On LPI/LPD Communication for Airborne Collaborative Systems

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Introduction

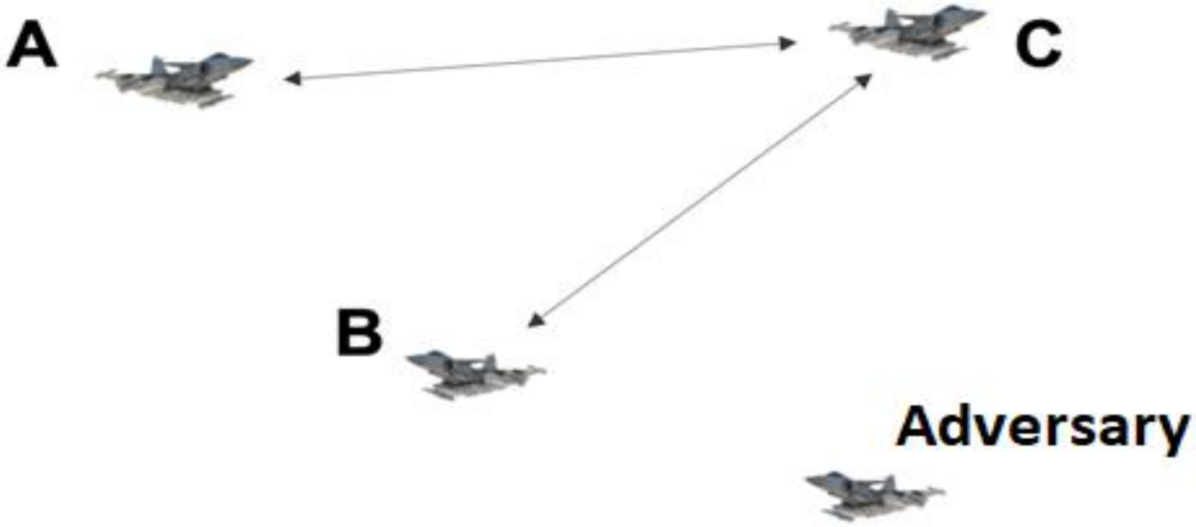
- Reliable and secure communication between airborne platforms is today more critical than ever
  - New threat systems and jamming techniques driven by digitalization can capitalizes on existing weaknesses of broadcast COM
  - Important realization is that L16 can be detected and jammed at very long distances (N*100 km)

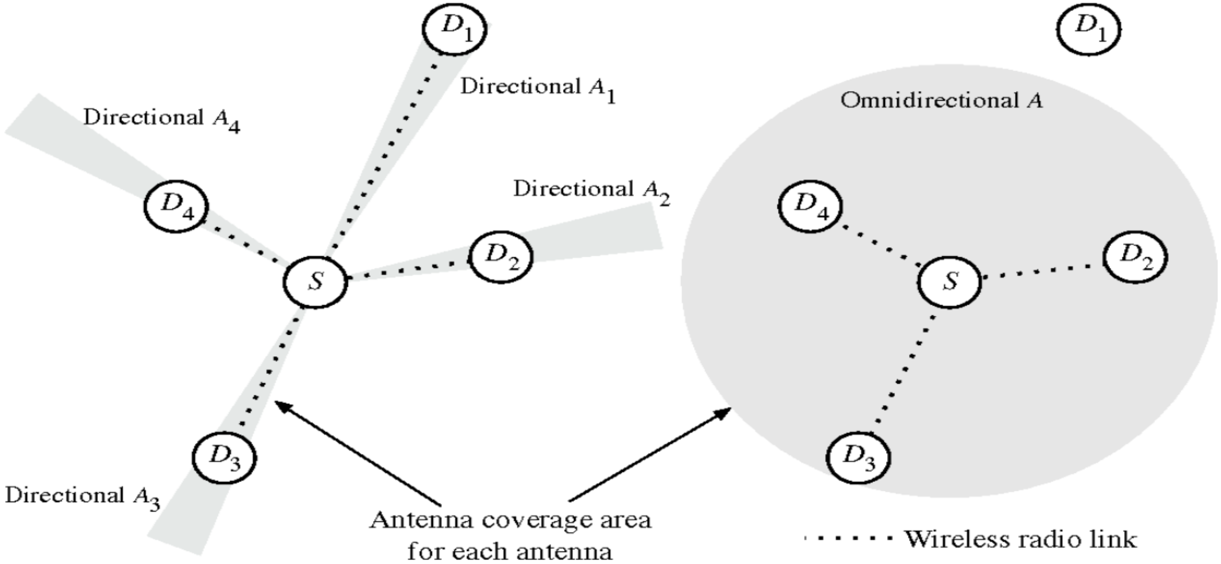
Cross-correlation detection (XCD) overcomes most LPI attempts and acquires the bearing to virtually all transmitting a/c at extreme ranges.

