Cryptography and Network Security Chapter 7

Fourth Edition

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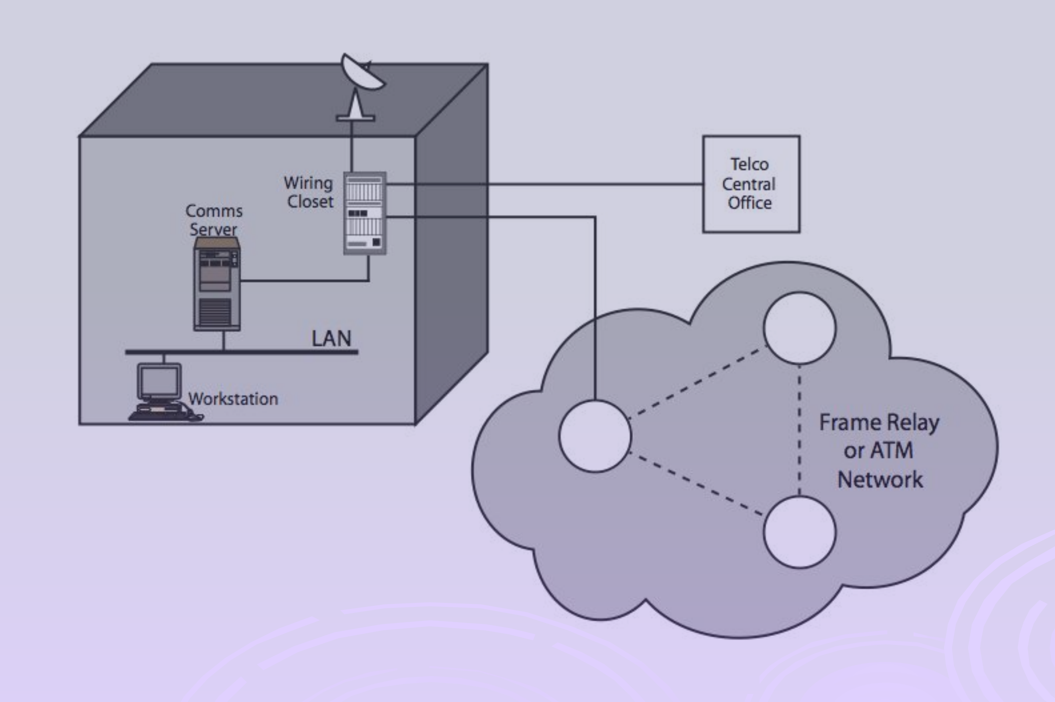
Chapter 7 – Confidentiality Using Symmetric Encryption

John wrote the letters of the alphabet under the letters in its first lines and tried it against the message. Immediately he knew that once more he had broken the code. It was extraordinary the feeling of triumph he had. He felt on top of the world. For not only had he done it, had he broken the July code, but he now had the key to every future coded message, since instructions as to the source of the next one must of necessity appear in the current one at the end of each month.

