5G for DoD and Public Safety Uses

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The road to 5G

	1G	2G/2.5G	3G	4G	5G
Time frame	1983-1990	1990-2004	2004-2010	2010-2020	2020-?
Technology	AMPS	GSM / IS-54 / IS-136 / IS-95	CDMA2000, EDGE, UMTS	LTE	5G
Throughputs	2 kbps	64 kbps	2 Mbps	300 Mbps	1.5 Gbps
Multiplexing	FDMA	TDMA/CDMA	TDMA/CDMA	OFDMA	OFDMA/Spatial
Primary Application	Analog voice	Digital voice and messaging	Digital voice, messaging, data	All IP service (includes voice)	EMBB, URLLC, IoT, V2X
Key features	Mobile voice	Security and large scale adoption	Better data services	Broadband internet / streaming video	High capacity and many use cases (all things to all people)
Weaknesses	No security	Limited data rates, circuit switched	Narrowband	Capacity can’t keep up with demand	Complexity

Cellular weaknesses for military and public safety use

Weaknesses

- **Can't support airborne vehicle speeds**
  - Standard designed for high speed rail applications, not fast mover aircraft
  - Implementations don't necessarily support even the high speed rail applications
- **LTE is designed for downlink heavy comms (higher downlink throughputs)**
  - DoD uses include many uplink heavy applications
- **Long range operation limited**
  - Practical max ranges of 100 - 150 km based on standards and implementation limitations
- **No device-to-device operation without infrastructure**
  - Is supported by standard (Proximity Services, or ProSe), but no chipsets have implemented this part of the standard
- **Not robust to interference/jamming**
  - LTE was designed for operation in clean licensed spectrum

Working around them

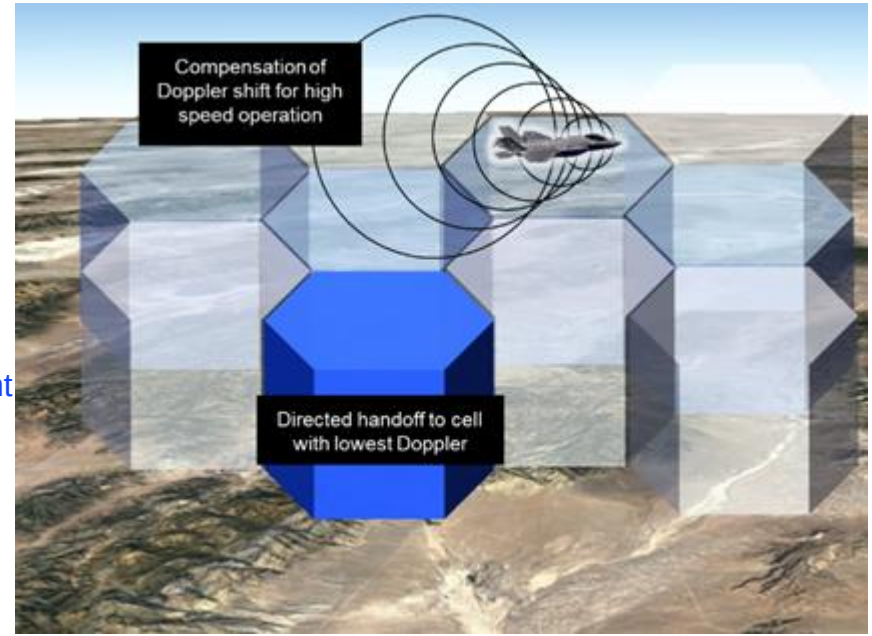
- **Work to add to or modify standards**
  - Can get you what you want in a future standard
  - But…doesn't guarantee that it's implemented
- **Appliqués**
  - Use highly integrated standards compliant parts and add to them
  - But…some fundamental limitations can't be overcome
- **SDR based open-source implementations**
  - Use commodity SDRs and open source software
  - But…won't be low SWaP-C