- To overcome the limitations of existing legacy system it is important to
  - Recognizing the vulnerabilities of legacy RF comms in modern scenarios
  - And employ mitigation techniques to enhance the effectiveness of collaborative missions via targeted and robust communication

Why directional communication?

- We must mitigate detection via
  - Narrow Tx beams with adaptive output power
  - Strive hard for narrow-band comms when possible
  - Restrict Tx power and forbid Tx towards known/likely, and possible threats
  - Minimize network & routing housekeeping traffic





- Typically directional networks are:
  - less power hungry, i.e., well suited for airborne platforms with limited power resources
  - narrow Tx beams means individual Tx/Rx lobes do not overlap with regard to angle of arrival, i.e., throughput increases with number of nodes
  - well suited for LPI/LPD constraints given their limited radiation areas

Background

- National Aeronautical Research Program, financied via Vinnova and INNOVAIR
- Collaboration between Saab (Surveillance/Aeronautics) and BTH (Dept. of Computer Science, DIDA)

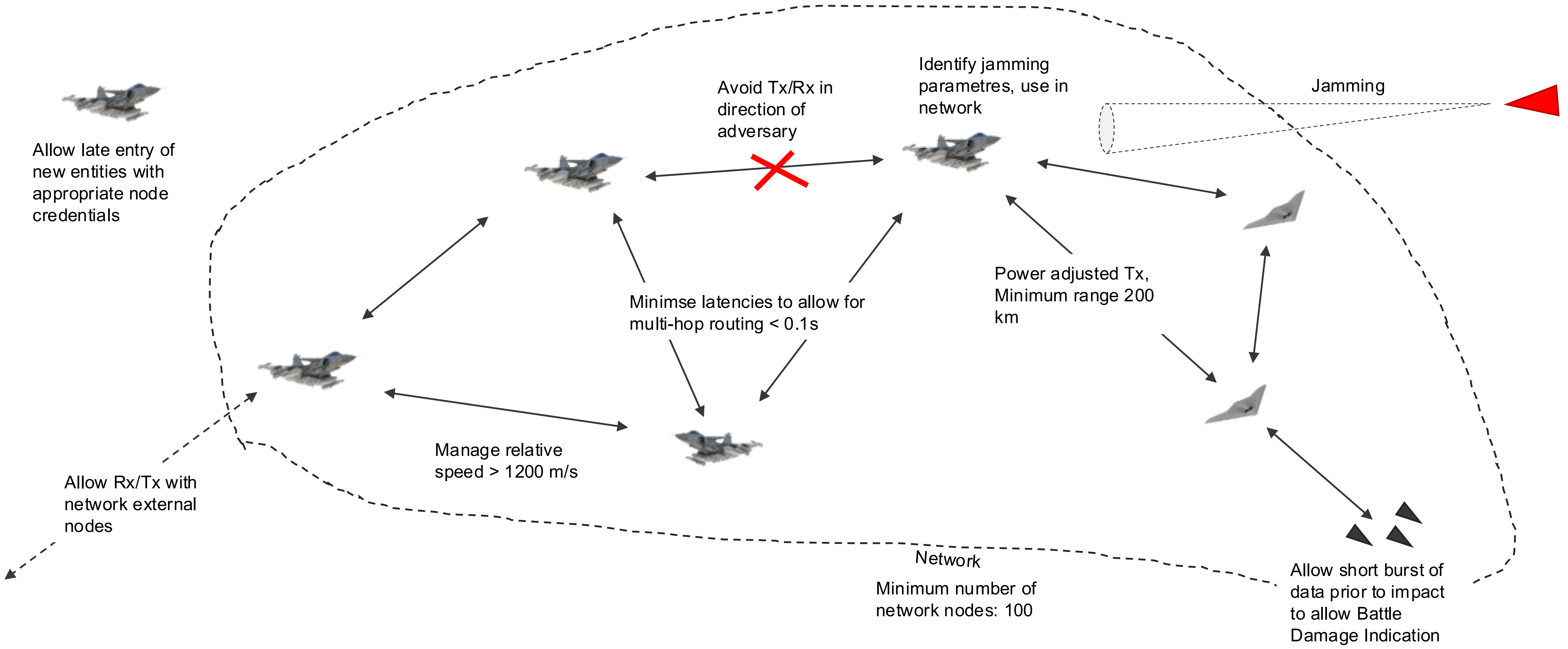
Saab lead:

