FORCES
FOUNDATIONS OF RESILIENT
CYBER-PHYSICAL SYSTEMS

Stochastic Message Authentication

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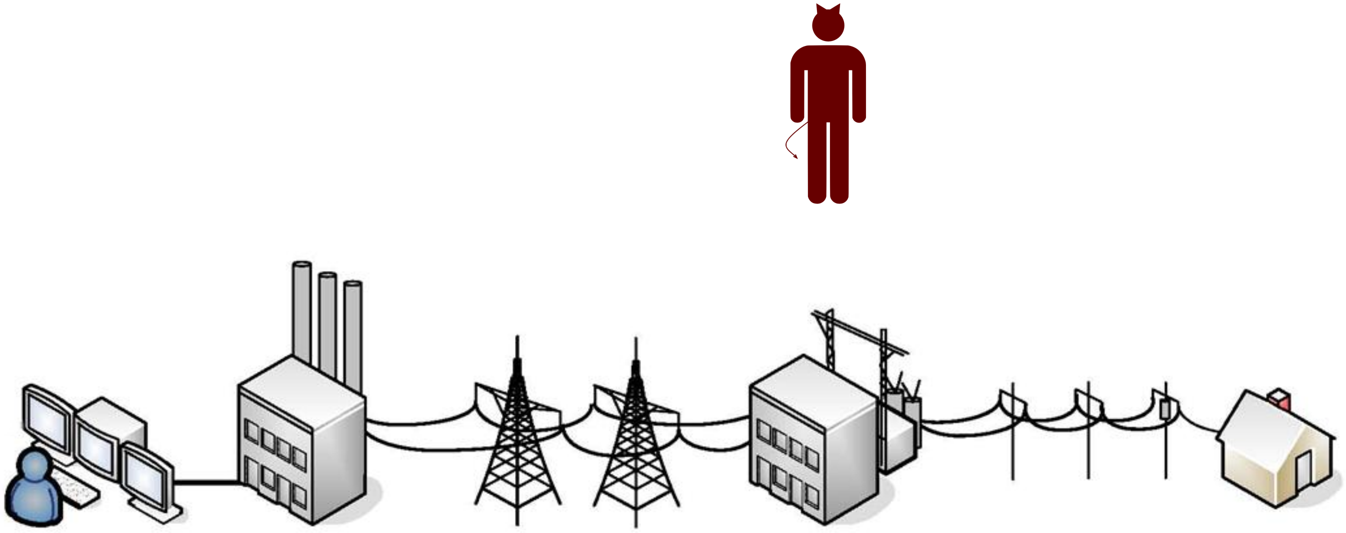
Motivation

- Attacks against networked cyber-physical systems
  - e.g. smart grid



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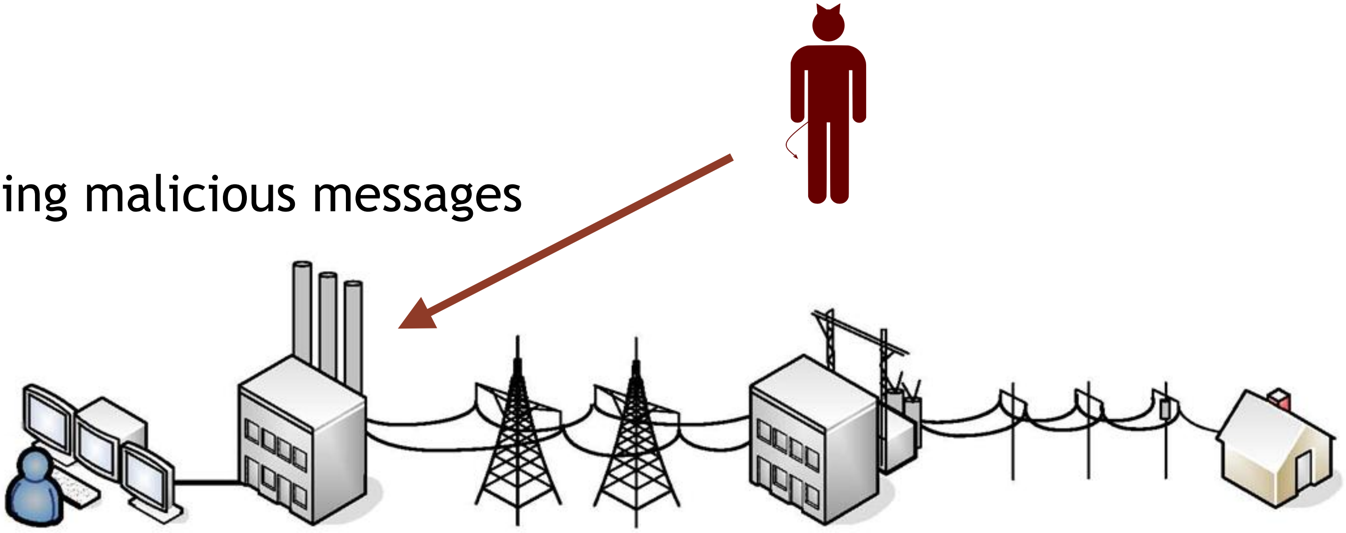

