CCCP: Secure Remote Storage for Computational RFIDs

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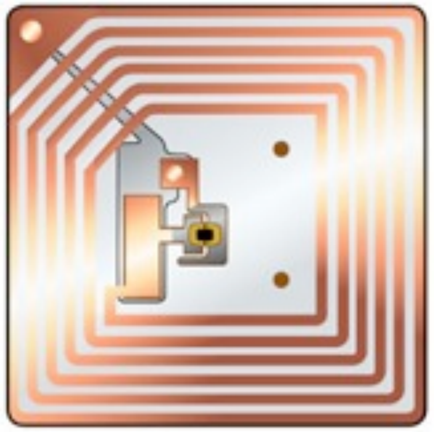
(RSA)

The Security Division of EMC

NSF-627529

RFID tags

RFID tags



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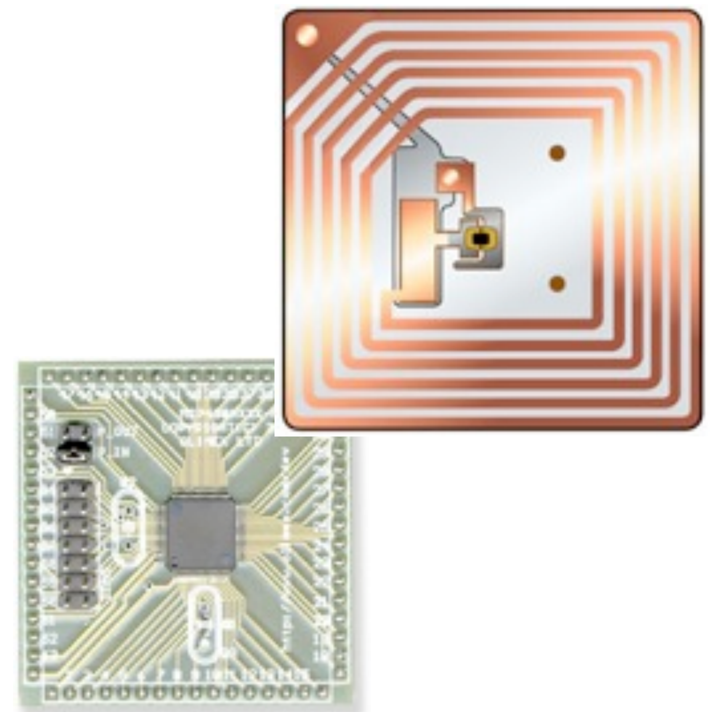

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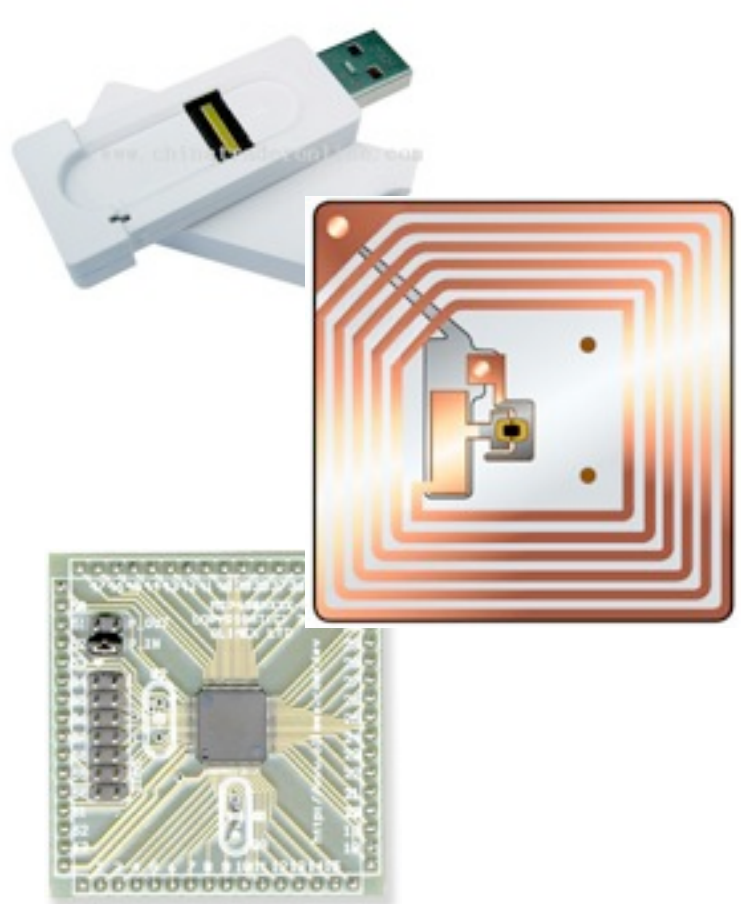
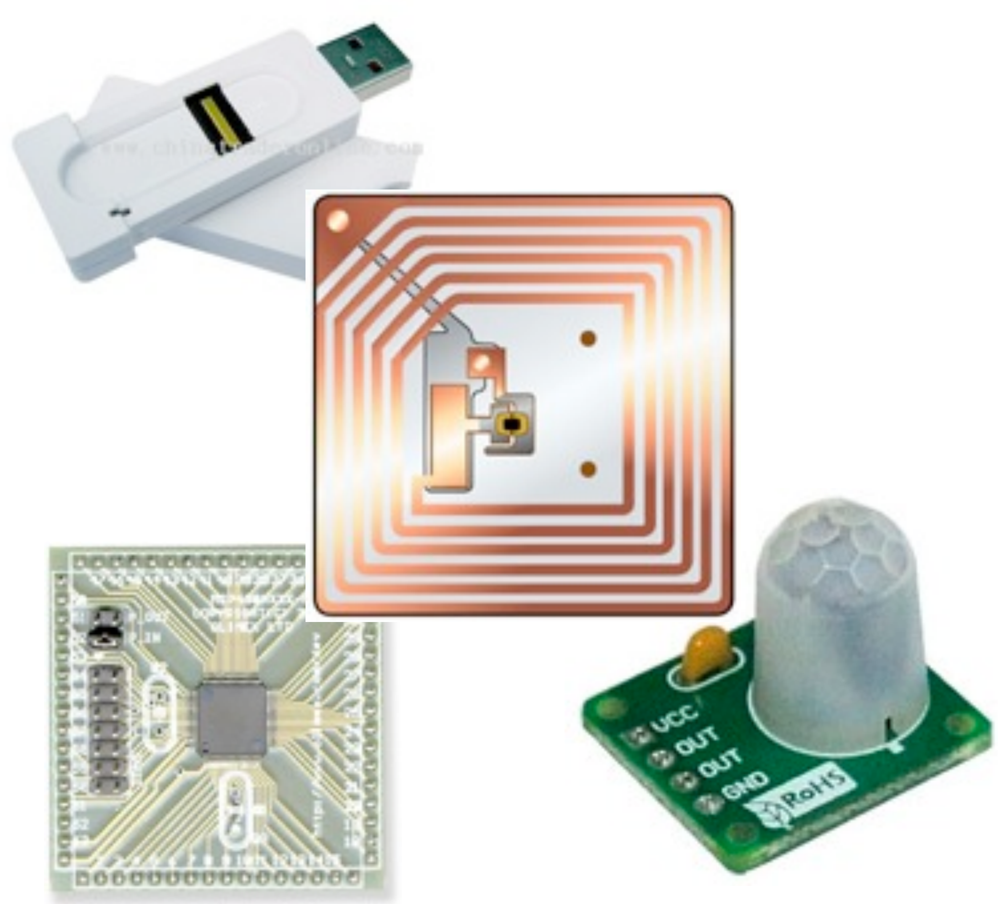
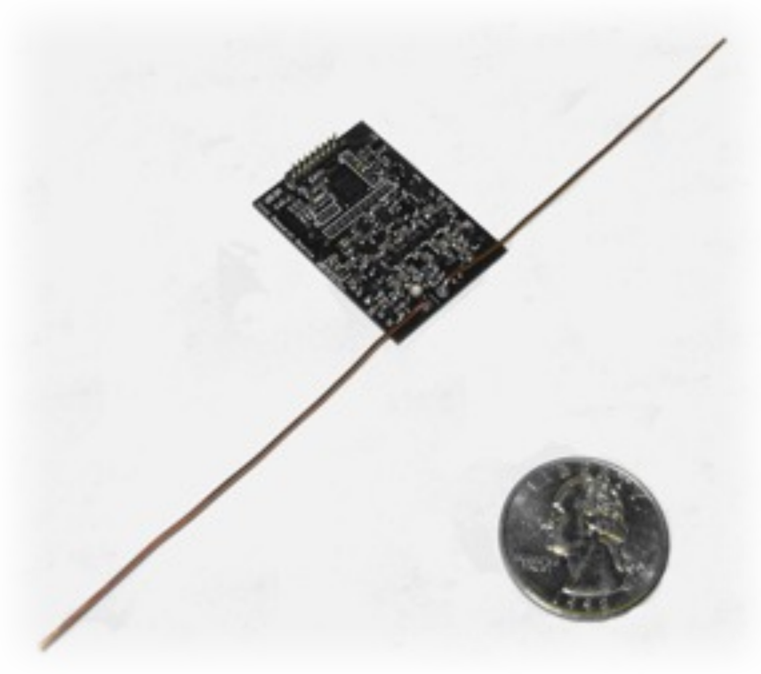


Computational RFID tags



CRFIDs

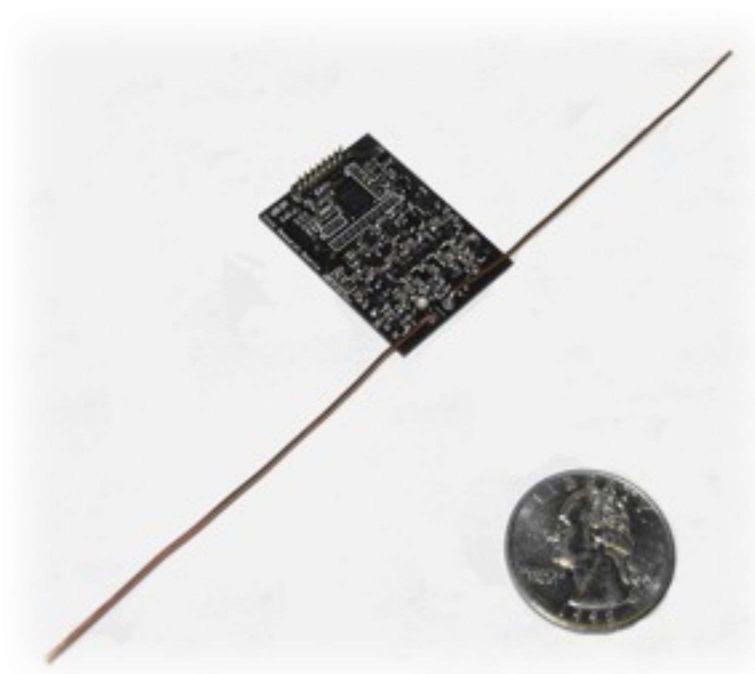
- Batteryless
- Powered by harvested energy
- Interact with RFID readers
- Programmable



WISP 1.0

CRFIDs

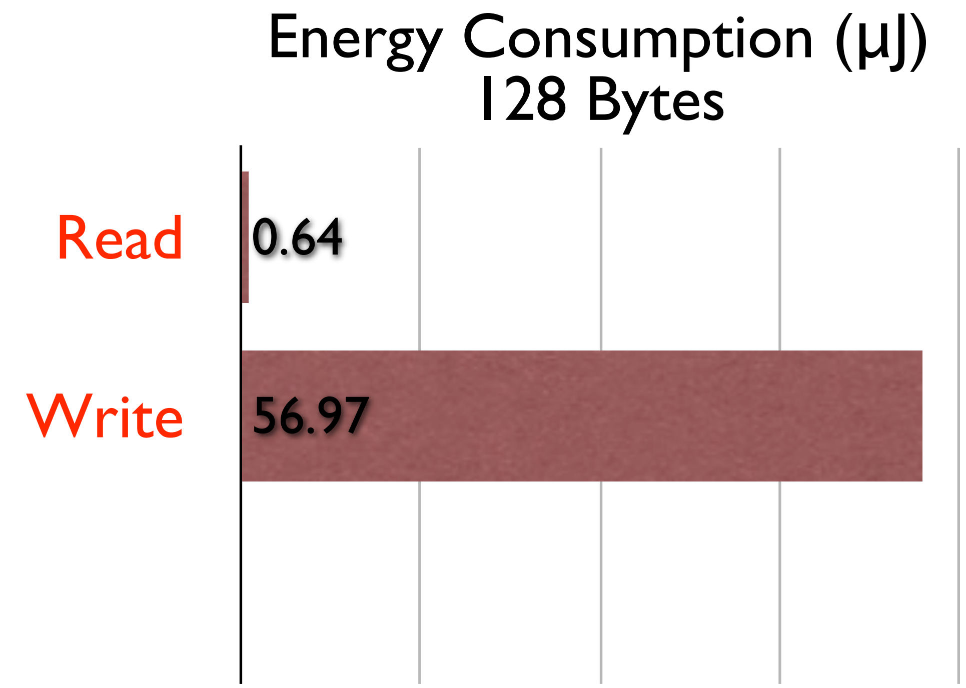
- Tiny energy reservoir
- Frequent power loss
- Limited use of local storage



