Test Resource Management Center (TRMC)

National Spectrum Consortium (NSC) / Spectrum Access R&D Program

LTE HANDOVER ENHANCEMENTS FOR HIGH SPEED CELLULAR RANGE TELEMETRY

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Approved for public release; distribution is unlimited

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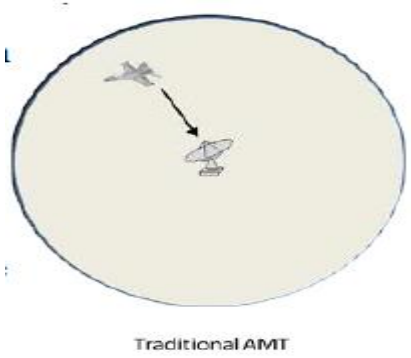
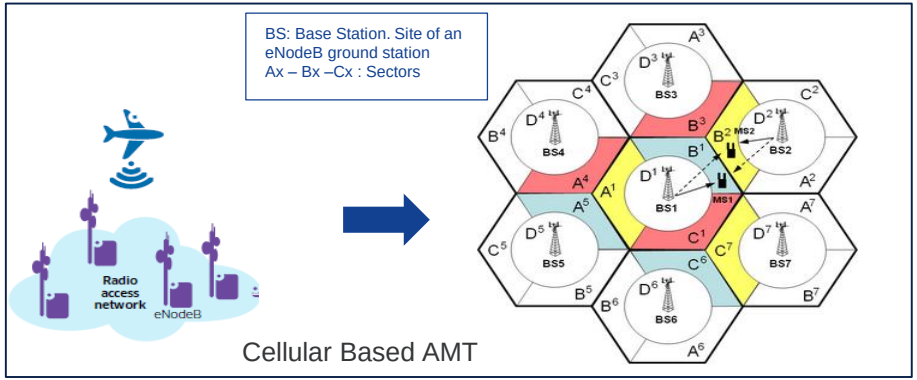
Cellular Range Telemetry





Technology focus

- Provide test range coverage using a “cellular” paradigm (frequency re-use with inter-cell handover)
- Use of lower C-Band spectrum which is less congested
- Use of LTE’s spectrally efficient OFDM waveform capable of providing high throughput
- Seamless handover as multiple test articles move across the cells covering the test range

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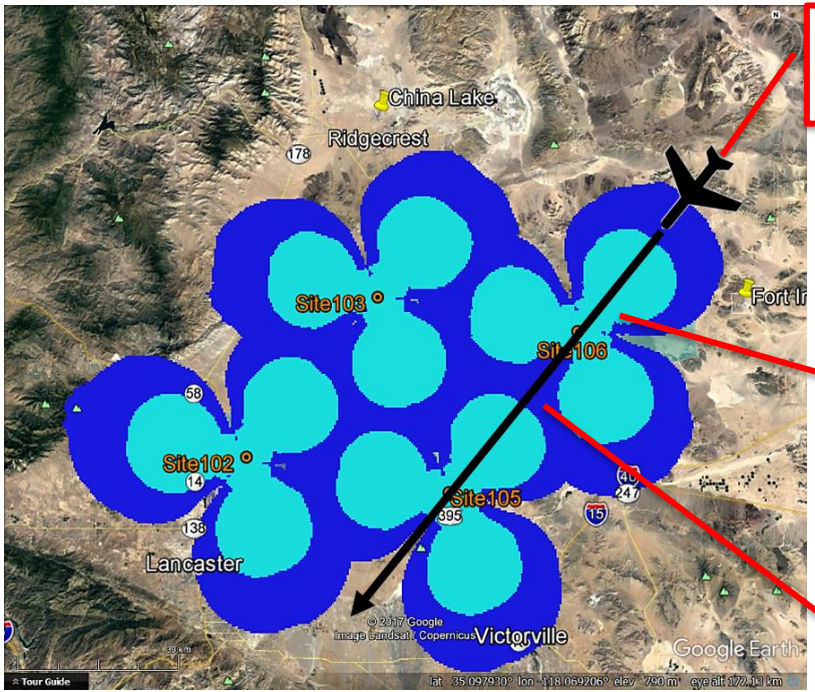
Why is Handover needed?

