Secure and Efficient Initialization and Authentication Protocols for SHIELD

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- Adversarial Models
- DARPA's Authentication Protocol
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- Proposed Authentication Protocol
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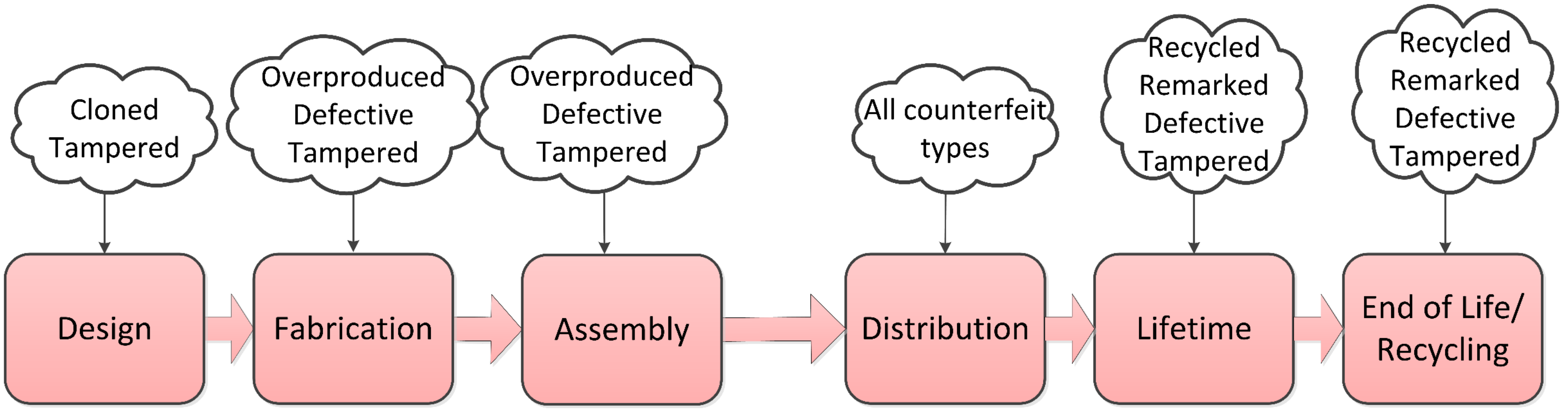
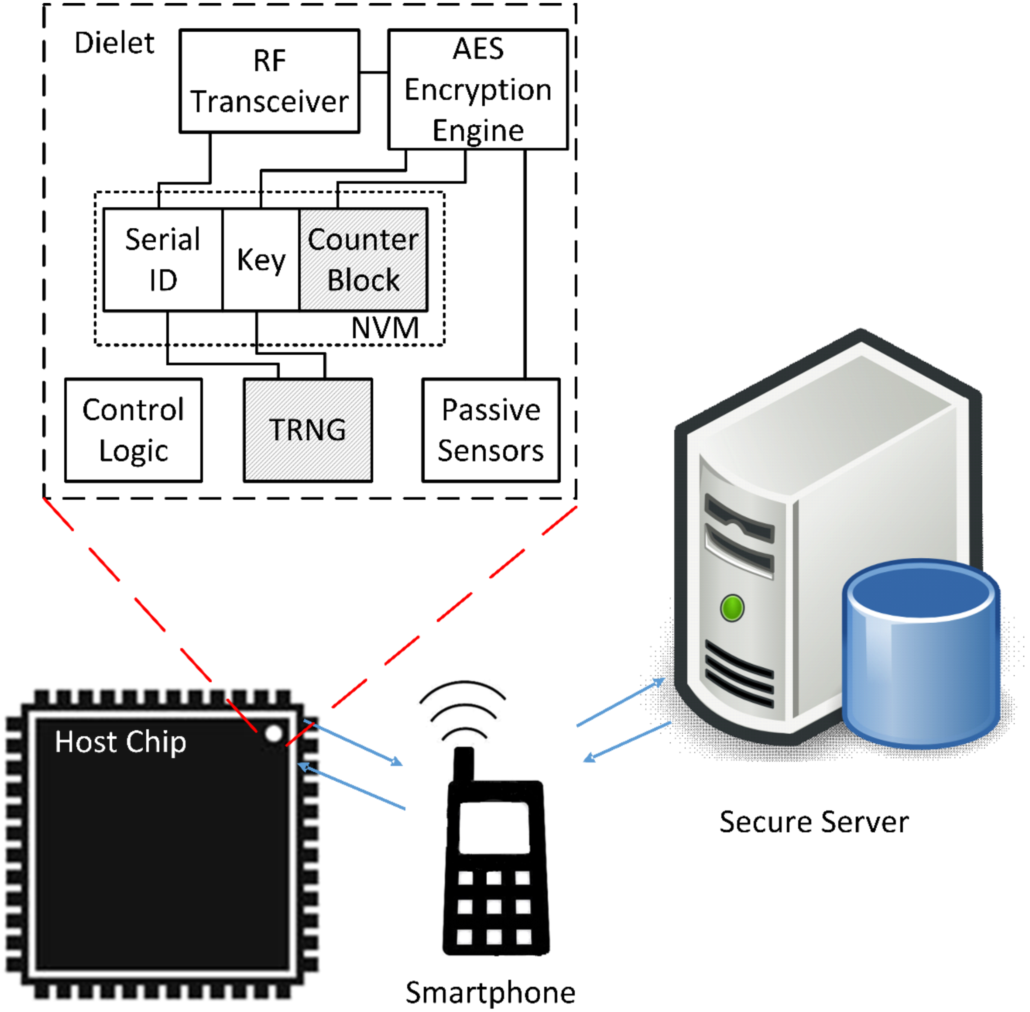
Motivation



