**VLSI-Infused Encryption in Master-Slave Drone Control**

**Abstract:**

The proposed integrated system and host-side communication framework collectively present a comprehensive architecture for secure and efficient communication in Unmanned Aerial Vehicles (UAVs). Incorporating fundamental components such as UART, Command Encoder/Decoder, Encryption/Decryption, and Bluetooth Command Encoder/Decoder, these designs synergistically establish a robust foundation for internal and wireless communication. With an emphasis on optimizing data transfer efficiency, ensuring UAV control precision, and fortifying security measures through encryption, the integrated system and host-side framework together provide a holistic solution for UAV communication, enabling seamless and protected interactions between the host system and UAVs in various operational scenarios.

**Introduction:**

In the evolving landscape of aerial technology, Unmanned Aerial Vehicles (UAVs) are anticipated to emerge as pivotal assets, as asserted by experts foreseeing their substantial role in future applications. This paper delves into the intricate design of a secure and efficient communication framework for UAVs, acknowledging their expanding significance beyond traditional military applications. As UAVs stand poised to provide vital support across diverse services for the population, this research aims to contribute to the ever-growing field by addressing the fundamental aspects of communication architecture, ensuring the seamless integration of UAVs into a myriad of scientific, applied, and civilian contexts.

The "master-slave" paradigm in Unmanned Aerial Vehicles (UAVs) presents a transformative approach that not only enhances operational efficiency but also unlocks new opportunities across various domains. By employing a "master-slave" model, UAVs can capitalize on coordinated teamwork, enabling a myriad of applications beyond their traditional military roles. In group formations, where one UAV assumes the role of the "master" guiding the actions of the "slave" UAVs, this hierarchical structure allows for precise and synchronized maneuvers, paving the way for innovative solutions.

This model opens avenues for increased area coverage, collaborative data gathering, and improved surveillance capabilities. In fields such as agriculture, environmental monitoring, and disaster response, the "master-slave" configuration allows UAVs to work collectively, providing comprehensive data that can inform decision-making processes. Additionally, the adaptability of the "master-slave" model offers opportunities for novel applications in entertainment, training, and research, showcasing the versatility of UAVs in diverse contexts.

Furthermore, the ability to simulate and fine-tune the "master-slave" model before deploying it in real-world scenarios brings a novel dimension to UAV operations. This pre-flight experimentation not only enhances safety but also opens avenues for innovation, allowing operators to explore and optimize the full potential of UAV capabilities.

In essence, the "master-slave" model in UAVs serves as a catalyst for unlocking new opportunities by fostering collaborative and coordinated behaviors. This paradigm shift expands the scope of UAV applications, making them integral not only in defense but also in civilian and commercial domains, thereby contributing to the realization of a future where UAVs are indispensable across a broad spectrum of services and industries.

**Related work:**

"Several advanced capabilities have been implemented with multiple networked UAVs, including military applications such as communications networking, reconnaissance, threat engagement, surveillance, and electronic attack." [1]

"One of the most widespread approaches to formation control is the 'master – slave' approach, where 'slave' UAVs build their relative positions only according to the 'master'." [1]

"A simulation model was developed using CoppeliaSimEDU to coordinate the swarm based on the parameters of the leader and follower controllers, while maintaining the distance between UAVs."[1]

Simulation and Visualization:

"CoppeliaSimEDU is a 3D robot simulation software used for modeling, editing, programming, and simulating robotic systems. The simulation model includes a 'master – slave' control method."[1]

"The developed program allows visualization of UAV flight according to the 'master – slave' model, enabling the adjustment of group work parameters before flying on real equipment."[1]

Conclusion and Scientific Novelty:

"The present work demonstrates the use of the 'master - slave' model for generating leader-follower behavior in a robot swarm, with results including a schema of interaction and a developed software product for visualization."[1]

"A swarm is generally defined as a group of behaving entities that together coordinate to produce a significant or desired result or behavior." [2]

"Advantages to swarm include time-savings, reduction in man-hours, reduction in labor, and a reduction in other costs." [2]

"The proposed cellular network UAV swarm architecture leverages strengths of both architectures while mitigating some weaknesses." [2]

**Block level design:**

A diagram of a computer

Description automatically generated

**Host:**

**Overview:**

The Host-Side Secure Communication Framework for Unmanned Aerial Vehicles (UAVs) is meticulously designed to fortify communication, control, and data exchange from the host system. Anchored by critical components like UART, Command Encoder/Decoder, Encryption/Decryption, and Bluetooth Command Encoder/Decoder, this framework prioritizes not only streamlined communication but also bolsters defenses against unauthorized access and data manipulation.

**Block Descriptions:**

**UART (Universal Asynchronous Receiver-Transmitter):**

Functionality: At the core of host-side communication, UART ensures reliable and bidirectional data transfer within the UAV system.

Role: Establishes a foundational communication layer, facilitating seamless data exchange between the host system and the UAV.

**Command Encoder/Decoder:**

Functionality: This module excels in encoding outbound commands for transmission and decoding incoming commands for further processing.

