PRIN COMMON-WEARS

Ongoing research (@UNITO)

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People @ UNITO & C

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- **Giorgio Audrito** (RTD B)
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- **Gianluca Torta** (RU)
- **Daniele Bortoluzzi** (Neolaureato, supervisionato da Gianluca Torta e Andrea Basso, vincitore Assegno di Ricerca, 2 anni a partire da marzo 2023), developer
- Lorenzo Testa (Dottorando, ciclo 36, Alto Apprendistato in Concept Reply)
- Marco Ottina (Dottorando, ciclo 37, Dottorato nazionale in AI - Industry 4.0)
- Yasir Shabir (Dottorando, ciclo 37, PON Green - con Synesthesia)

@Syneshesia (https://synesthesia.it/)

- **Andrea Basso** (https://www.linkedin.com/in/abasso1/): IoT/Edge AI, IoT security, Standardization,...

Aggregate Programming (AP)

Formal Methods and **Rigorous Software Engineering** perspective (when feasible)

ONGOING

1. FCPP Extensions [presented by Giorgio Audrito]
2. Secure FCPP [presented by Gianluca Torta]
3. AP for Cooperative ML Inference [presented by Gianluca Torta]

PLANNED

4. Testing for AP
5. Variability modeling for AP

Language Design, Algorithms and Properties of AP

Ongoing work:

- Dynamics and applications of aggregate processes
- Adding predictive capabilities to runtime verification

Planned work:

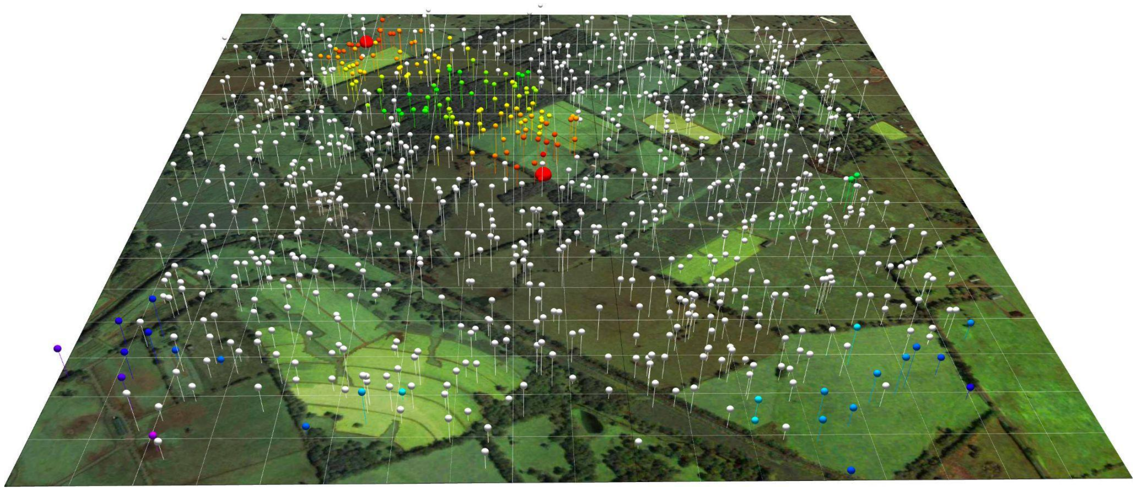
- Real-time guarantees for state-of-the-art resilient algorithms

FCPP Extension

FCPP tool chain [presented by Giorgio Audrito]

https://fcpp.github.io/

- efficient, portable, small footprint
- integrated graphical simulator for development and debugging
- **designed for execution on multiple platforms**



FCPP platform support

Some initial support:

- WandStem microcontrollers running MIOSIX (with PoliMI)
- Smartphones running Android (with HVL)
- HPC architectures for hybrid cloud-edge systems

Planned work:

- Linux companion computers in embedded systems
  - …also for **drones**

Industrial application scenario (with Synesthesia): swarms of drones and rovers

In the context of the CN AGRITECH we are buying

- a fleet of UAVs, two kinds
    - Crazyflie 2.1(https://www.bitcraze.io/products/crazyflie-2-1/), weight: 27g
    - **DJI Matrice M300 RTK**, weight: ~6.3Kg, payload: 2.7Kg
- budget: 50K Euro

In the context of the PNRR NODES Spoke1 (Mobility) we are:

- buying fleet of small rovers
- integrating with fleet of Crazyflies
- developing a demo based on logistics

Engineering Tools

There isn’t much existing literature on methods addressing engineering tasks such as analysis, design, development, deployment and testing on AP systems.