WISP 1.0

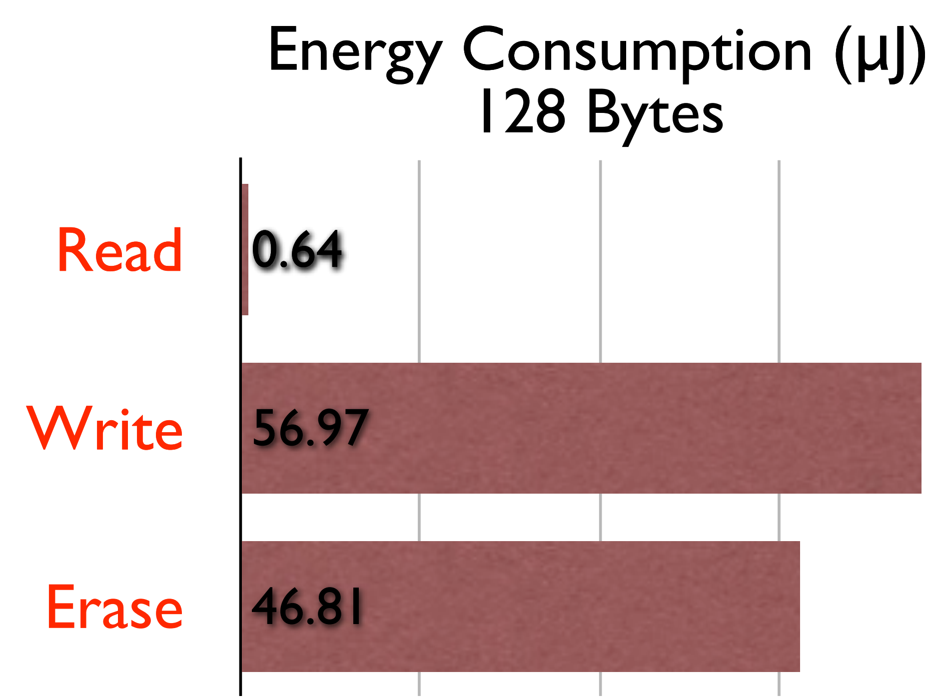
Local Storage... at a Price

- Energy intensive writes



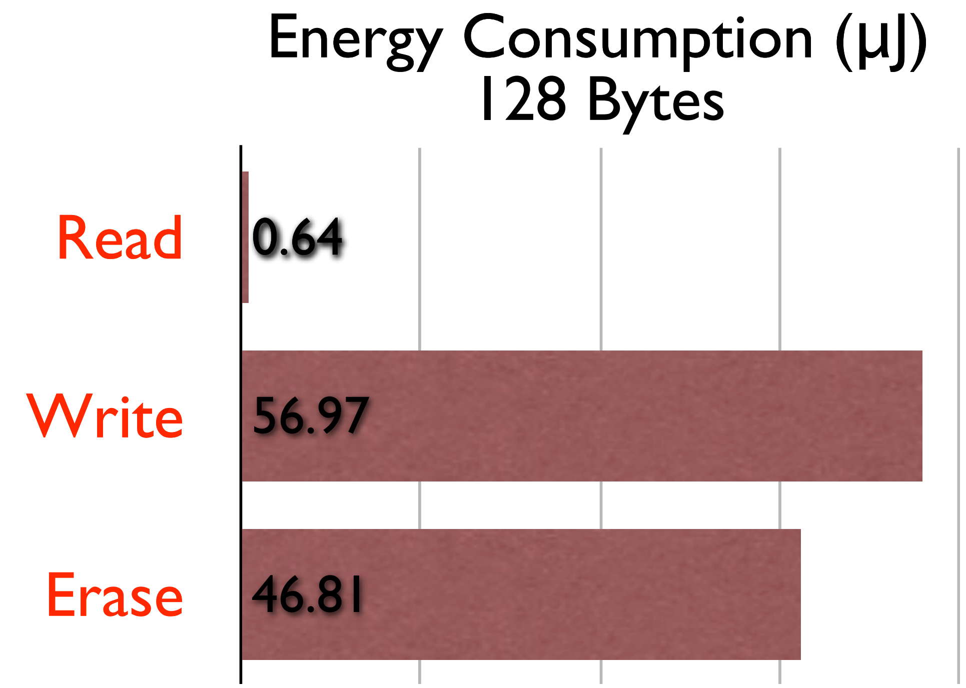
Local Storage... at a Price

- Energy intensive writes
- Erase-before-write

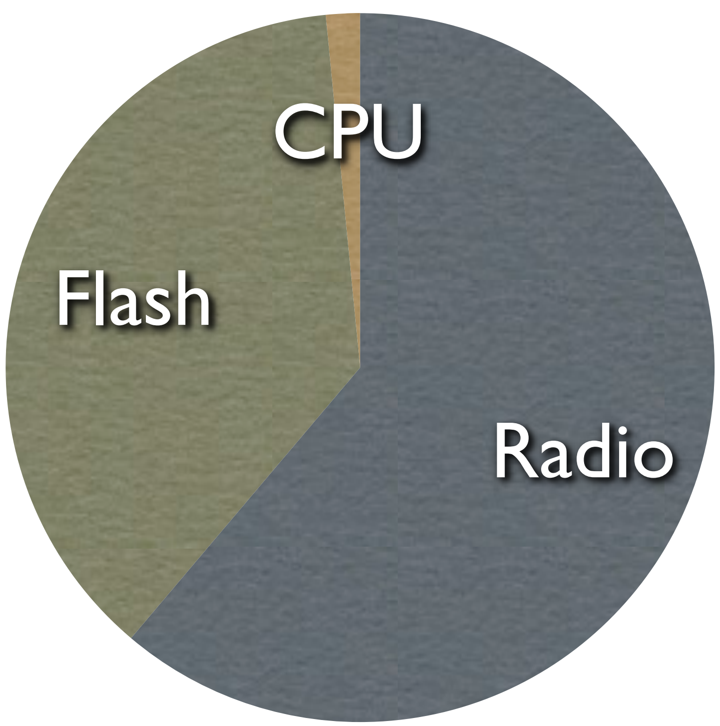


Local Storage... at a Price

- Energy intensive writes
- Erase-before-write
- Small nonvolatile memory
  - WISP 4.0: 32 KB flash

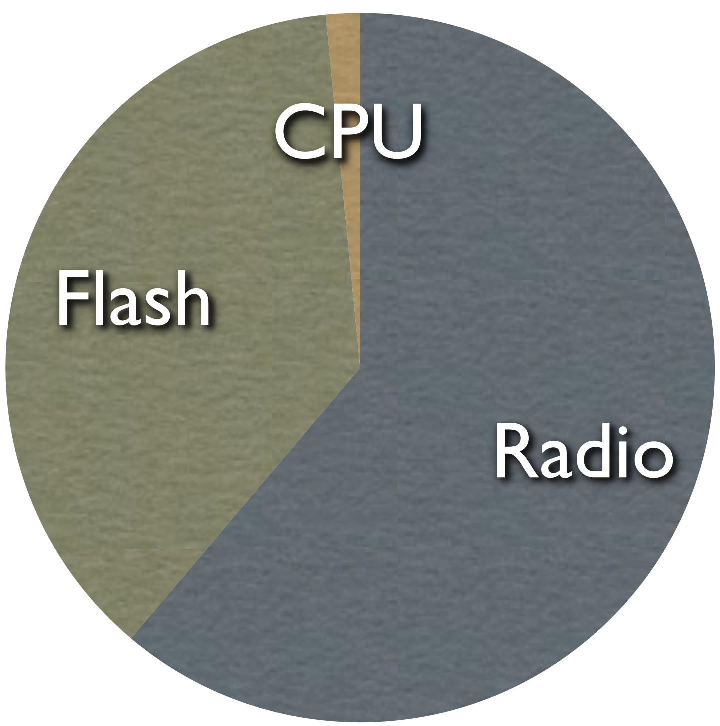


Inexpensive Radio



Mote
[Hydrowatch]

Inexpensive Radio



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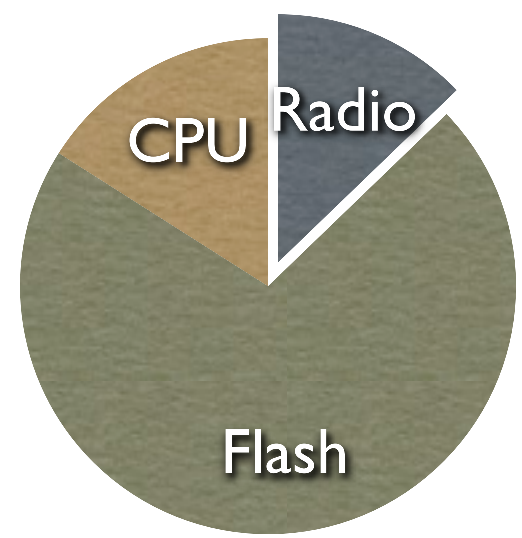
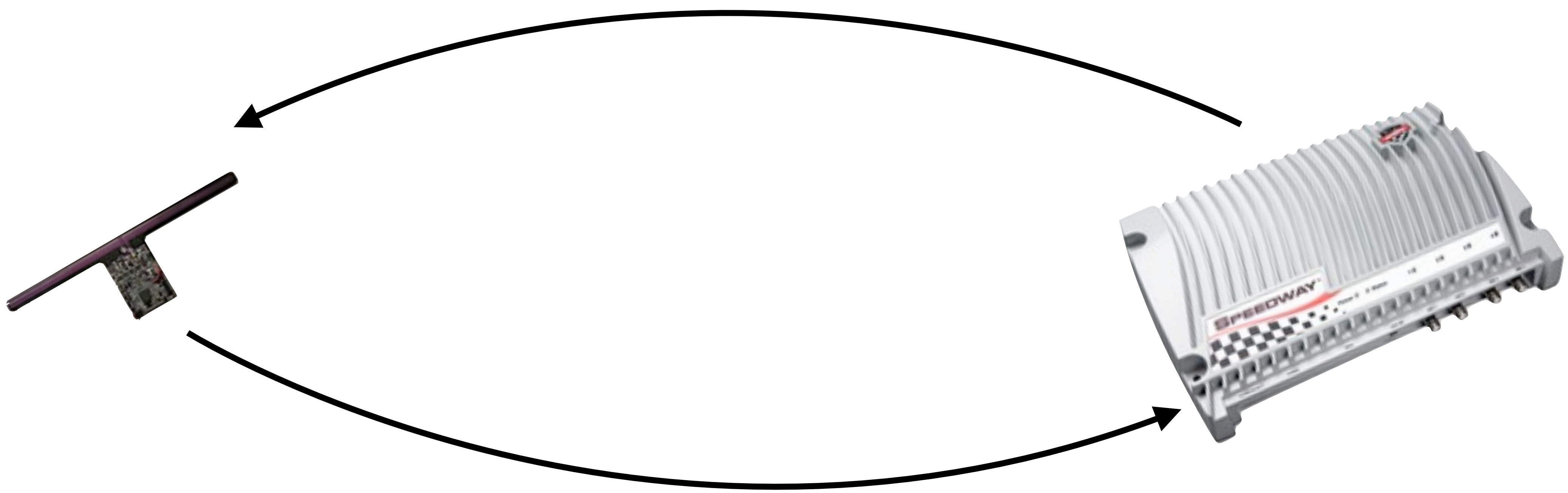


CRFID

Outsource Storage?



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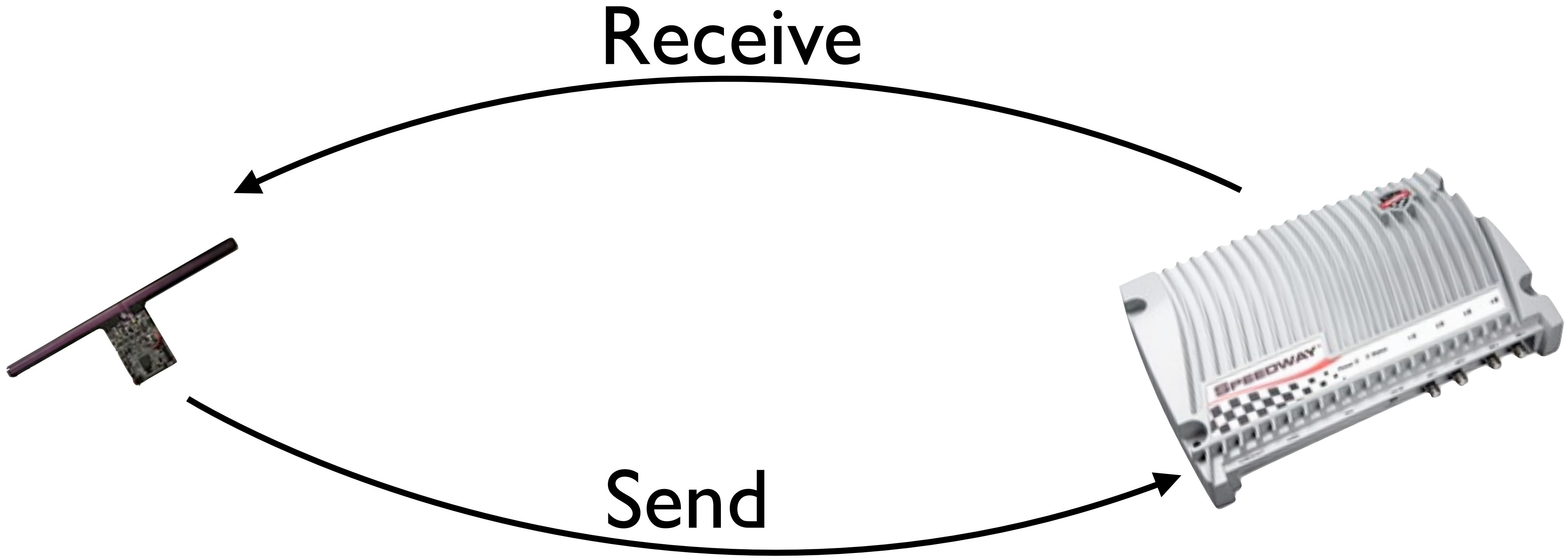

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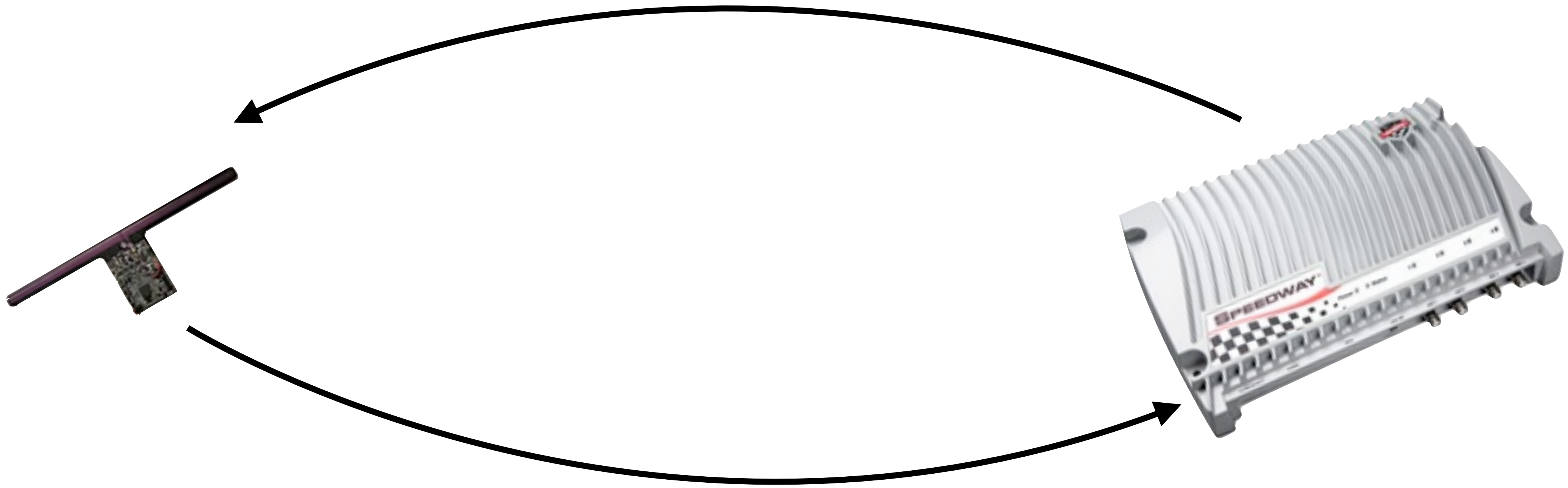
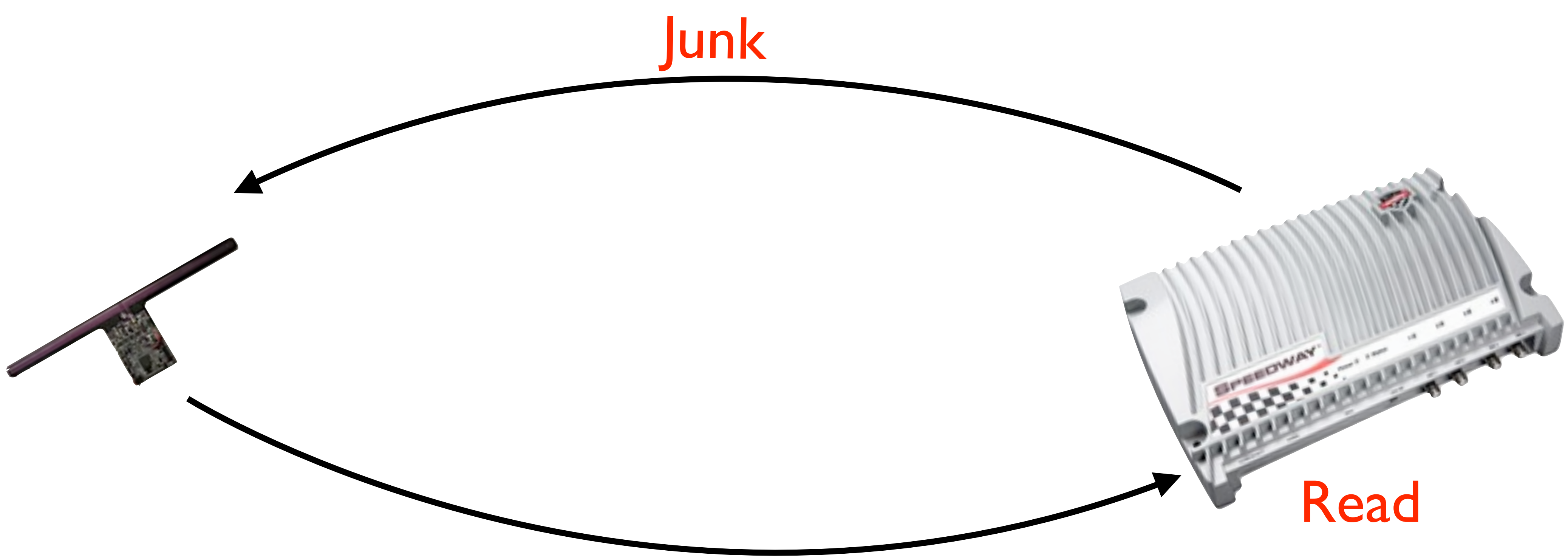


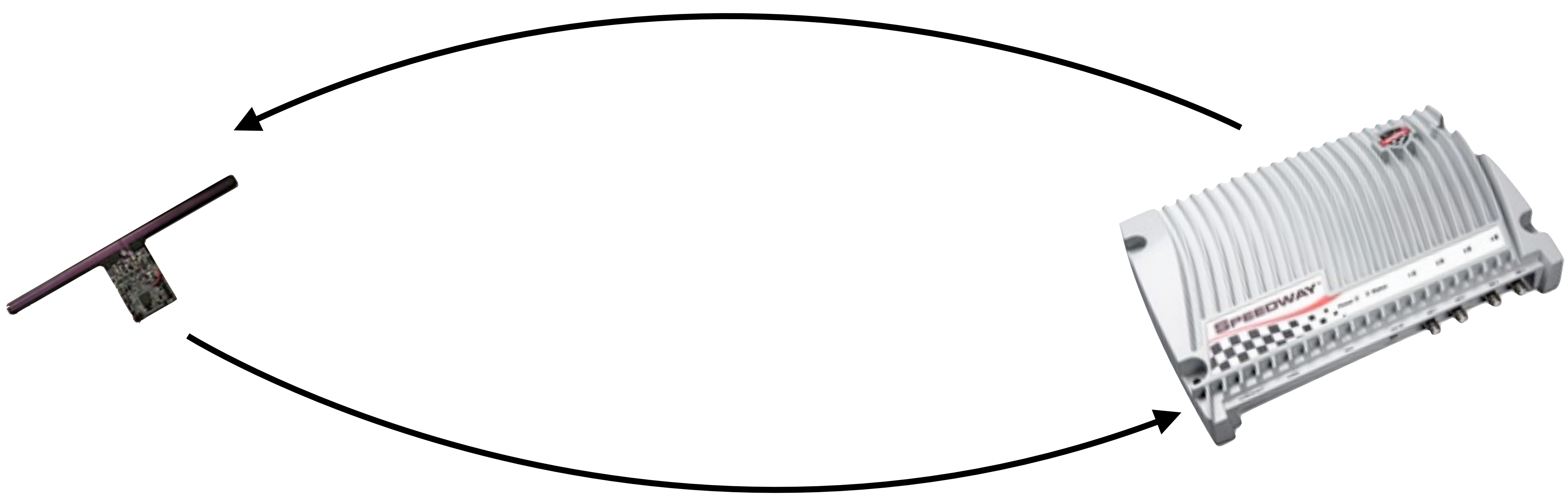
Problem: a reader is not necessarily trustworthy

Outsource Storage?

