N252-081: Intelligent Radio Access Network for Beyond 5G Resilient Tactical Networks

ADDITIONAL INFORMATION

N/A

TECHNOLOGY AREAS:

None

MODERNIZATION PRIORITIES:

Advanced Computing and Software | FutureG | Integrated Network Systems-of-Systems

KEYWORDS:

Tactical Airborne Networks; Mesh Networks; Directional datalink; Backward Compatibility; Time Division Multiple Access; TDMA; Experimentation

OBJECTIVE:

Research and develop cost-effective communication systems for use in Anti-Access and Area Denial (A2AD) environments via platform-assisted Intelligent Radio Access Network operating as a Beyond 5G (B5G) base station or relay in Resilient Tactical Networks.

DESCRIPTION:

Tactical operations are often set in remote locations where cellular infrastructure such as 5G are absent. Military operations such as intelligence, surveillance, and reconnaissance (ISR) can benefit immensely from high speed, low latency 5G communication links. The high-capacity links can enhance command and control (C2) with the high data rate 5G links enabling situation awareness between deployed troops. Another aspect to consider in practical tactical scenarios is user mobility, i.e., the soldiers/tactical vehicles with handheld 5G radios user equipment (UE) are not stationary. Mobility of users result in varying link conditions causing coverage holes in the network. The aerial 5G base station positioning must consider the dynamic link conditions due to mobility and other propagation effects such as Weather Disruptions, Jamming, and Distance/Fading loss due to signal strength. A traditional lookup table-based approach is not adaptive to learn from the dynamic UE environment.

This SBIR topic seeks the development of an inexpensive platform B5G communication system that can operate in contested/congested environments with challenging and dynamic realistic B5G operating conditions in both stationary and on-the-move (OTM) conditions. The platform 5G base station will extend 5G Radio Access Network (RAN) coverage and enable high data rate beyond Line of Sight (LoS) communication among the UEs. To provide this capability, a new intelligent link adaptation subsystem to the B5G RAN architecture is required to improve link resiliency by choosing the appropriate Modulation and Coding Scheme (MCS) scheme for the UE-to-base station link. Thus, the dynamic platform 5G-base station enables large-scale network coverage, UE mobility support, enabling networking to on-the-move for highly dynamic tactical mission consequently providing next generation of assured robust connectivity. The intelligent link adaptation module in conjunction with the platform 5G base station for multi-cell connectivity is envisioned to provide a significant performance leap in terms of UE mobility management, Quality of Service (QoS) specific high data rate guarantee, and sustain reliable connectivity in support of dynamic, remote tactical missions. The proposed scheme must be scalable and can easily accommodate multiple platform 5G-base stations and platform 5G relayers for very large network scenarios. The proposed approach must be able to perform multi-cell connectivity via multiple Unmanned Air Vehicles (UAV) equipped with 5G base stations and UAV 5G relayers and includes the following capabilities:

- High-Level Decision Maker—adaptive 5G UE support for efficient network routing strategy that minimizes 5G network control overhead (“Network control overhead” refers to the amount of additional 5G information required to maintain network services)
- Director—multifunction optimization and conflict resolution to accommodate 5G UE communication tasks,
- 5G Mesh Network Optimization and Learning Engine—dynamic, context-based learning recognizing a 5G disruption event, classifies the 5G disruption event then based on the type of 5G disruption, suggests a mitigation strategy for strengthening the 5G network topology and improving 5G network performance
- Weight Adjuster—discerning critical factors contributing to an effective 5G UE mesh network solution
- Compliant interfaces—seamless 5G UE connection to internal platform communication subsystems and external 5G systems

- Multi-objective reasoning in dynamically changing A2AD environments to enable transfer large data sets in minimal time in synchronous and asynchronous modes among UEs, using either or all the following: data throttling, data compression, Data Error Detection & Correction
- Context-based access management to minimize 5G UEs communication detection, intercept and targeting
- Efficient 5G system switching and mesh capability resource allocations in an A2AD environment
- Reinforcement learning framework that overcomes uncertainty and avoids reliance on static 5G MATLAB data flow model,
- Scalable across multiple different 5G transceivers to operate in A2AD dynamic contested environments
- Robust to different cyber environments through context-based authentication
- Software to sustain 5G link connectivity and if lost reacquisition of connections in A2AD environments
- Vendor-agnostic 5G equipment integration with UAVs and their respective systems and subsystems
- Hybrid decentralized approach for local decisions to support multiplatform 5G UEs collaboration in A2AD environments
- Near real-time mission feedback with reduced 5G system processing times
- Lightweight 5G signaling in a hierarchical command and control (C2) structure supporting battlefield applications with multiple 5G UE distributed platforms
- Negating radio frequency (RF), cyber takeover of unmanned and manned air vehicles
- Compliance with IEEE 802.15.3-2023: Standard for Wireless Multimedia Networks (Threshold (T))
- Compliance with IEEE 802.11ac: Wi-Fi 5 Standard (T)
- Compliance with IEEE 802.11ad: Multiple Gigabit Wireless System (MGWS) (Objective (O))
- Compliance with IEEE 802.11ax: Wi-Fi 6 Standard (O)
- Compliance with FCC CFR 47 Part 15 and Annex K regulations (T)

Proposers may use the multi-path transmission control protocol (MPTCP) published by the Internet Engineering Task Force (IETF). The MPTCP is implemented in layer 4 (transport).