- An initial study of the possible directions to explore can be found in:
  Casadei R, Pianini D, Aguzzi G, Audrito G, Torta G, Ottina M, Damiani F, Viroli M. *Towards Automated Engineering for Collective Adaptive Systems: Vision and Research Directions.* Proc. 1st International Workshop on COMMunity-OrieNted WEARrable Computing Systems, IEEE 2022

- Planned work on automated testing of aggregate programs in FCPP:
  genetic algorithms for generating critical simulations giving rise to errors

IoT Security and FCPP

Security on Embedded Systems

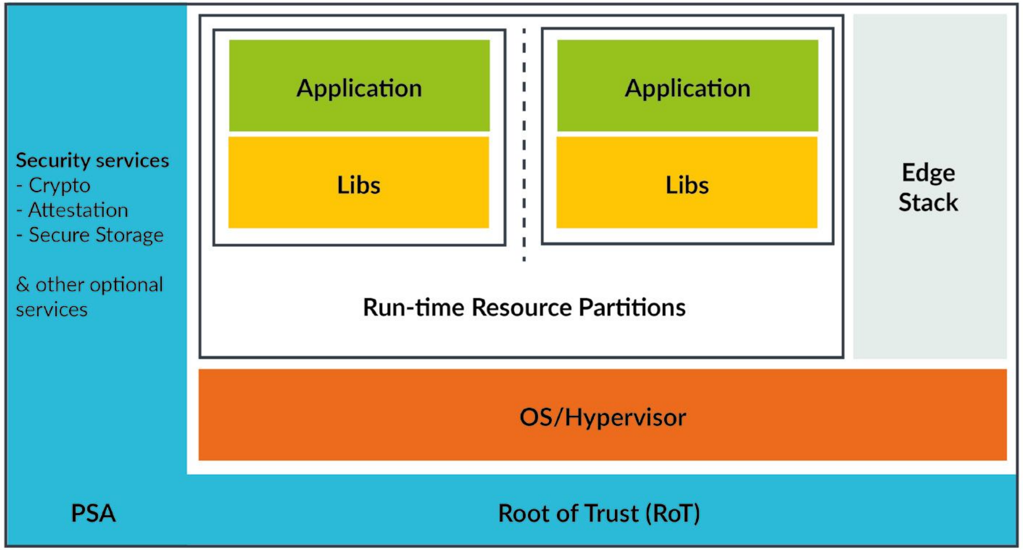
- several factors currently making the **cost of security** a concern for the **silicon vendors**, **software providers** and **device manufacturers** vital to IoT success [1]
- as IoT adoption grows, so does the **cyber risk** from bad actors wanting to exploit it
  - it's estimated that by 2025 cybercrime damages will total over $10 trillions
- PSA (Platform Security Architecture) [2]
  - security framework that allows security to be consistently designed in, at both a **hardware** and **firmware** level
  - fourth and final stage is **PSA Certified**, which currently offers certification for constrained IoT devices via an independent body

[1] PSA Certified. The IoT Industry Action Plan to Reduce the Cost of Security. White Paper (2022)

[2] ARM. The Importance of Security for the Infrastructure Edge. White Paper (2019)