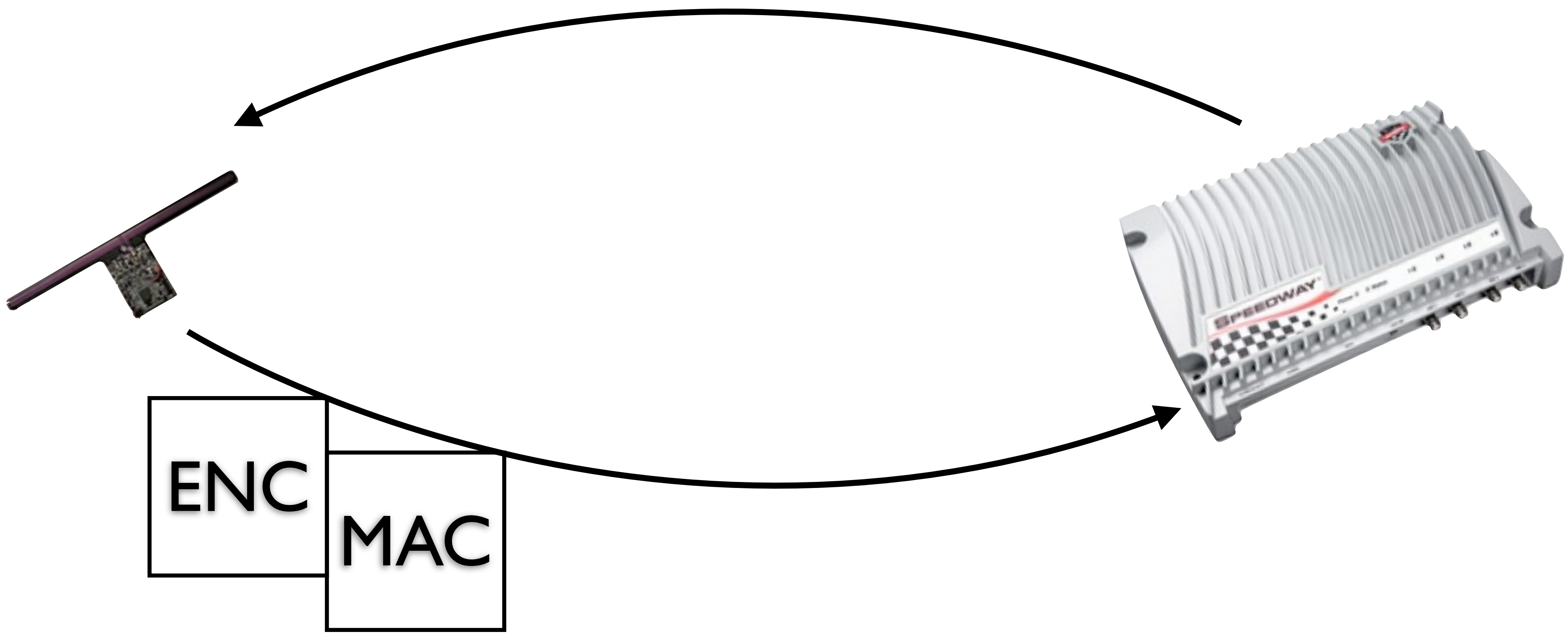


Problem: a reader is not necessarily trustworthy

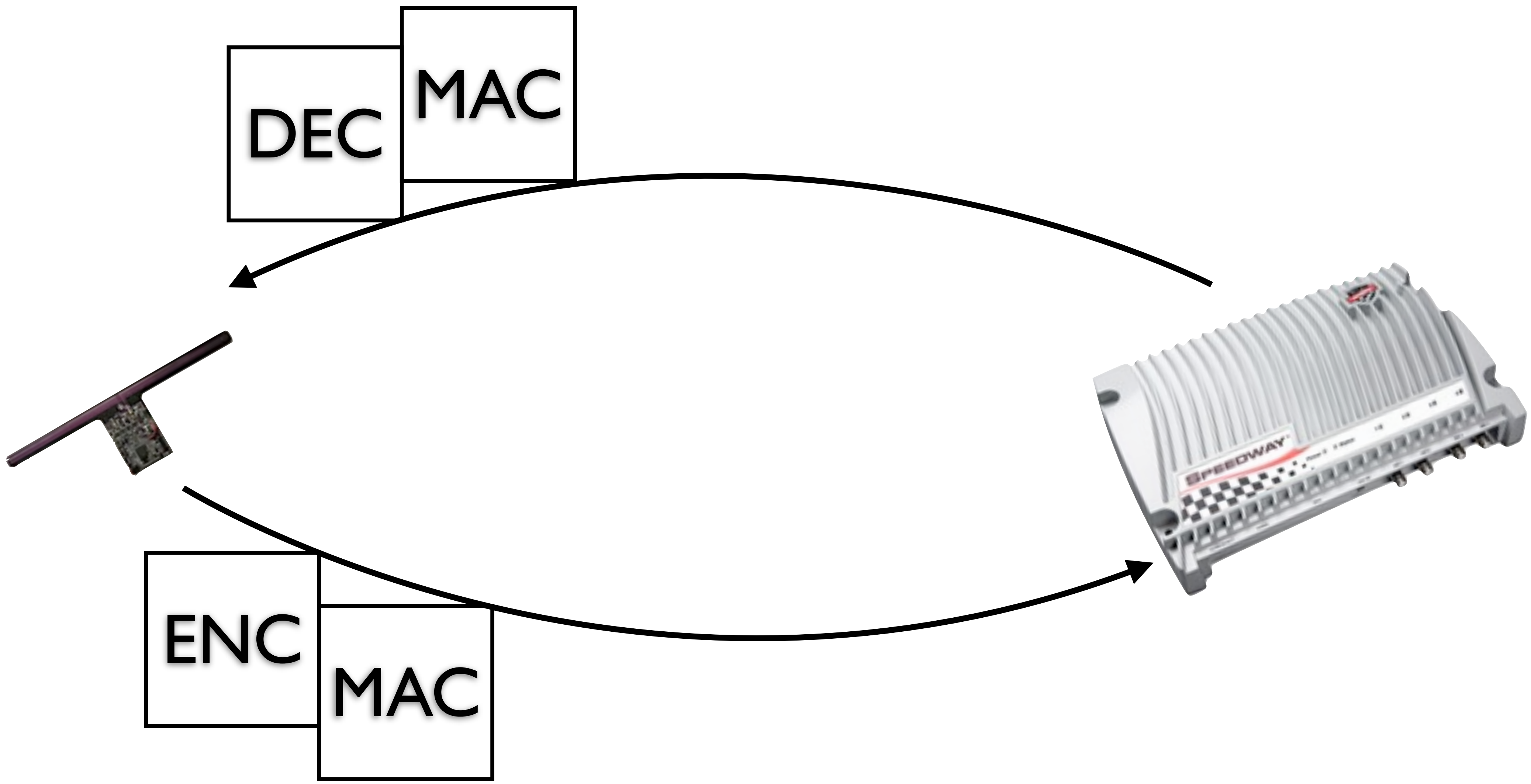
Cryptographic Computational Continuation Passing



Cryptographic Computational Continuation Passing



Cryptographic Computational Continuation Passing



Goal: Computational Progress

- Change of computational state toward a goal
  - Example: completion of a loop
- Eliminate Sisyphean tasks

Sisyphean Tasks

- Some workloads may never complete given typical energy availability

- Manually splitting tasks is not necessarily easy or effective

Mementos [Ransford '08]

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Task = { T1 | T2 | T3 | T4 }

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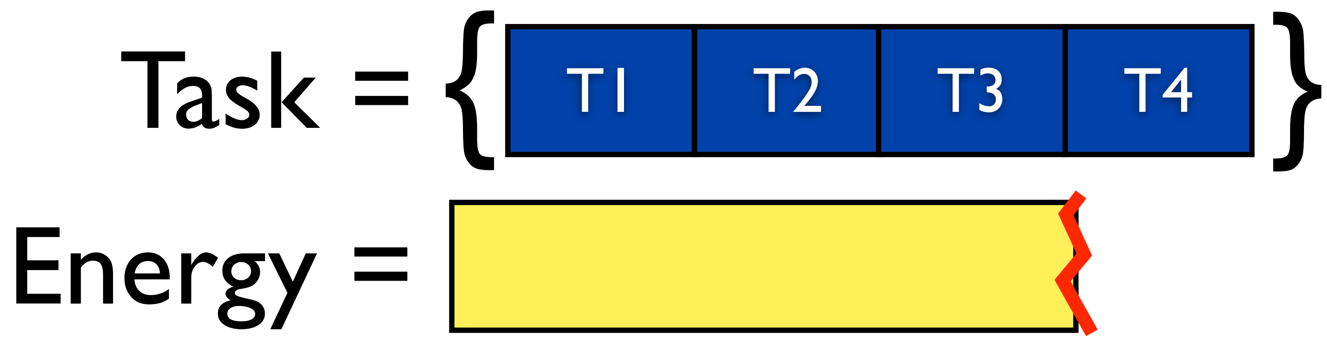
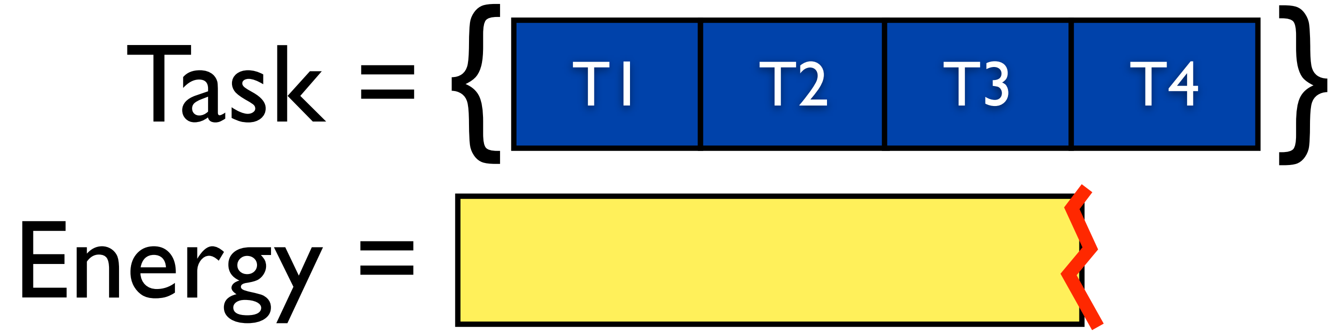
Energy =

Mementos [Ransford ’08]



- Checkpoint state (locally) as energy wanes
- Spread computations over multiple lifecycles

Mementos [Ransford ’08]



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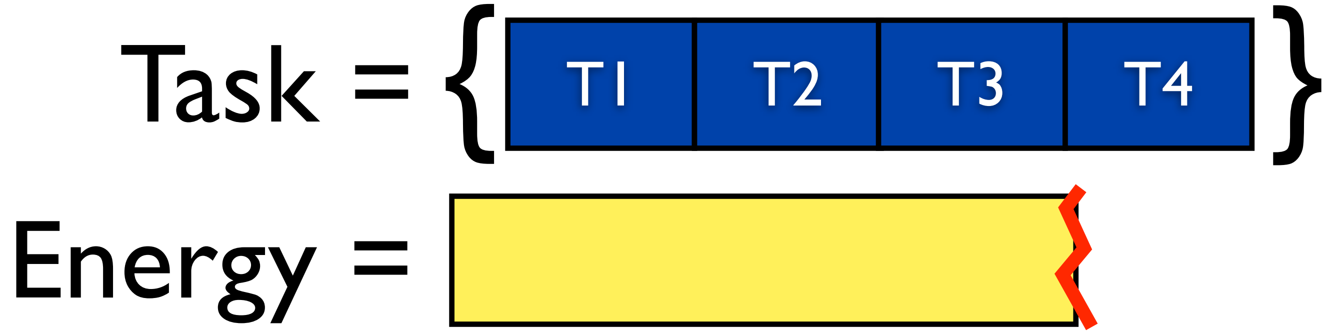

- Checkpoint state (locally) as energy wanes
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- **Problem:** flash write takes precious energy.

Security Goals

- Confidentiality
- Integrity
- Authentication
- Data Freshness
- Availability

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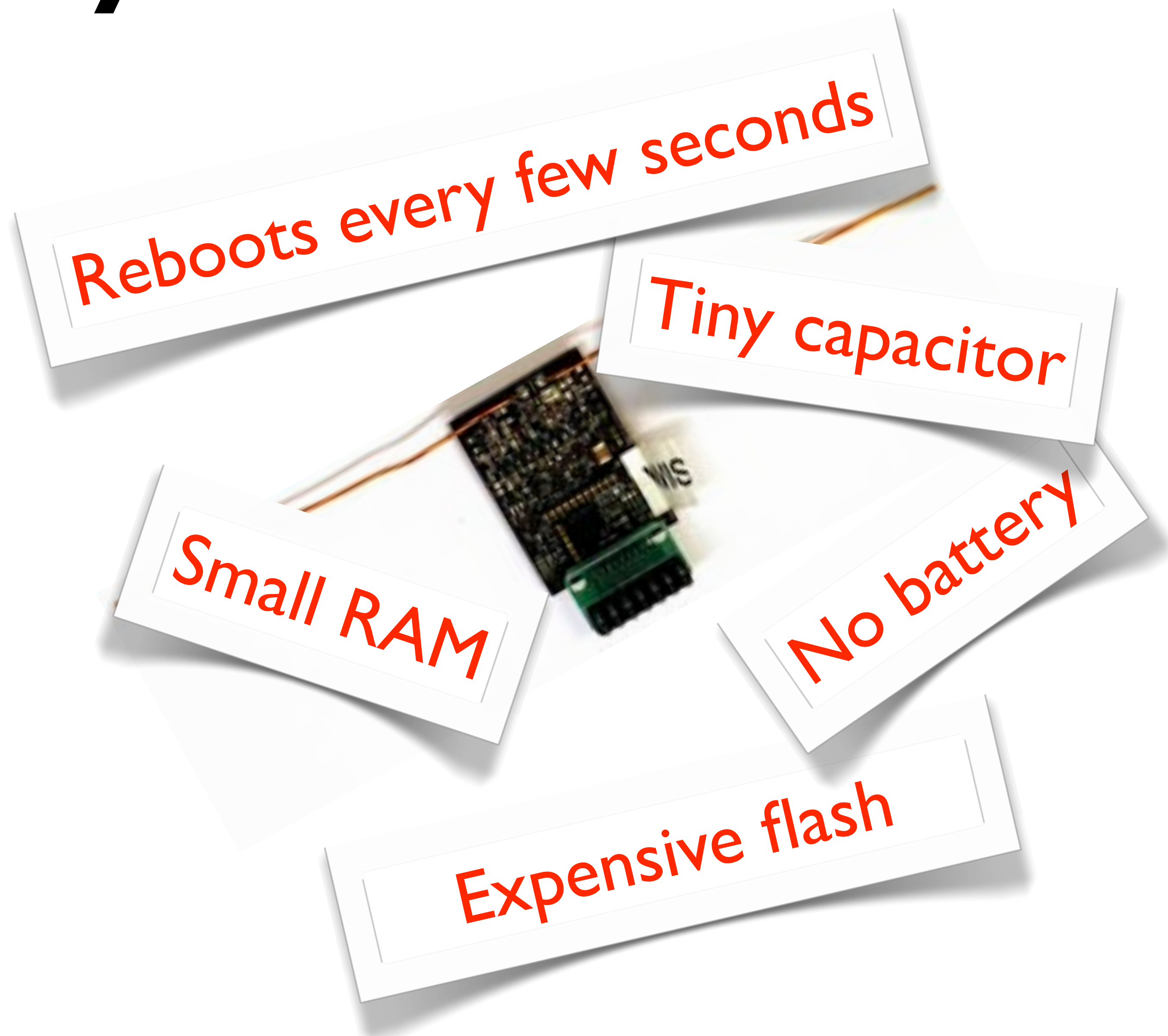

Security Primitives

- Stream cipher for confidentiality
- UMAC for integrity/authentication [Black '99]
- Low cost in terms of energy

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- Stream cipher for confidentiality
- UMAC for integrity/authentication [Black '99]
- Low cost in terms of energy
- Challenge: Maintaining the *keystreams*

Precomputation?

