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Attacks in Neural Networks from Hardware Perspective

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ECE 6011_25383

February 10, 2023

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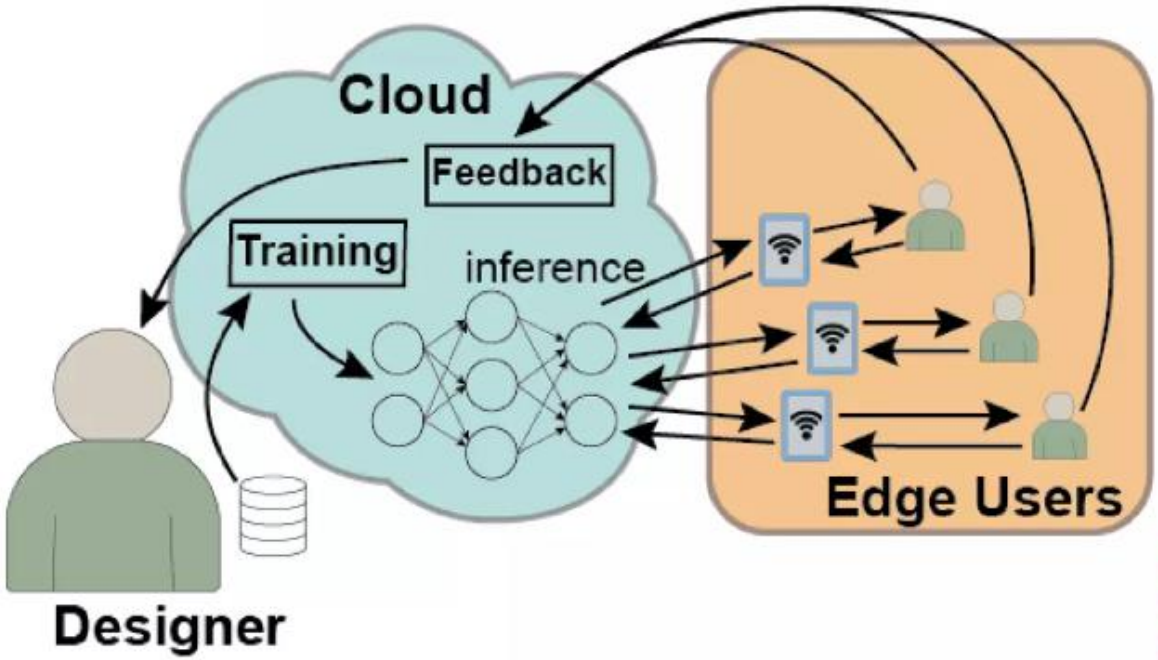
Outline

- Overview of Neural Networks.
- Overview of attacks.
- Adversarial scenarios in cloud and edge.
- Hardware Trojan Attack on Neural Networks.
- Illustration in memory.
- Conclusion and future direction.