Workarounds apply to 5G, as well

Addressing LTE weaknesses for high speed airborne mobile telemetry (AMT)

Appliqué approach to overcome limitations

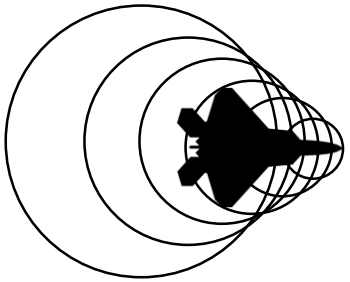
- Extreme speeds and channel conditions different than assumed for typical LTE use
  - High Doppler shift
  - Rapid handoff between cells
  - ❖ Our solution performs predictive directed handoff and a vendor independent Doppler compensating appliqué to allow existing LTE hardware to be used
- T&E available bands (L, S & C)
  - Not typical LTE 3GPP designated bands
  - ❖ Our solution uses unbanded and multi-band small cell equipment for band flexibility
- Asymmetric link
  - High rate (20 Mbps desired) needed from TA to ground stations (LTE uplink)
  - Typical LTE configurations favor downlink (ground station to TA)
  - ❖ Our solution optimizes LTE configuration parameters for uplink-heavy links



Doppler compensation appliqué on COTS hardware

Perspecta Labs vendor independent solution

- Our appliqué can be attached to any standard LTE equipment to compensate for Doppler induced by high speed
- Laboratory tested using emulated flight paths with speeds up to Mach 2.0 – 4.0 (depending on carrier frequency)
- Equipment has been installed at Edwards AFB and has been flight tested
- Working to integrate our Doppler compensation method into a commercial product



Signal arrives at aircraft shifted by Doppler

LTE C-Band Base Station

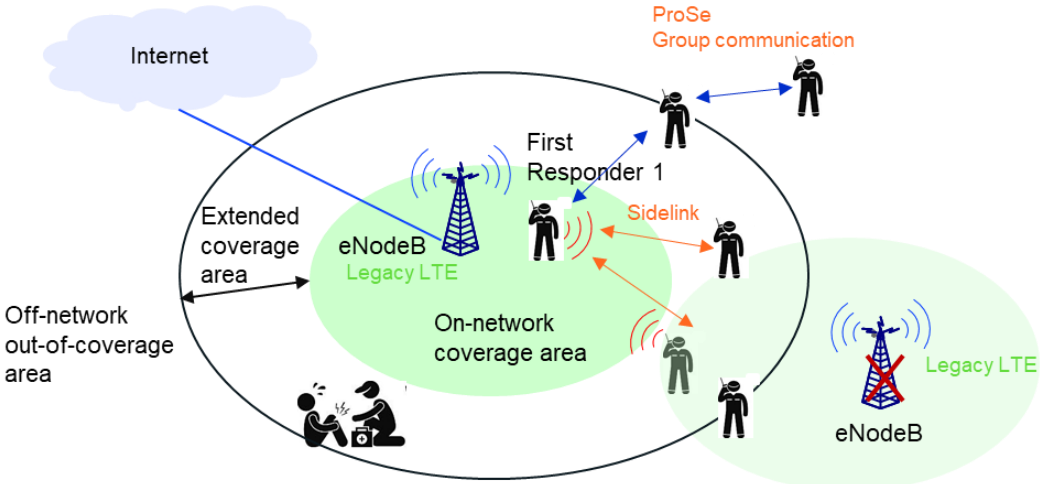
Signal arrives at base station with no frequency shift

LTE C-Band Modem with Perspecta Labs Doppler compensating appliqué

Device-to-Device LTE for Public Safety (DDPS)

Standardized but not available in devices…

- Despite standardization, there is no mature LTE D2D when infrastructure fails
- DDPS is an effort to facilitate the development of an LTE D2D ecosystem based on ProSe
- The key DDPS technologies include building a complete ProSe stack for Mission Critical Voice by extending the OAI implementation and solving key related problems
- DDPS testbed demonstrates feasibility of ProSe for first responder applications