Role: Optimizes data transfer efficiency by translating high-level commands into a format comprehensible to the UAV system, ensuring seamless control from the host.

**Encryption/Decryption :**

Functionality: Implementing cutting-edge encryption algorithms, this module safeguards the communication channel against unauthorized access and secures data integrity.

Role: Bolsters the security of transmitted information, particularly crucial when operating in environments susceptible to potential cyber threats.

**Bluetooth Command Encoder/Decoder:**

Functionality: Specifically tailored for wireless communication, this module manages the encoding and decoding of commands over Bluetooth.

Role: Empowers the host system with a secure and user-friendly interface for wireless UAV control, seamlessly integrating with the overall communication architecture.

**Integration:**

UART Integration: The UART module forms the backbone of host-side communication, establishing a robust link between the host system and the UAV.

Command Encoder/Decoder Integration: Seamlessly integrated with UART, this module ensures the efficient translation of commands, enabling precise control from the host.

Encryption/Decryption Integration: Interwoven into the communication flow, this module enhances security by safeguarding data against potential breaches, crucial for maintaining the integrity of host-side commands.

Bluetooth Integration: The Bluetooth Command Encoder/Decoder complements the Command Encoder/Decoder and Encryption/Decryption modules, offering a secure and wireless communication channel for UAV control from the host side.

This Host-Side Secure Communication Framework establishes a fortified foundation, empowering the host system to communicate securely with UAVs, ensuring reliable and protected interactions in diverse operational environments.

**Slave:**

**Overview:**

The proposed integrated system aims to create a robust and secure control mechanism for Unmanned Aerial Vehicles (UAVs). The system leverages key blocks such as UART, Bluetooth Command Encoder/Decoder, Encryption/Decryption, IMU Command Encoder/Decoder, IMU (SPI) Interface, and IMU breakout. Each block plays a critical role in ensuring the functionality, security, and efficient communication of the UAV control system.

**Block Descriptions:**

**UART (Universal Asynchronous Receiver-Transmitter):**

Functionality: Serves as the primary communication interface for data exchange between various components of the system.

Role: Facilitates seamless communication and coordination among different modules within the UAV control system.

**Bluetooth Command Encoder/Decoder:**

Functionality: Manages the encoding and decoding of commands exchanged wirelessly via Bluetooth, ensuring a reliable communication link.

Role: Enables wireless control of the UAV and provides a user-friendly interface for command transmission.

**Encryption/Decryption:**

Functionality: Implements robust encryption algorithms to secure the communication channel, preventing unauthorized access and data tampering.

Role: Safeguards sensitive information and ensures the integrity and confidentiality of the transmitted commands.

**IMU Command Encoder/Decoder:**

Functionality: Handles the encoding and decoding of commands for UAV control, optimizing data transfer efficiency.

Role: Translates high-level commands into a format understandable by the UAV system and decodes feedback for monitoring and analysis.

**IMU (SPI) Interface:**

Functionality: Establishes a communication link with the Inertial Measurement Unit (IMU) using the Serial Peripheral Interface (SPI) protocol.

Role: Collects real-time data on the UAV's orientation, acceleration, and angular velocity, providing essential information for precise control and navigation.

**IMU Breakout:**

Functionality: Interfaces with the IMU, extracting raw sensor data for further processing.

Role: Acts as a bridge between the UAV control system and the IMU, allowing efficient utilization of IMU data for control algorithms.

**Integration:**

The UART facilitates internal communication among the various modules, ensuring seamless data flow.

The Bluetooth Command Encoder/Decoder enables wireless communication for remote control and monitoring.

Encryption/Decryption ensures the security of transmitted commands, safeguarding against potential cyber threats.

Command Encoder/Decoder optimizes command processing for efficient UAV control.

The IMU (SPI) Interface and IMU Breakout together form a robust sensor interface, providing real-time data for accurate control and navigation.

This integrated system design ensures a comprehensive and secure approach to UAV control, leveraging VLSI design principles for efficiency and reliability.

**Results:**

Include a die photo,

give the chip size and technology used

Include measurements of the fabricated chip

I-V curves

Power

Be precise and quantitative.

Compare measured results against stated requirements, and to prior art.

Include a summary table of the design that highlights the specification and performance metrics.

Simulated results of your design project, including area, performance and power of the design.

[1] Pyvovar, Mariia & Pohudina, Olha & Pohudin, Andrii & Kritskaya, Olha. (2022). Simulation of Flight Control of Two UAVs Based on the “Master-Slave” Model. 10.1007/978-3-030-94259-5\_70.

<https://www.researchgate.net/publication/358748169_Simulation_of_Flight_Control_of_Two_UAVs_Based_on_the_Master-Slave_Model>

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[2] Campion, Mitch, Prakash Ranganathan, and Saleh Faruque. "A review and future directions of UAV swarm communication architectures." In *2018 IEEE international conference on electro/information technology (EIT)*, pp. 0903-0908. IEEE, 2018.

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