—*Talking to Strange Men,* Ruth Rendell

Confidentiality using Symmetric Encryption

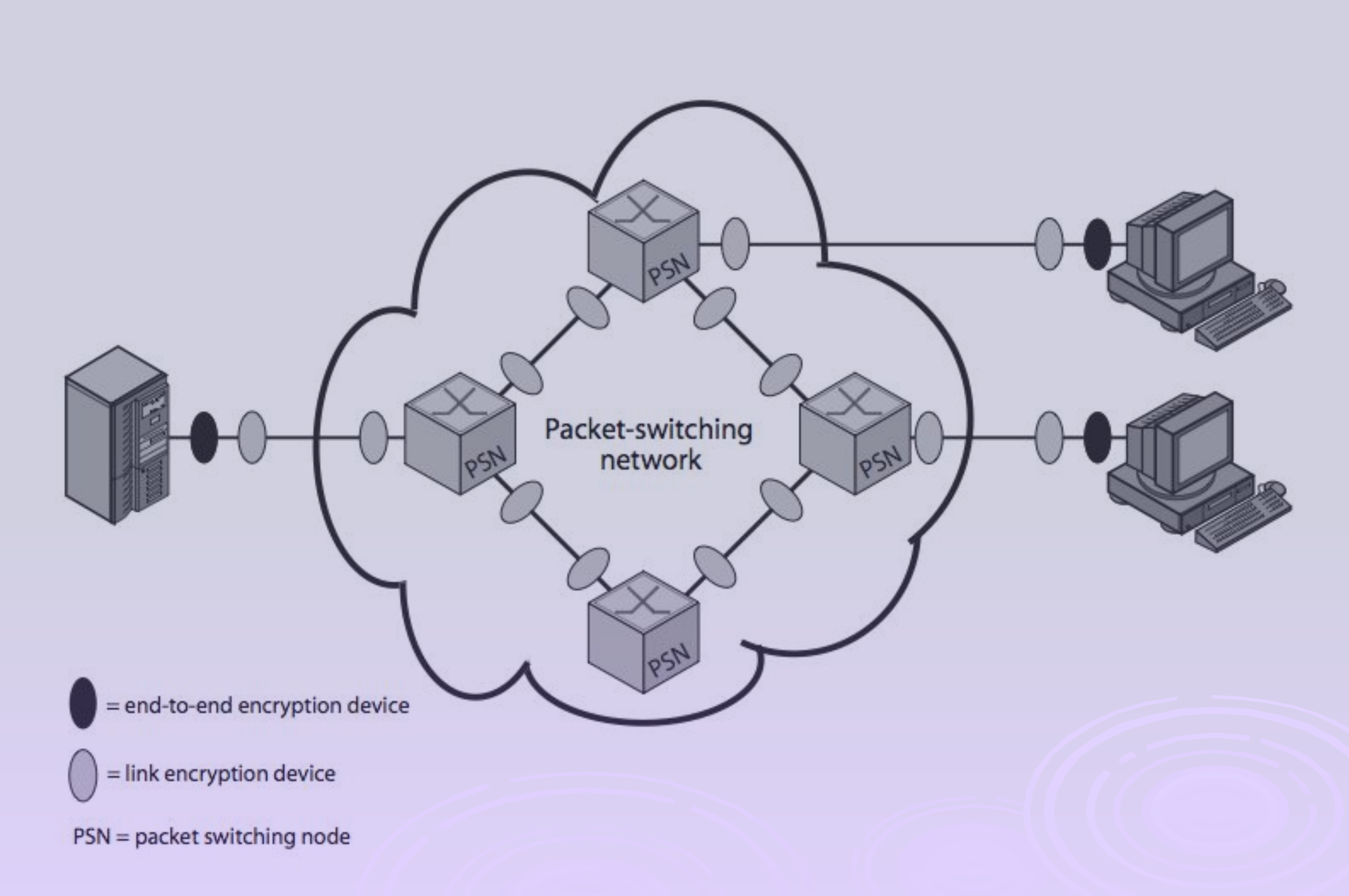
- traditionally symmetric encryption is used to provide message confidentiality



Placement of Encryption

- have two major placement alternatives
- **link encryption**
  - encryption occurs independently on every link
  - implies must decrypt traffic between links
  - requires many devices, but paired keys
- **end-to-end encryption**
  - encryption occurs between original source and final destination
  - need devices at each end with shared keys

Placement of Encryption


PSN
PSN
PSN
PSN
Packet-switching network
● = end-to-end encryption device
○ = link encryption device
PSN = packet switching node

