PECAM: Privacy-Enhanced Video Streaming and Analytics via Securely-Reversible Transformation

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[2]*Cornell University*

[3]*Microsoft Research*

[4]*Microsoft Azure for Operators*

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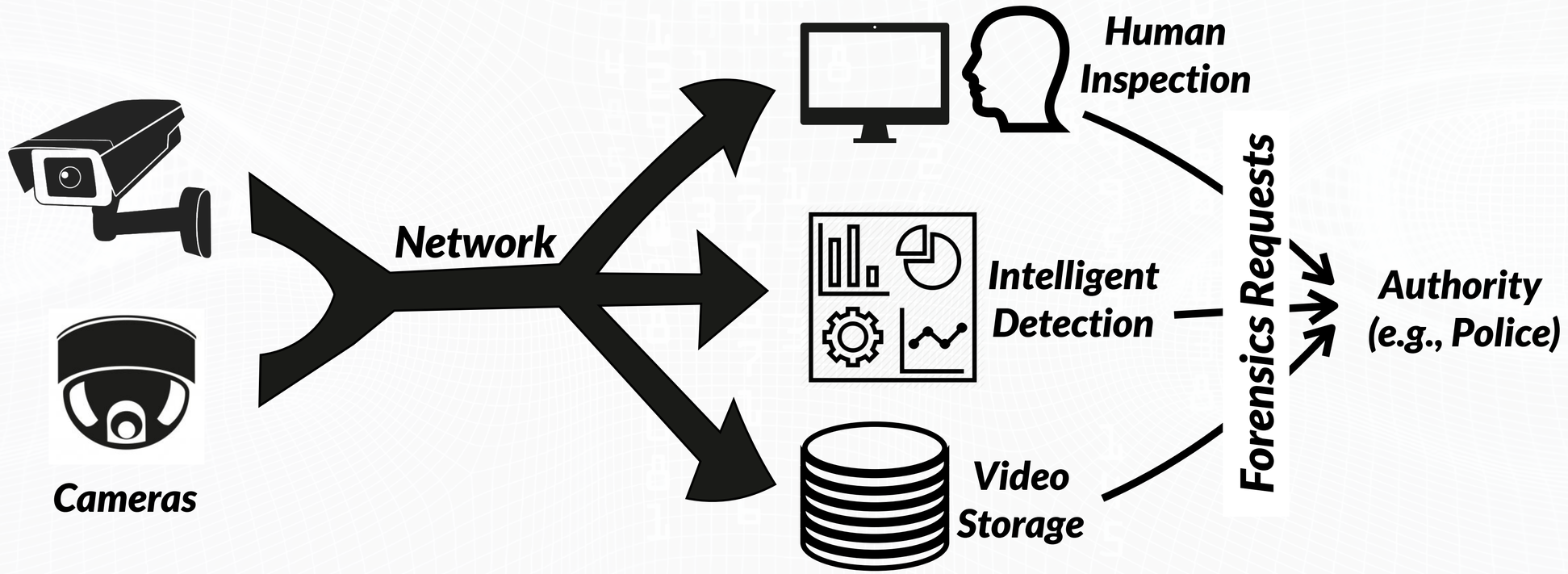
VSA brings privacy concerns



A typical Video Streaming & Analytics (VSA) system.

Laws and regulations about data protection

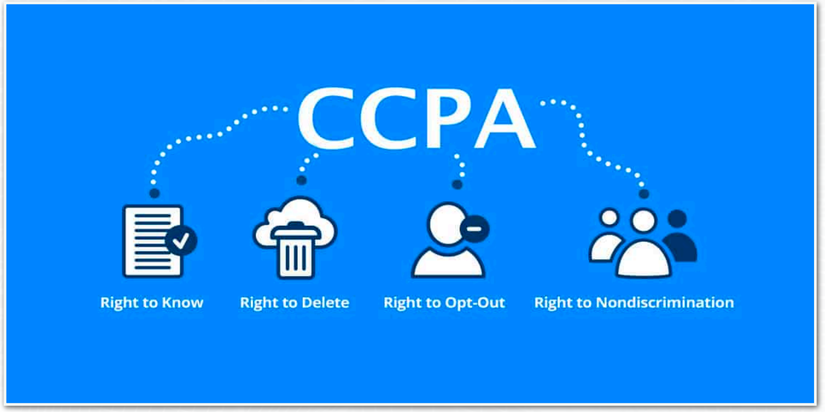

Proposal for a

REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

LAYING DOWN HARMONISED RULES ON ARTIFICIAL INTELLIGENCE (ARTIFICIAL INTELLIGENCE ACT) AND AMENDING CERTAIN UNION LEGISLATIVE ACTS

{SEC(2021) 167 final} - {SWD(2021) 84 final} - {SWD(2021) 85 final}

EU's Laying Down Harmonised Rules on AI and Amending Certan Union Legislative Acts



California Consumer Privacy Act (CCPA)

EU's GDPR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The National People's Congress of the People's Republic of China
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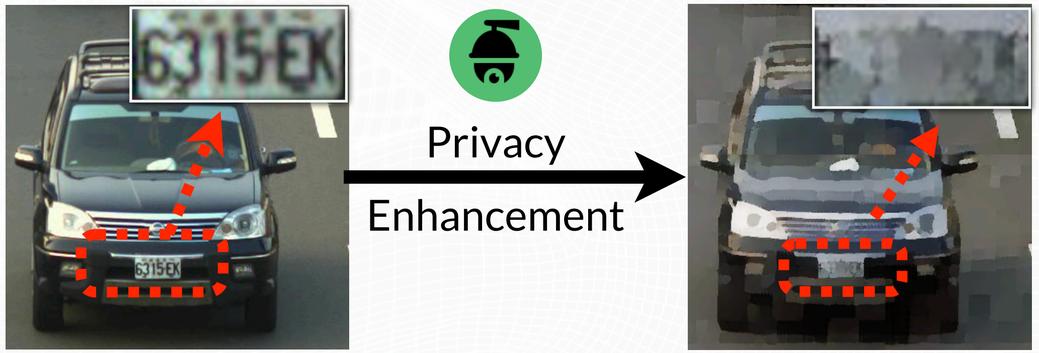
中华人民共和国数据安全法
(2021年6月10日第十三届全国人民代表大会常务委员会第二十九次会议通过)

Data Security Law (DSL) of the People's Republic of China

Privacy Protection Requirements

A case in the traffic scenario:



Original frame

Protected frame

Privacy Protection Requirements

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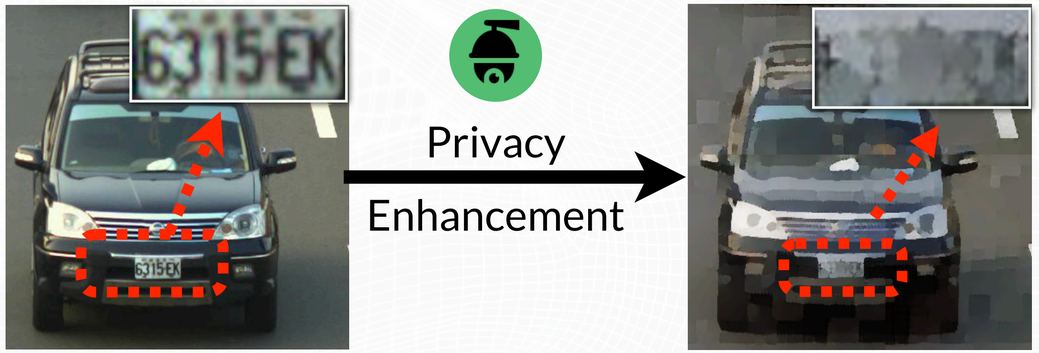

Original frame

Protected frame

Network

Backend: human inspection, automated analytics.