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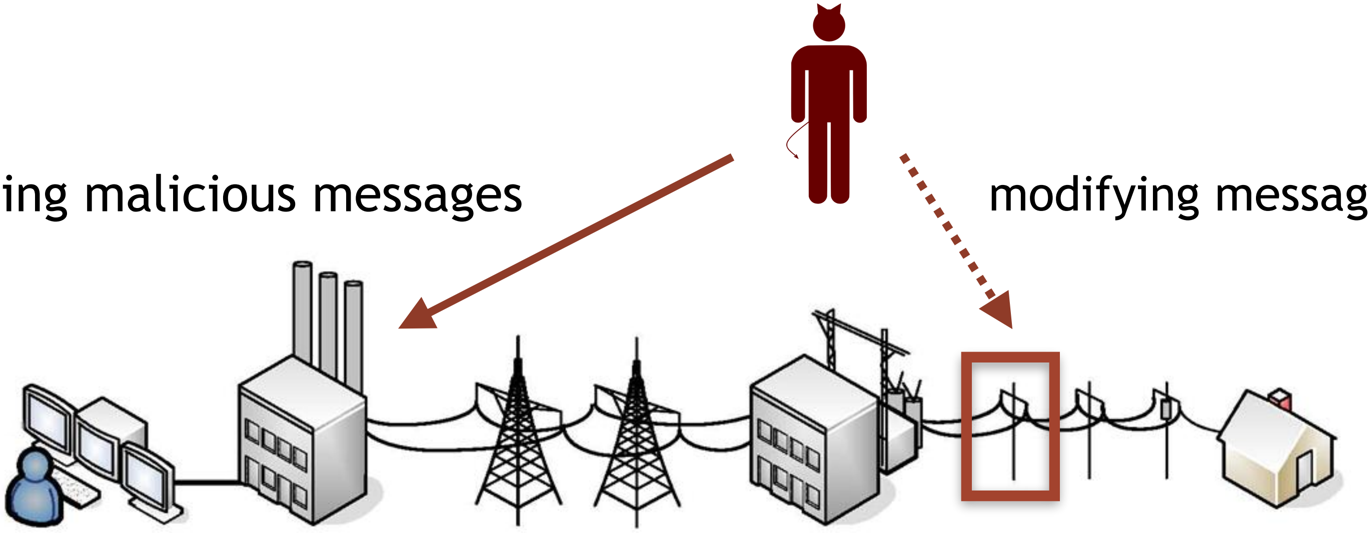

