Nano Drones: An OpenTitan-based SoC Design for Autonomous Flight and Cyber Security Supporting Visual Communication

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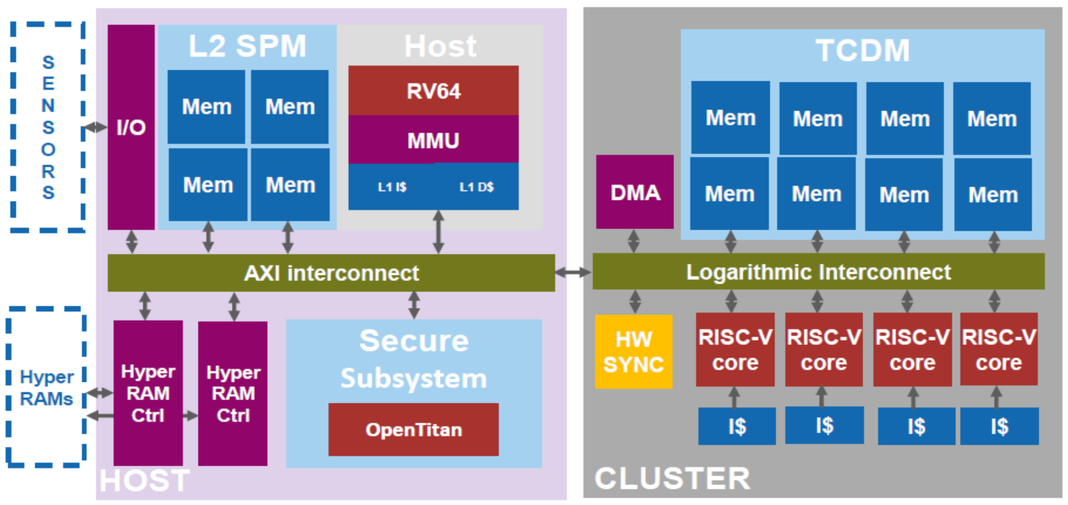
- **Versatility:** nano drones are small and agile, making them ideal for accessing hard-to-reach areas or tight spaces and performing inspection & maintenance.
- **Safety:** nano drones can be used to inspect hazardous environments
- **Cost-effectiveness:** nano drones are relatively inexpensive to produce and operate.

- **Security:** their vulnerability to cyber attacks or other forms of interference is a major concern. There is a need to develop stronger security protocols to protect these devices from hacking or tampering.
- **Energy Efficiency: t**heir battery life is limited. Developing more efficient power sources or improving energy management systems can help increase the operational lifespan of these devices.

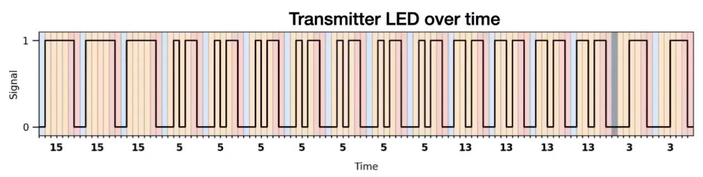
The proposed SoC design addresses the limitations of nano drones, ensuring ***Performance*** while maintaining ***Energy Efficiency*** and providing ***Cyber Security***. The design incorporates a Programmable Multi-Core Accelerator for neural network inference and a Secure Subsystem based on ***OpenTitan*** IPs to provide Cyber Security. The SoC supports ***Unconventional Visual Communication*.**

CONTRIBUTIONS



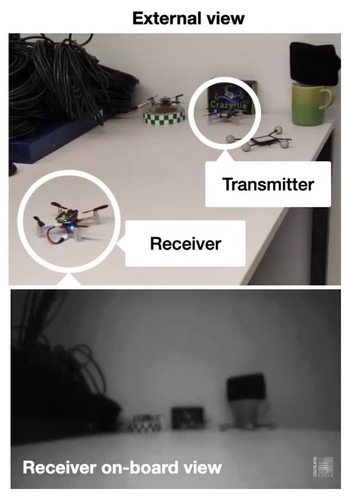
Transmitter console

```
payloadInteger    uint8_t    RW    3
```



Receiver console

```
[DECODER] New message received: 1111 --> 15
[DECODER] New message received: 1111 --> 15
[DECODER] New message received: 1111 --> 15
[DECODER] New message received: 0101 --> 5
[DECODER] New message received: 0101 --> 5
[DECODER] New message received: 0101 --> 5
[DECODER] New message received: 0101 --> 5
[DECODER] New message received: 0101 --> 5
[DECODER] New message received: 0101 --> 5
[DECODER] New message received: 1101 --> 13
[DECODER] New message received: 1101 --> 13
```



Scan for DEMO

Flight Controller SoC Design:

- CVA6-based Linux-Capable Host Domain.
- Programmable Multi-Core Accelerator for NN inference.
- Secure Subsystem based on OpenTitan Ips.