Privacy Protection Requirements

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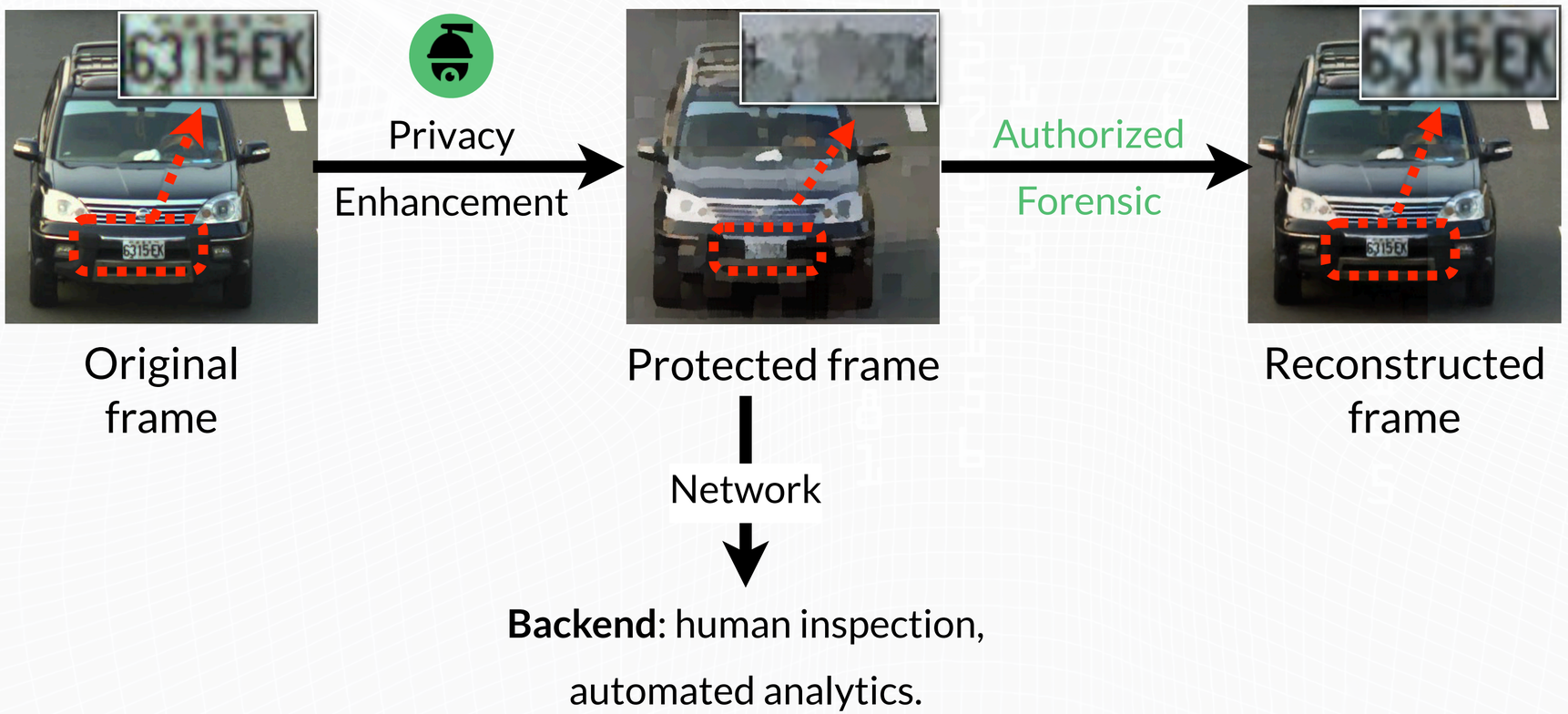

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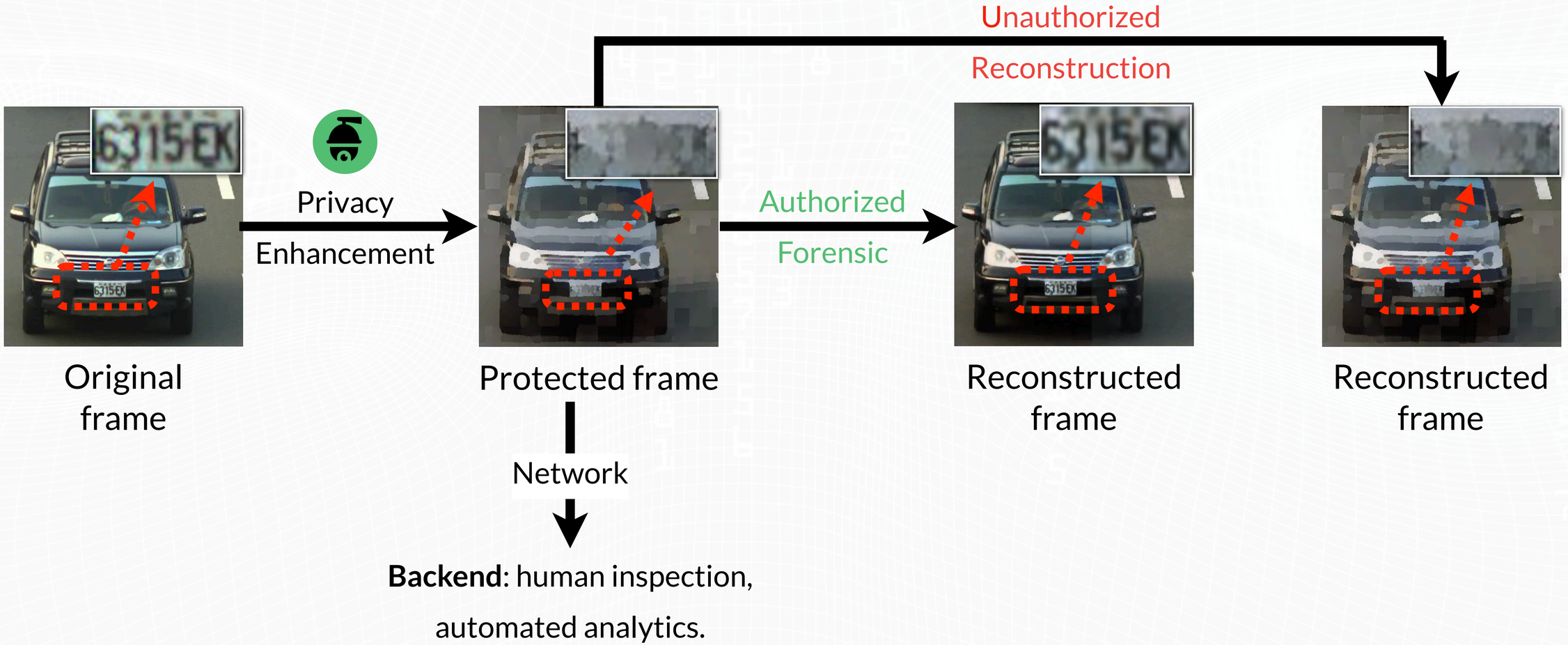

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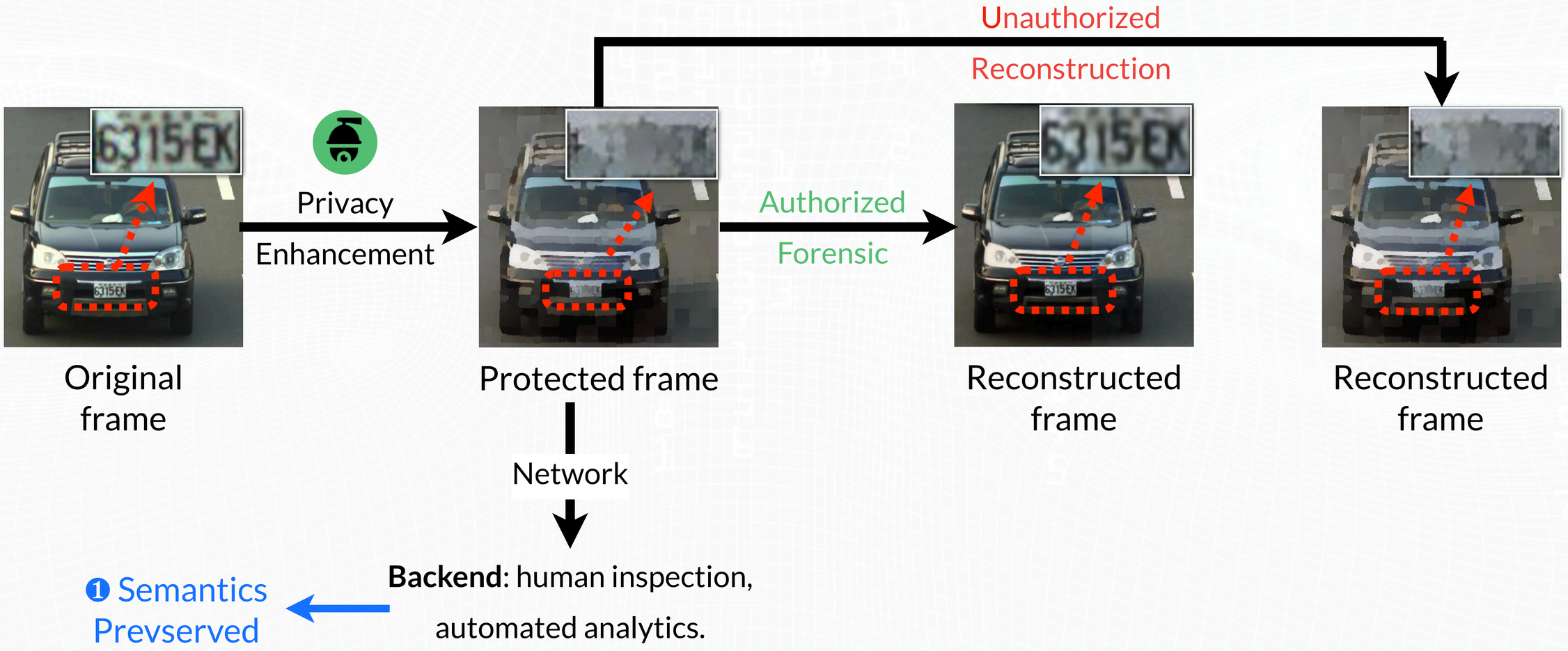