Overview of Neural Networks

- Cloud Based ML Paradigms



Overview of Neural Networks

- Constrained Applications

Security Systems

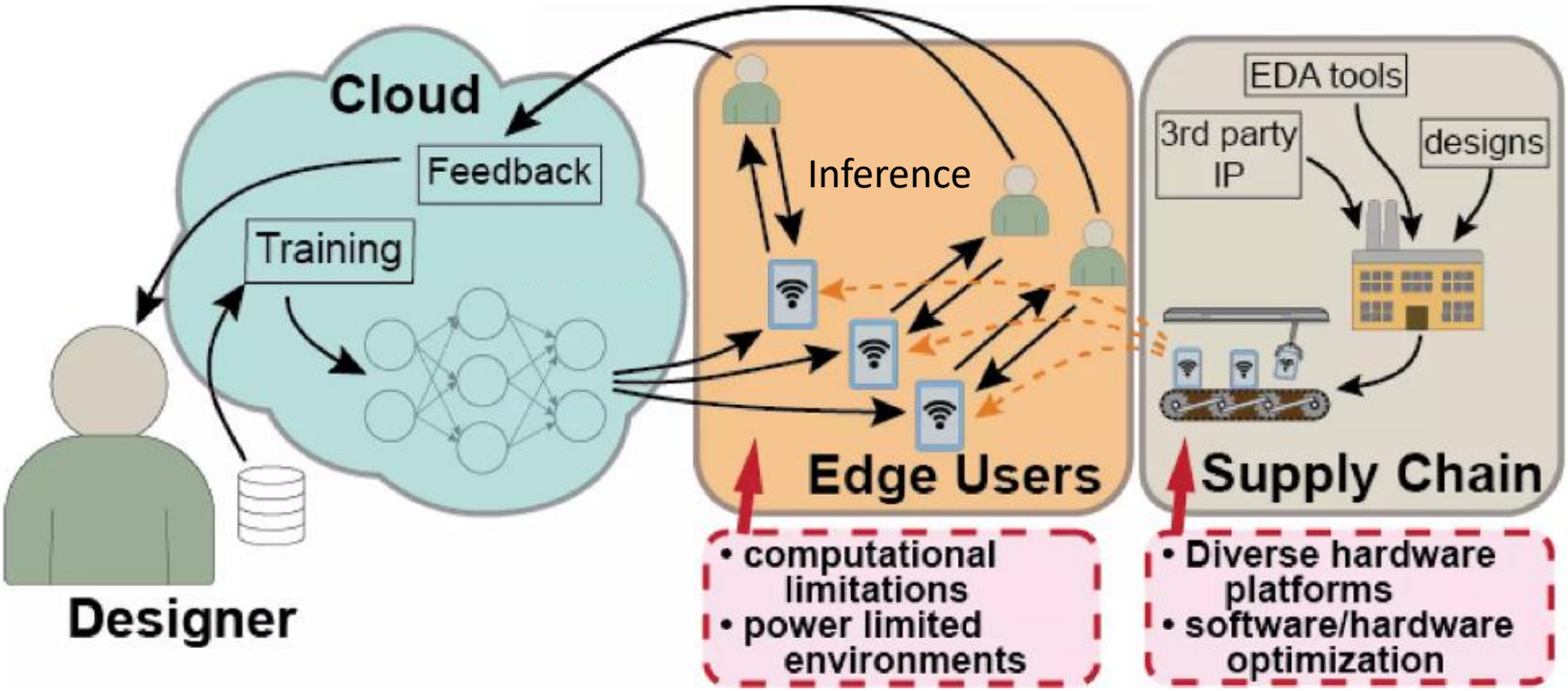
Mobile Applications

Automatic Driving

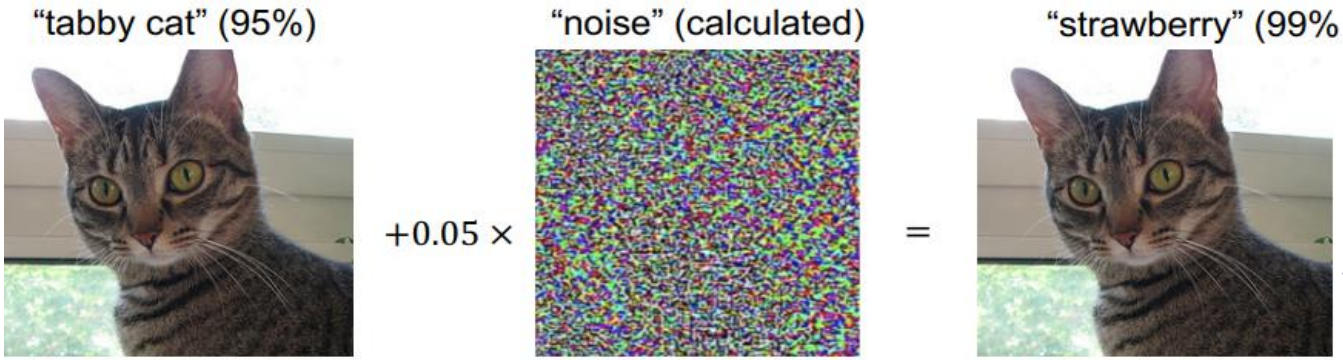
Wearable Technologies

Overview of Neural Networks

- Moving inference to the edge



Overview of Attacks on Neural Networks



Prediction (Adversarial example)

labels: dog, cat, mango, strawberry and so on.

Solution: Adversarial training

- Training Data (Poisoning)

Tay – a twitter bot developed by Microsoft seemed to learn some bad behavior on its own

Solution: Data sanitization/ Robust statistics

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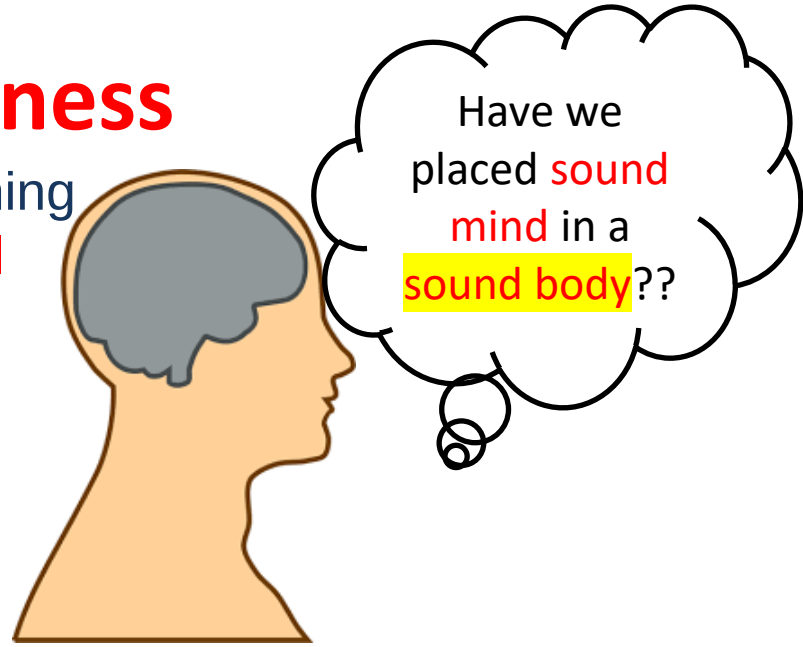
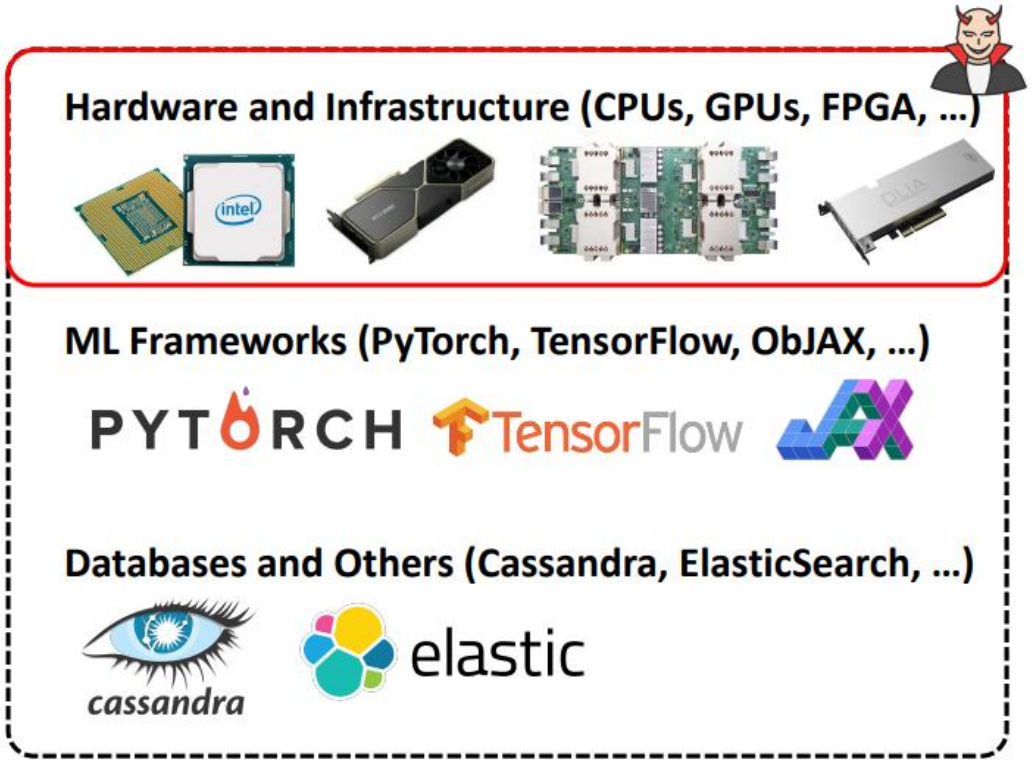
DNN Robustness