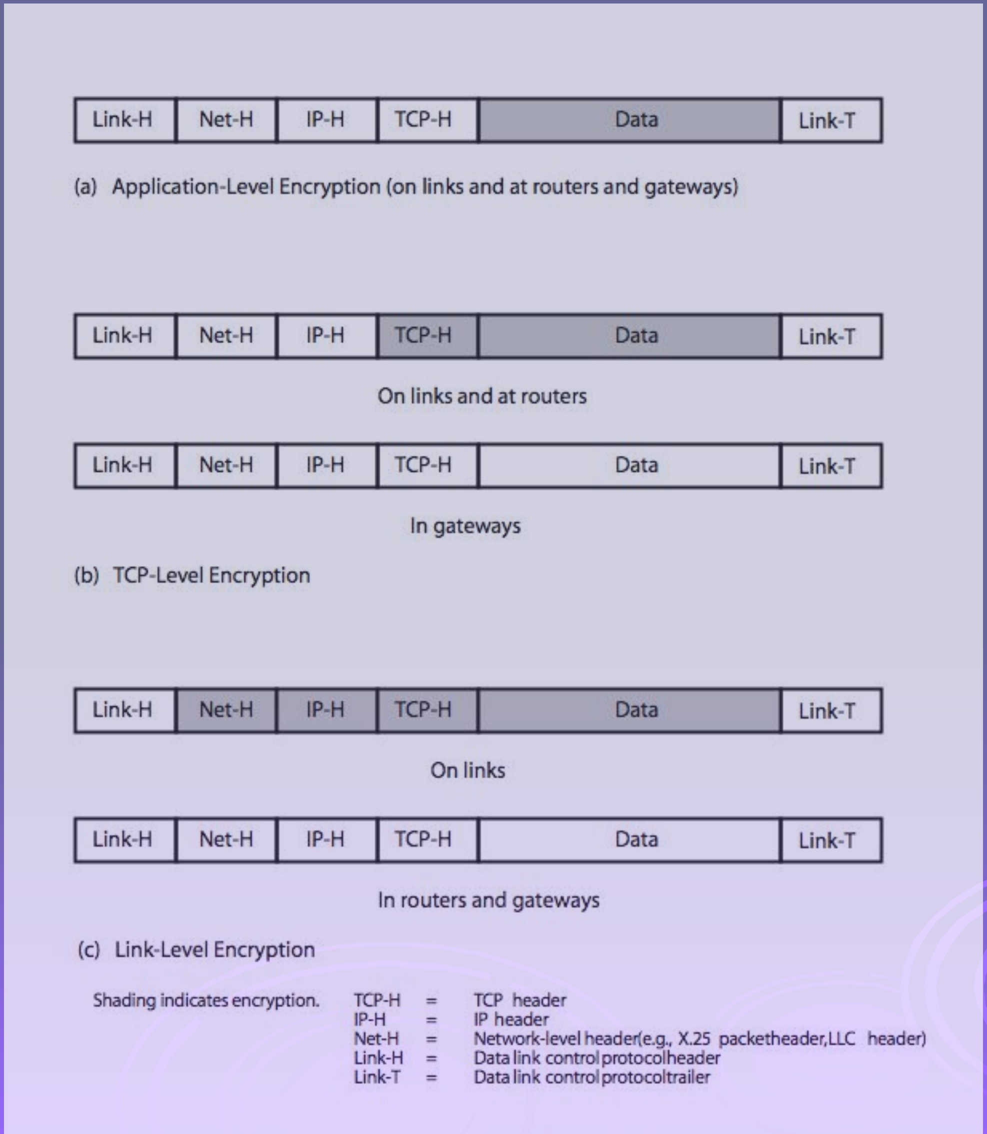
Placement of Encryption

- when using end-to-end encryption must leave headers in clear
  - so network can correctly route information
- hence although contents protected, traffic pattern flows are not
- ideally want both at once
  - end-to-end protects data contents over entire path and provides authentication
  - link protects traffic flows from monitoring

Placement of Encryption

- can place encryption function at various layers in OSI Reference Model
  - link encryption occurs at layers 1 or 2
  - end-to-end can occur at layers 3, 4, 6, 7
  - as move higher less information is encrypted but it is more secure though more complex with more entities and keys

Encryption vs Protocol Level



Link-H	Net-H	IP-H	TCP-H	Data	Link-T

(a) Application-Level Encryption (on links and at routers and gateways)

Link-H	Net-H	IP-H	TCP-H	Data	Link-T

On links and at routers

Link-H	Net-H	IP-H	TCP-H	Data	Link-T

In gateways

(b) TCP-Level Encryption

Link-H	Net-H	IP-H	TCP-H	Data	Link-T

On links

Link-H	Net-H	IP-H	TCP-H	Data	Link-T

In routers and gateways

(c) Link-Level Encryption

Shading indicates encryption.