- Project management, requirements/prerequisites, CONOPS development & evaluation, Summary & Report writing

BTH/DIDA lead:

- Directed network topology control protocol (concept development of a directed MANET suitable for multiplatform air operations)
- Waveform (concept development of a waveform that suits the network protocol, allows high platform speeds)
- Aim of project is fundamental low TRL research

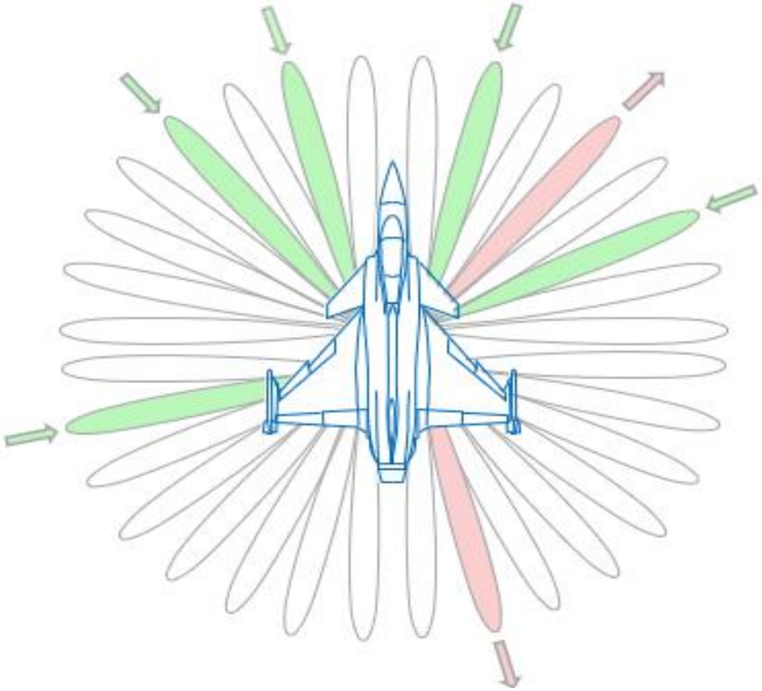
CONOPS – Concept of Operations