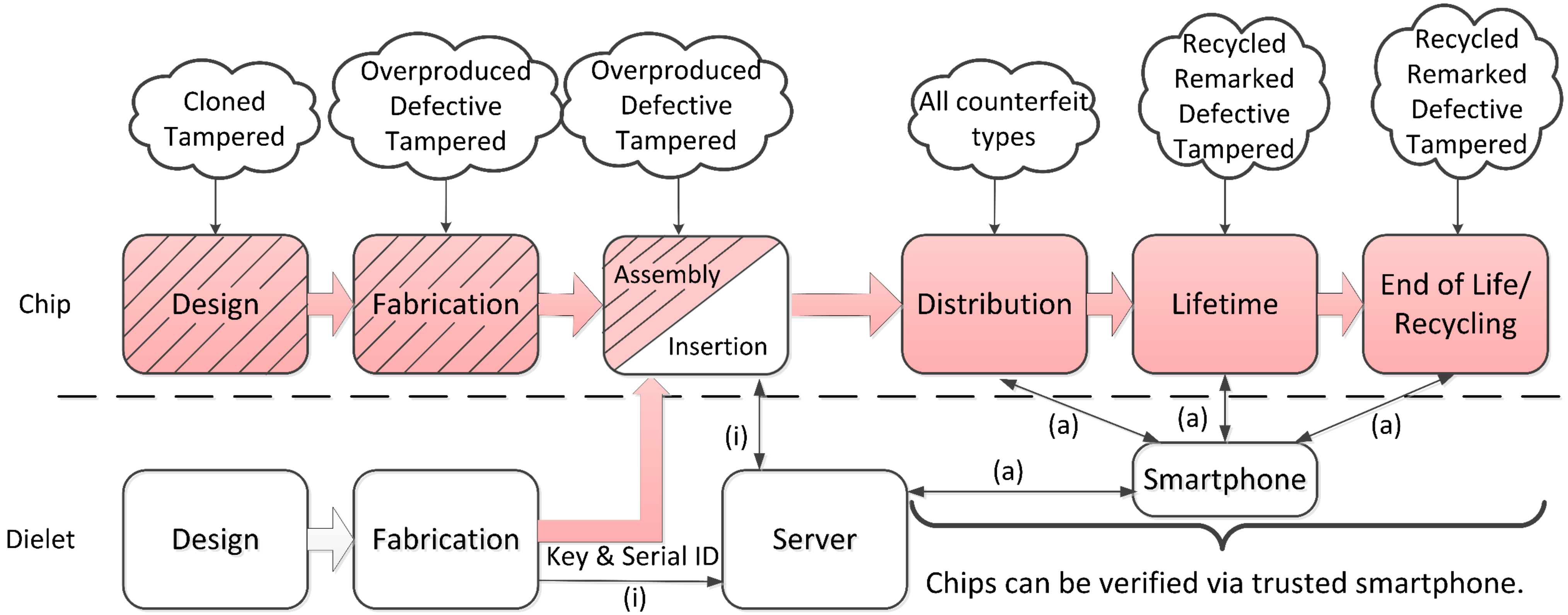
- Nowadays, untrusted IC supply chain introduces a variety of security threats.
- Many countermeasures are proposed. Usually they are specific for one security vulnerability in the supply chain.

SHIELD

- SHIELD (Supply Chain Hardware Integrity for Electronics Defense) was proposed by DARPA in 2014.
- A dielet chip inserted in the host package of a legitimate chip, in order to verify the host chip remotely.