TCP-H	=	TCP header
IP-H	=	IP header
Net-H	=	Network-level header(e.g., X.25 packetheader,LLC header)
Link-H	=	Data link control protocolheader
Link-T	=	Data link control protocoltrailer

Traffic Analysis

- is monitoring of communications flows between parties
  - useful both in military & commercial spheres
  - can also be used to create a covert channel
- link encryption obscures header details
  - but overall traffic volumes in networks and at end-points is still visible
- traffic padding can further obscure flows
  - but at cost of continuous traffic

Key Distribution

- symmetric schemes require both parties to share a common secret key
- issue is how to securely distribute this key
- often secure system failure due to a break in the key distribution scheme

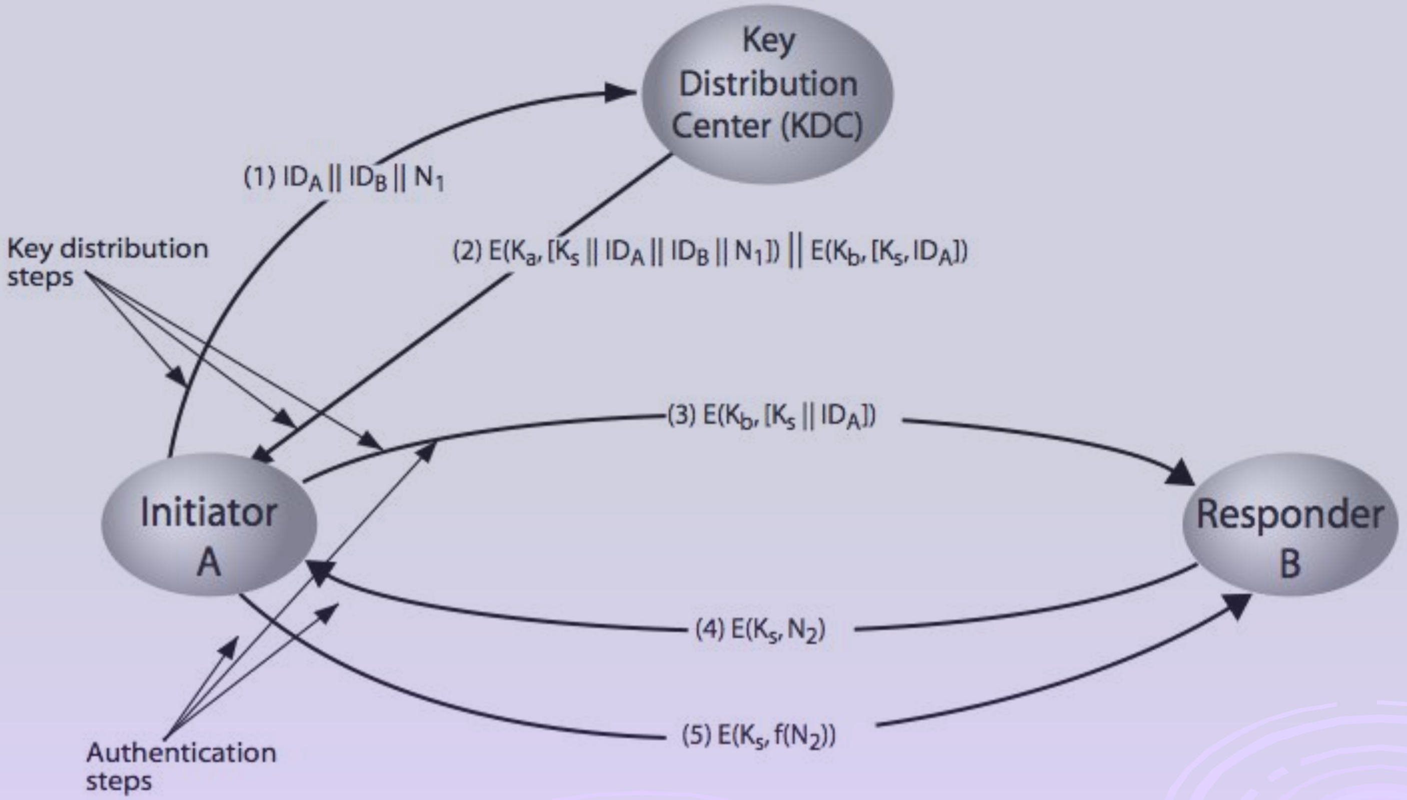
Key Distribution

- given parties A and B have various **key distribution** alternatives:
  1. A can select key and physically deliver to B
  2. third party can select & deliver key to A & B
  3. if A & B have communicated previously can use previous key to encrypt a new key
  4. if A & B have secure communications with a third party C, C can relay key between A & B

Key Hierarchy

- typically have a hierarchy of keys
- session key
  - temporary key
  - used for encryption of data between users
  - for one logical session then discarded
- master key
  - used to encrypt session keys
  - shared by user & key distribution center

Key Distribution Scenario


Key Distribution Center (KDC)
(1) $ID_A \| ID_B \| N_1$
(2) $E(K_a, [K_s \| ID_A \| ID_B \| N_1]) \| E(K_b, [K_s, ID_A])$