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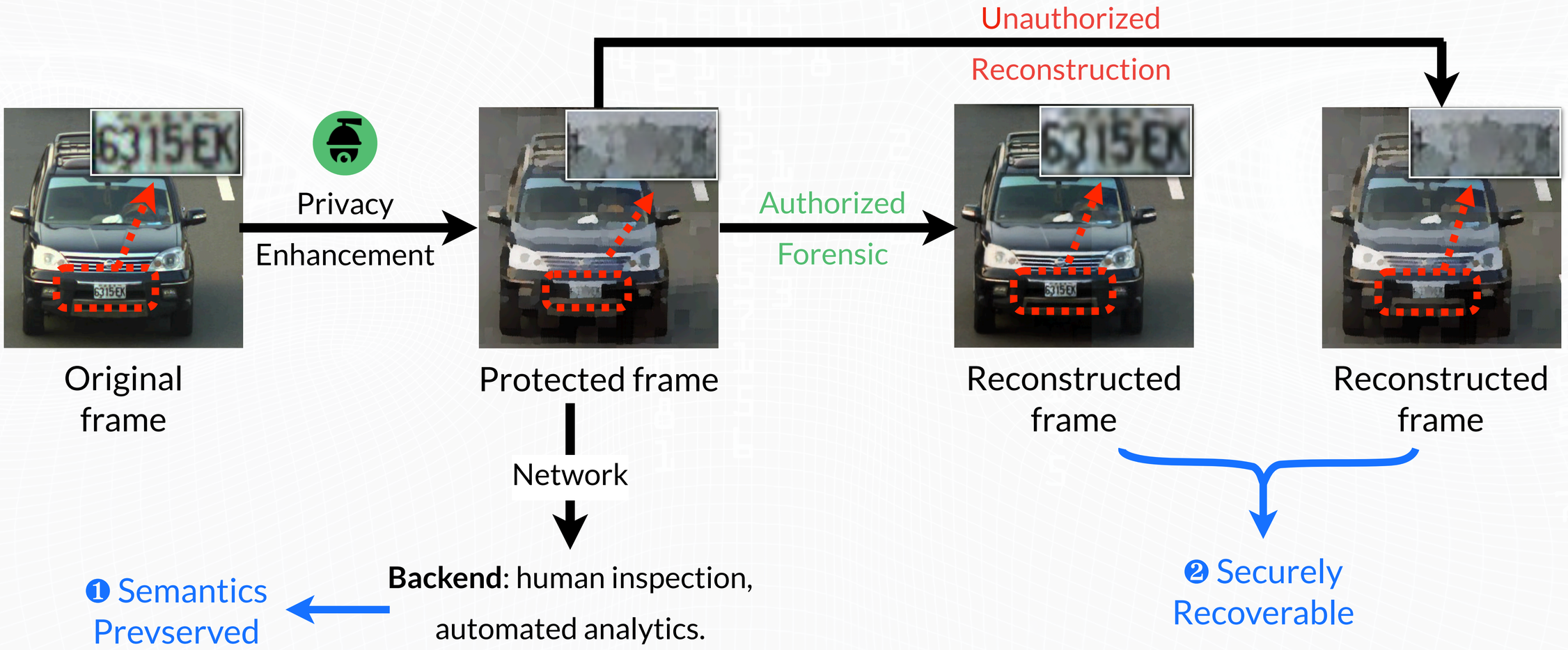

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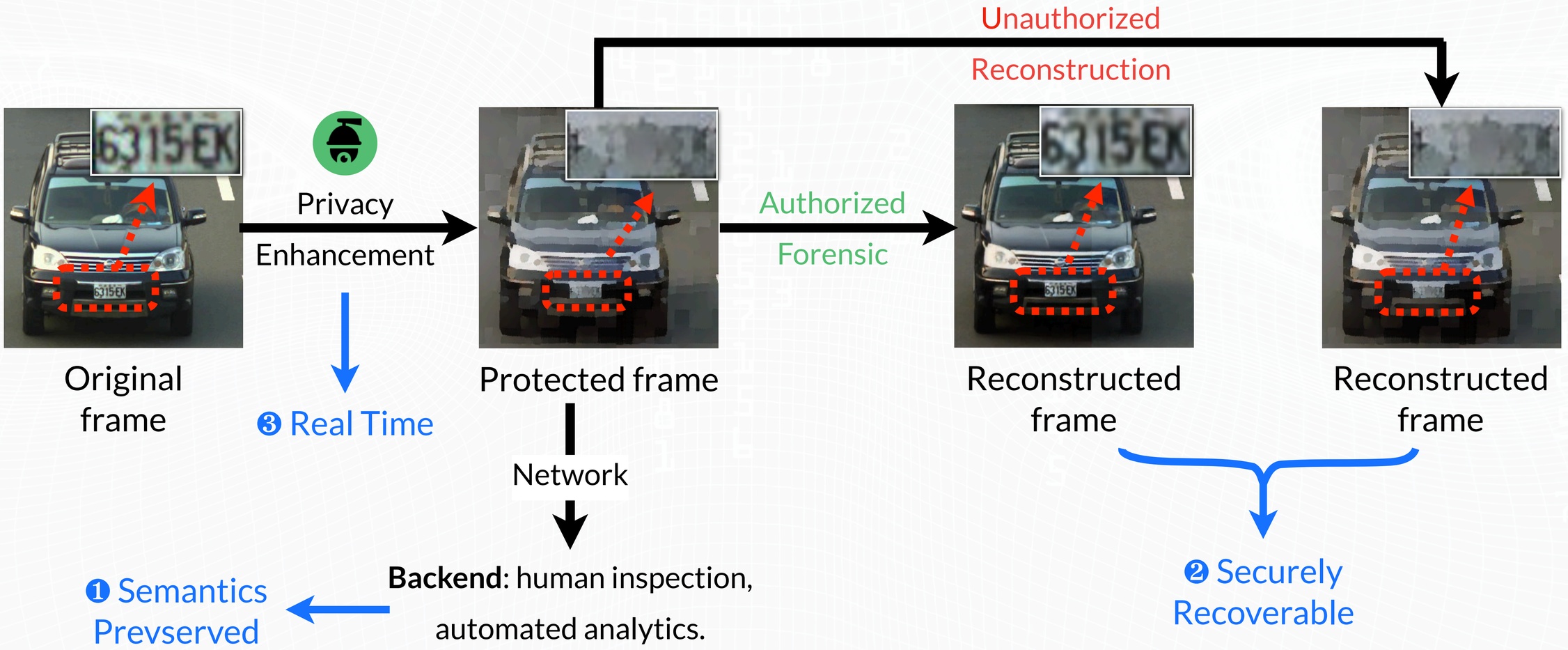

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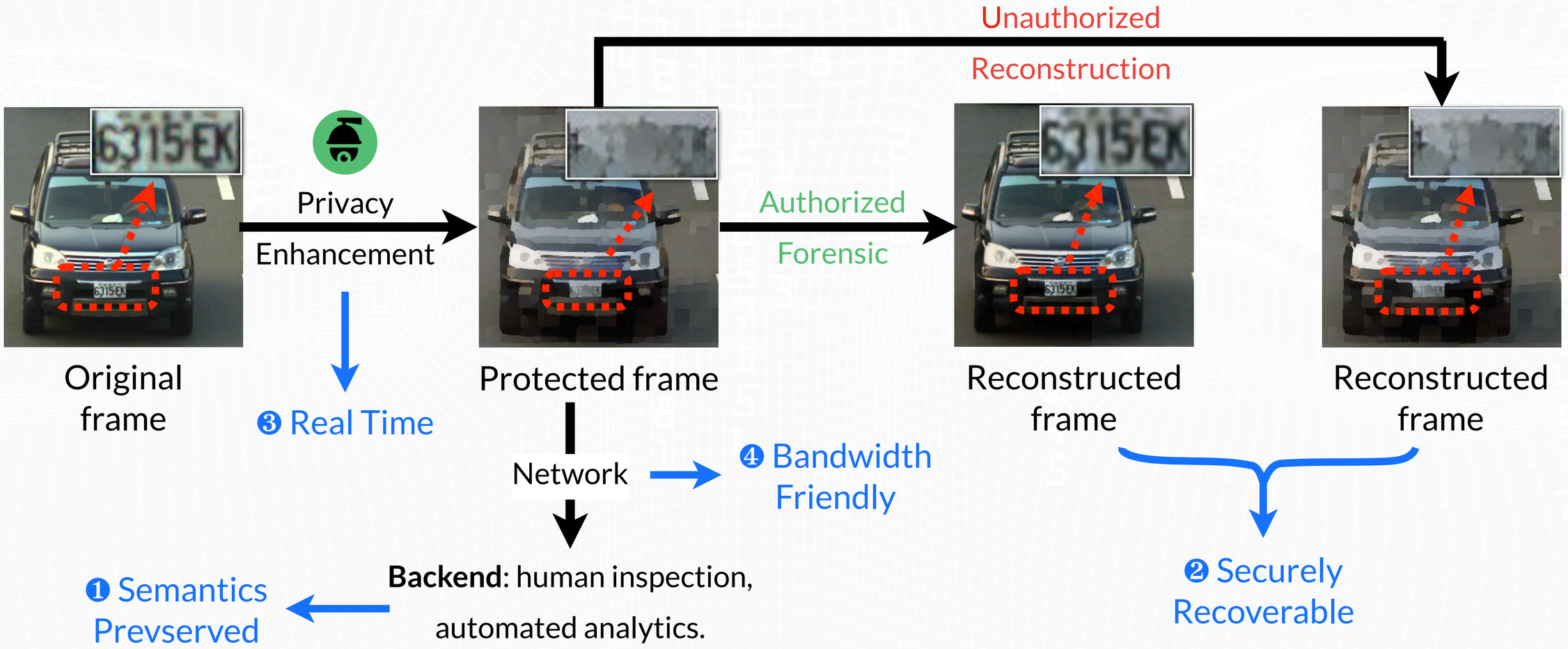
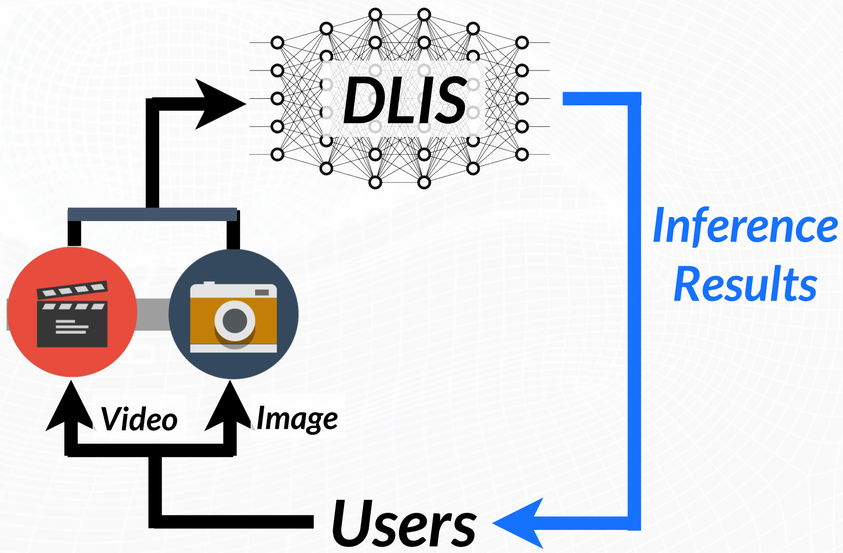