- Keystreams are required by the cipher and the MAC
- Cannot reuse keystream bits
- Not enough energy to compute on the fly

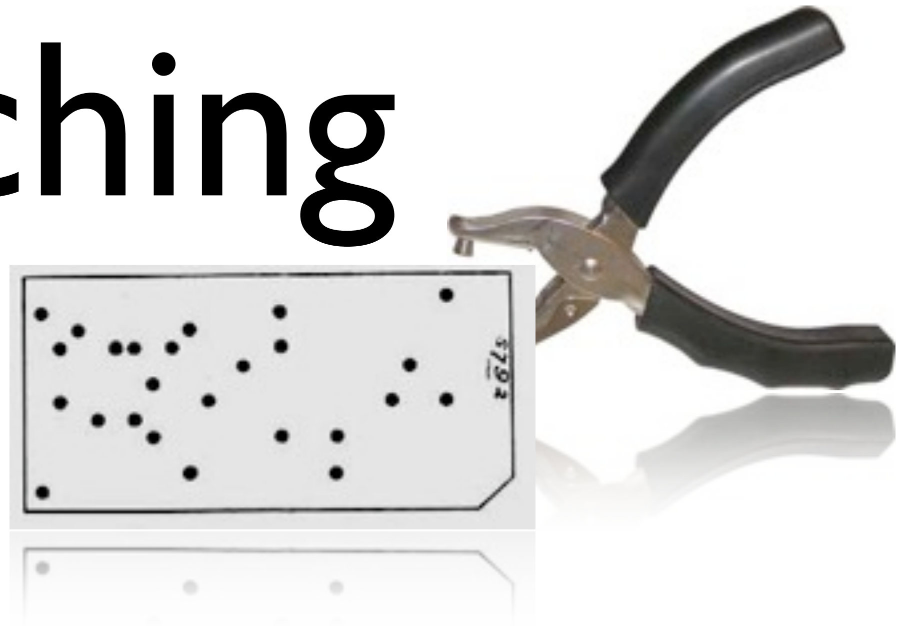
Good Power Seasons

- Times when the CRFID is idle
  - CRFID is awake and has no computation left to complete.
  - CRFID finds a reader that does not understand CCCP.
- Plentiful energy → time to produce keystream bits

Data Freshness

- Some state must be in trusted storage
- Nonvolatile memory is too expensive to use frequently
- How can we use it frugally?

Hole Punching



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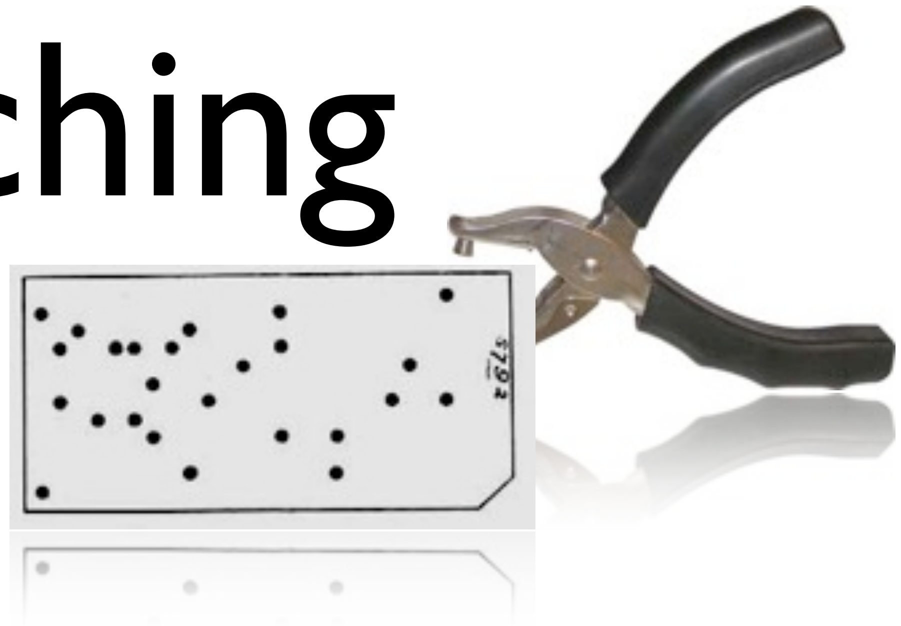
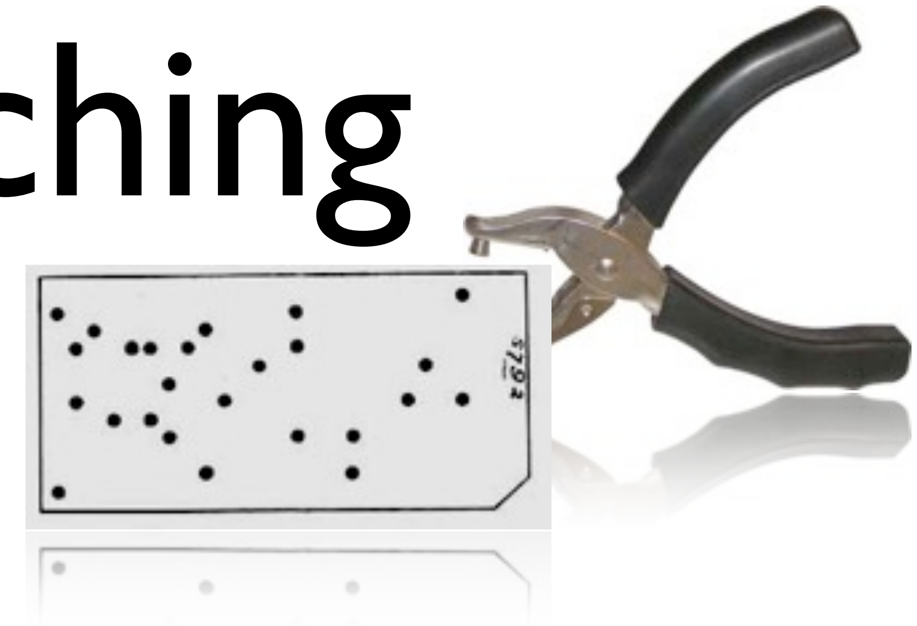


$00000111_2 \quad (=7_{10})$

(a) Binary Counter

Hole Punching



$00000111_2 \quad (=7_{10})$

$00001000_2 \quad (=8_{10})$

(a) Binary Counter

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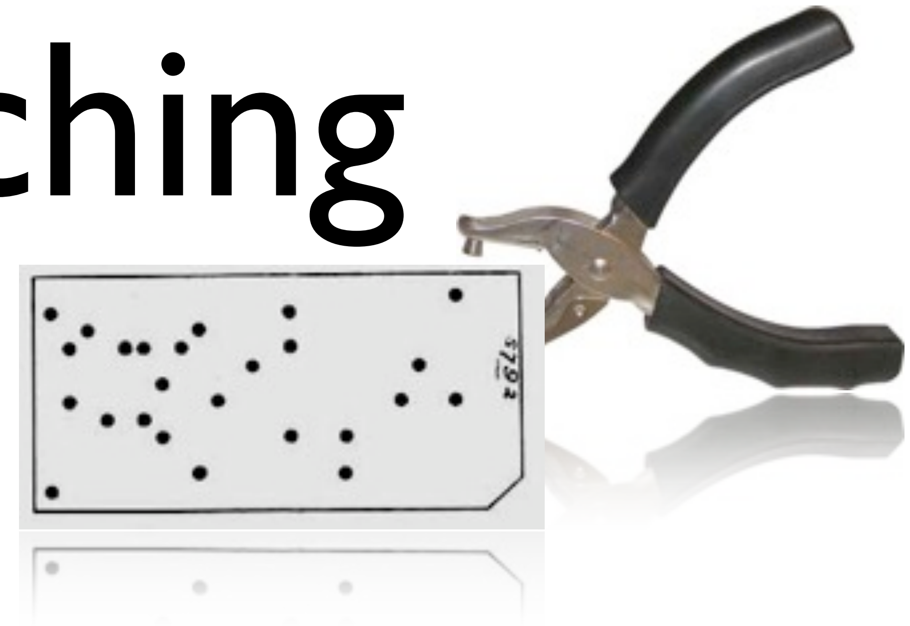

00000111_2 $(=7_{10})$

↓

11111111_2 (erase)

↓

00001000_2 $(=8_{10})$

(a) Binary Counter

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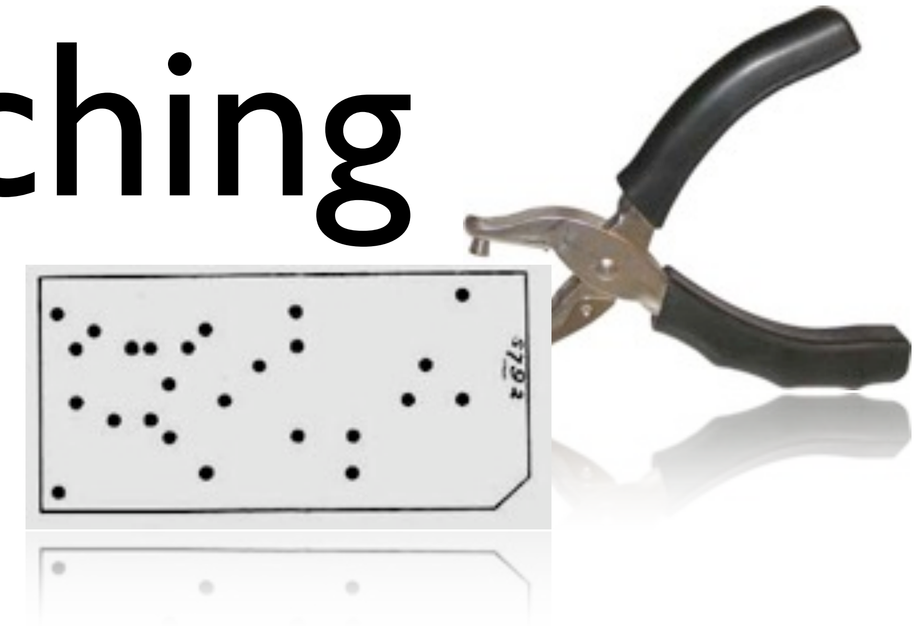

00000111_2 (=7_{10})

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11111111_2 (erase)

↓

00001000_2 (=8_{10})

(a) Binary Counter

1111000000_1 (=7_{10})

(b) Unary Counter (complemented)

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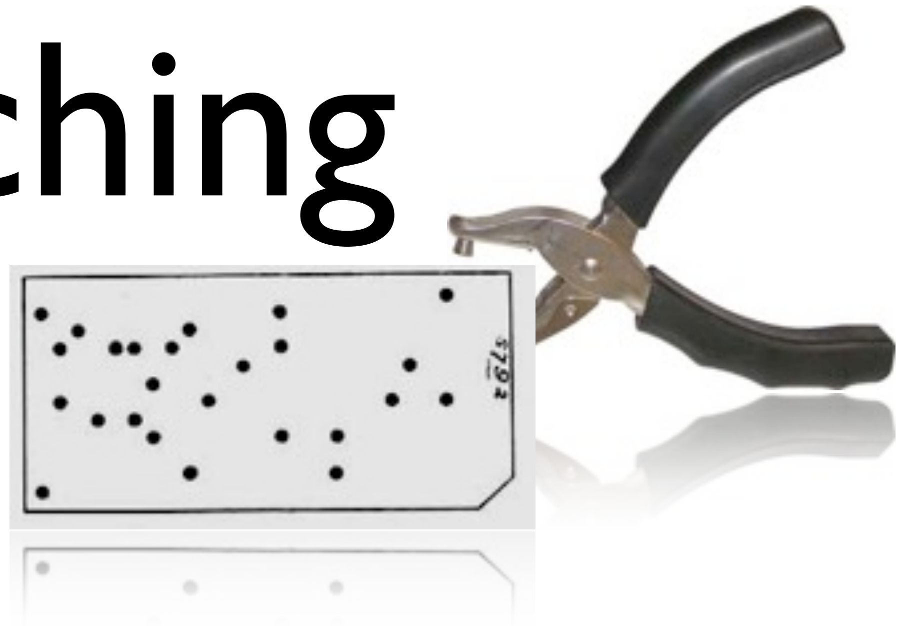

00000111_2 $(=7_{10})$

$\downarrow$

11111111_2 (erase)

$\downarrow$

00001000_2 $(=8_{10})$

(a) Binary Counter

11110000000_1 $(=7_{10})$

$\downarrow$

11100000000_1 $(=8_{10})$

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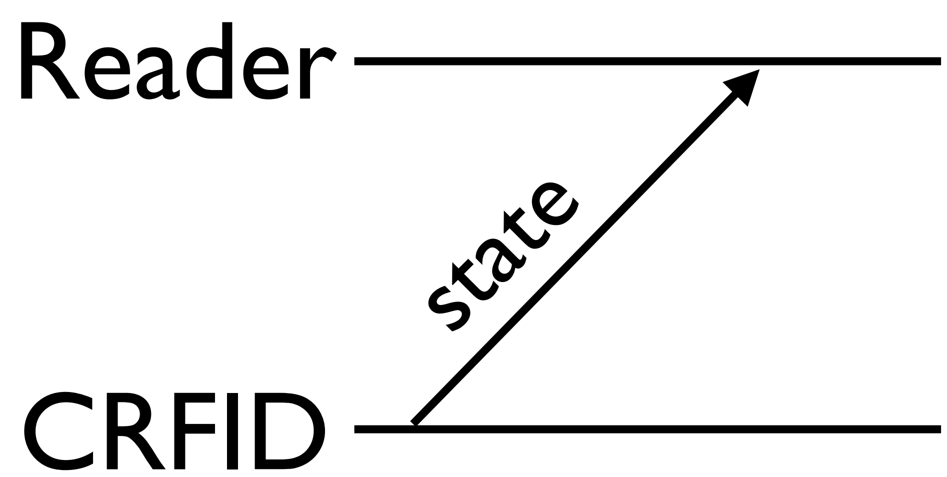
Protocol



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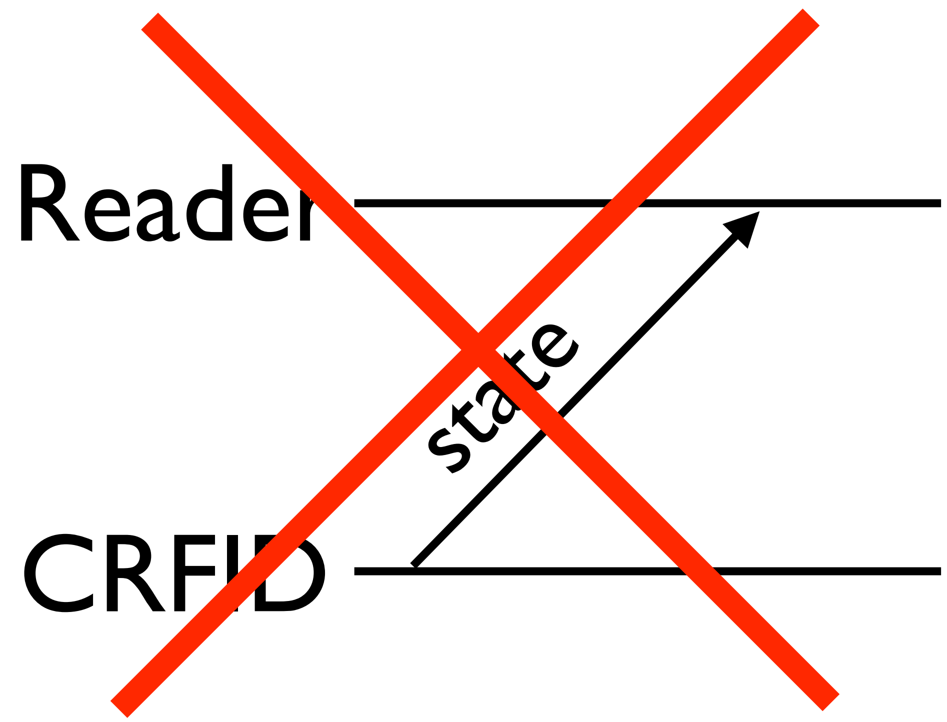