Satisfy needs of future collaborative air operation

- Low active signature
- Protocol and waveform transparency
- Stability

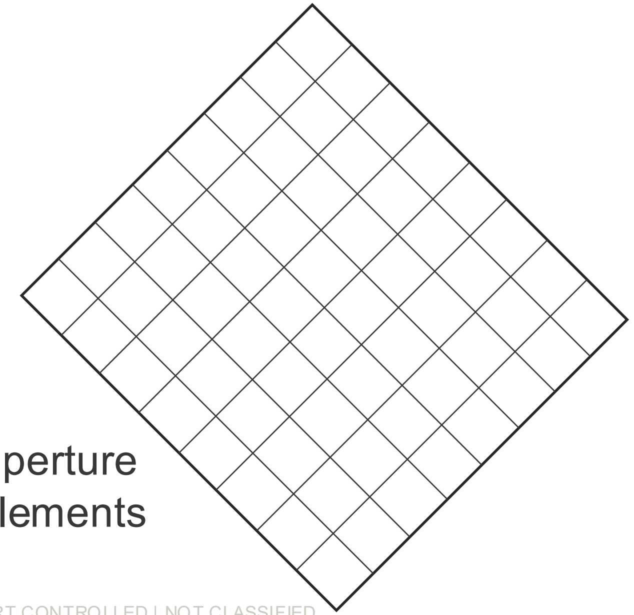
- Adaptivity
- Spectrum awareness
- Jamming resilience



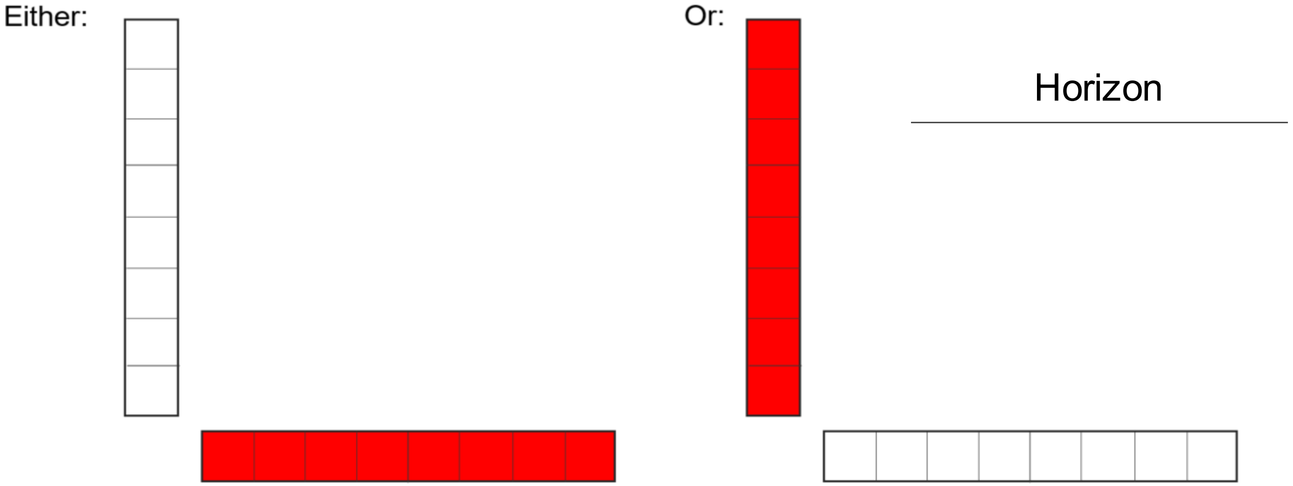
Directional data link antenna

- One ”antenna” consists of one Tx aperture and two Rx apertures
- The Tx aperture has 64 elements, and each Rx aperture has 8 elements

(13 – 18 GHz system = instantaneously available bandwidth)