Privacy protection efforts on visual data in DL scenario.



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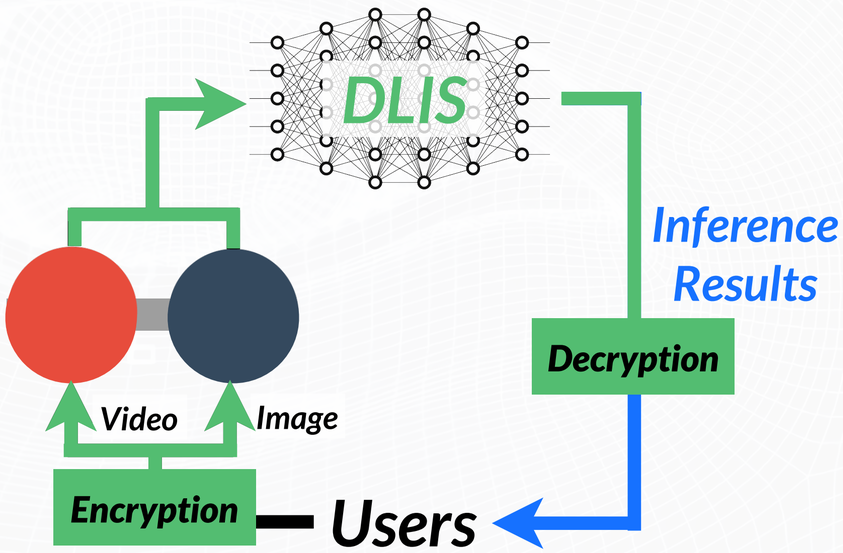

		Usability		Effectivness		Scenario
		Deployment costs	*User Experience*	Protection Effect	Security	
HE-based solution		✗	✗	✓	✓	◎
TEE-based solution		✗	◎	✓	✓	◎
Model partition-based solution		✗	✓	◎	◎	◎
Input transformation-based solution	ROI Removal	✓	◎	◎	✓	✓
	Non-adaptive Noise	✓	◎	◎	◎	✓
	Scenario-adaptive Transformation	✓	✓	✓	✓	✓

✓ *yes*, ✗ *no*, ◎ *partial*

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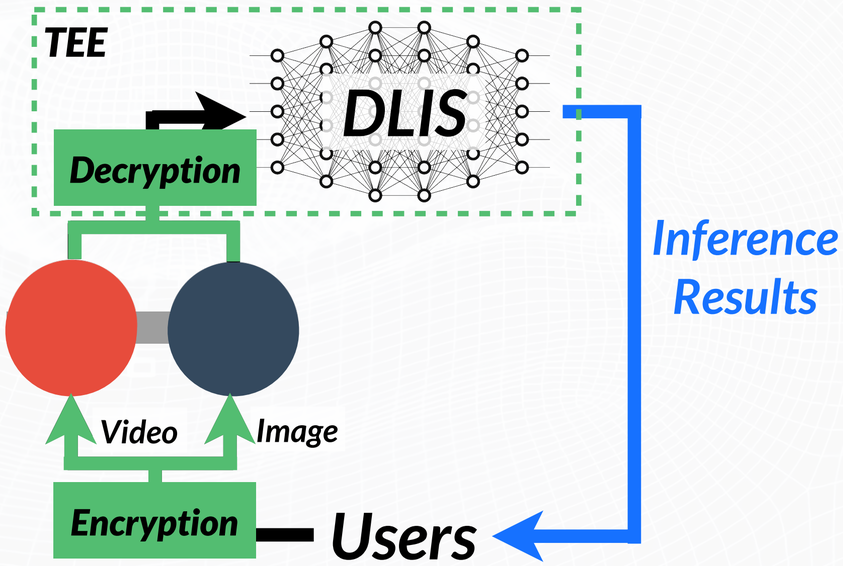

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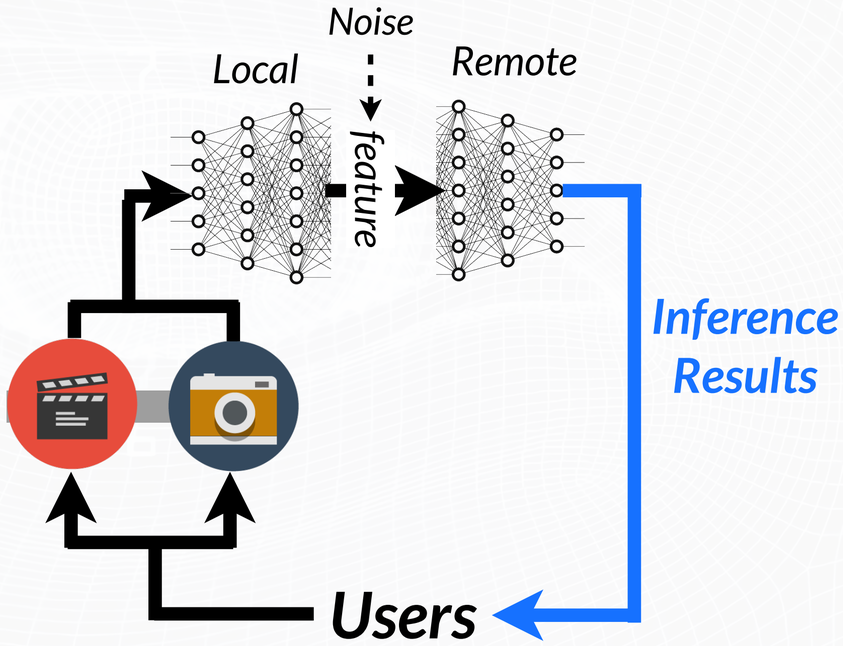

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Input transformation-based solution

ROI Removal

→ *(manully) define, find, and remove privacy info*

Non-adaptive Noise

→ *Drop information accorrding to data distribution*

Scenario-adaptive Transformation 1

→ *(automatically) define, find, and remove privacy info*

Scenario-adaptive Transformation 2

→ *Remove task unrelated info as much as possible*

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Privacy Protection VS Forensic Collection