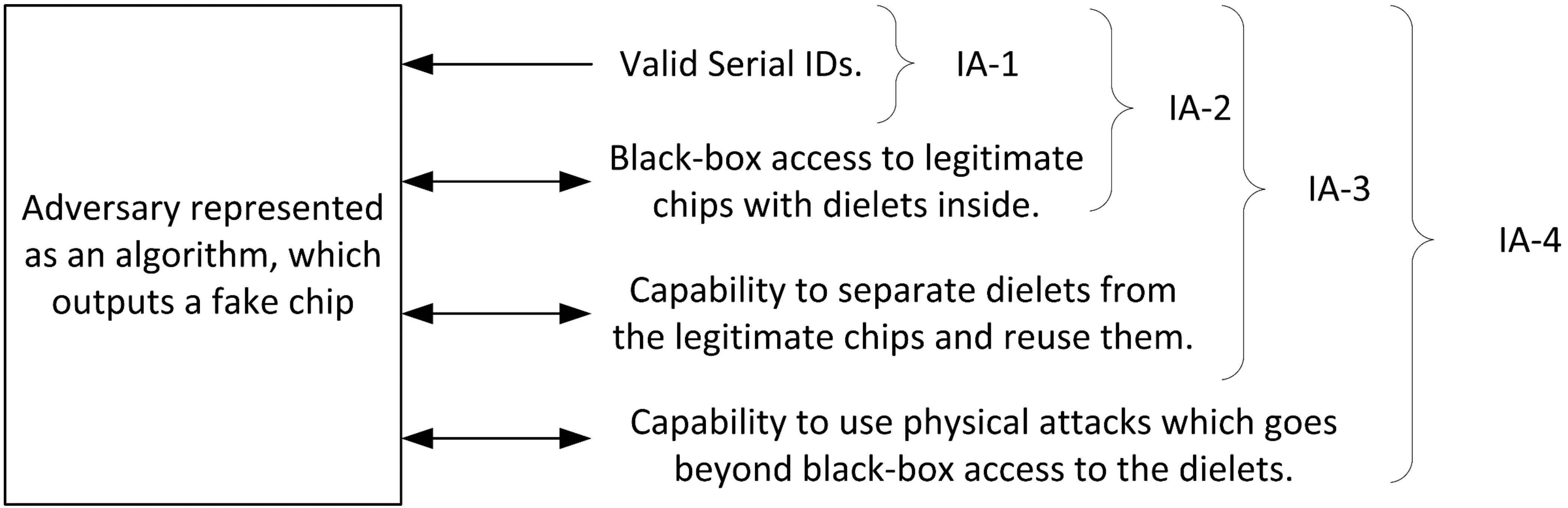


SHIELD Protected IC Supply Chain



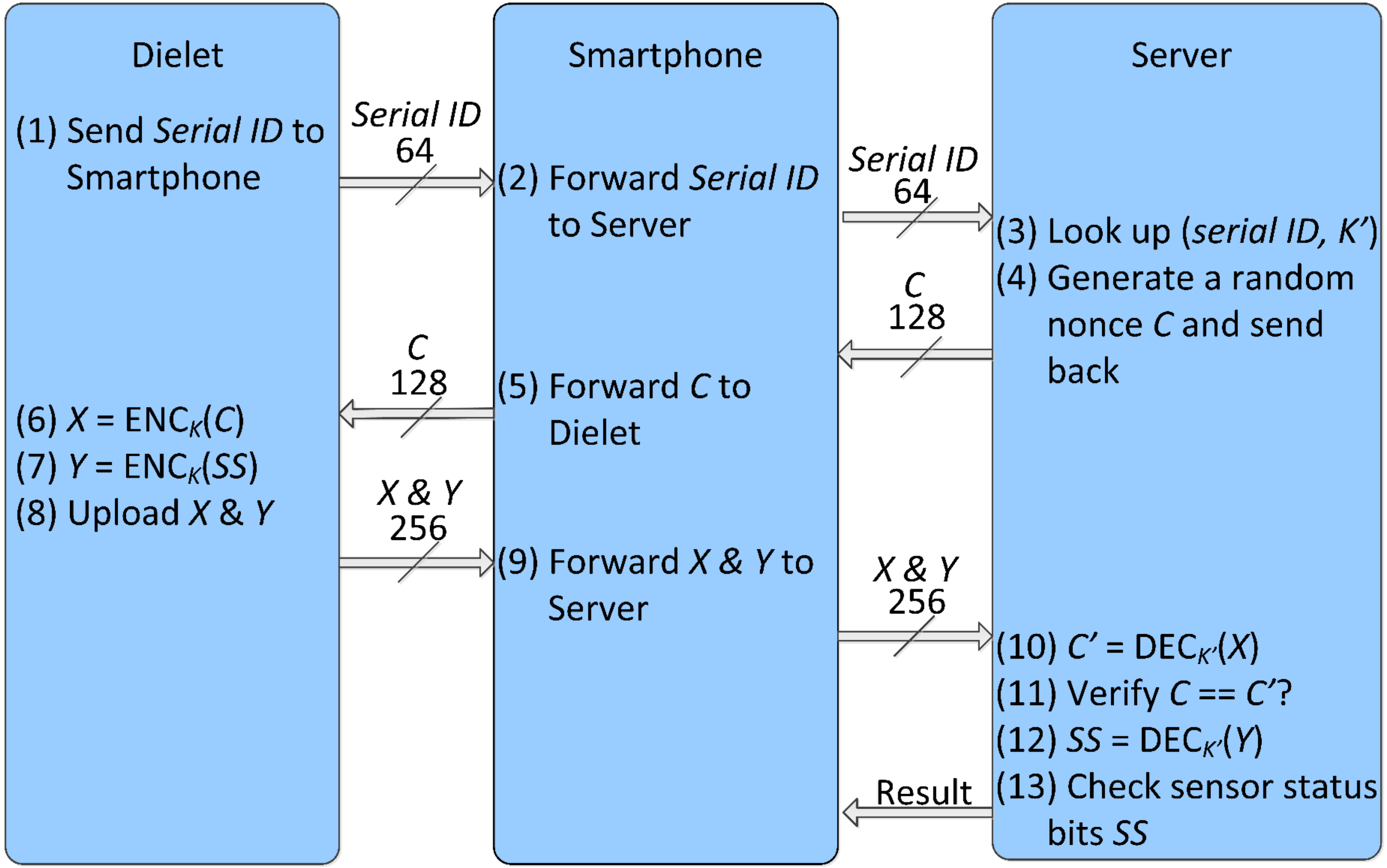
Adversarial Models

- Denial of Service (DoS):
  - Single dielet DoS: allowed by DARPA
  - Batch mode DoS: needs protection
- Impersonation Attacks (IA):