The Tx aperture
has 64 elements



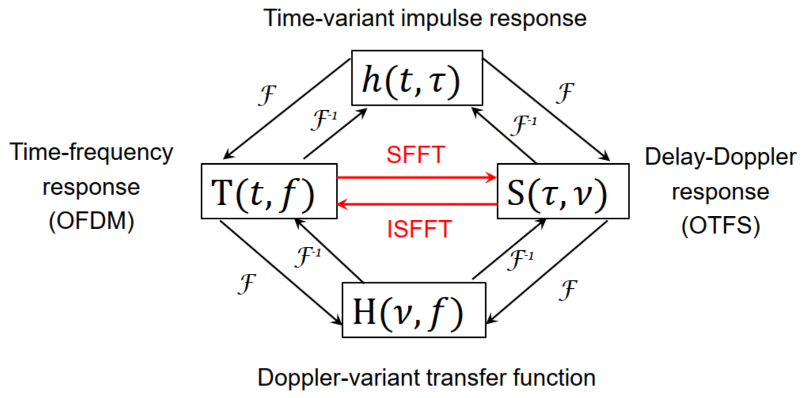
On Rx, either the vertical or the horizontal array is active, *i.e.* connected to the 8 digital receiver chains

Physical Layer Waveform

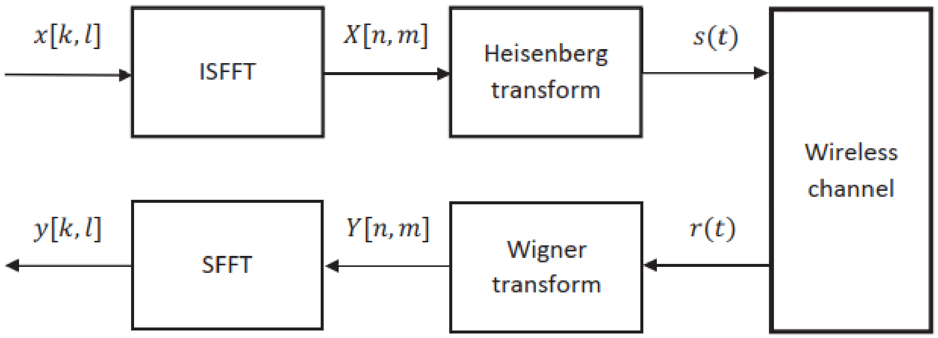
- Suitable propagation environments and Doppler profiles were required for performance simulations

- Where, an orthogonal time frequency space (OTFS) modulation technique was identified since it reaches channel capacity in high Doppler environments