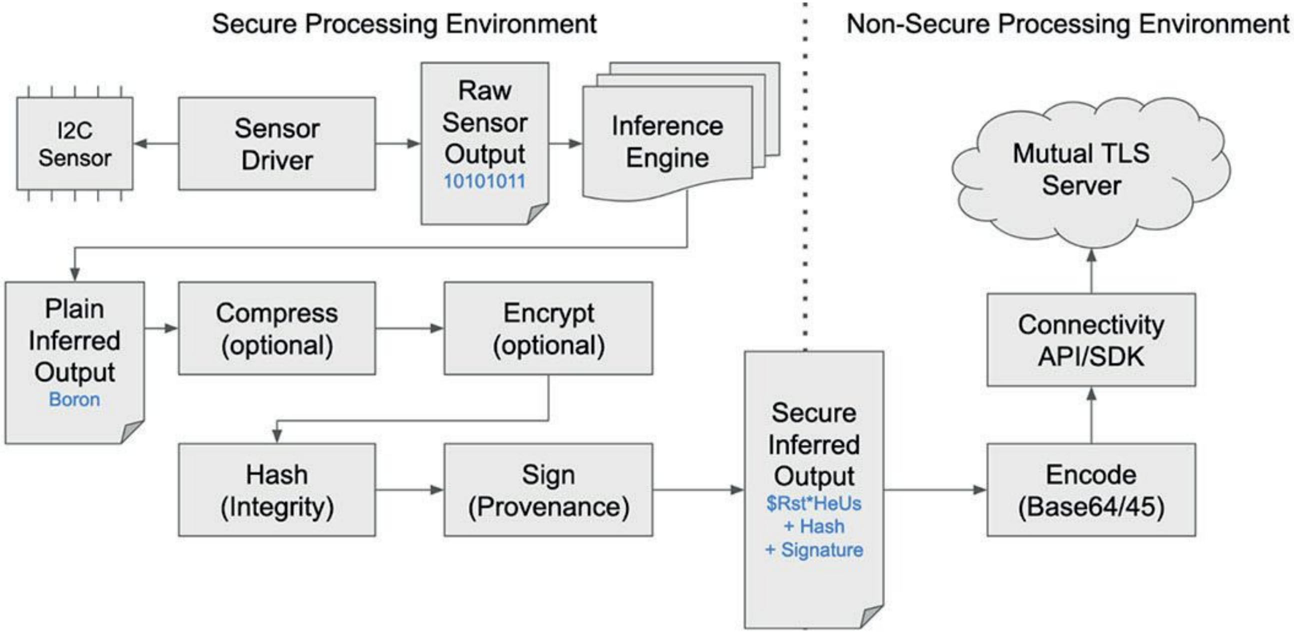
Secure HW and Firmware

- separate the world into “secure” (S) and “non-secure” (NS) at HW level (**ARM TrustZone**)
- security services in S partition (**Trusted Firmware M**)
    - crypto, attestation, secure storage
- further isolate (if needed) applications from each other



Secure ML

- Linaro is defining a framework for secure ML on MCUs (Confidential AI [1])



[1] B. Fletcher (Linaro). Confidential AI for MCUs. White Paper (2021)

Secure FCPP

- port FCPP to **STM32U585AI** MCU → Arm Cortex-M33 core with **TrustZone** and Armv8-M security extension
- ZephyrOS
  - fully supports **TF-M integration**
  - supports **more than 400 boards**
- TF-M security services
  - proximity-based **communication** → encryption/decryption, authentication, …
  - isolate AP **applications** running on top FCPP
- analogies with V2V communication
  - VPKI (public key infrastructure)
  - problem of scale [1]

[1] M. A.Simplicio , E. L. Cominetti , H. K. Patil, J. E. Ricardini and M. V. M. Silva, "The Unified Butterfly Effect: Efficient Security Credential Management System for Vehicular Communications," 2018 IEEE Vehicular Networking Conference (VNC) VNC), 2018

AP for Cooperative ML Inference

ML Inference at the (Far) Edge

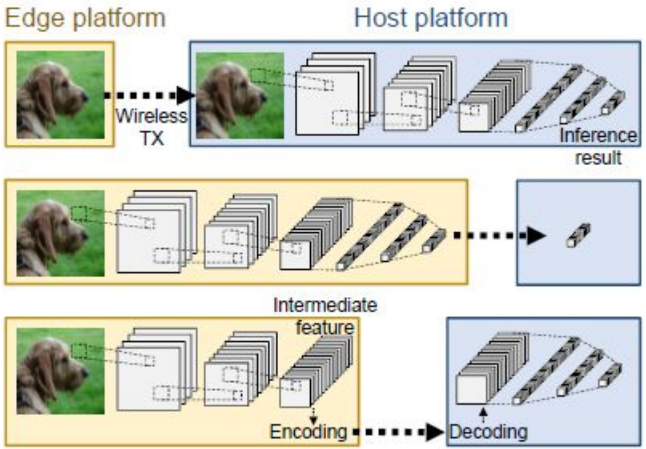
- performing (part of) **DNN inference on small constrained devices** at the far-edge is increasingly important [1,2]
  - privacy
  - latency
  - communication/energy costs
- **quantization** and **pruning** are well known techniques
- when devices are very low-end (TinyML) also **Neural Network partitioning** and **cooperative inference**