inserting malicious messages

modifying messages

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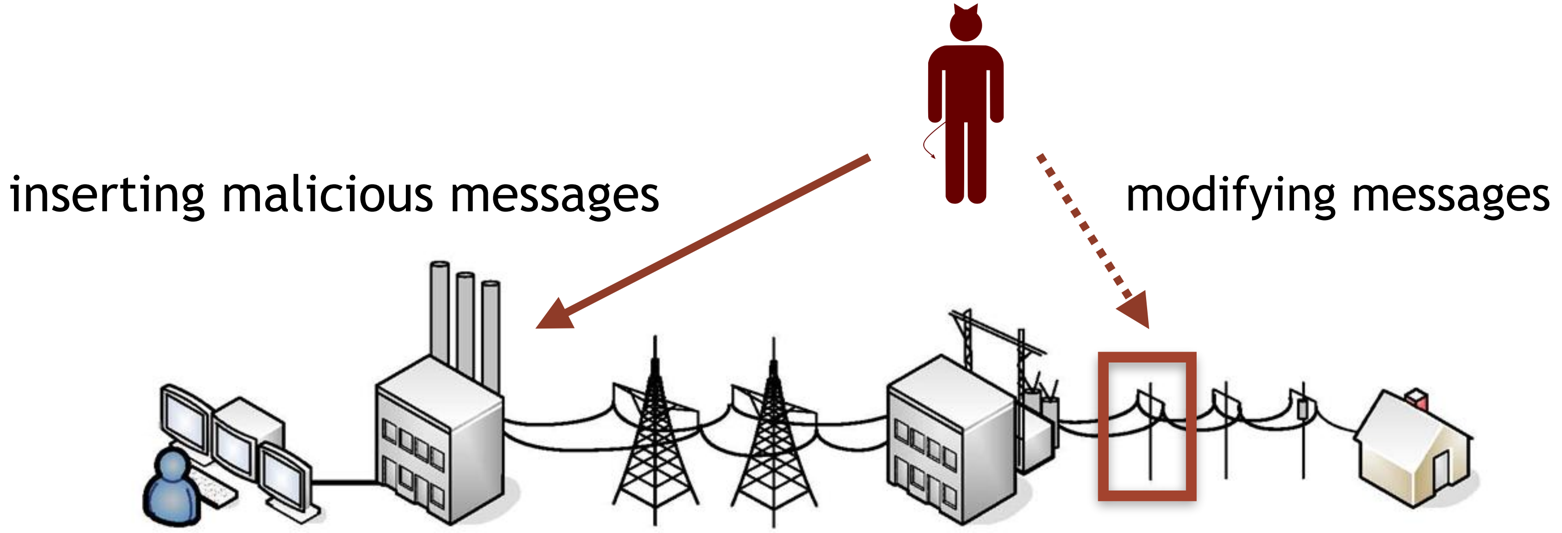
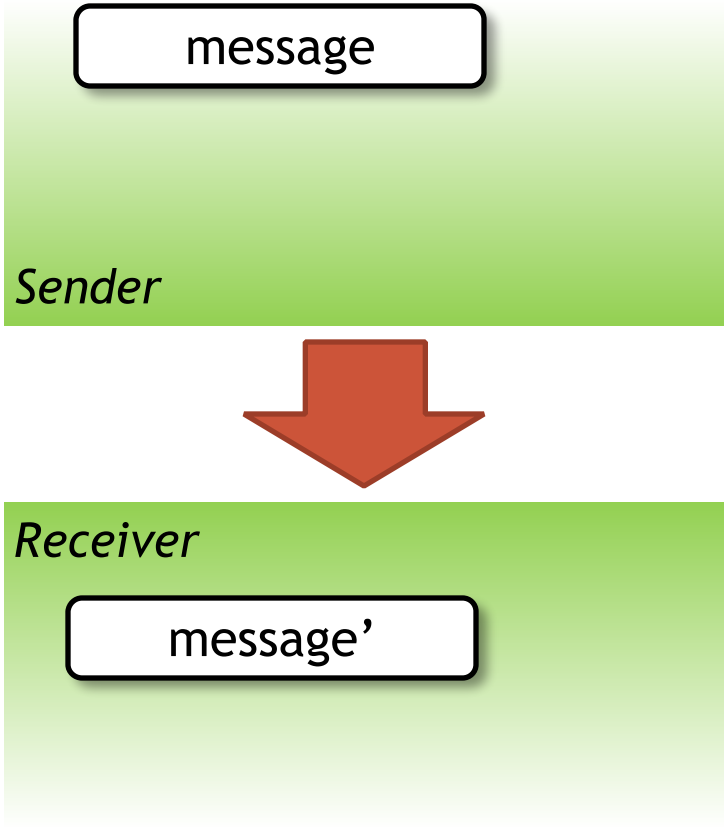


We need to be able to **verify** the **integrity** and **authenticity** of messages!

