



# Test and Evaluation/Science and Technology Program Spectrum Efficient Technology



## Challenges in implementing Telemetry over LTE

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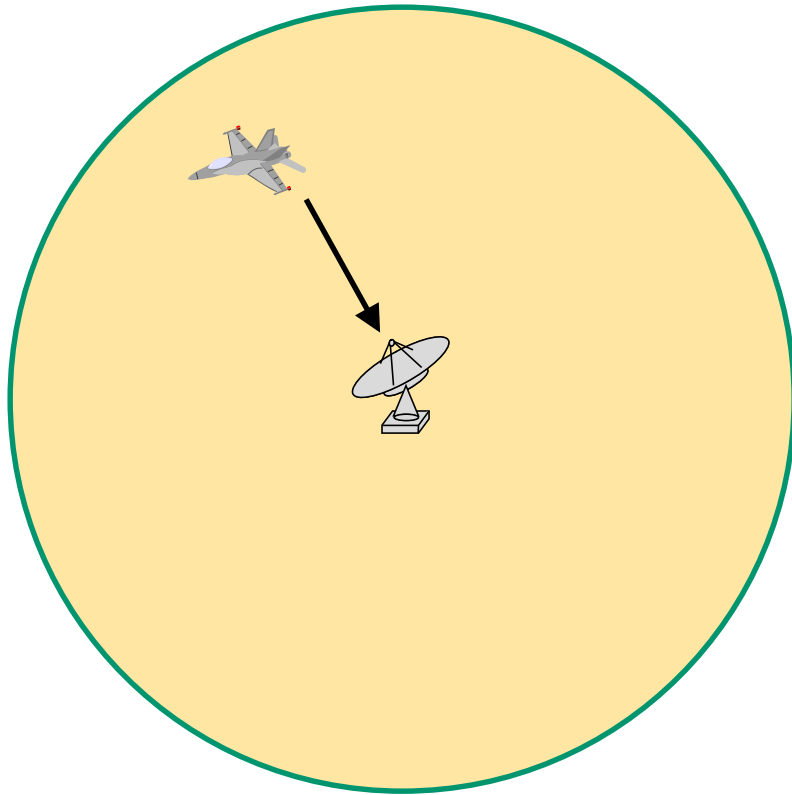


# Introduction

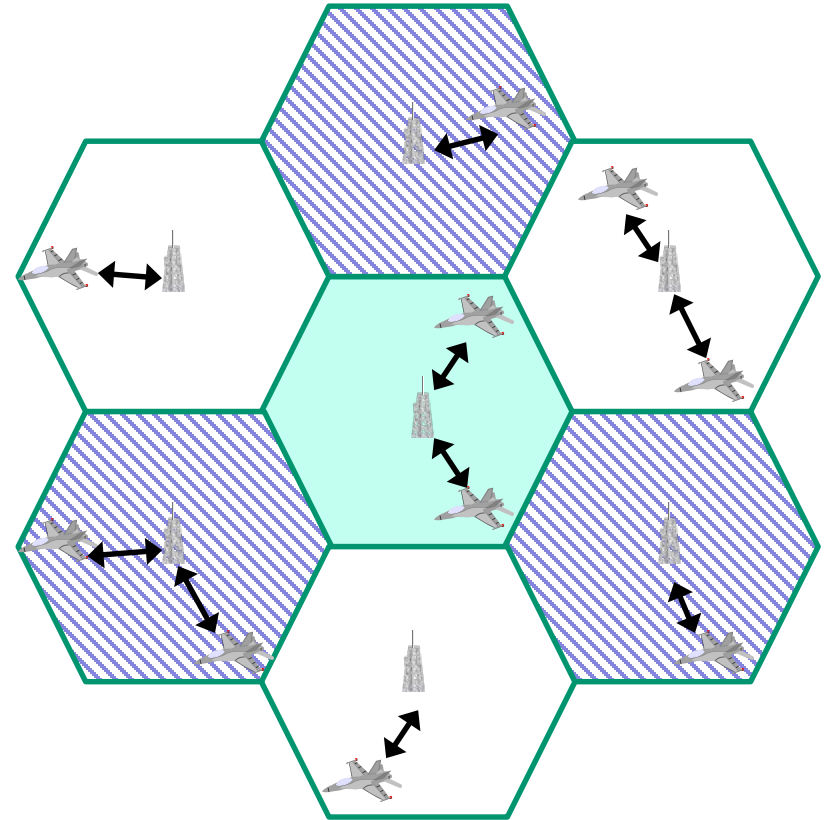
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- **Telemetry paradigms**
  - Traditional TM paradigm
  - Cellular base network telemetry paradigm
- **Resource Scheduling**
  - Current process is frequency based
  - Network TM will be bandwidth based
- **Cellular limitations**
  - Range limitations
  - Shared medium
  - Doppler
- **Paths forward**
  - Modifications of 3GPP standards
  - Adapter appliances
  - Investigate 5G technologies benefits

