Synergy: Collaborative Research: Security and Privacy-Aware Cyber-Physical Systems

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2015 CPS PI MEETING

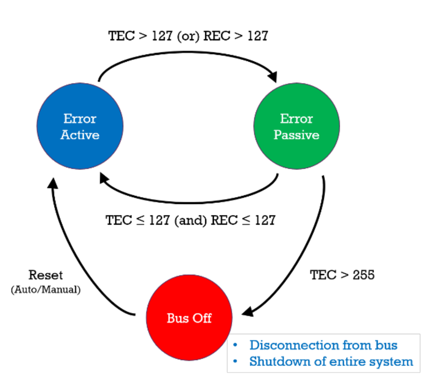
Platform support for security

Attack Model: "Bus-off Attack"

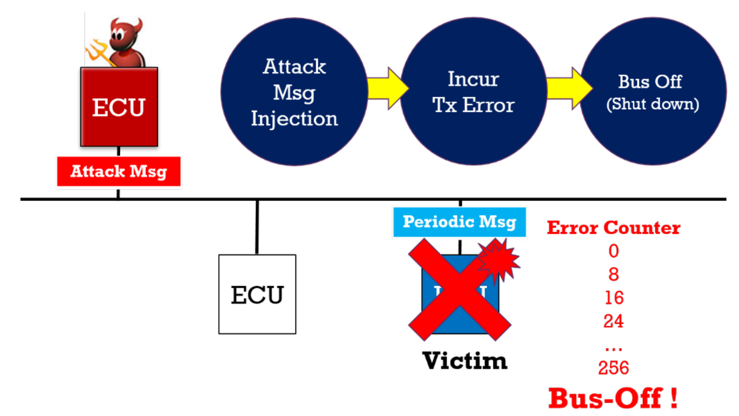
- Attacker's objective is to shut down or disconnect uncompromised (healthy) in-vehicle ECUs with minimal number of injections.

How to shut down the victim ECU?

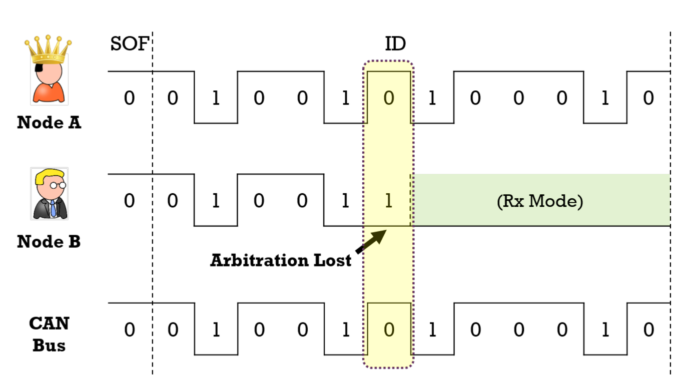
- Exploit the error handling mechanism in CAN and deceive the victim into thinking it is erroneous while is actually under attack.