- Prior works considered Machine Learning models as a standalone, mathematical concept.
- We need to consider hardware level vulnerabilities as well.





- Prior works considered: Hardware attack as weak attack and software attack as strong attack.

Not always

Security in Neural Network need both safe hardware and safe software

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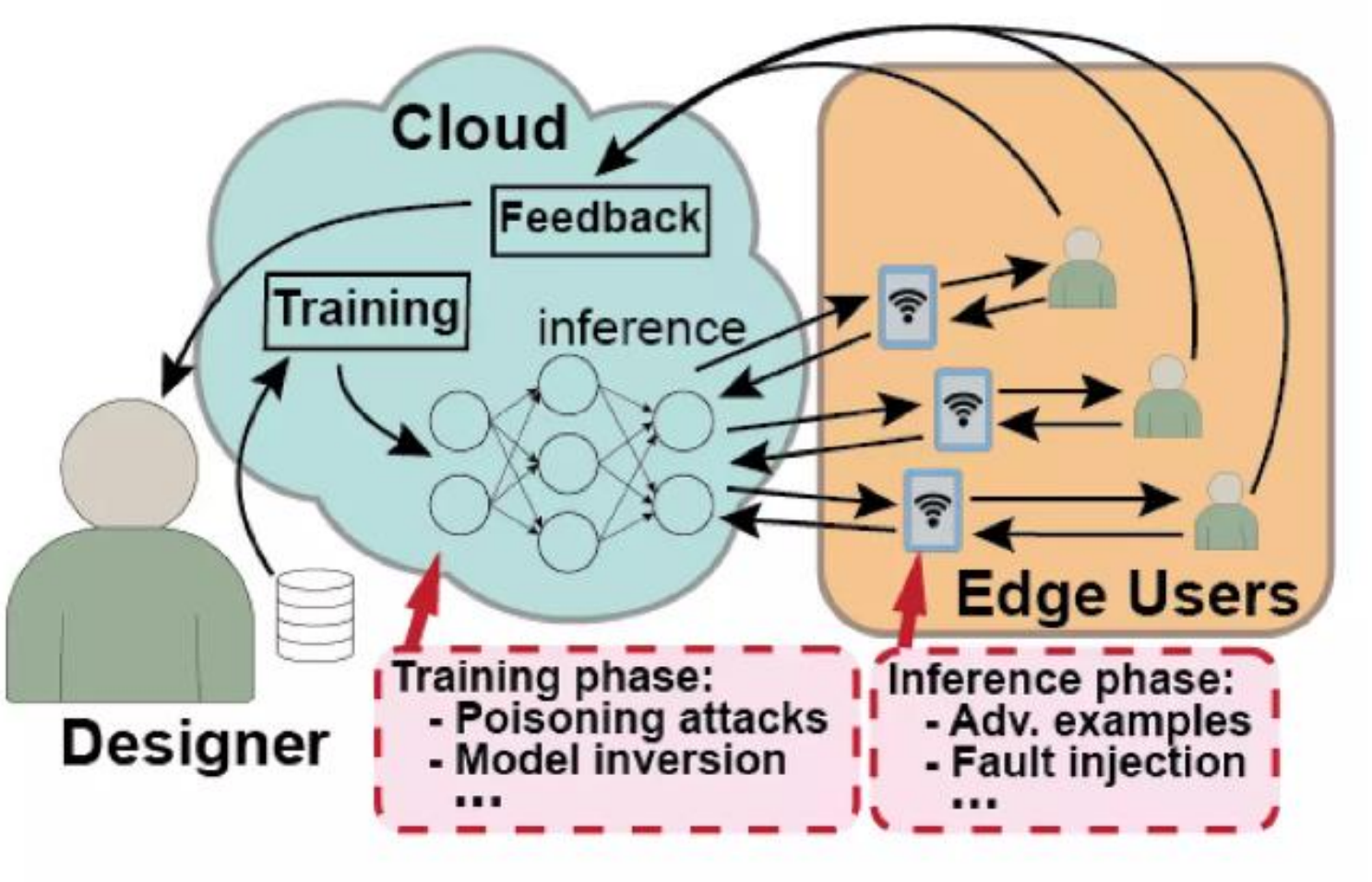
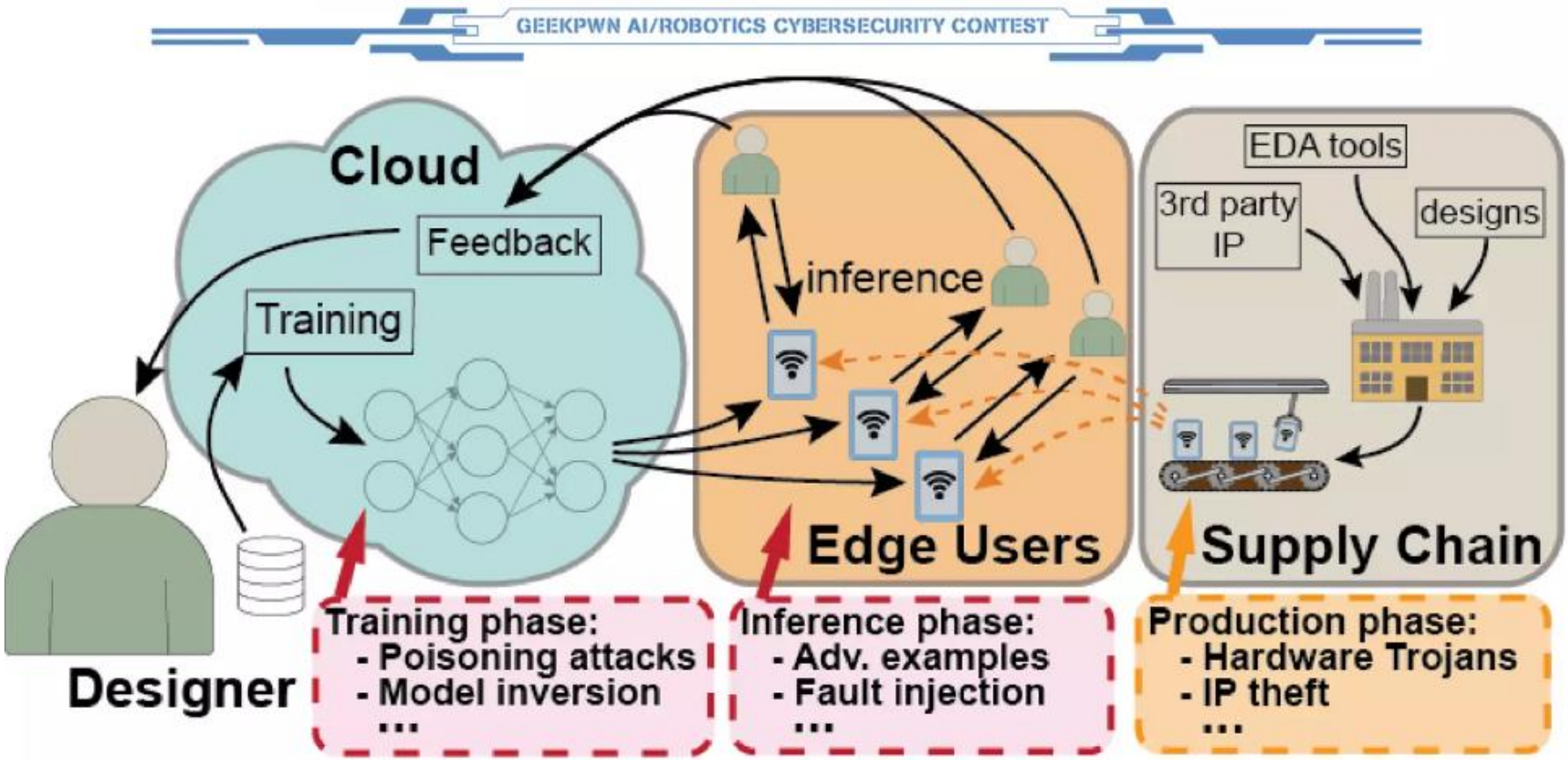
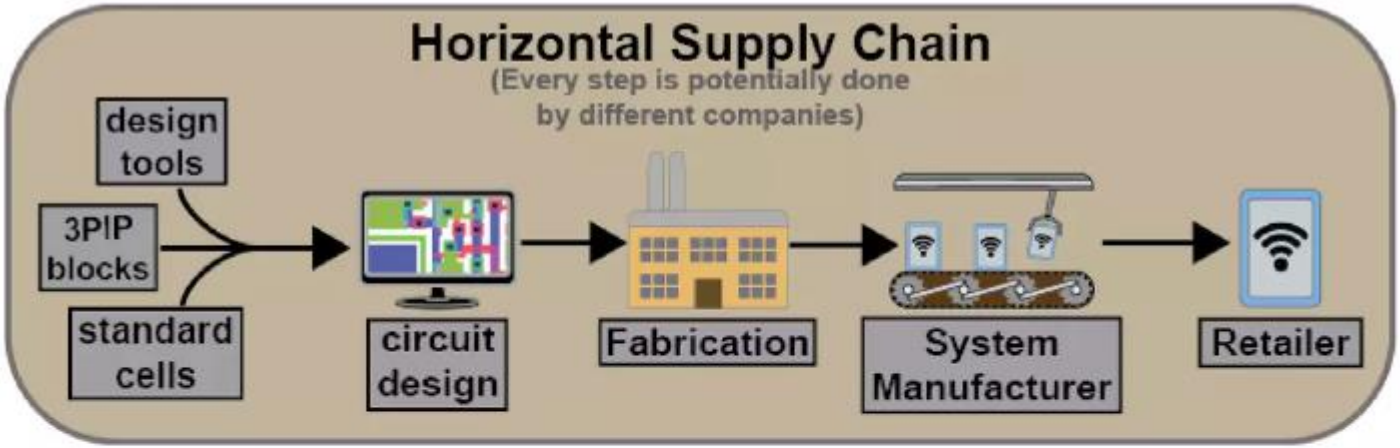
Adversarial Scenario in the Cloud