# Ground Infrastructure



**Traditional AMT**



**Cellular based AMT**



# Current Telemetry Paradigm



- **Point to Point links**
  - Omni antenna(s) on test article(s)
  - Directional high-gain antennas on the ground
  - One way link- “Broadcast”
  - Most still use PCM/FM, though usage of SOQPSK is increasing
- **Current paradigm allocates exclusive frequencies per test article**
  - Often frequencies must be coordinated over multiple ranges to minimize interference
  - Frequency de-confliction is a manual process
  - Frequencies assigned to test article before mission and not changed during mission
- **Spectrum scheduling and utilization**
  - Manual frequency assignments planned days in advance
  - Frequency excluded from use by others over large geographical areas
  - Little opportunities for frequency re-use



# Cellular AMT Paradigm



- **Frequency scheduling / planning**

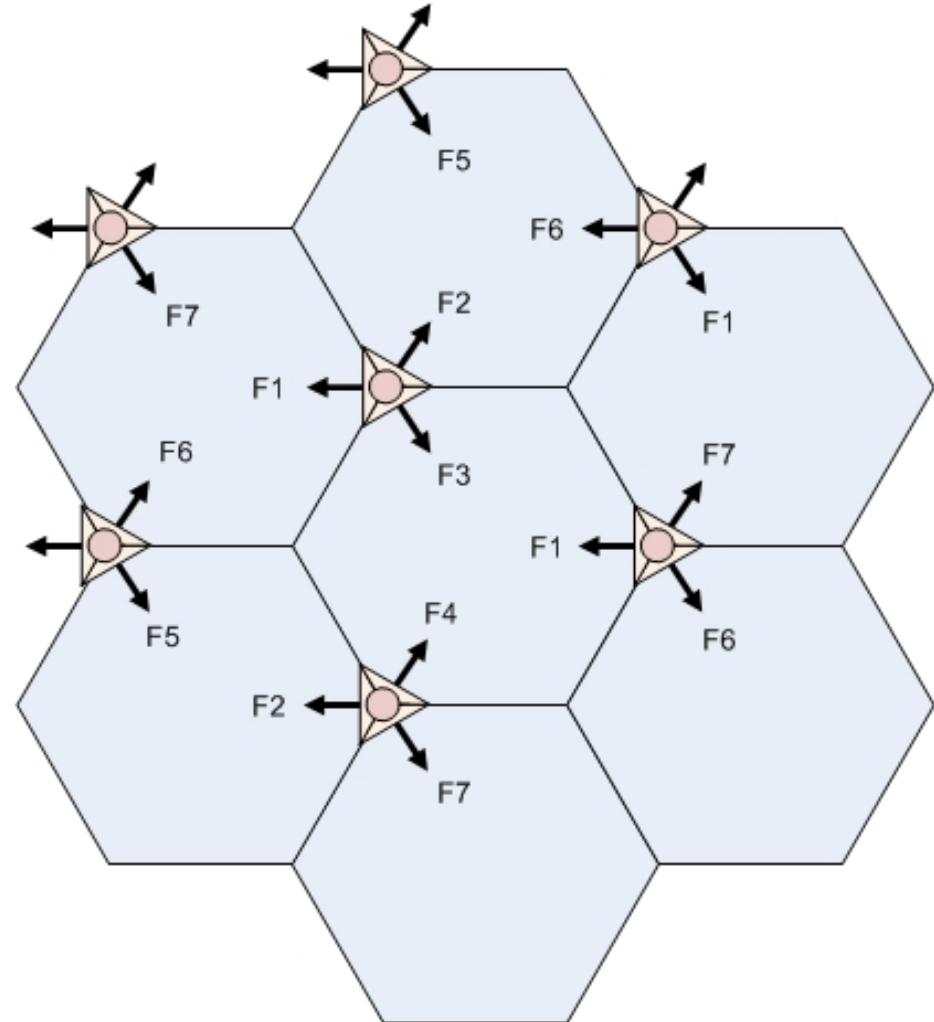
- Frequencies are planned during capability's initial rollout
- Spectrum plan is static, will change as system is expanded / modified
- Spectrum re-use is built into the frequency plan
- Spectrum plan is derived from bandwidth plan
- FDD has slightly greater throughput, but requires a strict frequency plan because of isolation filter requirements
- TDD has slightly less throughput, but has a flexible operating frequency making spectrum planning much simpler and allowing more spectrum to be used for TM