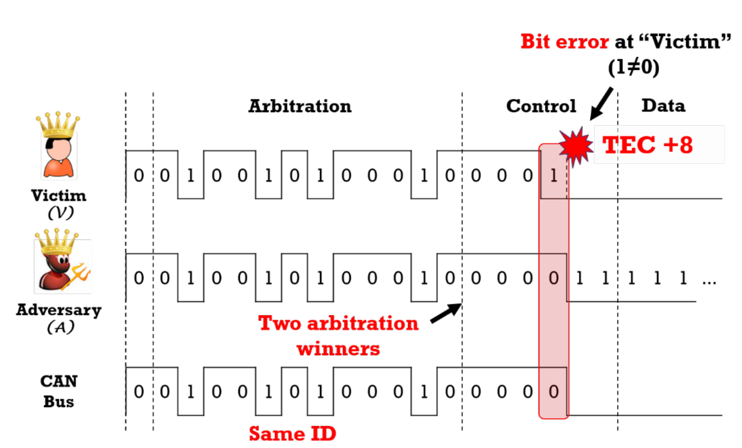
CAN Error Handling Mechanism



Bus-off Attack



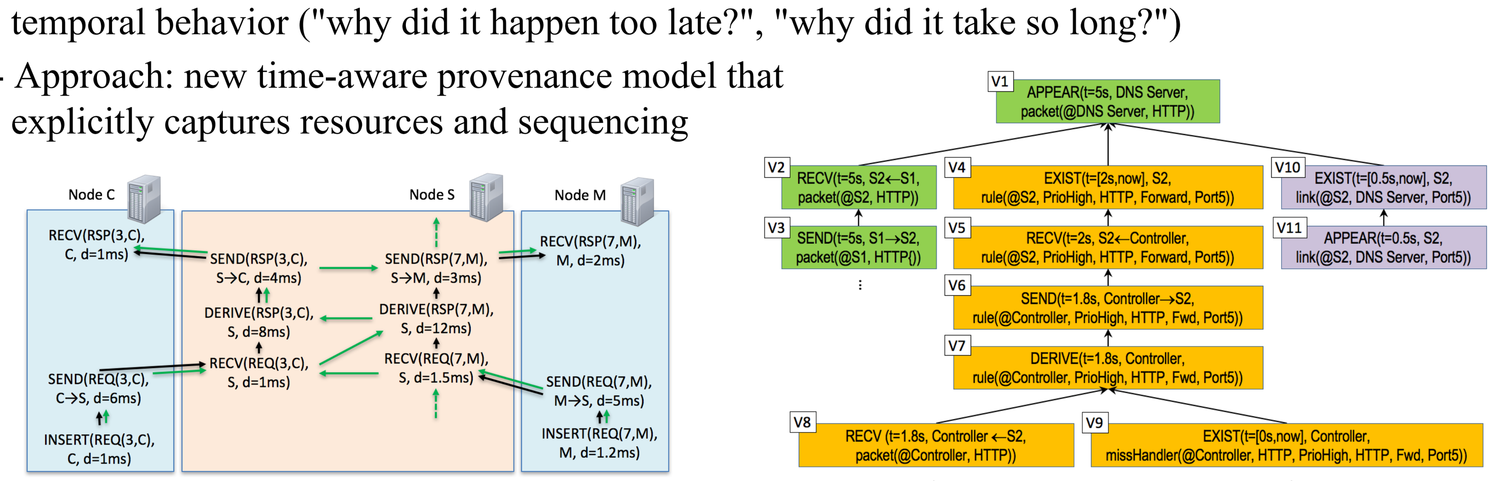
Only ONE arbitration winner !



But in the bus-off attack… TWO arbitration winners

How do we figure out what happened?

- Goal: System should be able to 'explain' to a forensic investigator why a given event occurred
- Idea: adapt the concept of data provenance from the database literature
- Problem: existing solutions only explain functional behavior ("why did this happen?") but not temporal behavior ("why did it happen too late?", "why did it take so long?")
- Approach: new time-aware provenance model that explicitly captures resources and sequencing