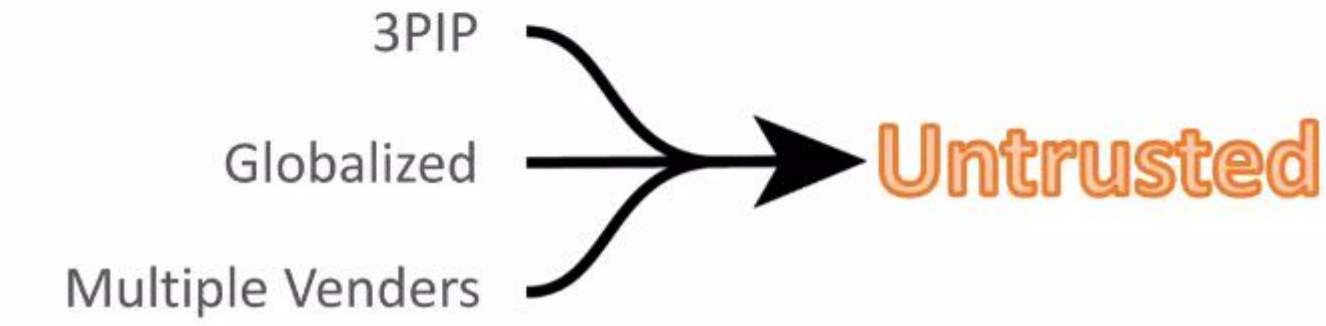


Adversarial Scenario on the Edge



Hardware supply chain





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Attacks in hardware domain

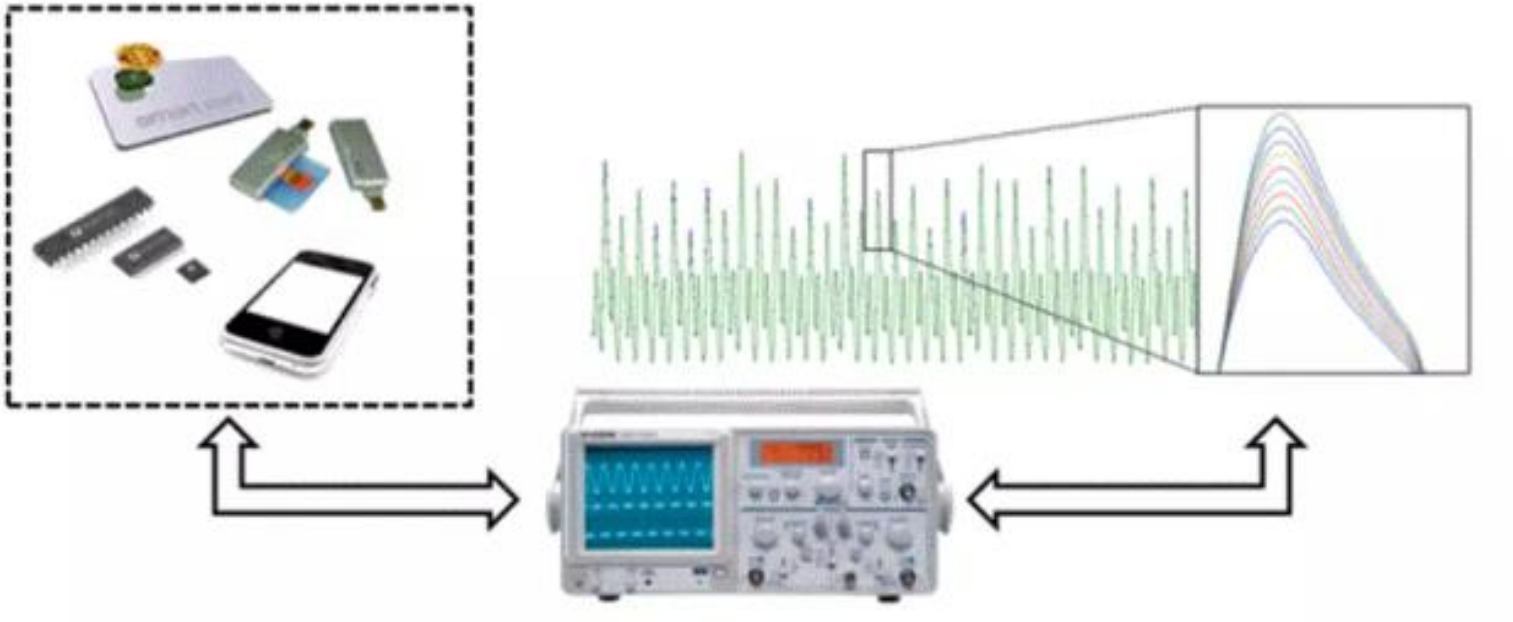
- **IP Piracy**: Produce IPs (or secretly more copies) without approval from original owner and provide them at low cost
- **Counterfeiting:** Generating a fake one. (Especially ICs)