Message Authentication



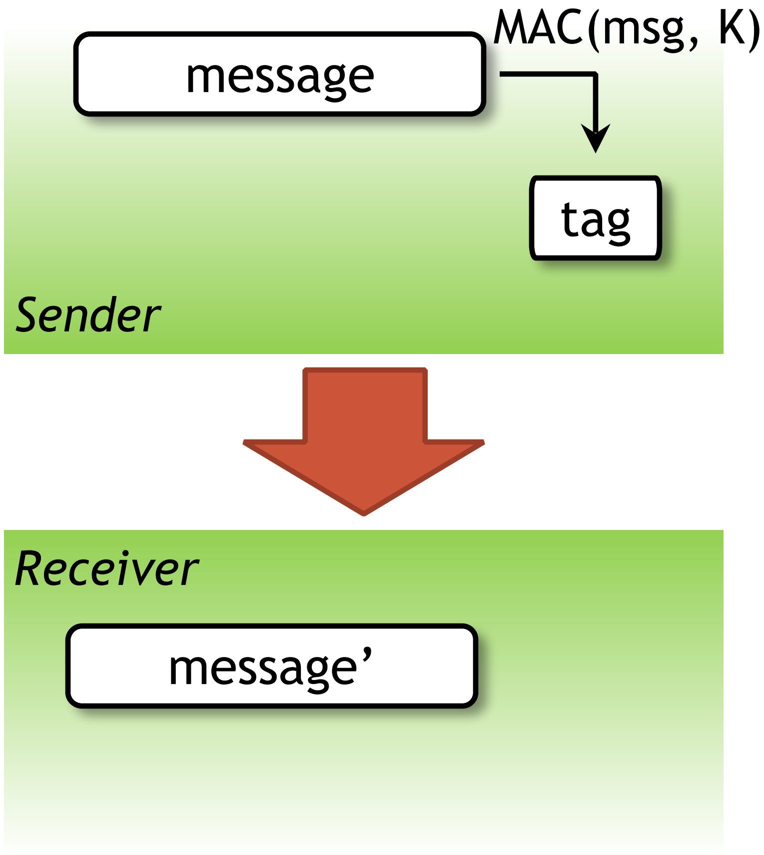
message

Sender

Receiver

message’

Message Authentication



- For each message, sender computes an “authentication tag” using a secret key

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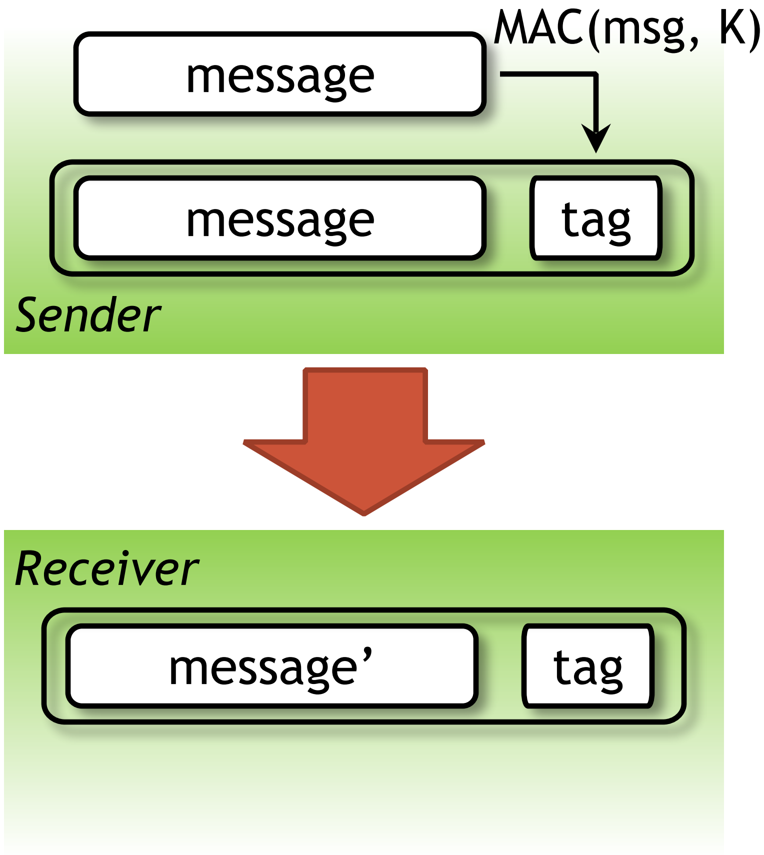

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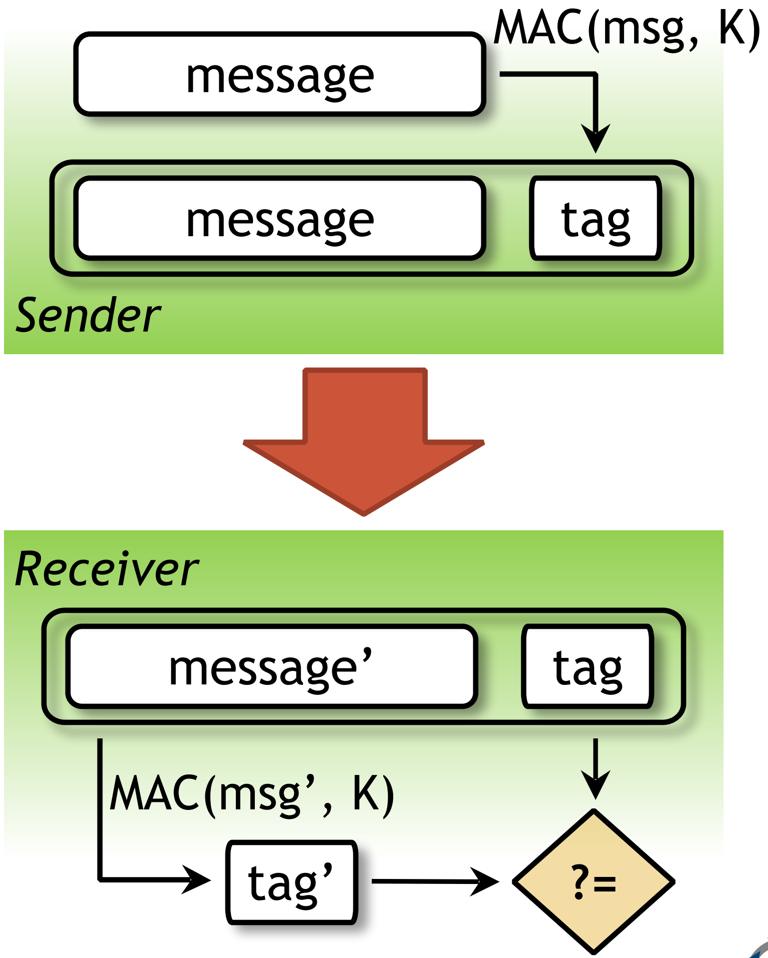

