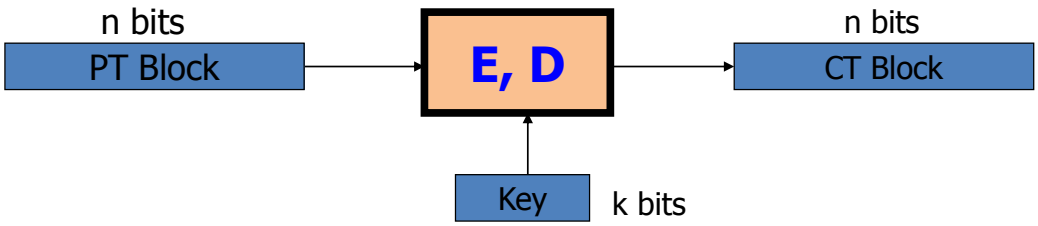
Block ciphers

What is a block cipher?

Block ciphers: crypto work horse

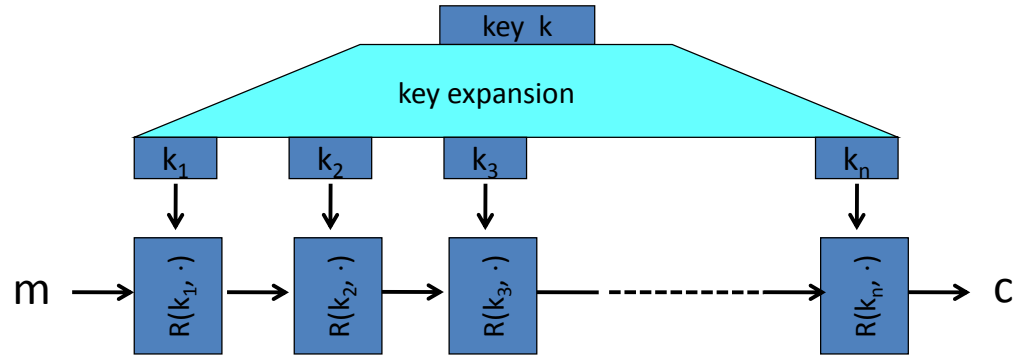


Canonical examples:

1. 3DES: n= 64 bits, k = 168 bits
2. AES: n=128 bits, k = 128, 192, 256 bits

Dan Boneh

Block Ciphers Built by Iteration



R(k,m) is called a round function

for 3DES (n=48), for AES-128 (n=10)

Dan Boneh

Performance:

Crypto++ 5.6.0 [Wei Dai]

AMD Opteron, 2.2 GHz (Linux)

	Cipher	Block/key size	Speed (MB/sec)
stream	RC4		126
	Salsa20/12		643
	Sosemanuk		727
block	3DES	64/168	13
	AES-128	128/128	109

Dan Boneh

Abstractly: PRPs and PRFs

- Pseudo Random Function (**PRF**) defined over (K,X,Y):

  $F: K \times X \rightarrow Y$

  such that exists "efficient" algorithm to evaluate F(k,x)

- Pseudo Random Permutation (**PRP**) defined over (K,X):

  $E: K \times X \rightarrow X$

  such that:

  1. Exists "efficient" deterministic algorithm to evaluate E(k,x)
  2. The function $E(k, \cdot)$ is one-to-one
  3. Exists "efficient" inversion algorithm D(k,y)

Dan Boneh

Running example

- Example PRPs: 3DES, AES, …

  AES: $K \times X \rightarrow X$ where $K = X = \{0,1\}^{128}$

  3DES: $K \times X \rightarrow X$ where $X = \{0,1\}^{64}$, $K = \{0,1\}^{168}$

- Functionally, any PRP is also a PRF.
  - A PRP is a PRF where X=Y and is efficiently invertible.