Key distribution steps
(3) $E(K_b, [K_s \| ID_A])$
Initiator A
Responder B
(4) $E(K_s, N_2)$
(5) $E(K_s, f(N_2))$
Authentication steps

- hierarchies of KDC’s required for large networks, but must trust each other
- session key lifetimes should be limited for greater security
- use of automatic key distribution on behalf of users, but must trust system
- use of decentralized key distribution
- controlling key usage

Random Numbers

- many uses of **random numbers** in cryptography
  - nonces in authentication protocols to prevent replay
  - session keys
  - public key generation
  - keystream for a one-time pad
- in all cases its critical that these values be
  - statistically random, uniform distribution, independent
  - unpredictability of future values from previous values

Pseudorandom Number Generators (PRNGs)

- often use deterministic algorithmic techniques to create “random numbers”
  - although are not truly random
  - can pass many tests of “randomness”
- known as “pseudorandom numbers”
- created by “Pseudorandom Number Generators (PRNGs)”

Linear Congruential Generator

- common iterative technique using:

  $X_{n+1} = (aX_n + c) \bmod m$
- given suitable values of parameters can produce a long random-like sequence
- suitable criteria to have are:
  - function generates a full-period
  - generated sequence should appear random
  - efficient implementation with 32-bit arithmetic
- note that an attacker can reconstruct sequence given a small number of values
- have possibilities for making this harder