Modeling Human Factors

***Problem*:**

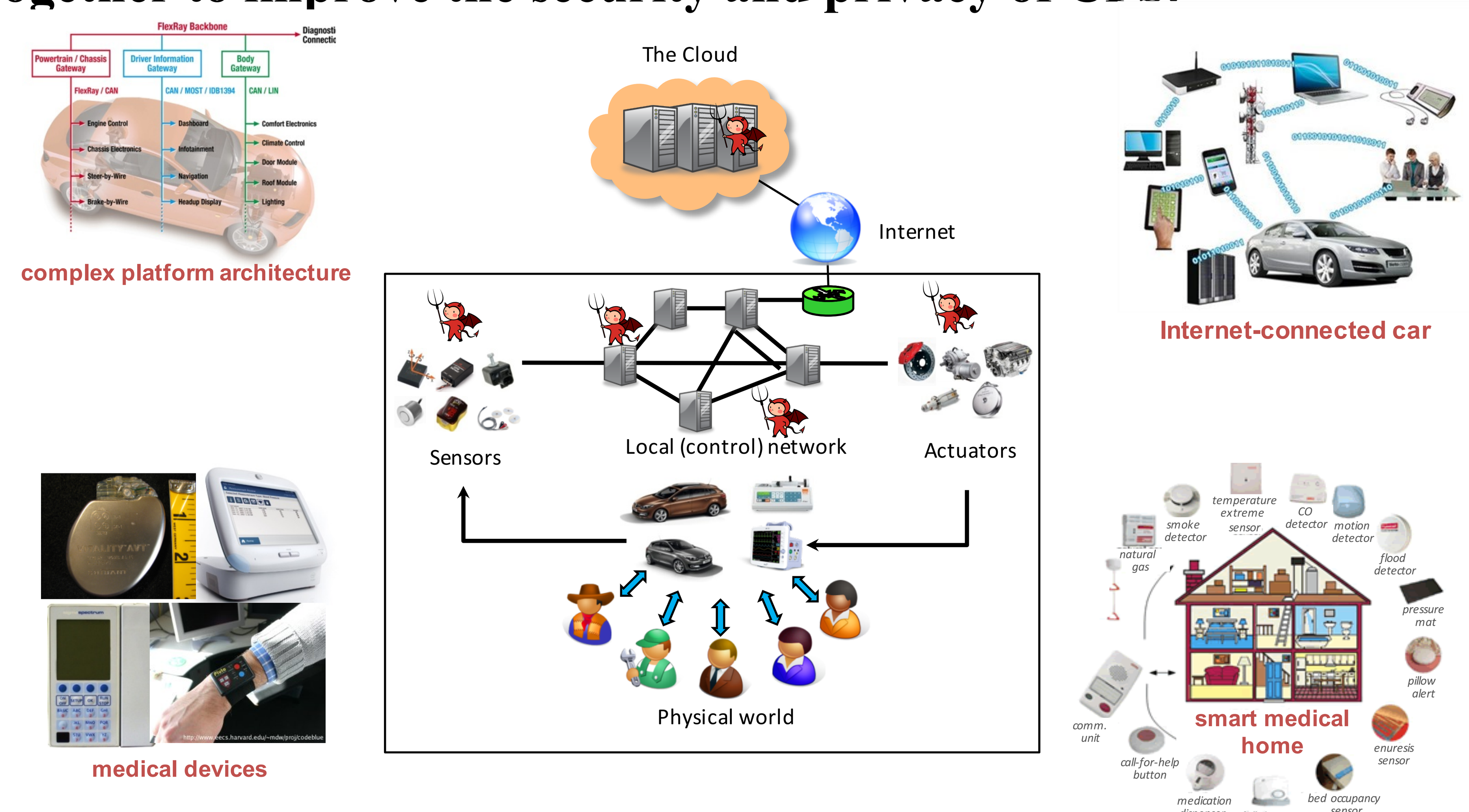
Users resort to workarounds when they feel that security features of a system prevent them from doing their work. How can we predict workarounds and analyze their effects?

***Approach*:**

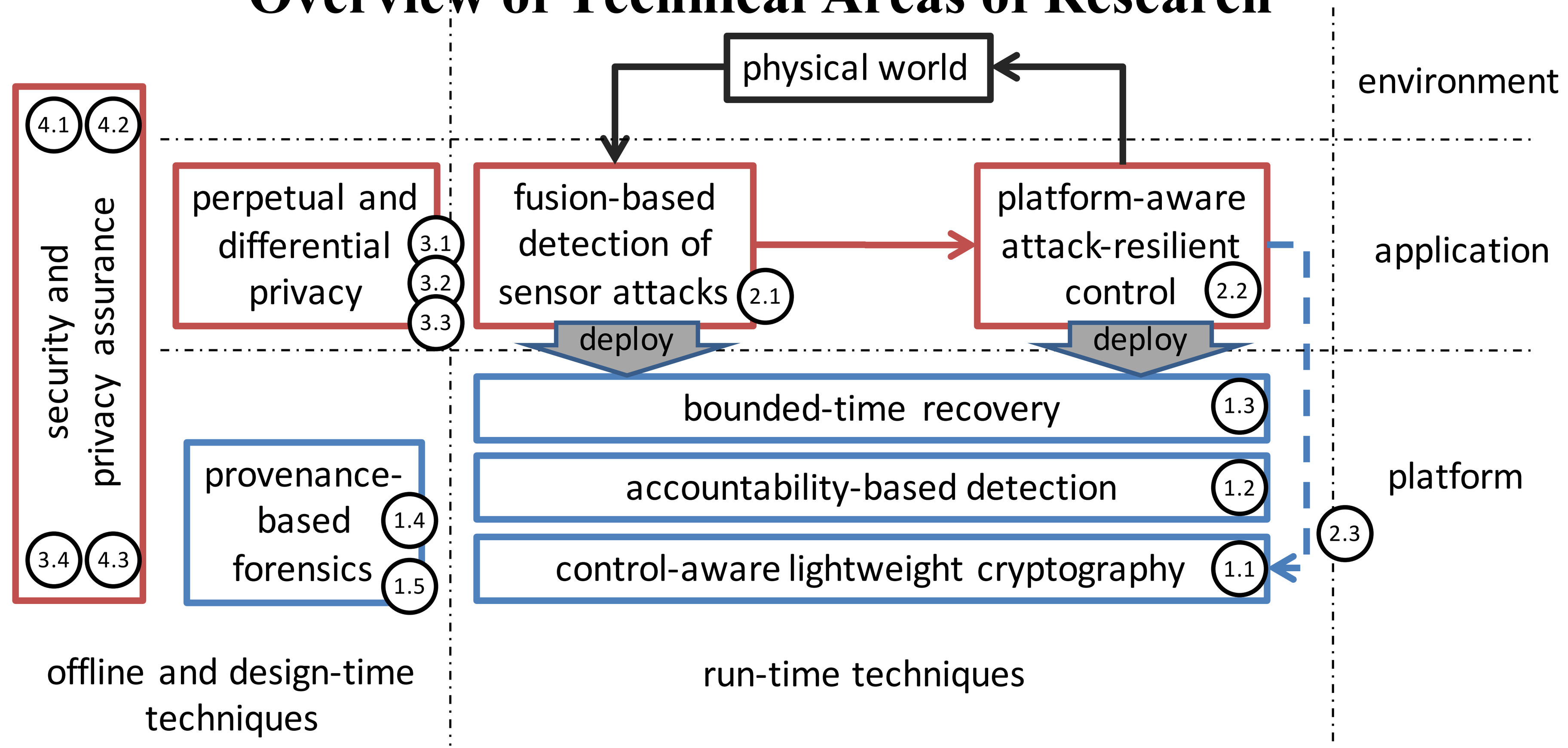
- Model potential workarounds as hazards and apply risk analysis
- Incorporate users' mental models into model-based design of CPS