DARPA's Authentication Protocol

Authentication Protocol



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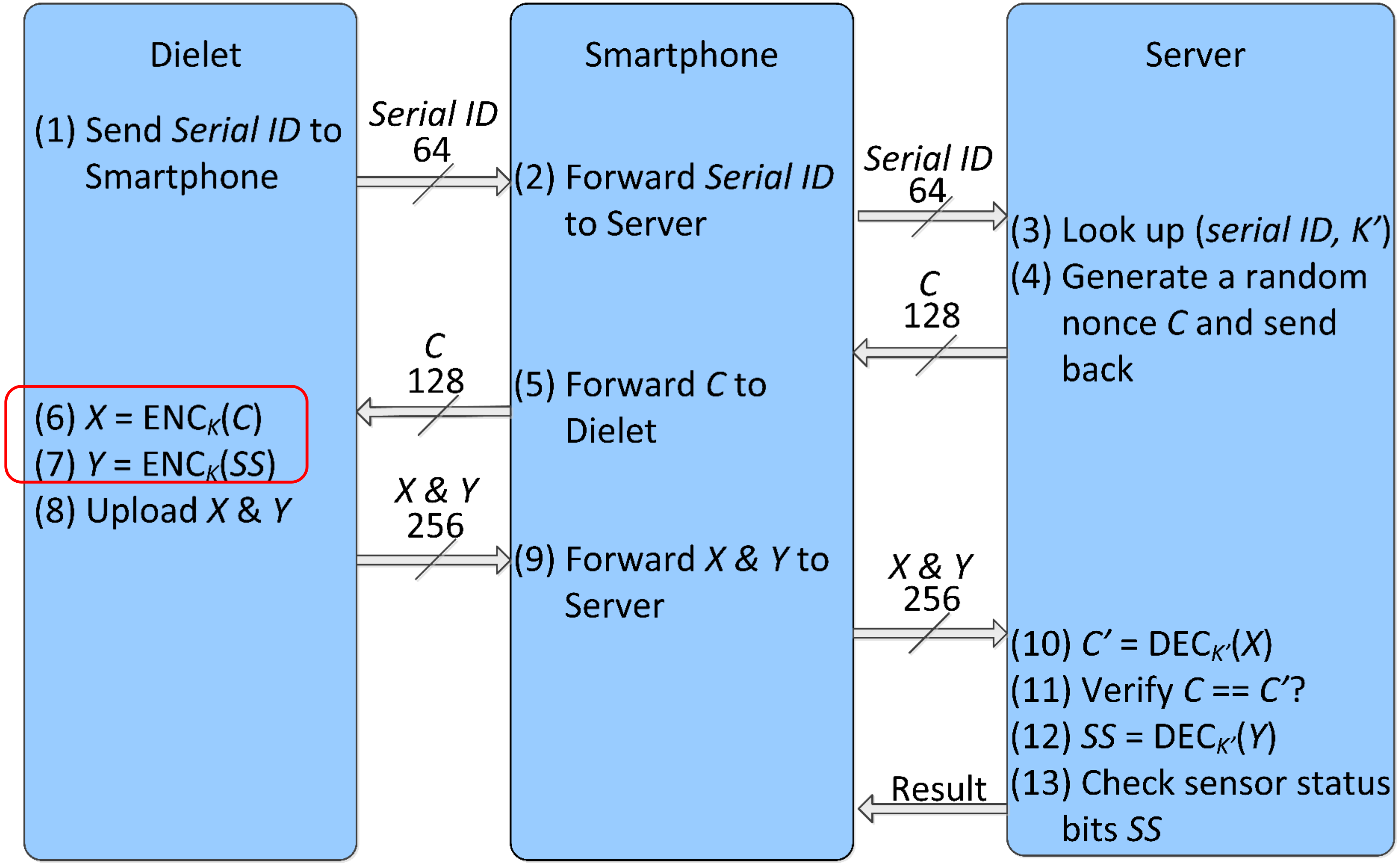

Deterministic Encryption!

Try-and-Check Attack

- Try-and-Check attack is one IA-3 attack, which nullifies the effectiveness of DARPA's authentication protocol in that the adversarial events will not be recorded and detected by the verifier.

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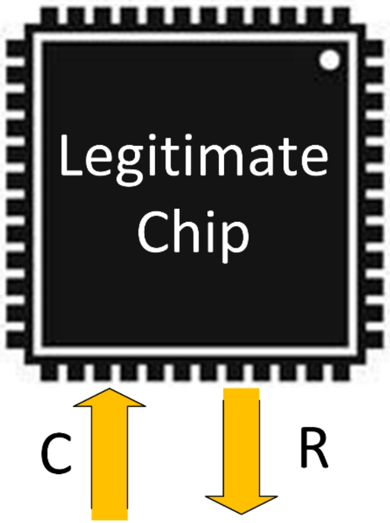
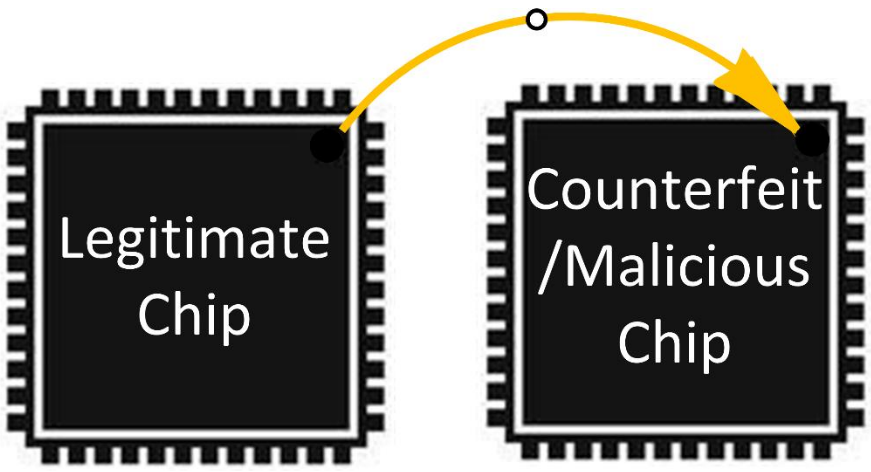
- 1. Apply Challenge C to a legitimate chip with a legitimate dielet inside, and store the response R = Enc(C) | Enc(S). S is the sensor status.