- For each message, sender computes an “authentication tag” using a secret key
- Adversary cannot forge a correct tag without knowing the key
- Receiver can verify the integrity and authenticity of the messages using the same key → detect any attack

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Challenges and Our Approach

- Computational demand of cryptographic primitives can be too high for **resource-bounded** devices
  - legacy devices in supervisory control systems
  - embedded or battery-powered devices (RFID tags, sensors)

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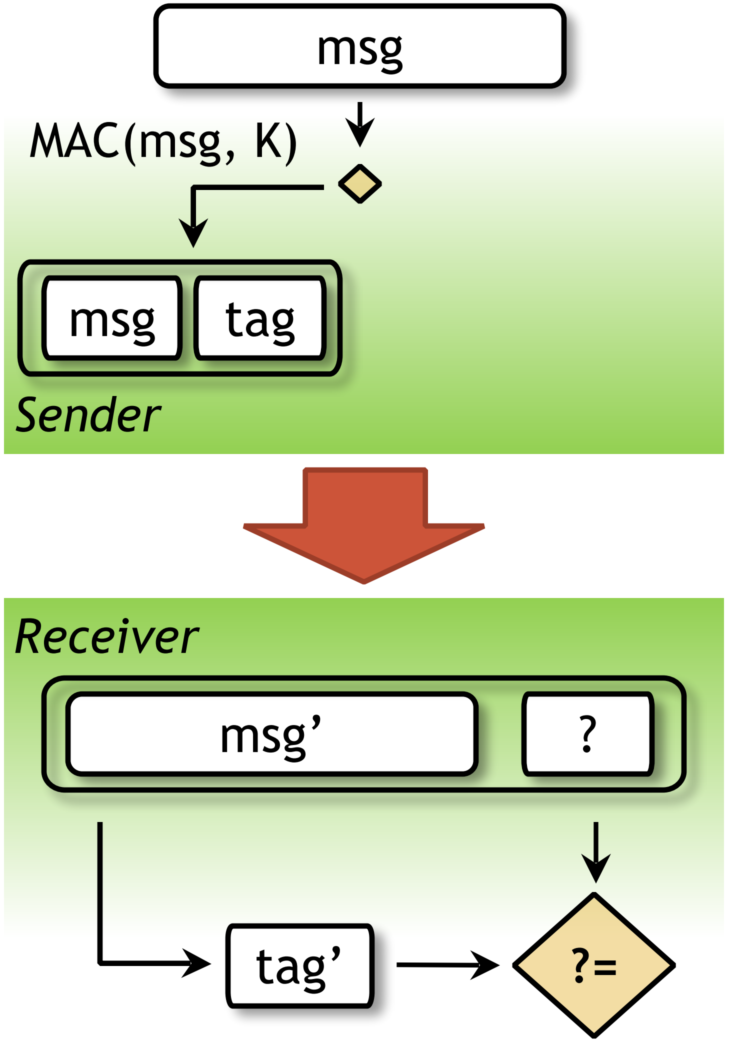
- “Lightweight” cryptographic primitives
  - Decision to secure a system is still **binary**: either security is employed, incurring some fixed overhead, or it is not
- Our approach:
  general-purpose framework for trading off security and computational demand using an existing MAC scheme
  → best-possible security for **arbitrary resource-bound**