Non-autonomous communication

Store Procedure

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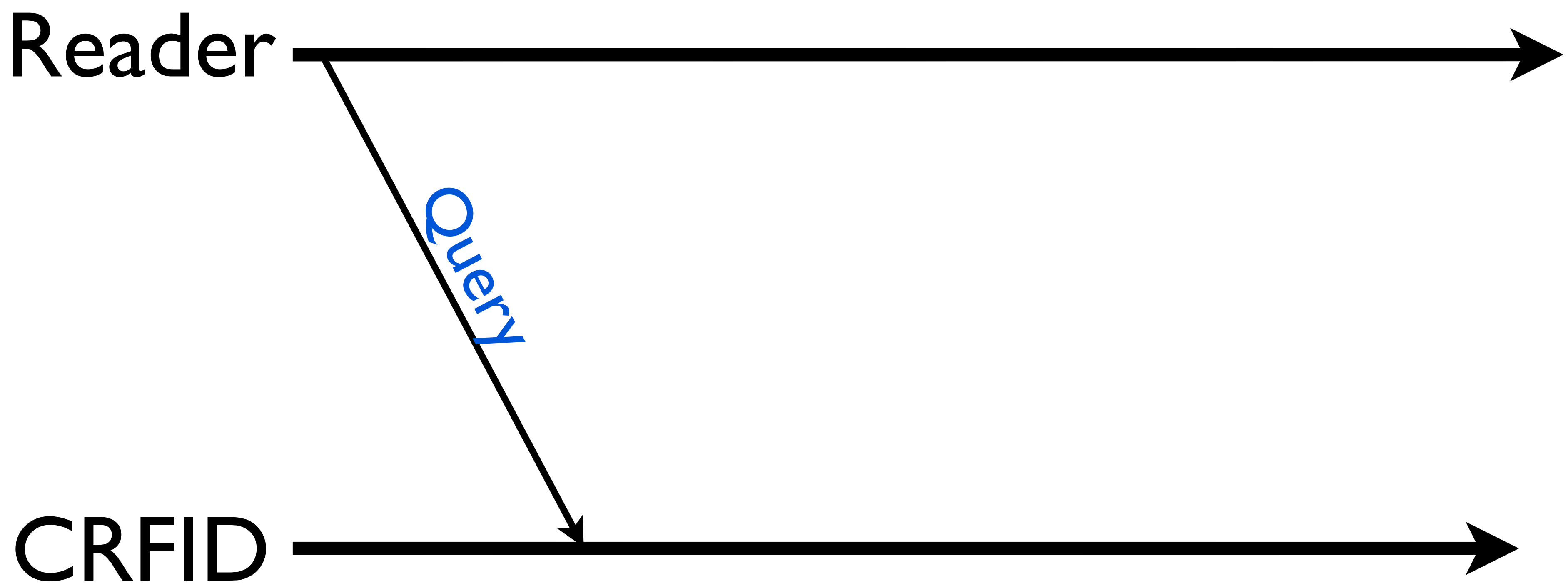

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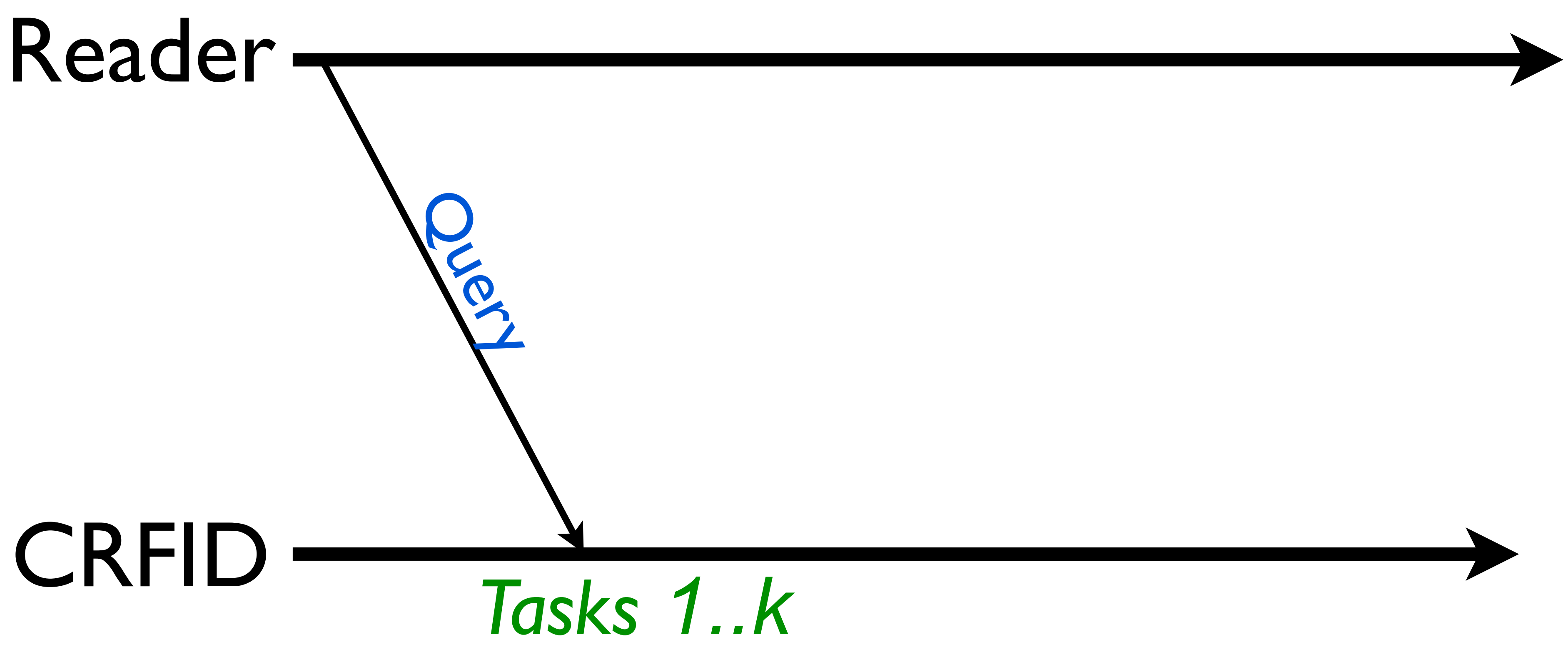

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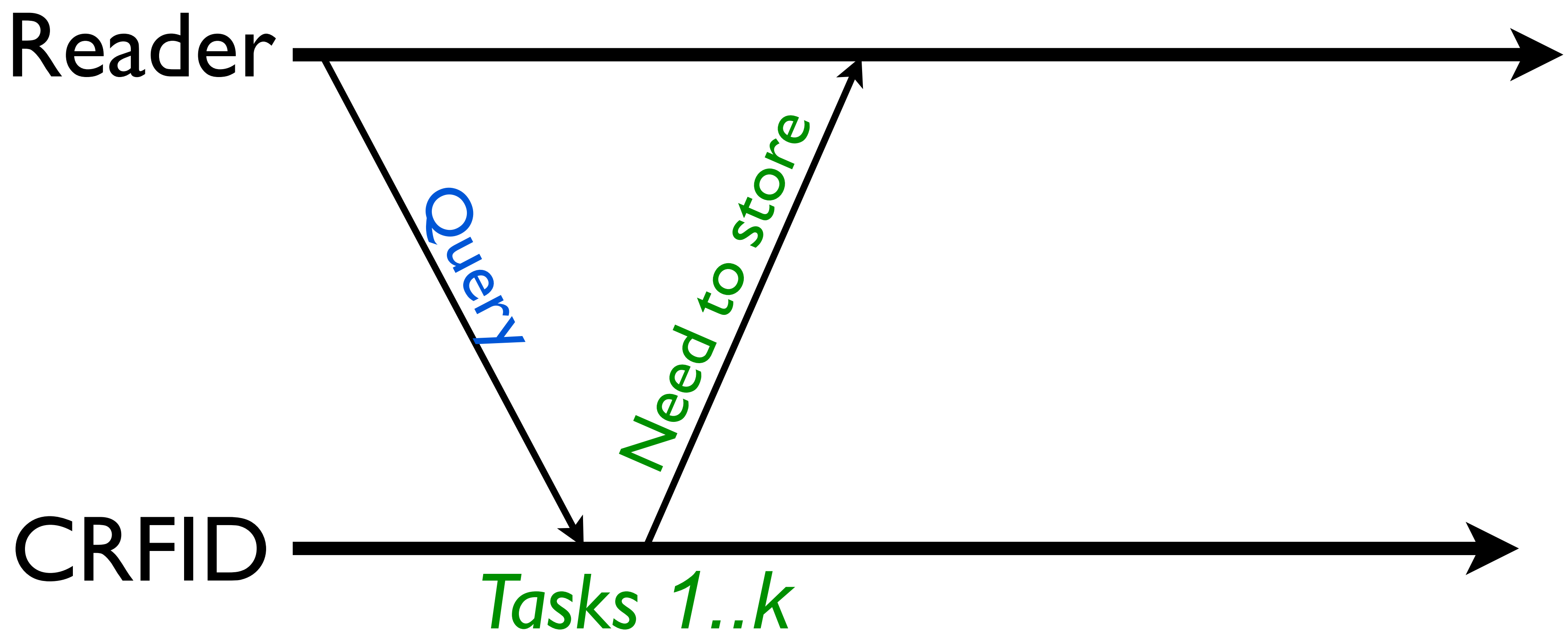

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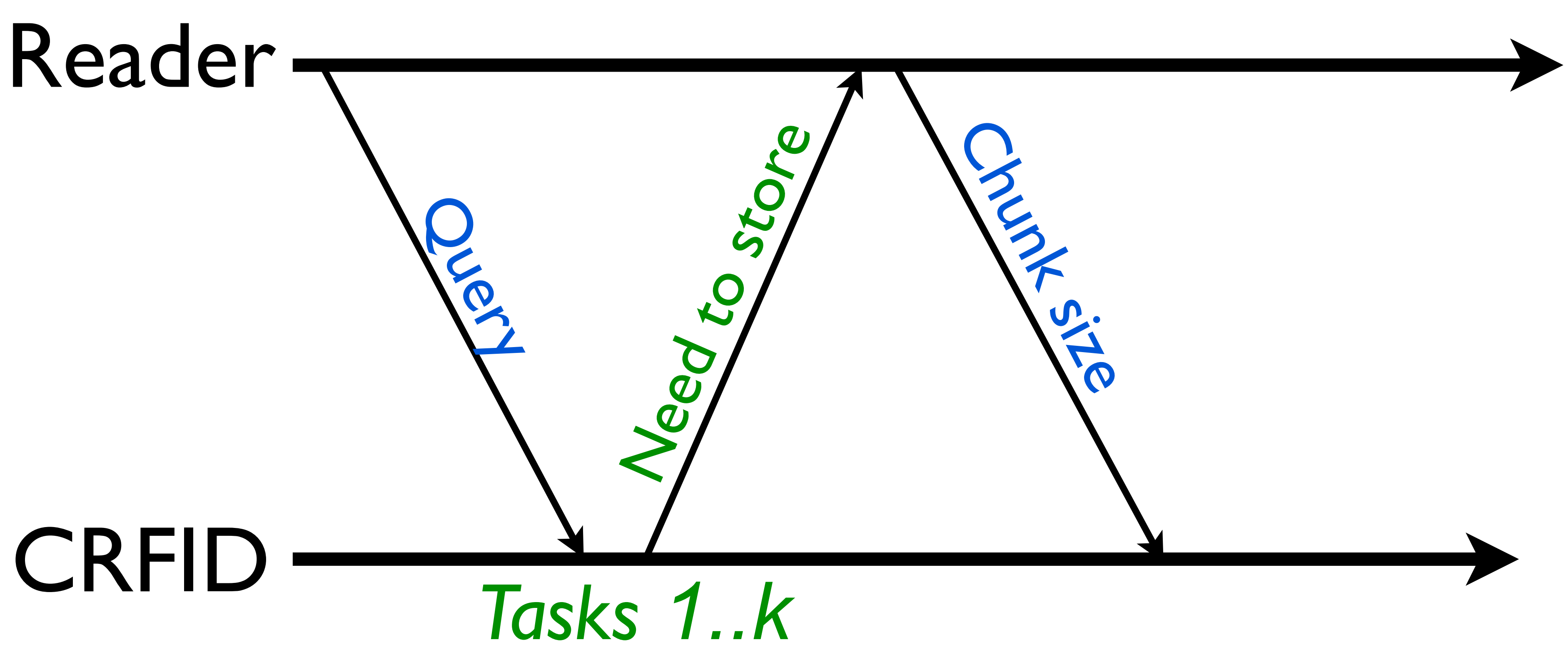

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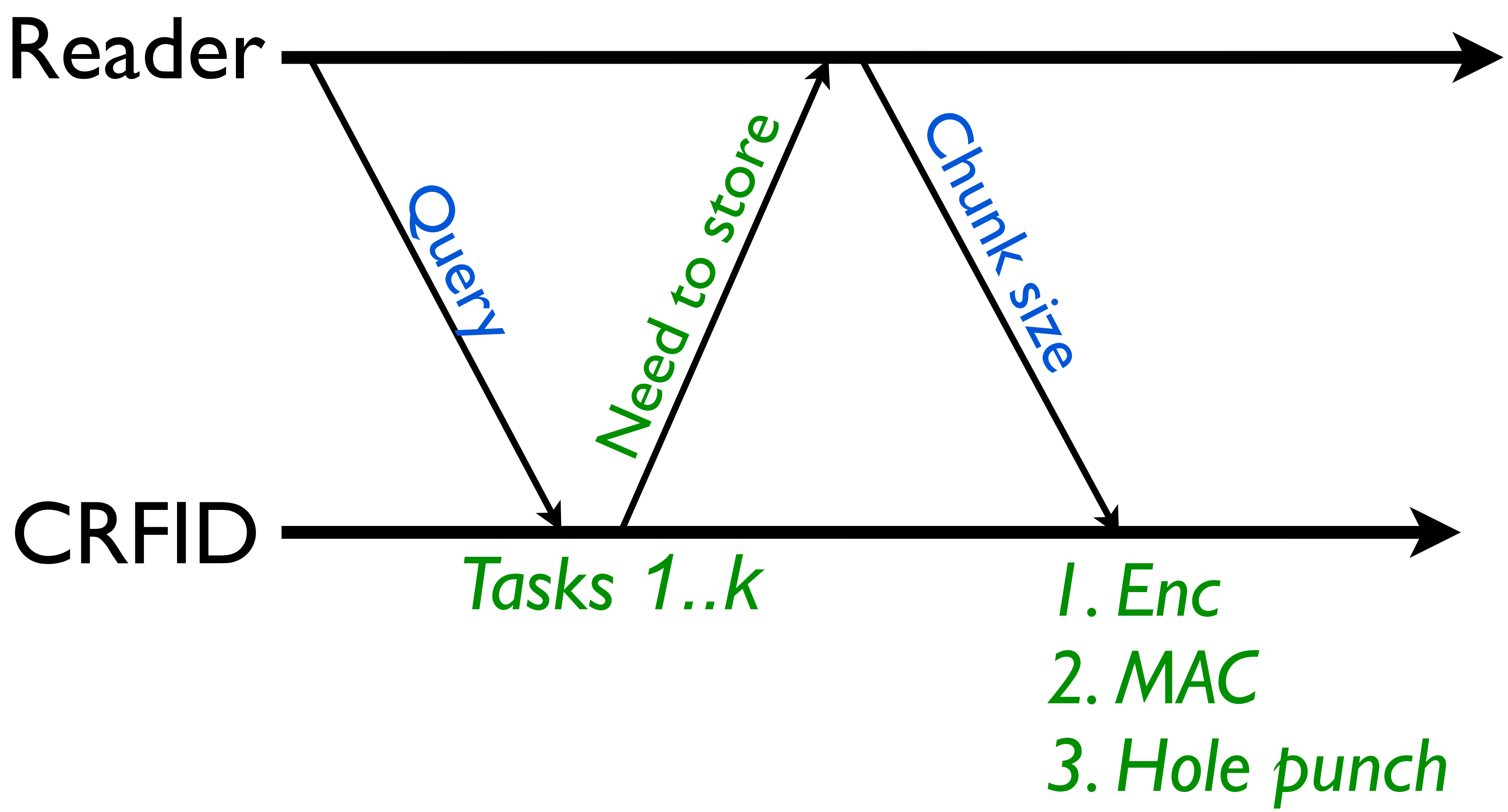