R = Enc(C) | Enc(S)

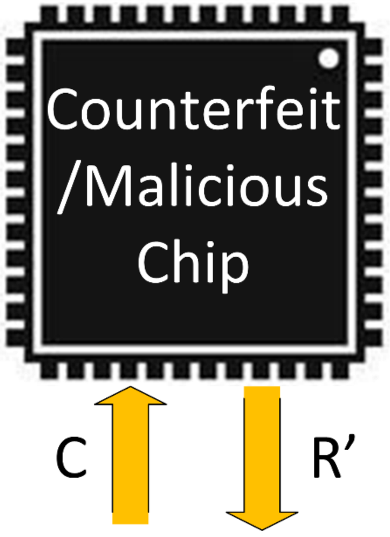
Try-and-Check Attack

- 2. Try to separate the dielet from the legitimate chip, and embed it into a counterfeit or malicious chip. This separation process may alter the sensor status S on the dielet.



Try-and-Check Attack

- 3. Check R = R’ ? If R = R’, it means that sensor status is not altered (S = S’). Therefore the attackers can conclude that this counterfeit/ malicious chip can be authenticated in the supply chain without being detected.



R’ = Enc(C) | Enc(S’)

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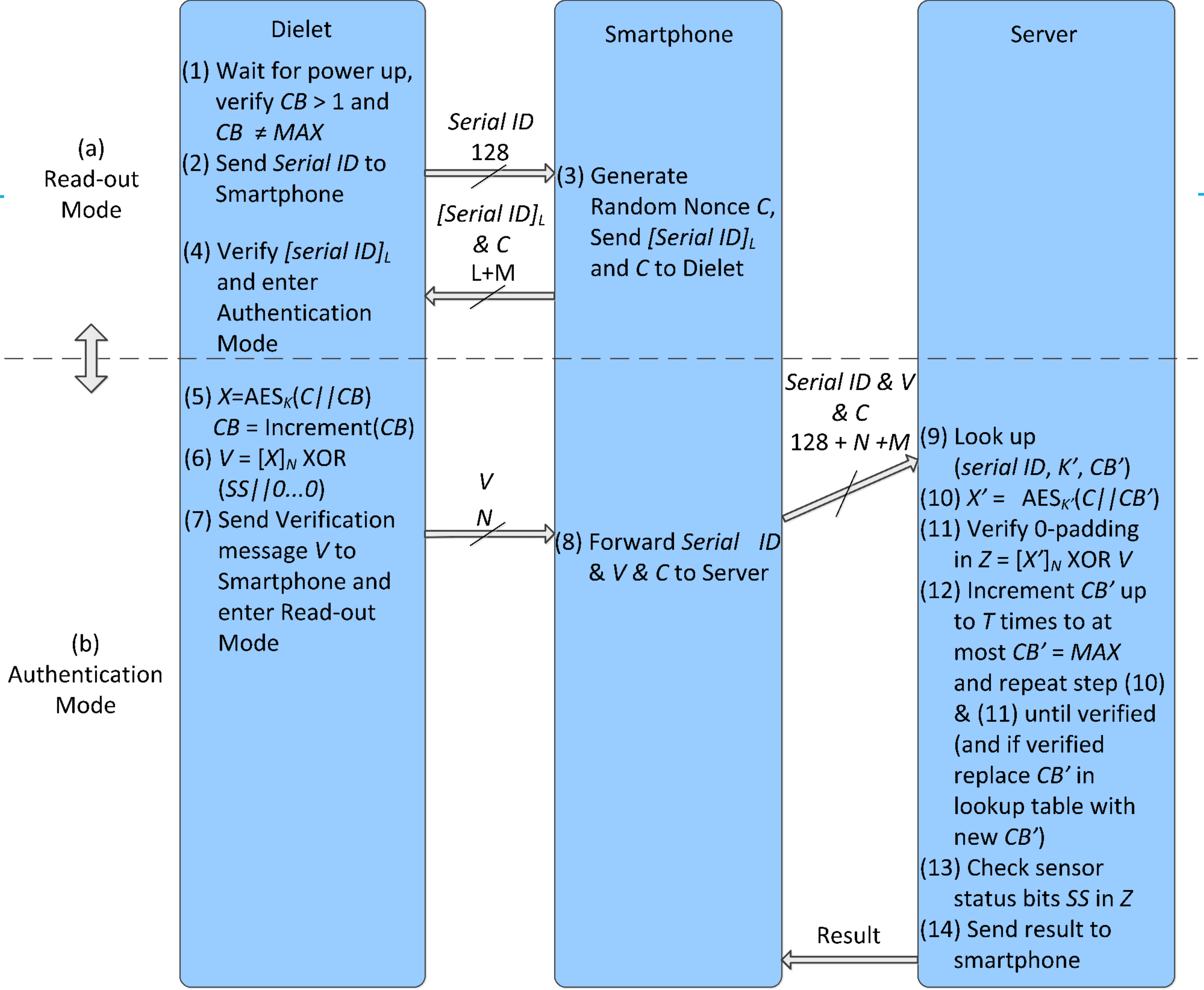
- Use probabilistic encryption instead of deterministic encryption.
- We suggest AES Counter Mode Encryption as an efficient solution.
- R = Enc(C|Counter) XOR S.
- Because this incremental counter value is never repeated, the same sensor status S will not generate the same response. This prevents Try-and-Check attack.