Stochastic Message Authentication



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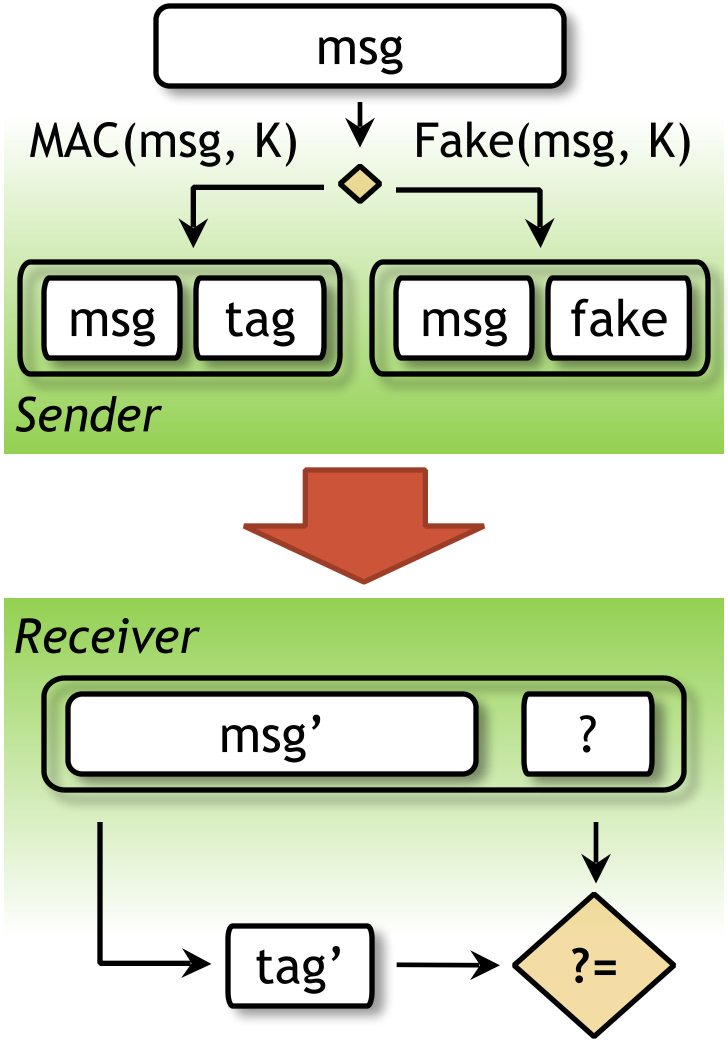

- For some messages, the sender computes a “fake tag”, which is computationally less demanding, but does not protect integrity

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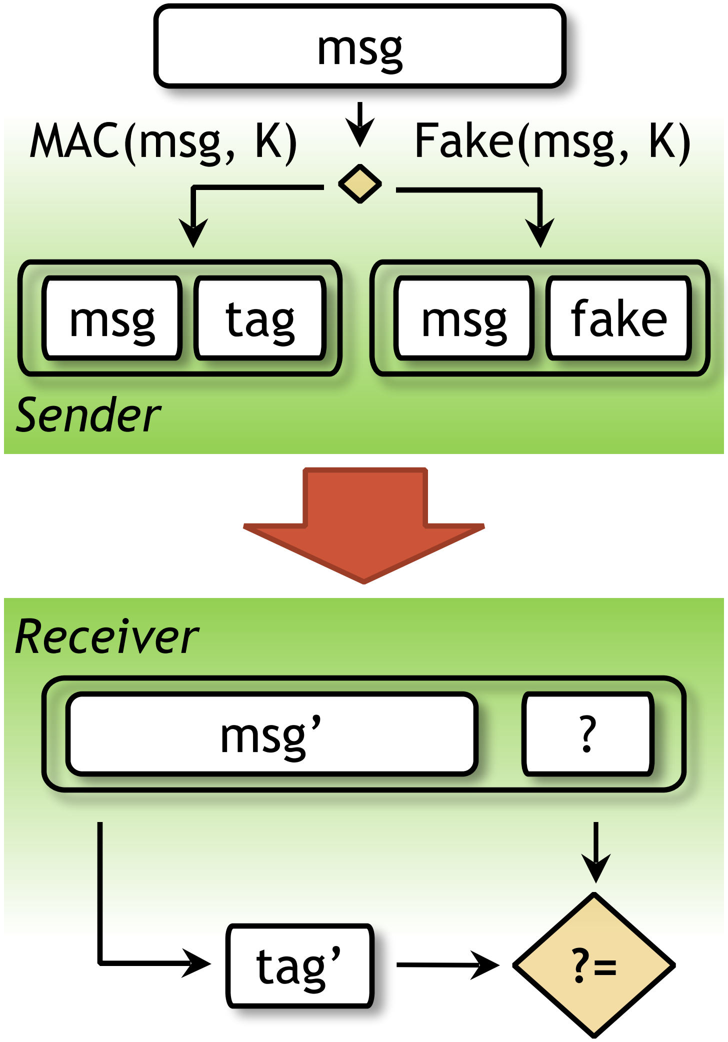