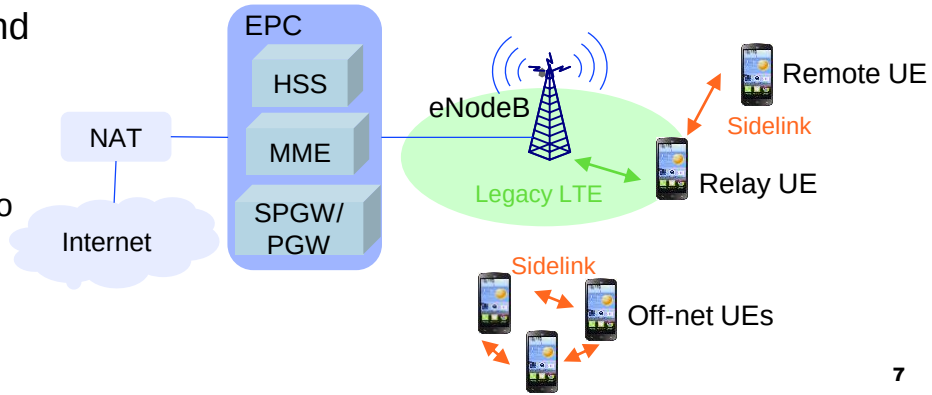


DDPS Solution

Open source software based radio approach

- Build a complete ProSe protocol stack in software
  - Extend OpenAirInterface™ (OAI) implementation to support D2D services on- and off-network based on 3GPP Rel-14 specifications
  - Help create an ecosystem that can ultimately lead to a small form factor platform
- Create test bed and demonstrate a full ProSe network prototype on SDR platform
- Extend OAI code to solve complex service continuity challenges

- Solve open issues related to resource allocation and time synchronization:
  - New scheduling algorithms for autonomous resource allocation to minimize collision probability.
  - Novel multi-antenna-based synchronization techniques to achieve significant improvement in UE autonomous synchronization

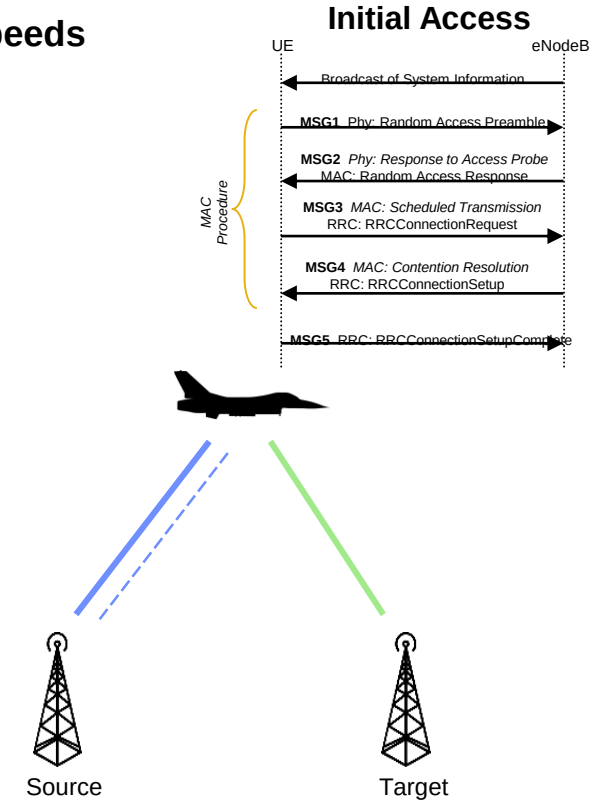


5G NR – mobility enhancements

Standards to the rescue

Increase robustness & speed (reduce interruption time) for high speeds

- Feature is currently in development
- Reduce Interruption Time (0 msec interruption): Adoption of Make-Before-Break (MBB) mechanism
  - RACH-less handover
    - Prepares all parameters of target cell in advance
  - Simultaneously connect to source & target using Dual Connectivity principles
- Increase Robustness
  - Conditional Handover: Prepare multiple cells as candidates to be the target
  - Fast handover failure recovery: Do not wait for system information broadcast measurements (SIB/MIB)
- This doesn't address high Doppler case directly, but other parts of standard help (flexible subcarrier spacing).