Proposed Authentication Protocol


Dielet
Smartphone
Server
(a) Read-out Mode
(1) Wait for power up, verify $CB > 1$ and $CB \neq MAX$
(2) Send *Serial ID* to Smartphone
Serial ID 128
(3) Generate Random Nonce *C*, Send $[Serial\ ID]_L$ and *C* to Dielet
$[Serial\ ID]_L$ & *C* L+M
(4) Verify $[serial\ ID]_L$ and enter Authentication Mode
(b) Authentication Mode
(5) $X = AES_K(C||CB)$ CB = Increment(CB)
(6) $V = [X]_N$ XOR $(SS||0...0)$
(7) Send Verification message *V* to Smartphone and enter Read-out Mode
V *N*
(8) Forward *Serial ID* & *V* & *C* to Server
Serial ID & *V* & *C* 128 + *N* +*M*
(9) Look up (*serial ID*, *K'*, *CB'*)
(10) $X' = AES_{K'}(C||CB')$
(11) Verify 0-padding in $Z = [X']_N$ XOR V
(12) Increment *CB'* up to *T* times to at most $CB' = MAX$ and repeat step (10) & (11) until verified (and if verified replace *CB'* in lookup table with new *CB'*)
(13) Check sensor status bits *SS* in *Z*
(14) Send result to smartphone
Result

Security Benefits

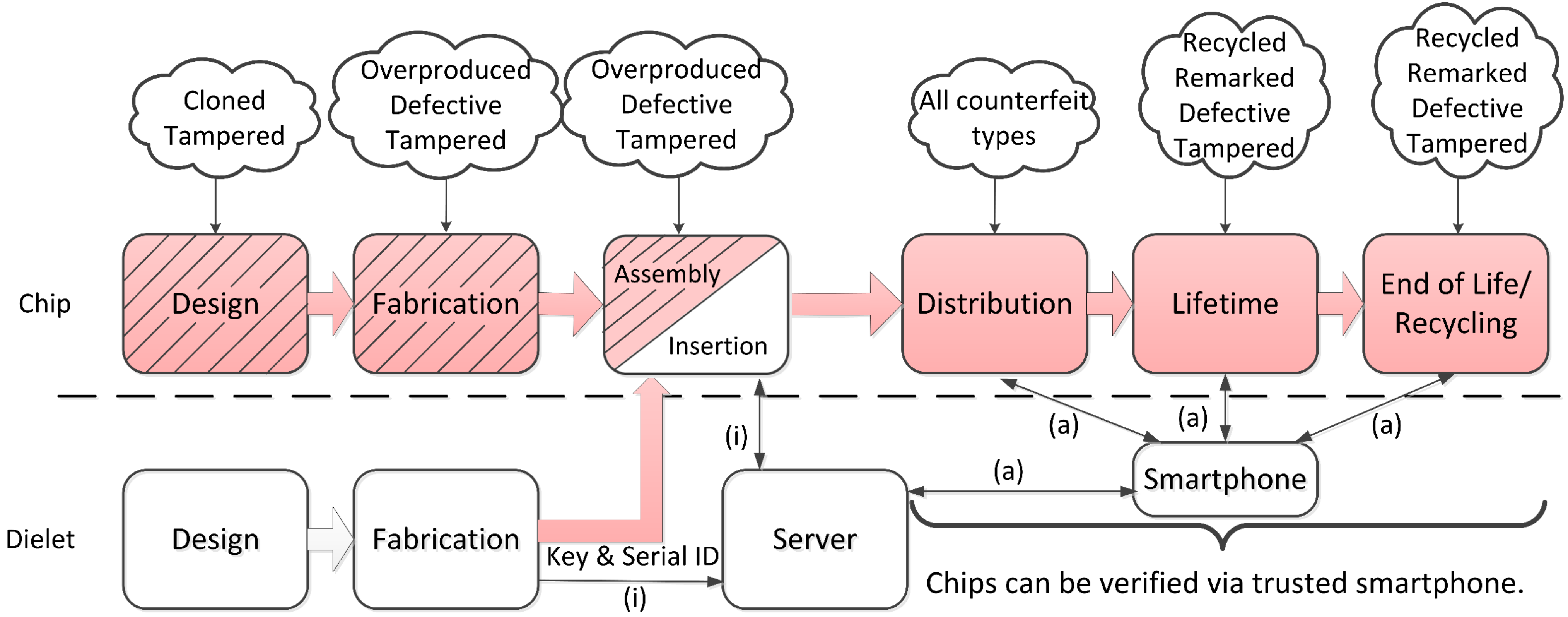
- Protect against IA-1, IA-2 and IA-3 attacks.
  - DARPA's protocol is vulnerable to Try-and-Check attack.
- Increase the difficulty of IA-4 attacks by limiting the power traces and incrementing counter values.
- Prevent batch mode DoS attack by adding a read-out mode before authentication mode.
- The counter of AES counter mode can be used as an indicator of suspicious offline behavior.

Performance Benefit

- Reduce the power consumption
  - Number of transmitted bits: 258 bits instead of 448 bits.
  - Number of encryptions: one encryption instead of two encryptions
- Speed up the protocol execution by halving the number of communication rounds with the server.

Dielet Initialization

- The main threat comes from the untrusted transit between dielet fabrication facilities and insertion facilities.