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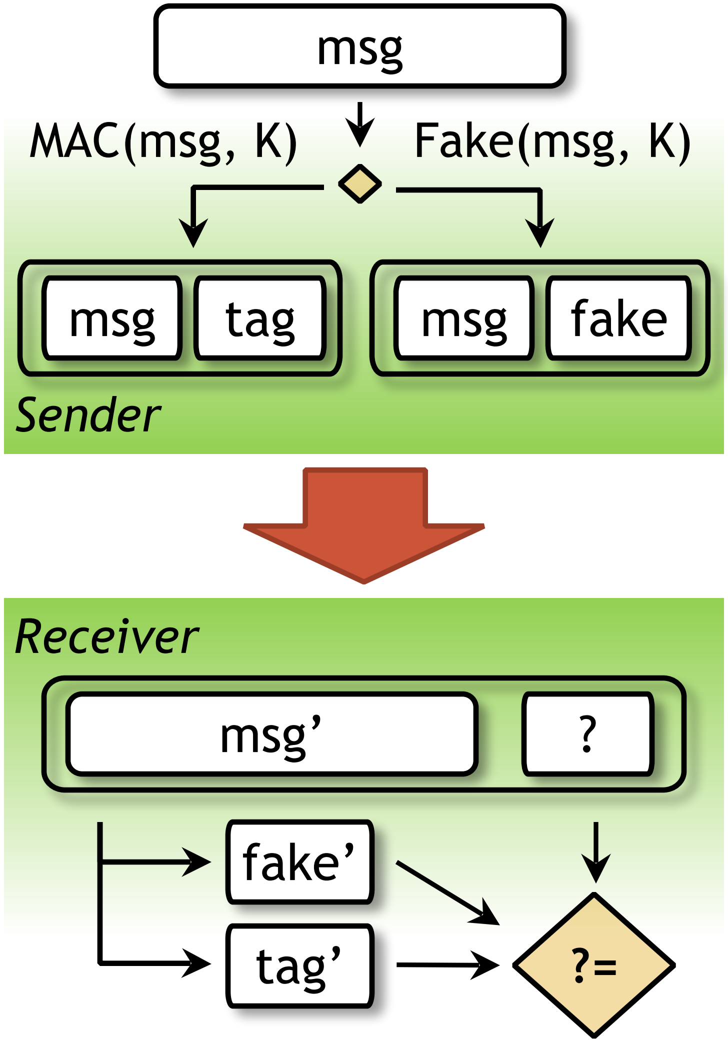

- For some messages, the sender computes a "fake tag", which is computationally less demanding, but does not protect integrity
- Adversary cannot distinguish fake tags from correct tags
- Receiver can verify if a message has a fake or a correct tag efficiently → detect attacks with high probability

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Game-Theoretic Model

- Stackelberg security game
  - we divide messages into C classes based on their potential to cause damage

	Defender	***Attacker***
Strategy choice	*for each class c, the probability of authentication p_c*	*for each class c, the number of modified / inserted messages a_c*

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Payoff	*attack undetected*	*loses amount of damage, i.e.,* -$\sum a_c L_c$	*gains amount of damage, i.e.,* $\sum a_c L_c$