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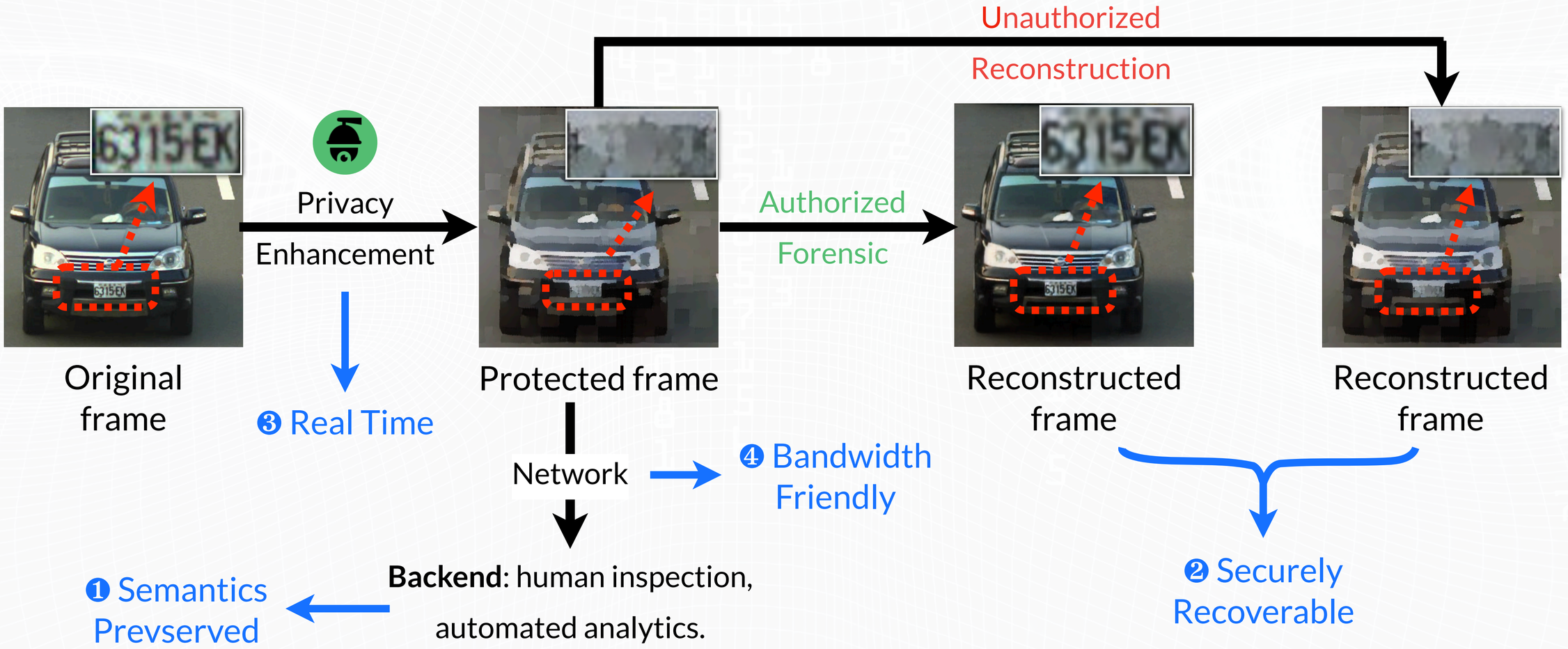
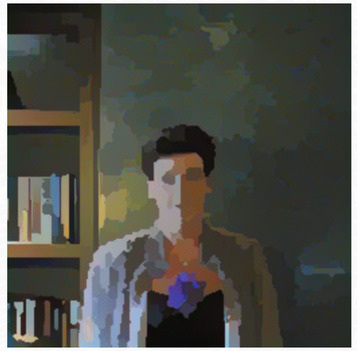
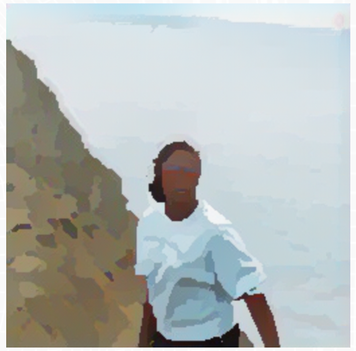


Technology 1: Semantic-preserved privacy protection

1: Determine Style **Video Analytics** *(People Tracking、People/Car Counting、Fall Detection)*

↓

Remove instance-level information, e.g., texture; Preserve category-level information, e.g., shape and color;
Maintain semantic information.e.g, spatial and pose information.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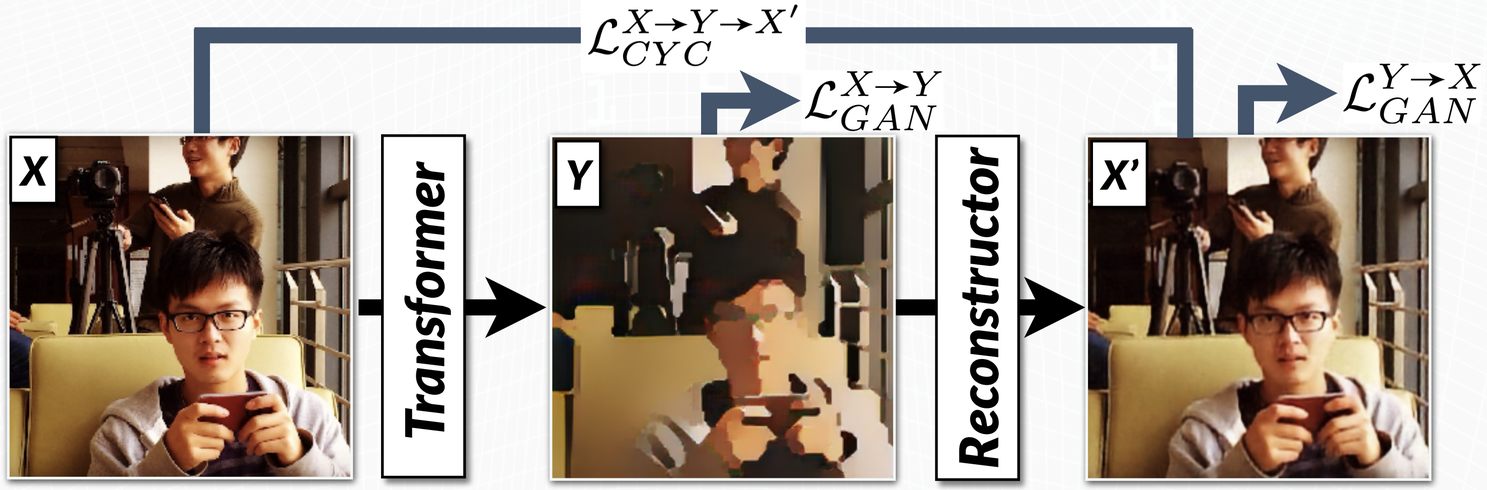
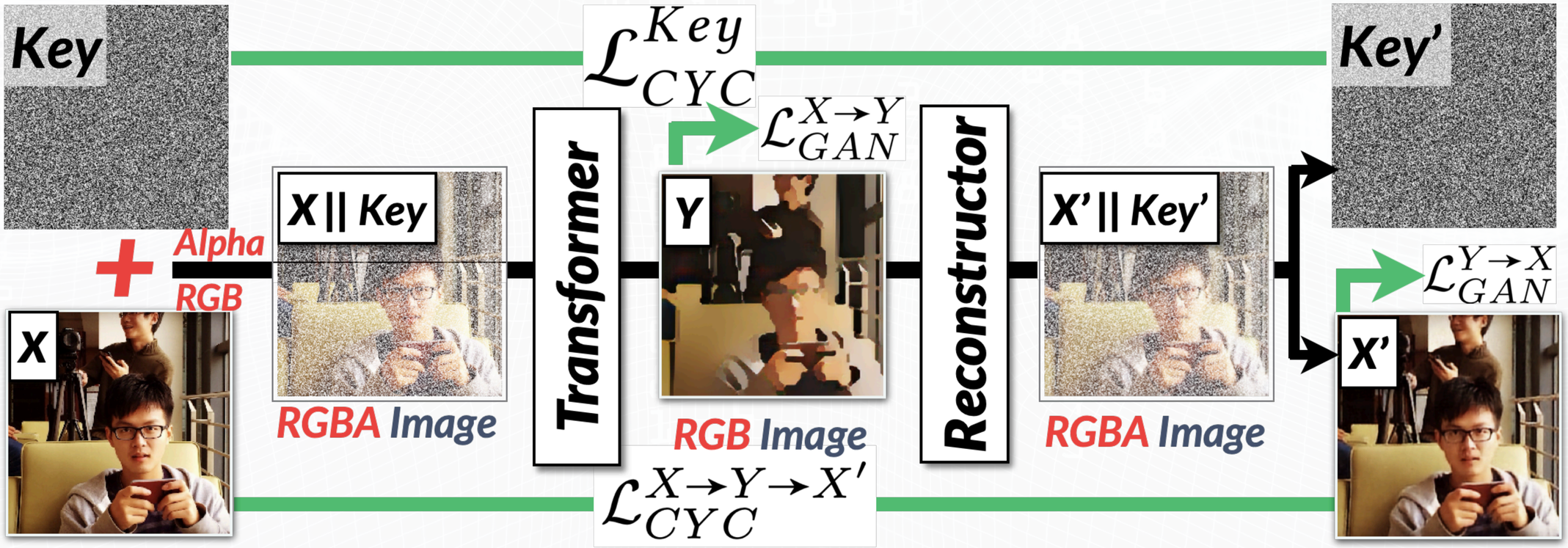
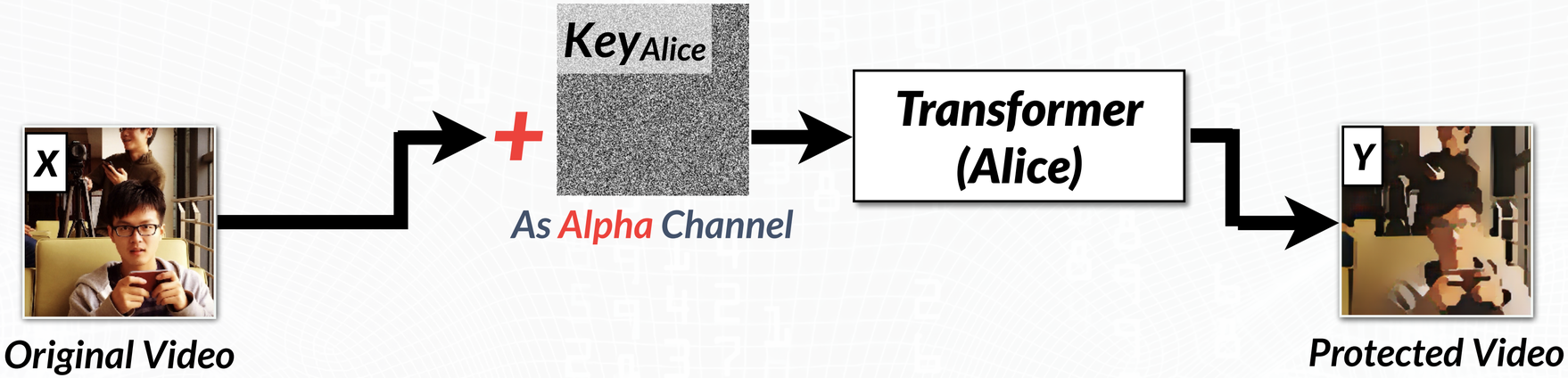
2: Learn Style