Original

Fake

Attacks in hardware domain (contd.)

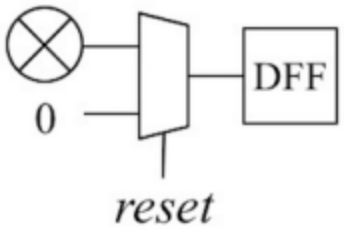
- Side-channel attacks: Exploit information from computer such as electromagnetic radiation.



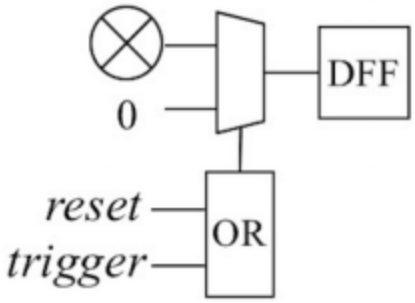
Attacks in hardware domain (contd.)

- Hardware trojans: Attacker attempts to maliciously modify a circuit design such that the functionality changes.

(Especially, if attacker have access to supply chain)



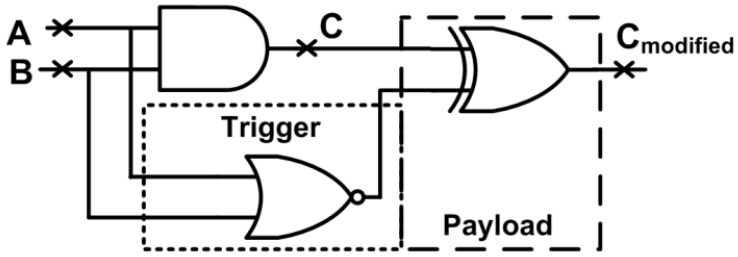
(a)



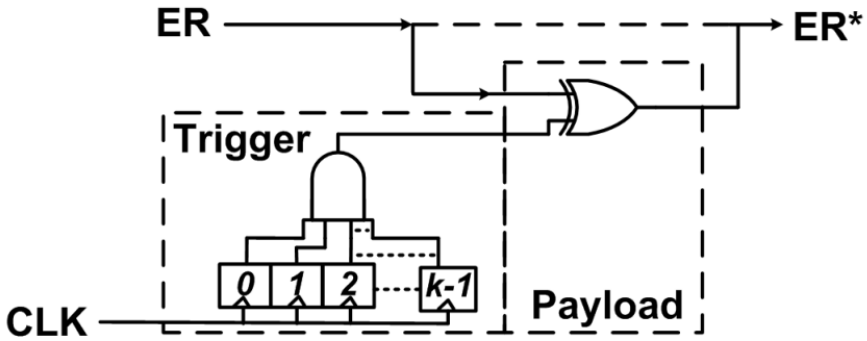
(b)

original

Trojaned



(a) Combinationally triggered Trojan



(b) Synchronous counter ("time-bomb") Trojan

Illustration of DNN (In memory Representation)