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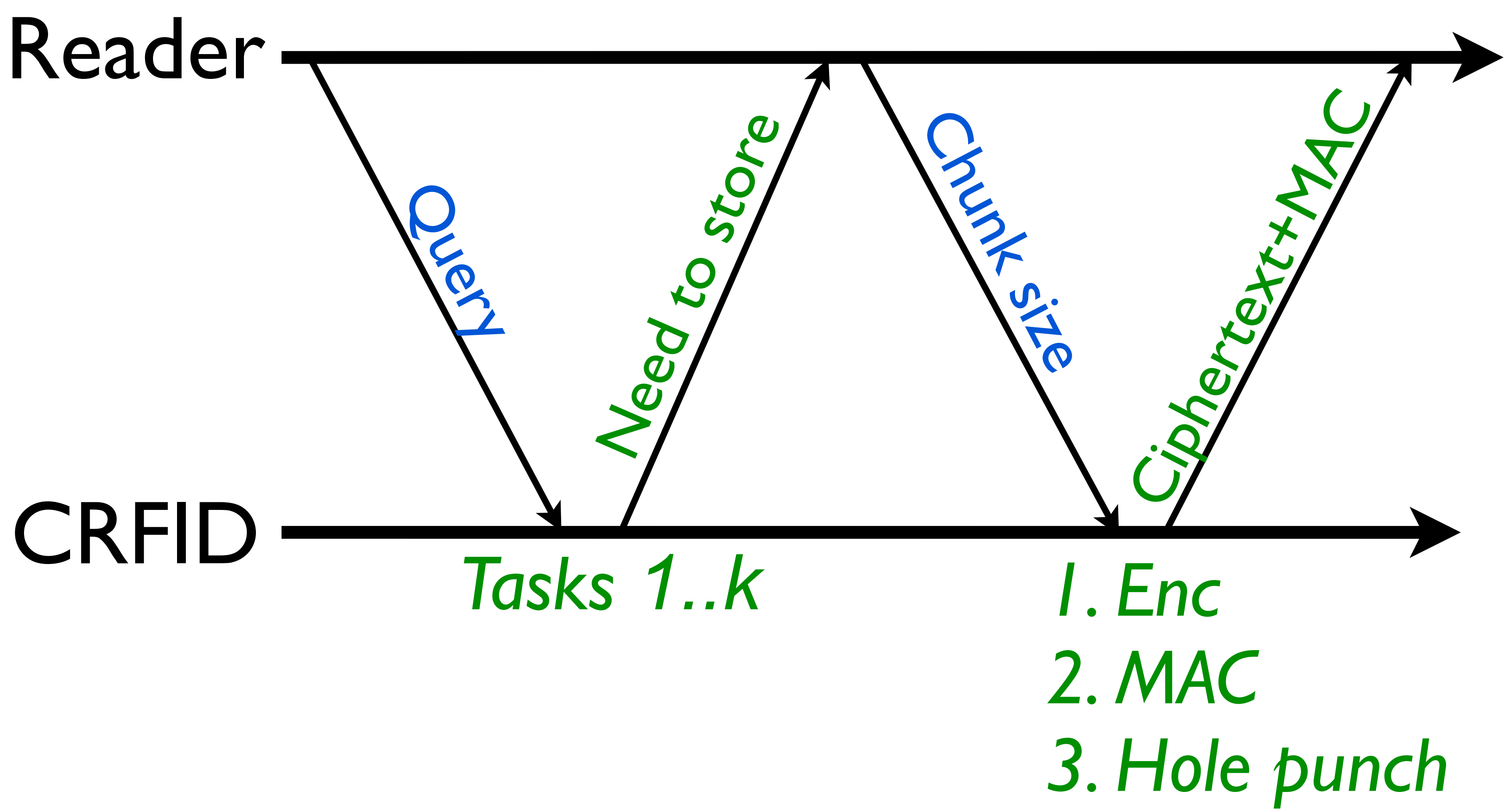

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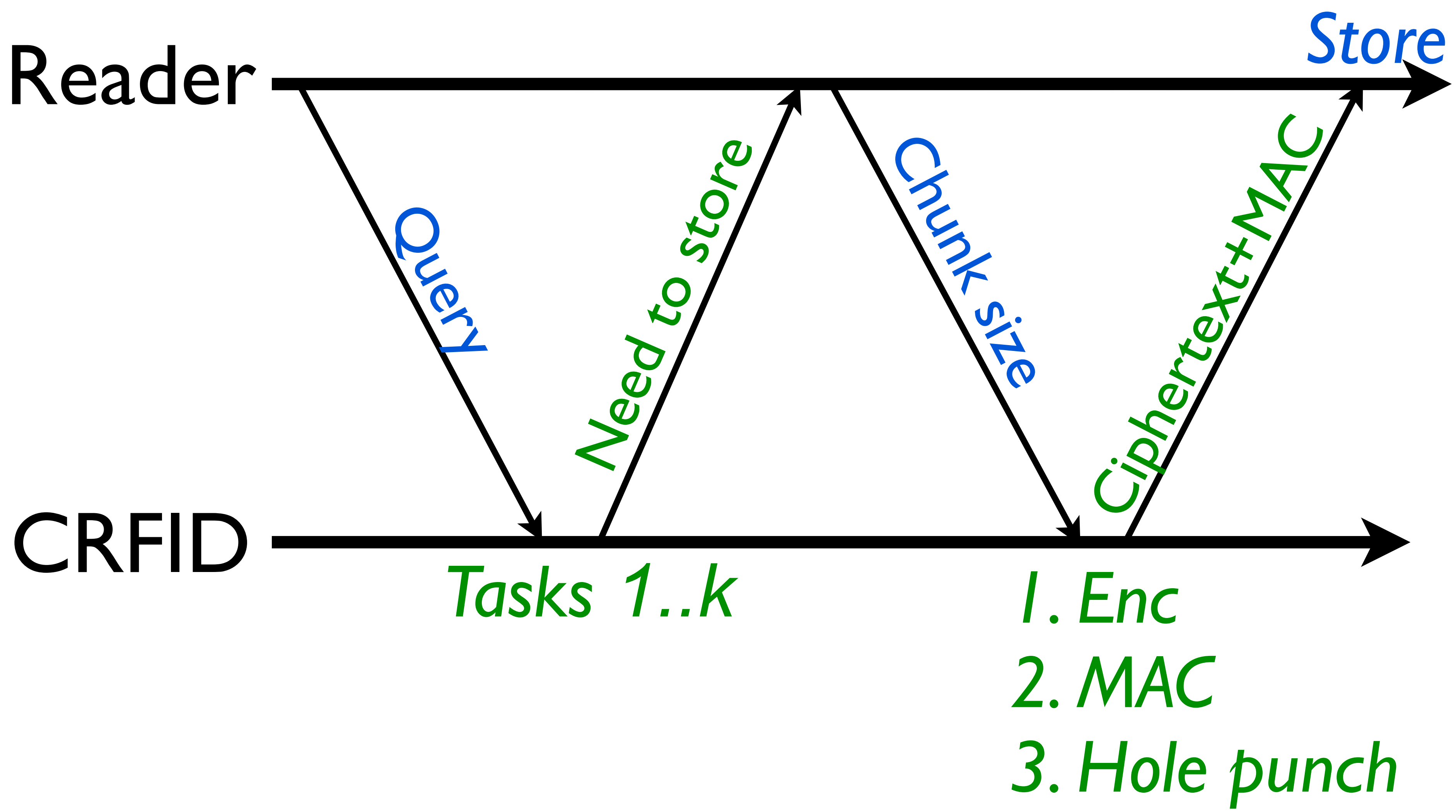
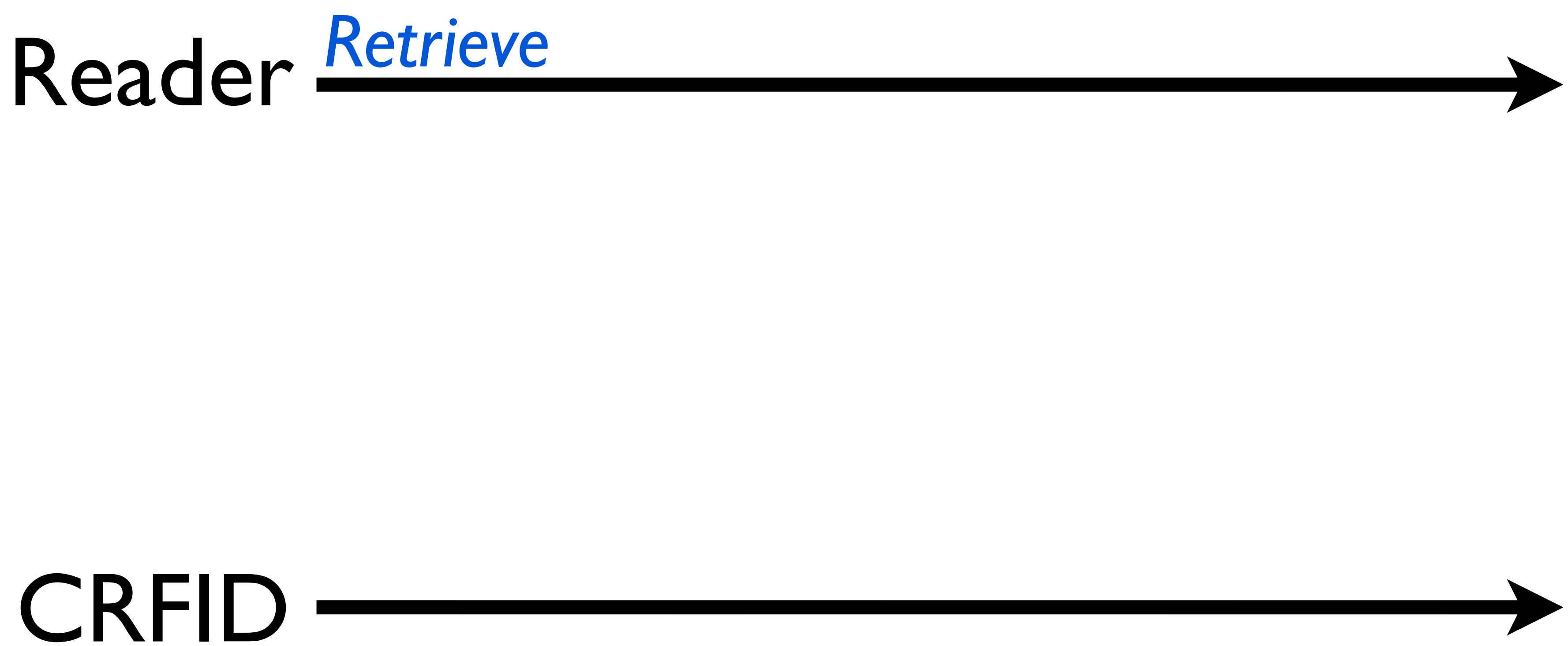


Retrieve Procedure

Reader

CRFID

Retrieve Procedure



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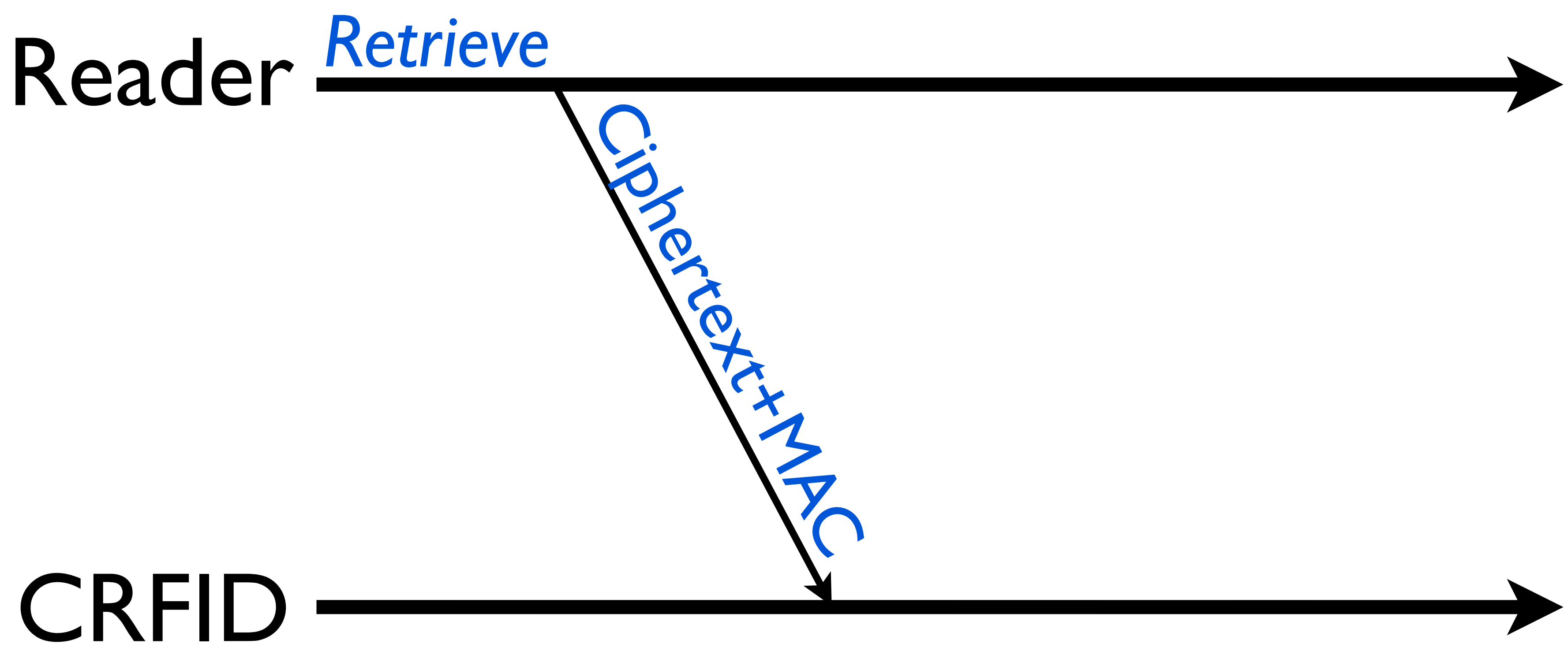