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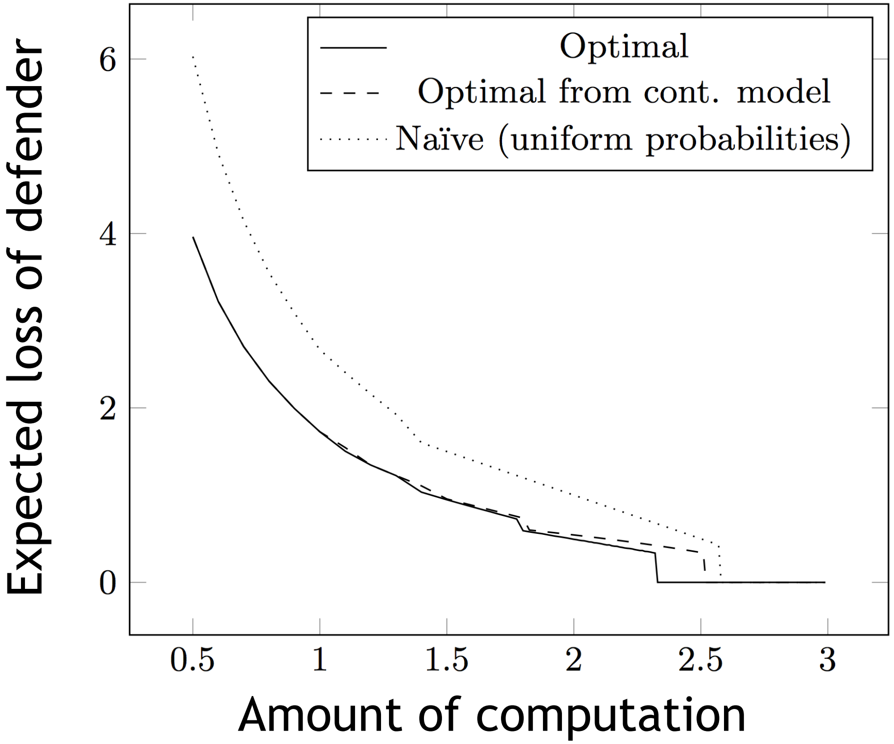
	attack detected	*zero*	*“punishment” -F*

Theoretical Results

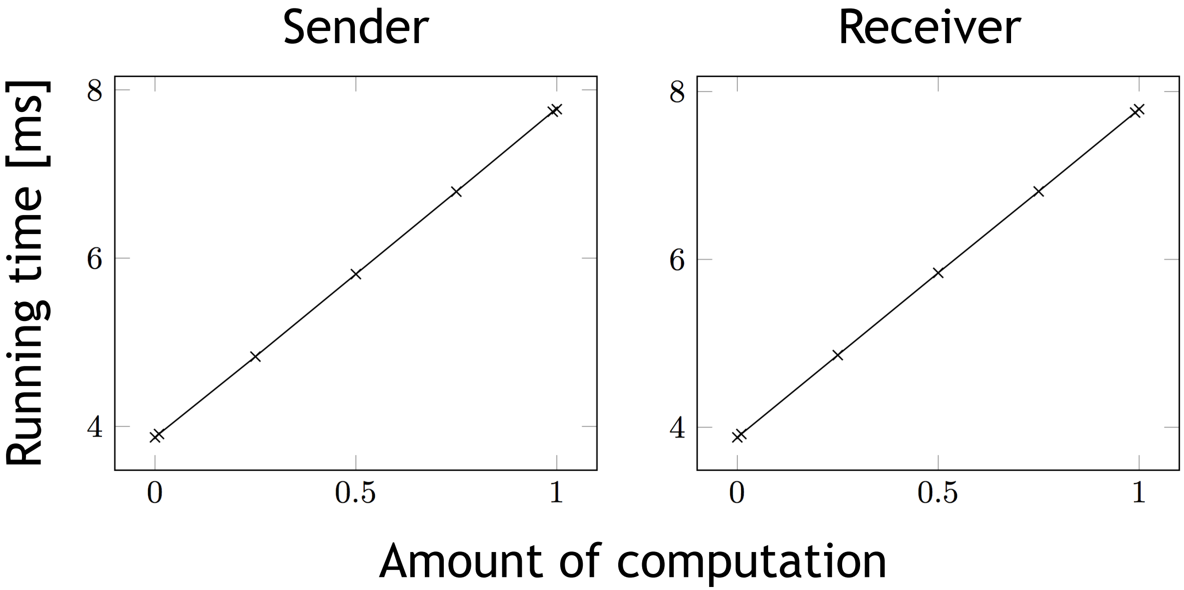
- Game-theoretic model of stochastic message authentication
  - Finding optimal authentication strategy

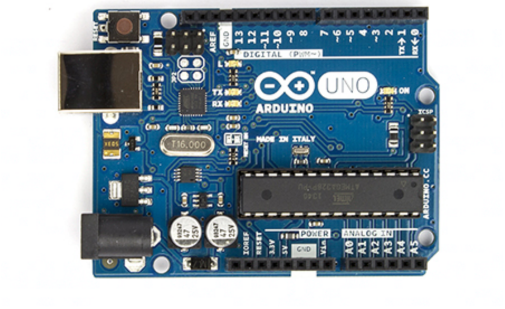


✓ trade-off between computation and security

Practical Results

- Proof-of-concept implementation using SHA-1 HMAC on an `ATmega328P` microcontroller





✓ for arbitrary resource bound

Thank you for your attention!

Questions?

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