Proposers may use vehicle-to-vehicle (V2V) or vehicle-to-everything (V2X) communication protocols specified by the 3GPP standards for 5G cellular networks.

While 5G networks provide significant benefits and opportunities in terms of high bandwidth and connectivity, traditional security models have major weaknesses in protecting the 5G network infrastructure. The unique characteristics of 5G networks include: (a) seamless connectivity of heterogeneous devices, (b) high network mobility, and (c) distributed network assets enabling access to cost-effective resources for all devices. While 5G networks enable new applications, the use of untrusted network elements arises major security concerns for DoD operations. Traditional network security models assume a known network perimeter as the critical resources to be protected against unauthorized access. The distributed resources and assets of 5G networks make the identification of network perimeter challenging – even impractical. Further, the high mobility of 5G networks requires a dynamic security and risk assessment. To address this issue, zero trust (ZT) principles must be part of the proposed B5G communication system. ZT principles include the trust of a subject requesting access to critical resources continually and dynamically assessed during the entire period of the access. In a 5G network specifically, the mobility of heterogenous devices in a varying environment calls for a dynamic model of the network state that provides information about the risks of accessing a particular resource by a given subject from a particular location.

PHASE I:

Perform a trade study between system size, architecture, operating frequency, operating bandwidth, efficiency enhancement schemes, modulation format, data rate, power consumption, anti-jamming capabilities, Low Probability of Intercept (LPI), and Low Probability of Detection (LPD), and zero trust (ZT). Develop a system level model of a Unmanned Aerial Vehicle (UAV) 5G base station transmitter/receiver based on optimized parameters selected from the trade study. Develop a small set of 6–8 independent intelligent yet cooperating UAV 5G systems, which will coordinate their activities to perform some limited-scope 5G communication scenarios and missions. Validate a system level model of a 6–8 UAV 5G base station transmitter/receiver based on optimized parameters in an Extendable Mobile Ad-hoc Network Emulator (EMANE). Required Phase I deliverables, in addition to the standard Contract Deliverables described in the BAA instruction, will include a report with a demonstration plan, UAV 5G system hardware and software designs, and performance goals. The Phase I effort will include prototype plans to be developed under Phase II.

PHASE II:

Fabricate and demonstrate 6–8 5G prototype hardware and associated software kits to be integrated and operated on 6–8 UAVs as prototype systems. Make available these UAV 5G prototype systems for evaluation to determine their capability in meeting the performance goals defined in the Phase I report and to perform to the Government's criteria for holding operational evaluation and capability demonstrations. Construct and demonstrate the operation of a TRL 6/7 5G UAV 5G prototype system-assisted Intelligent Radio Access Network operating as a B5G base station or relay in a Resilient Tactical Networks operating in a relevant over-the-air outdoor maritime environment. Incorporate the ZT principles and techniques developed in Phase I into the UAV 5G prototype systems. Deliver these UAV 5G prototype systems to the Government with an associated user manual, interconnect diagram, and a report documenting the results of the Phase II effort. Provide any virtual and/or on-site support requested by the Government during 5G prototype UAV systems' operational evaluation and capability demonstrations.

PHASE III DUAL USE APPLICATIONS:

Finalize software development of the manned-unmanned directional mesh networking system with compatibility to open architectures and address any unique requirements for Manned-Unmanned interoperability with a particular data link(s), perform a more formal systems integration task to provide effective software interfaces to particular naval assets, perform operational testing, and participate in integrated demonstrations of Manned-Unmanned networking systems operations.

Demonstrate a field-ready software system with mature implementation in an open relevant operational environment. Perform technology insertion and program integration using engineering model of proposed product/platform or software. Develop and provide a full report of development, capabilities and measurements (showing specific improvement metrics). Provide a user's guide and other documents as necessary for Navy to recreate and use the demonstration capability or software/hardware component(s). Identify and summarize opportunities and plans for potential commercialization.

Military Application: Increase the number and types of platforms able to connect into the UAV network. Improve the throughput, latency, and reliability of existing airborne networking technologies. 5G transceivers provide high data throughput, frequency agility, and covert operation in A2AD environments and will support a variety of military applications, including wireless networks of multiple manned or unmanned ground vehicles supporting ground V2V, vehicle-to-infrastructure, UAS-to-UAS, and UAS-to-ground vehicle/infrastructure communication links.

Commercial Application: Results from this work have applicability to cellular telephone and data networks, to vehicular networks, and to WiFi networking technologies. Civilian applications of 5G technology includes mmWave long-range links such as last mile, small cell networks, mobile backhaul, Internet of Things (IoT) wireless networks, and 5G networks that can benefit from the reduced interference and improved reliability for high-speed datalinks. In addition to commercial Unmanned Aircraft Systems (UASs) and ground vehicles mirroring the military applications, an emerging Vehicle-to-everything (V2X) market will benefit from the proposed transceiver capabilities, especially with the wide adoption of autonomous vehicles.

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