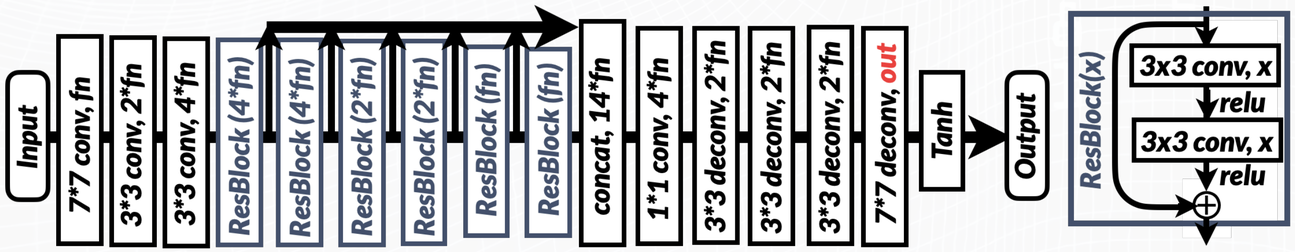
Technology 2: Securely-recoverable style transformation



Technology 3: Real-time protection with limited resources



The workflow of the protection procedure.



1: Litewight Network

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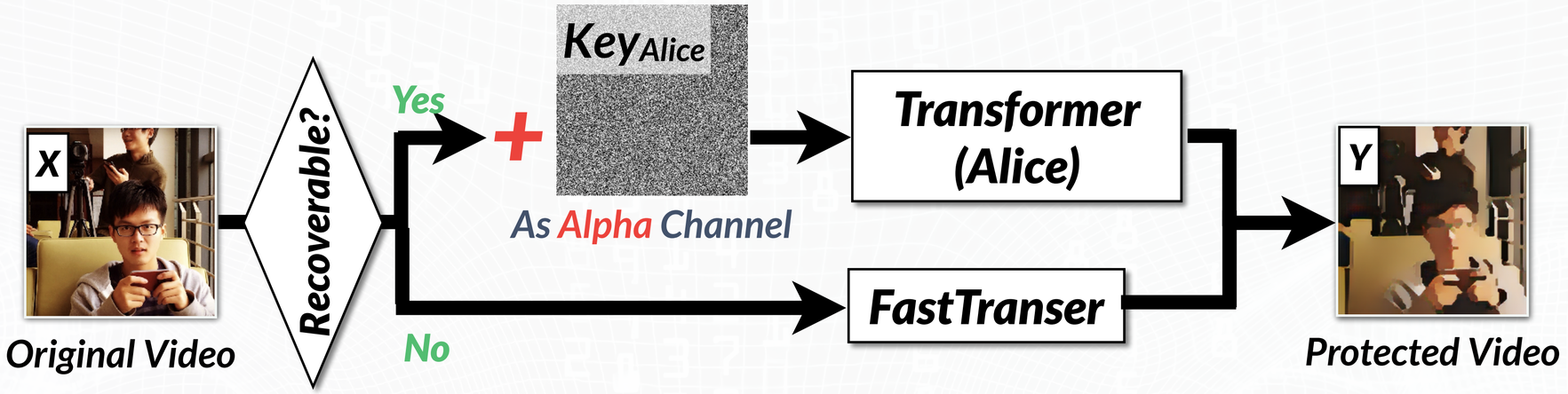

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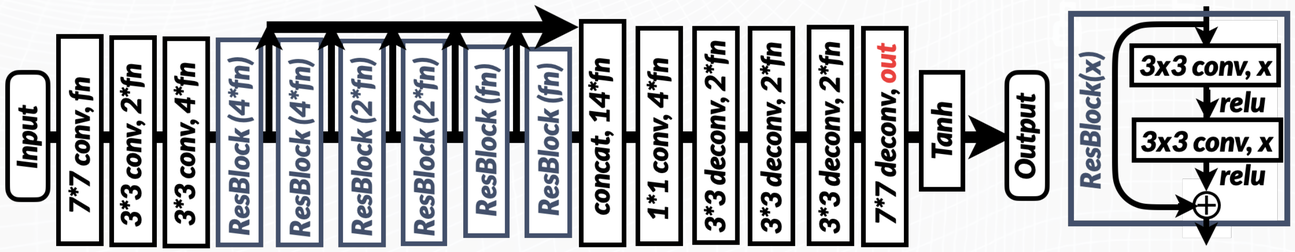

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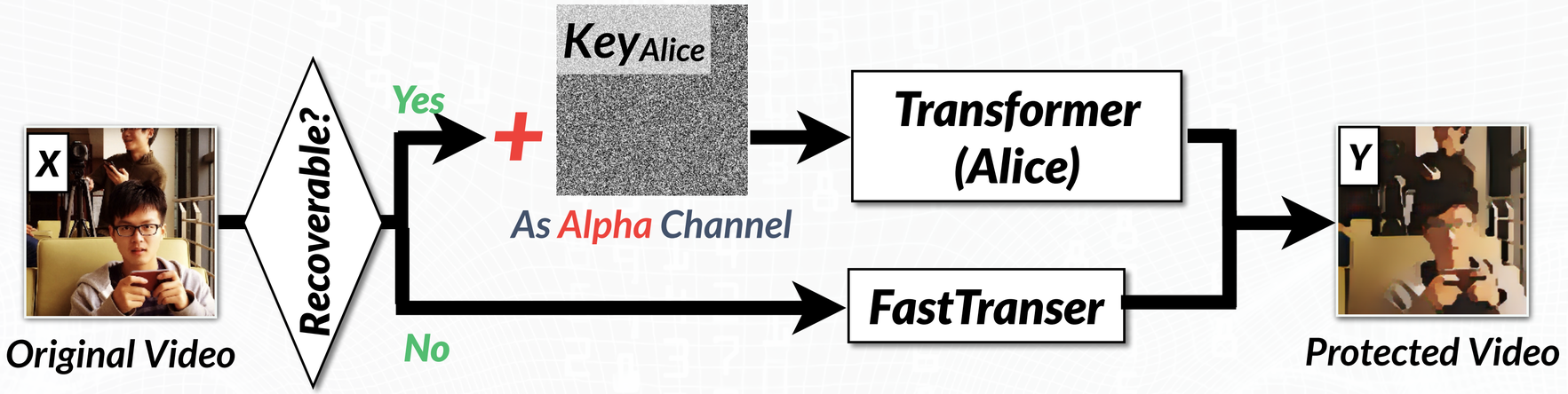

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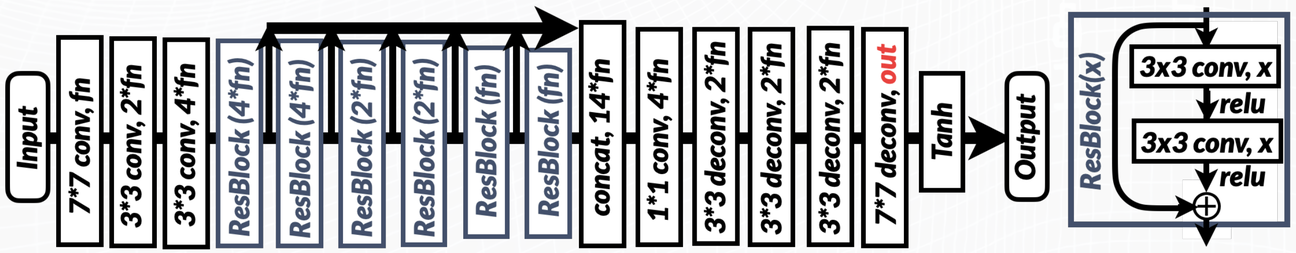