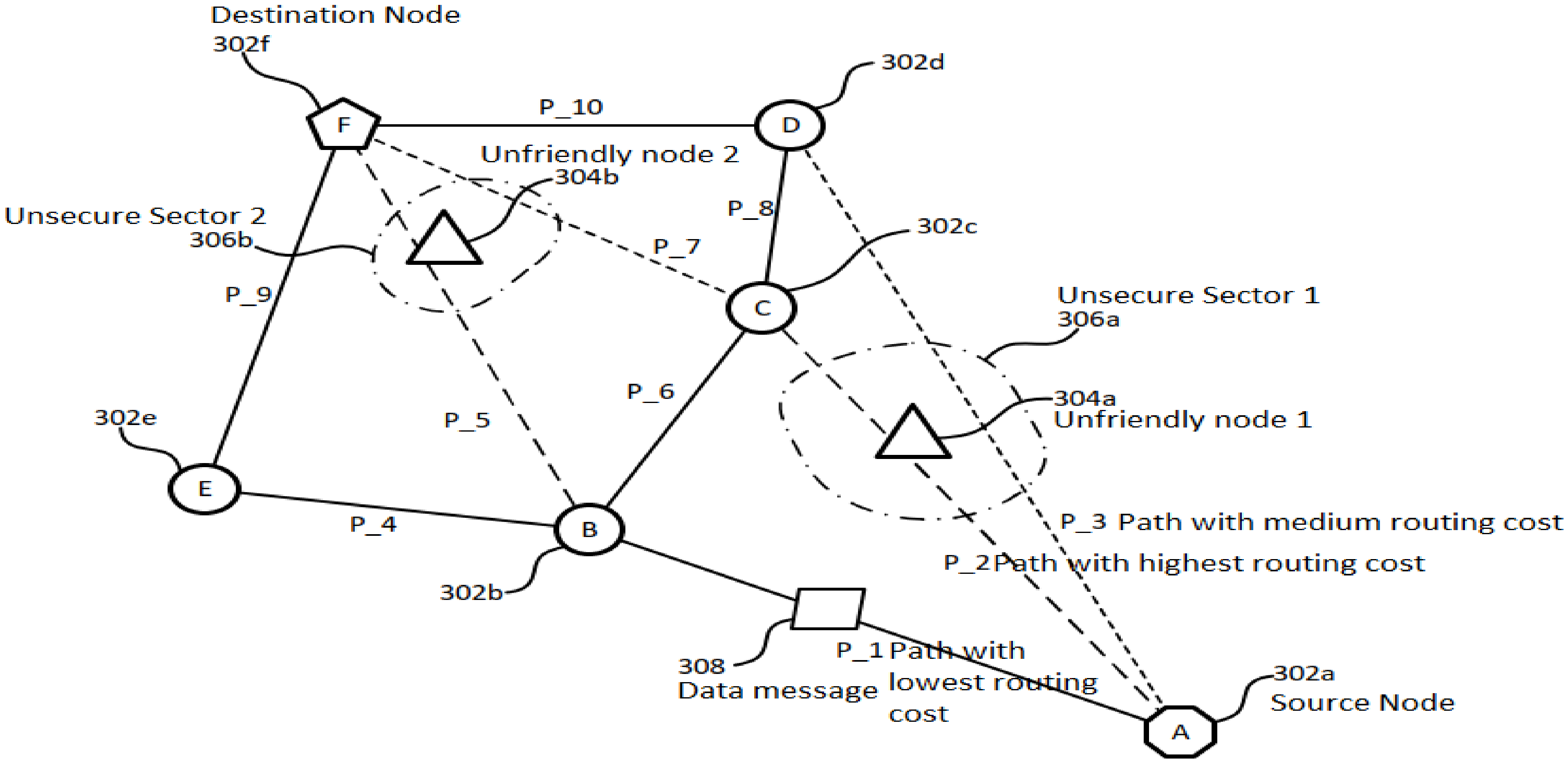
- Enabling simulation campaigns to be conducted in order to assess the performance of such systems with regard to velocity, carrier frequency and multipath propagation



SFFT = Symplectic FFT



Directional networks



Advantages

- Support of stealth operations
- Convergence of RF functions
- Platform RCS design freedom via hull integrated antenna apertures
- On the long term directional COM can resolve the limited radio spectrum resource

Conclusions

- Extended range and availability
- Enhanced security
- Flexibility and interoperability
- Spectrum efficiency

- Ultimately, this work aims to revolutionize airborne communication by providing a robust, secure, and adaptable solution that meets the evolving demands of modern air operations

For further details please see publication list 1/2

1) T. M. C. Chu and H.-J. Zepernick, “Modulation and Detection for High Doppler Channels: An Overview on OTFS Modulation”, Technical Report, Version 1.0, Aug. 2023. https://urn.kb.se/resolve?urn=urn:nbn:se:bth-25285

2) T. M. C. Chu, H.-J. Zepernick, A. Westerhagen, A. Höök, and B. Granbom, “Performance Assessment of OTFS Modulation in High Doppler Airborne Communication Networks,” Mobile Networks and Applications, vol. 27, pp. 1746–1756, Aug. 2022 Springer, https://doi.org/10.1007/s11036-022-01928-4