- Handover in LTE refers to the procedure used by the LTE network to provide continuous and seamless data service as the UE moves through the different cells of the network. As the UE moves from the coverage of one cell to another cell, the handover procedure is initiated to maintain seamless mobility. The basic objectives of handover procedures are to maintain the connectivity and the data service as the UE moves in the coverage area of the network.



Notional Flight Path

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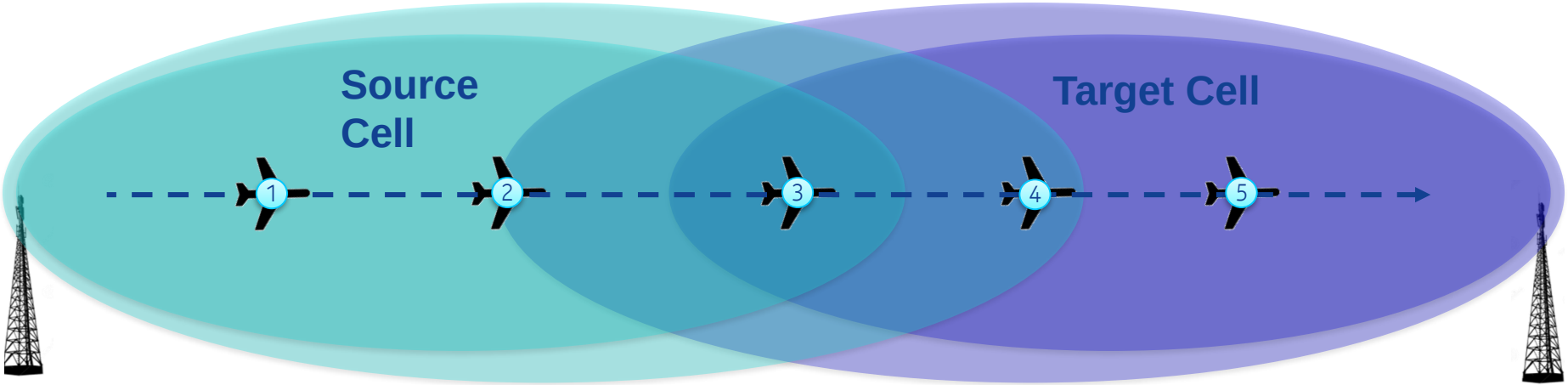
LTE Handover Procedure



1. UE connected to Source Cell
2. UE detects neighboring Target Cell, included in measurement report
3. Measurement report triggers handover initiation at Source Cell
4. Handover to Target Cell completes with RRC Connection Reconfiguration Complete message
5. UE connected to Target Cell

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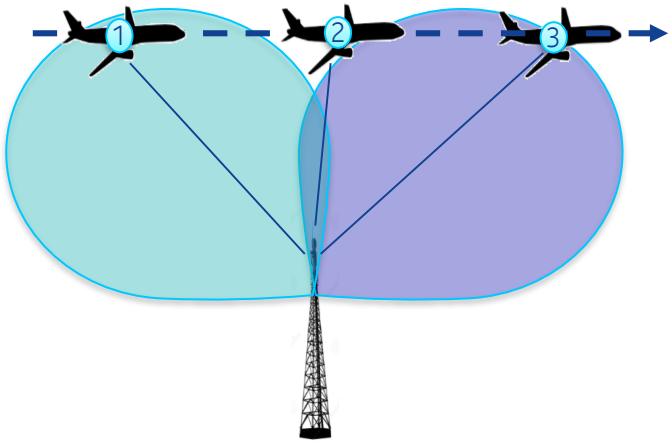
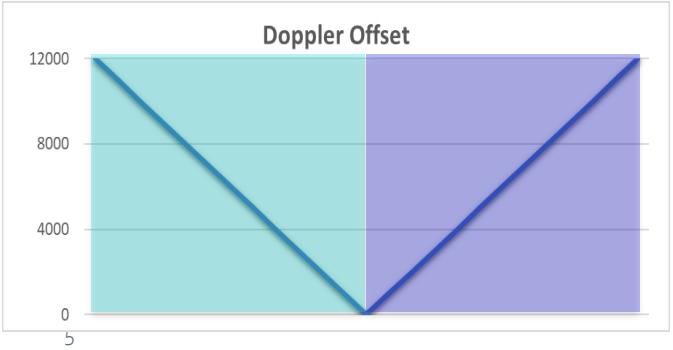
Intra Site Handover Analysis





Technical Challenge

Maximize handover success rates

- High Doppler impacts UE measurement capability & ability to connect target cell on handover.
- Handover execution time limit depends on the speed. Long time can result in failed handover

Analysis Results

Doppler impacts

- Doppler offset approaches zero at handover
  - Tangential or near-tangential flyby
  - Applies to over-flight, or fly-by

Handover execution timing

- Target cell measurements cannot start until Airborne terminal can "see" the target cell

Conclusions

- Doppler offset is of little to no concern for Intra Site handover.
- Time available for handover execution will impact Intra Site handover success rates.
- As part of RF planning need to design for maximum RF overlap between the sectors served by the same site.