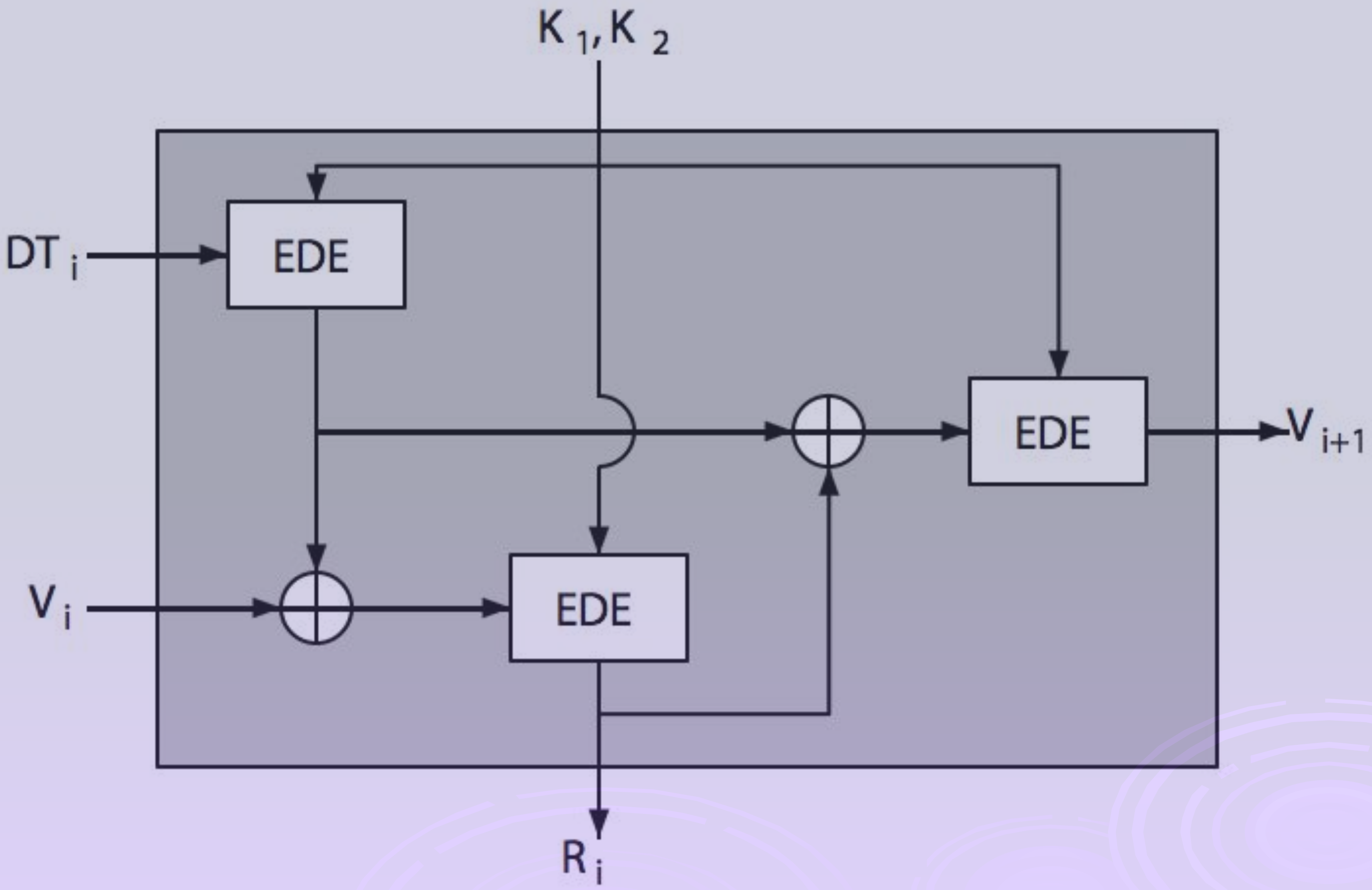
Using Block Ciphers as PRNGs

- for cryptographic applications, can use a block cipher to generate random numbers
- often for creating session keys from master key
- Counter Mode

  $X_i = \mathrm{E}_{Km}[\mathrm{i}]$
- Output Feedback Mode

  $X_i = \mathrm{E}_{Km}[X_{i-1}]$

ANSI X9.17 PRG



Blum Blum Shub Generator

- based on public key algorithms
- use least significant bit from iterative equation:
  - $x_i = x_{i-1}^2 \bmod n$
  - where $n=p.q$, and primes $p,q=3 \bmod 4$
- unpredictable, passes **next-bit** test
- security rests on difficulty of factoring N
- is unpredictable given any run of bits
- slow, since very large numbers must be used
- too slow for cipher use, good for key generation

Natural Random Noise

- best source is natural randomness in real world
- find a regular but random event and monitor
- do generally need special h/w to do this
  - eg. radiation counters, radio noise, audio noise, thermal noise in diodes, leaky capacitors, mercury discharge tubes etc
- starting to see such h/w in new CPU's
- problems of **bias** or uneven distribution in signal
  - have to compensate for this when sample and use
  - best to only use a few noisiest bits from each sample

Published Sources

- a few published collections of random numbers
- Rand Co, in 1955, published 1 million numbers
  - generated using an electronic roulette wheel
  - has been used in some cipher designs cf Khafre
- earlier Tippett in 1927 published a collection
- issues are that:
  - these are limited
  - too well-known for most uses

Summary

- have considered:
  - use and placement of symmetric encryption to protect confidentiality
  - need for good key distribution
  - use of trusted third party KDC’s
  - random number generation issues