Dan Boneh

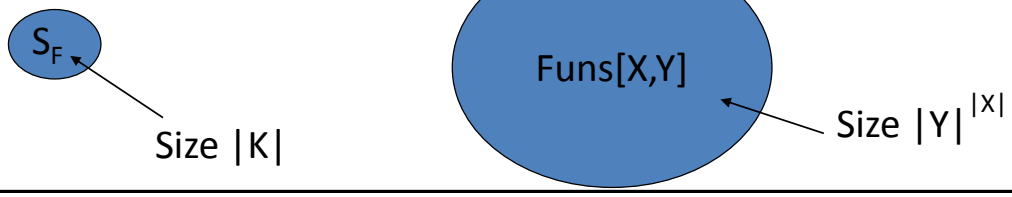
Secure PRFs

- Let $F: K \times X \rightarrow Y$ be a PRF

  Funs[X,Y]: the set of **all** functions from X to Y

  $S_F = \{ F(k,\cdot) \text{ s.t. } k \in K \} \subseteq$ Funs[X,Y]

- Intuition: a PRF is **secure** if
  a random function in Funs[X,Y] is indistinguishable from
  a random function in S_F



Dan Boneh

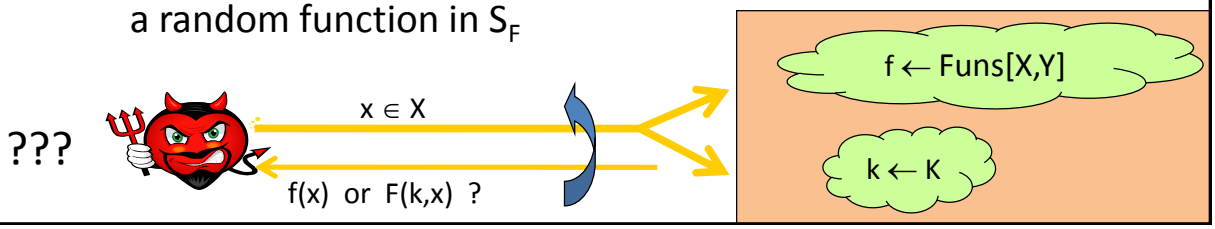
Secure PRFs

- Let $F: K \times X \rightarrow Y$ be a PRF

  Funs[X,Y]: the set of **all** functions from X to Y

  $S_F = \{ F(k,\cdot) \text{ s.t. } k \in K \} \subseteq$ Funs[X,Y]

- Intuition: a PRF is **secure** if
  a random function in Funs[X,Y] is indistinguishable from
  a random function in S_F



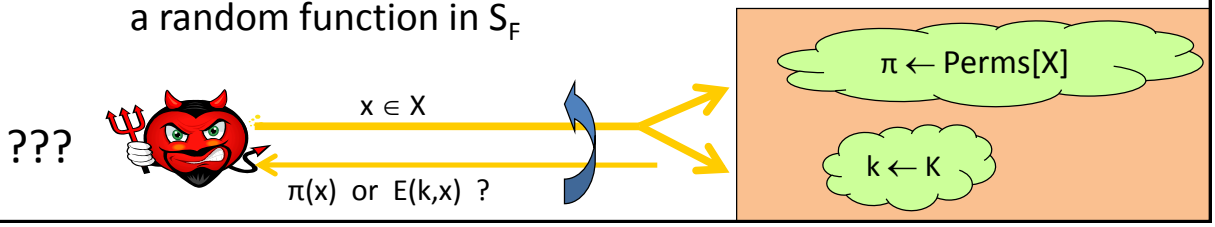
Secure PRPs (secure block cipher)

- Let $E: K \times X \rightarrow Y$ be a PRP

  Perms[X]: the set of all **one-to-one** functions from X to Y

  $S_F = \{ E(k,\cdot)$ s.t. $k \in K \} \subseteq$ Perms[X,Y]

- Intuition: a PRP is **secure** if
  a random function in Perms[X] is indistinguishable from
  a random function in S_F



Let $F: K \times X \rightarrow \{0,1\}^{128}$ be a secure PRF.

Is the following G a secure PRF?

$$G(k, x) = \begin{cases} 0^{128} & \text{if } x=0 \\ F(k,x) & \text{otherwise} \end{cases}$$

- ○ No, it is easy to distinguish G from a random function
- ○ Yes, an attack on G would also break F
- ○ It depends on F

An easy application: PRF ⇒ PRG

Let $F: K \times \{0,1\}^n \rightarrow \{0,1\}^n$ be a secure PRF.

Then the following $G: K \rightarrow \{0,1\}^{nt}$ is a secure PRG:

$$G(k) = F(k,0) \,||\, F(k,1) \,||\, \cdots \,||\, F(k,t-1)$$

Key property: parallelizable

Security from PRF property: $F(k, \cdot)$ indist. from random function $f(\cdot)$

Dan Boneh

End of Segment