- Accuracy: 99%

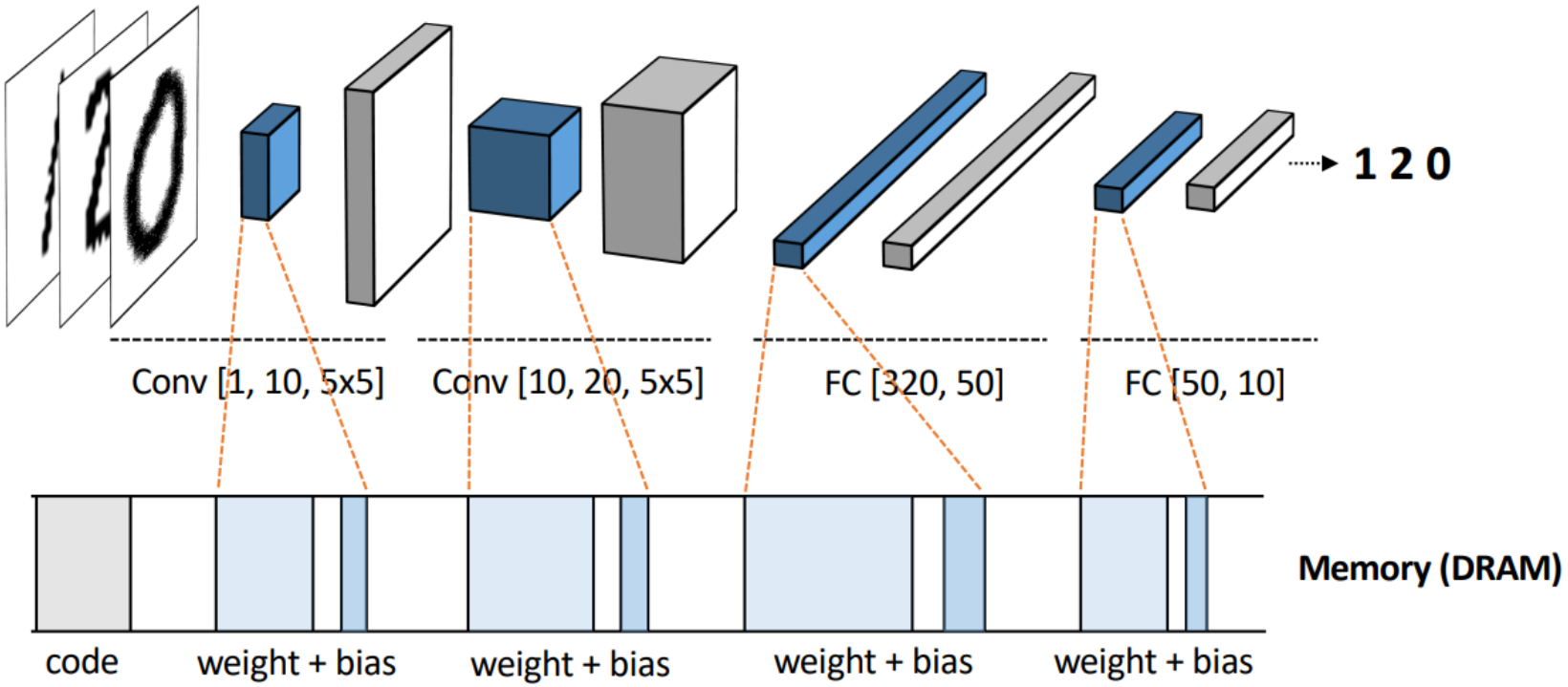


Illustration of DNN (In memory Representation)