- **Bandwidth**

- Bandwidth is the scheduled resource, not frequency
- Density of bandwidth is dependent upon number of cells (and carriers per cell) providing coverage in a range area (e.g. flight line, impact areas, super sonic corridors, etc.)
- Mission planning needs to take into account bandwidth available and mission bandwidth requirements to determine number of simultaneous missions that can be supported in a range area
- Leverage demand and diversity of networks

# Further Bandwidth Increases

- Add additional cells in areas that require more bandwidth density
- TDD offers more flexible frequency planning and more cell overlap than FDD
- Leverage LTE-A Carrier aggregation to increase bandwidth available in each cell





# Cellular (LTE) challenges

- **Cell Size (slant range limitations)**
  - Current LTE Cell size limited to ~ 150km
  - Limitation is not based on link margin but on Timing Advance function in LTE
  - Bandwidth available to individual test articles limited by link margin, as link margin decreases, lower order modulations are used, reducing bandwidth.
  - May not cover all large un-instrumented areas of range (e.g. sea ranges)
- **Shared Medium**
  - Bandwidth in a cell is shared between test articles in the same cell
  - Need to leverage network QoS
  - Bandwidth capacity planning important for implementing cellular technologies
  - Increase bandwidth availability in high demand areas with “densification” (adding additional cells and/or carriers to an area)
- **Doppler**
  - LTE sensitive to Doppler
  - For high speed test articles (~ >500km/h) doppler compensation required
  - Current TRMC cellular TM efforts feature Doppler compensation techniques for speeds up to ~ Mach 2



# Paths forward

- **Cell Size (slant range limitations)**

- Current LTE Cell size limited to ~ 100km (RACH Format 3)
- Limitation is not based on link margin but on Timing Advance function in LTE
- Investigate methods to modify Timing Advance to support larger cell radius
  - Custom LTE stack (Not ideal)
  - Modifications to LTE standard
  - Investigate 5G “Non-terrestrial networks” section of standards and possible benefits to increasing cell radius

- **Doppler**

- LTE sensitive to Doppler
- For high speed test articles (~ >350km/h) doppler compensation required
- Investigate methods to reduce impact of Doppler
  - Current TRMC cellular TM efforts feature Doppler compensation techniques for speeds up to ~ Mach 2 (verified with lab testing)
  - 5G standards may increase Doppler resistance
  - Investigate possible benefits of 5G “Non-terrestrial networks” section of standards

- **Bandwidth**

- 5G Millimeter wave can provide high bandwidth densities at shorter distances (e.g. flight line, hangars, etc.)
- Small Cell technologies also can provide increased bandwidth densities in congested areas at shorter distances (e.g. flight line, hangars, etc.)



# Conclusions

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- **Cell Size (slant range limitations)**

- Max cell radius of ~100km may limit LTE capability effectiveness for sea ranges or over larger areas where it is not practical to deploy cellular base stations
- Investigating methods to increase cell radius
  - 5G standards may address this issue
  - Modification of LTE stack
    - Keeping a standard stack increases equipment options and reduces acquisition and upgrade costs

- **Doppler**

- Compensation is required for LTE on fast moving aircraft
  - Currently developing and testing doppler compensation mechanisms
  - 5G may provide more tolerance to Doppler than LTE

- **Spectrum**

- Cellular technologies provide efficient re-use of spectrum
- Cellular changes frequency planning to bandwidth planning



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# Questions?

# REPORT DOCUMENTATION PAGE

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