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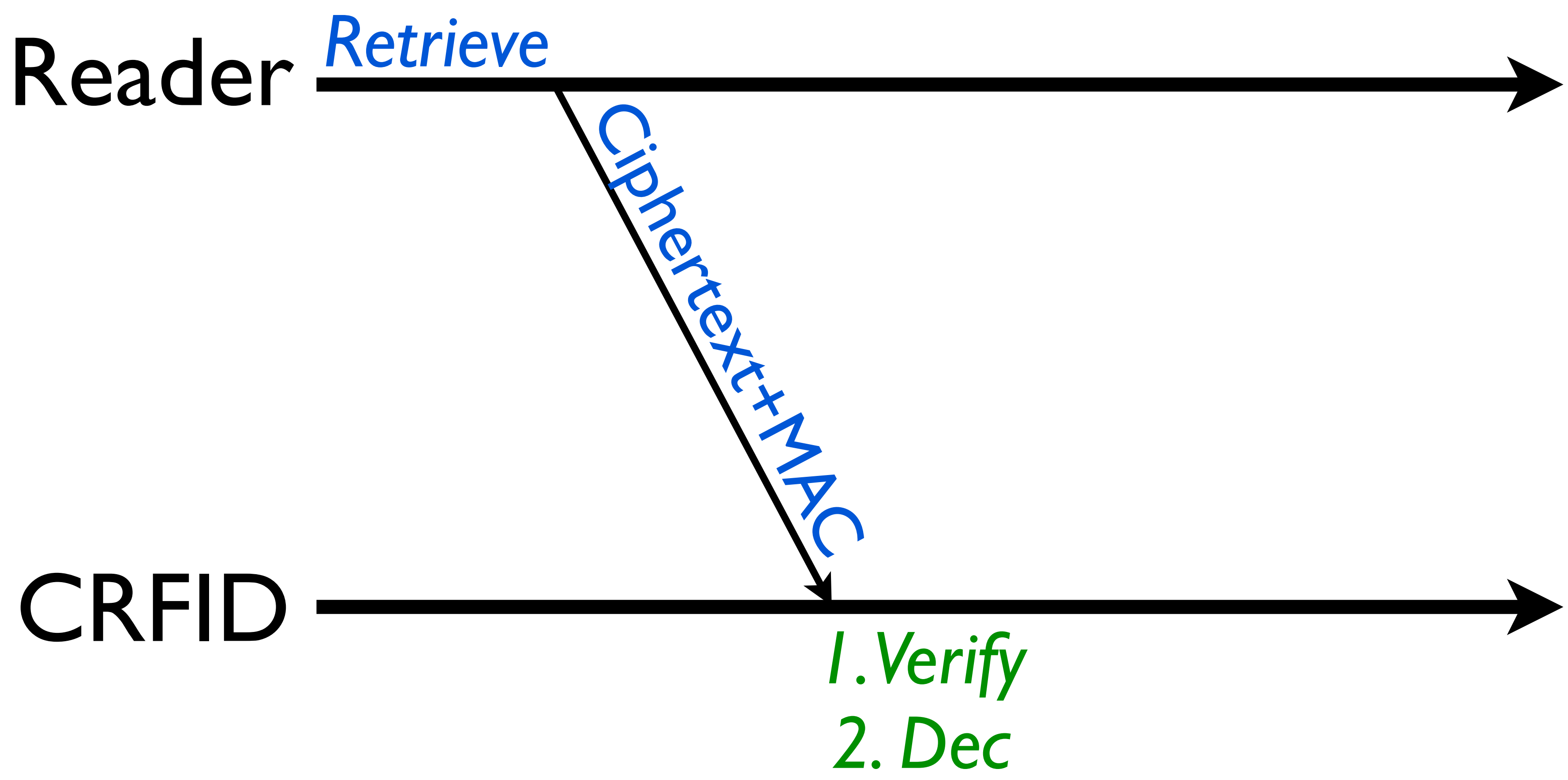

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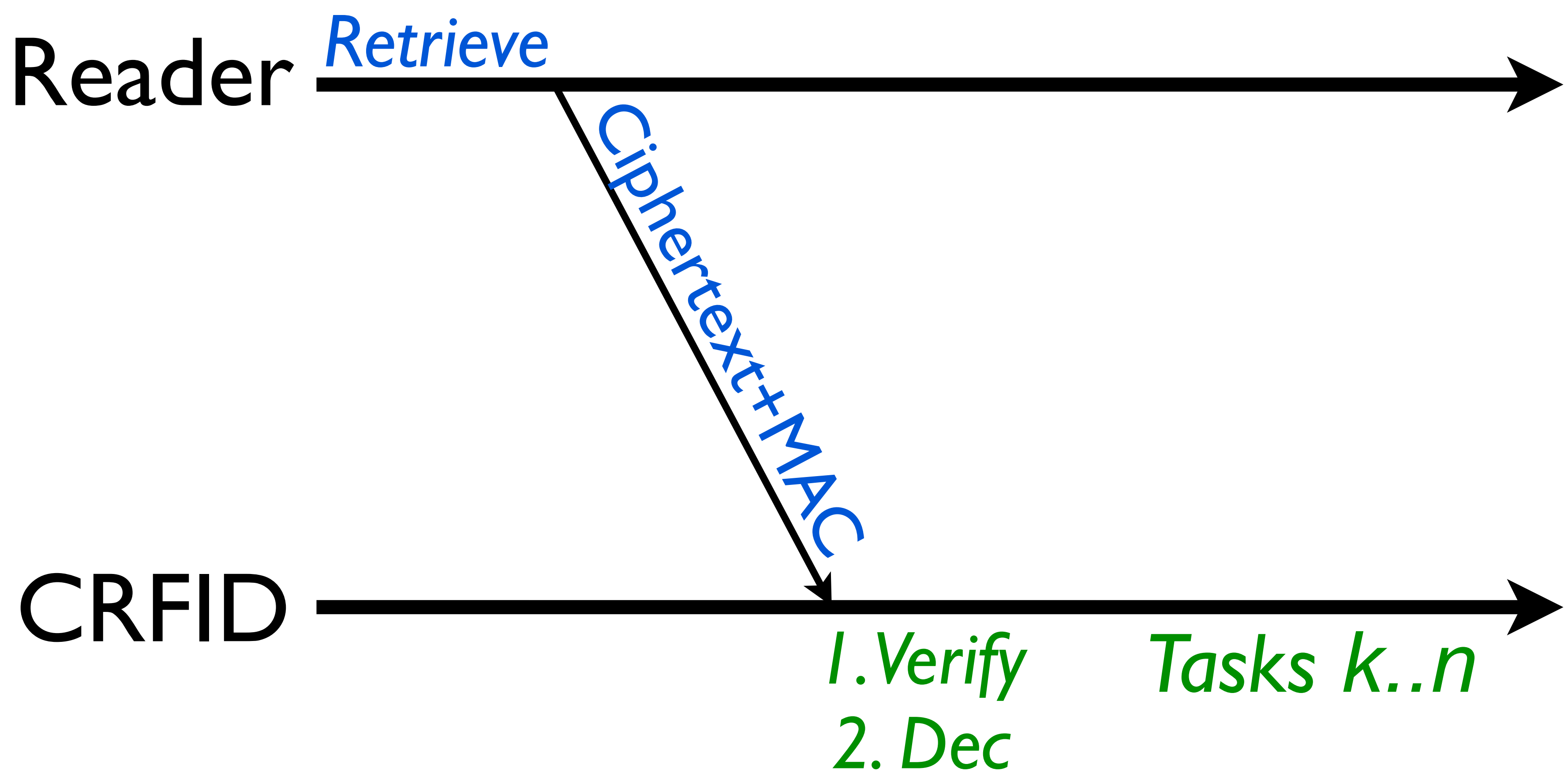
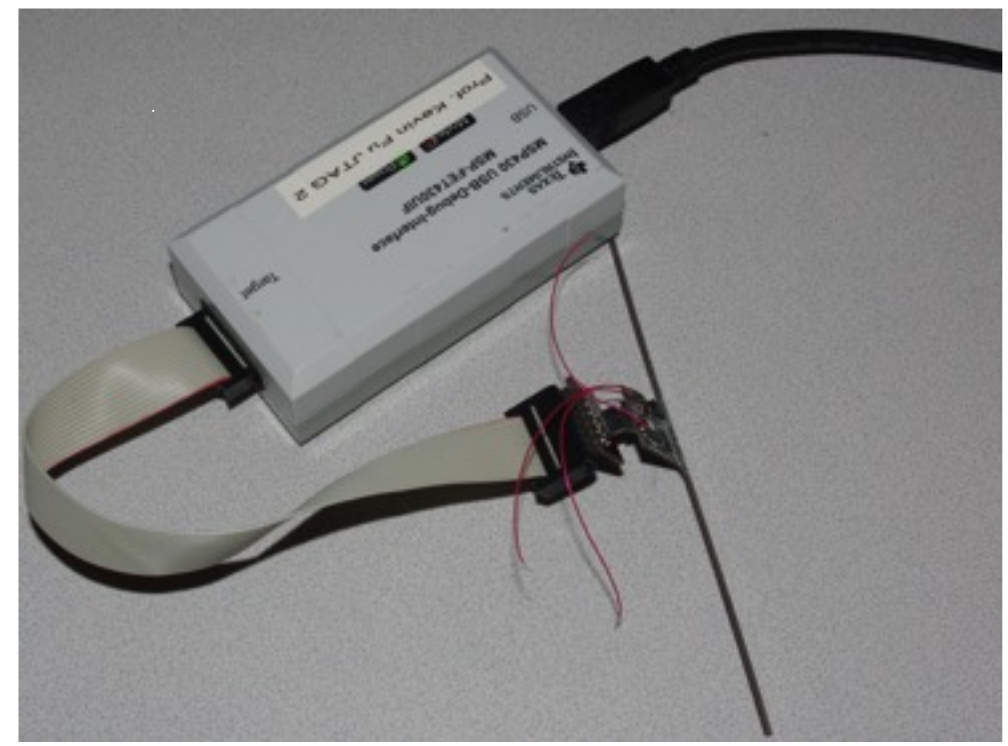


Evaluation

Experimental setup

Experimental setup

1. Program the CRFID with a task



Experimental setup

1. Program the CRFID with a task

2. Charge CRFID to voltage V

Experimental setup

1. Program the CRFID with a task

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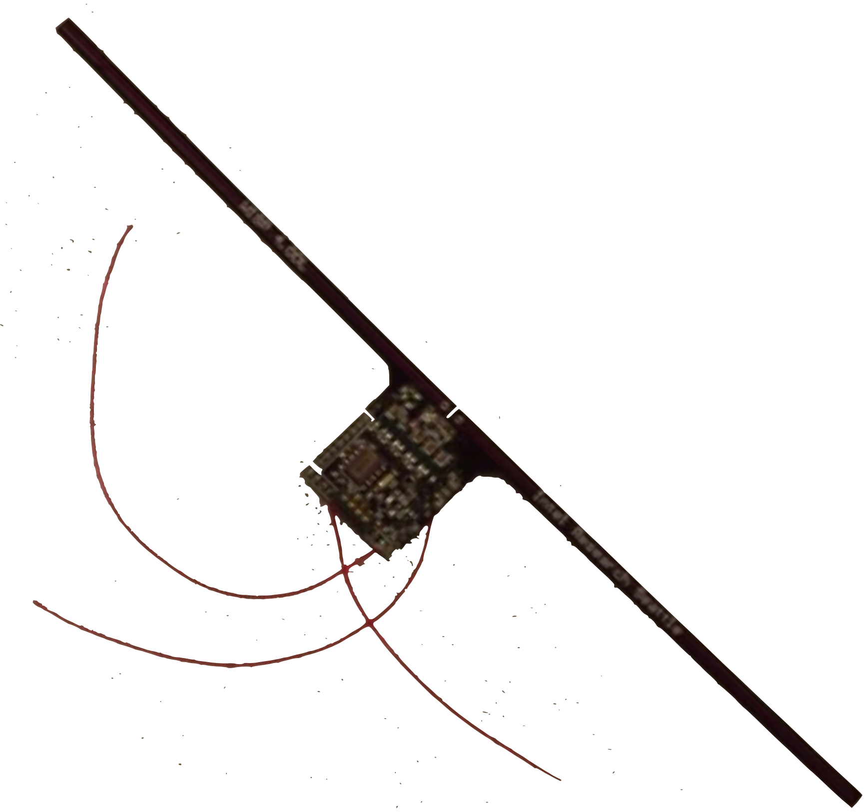
3. Disconnect the power supply



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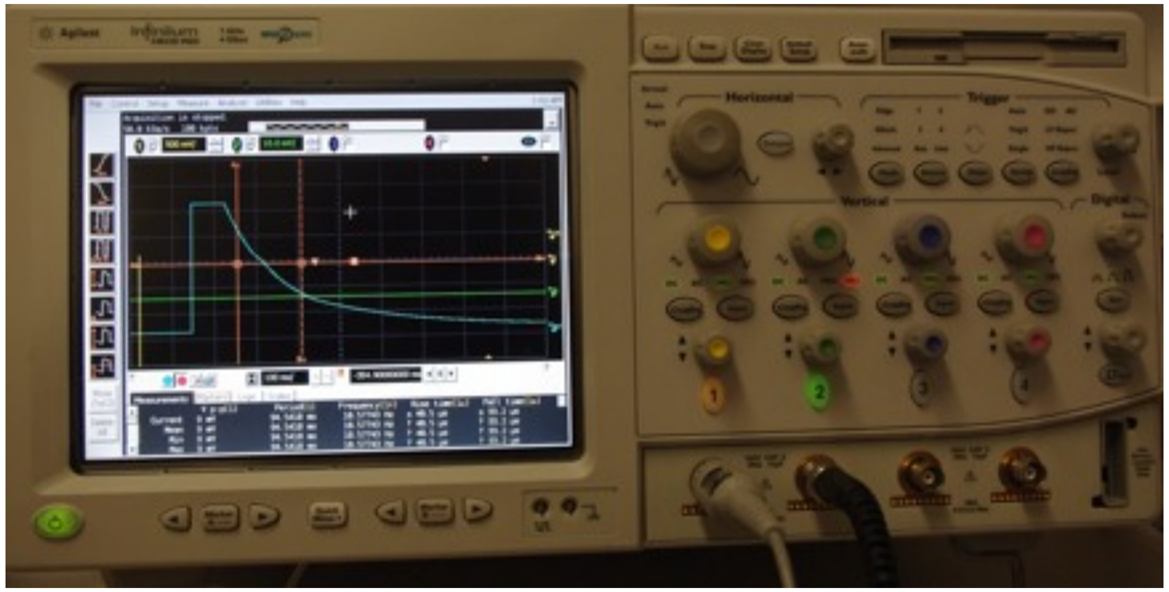
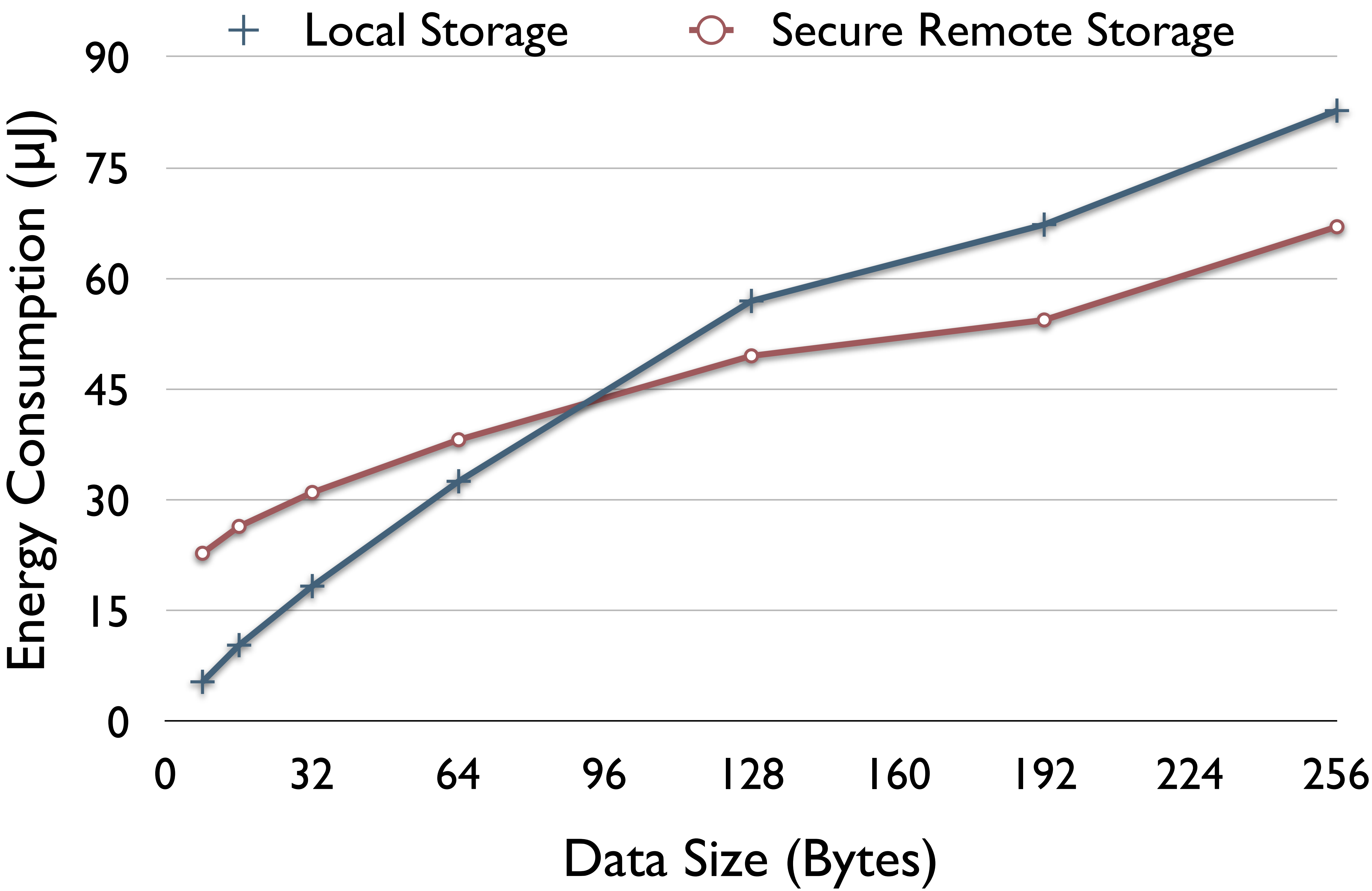
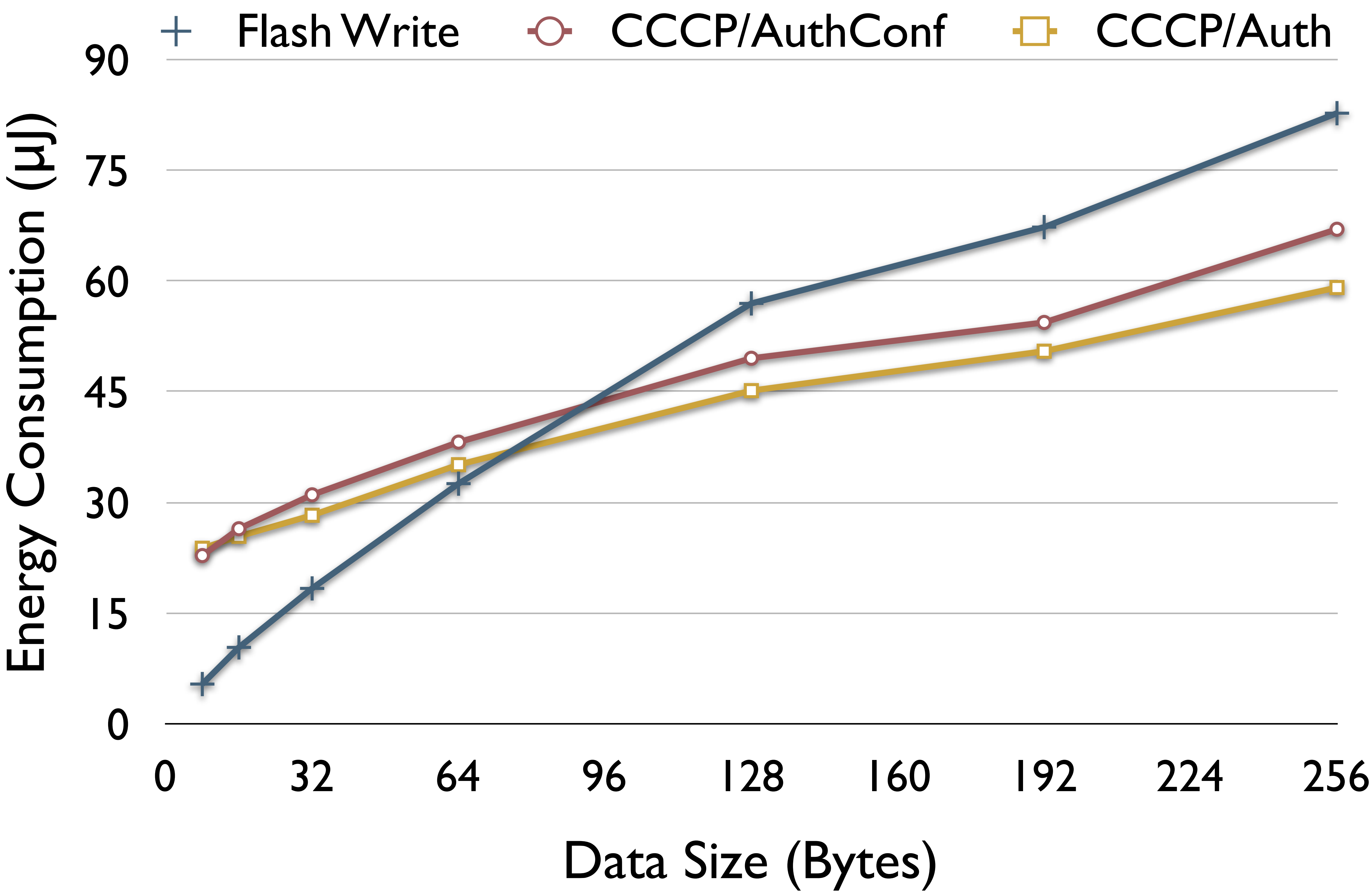