- Accuracy: **93.53% (5% drop)**

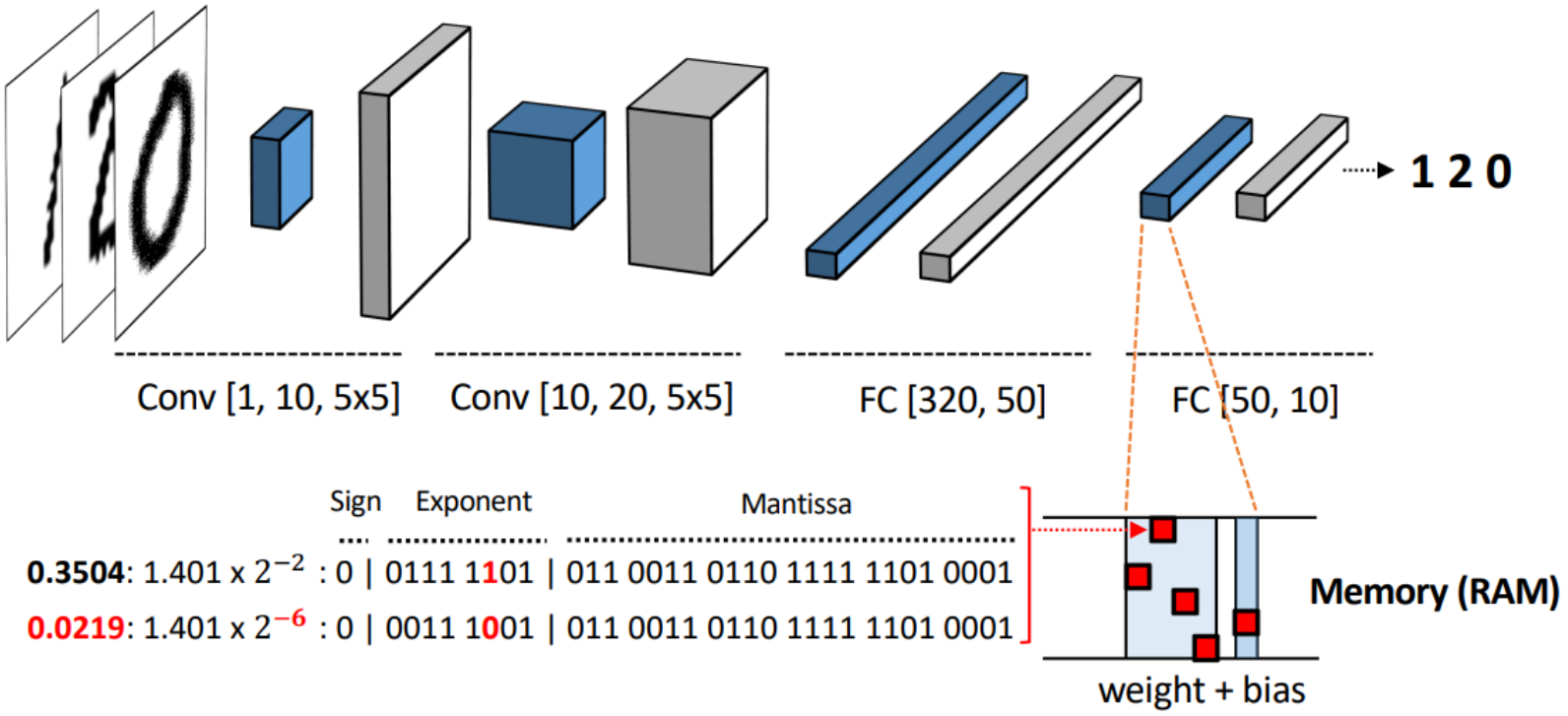
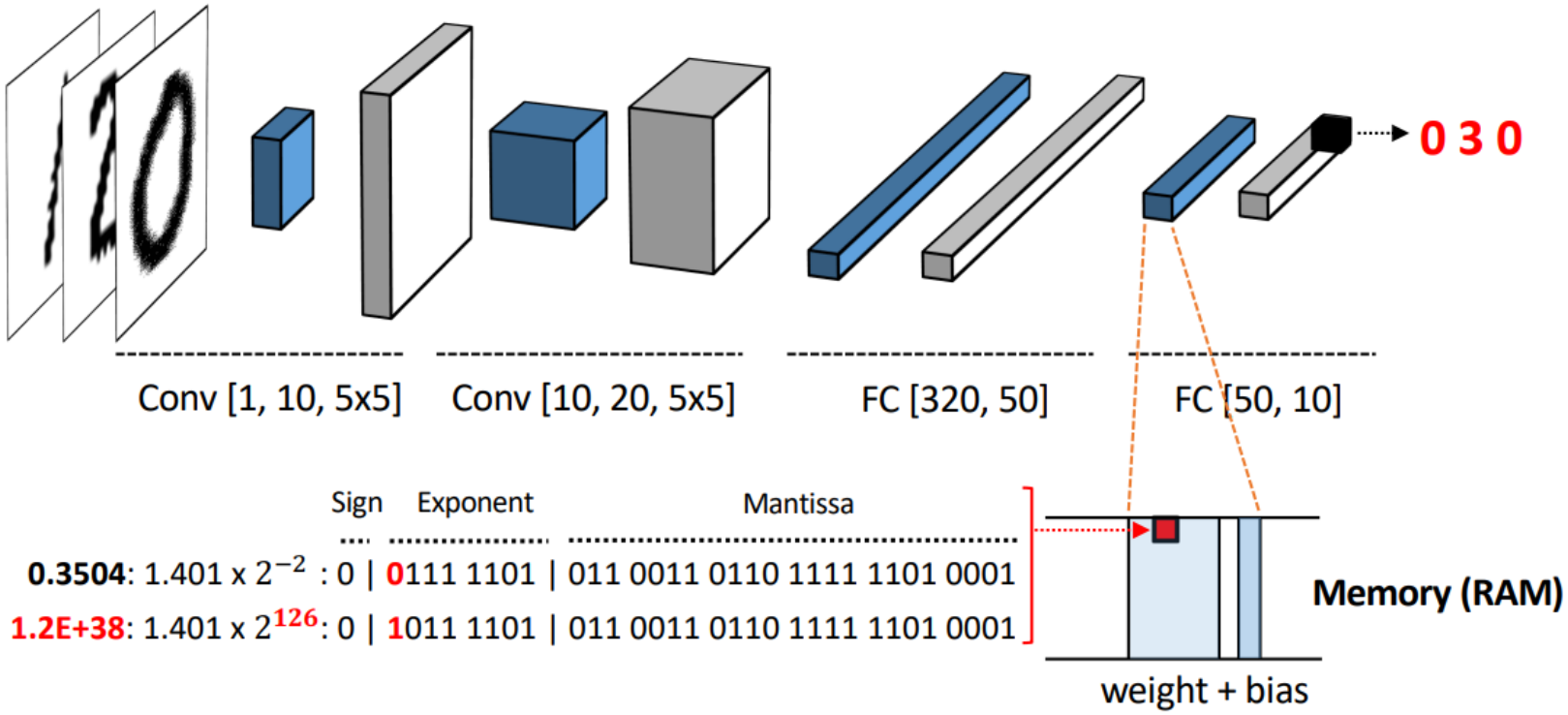


Illustration of DNN (In memory Representation)

- Accuracy: **57.52% (41.01% drop)**



Conclusion

- Hardware attack can break mathematically proven guarantees.
- Stealthy form of attack.
- Other attacks on machine learning models are possible through hardware implementations.
- Single-bit flip can inflict maximum damage if it's the most significant bit. (Achilles bit)

References

1. Hong, Sanghyun, et al. "Terminal Brain Damage: Exposing the Graceless Degradation in Deep Neural Networks Under Hardware Fault Attacks." *USENIX Security Symposium*. 2019.
2. Clements, Joseph, and Yingjie Lao. "Hardware trojan design on neural networks." *2019 IEEE International Symposium on Circuits and Systems (ISCAS)*. IEEE, 2019.
3. Clements, Joseph, and Yingjie Lao. "Hardware trojan attacks on neural networks." *arXiv preprint arXiv:1806.05768* (2018).
4. Hong, Sanghyun, and Maryland Cybersecurity Center MC. "A Sound Mind in A Vulnerable Body: Practical Hardware Attacks on Deep Learning."

Thank you for your attention!

Questions ??

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