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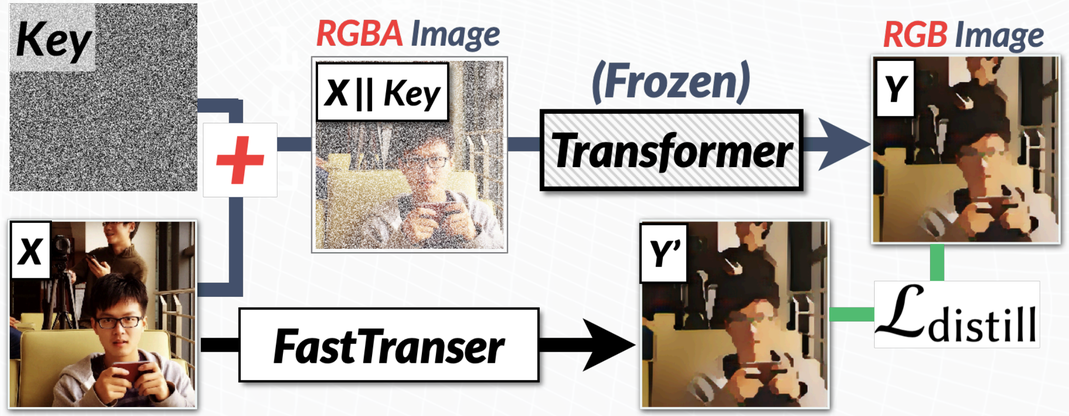
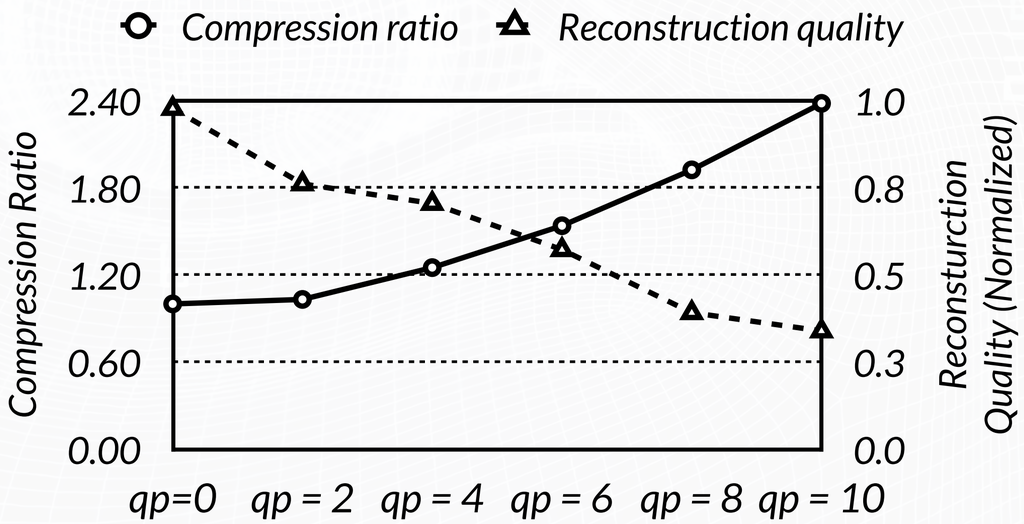


2: Fast transformer

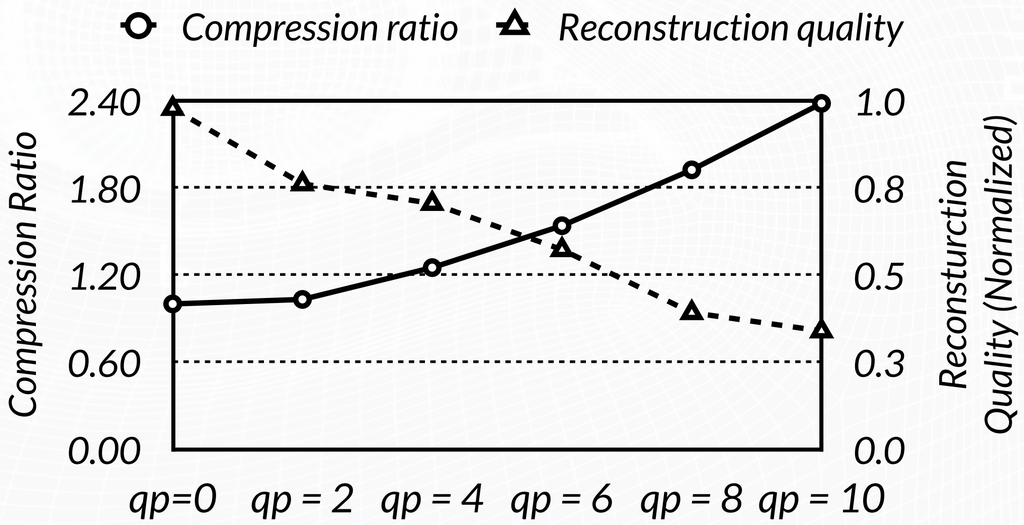
Technology 4: Bandwidth Usage Friendly Video Codec



Directly using the H.264 codec to compress the transformed frames generated by Transformer significantly reduces the reconstruction's quality.

Technology 4: Bandwidth Usage Friendly Video Codec

1: Losslessly and lossy encode the frames, adaptively.



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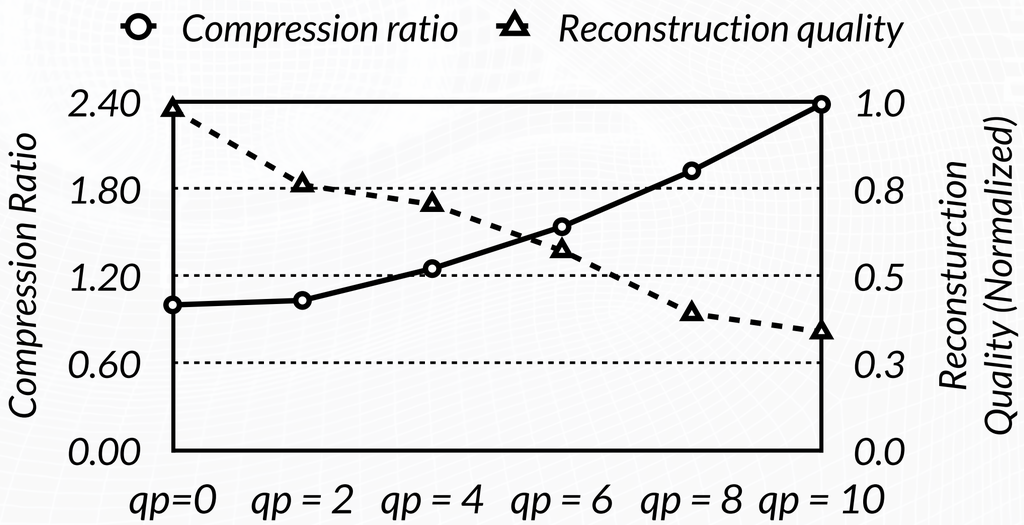