3) T. M. C. Chu, H.-J. Zepernick, A. Westerhagen, A. Höök, and B. Granbom, “Performance of OTFS Modulation over Rician Channels in Airborne Communication Networks”, in Proc. International Telecommunication Networks and Applications Conference, Wellington, New Zealand, Nov. 2022, pp. 1–6. https://doi.org/10.1109/ITNAC55475.2022.9998395

4) T. M. C. Chu, H.-J. Zepernick, A. Höök, A. Westerhagen, and B. Granbom, “OTFS Modulation for Non-Terrestrial Networks: Concepts, Applications, Benefits, and Challenges”, in Proc. International Conference on Signal Processing and Communication Systems, Bydgoszcz, Poland, Sep. 2023. doi. expected September 2023

5) D. Ilie, H. Grahn, L. Lundberg, “Topology Control for Directed Data Links between Airborne Platforms Creative description”, Technical Report, Version 1.0, Aug. 2023. https://urn.kb.se/resolve?urn=urn:nbn:se:bth-25288

6) D. Ilie, H. Grahn, L. Lundberg, A. Westerhagen, B. Granbom, and A. Höök. 2023. "Avoiding Detection by Hostile Nodes in Airborne Tactical Networks" Future Internet 15, no. 6: 204. https://doi.org/10.3390/fi15060204

7) A. Westerhagen, B. Granbom, D. Ilie, L. Lundberg, and H. Grahn, “A Computer Implemented Method for Secure Transmission of a Data Message from a Source Node to a Target Node,” filed in November 2022 as PRV (Swedish Intellectual Property Office) registration number SE 2200136-6

For further details please see publication list 2/2

8) L. Lundberg, A. Westerhagen, D. Ilie, H. Grahn, B. Granbom, “Dynamic Forward Error Correction Coding to Avoid Detection in Airborn Tactical Networks” in Proc. International Conference on Military Communication and Information Systems (ICMCIS), Koblenz, Germany, April 2024

9) T. M. C. Chu, H.-J. Zepernick, A. Höök, A. Westerhagen, and B. Granbom, “OTFS Modulation for Non-Terrestrial Networks: Concepts, Applications, Benefits, and Challenges”, in Proc. International Conference on Signal Processing and Communication Systems (ICSPCS), Bydgoszcz, Poland, Sep. 2023.10.1109/ICSPCS58109.2023.10261131

10) T.M.C. Chu and H.-J. Zepernick, “Performance Analysis of a Cognitive Radio Assisted Cooperative NOMA UAV System,” in Proc. IEEE International Symposium on a World of Wireless, Mobile and Multimedia Networks (WoWMoM), Perth, Australia, June 2024.

11) Thi My Chinh Chu and Hans-Jürgen Zepernick, “Hybrid Orthogonal-Nonorthogonal Multiple Access for CR-Assisted Cooperative UAV Systems,” IEEE International Conference on Communications and Electronics, Danang, Vietnam, July 2024

12) J. Jahr, J. Nguyen, Forward Error Correction Coding for Airborne Detection Prevention, An evaluation of Forward Error Correction codes. BTH MSc thesis 2024 in Engineering, Supervisor L. Lundberg (BTH), A. Westerhagen (SAAB)

13) T. M. C. Chu, H.-J. Zepernick, A. Westerhagen, On Weighted K-Means User Clustering for Flying Ad Hoc Networks in Disaster Scenarios in proceeding of the ANTEM 2025 conference in Canada.

14) T. M. C. Chu, H.-J. Zepernick, Outage of a NOMA-Based Cooperative UAV Network in Generic Scattering Environments in proceeding of the ANTEM 2025 conference in Canada.

15) L. Lundberg, A. Westerhagen, D. Ilie, H. Grahn, B. Granbom, and A. Svärd Olsson, “Evaluating Short Forward Error Correction Codes for Avoiding Detection in Airborne Networks,” Int. Conf. on Military Commun. and Information Systems, Oeiras, Portugal, May 2025.

Questions?

Thank you!

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