Project Overview

***Goals of the project*: to develop a framework in which the mix of prevention, detection, recovery and robust techniques work together to improve the security and privacy of CPS.**



Overview of Technical Areas of Research



Team

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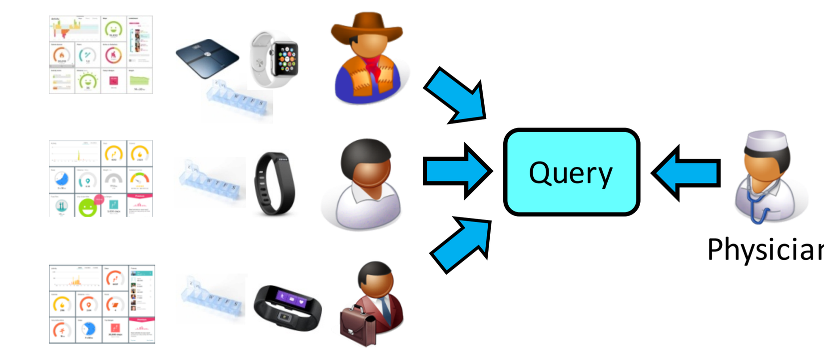
Working with Sensitive Data



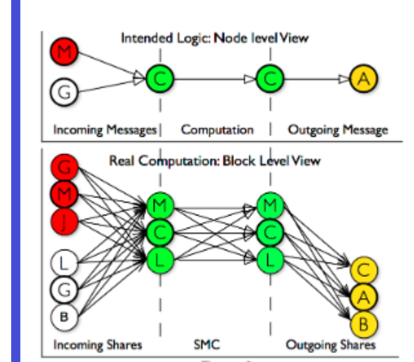
Who	What
Bob	Drug A
Charlie	Drug B
Fannie	Drug B
George	Drug A

Example: "Does drug X work better during rest periods, or during heavy exercise?"

***Problem*: Differential privacy guarantees for distributed systems while processing continuous data streams.**

Approaches

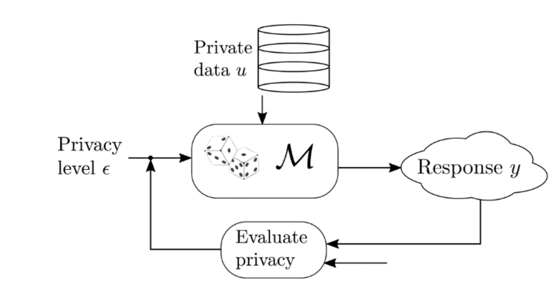
Distributed queries for differential privacy



- data never leaves user domain

Run-time differential privacy

A privacy-preserving mechanism that allows online relaxing privacy.