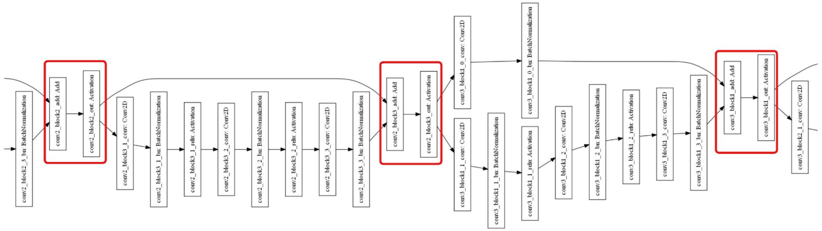
[1] Martins Campos de Oliveira F, Borin E. Partitioning convolutional neural networks to maximize the inference rate on constrained IoT devices. Future Internet. 2019 Sep 29;11(10):209

[2] Ko JH, Na T, Amir MF, Mukhopadhyay S. Edge-host partitioning of deep neural networks with feature space encoding for resource-constrained internet-of-things platforms. In2018 15th IEEE International Conference on Advanced Video and Signal Based Surveillance (AVSS) 2018 Nov 27 (pp. 1-6). IEEE.

Partition and Cooperative Inference

- partition computed in **centralized** or **distributed** way
- generates a **directed acyclic graph** of computation
- in **AP** proximity-based device network topology
    - **partition DAG** mapped to **device network**

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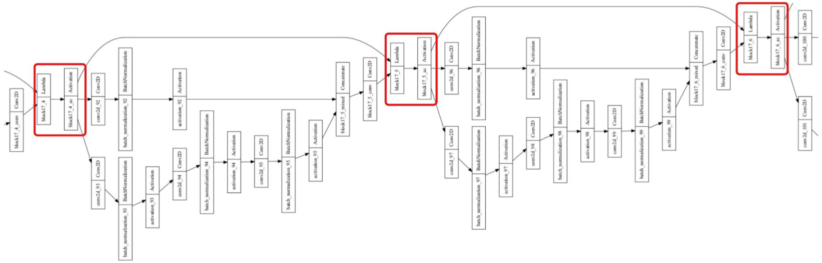
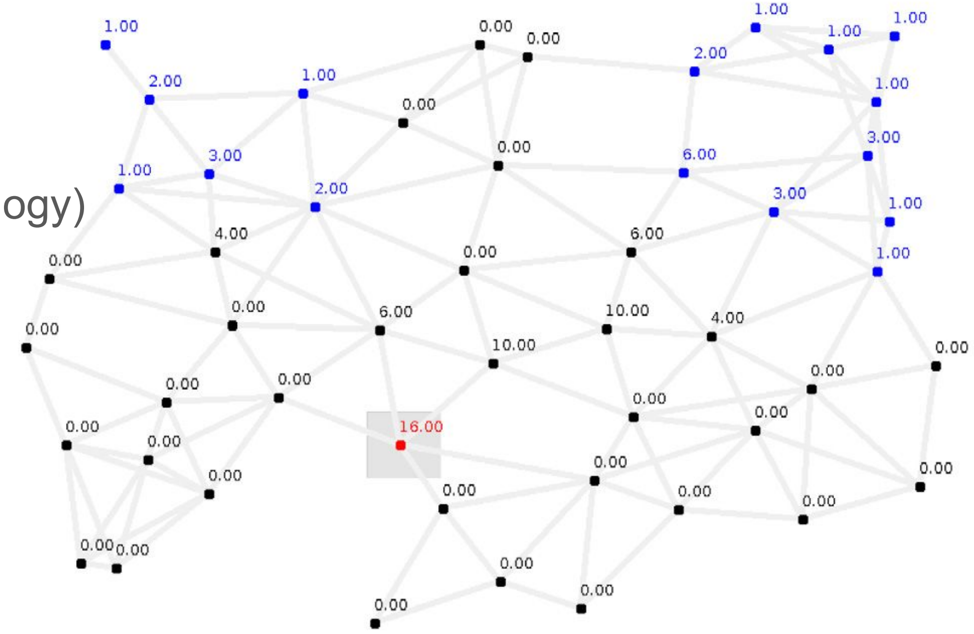


Adaptivity and Resilience with AP

- AP supports computation on a DAG
  - “collection” of result
- self-adapt to:
  - additional computational nodes
  - nodes failure/vanishing
  - nodes movements (change of topology)
  - improve performance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