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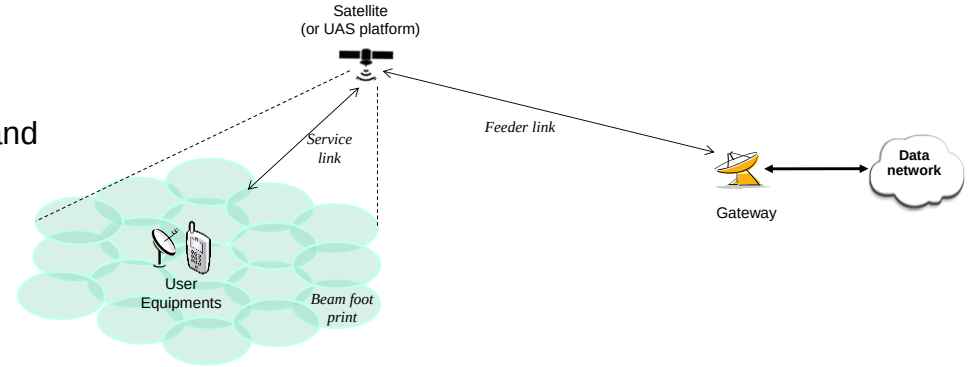
5G non-terrestrial networks (NTN)

Satellite and high-altitude links

- Strong industry interest has driven the study (and upcoming standardization for Rel-17) of NR to accommodate links between terrestrial (train and airplane inclusive) and LEO/MEO/GEO satellites or High Altitude aircraft.
- Development of pre-specification enhancements needed currently being drafted, TR 38.821:
  - Timing and Frequency Acquisition (augmented by ephemeris)
  - Timing Advance extension
  - Random access and response window
  - Physical layer link quality control loops and HARQ modifications
  - Window size changes for Layer 2/3 protocols, user plane timer extensions
  - Handover robustness to latency