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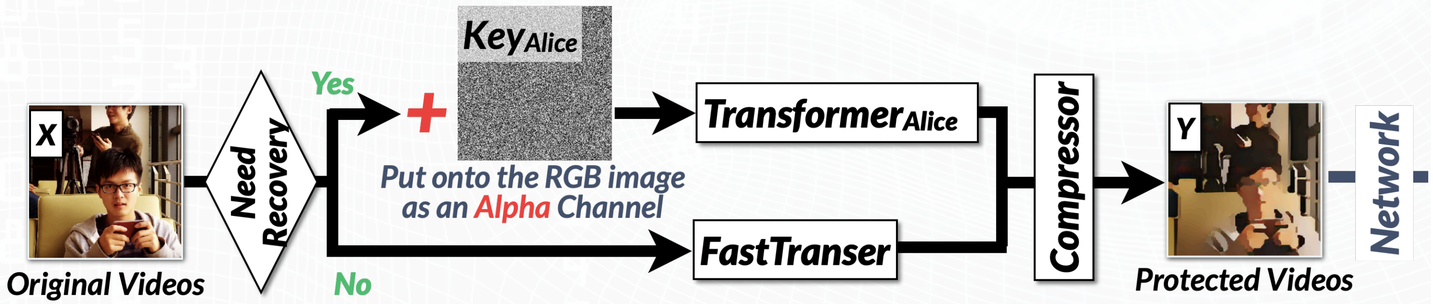
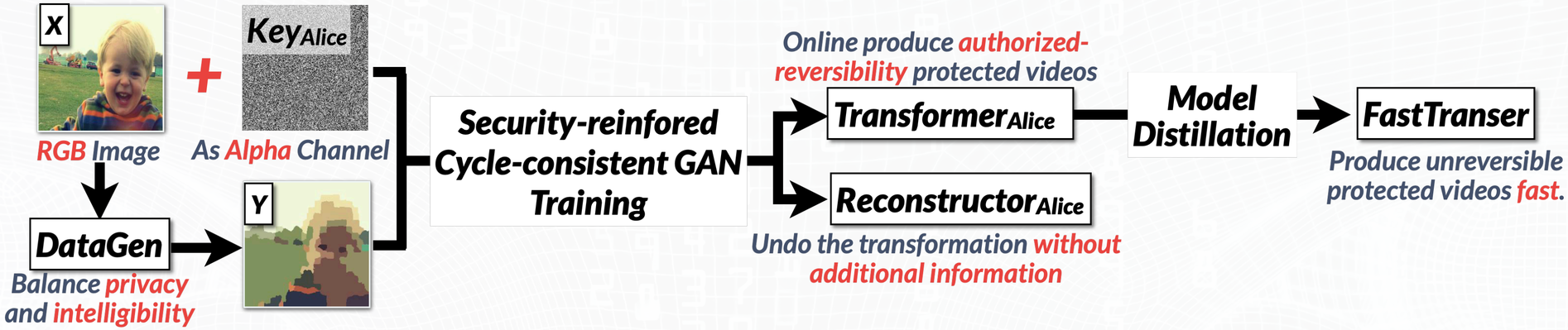
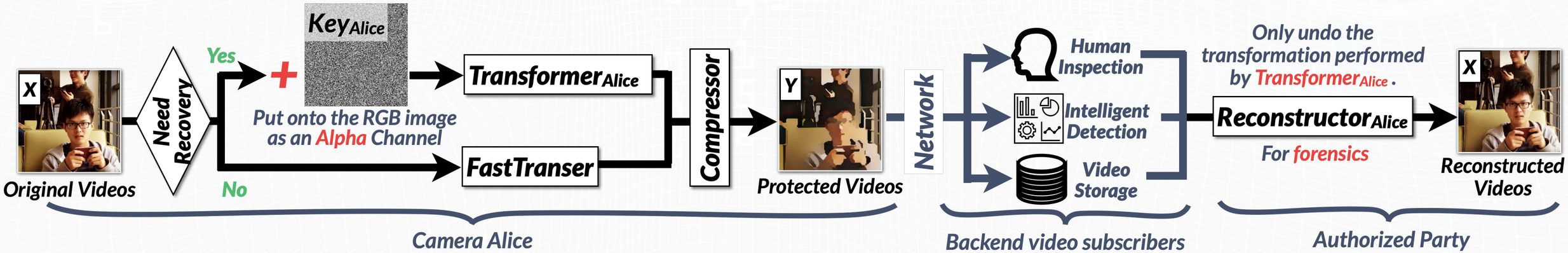


The video encoding procedure.

PECAM's workflow



(a) Preparation Stage of PECAM System.



(b) In-use Stage of PECAM system.

Is it much more difficult for an adversary to reverse the transformation?

Attacker1: *The adversary ignores the existence of secret and attempts to train an RGB-2-RGB transformation.*

Attacker2: *The adversary randomly chooses a secret to train another PECAM reconstructor.*

Attack results.

Evaluations

1. **Sematic maintaince:**

   Up to **96%** that of the original video.

2. **Privacy enhancement:**

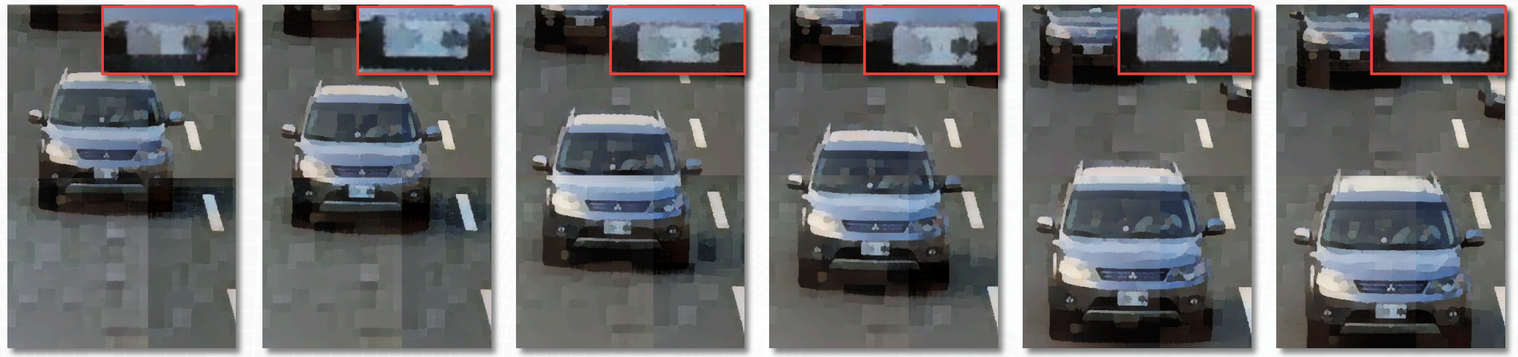
   Neither be **directly extracted** nor **indirectly reconstructed**.

3. **Bandwidth usage:**

   The bandwidth efficiency is **1.8x** that of H.264.

4. **System performance:**

   Run in **real time** , **12.3x** and **46.8x** that of baseline.



The PECAM-enabled frames in traffic monitoring scenario.

The PECAM-enabled frames in indoor monitoring scenario.

DEMO

Orignal video
(People Detection & Face recognition)

Transformed video
(People Detection)

Transformed video
(Face recognition)

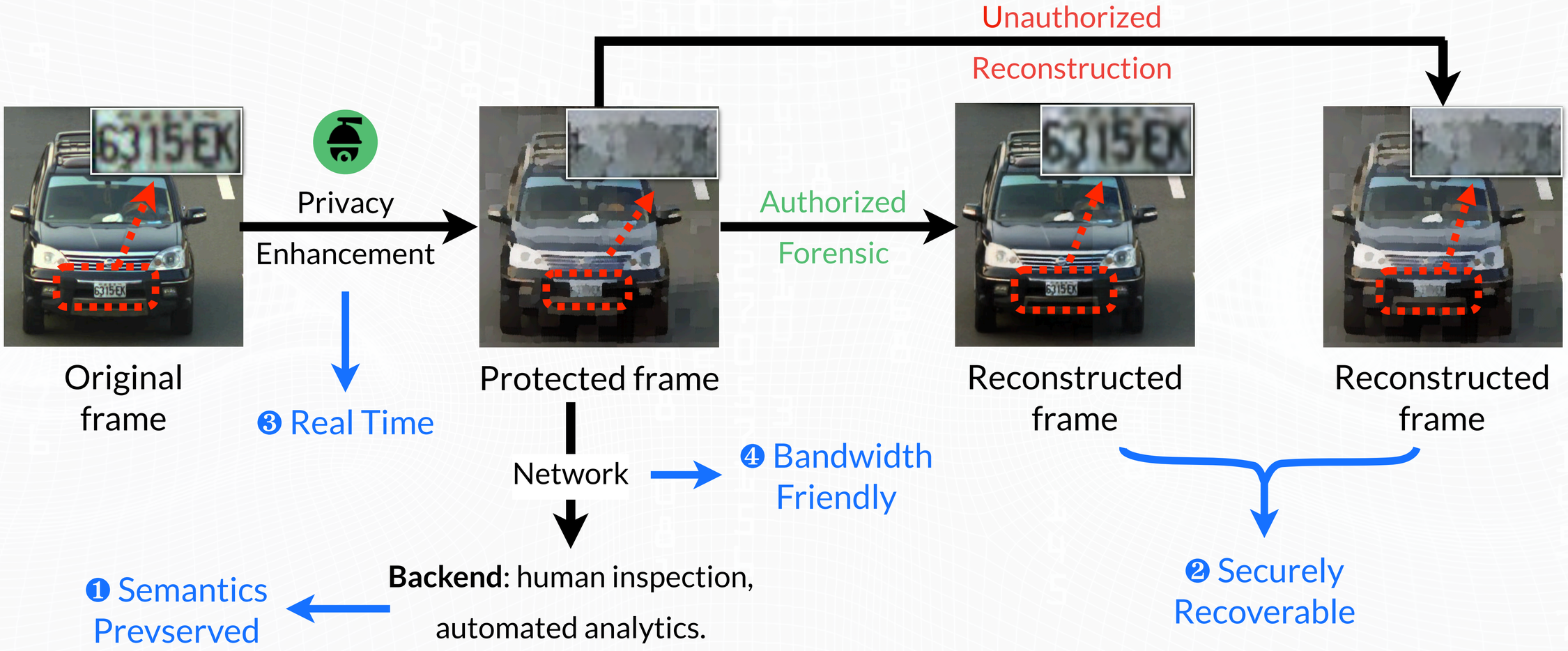
DEMO

Orignal video
(People Detection & Face recognition)

Transformed video
(People Detection)

Transformed video
(Face recognition)

Take away



Thanks!