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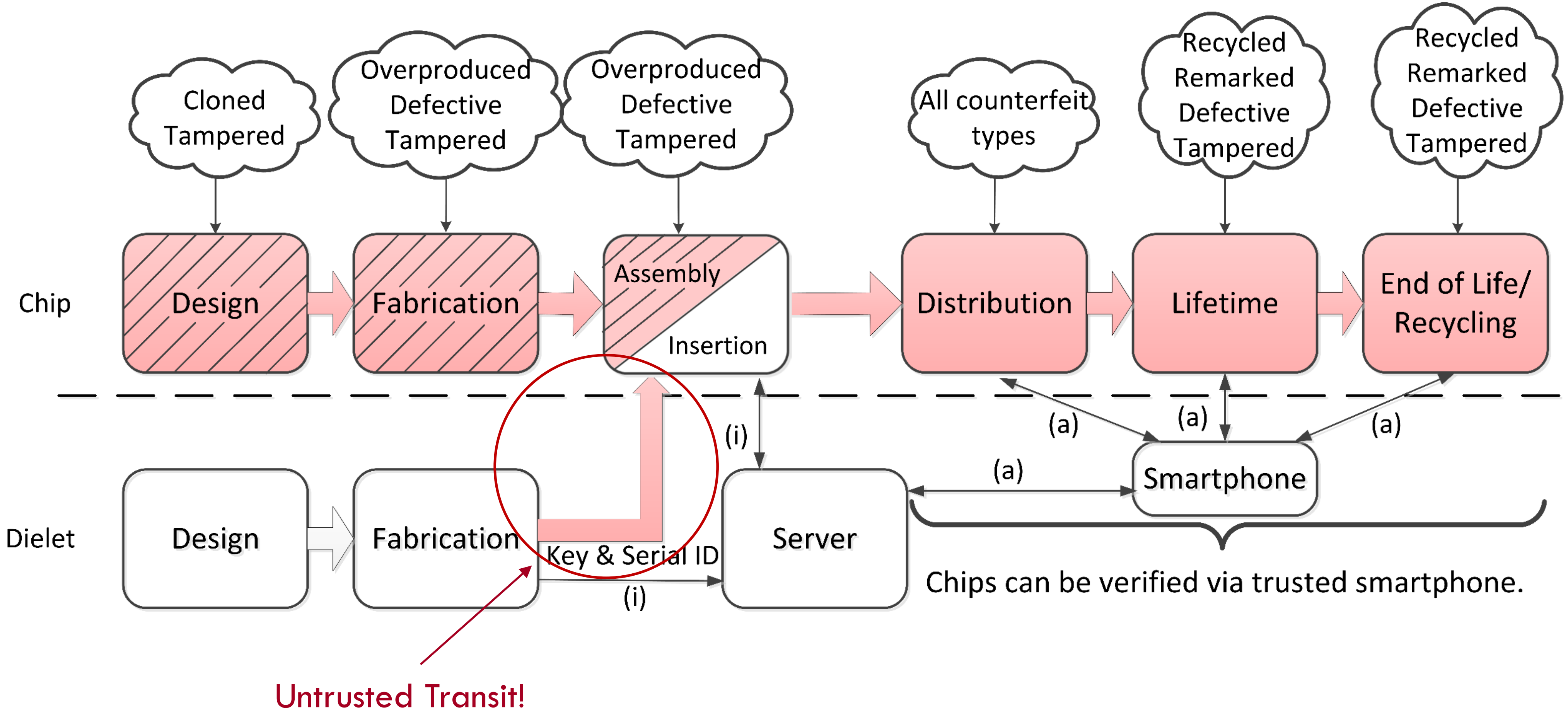