At the Test Range

- Serve remote areas over water and inter-range transitions

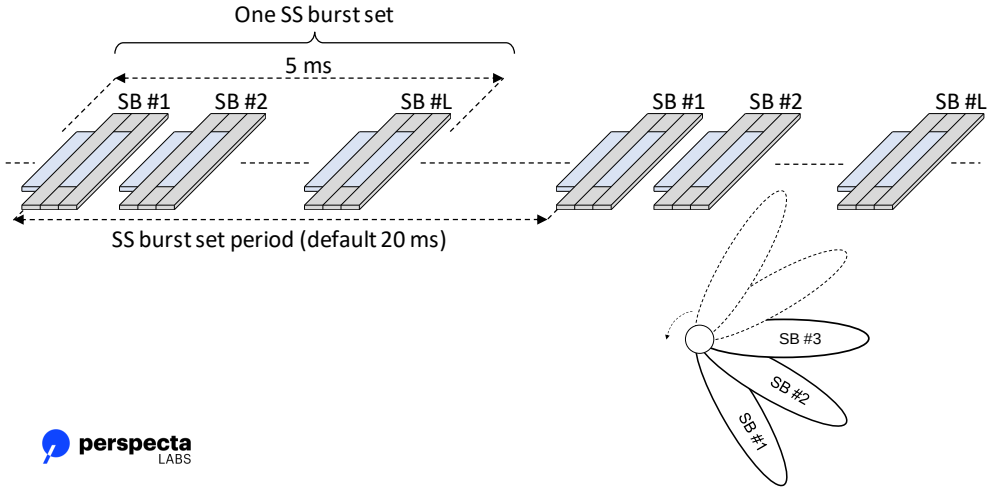


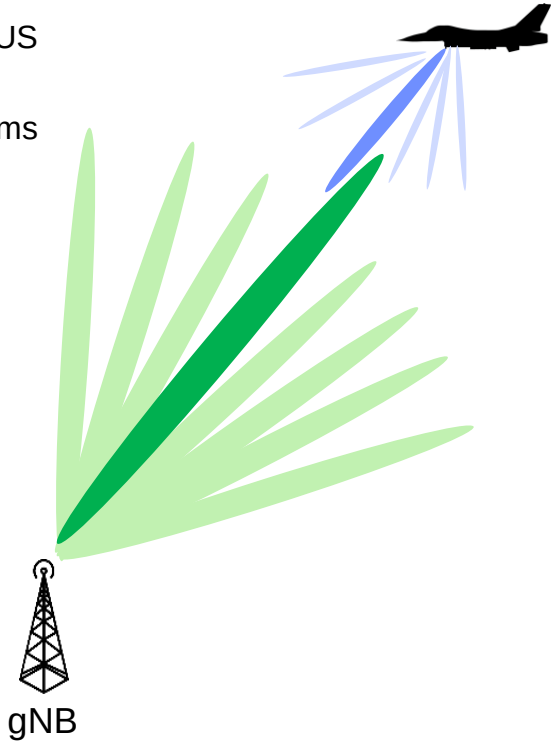
Field of view of the satellite (or UAS platform)

5G NR mm-wave & beamforming

LPI/LPD/LPJ

- To close the link in NR mmWave, beamforming is required at both the base station and the mobile device.
- Macro-cell coverage with mobility is already commercially trialed at 24GHz, in the US
- *5G* Signaling mechanisms enhanced to operate with beamforming
  - Cell search and initial random access include beam search with up to L=64 beams
  - Beam management implements the tracking
- **High gain beams help with LPI/LPD/LPJ operation**





Does 5G help for military and public safety?

Is 5G everything to everybody?

- The 5G standard introduces many new concepts, but do they make it ready for military and public safety use?
- Military comms must assume a contested environment and 5G was not designed for use in areas with intentional jamming
  - Built-in beamforming can help but it is designed to help close the link, but maybe not to avoid intentional jamming
  - **Externally directed beam/null forming as an adjunct helps**
- ProSe/D2D comms is included in the vehicle-to-everything (V2X) part of the release 16 standard
  - It is meant to enable vehicle based comms, not necessarily public safety infrastructureless applications in buildings
  - **Standards work that keeps the public safety use cases in mind helps**
- NTN parts of the standard enable 5G satellite comms
  - Doesn’t fully address very long distance terrestrial links
  - **Special-use variant NTN equipment for terrestrial would address this use**

Thank you

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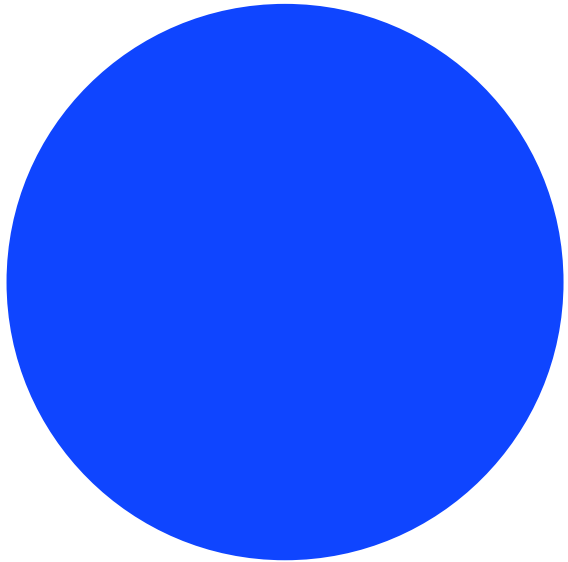

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