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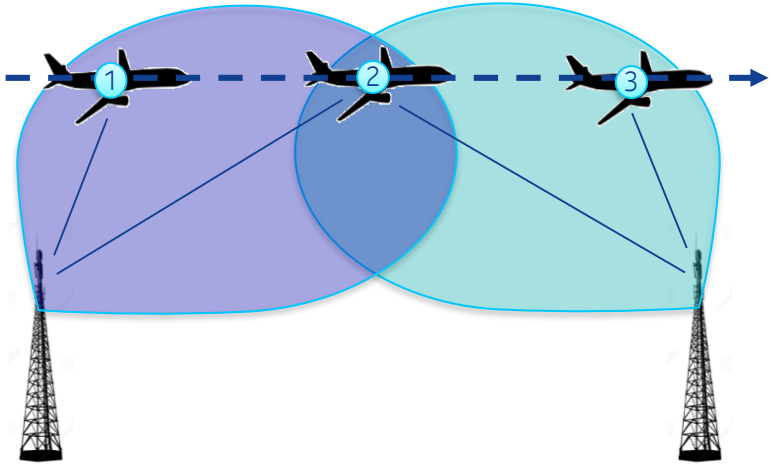
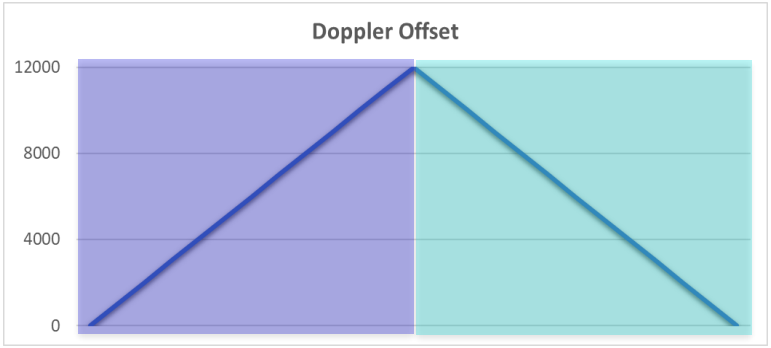
Inter Site Handover Analysis





Technical Challenge

Maximize handover success rates

- High Doppler impacts UE measurement capability & ability to connect target cell on handover.
- Handover execution time limit depends on the speed. Long time can result in failed handover

Analysis Results

Doppler impacts

- Maximized, due to extreme Doppler offset from each site.
- Transition from high negative Doppler to high positive offset during handover.

Handover execution timing

- Simpler timeline in this scenario due to significant Site-to-Site RF coverage overlap

Conclusions

- Doppler impact is the highest for Site-to-Site handover.
- For lower C-Band operation and speeds approaching MACH 2, the Doppler estimation component needs to handle Doppler offsets as high as 12KHz for the serving and neighbor cells.

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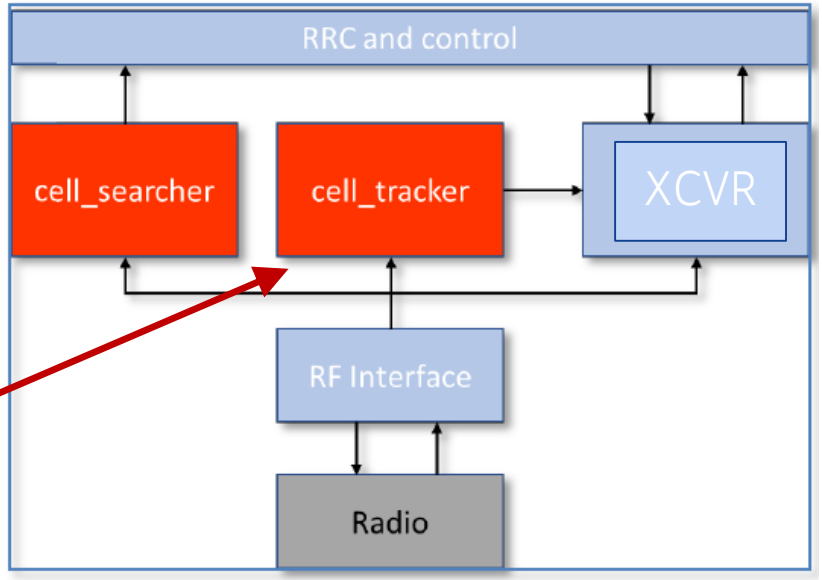
UE Doppler Estimation & Compensation Architecture