Security-Aware Control Design Attacks on Control Systems

Attack-Resilient State Estimation for Noisy Dynamical Systems

$$P_{0,\omega}: \min_{\bar{\mathbf{e}},\mathbf{x}} \|\bar{\mathbf{e}}\|_{l_2,l_0} \qquad P_{1,\omega}: \min_{\bar{\mathbf{e}},\mathbf{x}} \|\bar{\mathbf{e}}\|_{l_2,l_1}$$

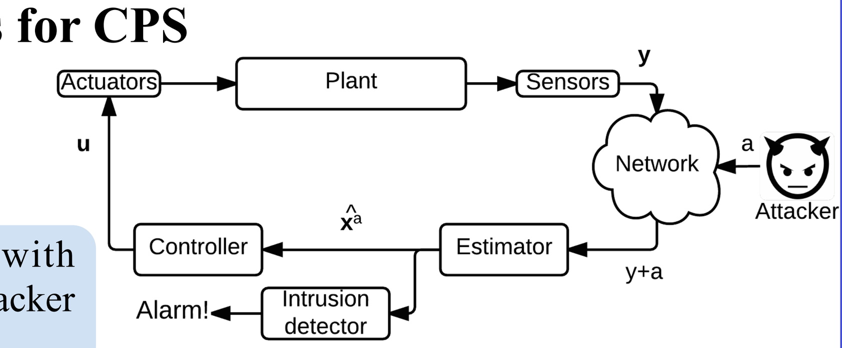
$$s.t. \quad \tilde{\mathbf{y}} - \mathbf{O}\,\mathbf{x}_0 - \bar{\mathbf{e}} = \bar{\mathbf{w}}, \quad \bar{\mathbf{w}} \in \Omega$$

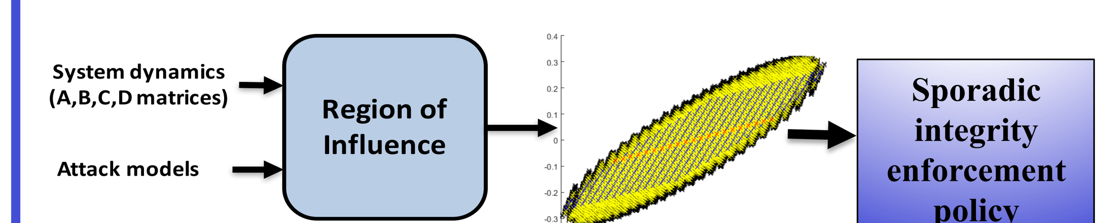
Formal robustness guarantees for the optimal l_0 and convex l_1 estimator

Relaxing Integrity Requirements for CPS

Sporadic integrity enforcement: If at step k, sensor integrity is enforced (e.g., with the use of MAC), then $\mathbf{a}_{\downarrow k} = 0$.

Theorem [Jovanov&Pajic'16]: Even with sporadic sensor integrity enforcement, the attacker cannot introduce unbounded estimation error.



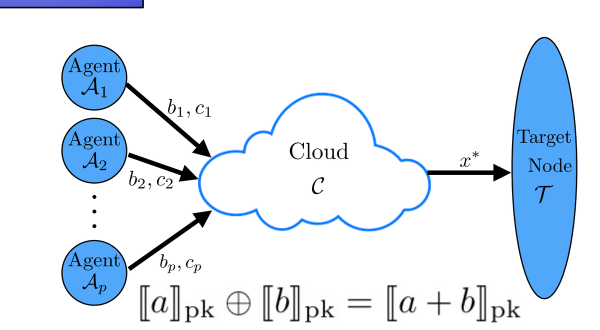


Limiting attack effects: Trajectory following study – attack induced estimation error < 5 cm when <20% of CAN packets contain MAC

Optimization and Control using Partially Homomorphic Encryption

Privacy-aware cloud-based optimization over sensitive data:

- Agents encrypt information before sending to untrusted cloud
- Cloud computes optimal solution **without learning** the **sensitive data** or the **final solution**



$$[\![a]\!]_{pk} \oplus [\![b]\!]_{pk} = [\![a+b]\!]_{pk}$$