Security Features:

- Secure boot.
- Cryptographic HW accelerators.
- eFuse memory.
- ECC & address/data scrambling.
- Breach detection.

Unconventional Visual Communicaton Use Case:

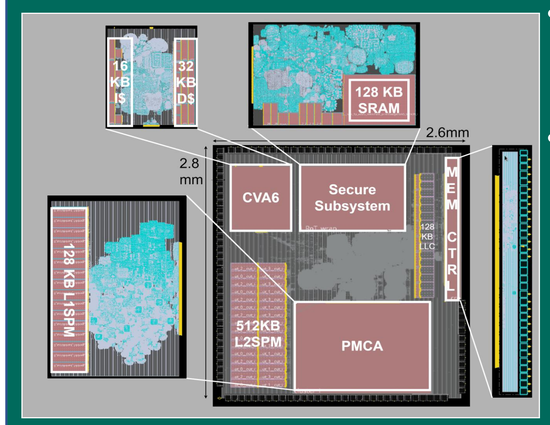
- The Secure Subsystem detects a breach, causing the Host Radio channel to become non-trustworthy.
- An SOS message is encoded as a blinking LED using OpenTitan Secure GPIOs: unconventional visual communication.
- Another drone in the swarm can use the Programmable Multi-Core Accelerator to run a neural network inference.
- The neural network can decode the SOS message and reports to the Swarm the corrupted drone.

RESULTS

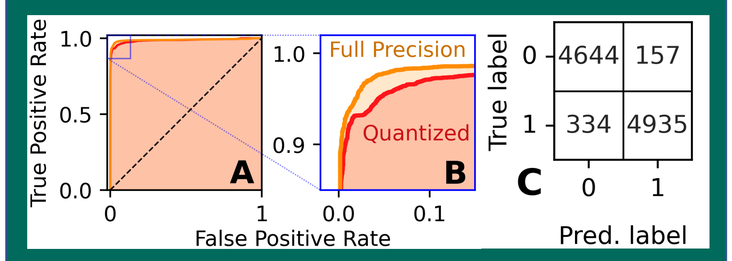
Hardware

	Area (mm^2)	Leakage (mW)	Dynamic ($\frac{uW}{MHz}$)	Max Freq (MHz)	Max Power (mW)
Top	7.28	4.23	214.7	450	100.53
CVA6	0.49	4.79	47.5	900	47.54
PMCA	1.56	5.78	206	400	88.18
Mem Ctrl.	0.27	0.14	2.3	450	1.16
Opentitan	0.86	4.53	16	350	10.13
Total	7.28	19.47	486.5	-	247.54

- **Synthesis in GF FDX 22nm tech with Synopsys DC**
- **Place & Route with Cadence Innovus**
- **Signoff with Synopsys PrimeTime**

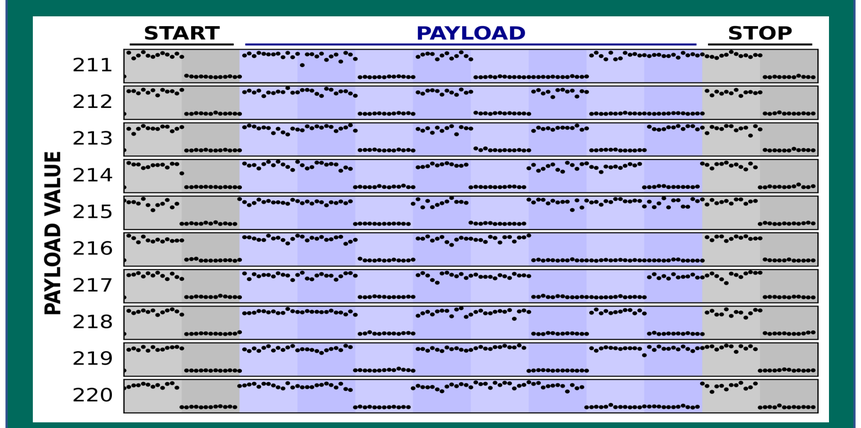


CNN



- **A. ROC curve for full/quantized precision**
- **B. Zoom on A**
- **C. Confusion Matrix**

Unconventional Visual Communication



- **Each dot denotes CNN predictions (12 predictions per bit)**
- **2 start & 2 end bits**
- **8 payload bits**

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