Search function scans for eNodeBs and provides Doppler estimates for cell attach and neighbor cell measurements

Track function follows Doppler of currently-connected eNodeB



Airborne Terminal PHY (**blue**) adjusts internal CFO tracking filter and compensates for corresponding transmitter Doppler offsets

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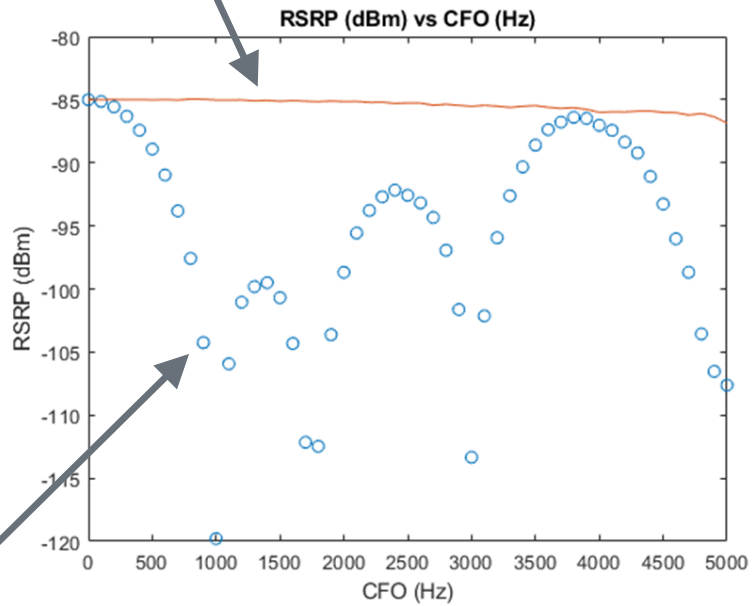
Searcher Performance – RSRP Estimation

Searcher estimates eNodeB Reference Signal Received Power (RSRP) in presence of:

- CFO estimation errors
- Timing estimation errors
- Doppler induced signal overlap

Searcher can identify Doppler shifted eNodeB signals and estimate RSRP for CFO up to ±12 KHz

Cell Searcher RSRP Estimate after Doppler Compensation



Standard RSRP Estimate with no Doppler Compensation

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Searcher Performance – Matlab Simulation

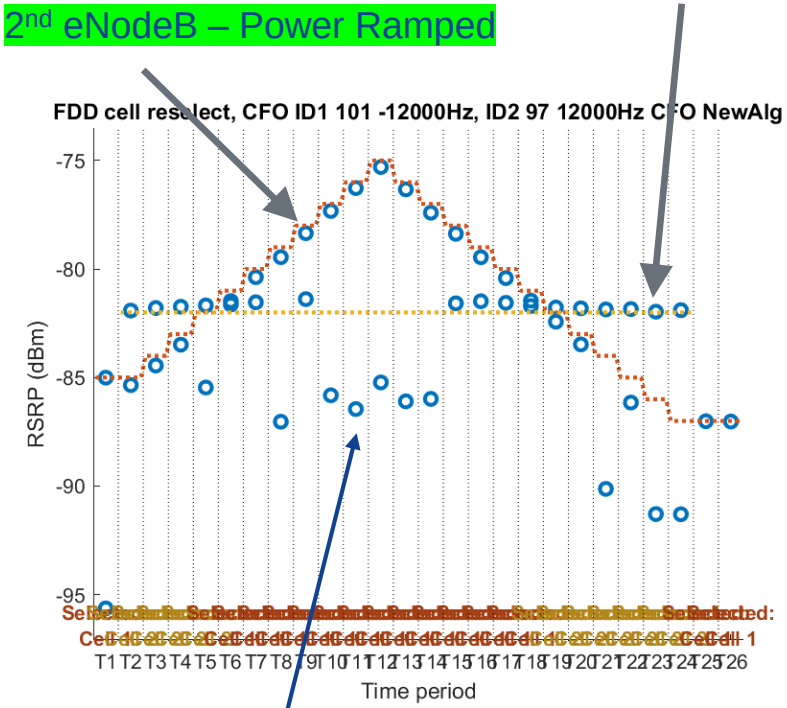
Two eNodeBs, Doppler-shifted to +12 kHz and -12 KHz respectively:

- First eNodeB power held at -82 dBm
- Second eNodeB power ramped up and down

Graph shows good estimation of RSRP when eNodeBs are doppler shifted +12 kHz and -12 KHz

1st eNodeB – Power Constant at -82 dBm

2nd eNodeB – Power Ramped



Matlab simulation - searcher errors due to low SNR & large CFO

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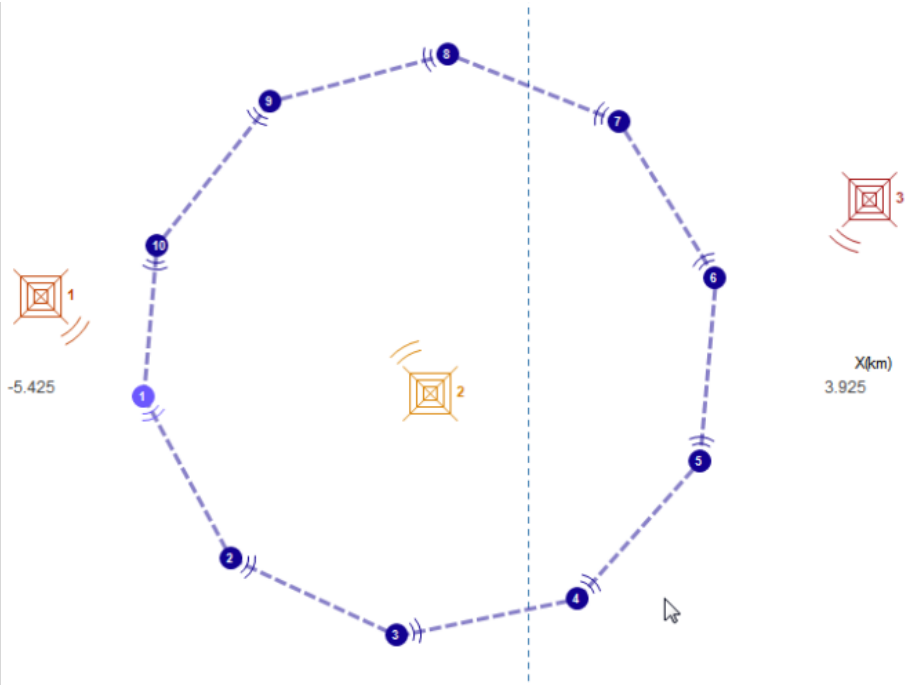
Handover Test – Intra and Inter eNodeB Handover

Handover Test Setup

- UE operating in C-Band
- 3 eNodeB Cells for Inter and Intra eNodeB Handover
- AT speed: 1000 km/hr or Mach .8
- eNodeB info
  - Cell 1 eNodeB1 Cell 2 (PCI 142)
  - Cell 2 eNodeB1 Cell 1 (PCI 141)
  - Cell 3 eNodeB2 Cell 1 (PCI 241)



Simulated Air Flight Profile

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Handover Test Results

OBSERVATIONS

- Successfully able to extend 3GPP Doppler compensation limits and UE Measurement Capabilities with Air 2 Ground Doppler compensation design.
- Testing for > MACH 1 speed and lower C-Band operation are in progress

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Conclusion

- This paper shows the challenges of extending 3GPP LTE seamless handover to work at high speeds for Aeronautical Mobile Telemetry.
- Nokia is building upon its commercial Air to Ground LTE solution to address these challenges for Cellular Range Telemetry.
- The simulations and lab tests performed by Nokia on prototype C-Band Air to Ground LTE equipment indicate that Doppler and handover timing constraints can be addressed with
  - modification to the Airborne Terminal's Doppler estimation and compensation algorithms
  - Optimization of the handover measurement configuration