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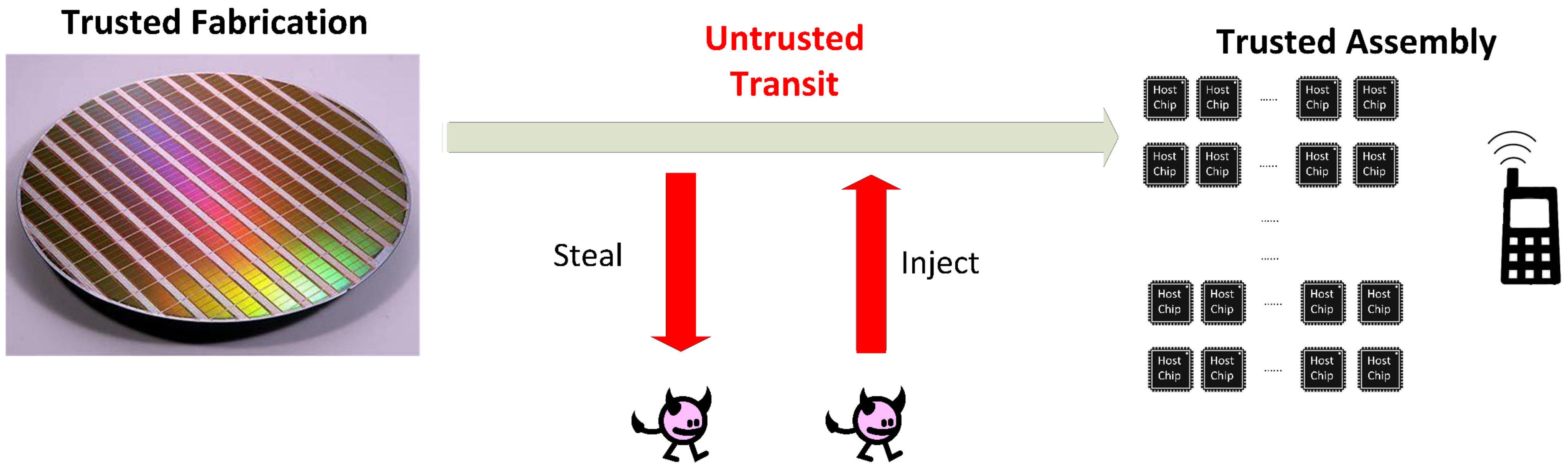
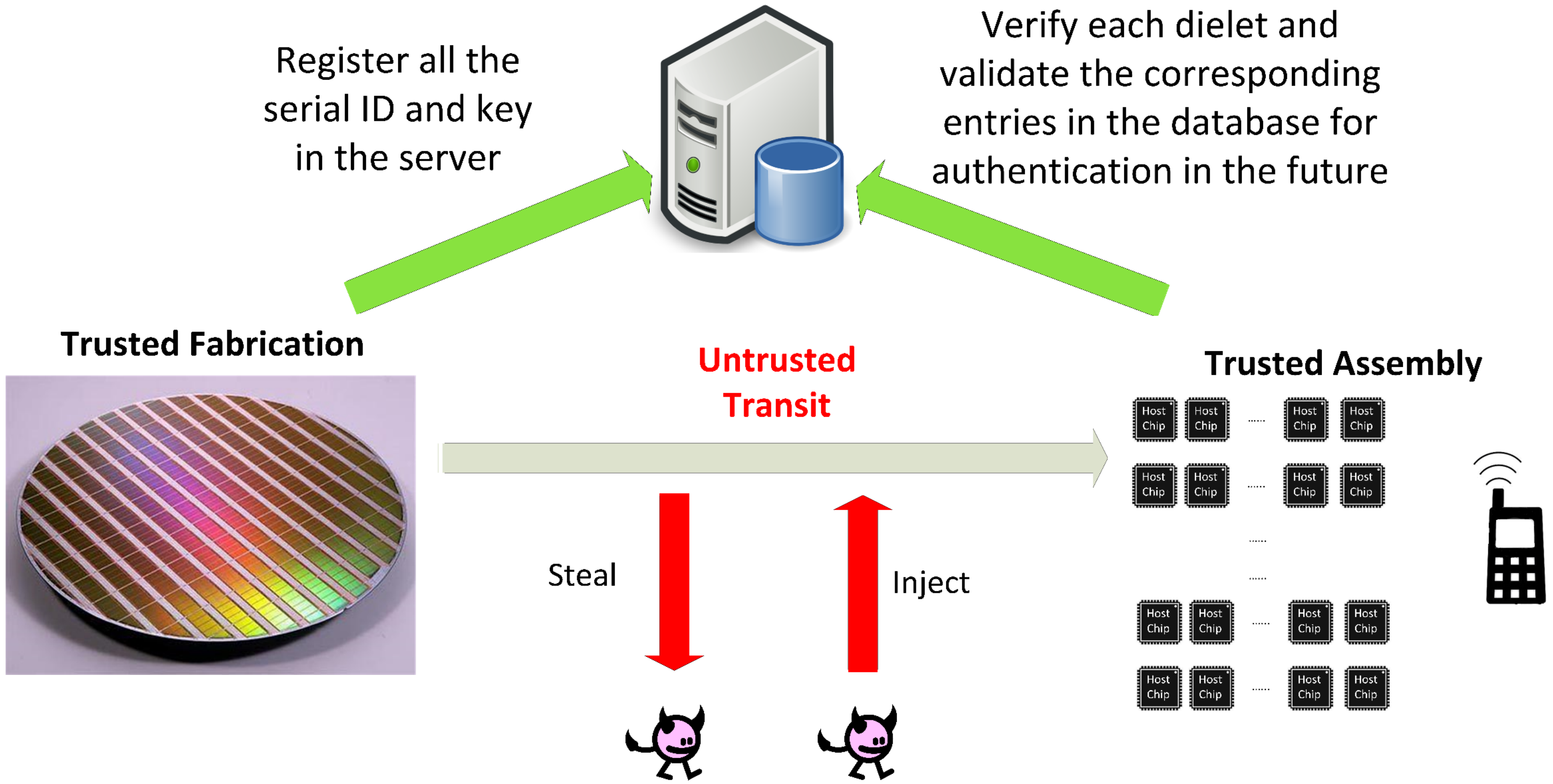
Initialization Protocol



Initialization Protocol



Benefits

- Due to a one-time initialization and two-phase activation construct in our initialization protocol, transits between trusted fabrication and trusted assembly facilities can be untrusted.
- On-board TRNG allows dielets to efficiently generate the secret keys and serial IDs in parallel.

Conclusion

- We introduce a "try-and-check" attack which nullifies the effectiveness of one of SHIELD's main goals of being able to detect and trace adversarial activities with significant probability.
- We introduce an improved authentication protocol which resists the try-and-check attack, compared to DARPA's example authentication protocol.
- We introduce the first concrete initialization protocol.
- The additional area utilization for our authentication and initialization protocols compared to DARPA's authentication protocol is only 4% of the allowed area of the dielet ($0.01mm^2$) in 32nm technology.
- Our findings and rigorous analysis are of utmost importance for the team which received DARPA's funding for implementing SHIELD.

ePrint available at: http://eprint.iacr.org/2015/210

Thank you!