA), "Summary of small unmanned aircraft rule (part 107)," https://www.faa.gov/uas/media/Part_107_Summary.pdf, June 2016.

Drone served by LTE network

- A drone on the ground will be served as a regular LTE smart phone
- Two main connectivity characteristics compared to ground UE
  - Drones may be served by the sidelobes of BS antennas that are downtilted
    -> change on the signal characteristics
  - Close to free-space propagation in the sky
    -> change on the co-channel interference scenario (signal coming from and to the drone)



3GPP LTE Rel-15 Study Item

- Rapporteurs: NTT Docomo, Ericsson
- Outcome: Technical Report (TR) 36.777
- Overall conclusions:
  - LTE and existing deployments are suitable for serving aerial vehicles
  - Enhancements needed/useful for:
    - Aerial UE identification
    - Flight mode detection
    - Interference detection/mitigation
    - Mobility enhancements
- TR includes field tests from Ericsson, Huawei, KDDI, Nokia, NTT Docomo, Qualcomm and ZTE
- TR includes channel models for Aerials served by LTE networks

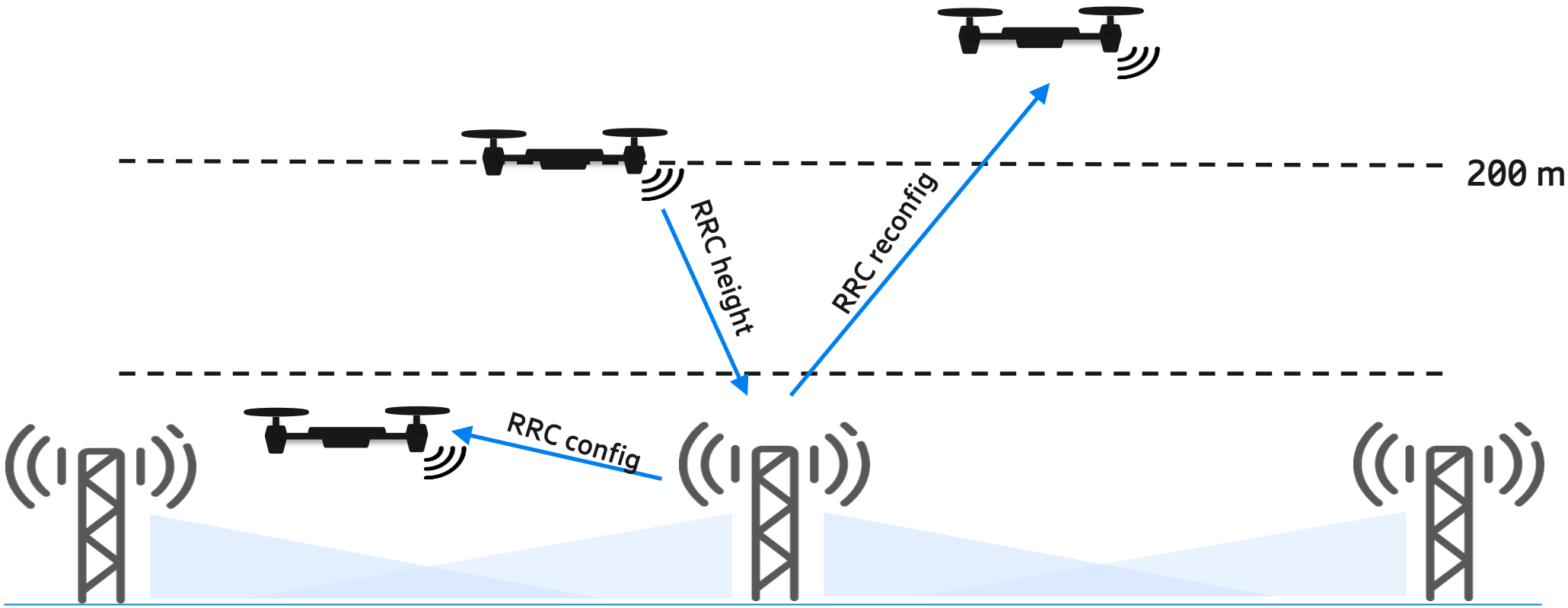
- Outcome of the SI referred in ECC PT1(18)074 "Use of drones in MFCN bands below 3.8GHz"

