•True random numbers generators

Several sources of randomness – natural sources of randomness

- •decay times of radioactive materials
- •electrical noise from a resistor or semiconductor
- •radio channel or audible noise
- •keyboard timings
- •disk electrical activity
- •mouse movements
- •Physical unclonable function (PUF)
- •Some are better than others

Combining sources of randomness

•Suppose r1, r2, …, rk are random numbers from different sources. E.g.,

r1 = electrical noise from a resistor or semiconductor

r2 = sample of hip-hop music on radio

r3 = clock on computer

b = r1⊕r2⊕…⊕rk

If any one of r1, r2, …, rk is truly random, then so is b

Many poor sources + 1 good source = good entropy

Pseudorandom Number Generators (PRNGs)

- True randomness is expensive
- **Pseudorandom number generator** (**PRNGs**): An algorithm that uses a little bit of true randomness to generate a lot of random-looking output
- Also called **deterministic random bit generators** (**DRBGs**)
- PRNGs are deterministic: Output is generated according to a set algorithm
- However, for an attacker who can't see the internal state, the output is *computationally indistinguishable* from true randomness

PRNG: Definition

- A PRNG has two functions:
  - ➢ PRNG.Seed(randomness): Initializes the internal state using the entropy

    Input: Some truly random bits
  - ➢ PRNG.Generate(*n*): Generate *n* pseudorandom bits

  Input: A number *n*

  Output: *n* pseudorandom bits

  Updates the internal state as needed

Properties

- •**Correctness**: Deterministic
- •**Efficiency**: Efficient to generate pseudorandom bits
- •**Security**: Indistinguishability from random
- •**Rollback resistance**: cannot deduce anything about any previously-generated bit

Example construction of PRNG

•Using block cipher in Counter (CTR) mode:

•If you want m random bits, and a block cipher with E_k has n bits, apply the block cipher m/n times and concatenate the result:

•PRNG.Seed(K | IV) = E_k(IV, 1) | E_k(IV, 2) | E_k(IV, 3) … E_k(IV, ceil(m/n)),

•| is concatenation

•Initialization vector (IV) / Nonce – typically is random or pseudorandom

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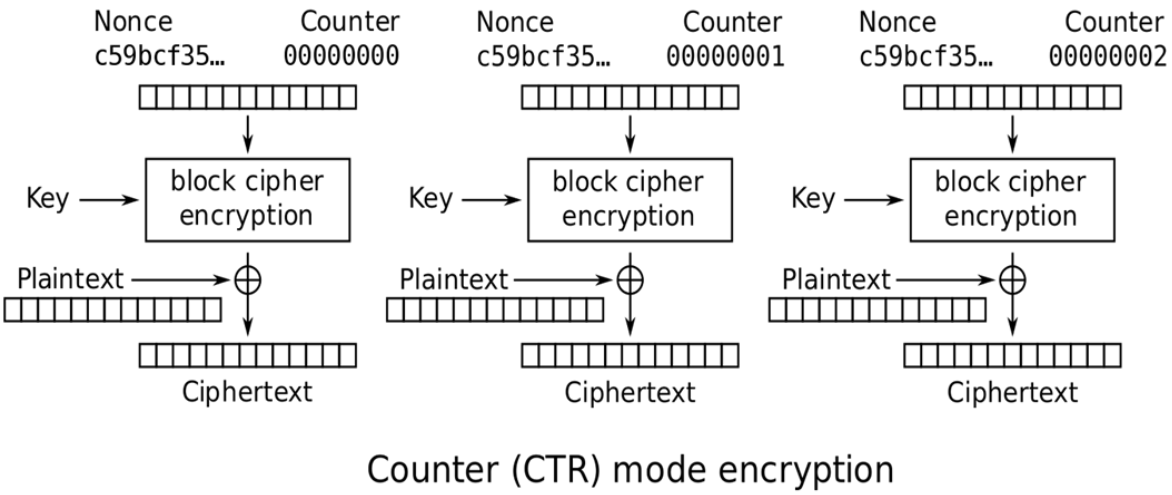

Counter (CTR) mode encryption

PRNG: Security

•Can we design a PRNG that is truly random?

•A PRNG cannot be truly random

•The output is deterministic given the initial seed

•A secure PRNG is computationally indistinguishable from random to an attacker

•Game: Present an attacker with a truly random sequence and a sequence outputted from a secure PRNG

•An attacker should be able to determine which is which with probability ≈ 0

•Equivalence: An attacker cannot predict future output of the PRNG

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Create pseudorandom numbers

•Truly random numbers are impossible with any program!

•However, we can generate seemingly random numbers, called pseudorandom numbers

•The function rand() returns a non-negative number between 0 and RAND_MAX

•For C, it is defined in stdlib.h

PRNGs: Summary

•True randomness requires sampling a physical process

•PRNG: An algorithm that uses a little bit of true randomness to generate a lot of random-looking output

•Seed(entropy): Initialize internal state

•Generate(n): Generate n bits of pseudorandom output

•Security: computationally indistinguishable from truly random bits

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