2. Charge CRFID to voltage V

3. Disconnect the power supply

4. Observe the voltage drop and execution time


Local Storage
Secure Remote Storage
Energy Consumption (μJ)
90
75
60
45
30
15
0
0
32
64
96
128
160
192
224
256
Data Size (Bytes)


Flash Write
CCCP/AuthConf
CCCP/Auth
Energy Consumption (μJ)
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0
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128
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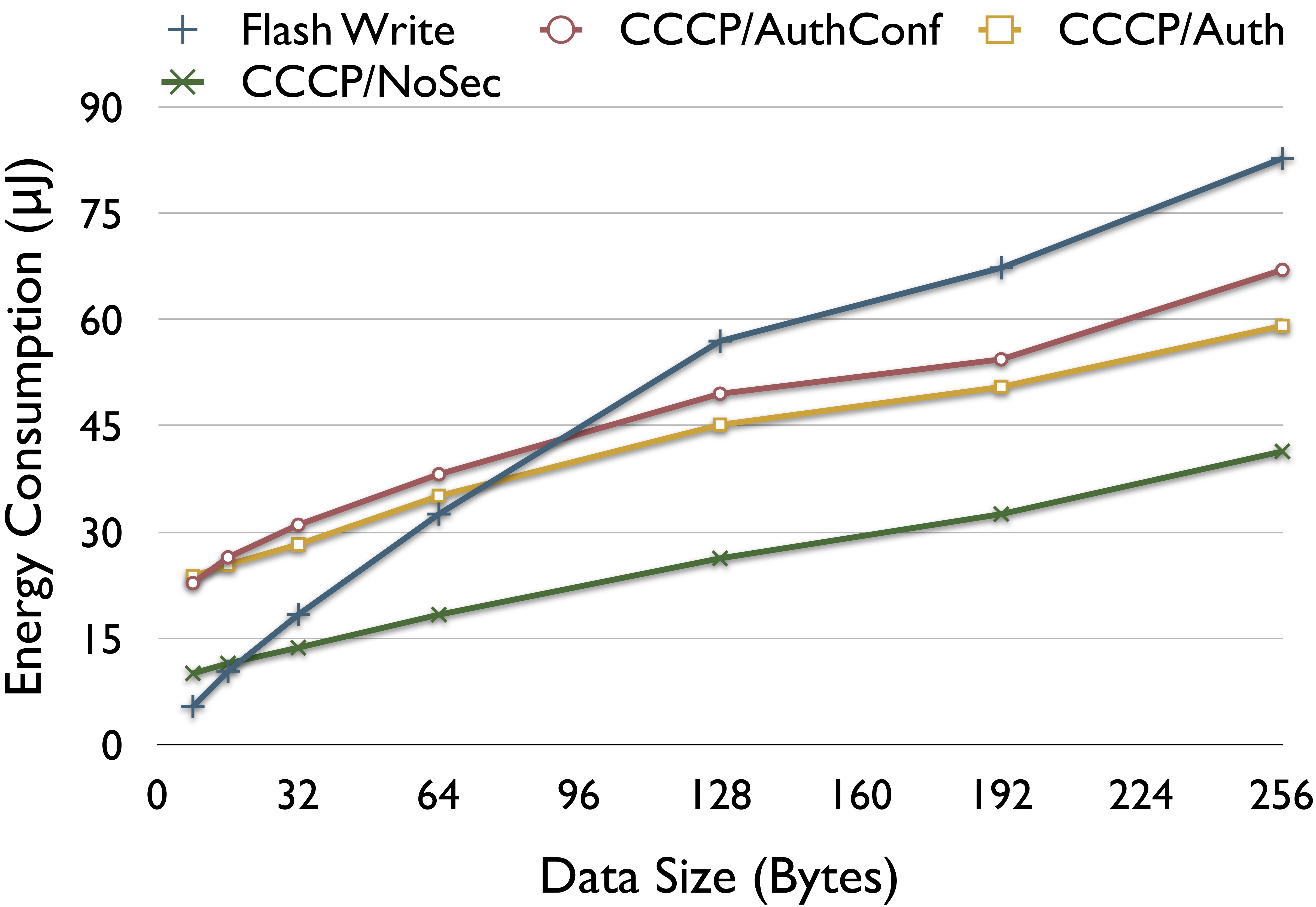
Data Size (Bytes)


Flash Write
CCCP/AuthConf
CCCP/Auth
CCCP/NoSec
Energy Consumption (μJ)
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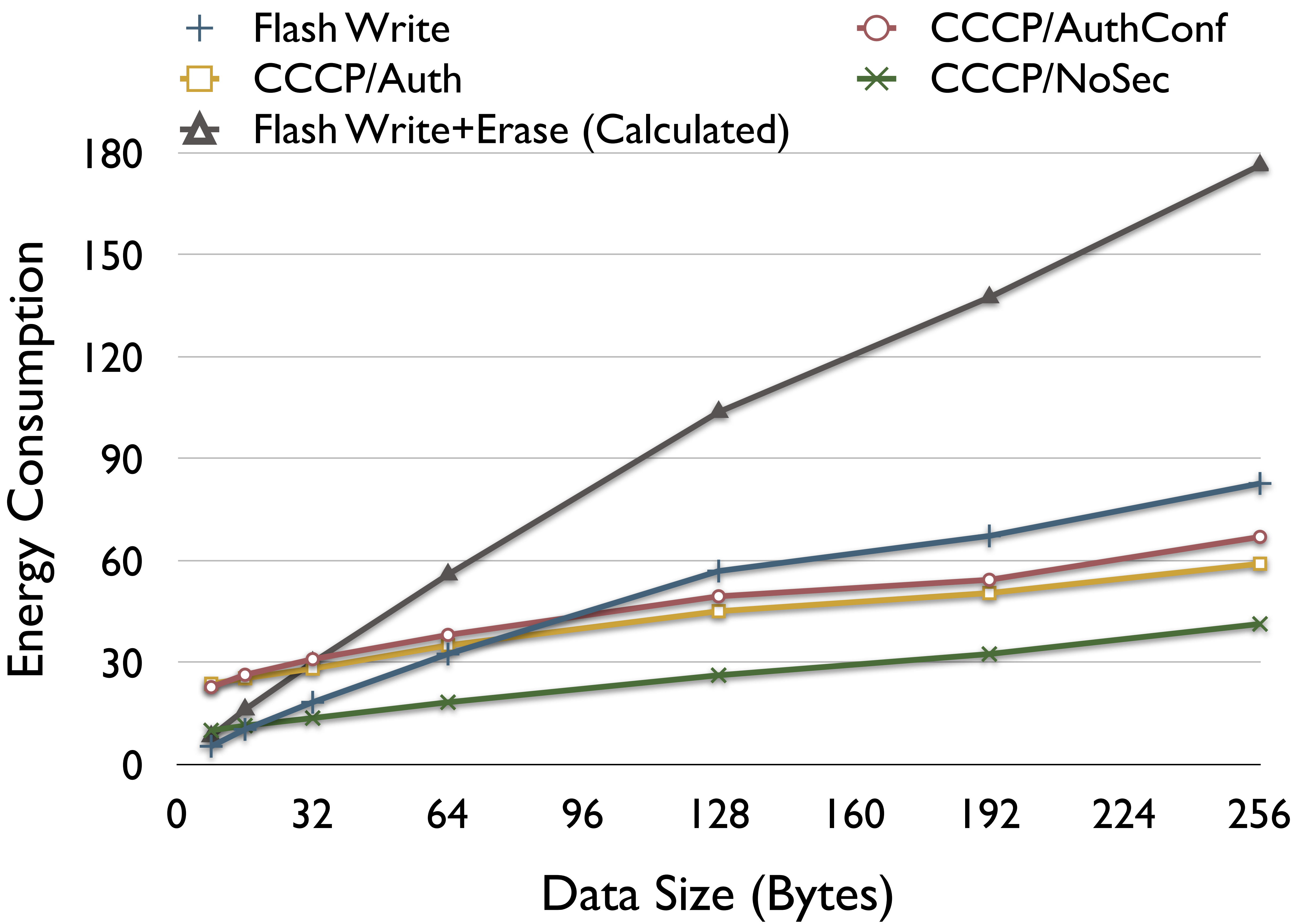
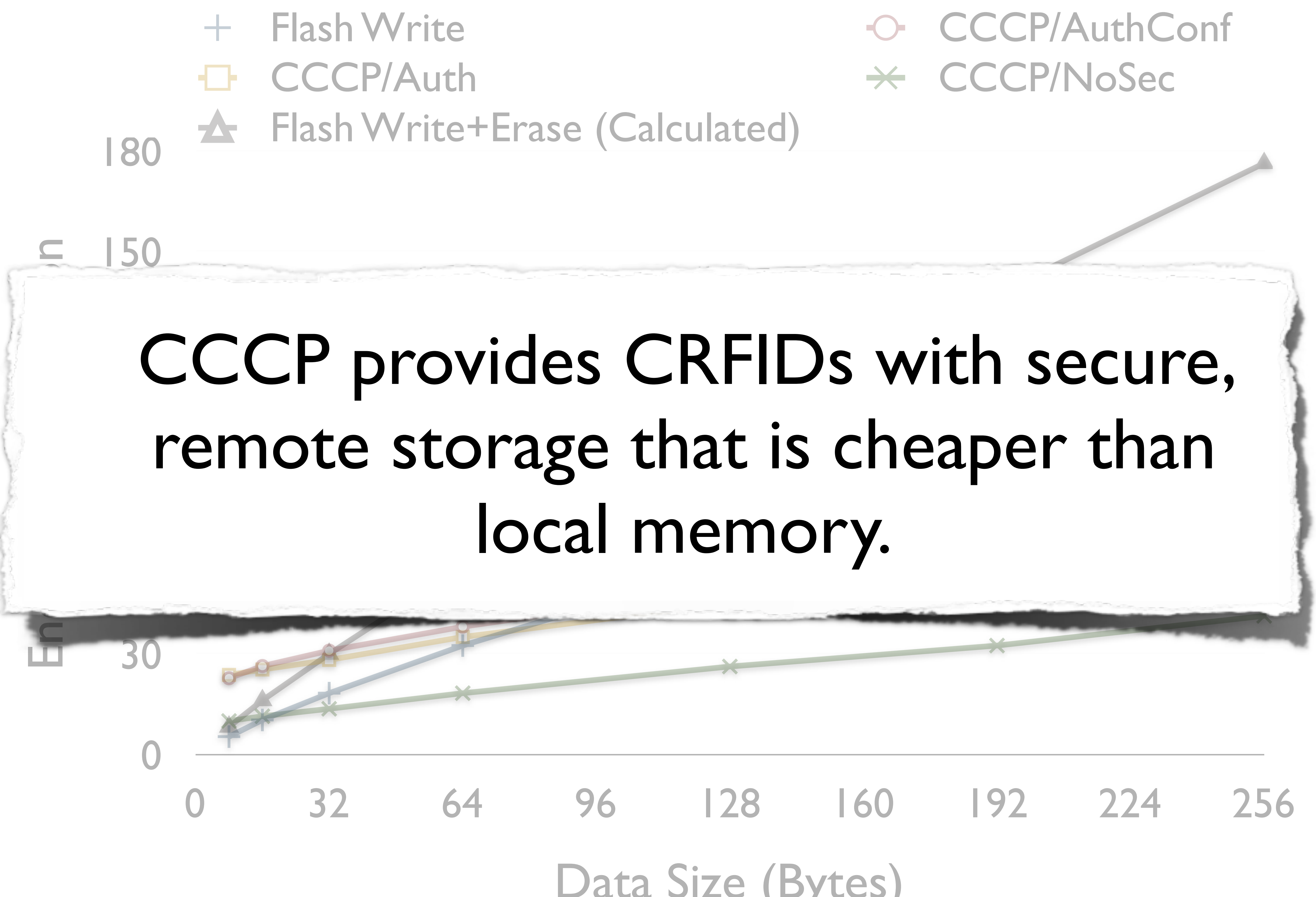

Flash Write
CCCP/Auth
Flash Write+Erase (Calculated)
CCCP/AuthConf
CCCP/NoSec
Energy Consumption
180
150
120
90
60
30
0
0
32
64
96
128
160
192
224
256
Data Size (Bytes)



Flash Write
CCCP/AuthConf
CCCP/Auth
CCCP/NoSec
Flash Write+Erase (Calculated)
180
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30
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224
256
Data Size (Bytes)
CCCP provides CRFIDs with secure, remote storage that is cheaper than local memory.

Extensions/Future Work

- CRFID hardware design
- Long-term storage
- WOM codes [Rivest '82]
- PKCS on CRFIDs

Summary

- CRFIDs can go where other platforms cannot
- They are limited by available energy
- Remote storage is cheap
- CCCP provides remote storage that is secure and yet less expensive than local storage.

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More info at: www.cs.umass.edu/~ssclark/crfid