3GPP LTE Rel-15 Work Item

- Rapporteur: Ericsson, RAN2-focused
- 4 main enhancements:
  - Support for subscription-based identification (SA2)
    - HSS-MME-eNB
  - Height reporting when UAV crosses height threshold (RAN2)
    - Report includes height, location (3D), horizontal and vertical speed
  - RSRP reporting per event of N cells' signal power above a threshold
    - Report includes RSRP/RSRQ/location(3D)
  - UE specific UL power control (RAN1)
  - Flight path information provided from UE to eNB (RAN2)
    - Network polling
    - List of waypoints(3D location), time stamp if available

Enhanced LTE Rel-15 UAV support

- Reconfiguration of UAV based on height report of interference detection report
- UAV reconfiguration for UL power control
- UAV reconfiguration of measurement parameters to improve mobility when flying



3GPP LTE/NR Rel-16

- Ongoing discussion for LTE continuation and for NR(5G)
- Rel-16 starts after 3GPP plenary 11th-14th June, (until end of 2019)

- Ericsson proposal for LTE-Rel16 to be submitted to plenary (DL 5th June.)
  - Objectives:
    - IDLE mode enhancements(broadcasting of height threshold)
    - Faster scaling of RRM/other parameters
    - …
- Ericsson proposal for NR Rel-16 to be submitted to plenary
  - Objectives
    - Subscription based identification
    - Height based reporting + location + airborne status
    - Flight path via RRC from UE

Executive summary

- Existing LTE networks can support initial UAV deployments
  - 3GPP SI confirms feasibility of reusing terrestrial networks for serving flying drones
  - Rel-15 LTE WI introduced enhancements to LTE
  - Further enhancements for LTE possible in Rel-16

- New NR networks hopefully enable basic UAV support from an early release
  - UAV identification, height based report, flight path
  - Mobility and interference detection enhancements need study before WI

Ericsson publications

- [Paper] The Sky Is Not the Limit: LTE for Unmanned Aerial Vehicles (https://ieeexplore.ieee.org/document/8337920/)
- [Paper] Mobile Networks Connected Drones: Field Trials, Simulations, and Design Insights (https://arxiv.org/abs/1801.10508)
- [Paper] Interference Mitigation Methods for Unmanned Aerial Vehicles Served by Cellular Networks (https://arxiv.org/abs/1802.00223)
- [Paper – jointly with CMCC] A Telecom Perspective on the Internet of Drones: From LTE-Advanced to 5G (https://arxiv.org/abs/1803.11048)
- [Paper] Mobility Support for Cellular Connected Unmanned Aerial Vehicles: Performance and Analysis (https://arxiv.org/abs/1804.04523)
- [Paper – jointly with NTT DOCOMO] An Overview of 3GPP Release-15 Study on Enhanced LTE Support for Connected Drones (https://arxiv.org/abs/1805.00826)
- [Paper] Rogue drone detection: A machine learning approach (https://arxiv.org/abs/1805.05138)
- [Blog] Managing drone air traffic with network services (Ericsson Research Blog)
- [Blog] How mobile networks can support drone communication (Ericsson Research Blog)
- [Youtube] Drone communication and traffic management over mobile networks (Ericsson Youtube Channel)
- [Youtube] Invited talk at Texas Wireless Summit on LTE for unmanned aerial vehicles (RCR Youtube Channel: starts at ~24:30)
- [News] Ericsson explains performance of drones on LTE networks (RCR Wireless News)